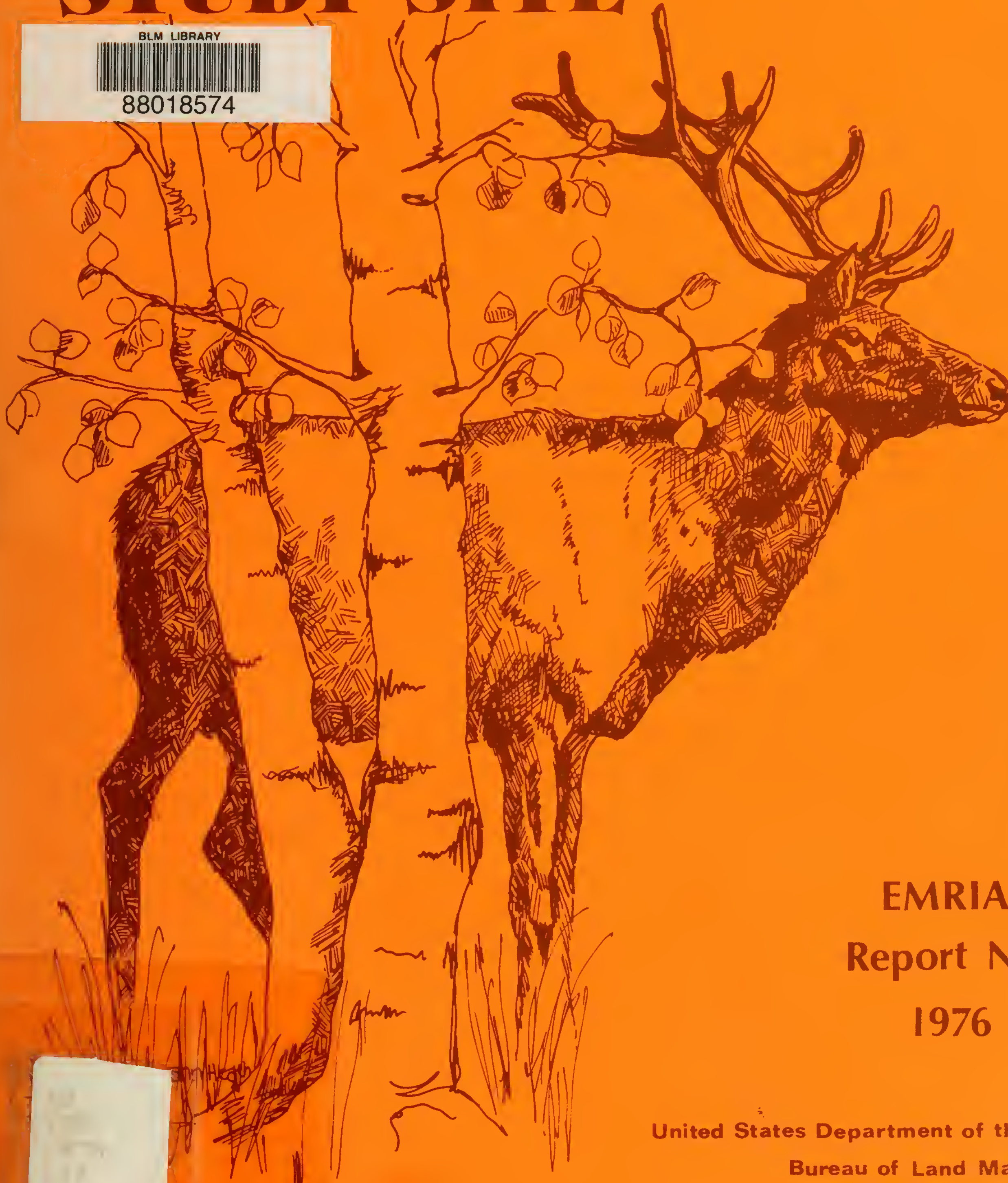
Resource & Potential Reclamation Evaluation

FOIDEL CREEK STUDY SITE



EMRIA
Report No. 6
1976

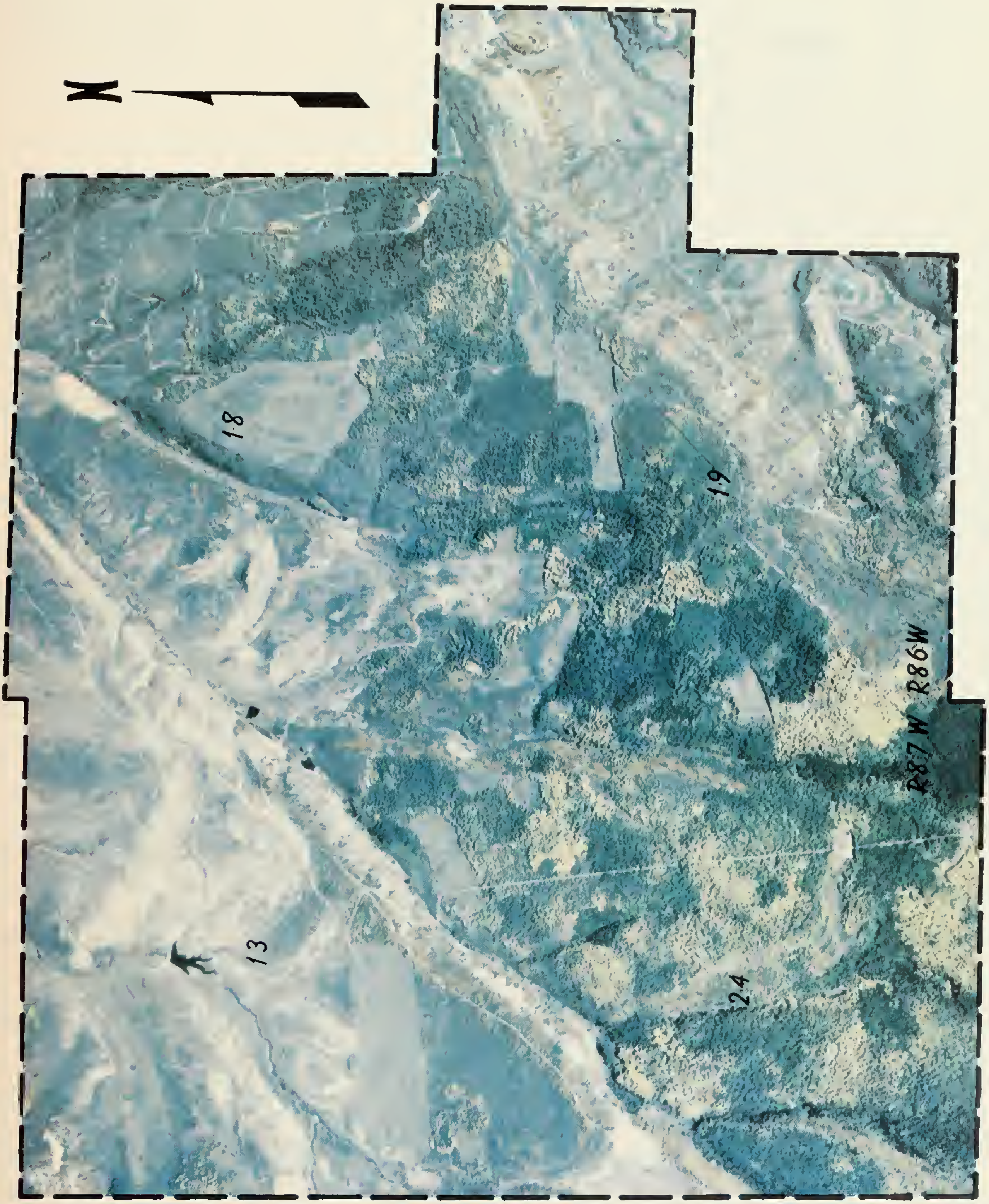
United States Department of the Interior
Bureau of Land Management
Bureau of Reclamation
Geological Survey

EMRIA - Energy Mineral Rehabilitation Inventory and Analysis

The purpose of the EMRIA program is to provide information on the reclamation potential of lands under consideration for mineral development or other major land disturbing activities

The objective of Reclamation Study Area Reports is to provide the information needed (in addition to existing information) to enable management officials to determine (1) can the area be effectively reclaimed, (2) what are the major problems involved in reclaiming the site, and (3) what measures would be necessary to establish conditions suitable for the intended post mining use.

These reports are prepared through the efforts of the Department of the Interior principally by the Bureau of Land Management, Bureau of Reclamation, and Geological Survey. Assistance is also provided by other Federal and State agencies.



FOIDEL CREEK STUDY AREA

— — APPROXIMATE BOUNDARY OF STUDY SITE

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SCALE OF FEET

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INTRODUCTION

An ever increasing need for energy has focused attention on the energy fuels and sources existent in the western states, primarily the Rocky Mountain and the Northern Great Plains Coal Provinces due to the abundance, simplicity of extraction, and the high quality of the resources present. It is the responsibility of the Bureau of Land Management to encourage and assist in meeting these energy demands and at the same time assure sound reclamation so that the disturbed lands are returned to a productive and useful state.

Purpose

The main purpose of this study is to determine the reclamation potential, the problems that would be involved in reclaiming the area, and the measures that would be required to establish satisfactory conditions.

Objectives

The overall objectives of the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program are as follows:

1. To evaluate environmental effects of surface mining of areas under consideration for coal development.

2. To provide resource and reclamation information for the leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource and reclamation information needed for development of effective lease stipulations as required by the mined land reclamation program.

4. To provide resource, impact, and reclamation information to support state and local regional development and land use planning efforts.

5. To determine the present and potential capability of the surface soil and subsurface resources to support vegetation on known energy fuel deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Technical Examination, Environmental Analysis Records, Environmental Impact Statements, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study.

Authority

1. Public Land Administration Act of July 14, 1969 (74 Stat. 506).

2. Federal Land Policy and Management Act of 1976.

3. Surface Mining Control and Reclamation Act of 1977.

Responsibility

The following agencies were involved in the study.

Bureau of Land Management

1. Select reclamation study areas for coordinated investigation of vegetation, soil geological structure, surface water, and ground water.

2. Prepare coordination and issue and monitor the execution of work orders.

3. Review and consolidate work order and field office data and prepare input to reports published by the Bureau of Reclamation.

4. Procure easements and rights-of-way to conduct the studies.

5. Distribute technical data, reports, and reclamation and rehabilitation recommendations to field offices.

Bureau of Reclamation

1. Conduct land studies, including a land classification, soil survey, and laboratory characterization program.

2. Conduct drilling operations for the procurement of core samples to be used for the analysis of geological strata in overburden materials.

3. Map surface geology.

4. Prepare geologic logs on drill holes.

5. Collect coal samples.

6. Install casing in holes selected for ground-water observation wells.

7. Characterize and interpret data available on soils and overburden materials as well as substrata immediately below the coal resources in relation to reclamation and revegetation.

8. Advise and recommend suitable plant species for use in areas to be reclaimed.

9. Advise and recommend reclamation techniques.

10. Coordinate, assemble, and print final report.

<u>Geological Survey</u>

1. Conduct soil/vegetation and sediment studies which will result in soil/vegetation maps, hydrologic properties of soils, and sediment data.

2. Assess reclamation potential based on water availability.

3. Prepare sediment yield maps.

4. Prepare erodability illustrations.

5. Determine rainfall-runoff relationships and analyze surface and subsurface waters for chemical quality.

6. Evaluate coal sections and prepare well logs.

7. Prepare coalbed maps showing coal resources.

8. Tabulation of coal resources estimates.

9. Table of analytical results on coal resources.

10. Graphic presentation of analytical results.

   a. Vertical - Plotted against well logs.
   b. Horizontal - Plan view if significant.

11. Evaluation of the effects of mining on the area hydrology and downstream.

Location and Setting

The area under consideration, referred to as the "Foidel Creek Study Site" is located approximately 25 miles southwest of Steamboat Springs. The lands being studied lie within Routt County described as follows:

T. 4 N., R. 87 W.	T. 4 N., R. 86 W.
sec. 13: All	sec. 18: All except E1/2E1/2
sec. 24: All	sec. 19: All except E1/2SE1/4 and the E1/2W1/2SE1/4

The surface ownership in the study site is private (held mostly by mining companies) but the coal minerals are owned by the Federal Government and administered by the Bureau of Land Management.

The communities of Craig, Hayden, and Steamboat Springs are located north along U.S. Highway No. 40. Colorado State Highway No. 131 is approximately 6 miles east of the study site.

Foidel Creek is the major drainage in the area. The study site lies at an elevation between 7000 and 8080 feet. Precipitation ranges between 15 and 20 inches. Vegetation consists of short grasses, brush, and aspen forest.

BIOLOGICAL RESOURCES

Wildlife

Big Game

Two of the ten species designated as big game in Colorado are found within the area in substantial numbers. These two species, mule deer (*Odocoileus hemionus*) and elk (*Cervis canadensis*), occupy the study site in varying densities dependent upon the condition of the food and cover, as well as climatic factors and the degree of harassment. Black bear (*Ursus americanus*) and cougar (*Felis concolor*) are found in the area but are relatively few in number.

Mule deer. - Mule deer may be found in any portion of the subject site at any time of the year; however, a greater population density occurs during the spring, summer, and fall months.


R.87W.
R.86W.
T.5N.
T.4N.
FOIDEL CREEK STUDY AREA
MINERALS OWNED BY
THE FEDERAL GOVERNMENT
Symbol
Mineral Rights
All Minerals
Coal Only
Oil and Gas Only
Oil, Gas, and Coal Only
Other
No symbol indicates no Federal minerals
Note: Acquired and L.U. may include term or fractional interest for mineral shown
scale 1:126,720
ALWAYS THINK SAFETY
FOIDEL CREEK STUDY AREA
LOCATION & MINERAL STATUS
DESIGNED
TECH. APPROVAL
DRAWN
SUBMITTED
CHECKED
ADMIN. APPROVED
DENVER, COLORADO
FIGURE 1

The study site provides marginal winter habitat and fair-to-good summer browse. Cover is provided by a combination of brush, aspen (Populus spp.), and topography, and appears to be adequate to meet the needs of the local deer. Water also appears to be of sufficient quality and quantity to meet their needs. Water is provided by Foidel and Middle Creeks and several scattered ponds or stock tanks.

Some important deer foods that are found within the study area are serviceberry, snowberry, bitterbrush, oak, common chokecherry, and big sagebrush.

Researchers in similar areas of northwestern Colorado have identified preferred classes of foods for the mule deer as shown in table 1. These study results are considered appropriate for the study area.

Table 1.--Preferred Classes of Food for Mule Deer

Season	Percent of Diet			
	Shrubs and trees	Forbs	Grasses and grasslikes	Total
Winter	97	2	1	100
Spring	79	9	12	100
Summer	94	6	0	100
Fall	97	3	0	100

SOURCE: Kufeld, R.C., et. al, Foods of Rocky Mountain Mule Deer.

Studies are being conducted by Dames and Moore (consultants for Energy Fuels Corporation) to determine the parameters for species composition, density, trend, and utilization by wildlife within the region. Tables 2 and 3 present the results of the first year's studies (1975).

Numbers of deer fluctuate, depending on several factors discussed previously; these fluctuations occur from year to year and within each year. Population estimates range from one deer/square mile during the severe cold winter months to seven deer/square mile in the mild summer months.

Elk. - The Foidel Creek Study Site provides good elk winter habitat and is used to some extent during these months. Wintering elk appear to concentrate along Middle Creek and Rattlesnake Butte as well as in and around the old spoils of the Energy Strip Mine No. 1. Elk do migrate through the area, and a calving ground is located at the south end in section 24.

TABLE 2

Browse Evaluation of the Mountain Shrub Vegetation Type on Section 21, T.5 N.,R.86 W. 1/

A. Browse Condition Summary

Form Class	Number of Plants: Snowberry	Big Sagebrush	Rabbitbrush	Serviceberry	Bitterbrush	Subtotal	Percent of Total
1 & 4 (light)	2	14	15	0	0	31	21%
2 & 5 (moderate)	27	17	2	22	3	71	47%
3 & 6 (heavy)	10	1	5	6	27	49	32%
Subtotal	39	32	22	28	30	Total 151	

B. Browse Trend Summary

Number of Young plants	39
Number of decadent plants	12
Total	51
20 percent of Total	10.2%
Difference between young and decadent	27

C. Key area evaluation

	Points
Browse condition	10
Browse trend	15
Total	25
Adjective rating	Good

1/ SOURCE: Baseline Environmental Report (Dames and Moore 1975).

TABLE 3

Browse Evaluation of the Mountain Shrub Vegetation Type on Section 9, T.4 N.,R.86 W. 1/

A. Browse Condition Summary

Form Class	Number of Plants: Snowberry	Big Sagebrush	Gambel Oak	Serviceberry	Subtotal	Percent of Total
1 & 4 (light)	10	12	14	5	41	32%
2 & 5 (moderate)	23	22	10	12	67	52%
3 & 6 (heavy)	8	3	2	7	20	16%
Subtotal	41	37	26	24	Total 128	

B. Browse Trend Summary

Number of young plants	16
Number of decadent plants	12
Total	28
20 percent of Total	5.6 (2.8)
Difference between yound and decadent	4

C. Key area evaluation

	Points
Browse condition	10
Browse trend	10 (15)
Total	20 (25)
Adjective rating	Fair to Good

1/ SOURCE: Baseline Environmental Report (Dames and Moore 1975).

Cover is provided by aspen, mountain shrub, and the topography; spoil piles also provide some protection from severe winter weather; cover appears to be adequate to meet the elks' needs. Water does not appear to be a limiting factor on the elk population; their water requirements are met in the form of snow, scattered ponds, stock tanks, and the creeks running through the area.

The Colorado DOW (Colorado Division of Wildlife) flew over portions of northwestern Colorado to locate big game concentrations; the area around the Energy Fuels mine complex was inventoried in spring 1975. The results of these flights indicated a population estimated at six elk/square mile. At least 30 elk are known to use Energy Strip Mine No. 1 spoils extensively (according to permanent mine workers' reports).

Black bear. - Little information is available concerning the use of the study site by this species. The Colorado DOW estimates five bears are located in this general area. Based on bear habitation in other parts of northwestern Colorado, the bears would be expected to remain in the bushy or forested vegetation types.

Cougar. - The only cougars known to inhabit the area are found along Middle Creek; estimates indicate two to four animals. No reports of lion predation have been reported to Colorado DOW in recent years, so it is assumed that cougar predation is not a serious problem to livestock operators. Both bear and cougars tend to avoid areas of concentrated human activity.

Small Game Mammals

Lagomorphs. - Data are presently unavailable to indicate population densities or habitat conditions for species of this group of mammals. Rabbit population densities have been very low over all of northwestern Colorado for the past few years as reported by local hide and fur dealers and verified by preliminary studies in the mine complex area.

As indicated by Armstrong (1972) three species of this order are expected to be found within the subject area. The Nuttalls cottontail (*Sylvilagus nuttallii*) is normally found along the forest edge. Snowshoe hare (*Lepus americanus*) spends most of the year associated with underbrush of coniferous forests and open forest meadows; occasionally they may be found in oak brush and aspen or rarely in sagebrush vegetation types.

White-tailed jackrabbit (*Lepus townsendii*) is not listed as a "small game" species by Colorado DOW, but this species belongs to the same taxonomic order as those described above and is included in this section. Like other jackrabbits, this species is most commonly found in open vegetation, generally in sagebrush, grassland, and cropland types.

Furbearers. - Several species of furbearers have been identified within the subject site; however, no population, harvest, or habitat data are presently available. Colorado DOW has indicated that beaver (Castor canadensis) and muskrats (Ondatra zibethicus) are found within the area.

Both longtailed weasel (Mustela frenata) and shorttailed weasel (Mustela erminea) are suspected to inhabit the area. Longtailed weasel can be found in any portion of the study area; shorttailed weasel is generally found only in conifers or aspens. Additional information is being collected on small mammals within the area and may provide more detailed habitat descriptions for these species.

Mammalian predators. - The cougar is listed as both predator and big game species. Other predator species that are found within this site include coyote (Canis latrans), bobcat (Lynx rufus), and red fox (Vulpes fulva). No specific data are available describing habitat or population parameters for these three species. However, since no predator problems have been reported to Colorado DOW, it would appear that fox, bobcat, and coyote populations are being maintained by native prey and are not surpassing the carrying capacity of the region. Fox and coyote population trends are reported rising; and with low rabbit populations of the past few years, these predators may have to turn to an alternate food source or the population will decline. Bobcat population trends in northwestern Colorado are generally stable to slightly declining.

Other Mammals

A variety of rodents, insectivors, bats, and skunks are found within the subject area.

Small mammals were trapped near the study site on three consecutive nights by Dames and Moore (August 6-8, 1975) using Sherman live traps. Four 12 x 12 grids (144 Sherman live traps per grid) were placed in each representative vegetative cover type, namely aspen, mountain shrub, sagebrush, and grassland. In addition to identifying, weighing, and recording the reproductive status of captured animals, vegetation at each grid site was sampled to compare mammalian diversity with cover types.

Twenty-one mammal species were recorded during the study. Aspen and mountain shrub types had the greatest species composition with 14 and 13 species, respectively. Eight species were identified in sagebrush habitat and only two in grassland. Mountain shrub and aspen areas appear to support a more diverse mammal fauna than do sagebrush or grassland, because a greater array of microhabitats are associated with woodland growth form and food resource.

All species were trapped in the aspen and mountain shrub areas, but only deer mice were trapped in sagebrush and meadow communities (table 4). Since the diversity was greatest in mountain shrub followed by aspen woodlands, these communities must be considered more important habitats for small mammals than sagebrush or meadows. The diets of the six species trapped in mountain shrub type ranged from animal matter to seeds and vegetation, suggesting that not only a diverse habitat exists but a diverse food resource base as well.

Unlike the woodland communities, sagebrush and meadows are more open and more restricted in growth form. The deer mouse, a predominantly seed-eating species although weakly omnivorous, was the only species to appear in these communities. The grasses at the meadow grid site were established through human manipulation, and the presence of deer mice and the absence of other rodents typifies the relationships between deer mice and exotic communities.

Data (table 5) indicate less breeding activity occurs in aspen woodland than in the other communities. This may reflect shorter reproduction seasons at higher elevation.

Waterfowl

Several species of waterfowl are known to migrate through the region, and many stop off at some ponds or creeks during this period. At least six species are known to nest in the general area: mallard (Anas platyrhynchos), pintail (Anas acuta), american widgeons (Mareca americana), greenwing teal (Anas cyanoptera), cinnamon teal (Anas cyanoptera), and bluewinged teal (Anas discors). Nesting densities are expected to be light and restricted to the creeks and ponds in areas that are not heavily grazed.

Peak for waterfowl numbers moving through the area is probably in March or April. Waterfowl food is restricted to aquatic habitats and adjacent lands with little use of croplands.

Blue grouse (Dendragapus obscurus) may be found scattered throughout the general area, generally in aspen vegetation type. More blue grouse are known to inhabit the conifer forests south of the subject area. Population densities, habitat conditions, or season of use information are not available for blue grouse at this time.

Hawks, Eagle, and Falcons

Several species of this order have been seen within the general area. The rough-legged hawk (Buteo lagopus) is a common winter resident, as is the firruginous hawk (Buteo regalis). The swainson's hawk (Buteo swainsoni) and the american kestrel (Falso sparverius) are summer visitors. The golden eagle (Aquila chrysaetos) and the redtailed

TABLE 4

Small Mammals Live-Trapped on the Four Mammal Grids - Energy Fuels Mine Area
August 1975

	Aspen	Oak	Sagebrush	Meadow	Total
Trap Nights	432	432	432	432	1,728
Total Species	5	6	1	1	13
Total Individuals	24	45	19	5	93
Total Biomass (gms.)	595	889	516	78	2,078
Trap Nights/Catch	18	9.6	22.7	86.4	
Percent Captures/Grid	5.6	10.4	4.4	1.2	
Density (Individuals/Acre)	3.6	6.7	2.8	0.7	

Trapped Population Only

Species	Comp.	Biomass	Comp.	Biomass	Comp.	Biomass	Comp.	Biomass
Shorttail Weasel	-	-	1	56	-	-	-	-
Least Chipmunk	11	290	3	87	-	-	-	-
Deer Mouse	1	23	18	266	19	516	5	78
Boreal Redback Vole	8	96	7	176	-	-	-	-
Mountain Vole	6	141	12	252	-	-	-	-
Western Jumping Mouse	3	45	4	52	-	-	-	-

SOURCE: Dames and Moore, 1975.

TABLE 5

Reproductive Status of Small Mammals Trapped on Four Grids, Energy Fuels Mine - August 1975

	Active		Inactive		
	Male	Female	Male	Female	Juvenile
Aspen					
Least Chipmunk	-	2	2	3	4
Deer Mouse	-	1	-	-	-
Boreal Redback Vole	2	-	1	-	-
Mountain Vole	1	2	-	1	2
Western Jumping Mouse	-	-	1	-	2
Oak Brush					
Short-tail Weasel	-	-	-	-	1
Least Chipmunk	-	-	1	1	1
Deer Mouse	2	4	1	-	11
Boreal Redback Vole	2	2	2	1	-
Mountain Vole	1	1	1	1	8
Western Jumping Mouse	-	2	2	-	-
Sagebrush					
Deer Mouse	4	11	-	-	3
Grass					
Deer Mouse	2	1	1	-	1

SOURCE: Dames and Moore, 1975

hawk (Buteo jamaicensis) are yearlong users in the area. Only the golden eagle and american kestrel are known to nest in the general area.

Domestic Fauna

Most of the lands within the study area are used by livestock primarily from late spring to early fall, May to October. Both cattle and sheep are domestic livestock within the study site.

VISUAL RESOURCES

The VRM (Visual Resource Management) system used by BLM (Bureau of Land Management), see BLM Manual 8411, provided the methodology for inventory and evaluation for visual resources existing on the Foidel Creek Study Site.

The study site is made up of sagebrush minimal relief, aspen, and mountain shrubs-steep slopes landscape types (or scenic quality rating units). VRM Class IV has been assigned the first two types and VRM Class III has been assigned to the latter type. The abovementioned system was used to determine these classes which prescribe management objectives desirable in order to consider the visual resource if development occurs. Each class allows different degrees of visual impacts to occur while maintaining the visual integrity of the landscape. A map showing the location of the class objectives is given in figure 2, page 16.

The class objectives for the study site are listed below:

VRM Class III. Impacts from mining and reclamation to these landscapes may be evident and begin to attract attention in their surroundings. The impacts from the activity and reclamation efforts, however, should be minimized to the point where they remain subordinate to and do not dominate their surroundings.

VRM Class IV. Visual impacts may attract attention and be dominant in their relationship to their surroundings in terms of scale (size proportions). The reclamation end results should borrow lines, colors, texture, and forms from these same elements in the surrounding landscapes.

The scenery quality ratings used in the VRM system are divided into three classes. The top or best class is defined as "A." The medium (average) class is "B" and the below average class is "C" category. All the scenery classes in the Foidel Creek Study Site fall into the B scenery class.

Landscape Types (Scenic Quality Rating Units)

Sagebrush Minimal Relief

Flat to gently undulating landforms, with sagebrush the dominant vegetation type, characterize this landscape. Channels of intermittent streams create diagonal lines in the landform as they flow down the hillside. Sagebrush colors the landscape gray to brown and results in a fine texture when viewed from County Road 27. Straight lines are formed by roads and trails. Manmade reservoirs trap water, which add variety and interest to the landscape. No structures are present in this landscape type.

The scenic quality rating for this landscape type is characteristic of B. All of the land area within the type on this lease tract has a low level of sensitivity and is seen within the foreground-middleground zone of County Road 27. This type is in VRM Class IV.

Aspen

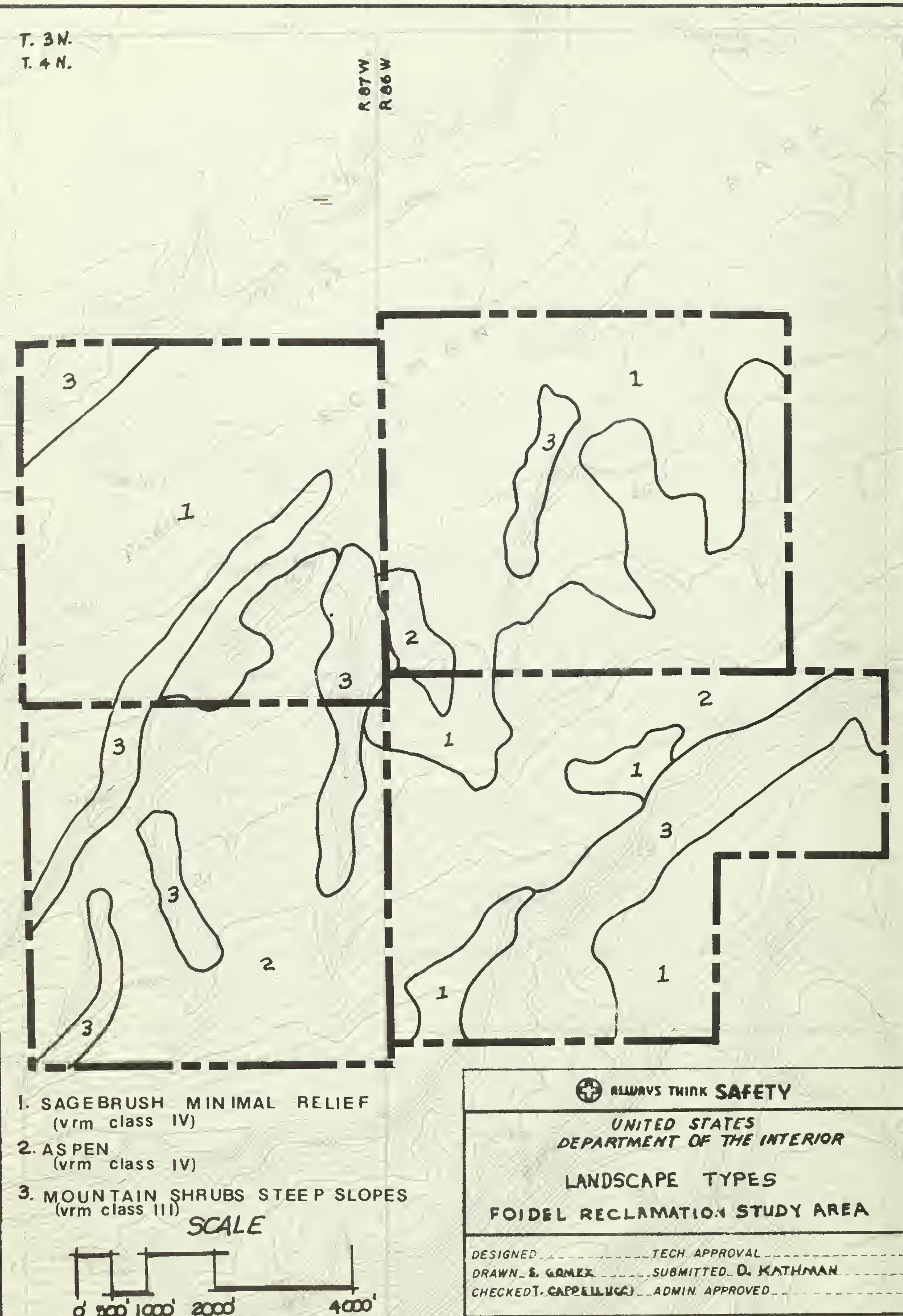
This landscape type consists of steadily rising north-facing slopes dissected by intermittent stream drainages. Large groves of aspen with occasional masses of mountain shrubs create irregular forms on the hillside. Colors in summer are shades of yellow and green while fall colors are orange and red. Viewed from County Road 27, texture is medium. Water is an ephemeral feature of the landscape except in several manmade reservoirs. Several roads and trails appear as light colored lines on the hillside when they are not hidden by vegetation.

Adjacent to this landscape type is the currently operating Energy Fuels surface mine. The presence of this intrusion significantly disrupts the natural continuity of landform and vegetation between this type and surrounding areas.

A scenic quality rating determined the aspen landscape type to be characteristic of B scenery. It is seen in the foreground-middleground zone of County Road 27 and has a low sensitivity level. VRM Class IV is assigned to the type.

Mountain Shrubs-steep Slopes

Steep slopes sparsely vegetated by various mountain shrub species and sagebrush make up this landscape type. Highly irregular masses of oak, chokecherry, and serviceberry show shades of green in summer, yellow and red in fall, and purple-brown during winter. Light buff-colored rock outcrops create horizontal lines that follow the natural contours of the slope. This type has a coarse texture in the foreground and middleground. Manmade structures and water are both


T. 3 N.
T. 4 N.
R 87 W
R 86 W
1
2
3
1. SAGEBRUSH MINIMAL RELIEF
(vrm class IV)
2. ASPEN
(vrm class IV)
3. MOUNTAIN SHRUBS STEEP SLOPES
(vrm class III)
SCALE
0 500' 1000' 2000' 4000'
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
LANDSCAPE TYPES
FOIDEL RECLAMATION STUDY AREA
DESIGNED
TECH. APPROVAL
DRAWN S. GOMEZ
SUBMITTED D. KATHMAN
CHECKED T. CAPPELLUCCI
ADMIN. APPROVED
DENVER, COLORADO
FIGURE 2

absent in this landscape type. VRM Class III is assigned to this type. This area has a B or characteristic scenic quality rating, a moderate level of sensitivity, and can be seen in the foreground-middleground zone from county roads.

CLIMATE

Rough topography of the general area causes significant channeling of air masses passing the region. During the evening and early morning hours, air moves toward lower elevations. Therefore in the study site, nighttime air masses are expected to move toward Foidel and Middle Creeks and then to the northeast. During the afternoon hours when the sun heats the earth's surface, air tends to flow toward higher elevations. It is estimated that downvalley flow occurs about 50 percent of the year and upvalley flow 10 to 20 percent of the year. The remainder of the year, wind direction is variable.

Average hourly wind speed varies with the time of day. Wind speeds reach average maximum values during summer afternoons and are usually associated with upvalley flow. It is estimated that afternoon wind speed will average 4 km/s (8 mi/h), and evening wind speed 3 km/s (6 mi/h). Wind speeds greater than 10 km/s (20 mi/h) will occur during abrupt weather changes or storms, primarily during the winter and spring months. Calm conditions can occur any time of day, but are far more frequent during the evening and early morning. Wind speeds of less than 1 km/s (2 mi/h) are expected nearly 20 percent of the time in the site.

Measurements of annual precipitation in the area are unavailable, but historical records from the towns of Hayden and Yampa indicate that about 41 cm (16 in) can be expected annually. It is estimated that 90 d/yr precipitation is greater than the detectable limit of 0.25 mm (0.01 in) in the general area.

Similar to the entire region, the study site is subject to large seasonal and daily temperature variations. In July, temperatures are expected to vary from 27° C (81° F) average maximum during the day to 6.7° C (44° F) average minimum at night. January temperatures vary from an average maximum of 0.0° C (32° F) during the day to an average minimum of -17° C (1.4° F) at night. The growing season is expected to be somewhat less than that recorded at Hayden, or about 60 to 70 days. There appear to be no climate limitations to reclamation under normal climatic conditions.

PHYSICAL PROFILE

Topography

The Foidel Creek EMRIA Study Site is located near the southern end of a finger of the Wyoming basin physiographic province. The Southern Rocky Mountain Province, represented here by the park range, lies only a few miles to the east.

Fenneman (1931) describes the Wyoming basin as consisting of elevated plains in various stages of erosion with isolated low mountains. The area in which the study site lies is one of dissected low mountains and cuestas.

Within the Wyoming basin is one of the most remarkable drainages in the United States. Most of the streams passing through or out of the basin cross one or more mountain ranges. The Yampa River, for instance, enters the Uinta range at its eastern end and traverses it lengthwise until it joins the Green River in the midst of the mountains.

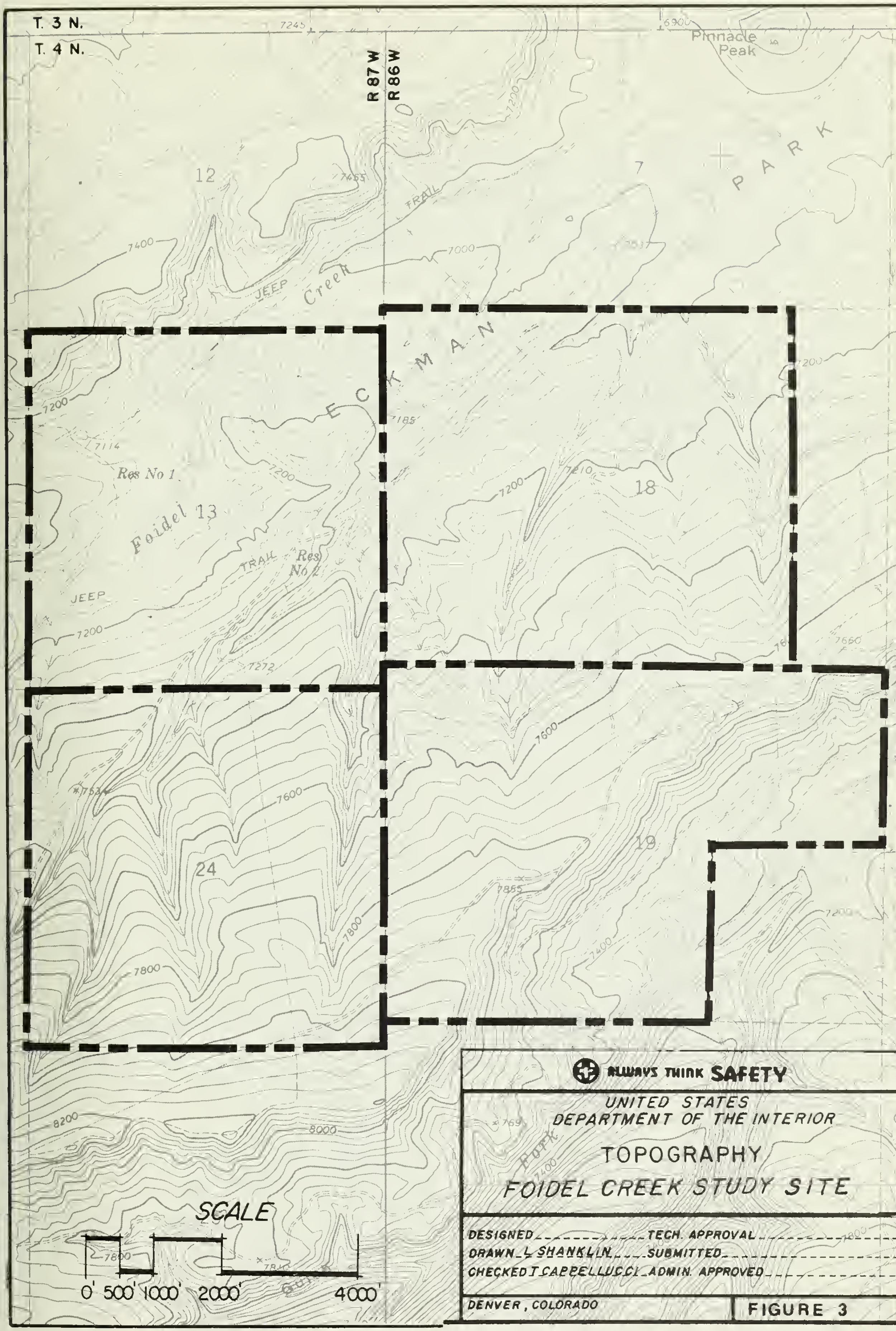
Within the study site boundaries, there is a total relief of about 1,100 ft. Actual elevations vary from 7000 to 8080 ft. Pinnacle Peak, a prominent topographic feature to the north, has an elevation of 7400 ft. Approximate elevation of each drill hole is shown on the individual log given in the Geology, Appendix A.

The landforms within the study site are directly controlled by the local geology. The general slope of the land is north to northeastward with a gradient of about 4 to 5 percent. This slope is also a dip slope and lies on the side of a monoclinal structure. Geomorphically, these gently sloping hills are known as cuestas.

The Foidel Creek EMRIA Study Site is drained by a number of intermittent streams and three constant flowing streams. Foidel Creek drains the northwest corner of the site; the North Fork of Middle Creek drains the southeast corner, and an unnamed stream drains the middle section. All the streams eventually enter the Yampa River which is a major contributor to the Green River and eventually the Colorado River.

Stream patterns are dendritic, and genetically the streams are subsequent in nature.

Figure 3 shows the location and topography of the Foidel Creek Study Site.


T. 3 N.
T. 4 N.
R 87 W
R 86 W
Pinnacle Peak
PARK
ECKMAN
JEEP TRAIL
Creek
Res No 1
Foidel
Res No 2
12
7
13
18
24
19
7200
7400
7600
7800
8000
8200
SCALE
0' 500' 1000' 2000' 4000'
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
TOPOGRAPHY
FOIDEL CREEK STUDY SITE
DESIGNED TECH. APPROVAL
DRAWN L SHANKLIN SUBMITTED
CHECKED T CAPPELLUCCI ADMIN. APPROVED
DENVER, COLORADO
FIGURE 3

Geology

Regional Geology

The subject study site, also a part of the Yampa coalfield, is located near the southeast margin of the Washakie structural basin of south-central Wyoming and northwestern Colorado. The entire Washakie basin is a synclinal structure modified by a number of smaller synclines and anticlines.

Depending on what part of the basin they are in, the rocks dip from 0° to as much as 16°. Two broad group of faults are found in the basin and are grouped according to their general strike direction. The dominant group strikes westward while the second group strikes more northward or northwestward. Just to the north of the study site, some classical examples of faulting are quite evident by the obvious offset of sandstone cliffs.

Most of the rocks in the basin are sedimentary although some volcanics are known to occur. Immediately to the east in the Park Range, both igneous and metamorphic rocks occur. Some volcanic necks exist southeast of the site.

A regional geology map is shown as figure 4 on page 32.

Site Specific Geology

The Foidel Creek EMRIA Study Site lies on the side of a northward dipping monocline. Dips on this slope seldom exceed 15°. This monoclinal structure is bounded on the west by the Fish Creek anticline and on the east by the Twentymile Park syncline.

A series of northwest striking faults are present in the area. They are quite obvious, even to the untrained eye, in places where they have offset the massive sandstone cliffs lying to the north of the study site. The geologic map, figure 4, page 32, of the area shows a maximum horizontal displacement of 1,000 ft. None of the drill holes encountered any fractured rock, but an effort had been made to locate the holes in nonfaulted areas.

Rock types present in the study site are those normal to a sedimentary sequence and include sandstone, siltstone, shale, and coal. Lesser amounts of carbonaceous material and montmorillonite were also found. Following are the approximate percentages of each rock type found:

Sandstone	57%
Shale	23%
Siltstone	10%
Coal	10%

Stratigraphy and Geologic Logs

All rocks present within the study site belong to two formations, the Williams Fork and the Iles, both of which belong to the Mesaverde Group. The Lewis shale lies just a very short distance to the north. Shown on page 38 is a stratigraphic column for the subject site and the immediate area. The Wadge bed lies within the Williams Fork Formation and is the unit that will be mined if the area is leased for coal development.

Geologic logs are shown in Geology, Appendix A. All core was logged in the field as soon as possible after it was removed from the core barrel. On the next page, table 6 explains the hardness scale used in the logs. The hardness scale is not based on Moh's Scale of Hardness, but rather on physical features that are easily understood and described and are rated on in increasing scale of hardness from one to ten. The core was delivered to the Regional Soils and Water Laboratory for further analysis and studies.

The drill program was laid out to obtain the best sampling with the minimum number of holes. No previous subsurface information was available in the area. Even the existing surface information was mapped years ago and is somewhat sketchy. The first holes were drilled to the top of the Trout Creek Sandstone Member, a prominent marker bed, and to the top of the Iles Formation. The core thus obtained information on the entire Lower Coal-bearing Member and a portion of the Marine Shale, member of the Williams Fork Formation. This also meant though, that these two holes went deeper than the 200-ft economical limit of a strip mine. Other holes went to either 200 ft or through the Wadge bed of coal.

Geologic Logs, Map, and Cross Section

The geologic logs of drill holes DH-1 through DH-5 are shown in Appendix A. These logs have been revised to include a comparison of the various rock types encountered in the drill holes with the suitability of using these rock types as a plant growing medium. Ratings of suitable, doubtful, and unsuitable are used and the basis for these ratings are discussed under "Overburden Evaluations."

The approximate location of the above drill holes is shown on the Surface Geologic Map, Plate 1, page 23. This map also indicates the locations of the geologic cross sections. Photographs showing the drill sites and surrounding Red Rim area are shown on pages 28 through 30.

Geologic cross sections A-A, B-B, C-C, and D-D, shown on plates 2, 3, and 4, are included to demonstrate general stratigraphic correlation. The dip of beds shown is adjusted for vertical exaggeration and is shown as an apparent dip along line of section. Specific correlation of coalbeds is described in the coal resources narrative.

TABLE 6

ROCK AND/OR SOIL MATERIAL HARDNESS AND COHESIVENESS CLASSIFICATION FOR USE IN GEOLOGIC LOGS

Subdivisions 1 through 4 are applicable to soils and the classification follows standard USBR terms for cohesive soils.

1. Very Soft: Full length of thumb can be jammed into in-place materials. Will not support its own weight when saturated; e.g., beach sand or organic swamp muck.

2. Soft: Thumb can be inserted to knuckle, granular materials cursh down completely and easily to individual grains.

3. Firm: In-place material can be thumb printed when moist.

4. Compact: (equals hard in cohesive soils terminology) Cannot be thumb printed. Beginning of cementation. Granular materials can be crushed in fingers, but may contain cemented aggregates difficult or impossible to crush in fingers; includes clay cemented material.

5. Poorly Cemented or Poorly Indurated: Does not break down or soften in water. Very difficult or impossible to crush in fingers, but edges can be scraped or crumbled, and grains rubbed off easily by hand.

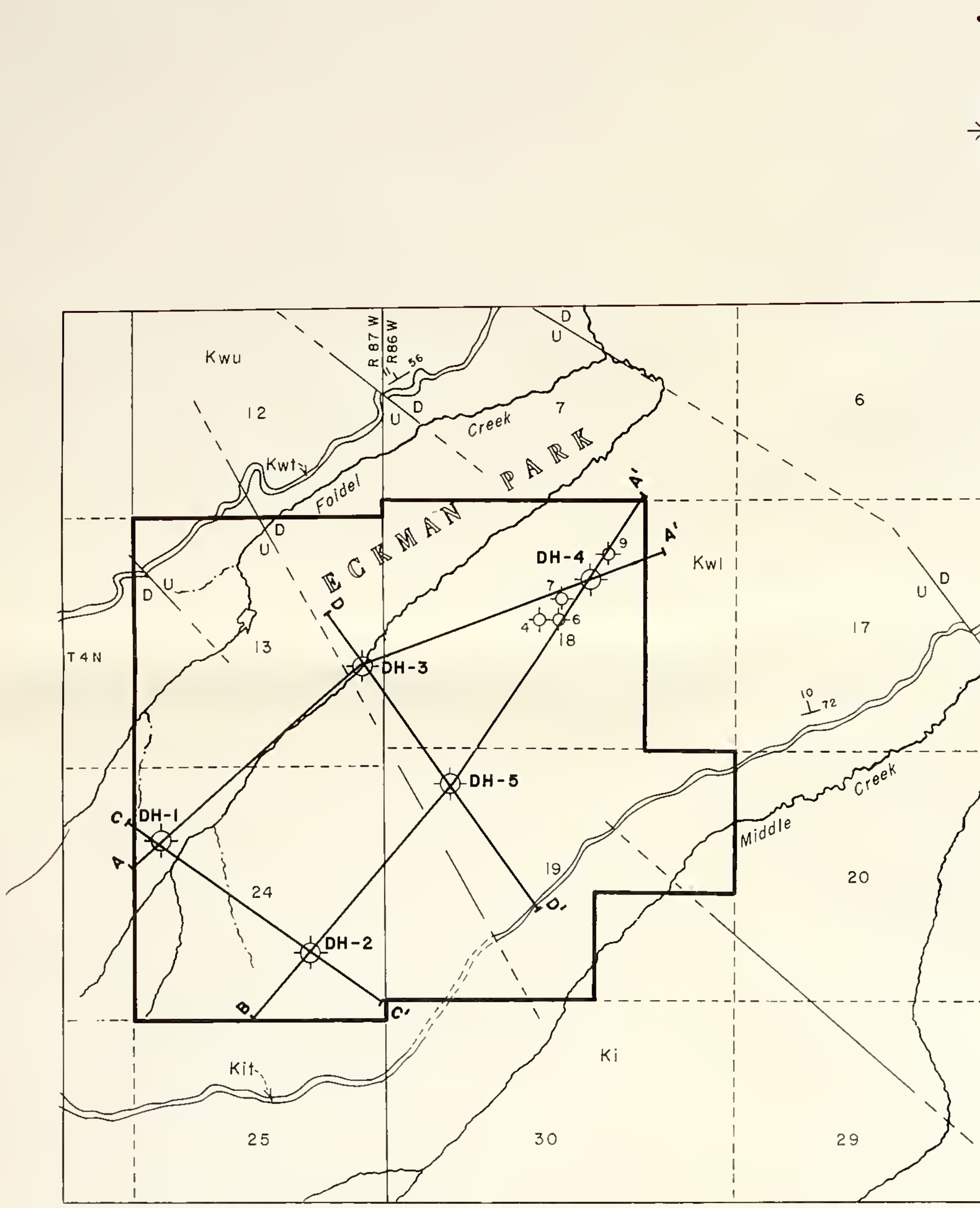
6. Cemented or Indurated: Grains can be scraped off with fingernail or knife blade. One-half inch lumps can be crushed with pliers, and there is a tendency for material to crush to powder. Nx core in 12-inch lengths can be broken in hands.

7. Well Cemented or Well Indurated: Only lumps smaller than 1/2-inch can be broken in pliers. When crushed there is a distinct tendency to break down to angular chips rather than individual grains.

8. Hard: Can be broken down to grains with a hammer, but does not ring.

9. Very Hard: Breaks through grains. Rings when hit with a hammer.

10. Hand specimen cannot be broken with hammer (rare).



EXPLANATION

Mesa Verde Group

Williams Fork Formation

Symbol	Description
Kwu	Kwu. Upper member. Sandstone; interbedded sandstone and mudstone; limestone; silty shale; Fish Creek coal bed.
Kwt	Kwt. Twentymile Sandstone member. Sandstone, gray, massive, cross-bedded in places.
Kwm	Kwm. Marine Shale member.
Kwl	Kwl. Lower member. Sandstones, silty sandstones, siltstones, shale, coal. Wadge and Wolf Creek coal beds.

Iles Formation

Symbol	Description
Kit	Kit. Trout Creek Sandstone member. White to light gray, fine grained, massive.
Ki	Ki. Iles Formation. Sandstone, gray marine; siltstone, gray; lower coal group.

Boundary, EMRIA - FOIDEL CREEK Study Site

Boundary, lithologic units

U / D Fault, dashed where uncertain

10 Strike and dip of beds

DH-1 Location of project drill hole

6 Location of private drill hole

A—A' Line of geologic cross section. See for cross sections A-A', B-B', C-C', D-D'

NOTE: Geology based on: Ryer, Thomas, EMRIA Report No. 6, 1976

2000 0 2000 4000 6000
SCALE OF FEET

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

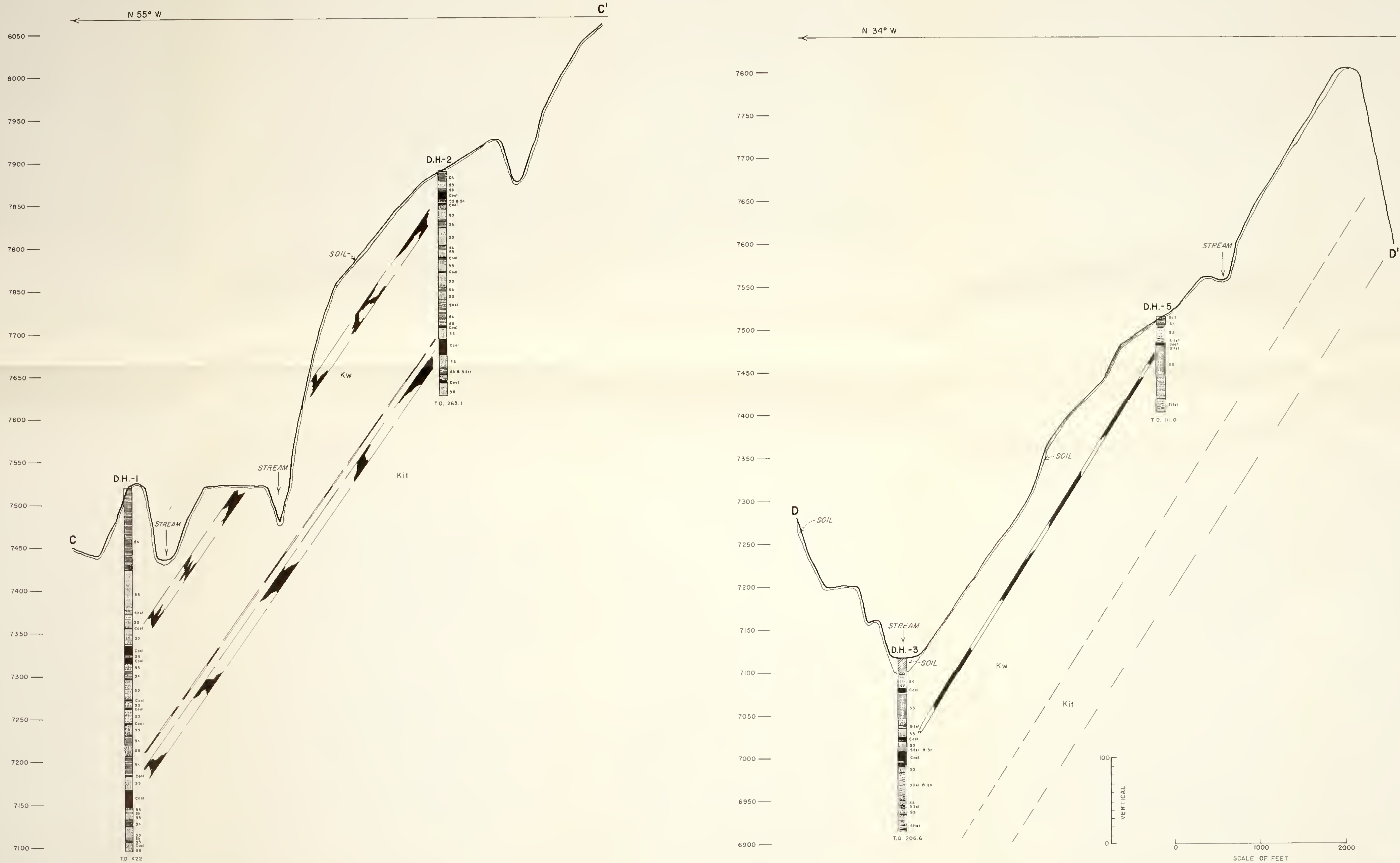
ENERGY MINERAL REHABILITATION INVENTORY AND ANALYSES

FOIDEL CREEK SITE
GEOLOGIC MAP

GEOLOGY	T. RYDER	SUBMITTED	J. TOMPKIN
DRAWN	W. F.	RECOMMENDED	J. TOMPKIN
CHECKED	J. TOMPKIN	APPROVED	[signature]
DENVER, COLORADO	OCT. 7, 1976	PLATE 1	


A
A'
N 48° E
N 70° E
7600
7550
7500
7450
7400
7350
7 00
7250
7200
7150
7100
7050
7000
6950
6900
6850
D.H.-1
D.H-3
D.H.-4
STREAM
STREAM
Soil
Soil
Approximate position of Wolf Creek coal bed
EXPLANATION
Surficial Soil Deposits
Soil Clay and silt, sandy.
Williams Fork Formation, Meso Verde Group. Kw
Sh Shale. Gray to black; clayey; may grade in and out of siltstone; may be calcareous, fossiliferous coaly.
SS Sandstone. White, gray, dark gray; fine-grained; often may be banded with black siltstone and carbonaceous layers. May include 10 % siltstone. Primarily slightly to moderately calcareous. Friable to moderately well-cemented.
Silst Siltstone. Dark gray to black, may be carbonaceous, calcareous. May have sandstone banding and thin coal.
Coal Middle coal group. Includes Wadge and Wolf Creek coal beds.
Trout Creek Sandstone Member, Iles Formation, Meso Verde Group. Ki
SS White to light grey, fine-grained, friable, massive.
Coal beds, estimated line of extension
Water level
Graphic log of drill hole
100
50
0
VERTICAL
0
1000
2000
HORIZONTAL
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES
FOIDEL CREEK SITE
GEOLOGIC CROSS SECTION A-A'
GEOLOGY N.B. SUBMITTED
DRAWN W.E. RECOMMENDED J.T.
CHECKED APPROVED
DENVER, COLORADO OCTOBER 7, 1976
PLATE 2


B
N 38° E
N 33° E
8000
7950
7900
7850
7800
7750
7700
7650
7600
7550
7500
7450
7400
7350
7300
7250
7200
7150
7100
7050
7000
D.H.-2
T.D. 263.1
Stream
Soil
D.H.-5
T.D. 111.0
Stream
Kit
Kw
f
Soil
D.H.-4
T.D. 172.9
B'
EXPLANATION
Surficial Soil Deposits
Soil Clay, weathered shale fragments
Williams Fork Formation, Meso Verde Group. Kw
SS Gray, black and white, white. Fine grained. May be friable; fossiliferous; have siltstone bands. May have coal, carbonaceous banding up to 50 %. No to moderately calcareous.
Sh Gray, black. May be carbonaceous, coaly, spotty calcareous, pyritic, fossiliferous. Clayey, laminated, fissile, or blocky.
Sltst Grey, black. Massive or banded with sandstone. Slighty to highly calcareous. May be carbonaceous, coaly.
Coal Middle coal group. Includes Wadge and Wolf Creek coal beds.
Trout Creek Sandstone Member, Iles Formation, Mesa Verde Group. Kit
SS White, dark gray, fine-grained, massive. Non to moderately calcareous, quartz crystals.
Coal beds, estimated line of extension
f Fault
Water level
Graphic log of drill hole
100
50
0
VERTICAL
0
1000
2000
HORIZONTAL
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES
FOIDEL CREEK SITE
GEOLOGIC CROSS SECTION B-B'
GEOLOGY N.B. SUBMITTED
DRAWN W.F. RECOMMENDED J.T.
CHECKED J.T. APPROVED
DENVER, COLORADO OCTOBER 7, 1976
PLATE 3



EXPLANATION

Soil	Surficial Soil Deposits
	Clay and silt, sandy.
	Williams Fork Formation, Meso Verde Group, Kw
SS	Gray, fine grained. Dark carbonaceous banding. Slightly to highly calcareous.
Sh	Grey to black, fossiliferous, grades in and out of siltstone, coal, sandstone.
Sltst	Dark gray to black. May be carbonaceous, calcareous. Interbedded with shale, sandstone, coal.
Coal	Middle coal group. Includes Wadge and Wolf Creek coal beds
Trout Creek Sandstone Member,	
	Iles Formation, Meso Verde Group, Kit
SS	White to lt grey. Fine grained, massive
	Coal Beds, estimated line of extension.
	Water level
	Graphic log of drill hole

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ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

FOIDEL CREEK SITE

GEOLOGIC CROSS SECTIONS C-C' & D-D'

GEOLOGY N.B. SUBMITTED
DRAWN W.F. RECOMMENDED J. TOMPKIN
CHECKED J. TOMPKIN APPROVED N.B. Bennett III

DENVER, COLORADO OCTOBER 7, 1976 PLATE 4

Engineering Geology and Physical Properties

The primary engineering geology problem of the EMRIA site is one of slope stability. The steeper the coal mining company can make the highwalls, the less excavation there will be and the effects in the environment will be reduced. However, steep slopes in the type of material present in the study site are often unstable. The sandstones are quite capable of standing on 1/2:1 slopes. The shales, however, are unstable at this great of an angle. Even a thin shale layer suffers from the process of desiccation. As the shale dries from air exposure, individual pieces fall off, aided by gravity, water, or wind. As the process continues, the overlying sandstone unit eventually becomes undercut and joint blocks fall. On a permanent cut, this would continue until the shale reaches stability at about a 1-1/2:1 slope. Designing a mine with the shales sloped at 1-1/2:1 and the sandstones and siltstones sloped at 1/2:1 could result in about an additional 960-ft^2 section being removed for every 100 vertical ft. This also means there would be an additional width of 25 ft at the top of a 100-ft cut, assuming that shale constitutes 25 percent of the sandstone-siltstone-shale combination.

In the case of a strip mine, the slopes would be temporary and provided that backfilling takes place shortly after excavation, steeper slopes may be used. Therefore, it is recommended that slopes of 1/2:1 to 3/4:1 be used and the pits backfilled with the removed overburden within 4 months following excavation. The fewer "wetting-drying" cycles the shales are subjected to, the more stable the slopes will be.

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View from drill hole, DH-1, looking northwesterly to the "Twentymile Sandstone" cliffs. White pipe on right side of photo was the type installed in all the drill holes for future water table observations.

General view of aspen grove in which drill hole, DH-2, was located.

Drillers removing core from core barrel on drill hole, DH-3.

View of drill rig on drill hole, DH-3. This hole sets in the bottom of a canyon and encountered artesian water.

View from drill hole, DH-4, looking northerly. White-colored cliffs are the "Twentymile Sandstone." Note the offset in the cliffs caused by faulting.

View from drill hole, DH-5, looking northeast toward Pinnacle Rock.

COAL

Introduction

This coal section describes the geology and coal resources of Upper Cretaceous rocks in a 134-km2 area located near the south-eastern margin of the Yampa coalfield in south-central Routt County, Colorado. The mapped area (fig. 4) includes parts of the Rattlesnake Butte and Dunckley 7.5-minute quadrangles, and is located approximately 27 km southwest of Steamboat Springs, the largest town in Routt County. Geologic study and mapping of the Foidel Creek area was undertaken in connection with BLM's evaluation of the reclamation potential of the Foidel Creek EMRIA site--an area of about 10.9 km^2 located in the southwestern part of the Foidel Creek area. The Foidel Creek EMRIA Reclamation Study Site is situated on the south slope of Eckman Park, which is developed upon gently northward-dipping strata of the lower coal-bearing member of the Williams Fork Formation. The Wadge coalbed may be strip mined beneath large areas of the south slope of Eckman Park and is presently being mined at the Energy Fuels Corporation's Energy Strip No. 1 mine, the largest producing mine in the State of Colorado in 1975. The Foidel Creek area includes the entire south slope of Eckman Park and areas of more steeply-dipping strata to the east and west.

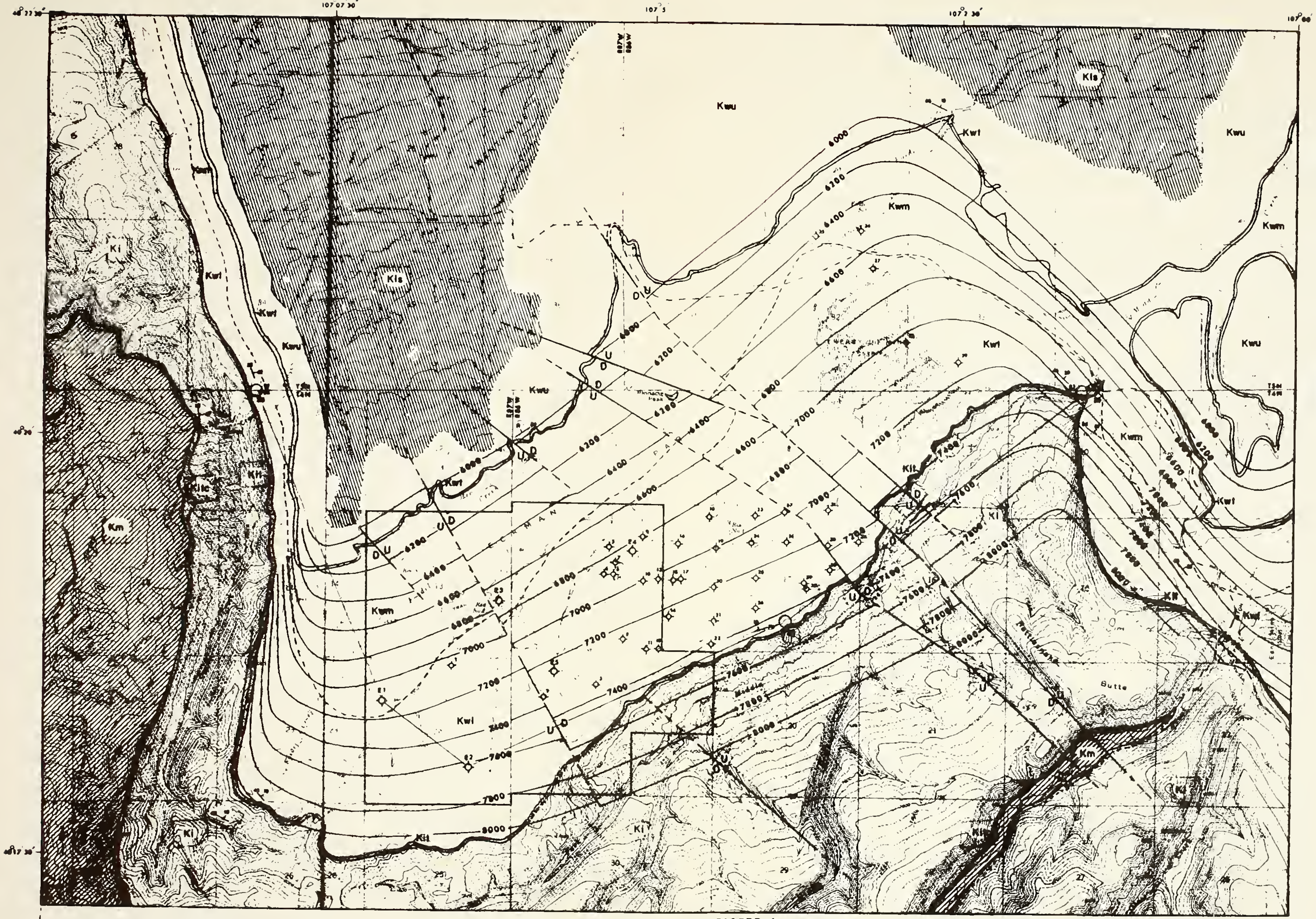
Particular attention has been focused in this study upon coal of the lower coal-bearing member of the Williams Fork Formation (middle coal group of the Yampa coalfield). Drill and core hole data including data from the five EMRIA core holes and drill hole data kindly provided by W. T. Davis, Vice President of Exploration, Energy Fuels Corporation, have been used to estimate the coal resources of the Wadge and Wolf Creek coalbeds in the Foidel Creek area. The coal resources of the lower and upper coal groups of the Yampa coalfield, which are also present in the area, have not been determined.

Paleogeography and Paleoenvironmental Setting

Sediments of the Mesaverde Group of northwestern Colorado, the lithostratigraphic unit of primary interest in the Foidel Creek area, accumulated some 75 million years ago (Gill and Cobban, 1966, p. A35) in offshore-marine, shallow-marine, and marginal-marine depositional environments close to the western edge of an epeiric seaway which occupied the Western Interior of North America during latest Early Cretaceous and most of Late Cretaceous time (Reeside, 1957; McGookey, 1975). Deformation produced by the Laramide orogeny and subsequent erosion have resulted in removal of Cretaceous rocks from much of the Rocky Mountain area. Cretaceous rocks are presently confined to a series of isolated structural basins. One such basin, the Washakie-Sand Wash basin of the Green River Region, contains the Yampa coalfield and the Foidel Creek area.

OPEN-FILE REPORT 77-303

THIS MAP IS PRELIMINARY AND HAS NOT BEEN EDITED OR REVIEWED FOR CONFORMITY WITH U.S. GEOLOGICAL SURVEY STANDARDS AND NOMENCLATURE.



EXPLANATION

Kls — LEWIS SHALE

WILLIAMS FORK FORMATION
Kwu, UPPER MEMBER
Kwt, TWENTYMILE SANDSTONE MEMBER
Kwm, MARINE SHALE MEMBER
Kwl, LOWER COAL-BEARING MEMBER

ILES FORMATION
Kit, TROUT CREEK SANDSTONE MEMBER
Kitc, TOW CREEK SANDSTONE MEMBER

Km — MANCOS SHALE

FAULT -- DASHED WHERE APPROXIMATELY LOCATED. U, UPTHROWN SIDE; D, DOWNTHROWN SIDE

EMRIA CORE HOLE

OTHER DRILL HOLE

MEASURED SURFACE SECTION

STRIKE AND DIP OF BEDS

STRUCTURAL CONTOUR, INTERVAL 200 FEET; DRAWN ON THE TOP OF THE TROUT CREEK SANDSTONE MEMBER OF THE ILES FORMATION

0 .5 1.0 MILE

0 5000 FEET

0 .5 1.0 KILOMETER

SECTION X-Y SHOWN ON FIGURE 9

BASE FROM U.S. GEOLOGICAL SURVEY RATTLESNAKE BUTTE AND BUCKLEY QUADRANGLES (1971)

FIGURE 4

UPPER CRETACEOUS BEDROCK GEOLOGY OF THE FOIDEL CREEK EMRIA SITE AND SURROUNDING AREA RATTLESNAKE BUTTE AND BUCKLEY QUADRANGLES ROUTT COUNTY, COLORADO

GEOLOGY BY THOMAS A. RYER 1976

Structural Setting

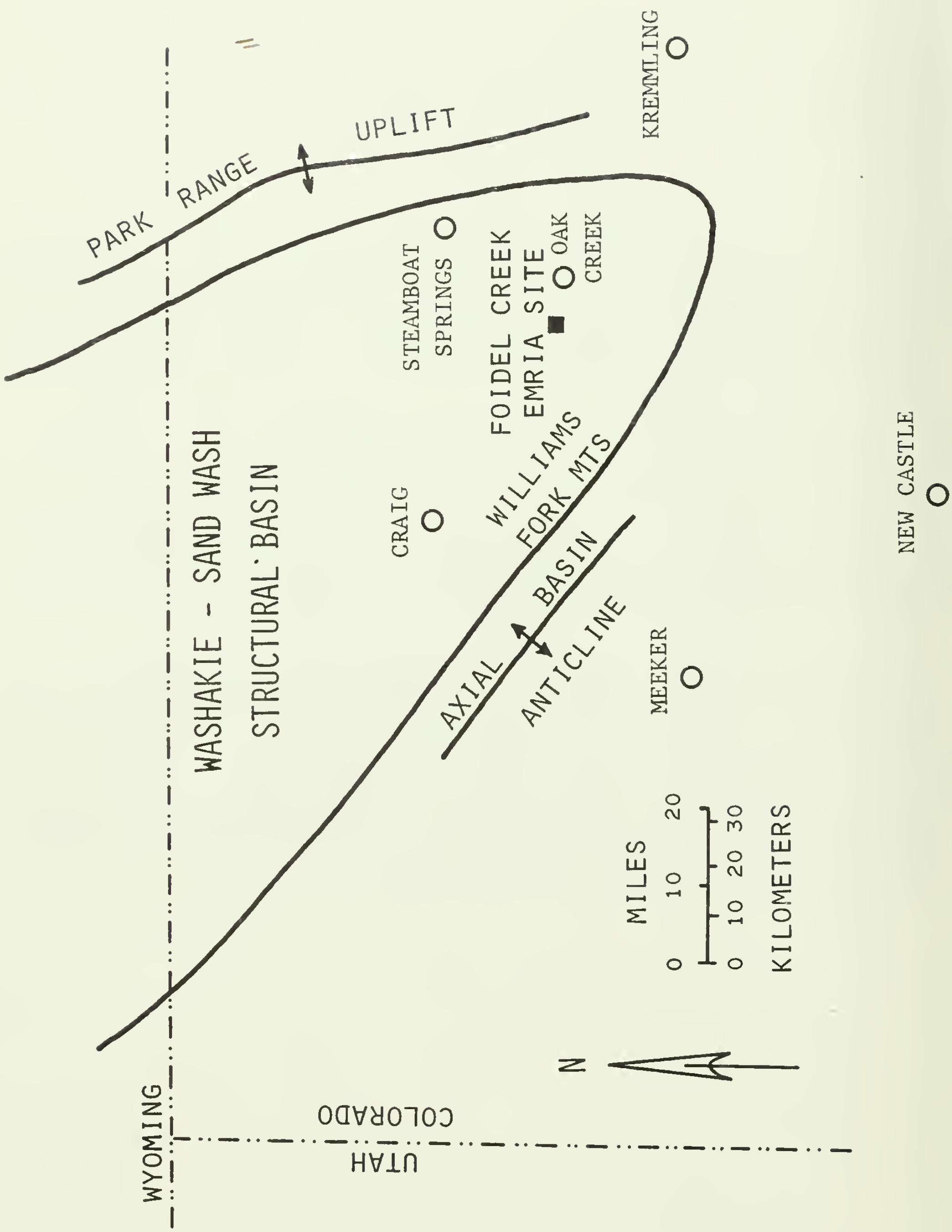
The Yampa coalfield constitutes a southeastward, synclinal extension of the Washakie-Sand Wash structural basin of south-central Wyoming and northwestern Colorado (fig. 5), the major synclinal structure being highly modified by several lesser synclines and anticlines. The field is limited on the east by the Park Range uplift and on the southwest by the Axial Basin anticline.

The Foidel Creek EMRIA Reclamation Study Site occupies the western part of a broad area in which the coal-bearing rocks dip gently to the north. West of this area, the dip steepens and the strike bends abruptly northward along the steeply dipping east flank of the north-south trending Fish Creek anticline. To the east, the dip steepens along the southward extension of the Twentymile Park syncline (figs. 5 and 6).

Stratigraphic Terminology and History of Study

Table 7 presents, in general, the sequence of Cretaceous rocks of northwestern Colorado. Of the stratigraphic units described, only the Mancos Shale, the Mesaverde Group, and the Lewis Shale are exposed in the southeastern part of the Yampa coalfield, in and near the area described here.

The history of previous work, introduction of stratigraphic terminology, and regional stratigraphic relations of Cretaceous rocks in northwestern Colorado are summarized by Bass, Eby, and Campbell (1955), Kucera (1959, 1962), Konishi (1959a, b), Masters (1959), Weimer (1959), and Collins (1976), among others. These topics will not be discussed at length here. The paper by Bass, Eby, and Campbell (1955) remains the most comprehensive work on stratigraphy and coal resources of the Yampa coalfield.



Fiqure 5 - Index Map, Northwestern Colorado

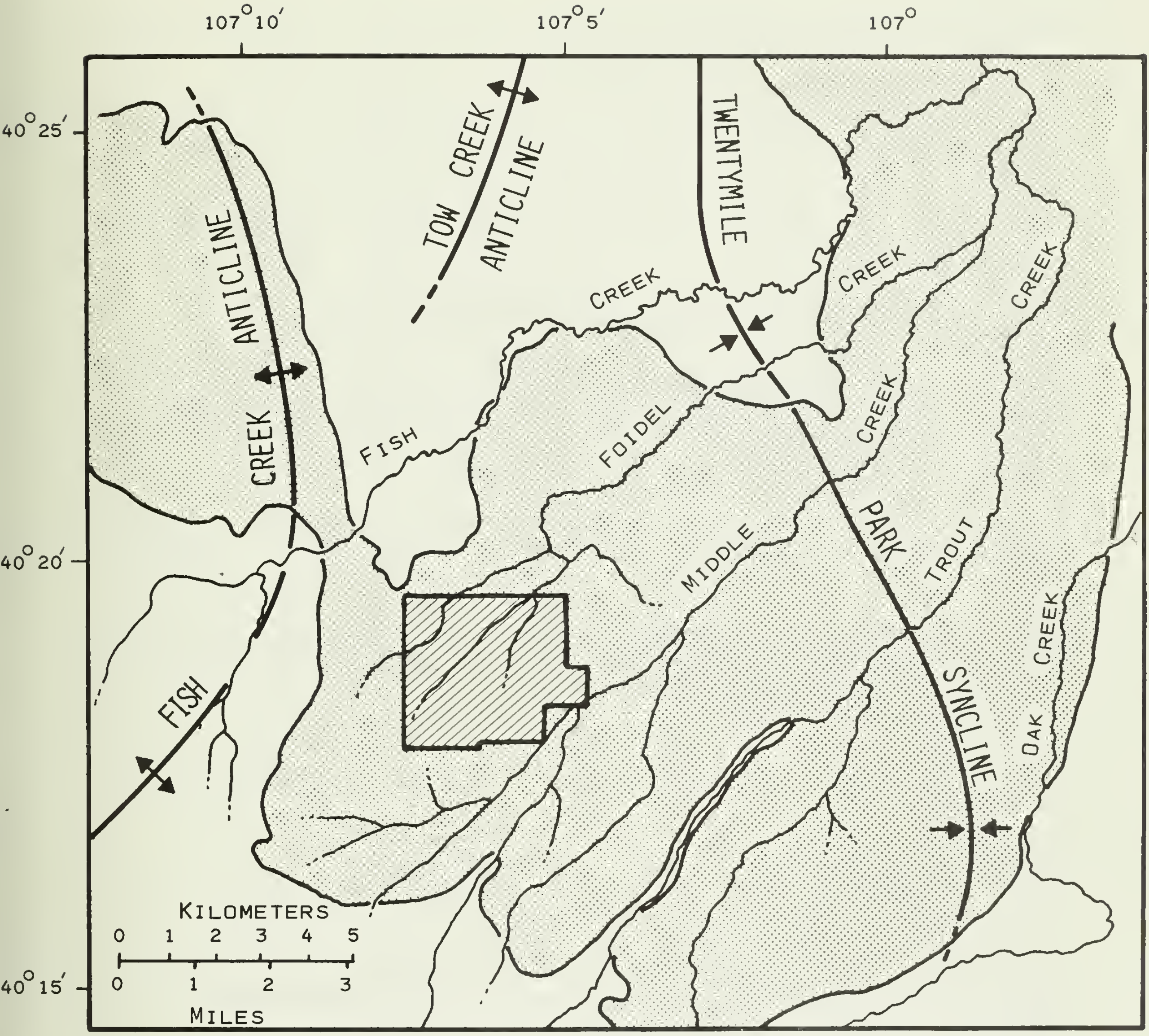


FIGURE 6.--STRUCTURAL SETTING OF THE FOIDEL CREEK EMRIA SITE (DIAGONAL RULING) AND ADJACENT AREAS. OUTCROP AREA OF THE MESAVERDE GROUP IS INDICATED BY STIPPLING.

Table 7.--Cretaceous Stratigraphic Units in Northwestern Colorado (Thicknesses after Bass, Eby, and Campbell (1955) and Kucera (1959)

Upper Cretaceous

Lance Formation. - Predominantly nonmarine sandstone, siltstone, and shale; some coal; a thick unit of marine sandstone (Fox Hills equivalent) at the base of the formation; conformably(?) overlain by the Fort Union Formation of Tertiary (Paleocene) age. Thickness 305 to 457 m.

Lewis Shale. - Dark-gray marine shale. Thickness 579 m.

Mesaverde Group (Williams Fork and Iles Formations). - Marine and marginal-marine sandstone, siltstone, and shale; numerous beds of coal; characterized by thick, laterally persistent, ledge-forming units of marine sandstone. Thickness 823 m.

Mancos Shale. - Dark-gray marine shale with several units of resistant marine sandstone in the upper 213 to 274 m. Thickness 913 m.

Niobrara Formation. - Predominantly medium- to light-gray, calcareous marine shale with associated limestone, siltstone, gypsum, and bentonite. Thickness 183 to 274 m.

Frontier Formation. - Dark-gray, silty marine shale with a thick unit of fossiliferous marine sandstone at the top. Thickness 82 to 113 m.

Lower Cretaceous

Mowry Shale. - Black, splintery, siliceous shale bearing teleost fish scales. Thickness 38 to 61 m.

Dakota Sandstone. - Marine, marginal-marine, and nonmarine sandstone, siltstone, shale, and conglomerate; unconformably overlies the Morrison Formation of Jurassic age. Thickness 27 to 50 m.

Stratigraphy of the Mesaverde Group in the Foidel Creek Area

The Foidel Creek EMRIA Reclamation Study Site is situated entirely within the outcrop belt of the Mesaverde Group, which consists of two formations of approximately equal thickness--the Iles Formation below, and the Williams Fork Formation above. The top of the Trout Creek Sandstone Member of the Iles is a readily mapped datum used to define the contact between the two formations (Hancock, 1925, p. 14).

Iles Formation

The Iles Formation is approximately 427 m thick and crops out in the southeastern and westernmost parts of the area mapped in this study. The formation may be conveniently divided into a lower and an upper part (fig. 7). The lower part of the formation is about 274 m thick. It contains four or five prominently exposed, thick, cliff-forming units of marine sandstone which form flatiron-shaped ridges in the rugged country south of Fish Creek Canyon. These sandstones are well exposed along the north side of the valley of Trout Creek. They include, in ascending order the Tow Creek Sandstone Member, the double ledge sandstone, and the Oak Creek Sandstone. The upper part of the formation, 152 m thick, is composed primarily of nonresistent, gray siltstone rarely seen in natural exposures. This thick siltstone unit weathers to form a steep-sided valley both north and south of Fish Creek Canyon and underlies the floor and much of the north slope of the Middle Creek valley. At the top of the Iles Formation is the cliff-forming Trout Creek Sandstone Member.

Tow Creek Sandstone Member

The Tow Creek Sandstone Member of the Iles Formation was named by Crawford, Willson, and Perini (1920) for prominent exposures on the flanks of the Tow Creek anticline where it crosses Yampa River, approximately 18 km north of the Foidel Creek area. The base of the member defines the boundary between the Mancos Shale and the Iles Formation. The contact is gradational; dark-gray shale and silty shale of the Mancos Shale grade upward to, and become interbedded with, silty sandstone and sandstone of the Tow Creek Sandstone Member. The member forms a high ridge along the western boundary of the mapped area. It is overlain by about 110 m of marine shale and silty shale, which form very poor exposures between the prominently exposed Tow Creek Sandstone Member and the double ledge sandstone.

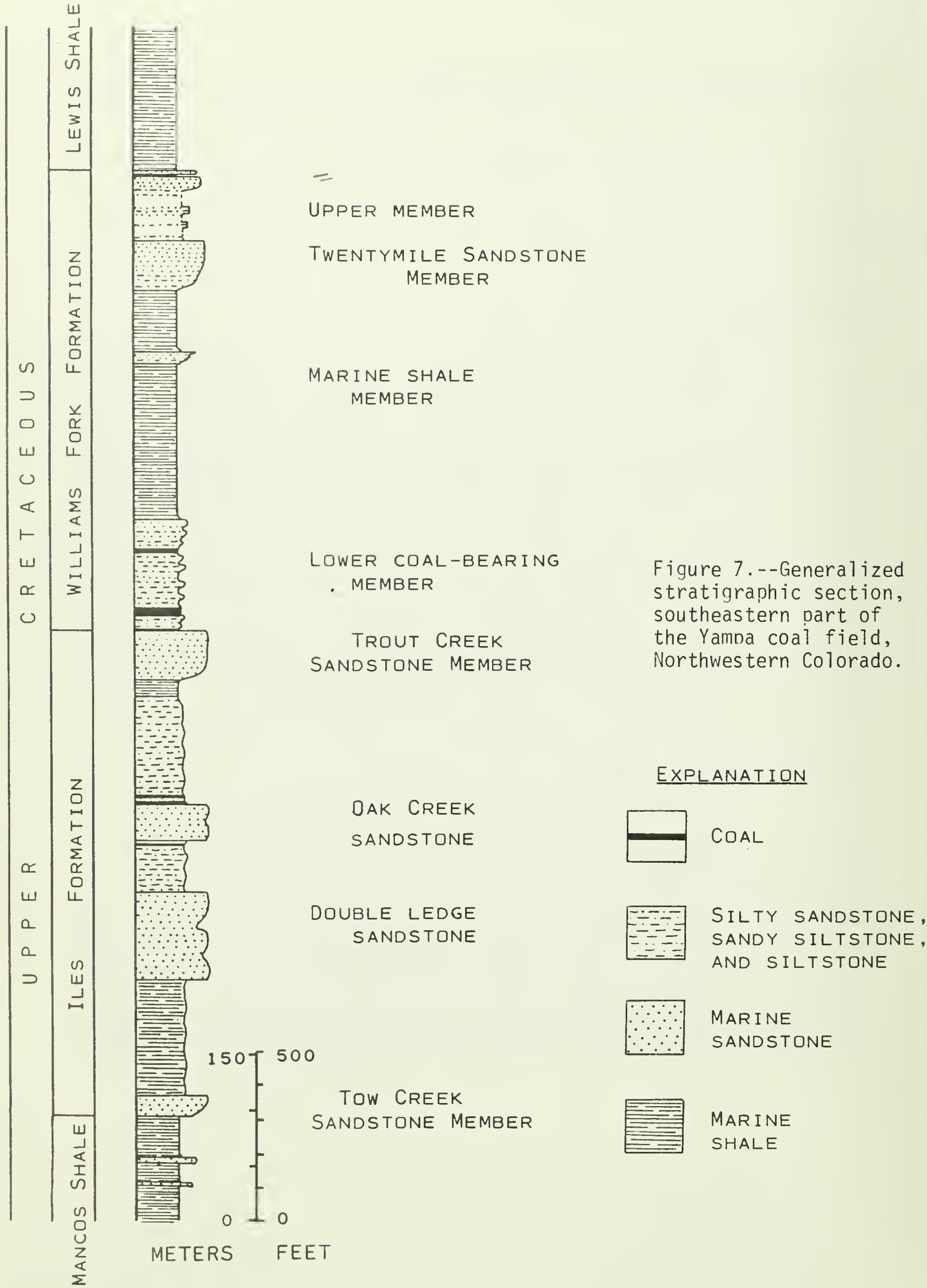


Figure 7.--Generalized stratigraphic section, southeastern part of the Yampa coal field, Northwestern Colorado.

Double Ledge Sandstone

The double ledge sandstone consists of one or more beds of marine sandstone at a level approximately 120 m stratigraphically above the base of the Iles Formation in the southern part of the Yampa coalfield. The unit is represented by a double ledge in the south-facing slopes of the Williams Fork Mountains, 26 km west of the Foidel Creek area, where it was first described and informally named by Bass, Eby, and Campbell (1955, p. 156). Kucera (1959) extended the correlation of the unit to the area just west of the town of Oak Creek. The double ledge sandstone is well exposed on the north side of Fish Creek Canyon, where it is approximately 75 m thick. Izett, Cobban, and Gill (1971, p. A3, A17) tentatively correlate the double ledge sandstone with the Hygiene Sandstone Member of the Pierre Shale near Kremmling, Colorado.

Oak Creek Sandstone of Kucera (1959)

Kucera (1959) applied the name Oak Creek Sandstone to a 30-m thick cliff-forming sandstone unit that crops out along the west side of Oak Creek near Haybro, 10 km east of the Foidel Creek EMRIA Study Site. The unit is associated with coalbeds of the lower coal group throughout the southeastern part of the Yampa coalfield (Bass, Eby, and Campbell, 1955).

The Oak Creek Sandstone is readily identified in the area mapped in this study. It forms a prominent hogback both north and south of Fish Creek Canyon, and is exposed on the north side of the North Fork of Middle Creek and along the west side of Little Middle Creek. The gentle slopes which dip northward into the valley of Middle Creek immediately overlie the top of the Oak Creek Sandstone.

Trout Creek Sandstone Member

The Trout Creek Sandstone Member, at the top of the Iles Formation, is a persistent unit throughout much of northwestern Colorado. It has been traced through the entire area of the Yampa coalfield (Bass, Eby, and Campbell, 1955; Kucera, 1959; Konishi, 1959a) and is recognized as far south as New Castle, in west-central Colorado (Gale, 1910; Hancock, 1925, p. 13-14; Cobban and Reeside, 1952, Cols. 45, 47; Collins, 1976, p. 24). The member was first named by Fenneman and Gale (1906, p. 26) for exposures along Trout Creek, 13 to 16 km northeast of the Foidel Creek area. The Trout Creek Sandstone Member forms a nearly continuous cliff along the north side of the Middle Creek Valley (fig. 8). Outcrop thickness here reaches 25 to 30 m. It is less well exposed along the eastern flank of the Fish Creek anticline. The structural contours on the geologic map (fig. 4) indicate the top of the Trout Creek Sandstone Member.

Figure 8.--Exposures of the cliff-forming Trout Creek Sandstone Member of the Iles Formation along the north side of Middle Creek. The steep slope above the Trout Creek Sandstone is produced by the lower coal-bearing member of the Williams Form formation. The debris covering parts of the slope is from the Energy Strip No. 1 Mine. Cliffs produced by the Twentymile Sandstone Member of the Williams Form Formation in distance at right.

The Trout Creek Sandstone Member is composed of tan to white, moderately hard, fine-grained sandstone. It is easily distinguished from overlying marginal-marine sandstones of the lower coal-bearing member of the Williams Fork Formation in cores recovered from drill holes in the Foidel Creek area by its coarser texture and by the presence of sand-sized grains of dark chert in the Trout Creek. In several of the natural exposures, the member shows a tendency towards upward coarsening of grain size. The trace fossil *Ophiomorpha* is locally abundant in the lower part of the member. Trough crossbedding and planar lamination are present, but these and other sedimentary structures are generally poorly displayed.

Izett, Cobban, and Gill (1971, p. A17) identified a sequence of marine shale beneath the Trout Creek Sandstone Member at a locality 10 km southeast of the Foidel Creek area. No exposures of the marine shale could be found in the mapped area, but it is presumably present in the steep, debris-covered slopes beneath the cliff formed by the Trout Creek Sandstone Member.

Williams Fork Formation

The Williams Fork Formation is exposed in a broad belt which trends from southwest to northeast across the center of the mapped area. The formation is approximately 400 m thick and is here divided into four members: a lower coal-bearing member; a marine shale member composed of dark-gray shale, silty shale, and siltstone; the Twentymile Sandstone Member; and an upper member. The Williams Fork Formation contains only one thick unit of resistant marine sandstone--the Twentymile Sandstone Member--and therefore, tends to form more subdued topography than does the generally more resistant Iles Formation.

Lower Coal-bearing Member

The Trout Creek Sandstone Member of the Iles Formation is conformably overlain by approximately 100 m of strata deposited in a marginal-marine environment. The contact is sharp, the top of the Trout Creek Sandstone Member being overlain by about 0.3 m of carbonaceous sandstone or coal at all exposures where it was examined and in EMRIA deep core holes No. FC-1 and FC-2.

The lower coal-bearing member is moderately resistant and forms a steep slope above the cliff formed by the Trout Creek Sandstone Member in the north slope of the Middle Creek Valley (fig. 8). The gentle slope which dips northward into Eckman Park, south of Foidel Creek, is formed upon resistant strata in the upper part of the member. Both the Foidel Creek EMRIA Reclamation Study Site and the Energy Fuels Corporation's Energy Strip Mine No. 1 are situated on this dip slope.

The predominant sediment type of the lower coal-bearing member is medium-gray to dark-gray siltstone. Very fine grained, tan to gray sandstone and silty sandstone are present at numerous levels, shale and carbonaceous shale being subordinate rock types. The member contains many beds of coal belonging to the middle coal group of the Yampa coalfield. Of these, the Wolf Creek and Wadge coalbeds are the thickest and laterally most persistent (fig. 9).

Sandstone, silty sandstone, and sandy siltstone of the lower coal-bearing member display symmetric, long-crested ripples and ripple-drift lamination at most exposures. Generally, however, the laminae are disrupted. Lamination planes, which are largely defined in this interval by concentrations of dark, carbonaceous material, are highly contorted and are penetrated by tubular structures, many of which probably represent infilling of cavities produced by the roots of plants. Others may record the burrowing activities of invertebrate organisms. Coarser sediments of the member frequently contain impressions of large fragments of deciduous plants. Fossils of the brackish-water bivalves Corbula perundata and Crassostrea spp. were encouraged at several localities.

Marine Shale Member

The Williams Fork Formation contains a thick unit of marine shale in the southeastern part of the Yampa coalfield. Because of poor exposure, the thickness of the marine shale member could not be measured directly. It is estimated, however, to be about 200 m thick in the area northeast of the Foidel Creek EMRIA Study Site. The member underlies much of the northern slope of Foidel Creek Canyon, where it forms rubble-strewn slopes beneath cliffs produced by the Twentymile Sandstone Member. It is best exposed in the eastern part of the mapped area in a series of roadcuts along the county road between the crossings of Trout and Middle Creeks. The unit is also exposed in railroad cuts on the west slope of Pinnacle Peak and northeast of the old Foidel school.

The marine shale member is composed of homogeneous, essentially non-fissile, dark-gray to dark-tan shale and silty shale with occasional interbeds of tan siltstone. Marine invertebrate fossils collected by J. R. Gill from this unit near the eastern edge of the mapped area (sec. 14, T. 4 N., R. 86 W.) and identified by W. A. Cobban indicate that the unit is of Late Campanian age (Range Zone of Baculites reesidei).

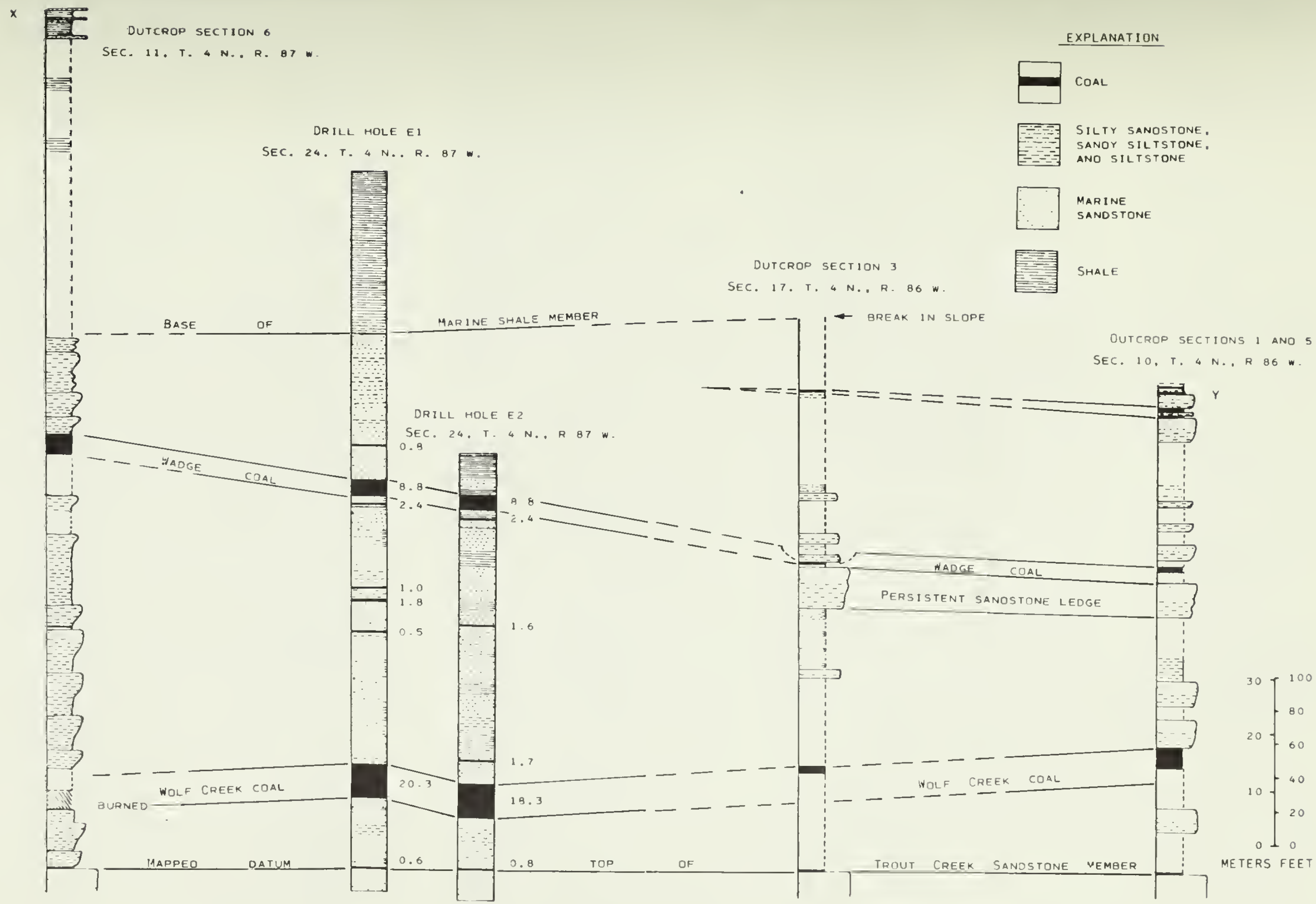


Figure 9 East-west geologic cross section X-Y, lower coal-bearing member of the Williams Fork Formation, Foidel Creek area. Location of the cross section is shown on figure 4. Numbers to the right of the core-hole sections are thicknesses of coal beds, in feet.

The contact of the marine shale member with the overlying Twentymile Sandstone Member is gradational. The marine shale becomes increasingly silty upward, grading to silty shale and siltstone, which becomes interbedded with planar-laminated silty sandstone and sandstone. The beds of sandstone become thicker and more closely spaced as the base of the Twentymile Sandstone Member is approached. The contact is drawn at the level where sandstone beds predominate over those of siltstone and shale.

Twentymile Sandstone Member

The Twentymile Sandstone Member of the Williams Fork Formation was named by Fenneman and Gale (1906, p. 27) for exposures "in and around Twentymile Park," a part of which is included in the northeastern part of the mapped area. The outcrop thickness of the member is 36 m in the area north of the old Foidel school. The lower 20 m, as exposed here, consists of thoroughly bioturbated, tan, very fine-grained sandstone which displays only very poorly defined, thick bedding. The upper 15 m consists of very fine to fine-grained, light-tan sandstone with chert grains, and displays trough cross-bedding and planar lamination. Bioturbation of sediment comprising the upper part of the member was less intense than that of the lower part.

Upper member

The upper member of the Williams Fork Formation is approximately 60 m thick in the area north of the old Foidel school. Exposures of the member in the Foidel Creek area are generally poor and a complete section could not be measured. The contact with the Twentymile Sandstone Member is sharp and is overlain by several centimeters of silty, sandy, carbonaceous shale and coal which is, in turn, overlain by at least 4.5 m of fine-grained tan sandstone irregularly interbedded with gray siltstone containing chips of dark-gray silty shale.

Most of the member is composed of light-gray to tan, silty, very fine-grained laminated sandstone interbedded with medium to dark gray, homogeneous to laminated siltstone. Lamination planes in both the sandstone and siltstone are covered with very finely divided plant debris. A variety of trace fossils are present in the sandstones.

Near the top of the member is a unit of fine-grained, very light tan to white sandstone containing grains of chert and thus resembling, both in texture and composition, shallow-marine sandstone units found lower in the section. The base of the unit is not exposed. Outcrop thickness is 1.8 m. The sandstone unit is overlain by a covered interval 3.0 m thick in which several prospect pits have been dug for coal of the Fish Creek coalbed. Bass, Eby, and Campbell (1955, pl. 23) indicate that the Fish Creek bed is approximately 1.2 m thick in the area north of the old Foidel school. The coal-bearing interval is overlain by 1.8 m of very fine-grained tan sandstone that contains casts of brackish-water bivalves. This unit is overlain by the Lewis Shale and thus marks the top of the Williams Fork Formation in this area.

COAL IN THE FOIDEL CREEK AREA

Stratigraphic Distribution and Production

Lower, middle, and upper coal groups are recognized in the Mesaverde Group of the Yampa coalfield (Bass, Eby, and Campbell, 1955). Coal is presently being produced from each of the three coal groups within the area mapped in this study.

Lower Coal Group

The lower coal group includes coalbeds in the upper part of the Iles Formation. These are best developed in the vicinity of the town of Oak Creek, 5.6 km southeast of the mapped area. Mining of lower coal group coals in the Oak Creek area began in 1906, the year that the Moffat Road of the Denver and Rio Grande Western Railroad first provided a rail connection with Denver (Campbell, 1923). Within the mapped area, a coalbed belonging to the lower coal group is presently being mined underground at the Apex No. 1 mine, on the north side of Trout Creek (sec. 22, T. 4 N., R. 86 W.). Coal from the Apex mine is sold for local consumption. Production in 1975 totaled 16 780 metric tons (Colorado Division of Mines, 1976).

Middle Coal Group

The middle coal group includes coalbeds that occur between the Trout Creek Sandstone Member of the Iles Formation and the Twentymile Sandstone Member of the Williams Fork Formation. In the southeastern part of the Yampa coalfield, coalbeds are restricted to the lowermost 90 m of this interval. The Wadge and Wolf Creek beds are the thickest and most continuous of the coalbeds. The stratigraphic position of these beds are shown in geologic cross section X-Y (fig. 9).

Wolf Creek bed. - The base of the Wolf Creek coalbed is situated approximately 6 to 15 m stratigraphically above the top of the Trout Creek Sandstone Member. Though it locally reaches thicknesses of 6.1 m, the Wolf Creek bed is highly irregular in thickness and locally contains thick partings of claystone. It was penetrated by EMRIA core holes 1 and 2 (FC-1 and FC-2) and by two holes drilled by the Energy Fuels Corporation in the area just east of the Foidel Creek EMRIA Study Site.

The maximum (6.2 m) and minimum (1.2 m) thicknesses encountered occur in EMRIA core hole No. 1 and other drill hole No. 20, respectively. These two holes are only 3.9 km apart. Marked variation in thickness over relatively short distances is characteristic of the Wolf Creek bed elsewhere in the Yampa coalfield (Bass, Eby, and Campbell, 1955). The Wolf Creek bed is not now being mined in the Foidel Creek area.

Wadge bed. - The Wadge coalbed, which occurs approximately 60 m stratigraphically above the top of the Trout Creek Sandstone Member, is the most uniform in thickness of the coalbeds in the middle coal group and has been mined and prospected at numerous localities (Bass, Eby, and Campbell, 1955). The Wadge coalbed has an average thickness of 2.8 m in the drill holes shown on the geologic map (figure 4), and attains a maximum reported thickness of 4.0 m (table 8). It is presently being mined at the Energy Fuels Corporation's Energy Strip Mine No. 1 (thickness 2.7 m), just east of the Foidel Creek EMRIA Study Site, and at the Pittsburgh and Midway Coal Mining Company's Edna strip mine (thickness 1.8 m), near the east margin of the mapped area (Colorado Division of Mines, 1976). Total production for 1975 from the Energy Strip No. 1 mine was 1.12 million metric tons. Cumulative production to January 1, 1976, totaled 7.38 million metric tons (Jones and Murray, 1976; Colorado Division of Mines, 1976).

Lennox bed. - The Lennox coalbed occurs near the top of the lower coal-bearing member of the Williams Fork Formation. According to Bass, Eby, and Campbell (1955, p. 173), it is 0.9 to 1.2 m thick at most places. It is 1.2 to 1.5 m thick at the Edna strip mine where it has been mined along with the Wadge bed (Hayes, 1966). The Lennox bed cannot be recognized with certainty in drill holes within the mapped area. A number of lenticular coalbeds ranging from 0.5 to about 1.8 m in thickness have been encountered at approximately the stratigraphic level of the Lennox bed.

Upper Coal Group

The upper coal group of the Yampa coalfield consists of coalbeds overlying the Twentymile Sandstone Member. The upper coal group contains only one economically important coalbed--the Fish Creek bed--in the Foidel Creek area. The Fish Creek bed is presently being mined in the Energy Strip Mine No. 1 , where the bed is 1.4 m thick (Jones and Murray, 1976). The mine is operated by the Energy Fuels Corporation and is located in secs. 19, 25, and 30, T. 5 N., R. 87 W., (mine not shown on the geologic map, fig. 4). Total production in 1975 was 0.76 million metric tons. Cumulative production to January 1, 1976, amounts to 1.47 million metric tons.

Table 8--Elevation, depth, and thickness, in feet, of Lennox, Wadge, and Wolf Creek coal beds in 44 drill holes in the Foidel Creek area. Location of drill holes is shown on fig. 1

[Metric conversion: 1 foot = 0.305 meter]

Drill hole number	Surface elevation	Lennox coal 1/			Wadge coal			Wolf Creek coal		
		Elevation	Depth	Thickness	Elevation	Depth	Thickness	Elevation	Depth	Thickness
1	7350	-	-	-	7272	78	8.5	-	-	-
2	7650	7635	15	0.5	7550	100	8.0	-	-	-
3	7680	-	-	-	7604	76	12.0	-	-	-
4	7220	-	-	-	7140	80	0.5	-	-	-
5	7097	7087	10	2.9	6997	100	10.0	-	-	-
6	7218	-	-	0	7115	103	10.6	-	-	-
7	7180	7093	87	2.7	-	-	-	-	-	-
8	7580	-	-	-	7500	80	11.5	-	-	-
9	7178	-	-	0	7081	97	10.6	-	-	-
10	7290	-	-	-	7227	63	10.3	-	-	-
11	7608	7573	35	1.8	7498	110	10.7	-	-	-
12	7600	-	-	-	7535	66	10.3	-	-	-
13	7292	-	-	-	7252	40	10.9	-	-	-
14	7439	-	-	-	-	-	0	-	-	-
15	7326	-	-	-	7286	40	- 2/	-	-	-
16	7229	-	-	-	7173	56	10.1	6859	238	6.5
17	7368	-	-	-	7311	57	10.6	-	-	-
18	7190	7179	11	2.0	7110	80	13.0	-	-	-
19	7324	-	-	0	7242	82	10.4	-	-	-
20	7486	-	-	-	7427	59	10.3	7292	194	4.0
21	7635	-	-	-	7568	67	10.5	-	-	-
22	7709	-	-	-	7659	50	10.3	-	-	-
23	7236	7230	6	5.4	7155	81	10.6	-	-	-
24	7376	-	-	-	7318	58	10.2	-	-	-
25	7513	-	-	-	7466	47	10.3	-	-	-
26	7666	-	-	0	7591	75	10.0	-	-	-
27	7289	-	-	-	7222	67	11.0	-	-	-
28	7431	-	-	-	7369	62	9.4	-	-	-
29	7654	-	-	-	7595	59	9.4	-	-	-
30	7681	-	-	-	7628	53	10.0	-	-	-
31	7372	-	-	0	7290	82	10.3	-	-	-
32	7486	-	-	0	7412	74	10.2	-	-	-
33	7615	-	-	-	7561	54	7.3	-	-	-
34	7510	-	-	-	7480	30	10.3	-	-	-
35	6840	6713	127	2.5	6652	188	10.0	-	-	-
36	6840	6785	55	1.3	6726	114	9.5	-	-	-
37	6960	-	-	-	6930	30	8.1	-	-	-
38	7280	-	-	-	7245	35	7.3	-	-	-
39	7460	-	-	-	7418	42	6.8	-	-	-
E1	7520	-	-	0	7338	182	8.8	7170	350	20.3
E2	7890	-	-	-	7867	23	8.8	7694	196	18.3
E3	7117	7085	32	5.9	7010	107	9.1	-	-	-
E4	7160	-	-	-	7072	88	10.6	-	-	-
E5	7515	7485	-	-	-	-	-	-	-	-

1/ The Lennox coal is not a laterally continuous seam, as are the Wadge and Wolf Creek coals. Rather, it is a series of lenticular beds that rise stratigraphically from east to west within the mapped area.

2/ Only the upper part of the coal bed was drilled--thickness undetermined.

Coal Resources of the Foidel Creek Area

Coal resources of the Wolf Creek and Wadge beds have been calculated for the Foidel Creek EMRIA Reclamation Study Site and for the entire mapped area (fig. 4). These data are presented in tables 9 and 10.

Because of their lenticularity, coalbeds at the stratigraphic level of the Lennox bed have not been considered in the analysis of coal resources. Resource calculations were performed for each section whose entire coal-bearing area falls within the boundaries of the geologic map. Sections along the margins of the map were lumped for resource analysis. Coal has been separated into five overburden categories (0-30 m; 30-61 m; 61-305 m; 305-610 m; >610 m) and, within these categories, into "demonstrated" and "inferred" coal resources. "Demonstrated" coal occurs within a distance of 1.21 km from points of observation (drill and core holes, mines, outcrops). "Inferred" coal occurs in a belt extending 3.62 km from points of observation (Bureau of Mines and Geological Survey, 1976).

Wolf Creek Bed

The Foidel Creek EMRIA Reclamation Study Site is estimated to contain 49.7 million metric tons of Wolf Creek coal. Of this amount, only about 11.8 million metric tons occur beneath overburden of 61 m or less. Overburden thickness is less than 30 m only beneath the steep slopes immediately above the cliff formed by the Trout Creek Sandstone Member. The mapped area is estimated to contain a total of 434 million metric tons of Wolf Creek coal.

Wadge Bed

The Wadge bed in the Foidel Creek EMRIA Study Site contains approximately 36.1 million metric tons of coal. Of this amount 28.1 million metric tons occurs beneath overburden thicknesses of 61 m or less, and all but 2.0 million metric tons is classified as demonstrated. Total Wadge coal within the mapped area is estimated to be 317 million metric tons.

ANALYSES OF COAL FROM THE FOIDEL CREEK AREA

Thirteen coal samples from the core holes in the Foidel Creek EMRIA Reclamation Study Site were submitted to the Bureau of Mines, Pittsburgh, Pennsylvania, for proximate, ultimate, Btu, and forms-of-sulfur analyses; and to the Geological Survey, Denver, Colorado, for minor and trace element analyses. The complete analyses of these samples and information relating the samples to the EMRIA core holes are presented in tables 11, 12, 13, and 14. Two samples are from a

Table 9.--Estimated coal resources, in short tons, of the Wolf Creek coal bed in the Foidel Creek area, recorded by section, overburden thickness, and degree of geologic assurance.

[D=demonstrated; I=inferred; !=very small amount, included in 100-200 feet overburden thickness category; *=very small amount, included in 200-1,000 feet overburden thickness category; metric conversions: 1 foot = 0.305 meter; 1 short ton = 0.907 metric ton; [EMRIA] indicates areas that are included in the Foidel Creek EMRIA reclamation study site.]

Township and range	Section	Thickness of overburden, in feet										Total
		0-100		100-200		200-1000		1000-2000		2000		
		D	I	D	I	D	I	D	I	D	I	
T. 5 N. R. 86 W.	27	-	-	-	-	-	-	-	16.9	-	0.9	17.8
	28	-	-	-	-	-	4.9	-	13.2	-	0.5	18.6
	29	-	-	-	-	-	6.3	-	8.5	-	-	14.8
	30	-	-	-	-	-	-	-	13.3	-	-	13.3
	31	-	-	-	-	-	9.2	-	3.7	-	-	12.9
	32	-	-	-	5.3	-	11.0	-	-	-	-	16.3
	33	!	!	4.3	5.8	2.1	8.1	-	1.1	-	-	21.4
	34	!	-	1.0	-	3.8	-	7.2	9.5	-	-	21.5
T. 5 N. R. 87 W.	25	-	-	-	-	-	-	-	10.9	-	1.1	12.0
	26	-	-	-	-	-	-	-	1.1	-	10.5	11.6
	27	-	*	-	*	-	0.5	-	2.1	-	10.1	12.7
	28	-	*	-	*	-	1.9	-	0.8	-	-	2.7
	34	-	*	-	*	-	2.9	-	7.0	-	3.7	13.6
	35	-	-	-	-	-	-	-	12.0	-	1.4	13.4
	36	-	-	-	-	-	0.5	-	12.4	-	-	12.9
T. 4 N. R. 87 W.	11	-	*	-	*	-	2.1	-	5.7	-	-	7.8
	12	-	-	-	-	-	1.0	-	8.2	-	-	9.2
[EMRIA]	13	-	-	-	-	5.3	9.3	-	1.2	-	-	15.8
	14	-	*	-	*	3.1	6.6	-	3.3	-	-	13.0
	23	-	!	0.5	3.8	11.4	3.5	-	-	-	-	19.2
[EMRIA]	24	-	-	5.2	-	16.5	-	-	-	-	-	21.7
	25	!	!	4.8	0.7	-	-	-	-	-	-	5.5
	26	-	!	-	2.5	-	-	-	-	-	-	2.5
T. 4 N. R. 86 W.	7	-	-	-	-	4.3	4.1	-	1.3	-	-	9.7
	8	-	-	-	3.3	0.8	4.8	-	-	-	-	8.9
	9	!	!	0.3	5.9	-	-	-	-	-	-	6.2
	10	!	!	3.1	0.7	5.3	0.9	-	-	-	-	10.0
	15	-	!	-	3.2	-	0.3	-	-	-	-	3.5
	16	-	-	-	-	-	0.5	-	-	-	-	0.5
	17	!	!	5.2	0.3	1.6	1.5	-	-	-	-	8.6
	18	-	-	1.4	-	8.4	0.3	-	-	-	-	10.1
[EMRIA]	18(part)	-	-	(0.4)	-	(6.9)	(0.3)	-	-	-	-	(7.6)
[EMRIA]	19	!	!	4.2	3.1	0.8	1.6	-	-	-	-	9.7
	30	!	-	0.6	-	-	-	-	-	-	-	0.6
Total		-	-	30.6	34.6	63.4	81.8	7.2	132.2	0	28.2	

Total Wolf Creek coal in sections included in analysis = 378.0 x 10^6 tons

Wolf Creek coal in sections at margins of map = 100 x 10^6 tons

Total Wolf Creek coal in mapped area = 478 x 10^6 tons

Table 10 --Estimated coal resources, in short tons, of the Wadge coal bed in the Foidel Creek area, recorded by section, overburden thickness, and degree of geologic assurance.

[D=demonstrated; I=inferred; *=very small amount, included in 200-1,000 feet overburden thickness category; metric conversion: 1 foot = 0.305 meter; 1 short ton = 0.907 metric tons] [EMRIA] indicates areas that are included in the Foidel Creek EMRIA reclamation study site.]

Township and range	Section	Thickness of overburden, in feet: 0-100 D	0-100 I	100-200 D	100-200 I	200-1000 D	200-1000 I	1000-2000 D	1000-2000 I	2000 D	2000 I	Total
T. 5 N. R. 86 W.	27	-	-	-	-	-	-	-	9.5	-	-	9.5
	28	-	-	0.1	-	4.2	1.5	-	5.5	-	-	11.3
	29	-	-	0.5	-	5.2	-	2.6	2.4	-	-	10.7
	30	-	-	-	-	-	-	2.3	8.8	-	-	11.1
	31	-	-	0.8	-	3.0	4.6	0.2	1.8	-	-	10.4
	32	2.6	-	1.9	-	0.6	-	-	-	-	-	5.1
	33	4.2	-	0.8	-	1.6	0.4	-	-	-	-	7.0
	34	0.2	0.3	0.1	0.3	0.1	1.7	-	5.7	-	-	8.4
T. 5 N. R. 87 W.	25	-	-	-	-	-	-	-	11.6	-	0.3	11.9
	26	-	-	-	-	-	-	-	2.3	-	10.1	12.4
	27	-	*	-	*	-	0.7	-	2.1	-	11.4	14.2
	28	-	*	-	*	-	2.1	-	0.9	-	-	3.0
	34	*	*	*	*	2.1	1.4	6.7	1.5	0.2	3.6	15.5
	35	-	-	-	-	-	-	1.0	13.0	-	0.7	14.7
	36	-	-	-	-	-	1.4	-	12.6	-	-	14.0
T. 4 N. R. 87 W.	11	*	*	*	*	1.9	0.2	4.0	2.0	-	-	8.1
	12	-	-	-	-	0.6	1.4	-	7.4	-	-	9.4
[EMRIA]	13	0.8	-	0.9	-	6.8	1.1	-	0.2	-	-	9.8
	14	-	*	-	*	2.0	5.1	-	1.9	-	-	9.0
	23	2.0	2.9	1.1	0.1	2.1	0.4	-	-	-	-	8.6
[EMRIA]	24	8.1	-	1.2	-	0.7	-	-	-	-	-	10.0
	25	2.2	0.3	-	-	-	-	-	-	-	-	2.5
	26	-	1.1	-	-	-	-	-	-	-	-	1.1
T. 4 N. R. 86 W.	7	0.1	-	1.1	-	6.2	3.8	-	0.8	-	-	12.0
	8	4.0	-	2.4	-	1.6	-	-	-	-	-	8.0
	9	1.2	-	-	-	-	-	-	-	-	-	1.2
	10	-	1.5	-	1.5	-	0.7	-	-	-	-	3.7
	15	-	1.4	-	-	-	-	-	-	-	-	1.4
	16	0.04	-	-	-	-	-	-	-	-	-	0.04
	17	8.4	-	-	-	-	-	-	-	-	-	8.4
	18	11.3	-	2.7	-	2.2	-	-	-	-	-	16.2
[EMRIA]	18(part)	(7.2)	-	(2.7)	-	(2.2)	-	-	-	-	-	(12.1)
[EMRIA]	19	7.9	-	-	-	-	-	-	-	-	-	7.9
	30	0.3	-	-	-	-	-	-	-	-	-	0.3
Total		53.3	7.5	13.6	1.9	40.9	26.5	16.8	90.0	0.2	26.0	

Total Wadge coal in sections included in analysis = 276.8 x 10^6 tons

Wadge coal in sections at margins of map = 72 x 10^6 tons

Total Wadge coal in mapped area = 349 x 10^6 tons

Table 11.--EMRIA core hole number, location, name of coal bed, and depth interval of coal samples, the analyses of which are presented in Tables 6, 7, and 8.

[Metric conversion: 1.0 foot = 0.305 meter]

Test No.	EMRIA Core Hole No.	Location Sec.	T.	R.	Name of coal bed (if named)	Depth interval
D178117	1	24	4N	87W	Wadge	182.4-191.2
D178118	1	24	4N	87W	-----	196.4-198.8
D178119	1	24	4N	87W	-----	253.9-255.7
D178120	1	24	4N	87W	Wolf Creek (upper part)	350.2-352.5
D178121	1	24	4N	87W	Wolf Creek (middle part)	352.5-362.5
D178122	1	24	4N	87W	Wolf Creek (lower part)	362.5-370.5
D178123	2	24	4N	87W	Wadge	23.4- 32.2
D178124	2	24	4N	87W	Wolf Creek	195.8-214.7
D178125	3	13	4N	87W	Lennox?	32.4- 38.3
D178126	3	13	4N	87W	Wadge	106.7-117.8
D178127	3	13	4N	87W	-----	119.9-121.9
D178128	4	18	4N	86W	Wadge	88.3- 98.9
D178129	5	19	4N	86W	Lennox?	29.5- 32.7

Table 12 --Proximate, ultimate, Btu, and forms-of-sulfur analyses of 13 coal samples from the Foidel Creek EMRIA site, Routt County, Colo.

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: 1, as received; 2, moisture free; 3, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburg, Pa. Vol.Mtr. = volatile matter; A.d. = air-dried.]

		Proximate analysis				Ultimate analysis				
Sample	Form of analysis	Moisture	Vol.Mtr.	Fixed C	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
D178117	1	10.5	34.0	46.9	8.6	5.7	62.5	0.9	21.8	0.5
	2	-	38.0	52.4	9.6	5.1	69.8	1.0	13.9	.6
	3	-	42.0	58.0	-	5.6	77.3	1.1	15.4	.6
D178118	1	10.5	32.9	45.2	11.4	5.4	60.0	.7	21.9	.6
	2	-	36.8	50.5	12.7	4.7	67.0	.8	14.0	.7
	3	-	42.1	57.9	-	5.4	76.8	.9	16.1	.8
D178119	1	9.9	36.8	46.6	6.7	5.7	64.5	1.0	21.5	.6
	2	-	40.8	51.7	7.4	5.1	71.6	1.1	14.1	.7
	3	-	44.1	55.9	-	5.5	77.3	1.2	15.2	.7
D178120	1	8.8	34.7	46.3	10.2	5.5	62.8	.8	20.1	.6
	2	-	38.0	50.8	11.2	5.0	68.9	.9	13.5	.7
	3	-	42.8	57.2	-	5.6	77.5	1.0	15.2	.7
D178121	1	9.4	33.2	44.3	13.1	5.4	60.0	.8	20.3	.4
	2	-	36.6	48.9	14.5	4.8	66.2	.9	13.2	.4
	3	-	42.8	57.2	-	5.6	77.4	1.0	15.4	.5
D178122	1	9.5	34.5	43.6	12.4	5.3	60.5	1.0	20.2	.6
	2	-	38.1	48.2	13.7	4.7	66.9	1.1	13.0	.7
	3	-	44.2	55.8	-	5.4	77.5	1.3	15.1	.8
D178123	1	17.1	27.5	38.5	16.9	5.4	49.6	.8	26.9	.4
	2	-	33.2	46.4	20.4	4.2	59.8	1.0	14.1	.5
	3	-	41.7	58.3	-	5.3	75.2	1.2	17.7	.6
D178124	1	8.9	34.1	42.3	14.7	5.0	58.6	.7	20.4	.6
	2	-	37.4	46.4	16.1	4.4	64.3	.8	13.7	.7
	3	-	44.6	55.4	-	5.3	76.7	.9	16.3	.8
D178125	1	8.0	40.3	44.7	7.0	5.8	64.4	1.4	18.8	2.6
	2	-	43.8	48.6	7.6	5.3	70.0	1.5	12.7	2.8
	3	-	47.4	52.6	-	5.8	75.8	1.6	13.8	3.1
D178126	1	9.6	32.9	45.5	12.0	5.3	60.4	.5	21.3	.5
	2	-	36.4	50.3	13.3	4.7	66.8	.6	14.1	.6
	3	-	42.0	58.0	-	5.4	77.0	.6	16.3	.6
D178127	1	11.3	34.5	45.4	8.8	5.6	61.1	1.1	22.7	.7
	2	-	38.9	51.2	9.9	4.9	68.9	1.2	14.3	.8
	3	-	43.2	56.8	-	5.4	76.5	1.4	15.8	.9
D178129	1	7.5	34.5	35.0	23.0	4.9	51.3	1.1	16.6	3.1
	2	-	37.3	37.8	24.9	4.4	55.5	1.2	10.7	3.4
	3	-	49.6	50.4	-	5.9	73.8	1.6	14.3	4.5
D178128	1	9.4	34.3	48.8	7.5	5.5	64.1	0.8	21.6	0.5
	2	-	37.9	53.9	8.3	4.9	70.8	.9	14.6	.6
	3	-	41.3	58.7	-	5.4	77.1	1.0	15.9	.6

Table 12--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 13 coal samples from the Foidel Creek EMRIA site, Routt County, .--Continued

Sample	Form of analysis	Btu	A.d.loss	Forms of sulfur: Sulfate	Pyritic	Organic
D178117	1	10870	1.0	0.01	0.07	0.44
	2	12150	-	.01	.08	.49
	3	13440	-	.01	.09	.54
D178118	1	10460	1.1	.01	.05	.57
	2	11690	-	.01	.06	.64
	3	13390	-	.01	.06	.73
D178119	1	11240	.8	.01	.06	.57
	2	12480	-	.01	.07	.63
	3	13480	-	.01	.07	.68
D178120	1	10940	.6	.01	.03	.58
	2	12000	-	.01	.03	.64
	3	13510	-	.01	.04	.72
D178121	1	10430	.7	.01	.02	.40
	2	11510	-	.01	.02	.44
	3	13460	-	.01	.03	.52
D178122	1	10550	.8	.01	.13	.46
	2	11660	-	.01	.14	.51
	3	13510	-	.01	.17	.59
D178123	1	8500	7.8	.01	.04	.37
	2	10250	-	.01	.05	.45
	3	12880	-	.02	.06	.56
D178124	1	10180	.6	.01	.12	.51
	2	11170	-	.01	.13	.56
	3	13320	-	.01	.16	.67
D178125	1	11540	.2	.01	.36	2.27
	2	12540	-	.01	.39	2.47
	3	13580	-	.01	.42	2.67
D178126	1	10550	.7	.01	.05	.45
	2	11670	-	.01	.06	.50
	3	13460	-	.01	.06	.57
D178127	1	10750	2.4	.01	.09	.60
	2	12120	-	.01	.10	.68
	3	13450	-	.01	.11	.75
D178129	1	9250	.5	.01	2.18	.92
	2	10000	-	.01	2.36	.99
	3	13310	-	.01	3.14	1.32
D178128	1	11250	0.6	0.01	0.05	0.41
	2	12420	-	.01	.06	.45
	3	13540	-	.01	.06	.49

Table 3.--Major, minor, and trace element composition of 13 coal samples from the Foidel Creek EMRIA site, Routt County, Colo., reported on whole-coal basis

[Values are in either percent or parts per million. Si, Al, Ca, Mg, Na, K, Fe, Mn, Ti, P, Cl, Cd, Cu, Li, Pb, and Zn values were calculated from analysis of ash. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, N means not detected, and B means not determined. S after element titles means that the values listed were determined by semiquantitative spectrographic analysis.]

Sample	Si %	Al %	Ca %	Mg %	Na %	K %	Fe %	Mn ppm	Ti %	P ppm
D178117	2.7	1.3	0.27	0.064	0.037	0.086	0.15	5.3	0.051	480
D178118	4.0	1.1	.21	.062	.055	.12	.15	8.4	.062	560 L
D178119	1.5	.83	.22	.041	.023	.045	.088	11	.040	710
D178120	2.2	1.7	.29	.053	.052	.037	.097	6.8	.065	910
D178121	3.7	1.5	.37	.158	.080	.077	.20	47	.060	590 L
D178122	3.3	1.6	.25	.105	.093	.056	.15	9.5	.064	550 L
D178123	7.6	1.9	.16	.108	.059	.32	.22	26	.089	990 L
D178124	3.6	1.5	.41	.126	.030	.097	1.1	200	.064	680 L
D178125	.94	.57	.38	.067	.032	.021	1.6	31 L	.033	360
D178126	3.4	1.5	.24	.083	.071	.12	.15	8.8	.057	550 L
D178127	3.1	.86	.090	.053	.024	.084	.71	40 L	.050	450 L
D178129	1.9	1.1	.36	.104	.019	.037	.14	11	.039	380 L
D178128	5.9	1.5	.22	.102	.039	.16	1.6	24	.093	1000 L

Sample	Cl %	As ppm	Cd ppm	Cu ppm	F ppm	Hg ppm	Li ppm	Pb ppm	Sb ppm	Se ppm
D178117	0.021L	2	0.11L	6.2	145	0.04	11.9	4.8	0.2	1.0
D178118	.026L	1	.13	8.0	215	.04	11.6	5.2	.8	.9
D178119	.014L	1 L	.07L	4.2	200	.02	8.6	3.4	.4	.9
D178120	.021L	1 L	.10	7.8	225	.08	12.2	3.1	.2	1.2
D178121	.027L	1 L	.14	5.8	75	.02	5.3	5.4	.2	.8
D178122	.025L	2	.13	6.0	160	.06	8.9	3.8	.2	1.1
D178123	.045L	1	.23	9.9	440	.08	21.2	6.8	.5	1.1
D178124	.031L	1 L	.16L	5.9	90	.05	11.1	5.5	.3	.8
D178125	.016L	2	.08L	3.3	70	.23	3.1	2.0L	.2	1.1
D178126	.025L	1	.13L	5.9	240	.04	10.6	5.0	.3	.8
D178127	.021L	2	.10	5.1	75	.02	13.9	6.2	.5	1.0
D178129	.017L	1 L	.09L	4.6	140	.02	6.1	3.9	.1	.7
D178128	.049L	6	.24L	10.7	330	.29	26.2	6.1L	.4	1.3

Sample	Th ppm	U ppm	Zn ppm	B ppm-S	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Ga ppm-S
D178117	3.0L	0.8	5.7	70	200	1.5	N	1 L	3	3
D178118	4.3	.7	13.0	100	200	2	70 L	2	10	5
D178119	4.2	.6	3.0	70	300	2	30 L	1.5	5	3
D178120	3.0L	.9	4.6	70	300	1.5	50 L	1	3	5
D178121	3.0L	1.2	6.0	100	500	1	N	1.5 L	5	5
D178122	3.0L	1.5	3.7	100	300	1	70 L	1.5 L	2	3
D178123	5.8	1.4	19.9	100	200	1	N	2 L	15	7
D178124	5.6	1.1	9.2	100	200	.7	70 L	1.5 L	5	5
D178125	3.0L	.4	2.6	150	200	.5	N	.7 L	2	2
D178126	5.4	.8	12.9	150	200	1	70 L	1.5 L	3	3
D178127	3.0L	.6	4.2	70	150	1.5	N	1 L	3	5
D178129	3.0L	.8	3.9	150	150	1	50 L	1 L	2	5
D178128	3.0L	1.5	23.1	70	300	1.5	N	2 L	15	7

Table 13--Major, minor, and trace element composition of 13 coal samples from the Foidel Creek EMRIA site, Routt County, Colo., reported on whole-coal basis--Continued

Sample	Ge ppm-S	La ppm-S	Mo ppm-S	Nb ppm-S	Nd ppm-S	Ni ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S	Y ppm-S
D178117	N	10 L	N	3	N	1.5	1.5	150	7	7
D178118	N	15 L	N	5	N	2	2	100	15	10
D178119	2	7	.5	3	10 L	2	2	200	20	7
D178120	N	10 L	.7	3	N	1	1.5	150	10	5
D178121	N	15 L	1	5	N	1.5 L	2	150	10	7
D178122	N	15 L	1	3	N	1.5 L	2	100	10	10
D178123	N	20 L	1.5	7	N	3	3	70	15	7
D178124	N	15 L	N	3	N	1.5	2	100	10	7
D178125	N	7 L	.7	1.5	N	1.5	1.5	70	15	5
D178126	N	15 L	1	3	N	1.5	2	100	15	10
D178127	N	10 L	.7	3	N	1	1.5	70	7	7
D178129	N	10 L	.7	2	N	1	1.5	50	7	7
D178128	N	N	N	5	B	3	3	200	30	15

Sample	Yb ppm-S	Zr ppm-S
D178117	0.5	20
D178118	1	20
D178119	.7	20
D178120	.5	20
D178121	.7	20
D178122	.7	20
D178123	1	30
D178124	.7	20
D178125	B	15
D178126	.7	20
D178127	.5	30
D178129	.5	15
D178128	1.5	30

Table 14--Major and minor oxide and trace element composition of the laboratory ash of 13 coal samples from the Foidel Creek EMRIA site, Routt County, Colo.

[Values are in either percent or parts per million. The coals were ashed at 525°C. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68 percent, or two brackets at 95 percent confidence.]

Sample	Ash %	SiO2 %	Al2O3 %	CaO %	MgO %	Na2O %	K2O %	Fe2O3 %	MnO %	TiO2 %
D178117	10.7	55	23	3.6	1.00	0.47	0.96	2.1	0.006	0.79
D178118	12.9	67	16	2.3	.80	.58	1.1	1.7	.008	.80
D178119	6.8	47	23	4.6	1.00	.46	.79	1.9	.020	.98
D178120	10.4	45	31	3.9	.85	.67	.42	1.3	.008	1.0
D178121	13.6	58	21	3.8	1.93	.80	.68	2.1	.045	.73
D178122	12.7	55	24	2.8	1.38	.99	.53	1.7	.010	.84
D178123	22.6	72	16	1.0	.80	.35	1.7	1.4	.015	.65
D178124	15.6	50	19	3.7	1.34	.26	.75	9.9	.17	.68
D178125	8.1	25	13	6.7	1.38	.53	.31	29	.050L	.69
D178126	12.6	58	22	2.7	1.10	.76	1.1	1.7	.009	.76
D178127	10.3	64	16	1.2	.85	.31	.97	9.9	.050L	.80
D178129	8.6	48	25	5.8	2.01	.30	.52	2.3	.016	.77
D178128	24.3	52	12	1.2	.70	.22	.80	9.4	.013	.64

Sample	P2O5 %	SO3 %	Cl %	Cd ppm	Cu ppm	Li ppm	Pb ppm	Zn ppm	B ppm-S	Ba ppm-S
D178117	1.0	3.0	0.20 L	1.0L	58	111	45	53	700	2000
D178118	1.0 L	2.6	.20 L	1.0	62	90	40	101	700	2000
D178119	2.4	5.1	.20 L	1.0L	62	126	50	44	1000	5000
D178120	2.0	2.8	.20 L	1.0	75	117	30	44	700	3000
D178121	1.0 L	2.6	.20 L	1.0	43	39	40	44	700	3000
D178122	1.0 L	2.6	.20 L	1.0	47	70	30	29	700	3000
D178123	1.0 L	.97	.20 L	1.0	44	94	30	88	500	1000
D178124	1.0 L	3.7	.20 L	1.0L	38	71	35	59	700	1500
D178125	1.0	11	.20 L	1.0L	41	38	25 L	32	1500	3000
D178126	1.0 L	1.7	.20 L	1.0L	47	84	40	102	1000	1500
D178127	1.0 L	2.6	.20 L	1.0	50	135	60	41	700	1500
D178129	1.0 L	4.1	.20 L	1.0L	53	71	45	45	1500	2000
D178128	1.0 L	1.1	.20 L	1.0L	44	108	25 L	95	300	1500

Table 14.--Major and minor oxide and trace element composition of the laboratory ash of 13 coal samples from the Foidel Creek EMRIA site, Routt County, Colo.--Continued

Sample	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Ga ppm-S	Ge ppm-S	La ppm-S	Mo ppm-S	Nb ppm-S	Nd ppm-S
D178117	15	N	10 L	30	30	N	100 L	N	30	N
D178118	15	500 L	15	70	30	N	100 L	N	30	N
D178119	30	500 L	20	70	50	30	100	7	50	150 L
D178120	15	500 L	10	30	50	N	100 L	7	30	N
D178121	7	N	10 L	30	30	N	100 L	7	30	N
D178122	7	500 L	10 L	20	30	N	100 L	7	30	N
D178123	5	N	10 L	70	30	N	100 L	7	30	N
D178124	5	500 L	10 L	30	30	N	100 L	N	20	N
D178125	5	N	10 L	30	30	N	100 L	7	20	N
D178126	7	500 L	10 L	30	30	N	100 L	7	30	N
D178127	15	N	10 L	30	50	N	100 L	7	30	N
D178129	10	500 L	10 L	30	50	N	100 L	7	30	N
D178128	7	N	10 L	70	30	N	N	N	20	B

Sample	Ni ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zr ppm-S
D178117	15	15	1500	70	70	5	200
D178118	15	15	700	100	70	7	200
D178119	30	30	3000	300	100	10	300
D178120	10	15	1500	100	50	5	200
D178121	10 L	15	1000	70	50	5	150
D178122	10 L	15	700	70	70	5	200
D178123	15	15	300	70	30	5	150
D178124	10	15	700	70	50	5	150
D178125	15	15	1000	150	50	B	150
D178126	10	15	700	100	70	5	200
D178127	10	15	700	70	70	5	300
D178129	10	15	500	70	70	5	200
D178128	15	15	1000	150	70	7	150

coalbed tentatively identified as Lennox, four of the samples are from the Wadge bed, and four are from the Wolf Creek bed. The Wolf Creek, Wadge, and Lennox coalbeds of the middle coal group in the Foidel Creek area are all classified as high-volatile C bituminous in rank (American Society for Testing and Materials, 1974), based on the analyses presented in table 12.

Four analyses of Wolf Creek coal from the Foidel Creek EMRIA Study Site, on an as-received basis, averaged 9.2 percent moisture, 34.1 percent volatile matter, 44.1 percent fixed carbon, 12.6 percent ash, with 0.6 percent sulfur, and had a heating value of 10,530 Btu. By comparison, twelve analyses of Wolf Creek coal from the southeastern part of the Yampa coalfield reported by Bass, Eby, and Campbell (1955, p. 184-207) averaged, on an as-received basis, 10.1 percent moisture, 36.6 percent volatile matter, 43.1 percent fixed carbon, and 9.9 percent ash, with 0.5 percent sulfur, and had a heating value of 10,990 Btu.

The four analyses of Wadge coal from the Foidel Creek EMRIA Study Site, on an as-received basis, averaged 11.7 percent moisture, 32.2 percent volatile matter, 44.9 percent fixed carbon, and 11.3 percent ash, with 0.5 percent sulfur, and had a heating value of 10,290 Btu. Thirty-three analyses of Wadge coal reported by Bass, Eby, and Campbell (1955, p. 184-207) averaged 10.7 percent moisture, 37.0 percent volatile matter, 46.3 percent fixed carbon, and 5.9 percent ash, with 0.5 percent sulfur, and had a heating value of 11,430 Btu.

The major, minor, and trace element composition of the 13 coal samples from the Foidel Creek EMRIA Study Site are presented in tables 13 and 14. Comparisons of these values with those presented by Hatch and Swanson (1977) indicate that the elemental compositions of the Foidel Creek area samples are typical of coal in the Rocky Mountain province, all values falling well within the ranges of values reported for the province.

INTERPRETATIONS FOR SOIL AND BEDROCK MATERIAL AS A POTENTIAL SOURCE FOR REVEGETATION

Major Soil Bodies

Three major soil bodies are generally recognized within the Foidel Creek Study Site. Parent material and topographic position are the primary factors used in this categorization. These major soil bodies are designated as: (1) Soils which are forming on sandstones occupying sloping to strongly sloping mountain foothills, (2) soils occurring on the shaley formations which occupy very gently sloping to sloping, smoothly rounded uplands, generally located below or at lower elevations than the soils described in (1), and (3) alluvial soils of mixed origin which occupy the principal stream valleys.

Following are general descriptions of the above-mentioned major soil bodies which occur within the Foidel Creek Study Site. (Note: Reference is made at random to the categories by the number given in parentheses.)

Soils (1) occurring on the sandstone member in sections 24 and 19 are generally somewhat coarse in texture but have moderately high water holding capacities, ranging generally from 1.5 to 2.0 in/ft of depth. Permeabilities of these soils are quite rapid due to their sandy texture, and surface infiltration rates would be generally over 1.5 to 2.0 in/h. Structural grades within the developed profiles are not strong and; therefore, are physically not very stable when disturbance occurs, even though they are quite stable in-situ. These soils are moderately deep to deep, ranging from about 30 to over 60 in in depth, with the exception of very steep or highly eroded shallower areas. Electrical conductivity of the saturation extract ranges from 2 to 9 mmhos/cm and exchangeable sodium percentages were less than 1 percent. The pH values range from 5.6 to 6.7. Based on the chemical and physical properties, these soils are rather highly suited as a source of plant growth medium. Soils (2) occurring on the shaley formations in the south and west part of the study site are fine textured, being generally heavy clay loams to clays, and have high available water holding capacities (generally 2 to 3 in/ft of depth). Permeabilities of these soils are generally very slow due to their heavy texture and poor physical condition. Poor surface permeabilities are typical of these soils, with infiltration rates being generally less than 0.25 in/h. Structural grades within these soils are weak to moderately strong, but they are quite stable and should withstand a considerable amount of physical disturbance. Depth of these soils generally ranges from 18 to 40 in over consolidated or slightly weathered shales and sandstones but can be considerably shallower in very steep or highly eroded areas.

Electrical conductivities of the saturation extract were low (0.21 to 0.42 mmhos/cm) as were the exchangeable sodium percents (0.08 to 1.38 percent) for the representative soil profile within this category. The pH values ranged from 6.1 to 7.3. These soils have a fair suitability for use as a planting medium with the major limiting factor being the soil water relationships due to the silty clay, clay loam, and clay textures.

The alluvial soils (3) of the principal stream valleys, traversing the study site, vary widely in their physical characteristics. These variations are primarily the result of the origin of parent materials present in the different alluvial areas as well as the depth of alluvial deposition within the valleys.

The soils of the valley of the north fork of Middle Creek which traverses the southeast tip of the study site are predominantly moderately coarse to moderately fine (fine sandy loams to clay loams) and have medium to moderately high available water holding capacities (1.5 to 2.0 in/ft of depth). Permeabilities of these soils are moderate to moderately slow except where high water table conditions have resulted in the development of poor physical condition including a lack of structure. Infiltration rates of these soils are moderate, and range generally from 0.3 to 0.75 in/h. Structural grades within these soils are generally weak, since alluvial deposition is recent and continuing. Mottling to within 18 in of the surface is common, indicating the presence of intermittent high water tables.

The soils of Foidel Creek Valley and one of its major tributaries which traverse the northwest corner of the study site are predominantly of clay loams or clay textures. They have a high water holding capacity and a slow rate of permeability. Structurally, these soils are relatively weak due to the recent nature of parent material deposition. Some indications of periodic high water tables (mottling, etc.) to within 18 in of the surface are evident in many of these soils.

The alluvial soils of the principal stream valleys in the study site (Foidel Creek and the North Fork of Middle Creek) are chemically well suited as a planting medium. The electrical conductivity of the saturation extract is fairly low (0.36 to 0 80 mmhos/cm) and exchangeable sodium percent ranges from 0.07 to 0.71 percent. The pH values are slightly acid ranging from 6.0 to 6.8. The alluvial soils of Foidel Creek Valley appear to be somewhat poorly suited; however, because of the heavy textures which result in slow permeabilities and infiltration rates.

The soils of the North Fork of Middle Creek have a fair suitability for use as a planting medium, the weak structural grades of the soil aggregates being the limiting factor for use as a planting medium.

Overburden Characteristics

Land Suitability

A detailed land suitability survey was made of the study area land. Its purpose was to characterize and evaluate the surface and upper material (5 ft) in relation to its suitability as a source of planting media for resurfacing shaped spoils following surface mining. This survey provides data on the quality and quantity of surface material in relation to revegetation and the cost and ease of stripping. Basic data on the present physical and chemical properties of the soils (upper 5 ft) are also provided by the survey.

Land classification specifications to establish ranges of land suitability as a source of planting media were developed specifically for the study. Factors included in the specifications for quality consideration were: texture, salinity, sodicity, permeability, available water holding capacity, and erodability. Quantity considerations were primarily the depth of suitable material. Excessive slope and bedrock outcrops were factors considered in relation to stripping and stockpiling of material. The specifications for the Foidel Creek study are given in table 15 on the following pages.

Four land classes (1, 2, 3, and 6) were utilized in the land suitability survey of the Foidel Creek Study Site. These correspond to classes used in the Bureau of Reclamation land classification system. Class 1 lands are the most desirable as a source of topsoil for surfacing shaped spoils. They will supply a large quantity of highly suitable material which is easily stripped and stockpiled for postmining use on the lands they occupy and possible for adjacent areas where sufficient material is not adequate. Class 2 lands have adequate resurfacing material, but they may require good placement practices to meet the requirements and be less desirable in quality for difficult to strip and stockpile. Class 3 lands are similar to Class 2 except the deficiencies are greater, or there is a combination of deficiencies. Lands in this class are marginal as a source of material, but with good procedures for stripping and stockpiling

Table 15

LAND CLASSIFICATION SPECIFICATIONS - EMRIA PROGRAM 1/
FOIDEL CREEK SITE - COLORADO

SOILS 2/	LAND CLASS 1	2	3
TEXTURE	FSL - CL	LFS - C (friable)	FS - C
AVAILABLE WATER HOLDING CAPACITY	>1.5"/ft.	>0.8"/ft.	>0.6"/ft.
HYDRAULIC CONDUCTIVITY (INTERNAL DRAINAGE)	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	May be slightly restricted resulting in decreased drainage and aeration in the root zone and at reduced infiltration rate.	Restricted to the extent that internal drainage may limit choice of vegetation and/or require special practices to control erosion.
SALINITY (AT EQUILIBRIUM)	<4 Millimhos	<8 Millimhos	<12 Millimhos
SODICITY (AT EQUILIBRIUM)	<10 ESP - May be higher if hydraulic conductivity meets limits for Class 1.	<10 ESP - May be higher if hydraulic conductivity meets limits for Class 2.	<15 ESP - May be higher if hydraulic conductivity meets limits for Class 3.
ERODABILITY	Subject to slight erosion.	Subject to moderate erosion.	Susceptible to severe erosion, but can be controlled with proper management.

Table 15 Continued

	LAND CLASS		
SOILS 2/	1	2	3
WEATHERABILITY 3/	Breaks down rapidly upon exposure to normal weathering in the surface environment.	May require a short to moderate period to break down following exposure.	May require an extended period to break down into optimum particle size distribution, but is useable in a practically achievable state with a reasonable time period.
DEPTH	>36" of useable and strippable material.	>24" of useable and strippable material	>6" of useable and strippable material 4/
Topography 5/			
SLOPE	<20 percent	<20 percent	<25 percent - Can be greater in areas situated at uphill ends of excavated strips where these materials are customarily used.
SURFACE ROCKS Decomposed or fractured sandstone and/or shale.	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5" 5% 2.5-10" <5%	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5" 10% 2.5-10" <10%	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5" 25% 2.5-10" <15%

Table 15 Continued

TOPOGRAPHY 5/	LAND CLASS 1	LAND CLASS 2	LAND CLASS 3
BEDROCK OUTCROPS	Will not affect stripping or quantity of suitable material.	Numerous enough to reduce quantity of suitable material slightly and make stripping more expensive.	Numerous enough to reduce quantity of suitable material appreciable and make stripping considerably more expensive.
DRAINAGE	Because of land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material is not a factor in the classification. Hydraulic conductivity requirements are covered under Soils.		
Class 6	All areas not meeting requirements for Classes 1, 2, or 3. These materials are unsuited as a source of material for revegetation.		

1/ Specifications are based on natural rainfall or minimum irrigation for starting and establishing plantings.

2/ The limitations under soils are applicable to the evaluation of both the soil and the overburden material between the soil and mineable coal,

3/ Weatherability is applicable only to bedrock or unconsolidated material.

4/ Six inches is considered as the minimum strippable depth.

5/ Related primarily to stripping operations and to final slope after reshaping.

they will meet the requirements. Class 6 lands generally do not have adequate or suitable material for topsoil use or if available, they cannot be practically stripped and stockpiled. If Class 6 lands are disturbed by surface mining, it will be necessary to borrow or improve the available material if revegetation is to be successful.

Since aerial photographic coverage was not available for the study site, GS (Geological Survey) quadrangle, 7.5-minute series, topographic maps (1:24,000) with 20-ft conto§r intervals were used entirely in the field work. Representative soil sites were selected and the profiles examined, evaluated, and recorded. This information was supplemented by other profiles that were examined but not recorded. The soil profiles were exposed or drilled out with a hand auger. Soil structure, consistence, texture, color, root distribution, mottling, and other features of the profile were observed on the representative sites recorded. Salinity and sodicity were based primarily on laboratory data. Soil samples for laboratory analyses were collected by soil layers or horizons from representative profiles.

relationships of the material. A tentative land suitability class was established by evaluating these basic soil characteristics combined with observations of other land features such as stones, exposed indurated bedrock, and slope. The final land class was not determined until the laboratory data was available.

The land suitability survey show that approximately 91 percent of the study site has adequate material for postmining reclamation purpose. Deficiencies observed by the survey were fine textures, steep slopes, and amount of surface rock which hinder stripping. The acreages of the various land subclassed (by section and for the entire study area) are presented on table 16 and the composite land suitability map is found on page 68. Land classification sheets by section are shown on figures C1 through C4 in appendix C.

The land suitability classification provides adequate data for developing lease stipulations and the reclamation portion of the required mining plan. It does not, however, provide adequate detail for stripping and stockpiling operations immediately prior to the surface mining. Procedures similar to those used in the land classification can be used to more accurately determine the quantity, location, and quality of the available material. This would entail additional field borings and observations supported by laboratory analysis. Following is a description of the major land classes in the land suitability survey.

Class 1. - Lands in this class have an average minimum depth of 36 in of good quality soil that is suitable for plant media. These soils are forming generally on alluvium of local origin. The most common textures are fine sandy loam, sandy clay loam, and clay loam. Aggregate stability is moderately weak and water enters the profiles readily. Internal drainage is moderate and adequate moisture is stored for plant use.

These soils are nonsaline and nonsodic. They are noncalcareous in the upper 36 in of the soil profile and generally only slightly calcareaous from 3 to 5 ft.

Land features. - The topography includes gently sloping upland fans adjacent to ephemeral streams. These topographic features will not hinder stripping and stockpiling of overburden materials.

Class 2. - Class 2 lands were subdivided into those having a soil deficiency (Class 2s) and those with a topographic deficiency (Class 2t).

Class 2s. - Lands in Class 2s are similar in most respects to Class 1 soils. However, Class 2s lands in the Foidel Creek Study Site have moderately fine and fine textured soils (heavy clay loam, silty clay, and clay) which impede water movement and depth of rooting. Levels of alkalinity and salinity are fairly low and thus do not pose any serious problems.

Land features. - Class 2s lands occur on gently rolling grass-covered ridges along the west edge of the study site. These soils generally have formed by the weathering of dark colored marine shale layers.

Lands designated as Class 2t in the Foidel Creek Study Site are similar in most respects to Class 1 lands. They are less well suited because of surface rock on steep slopes, either which will hinder strip mining operations. Based on field observations and laboratory analyses, these lands are considered to be nonsaline and nonsodic.

Land features. - The primary physiographic land form associated with Class 2t lands are steep upland hillsides on which are located stands of lodgepole pine and aspen. Also included are somewhat broken steep south-facing slopes under grass cover.

Class 3. - Class 3 lands were subdivided into Class 3s - lands having a soil deficiency - and Class 3st - lands having both soil and topographic deficiencies.

Class 3s. - Included in this class are lands which are similar to Class 2s land in that they are dominated by soils of moderately fine and fine textures. Generally the soil textures are silty clay or clay. However, they differ from Class 2s lands because the weathered soil material generally is less than 24 in thick and overlays shales which have a low degree of weatherability.

These soils are generally nonsodic and nonsaline.

Land features. - These lands generally occupy gently sloping uplands, a large portion which is represented by smoothly rounded ridge crests.

Class 3st. - The lands which are included in this class have similar soil characteristics to Class 3s lands. They have been separated from Class 3s lands because they also have an appreciable quantity of surface rocks and because they occupy steeper slopes.

Land features. - Class 3st lands normally occupy steeply sloping uplands, primarily the sidehills.

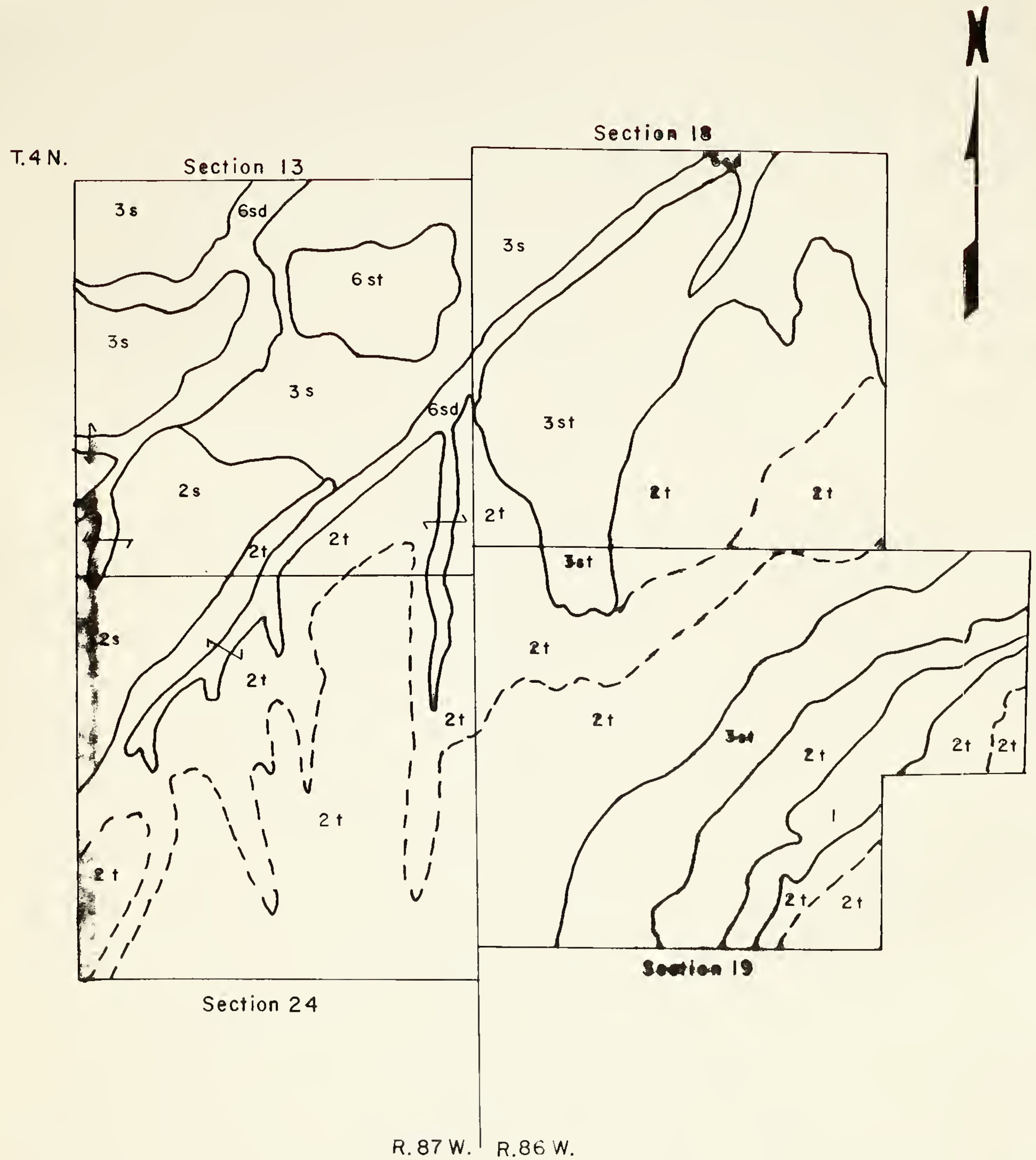
Class 6. - Class 6 lands are subdivided into Class 6sd - lands having soils which have restricted hydraulic conductivity - and Class 6st - very shallow (less than 12 inches of weathered soil material overlaying relatively impervious shale) silty clay or heavy clay loam soils which are found on steeply sloping upland knobs and hills.

Land features. - Class 6st lands represent two distinct physiographic land forms. These are (1) the major drainage ways in the study site and (2) uppermost knobs in the northwest portion of the study site which are underlain by dark gray marine shales.

The following table 16 gives the acreage and percentage of each represented land subclass for the entire study site and also by individual section.

Table 16.--Composite Land Suitability

Class	Section - Township North - Range West				Total acres	Percent of study area
	13-4-87	24-4-87	18-4-86	19-4-86		
1	-	-	-	72.6	72.6	2.6
2s	101.5	62.1	-	-	163.6	6.0
2t	79.9	559.0	196.8	527.3	1363.0	49.7
3s	274.5	-	94.6	-	369.1	13.5
3st	-	-	339.0	188.4	527.4	19.2
6sd	108.4	27.4	38.9	-	174.7	6.3
6st	74.6	-	-	-	74.6	2.7
Totals	638.9	648.5	669.3	788.3	2745.0	100.0



COMPOSITE LAND SUITABILITY

Class	Section–Township North–Range West: 13-4-87	24-4-87	18-4-86	19-4-86	Total Acres	Percent of Study Area
1	–	–	–	72.6	72.6	2.6
2s	101.5	62.1	–	–	163.6	6.0
2t	79.9	559.0	196.8	527.3	1363.0	49.7
3s	274.5	–	94.6	–	369.1	13.5
3st	–	–	339.0	188.4	527.4	19.2
6sd	108.4	27.4	38.9	–	174.7	6.3
6st	74.6	–	–	–	74.6	2.7
Totals	638.9	648.5	669.3	788.3	2745.0	100.0

1000 0 1000 2000
SCALE OF FEET

FOIDEL CREEK STUDY AREA
COLORADO

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COMPOSITE LAND SUITABILITY

LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED ____ TECH. APPROVAL ____
DRAWN ____ SUBMITTED ____
CHECKED ____ ADMIN. APPROVED ____
DENVER, COLORADO
PLATE 5

Overburden Evaluation (5 ft to bottom coal seam)

An attempt was made to evaluate overburden material for use as a planting medium in the event adequate topsoil was not available. These evaluations were based on data derived from chemical and physical laboratory tests performed on core taken from five deep hole borings drilled on the site. Because of the low number of holes drilled and the diverse nature of the geologic material, the quality evaluations apply only to the specific core site and may not be accurately projected between core locations.

The suitability of overburden was illustrated as suitable, doubtful, or unsuitable and was based on the applicable parts of the specifications used for the land suitability survey given on pages 62, 63, and 64. Suitable is equivalent to the Class 1 and the lower part of Class 2, doubtful to the lower part of Class 2 and Class 3, and unsuitable relates to Class 6.

Results of the core evaluations are presented below and these same evaluations are outlined later on the geologic logs of the drill holes in the Geology, Appendix A.

Deep Hole No. 1

Depth (ft)	Material	Evaluation	Remarks
0-0.6	Soil	Suitable	
0.6-10.0	Shale	-	0% Core Recovery
10.0-51.2	Shale	Suitable	
51.1-85.6	Shale	Unsuitable	High SAR, fine textured 2/
85.6-94.1	Shale	Suitable	
94.1-113.5	Sandstone	Suitable	
113.5-129.0	Sandstone	Doubtful	Coarse texture 1/
129.0-162.1	Sandstone	Suitable	
162.1-162.9	Coal	Unsuitable	
162.9-180.9	Sandstone	Suitable	
180.9-182.4	Shale	Suitable	
182.4-191.2	Coal	Unsuitable	
191.2-195.6	Sandstone and carbonaceous material	Doubtful	Slightly coaly
195.6-202.3	Coal and carbonaceous material	Unsuitable	
202.3-211.2	Sandstone	Suitable	

Deep Hole No. 1 - (continued)

Depth (ft)	Material	Evaluation	Remarks
211.3-221.0	Shale	Suitable	
221.0-244.5	Sandstone	Doubtful	Coarse textured 1/
244.5-245.5	Coal	Unsuitable	
245.5-253.9	Sandstone and siltstone	Suitable	
253.9-255.7	Coal	Unsuitable	
255.7-271.6	Sandstone	Unsuitable	Acidity
271.6-272.1	Coal	Unsuitable	
272.1-280.0	Sandstone and siltstone	Suitable	
280.0-285.3	Sandstone	Doubtful	Coarse textured 1/
285.3-297.9	Shale	Suitable	
297.9-309.8	Sandstone	Suitable	
309.8-333.8	Shale	Suitable	
333.8-334.3	Coal	Unsuitable	
334.3-350.2	Sandstone and siltstone	Suitable	
350.2-370.5	Coal	Unsuitable	
370.5-375.6	Sandstone	Doubtful	Coarse textured
375.6-380.0	Sandstone and shale	Doubtful	Coarse textured and coaly
380.0-384.8	Sandstone	Doubtful	Acidity
384.8-393.0	Siltstone	Doubtful	Coarse textured very thin coal
393.0-405.2	Sandstone	Doubtful	Coarse textured
405.2-408.0	Shale and sandstone	Doubtful	Thin coal seams
408.0-408.6	Coal	Unsuitable	
408.6-415.0	Shale and sandstone	Doubtful	Coarse textured
415.0-422.0	Sandstone	Doubtful	Coarse textured

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

Although weathering tests indicated that the shale member depth 63.0 to 70.1 ft appears to break down sufficiently for possible usage, chemical and physical tests indicate high SAR values and restricted disturbed hydraulic conductivity for the depths 51.2 to 85.6 ft and these shales were evaluated unsuitable. Another shale member, depth 285.3 to 297.9 ft, was tested chemically and physically and was evaluated suitable for possible use as a planting medium; this shale material, depth 292.0 to 297.9 ft, broke down sufficiently during weathering tests, was spotty calcareous, and was typical of other shale materials evaluated suitable in deep hole No. 1.

Sandstone samples, depth 229.0 to 237.0 ft and depth 415.0 to 422.0 ft, exhibited little or no breakdown at all during weathering tests. These depths, when tested in the laboratory, exhibited low cation exchange and water-holding capacities further hindering their suitability as a planting medium. Other sandstone members in deep hole No. 1 such as depth 342.0 to 350.2 ft appear to be chemically suitable with neutral pH values, low salt contents, and low exchangeable sodium percentages and were evaluated suitable; however, there may be some problems in the breaking down or weathering of these types of sandstone as exhibited in the weathering tests.

Deep Hole No. 2

Depth (ft)	Material	Evaluation	Remarks
0-13.6	Shale	Suitable	Superficial soil 0-1.7'
13.6-20.4	Sandstone	Suitable	
20.4-23.4	Shale	Suitable	
23.4-32.2	Coal	Unsuitable	
32.2-37.0	Shale and sandstone	Suitable	
37.0-39.4	Coal	Unsuitable	
39.4-43.8	Shale and sandstone	Suitable	
43.8-56.4	Shale and sandstone	Suitable	Fossiliferous
56.4-66.4	Shale	Suitable	
66.4-73.7	Sandstone	Suitable	
73.7-86.8	Sandstone	Doubtful	Coarse textured 1/
86.8-91.3	Shale	Suitable	
91.3-100.4	Sandstone	Doubtful	Coarse textured 1/
100.4-102.0	Coal	Unsuitable	
102.0-102.8	Shale	Unsuitable	Coaly
102.8-117.6	Sandstone	Doubtful	Coarse textured 1/
117.6-118.9	Shale	Unsuitable	Coaly
118.9-123.7	Sandstone	Doubtful	Coarse textured 1/
123.7-135.3	Sandstone	Suitable	

Deep Hole No. 2 - (continued)

Depth (ft)	Material	Evaluation	Remarks
135.3-141.3	Shale	Suitable	
141.3-150.2	Sandstone	Doubtful	Coarse textured 1/
150.2-160.3	Sandstone and siltstone	Suitable	
160.3-176.1	Shale	Suitable	Fossiliferous
176.1-180.0	Sandstone	Suitable	
180.0-182.4	Coal	Unsuitable	
182.4-195.8	Sandstone	Suitable	
195.8-214.1	Coal	Unsuitable	
214.1-221.0	Sandstone	Doubtful	Coarse textured 1/
221.0-228.8	Sandstone	Suitable	
228.8-239.4	Shale and siltstone	Suitable	
239.4-244.9	Sandstone and siltstone	Suitable	
244.9-246.4	Shale	Doubtful	Acidity
246.4-247.2	Coal	Unsuitable	
247.2-263.1	Sandstone	Suitable	

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

The shale materials appear to be suitable with the exception of those shales that are coaly. The sandstone materials that were weathered and suitable chemically were evaluated suitable. The fine and very fine sandstones were evaluated doubtful and breakdown into suitable material will be difficult as exhibited in the weathering study for these types of sandstones.

Deep Hole No. 3

Depth (ft)	Material	Evaluation	Remarks
0-3	Clay	Suitable	
3-18	Clay and silt	Doubtful	Salinity fine textured 2/
18-32.4	Sandstone	Suitable	

Deep Hole No. 3 - (continued)

Depth (ft)	Material	Evaluation	Remarks
32.4-38.3	Coal	Unsuitable	
38.3-39.3	Shale	Unsuitable	Coaly
39.3-52.0	Sandstone	Suitable	
52.0-60.0	Sandstone	Doubtful	Coarse textured 1/
60.0-76.9	Sandstone	Suitable	
76.9-79.9	Siltstone	Suitable	
79.9-89.9	Sandstone	Suitable	
89.9-92.9	Shale and coal	Unsuitable	
92.9-95.3	Siltstone	Suitable	
95.3-104.7	Sandstone	Doubtful	Massive
104.7-106.7	Siltstone and shale	Suitable	
106.7-117.8	Coal	Unsuitable	
117.8-119.9	Siltstone	Suitable	
119.9-121.9	Coal	Unsuitable	
121.9-124.3	Shale, siltstone, and sandstone	Doubtful	Thin bedded
124.3-131.0	Sandstone	Doubtful	Coarse textured 1/
131.0-164.5	Siltstone	Suitable	
164.5-169.9	Sandstone	Suitable	
169.9-173.5	Siltstone	Suitable	
173.5-180.1	Sandstone	Doubtful	Very fine
180.1-180.9	Coal	Unsuitable	
180.9-192.9	Sandstone	Suitable	
192.9-197.4	Siltstone	Suitable	
197.4-200.6	Sandstone	Suitable	

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

The superficial soil was deep (18 ft) in this area; however, the clay material, depth 3.0 to 18.0 ft, is fine textured and could exhibit problems with restricted infiltration if used as a planting medium. The siltstone materials appear to break down in the weathering tests, and those siltstones that are slightly to moderately calcareous appear to be suitable. The sandstone sample, depth 95.3 to 104.7 feet, appears to be suitable chemically but this sandstone is massive, very fine grained, hardness (6+), and exhibited little or no breakdown during weathering. These sandstones as previously indicated would be evaluated doubtful as a planting medium.

Deep Hole No. 4

Depth (ft)	Material	Evaluation	Remarks
0-1.8	Clay	Suitable	
1.8-10.3	Shale	Doubtful	Acidity, fine textured 2/
10.3-15.0	Sandstone	Suitable	
15.0-21.0	Sandstone	Doubtful	Coarse textured 1/
21.0-26.0	Sandstone	Suitable	
26.0-31.0	Sandstone	Doubtful	Coarse textured 1/
31.0-49.9	Sandstone	Suitable	
49.9-51.2	Shale	Suitable	
51.2-55.4	Sandstone	Suitable	
55.4-71.4	Siltstone	Suitable	
71.4-71.8	Coal	Unsuitable	
71.8-74.1	Siltstone	Suitable	
74.1-86.9	Sandstone	Suitable	
86.9-88.3	Siltstone	Suitable	
88.3-98.9	Coal	Unsuitable	
98.9-99.6	Shale	Unsuitable	Coaly
99.6-105.0	Sandstone	Suitable	
105.0-110.4	Sandstone	Doubtful	Coarse textured 1/
110.4-114.7	Sandstone	Suitable	
114.7-142.2	Shale	Suitable	
142.2-160.5	Sandstone	Suitable	
160.5-161.9	Coal	Unsuitable	
161.9-162.2	Shale	Suitable	Carbonaceous
162.2-172.9	Sandstone	Suitable	

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

The shale layer, depth 1.8 to 10.3 ft, while highly weathered was evaluated doubtful due to acidity and its fine texture. The other shales in deep hole No. 4 appear suitable with the exception of those shales which are coaly in nature. Weathering tests on shale sample FC-4-24, depth 120.4 to 130.4 ft, appears to indicate some breakdown with freeze-thaw cycles. The siltstone members also appeared to have broken down sufficiently for possible use while the sandstone materials were evaluated the same as in holes No. 1, 2, and 3.

Deep Hole No. 5

Depth (ft)	Material	Evaluation	Remarks
0-4.2	Soil	Suitable	
4.2-12.5	Shale	Doubtful	Salinity
12.5-29.5	Sandstone and siltstone	Suitable	
29.5-32.5	Coal	Unsuitable	
32.5-35.8	Siltstone	Suitable	
35.8-39.0	Sandstone	Doubtful	Coarse textured 1/
39.0-68.0	Sandstone	Suitable	
68.0-73.0	Sandstone	Doubtful	Coarse textured 1/
73.0-83.0	Sandstone	Suitable	
83.0-88.0	Sandstone	Doubtful	Coarse textured 1/
88.0-95.0	Sandstone	Suitable	
95.0-111.0	Siltstone	Suitable	

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

The only shale member in this hole (4.2 to 12.5 ft) was evaluated doubtful because of salinity and fine texture; this material is clayey and similar in nature to depth 3.0 to 18.0 ft in deep hole No. 3. Some of the sandstones encountered are friable and were evaluated suitable while other sandstone materials are very fine grained, low in cation exchange and moisture holding capacities, and were evaluated doubtful.

The weathering tests and greenhouse studies are presented in the appendix of this report, but were considered in the above evaluations.

The major deficiencies of the core material rated as unsuitable in the five deep holes are fine and coarse textured weathered materials, sodic conditions, and salinity. Wherever suitable topsoil exists in sufficient quantities, they should be stockpiled and utilized as top priority plant growing material.

Toxic Materials

Elements identified which may be toxic in high concentrations in the overburden materials were limited to sodium and choloride and sulfate salts. These elements are not of the magnitude to be toxic to plant growth in the soil and overburden materials rated as suitable. However, more detailed studies conducted prior to mining may reveal specific toxic materials or others unfavorable for plant growth. If this occurs, these materials must be properly identified and plans made to dispose of them so that planting media and water supplies are not contaminated.

Laboratory Support

Chemical and physical characterizations of genetic soil profiles and bedrock materials were an important aspect of analyzing the material resources of the Foidel Creek Study Site. Soil samples were taken within the study site. The soil sampling sites are correlated with mapping units and represent typical site chemical and physical characteristics. The bedrock material was obtained from drill borings with the drill cores being received in the laboratory at the conclusion of the field program. The deep boring sites were selected on a geological basis and the drill hole sites became the master sites for characterizing the bedrock material.

The results of these analyses are shown on pages C5 to C8 of the Soils C Appendix.

After the drill cores were received in the laboratory, they were separated into samples for bedrock evaluation. The basis of separation included geological characteristics and visually observable characteristics (lensing, straining, cementation, etc.).

Textural composition (fine, medium, coarse, etc.) was also a factor. The majority of the samples are comprised of no more than 5 to 10 feet of the core. A screening technique was used in laboratory characterizations. Pages C9 to C12 in the appendix outline the screenable soil characterizing program followed. The following screening tests were run of all samples: electrical conductivity in mmhos/cm and pH (1:5 soil water ratio suspensions and 1M $CaCl_2$), settling volume, fragmented hydraulic conductivity, cation-exchange-capacity, total sodium, and percent moisture at 15 bars. Based on the results of the screenable testing program and field observations, additional analyses were made on those samples which appeared to have deficiencies. These included electrical conductivity in mmhos/cm, Na, Ca + Mg, and SAR of the saturation extract, saturation percentage, and exchangeable sodium (ES). The procedures used are outlined briefly in appendix C.

In addition to the screenable testing program, greenhouse pot studies were made on selected samples to indicate possible toxic or other unfavorable plant growth conditions. With the procedures used in the greenhouse studies, the results do not reflect many adverse physical conditions. Results of the pot studies are shown on pages C24 to C35 in appendix C.

Representative core sections were exposed to freeze-thaw and wetting and drying cycles to provide an indication of how the geologic material would break down if exposed to the weather. Correlation of these results with actual field conditions is difficult, but they do provide an indication. Results of these studies are shown on pages C15 to C23 of appendix C.

Soil Inventory

Fieldwork regarding soils investigations began in July 1975, with a reconnaissance of the entire area. The classifiers familiarized themselves with the topography, landforms, and probable complexity of the soils.

Later on, the soils were examined and compared with each other to determine the taxonomic classification. Profile descriptions that were written and the aforementioned classification process resulted in a working mapping legend for the soils inventory. Modifications were made to the mapping legend as work progressed to make it more closely reflect the field observations.

Samples for laboratory analysis were taken of representative profiles of all major soil types. These laboratory analyses facilitated confirming or modifying the mapping legend as well as ascertaining the chemical and physical suitability of the materials for revegetation purposes.

The mapping units are essentially soil types (soil series name plus the texture of the topsoil) with the general range of soil slopes. Classification of the soil series identified in the Foidel Creek Study Site is given in table 17, page 86 and the composite soil inventory map is found on page 88.

The standards for soil inventory on this site are fairly consistent with those commonly used by the SCS (Soil Conservation Service) for a high intensity soil survey. Although it was not possible to arrange an onsite review by the SCS of the Foidel Creek area soil inventory, series descriptions of those soils identified and classified by the SCS in the immediate local were obtained. Also, a subsequent soil inventory for the Fish Creek EMRIA area, which is in the same general area, was reviewed by the Chief, SCS Soil Surveys, Craig, Colorado.

As these sites are fairly similar in climate, topography, and other aspects, a degree of confidence is added to this earlier Foidel Creek work and correlation between the two sites.

6010-BD. - Aaberg clay loam, 1 to 7 percent slope:

Soil. - This soil is moderately deep, poorly drained internally, and developing residually on shaley formations underlying the north and west portion of the study site. Annual precipitation ranges from 15 to 20 inches (with about 60 to 70 percent being in the form of snow), meaning annual soil temperature is less than 8° C, and the frost-free season is approximately 85 days. The soil under discussion occurs on slopes varying from 1 to 7 percent with 2 percent slopes being dominant. Important inclusions within this mapping unit are soils which are similar in profile characteristics but have shallower depths to shale and occur in localized more steeply sloping areas. These inclusions comprise less than 20 percent of the mapping unit.

The surface layer of this mapping unit is normally a clay loam or silty clay loam in texture, light brown in color, and ranging 2 to 4 in in thickness. The subsoil is a light grayish brown or light olive brown silty clay, having a weak to moderate medium subangular blocky structure, and ranging in thickness from 4 to 10 in. The substratum of this soil is normally light olive brown in color, silty clay in texture, has a very weak coarse blocky to massive structure, and ranges in depth from 18 to 30 in overlying the partially decomposed or fractured fine textured shales. These profiles are only very weakly calcareous to noncalcareous, and range in pH from 6.8 to 7.9 in a 1:5 water solution with electrical conductivities ranging generally from 0.04 to 0.16 mmhos/cm.

The most important variations within this mapping unit are in depth to the underlying shale and in minor textural differences due to localized differences in composition of the parent rock. Depths to bedrock vary from 36 in to over 48 in, and textures vary from silty clays or clays to heavy silty clay loams.

Permeabilities of these soils are very slow, water holding capacities are high, rooting depths are shallow to moderately deep, surface runoff is rapid, and erosion hazard is moderately high.

Approximately 40 percent of this soil map unit is on slopes of 1 to 3 percent and approximately 60 percent is on slopes of 3 to 7 percent.

Soil Behavior. - Aaberg soils are presently used as pasture, and the production of native forage is low to moderate. The most probable use of these soils is for continued grazing, since the soils are not highly suited for use as backfill for revegetation of strip mines and are not in close proximity to the area which will be mined. These soils are moderately well suited for grazing and could be expected to remain a fairly productive forage producer if properly managed and not overgrazed.

The use of these soils as a source of backfill material is not expected to be common. However, should this use occur, revegetation and management could be rather difficult to revegetate and manage owing to their heavy texture, low permeability, and less than desirable chemical characteristics. Once disturbed, these soils will lose the small amount of natural structure which they now have and will become relatively impermeable to water. Revegetation would likely be a slow process on such material, and the hazard of erosion (particularly by wind) on this fine-textured material would be high.

6020-BC. - Moyerson clay loam, 3 to 12 percent slopes:

Soil. - Their soils are shallow, poorly drained internally, and occurs residually on shaley formations underlying the north and west portion of the study site. Annual precipitation ranges from 15 to 20 in (with about 60 to 70 percent being in the form of snow); meaning annual soil temperature is less than 8° C, and the frost free season is approximately 85 days. Moyerson soils have developed on slopes varying from 3 to 12 percent, with 5 to 6 percent slopes being dominant. Important inclusions within this mapping unit are soils which are similar in profile characteristics but which are deeper to underlying bedrock. They occur in less steeply sloping areas or areas of localized colluvial deposition. These inclusions comprise less than 15 percent of the mapping unit.

The surface layer is normally a clay loam or silty clay loam in texture, light brown in color, and ranges from 2 to 4 in in thickness. The subsoil is a light grayish brown or light olive brown silty clay having a weak to moderate medium subangular blocky structure and ranging in thickness from 3 to 8 in. The substratum is normally light olive brown, silty clay having a very weak coarse blocky to massive structure, and ranged in thickness from 6 to 18 in. These profiles are very weakly calcareous or noncalcareous, and range in pH from 6.8 to 7.9 in a 1:5 water solution having electrical conductivities (EC x 10^3) ranging generally from 0.04 to 0.16 mmhos/cm.

The most important variations within this mapping unit are in depth to underlying shale, and in minor textural differences due to localized changes in composition of the parent rock. Depths to bedrock vary from 8 in to about 24 in, and textures may vary between silty clays or clays to heavy silty clay loams.

Permeabilities of these soils are very slow, water holding capacities are moderate, rooting depths are shallow, surface runoff is rapid, and erosion hazard is quite high.

Soil Behavior. - Moyerson soils are presently used as pasture, and the production of native forage is relatively low. The most probable use of these soils is for continued forage production, since it is not likely to prove suitable for use as backfill for strip mine reclamation. They are only moderately well suited for grazing, but could be expected to be fairly productive under proper management.

This soil would not be well adapted for use as a source of backfill due to its heavy texture, slow permeability, and potential erosion hazard. Additionally, its shallow depth would result in a poor source of backfill from a quantity point of view.

6030. - Hesperus loam, 3 to 40 percent slope:

Soil. - These soils are deep, moderately well drained, and occur residually on mixed sandstones and shales which underlie the south-central part of the study site. Annual precipitation ranges from 15 to 20 in (with a large portion being in the form of snow), annual soil temperature is less than 8° C, and the frost-free season is approximately 80 days. The slopes on which these soils occur vary from 3 to 40 percent with 7 to 12 percent slopes being dominant. Important inclusions within this mapping unit are soils of mapping unit 6040, which are lighter in texture, in localized areas where parent rock is more sandstone than shale. These inclusions comprise less than 20 percent of the mapping unit.

The surface layer of this mapping unit is normally a loam or very light clay loam in texture, dark brown to very dark brown in color, and ranges from 2 to 8 in in thickness. Overlying this surface mineral soil, in areas of woody vegetative cover, is a layer of partially decomposed organic material mixed with some mineral material. It is usually a loam in texture, very dark gray-brown to black in color, and ranges from 1 to 2 in in thickness. The subsoil is normally a dark brown to brown clay loam having a moderate medium subangular blocky structure and ranging from 18 to 30 in in thickness. The substratum material is normally quite variable in texture but is commonly a light brown to light olive brown, massive clay loam containing many sandstone and shale fragments, and ranges from 6 in to 2 ft in thickness over relatively consolidated sandstone and shale bedrock material. These profiles are normally noncalcareous to the underlying sandstone and/or shale, which may be weakly to moderately calcareous. The pH's range from 5.5 to 7.2 in the soil profile and from 6.8 to 7.5 in the underlying bedrock material. Electrical conductivity (EC x 10^3) of the saturation extract range generally from 0.03 to 0.10 mmhos/cm.

The most important variations within this mapping unit are in depths to underlying bedrock materials, and in minor textural differences resulting from variations in composition of the underlying rock materials. Depths to bedrock within this mapping unit vary from 36 to over 60 in, and textures vary from heavy sandy loams to light clays.

Permeabilities of these soils are moderate, water holding capacities are relatively high, rooting depths are deep, surface runoff is slow, and erosion hazard is moderate.

This soil type was separated into four mapping units based on slope. Twelve percent of 6030 is on 3 to 7 percent slopes (6030B), 36 on 7 to 12 percent (6030C), 40 on 12 to 20 percent (6030D), and 12 on 20 to 40 percent slopes (6030E).

Soil Behavior. - Hesperus soils are presently being utilized for pasture, and production of native forage is relatively high. The most probable use for these soils will likely be as backfill material for revegetation purposes in reclaiming strip mined areas. Its characteristics render it highly suitable for this purpose. Infiltration rates should be adequate, even with the heavier textured horizons on the surface, and water holding capacities should be very good (about 3 to 4 in/ft of depth). The use of the underlying consolidated bedrock per foot of depth). The use of the underlying consolidated bedrock parent materials for backfill would result in a plant growth medium of much less desirability than use of the soil material itself due to its relatively heavy texture. Since these soils are relatively deep, a sufficient quantity of soil material should be available without the necessity of using the underlying bedrock formations.

6040. - Pachic Cryoboroll, fine sandy loam, mixed 7 to 20 percent slope:

Soil. - These soils are moderately deep, well drained, and are forming residually on medium textured sandstones occurring in the central and southern part of the study site. Annual precipitation ranges from 15 to 20 in/yr (with a large portion being in the form of snow). Annual soil temperature is not precisely known but is probably about 5.5° C, and the frost free season is approximately 80 days. The slope of this soil varies from 7 to 12 percent, with 6 to 8 percent slopes being dominant. Important inclusions within this mapping unit are soils which are somewhat shallower (Lithic Cryoborolls) in areas of slightly steeper slopes or in areas of accelerated erosion. These inclusions comprise less than 10 percent of the mapping unit.

The surface layer of this mapping unit is normally a very fine or fine sandy loam of a dark brown color, and ranging in thickness from 4 to 10 in. This surface mineral horizon is frequently overlain (in wooded areas) by a shallow (2 to 4 in) layer of decomposed leaf litter. The subsoil is normally a dark brown very fine sandy loam having a very weak medium subangular blocky structure, and ranging from 6 to 12 in in thickness. The substratum usually consists of partially decomposed, soft, fractured sandstone which is usually light brown to light reddish brown fine sandy loam, and is essentially structureless. This substratum is usually about 4 to 8 in in thickness, but fairly wide variations occur within the mapping unit. Beneath this decomposed sandstone layer, the solid sandstone of the underlying geologic formation is encountered, normally at a depth of 24 to 36 inches below the surface. These profiles are normally noncalcareous, and range in pH from 6.6 to 8.1. Electrical conductivities (EC x 10^3) of these soils generally range from 0.04 to 0.10 mmhos/cm.

Variations within this mapping unit consist primarily of localized areas of soils which are shallower to underlying sandstone (Lithic Cryoborolls), and in minor variations of texture within the profile. Depths to bedrock are seldom less than 18 to 20 in, and textures frequently approach loamy fine sands in both the A and B horizons.

Permeabilities of these soils are rapid, and water holding capacities are moderately low. Rooting depth in these soils is moderate with many roots being found which penetrate into the underlying soft sandstone. Surface runoff from these soils is slow, and erosion hazard is only moderate.

Soil Behavior. - These soils are presently used primarily as sheep pasture and native forage production is moderately high. Care must be exercised in the management of these soils to avoid overgrazing and increasing the erosion hazard.

The most probable future use of these soils within the site is as a source of backfill material for strip mine reclamation. For this purpose, they are considered to be moderately well suited. Infiltration rates are rather rapid, and water holding capacities (about 2.5 to 3 in/ft of depth) should be adequate. Quantities of backfill material available for stockpiling from this mapping unit would be somewhat restricted, but the underlying soft sandstone would be suitable for mixing with the soil material and should result in an adequate source of backfill material.

6050. - Splitro fine sandy loam, 0 to 20 percent slope:

Soil. - Splitro soils are shallow, well drained, and occur residually on medium textured sandstones found in the central and southern portion of the study site. Annual precipitation ranges from 15 to 20 in/yr (with a large portion being in the form of snow), annual soil temperature is less than 8° C, and the frost-free season is approximately 85 days. The slope on which these soils have developed varies from 7 to 12 percent, with 8 to 10 percent slopes being dominant. Important inclusions within this mapping unit are soils which are somewhat deeper (Argic Cryoborolls) in areas of lesser slopes or colluvial deposition. These inclusions comprise less than 15 percent of the mapping unit.

The surface layer of this mapping unit is normally a very fine sandy loam or fine sandy loam of a dark brown color ranging from 2 to 8 in in depth. In wooded areas, this surface mineral layer is frequently overlain by a shallow (2 to 4 in) layer of organic material (decomposed leaf litter). The subsoil is normally a dark brown very fine sandy loam having a very weak medium subangular blocky structure and ranging from 4 to 10 in in thickness. The substratum normally consists of partially decomposed, soft, fractured sandstone which is usually light brown to light reddish brown in color, is a fine sandy loam in texture, and is essentially structureless. This substratum is usually about 2 to 4 in in thickness, but fairly wide variations occur within this mapping unit. Beneath this decomposed sandstone layer, the solid sandstone of the underlying geologic formation is encountered, normally at a depth of 18 to 20 in below the surface. These profiles are normally noncalcareous, and range in pH from 6.7 to 7.3. Electrical conductivity of the saturation extract of these soils generally range from 0.3 to 0.7 mmhos/cm.

Variations within this mapping unit consist primarily of localized areas of increased depth to underlying sandstone (Pachic Cryoboroll), and in minor variations of textures throughout the profile. Depths to bedrock seldom exceed 24 in, and textures frequently approach loamy fine sands. Permeability of these soils is rapid, and water holding capacities are moderately low. Rooting depths in these soils are moderate, with many roots frequently penetrating into the soft sandstone. Surface runoff is slow, and erosion hazard is moderate.

This soil type is represented by two mapping units. Splitro fine sandy loam on a 3 to 7 percent slope comprises 44 percent of this soil type while that portion on a 12 to 20 percent slope comprises 56 percent.

Soil Behavior. - Splitro soils are presently used primarily as pasture for sheep, and native forage production is moderately high. Care must be exercised in the management of these soils for this use. Excessive removal of vegetative cover would result in a high erosion potential.

The most probable future use of these soils is for use as backfill material for strip mine reclamation. For this purpose, splitro soils should be considered moderately well suited. Infiltration rates are rapid, and water holding capacities, while somewhat low (about 1.5 in/ft of depth) should be adequate. The quantity of soil material available for stockpiling from this mapping unit will be somewhat restricted, but the underlying soft sandstone will, when pulverized or fractured by mining operations, also be usable to mix with the soil material for use as backfill.

6060. - Cumulic Cryaquolls (stream bottom land), 0 to 7 percent slope:

Soil. - This undifferentiated mapping unit is composed of recent alluvial materials of diversified textures and depths over bedrock distributed in complex patterns. This interrelated complexity creates a soil pattern that would be difficult to delineate into individual mapping units, and even if accomplished, such a separation would not be practical.

This complex is found primarily in the alluvial bottoms of the north fork of Middle Creek and Foidel Creek as well as some tributaries to these streams. Annual precipitation ranges from 15 to 20 in (with a large portion being in the form of snow), annual soil temperature is in the range of 3° to 7° C, and the frost-free season is about 80 days. The slopes which this soil complex occupy vary from about 0 to 7 percent, with slopes of 1 to 2 percent being predominant.

This complex can be generally said to be lighter in texture in the area of the north fork of Middle Creek, and heavier in the Foidel Creek area. Included within this unit are soils which generally have loam to clay loam surfaces, and underlying horizons of similar to somewhat heavier textures. Water tables are common in this mapping unit, particularly on the north fork of Middle Creek Valley, and mottling is frequently found to within 12 in of the surface. The color of both the surface and underlying horizons of the north fork Middle Creek Valley soils is very dark, while surface soil color in the Foidel Creek Valley is somewhat lighter. The soil materials within this complex are generally deep over bedrock (usually over 60 in), are generally noncalcareous and have electrical conductivities ranging from 0.05 to 0.15 mmhos/cm.

The most important variations within this mapping unit include isolated areas of very heavy textures (clays) and very light textures (loamy sands) as well as localized spots of high salinity.

Permeabilities of these soils are generally adequate, as are water holding capacities. Rooting depths are deep (where not affected by high water tables), surface runoff is generally moderate, and erosion hazard is slight to moderate.

Soil Behavior. - Soils of this complex are presently used for the production of native forage and pasture. Production is moderate to high, particularly in the north fork of Middle Creek Valley. Their most probable future use is for continued grazing, since removal of soil material in these drainageways would render them susceptible to excessive erosion, and since adequate amounts of backfill materials are likely to be available from more suitable sites. These soils are generally well suited to forage production and could be expected to remain productive under proper management. Table 18 gives the range of slope, total acres, and percent of each mapping unit previously described in the study site.

TABLE 17

Taxonomic Classification of Soils Studied

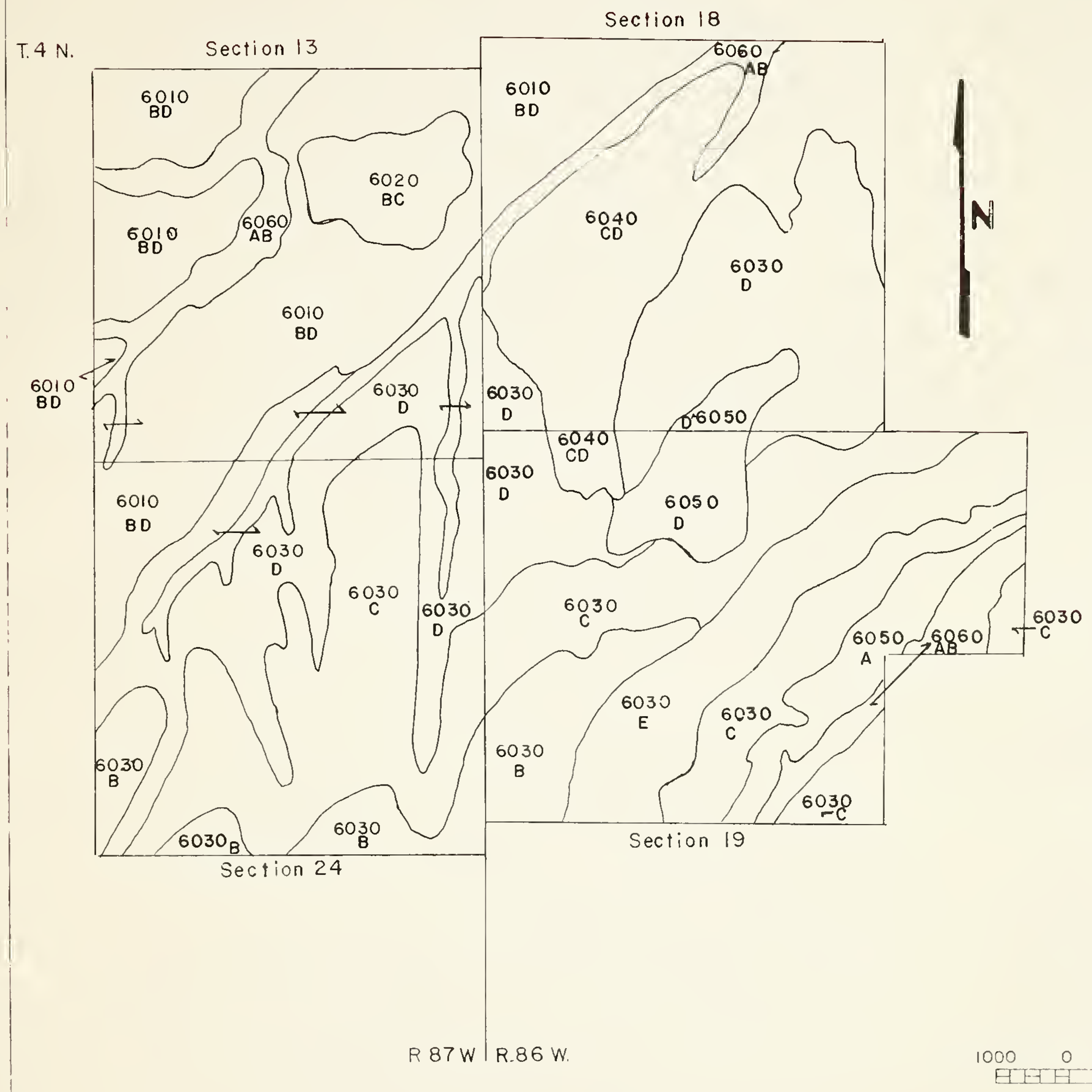
Series	Family	Subgroup	Order
Aaberg	fine, montmorillinitic	Borollic Vertic Camborthid	Aridisal
Gallatin	fine-loamy, mixed	Pachic Cryoboroll	Mollisol
Hesperus	Fine-loamy, mixed	Argic Pachic Cryoboroll	Mollisol
Moyerson	Clayey, montmorillinitic, calcareous, frigid, shallow	Ustic Torriorthent	Entisol
Splitro	loamy, mixed	Lithic Cryoboroll	Mollisol
(Referred to as undifferentiated Cryaquoll)	Note: more than one family	Cryaquoll	Mollisol
Unnamed 1/ Soils	Loamy, mixed	Pachic Cryoboroll	Mollisol

1/ The Soil Conservation Service has not correlated this soil to the series level, probably due to minimal areal extent.

Table 18

Composite Soil Inventory

Mapping Unit Number	Name	Range of Slope	Total Acres	Percent of Study Area
6010BD	Aaberg Clay Loam	3 to 20%	532.8	19.4
6020BC	Moyerson Clay Loam	3 to 12%	74.6	2.7
6030B	Hesperus Loam	3 to 7%	181.2	6.6
6030C	Hesperus Loam	7 to 12%	523.4	19.1
6030D	Hesperus Loam	12 to 20%	585.0	21.3
6030E	Hesperus Loam	20 to 40%	170.5	6.2
6040CD	Unnamed Fine Sandy Loam	7 to 20%	295.8	10.8
6050A	Splitro Fine Sandy Loam	0 to 3%	72.6	2.6
6050D	Splitro Fine Sandy Loam	12 to 20%	90.7	3.3
6060AB	Cumulic Cryaquolls (Alluvial Stream Bottoms)	0 to 7%	218.4	8.0



Composite Soil Inventory

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6030D	Hesperus Loam	12 to 20%	585.0	21.3
6030E	Hesperus Loam	20 to 40%	170.5	6.2
6040CD	Unnamed Fine Sandy Loam	7 to 20%	295.8	10.8
6050A	Splitro Fine Sandy Loam	0 to 3%	72.6	2.6
6050D	Splitro Fine Sandy Loam	12 to 20%	90.7	3.3
6060A8	Cumulic Cryaquolls (Alluvial Stream Bottoms)	0 to 7%	218.4	8.0

FOIDEL CREEK STUDY SITE COLORADO

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COMPOSITE SOIL INVENTORY

DESIGNED ______ SUBMITTED A SHINEMAN
DRAWN L SHANKLIN RECOMMENDED ______
CHECKED T CAPPELLUCCI APPROVED ______

LM REGION, DEN., COLO. | PLATE 6

VEGETATION

Variations in climate, soils, and topography causes vegetation heterogeneity within the Foidel Creek Reclamation Study Site. Five vegetative types are found within the four section area: broadleaf trees, mountain shrub, sagebrush, grass, and meadow.

The vegetation of the study site is mapped by vegetative subtypes, figure 10, and described in the following paragraphs. Composition of the subtypes is found in table 19.

Type designations and numbers are those used by BLM for Automatic Data Processing (BLM Manual - 1265).

Aspen Subtype - 101

The aspen (*Populus tremuloides*) subtype occupies the north-facing slopes. At higher elevations it continues to the south-facing mountain shrub subtype. At lower elevations it gives way to north-facing mountain shrub subtypes.

The soils are loam to fine sandy loam with depth of 14 to 18 in. A combination of soil depth, soil moisture, and position influence the medium for aspen growth.

Canopy varies from open to very dense, with an average of 62 percent, table 19. Mountain shrub type understory occurs with an open aspen canopy. Here the aspen is mixed with serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*), and mountain snowberry (*Symphoricarpos oreophilus*).

The area also supports a variety of grasses and forbs, including: smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), american vetch (*Vicia americana*), and sweet cicely (*Osmorhiza spp.*) table 19.

Gambel's Oak - Snowberry Subtype - 058-A

This mountain shrub subtype occupies the rock outcrops on south aspects. The soils are loam to fine sandy loam with depth of 6 to 12 in.

Understory vegetation is not dense and much of the area is covered by bare rock. The dominate species include: Gambel's oak (*Quercus gambelii*), mountain snowberry, low sagebrush (*Artemesia arbuscula*) and Kentucky bluegrass, table 19.

Snowberry - Gambel's Oak Subtype - 058-B

This mountain shrub subtype occupies the steep lower north aspect slopes of the site. The soils are loam to fine sandy loam with a depth of 12 to 20 in.

The vegetation has a greater diversity, is denser, and is somewhat diverse when compared to the south slope mountain shrub subtype, table 19. This is due to the deeper soils and more available moisture. The dominate species include: big sagebrush (Artemesia tridentata), Gambel's oak, mountain snowberry, Kentucky bluegrass, and mules ear (Wyethia amplexicaulis), table 19.

Big Sagebrush - Subtype - 041-A

This sagebrush subtype occurs below the elevation range of the mountain shrub and aspen subtypes. The transition zone between the communities is often wide making them difficult to separate. The soils are clay loam from 6 to 12 in deep.

The vegetation has a great diversity. The dominate species include: big sagebrush, mountain snowberry, western wheatgrass (Agropyron smithii), and Kentucky bluegrass, table 19.

Big Sagebrush - Smooth Brome - Subtype - 041-B

This sagebrush subtype is unique in that these areas appear to have been part of the aspen community years ago. The aspens were removed from these fairly level areas and now support a good growth of sagebrush and grass. The soils, like the adjacent soils in the Aspen, are a loam to fine sandy loam with a depth of 14 to 18 in and show good soil moisture properties.

Big sagebrush and smooth brome dominate the site accounting for 63 percent of the total composition. Other species are associated with this subtype, each making up less than 5 percent of the total composition, table 19.

Silver Sagebrush - Subtype - 044

The silver sagebrush (Artemesia cana) subtype occurs in areas similar to big sagebrush subtype, below the elevation range of the mountain shrub and aspen subtypes. The soils are clay to clay loam with depth of 4 to 12 in.

Species associated with silver sagebrush include: Idaho fescue (Festuca idahoensis), Kentucky bluegrass, western yarrow (Achillea millefolium), and sticky geranium (Geranium viscosissimum), table 19.

Low Sagebrush - Subtype - 042

The low sagebrush (Artemesia arbuscula) subtype occupies a small area within the study site. It is located at the lowest elevation in the study site. The soils are high in clay and shallow.

The vegetation is low in diversity and bare ground is prevalent. Low sagebrush accounts for nearly 55 percent of the composition with other species accounting for less than 3 percent each, table 19.

Mules Ear - Western Wheatgrass - Subtype - 013

This subtype covers a small area between an aspen and mountain shrub subtype. The soils have a higher clay content, clay to clay loam, than the two surrounding communities.

The dominate vegetation includes: silver sagebrush, western wheatgrass, milkvetch (Astragalus spp.), dandelion (Taraxicum officinale), and mules ear, table 19.

Wet Meadow - Subtype - 021

The wet meadow subtype is the bottomland around Foidel Reservoir Number 1 and adjacent stream beds. The soils are clay to clay loam with depths of 6 to 12 in.

The vegetation is dominated by sedge (Carex spp.) and rush (Juncus spp.) accounting for 77 percent of the composition, table 19.

Dry Meadow - Subtype - 022

The dry meadow is an area used primarily for sheep pasture. It is surrounded by aspen and mountain shrub subtypes. The soils are similar to those of the surrounding area.

The vegetation of this subtype was not sampled. An ocular view of the area indicates the primary vegetation includes: bromes, fescues (Festuca spp.), wheatgrasses, and Timothy (Phleum pratenses).

Table 19
Percentage Aerial Cover, Mulch, and Bare Soil or Rock for the Vegetation Types on the Foidel Creek Study Site1/

Species		Big Sagebrush 041-A2/	Big Sagebrush 041-B2/	Low Sagebrush 0422/	Silver Sagebrush 0442/	Forb 0132/	Wet Meadow 0212/	Mountain Shrub 058-A2/	Mountain Shrub 058-B2/	Aspen 1012/
Trees										
Populus tremuloides	Aspen									74.43/
Pseudotsuga menziesii	Douglas Fir									1.1
Shrubs										
Amelonchier alnifolia	Serviceberry	0.9		54.7					1.9	23.0
Artemesia arbuscula	Low Sagebrush	3.6			0.1			6.4	0.2	
Artemesia cana	Silver Sagebrush	0.4			26.9	6.0				
Artemesia tridentata	Big Sagebrush	20.3	37.2		2.4	1.0		3.9	8.2	
Chrysothamnus viscidiflorus	Green Rabbitbrush	1.0			1.8			3.2		
Potentilla fruticosa	Shrubby cinquefoil									
Prunus virginiana	Chokecherry	1.7						1.6	1.3	12.4
Quercus gambellii	Gambel's Oak							39.6	13.0	
Rosa woodsii	Wild Rose	0.6							0.2	
Symphoricarpos oreophilus	Mountain Snowberry	5.6	1.3		2.2			13.4	17.7	12.7
Grasses										
Agropyron cristatum	Crested Wheatgrass		4.5							
Agropyron smithii	Western Wheatgrass	5.4		1.3	3.1	20.0		1.5		
Agropyron trachycaulum	Slender Wheatgrass	0.3				3.7			0.4	
Bromus inermis	Smooth Brome		25.8		0.6			0.2	1.3	7.9
Bromus marginatus	Mountain Brome									3.1
Bromus tectorum	Cheatgrass Brome	0.1						0.5		
Carex spp.	Sedge						28.7			
Elymus cinerus	Giant Wildrye	1.0	0.8					0.8		
Festuca elatior	Meadow Fescue						3.0			
Festuca idahoensis	Idaho Fescue	4.1			6.6	1.7			0.8	
Hordeum jubatum	Foxtail Barley	0.3								
Melica spectabilis	Purple Oniongrass	0.5			0.3	1.3		0.3	2.0	0.2
Phleum pratense	Timothy Grass	0.1	0.7	1.7	0.9		3.0		1.4	
Poa canbyi	Canby Bluegrass	0.7		2.7	3.3	0.3				
Poa pratensis	Kentucky Bluegrass	9.8	4.4		10.6	0.3	4.7	8.0	8.8	6.3
Poa secunda	Sandberg Bluegrass			1.5						
Stipa viridula	Green Needlegrass	4.4	0.2		1.2			0.8		

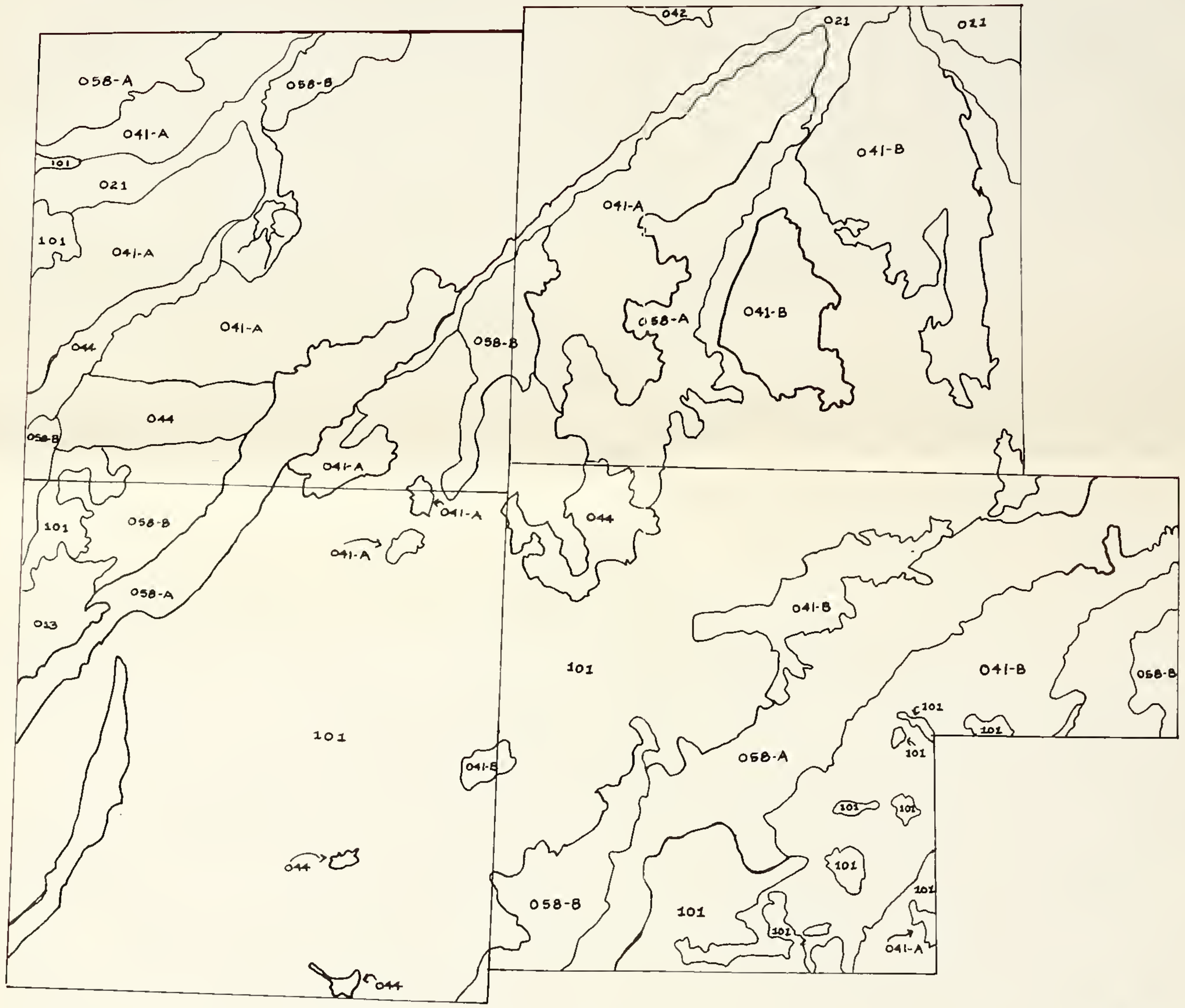
Table 19 (Continued)

Species [1]		041-A	041-B	042	044	013	021	058-A	058-B	101
		Vegetation Types								
Forbs										
Achillea millefolium	Western Yarrow	4.5	0.1		6.0	3.7		0.8	3.0	1.2
Agastache urticifolia	Giant-Hyssop	1.1	0.2		2.2			0.3	1.6	3.4
Antennaria aprica	Pussytoes			1.0						
Astragalus spp.	Milkvetch	0.1			3.5	5.0				
Balsamorhiza sagittata	Arrowleaf Balsamroot							0.4		
Cirsium foliosum	Elk Thistle	0.4			0.3		1.3			
Collomia linearis	Collomia	1.2						0.4	3.7	
Delphinium nelsoni	Low Larkspur		0.8						0.2	
Delphinium occidentale	Duncecap Larkspur	0.4								1.5
Equisetum spp.	Horsetail						1.7			
Erigeron compositus	Cutleaf Daisy			0.7	2.5					
Galium spp.	Bedstraw		1.9					0.5	0.8	1.8
Geranium viscosissimum	Sticky Geranium	1.9			5.7		1.3	0.5	4.3	0.2
Juncus spp.	Rush	0.1					48.3			
Linum lewisii	Blue Flax	0.9							3.7	
Lupinus argenteus	Lupine	2.8			2.1		2.7	2.7		
Osmorhiza spp.	Sweet Cicely									5.1
Phlox longifolia	Longleaf Phlox	0.1								
Pteridium aquilinum	Bracken Fern									1.5
Senecio integerrimus	Groundsel	0.1	0.9			2.7		0.7	0.1	
Smilacina racemosa	False Solomon's Seal									2.0
Taraxicum officinale	Dandelion	0.6	0.7	0.5	0.9	7.3		0.5		
Thalictrum fendleri	Meadow Rue							0.3		4.1
Tragopogon dubius	Salsify	0.1			0.8					
Trifolium spp.	Clover	0.1				1.7	1.3			
Vicia americana	American Vetch	1.4	4.4	2.0	0.8			3.9	3.5	6.7
Viola nuttallii	Yellow Violet	0.2								
Wyethia amplexicaulis	Mules Ear	1.0				35.3		0.3	11.9	
Mulch		13.7	13.8	24.7	12.6	1.3	4.3	4.8	4.7	5.8
Bare		8.7	2.4	9.3	2.8	8.7	0.0	3.1	1.1	0.0

1/ Each number is the mean value for the transects sampled in each type.

2/ 041-A, Big Sagebrush-Kentucky Bluegrass; 041-B, Big Sagebrush-Smooth Brome; 042, Low Sagebrush; 044, Silver Sagebrush, 013, Mules Ear-Western Wheatgrass; 021, Rush-Carex; 058-A, Gambel's Oak-Snowberry (South Facing Slopes); 058-B, Snowberry-Gambel's Oak (North Facing Slopes); 101, Aspen.

3/ Cover value presented for the Aspen canopy is in addition to all other cover.



LEGEND

SYMBOL	VEGETATION
041-A	BIG SAGEBRUSH - KENTUCKY BLUEGRASS
041-B	BIG SAGEBRUSH - SMOOTH BROME
042	LOW SAGEBRUSH - CANBY BLUEGRASS
044	SILVER SAGEBRUSH - KENTUCKY BLUEGRASS
013	MULES EAR - WESTERN WHEATGRASS
021	RUSH - SEDGE
058-A	GAMBEL'S OAK - SNOWBERRY (SOUTH FACING SLOPES)
058-B	SNOWBERRY - GAMBEL'S OAK (NORTH FACING SLOPES)
101	ASPEN

SCALE

ALWAYS THINK SAFETY

SUBVEGETATION TYPES

FOIDEL CREEK STUDY AREA

DESIGNED __________ SUBMITTED __________

DRAWN __________ RECOMMENDED __________

CHECKED __________ APPROVED __________

FIGURE 10

1. Wet Meadow subtype-021, surrounded by Big Sagebrush subtype 041-A.

2. Big Sagebrush - Smooth Brome subtype-041-B, and Aspen subtype - 101.

3. Gambel's Oak - Snowberry subtype - 58-A, on left, changing to Big Sagebrush - Smooth Brome subtype - 041-B at toe of slope. Dry Meadow subtype-022, occupies area on each side of the drainage, right hand side.

HYDROLOGY

To assess potential effects of mining on local water resources, an understanding of the hydrology of the Foidel Creek Study Site is needed. This report describes the hydrology of the area after 2 to 3 years of data collection in the area. The report is only the first phase of a continuing study and data collection effort in this area of Colorado.

The Foidel Creek Study Site is located in the Middle Creek drainage basin near the headwaters of Foidel Creek. Middle Creek is tributary to Trout Creek and is completely surrounded by Trout Creek to the east and Fish Creek, the major tributary to Trout Creek to the west (fig. 11). Historical data indicate the streamflow of Fish and Trout Creeks is perennial.

Surface Water

Three stream gaging stations, two on Foidel Creek 2.3 and 8.8 mi downstream from the study site and one on Middle Creek 7.8 mi downstream from the study site, have been in operation since October 1, 1975 (figure 11). Data from these stations indicate that streamflow in the Middle Creek basin is intermittent and that most of it occurs from March to June during spring runoff.

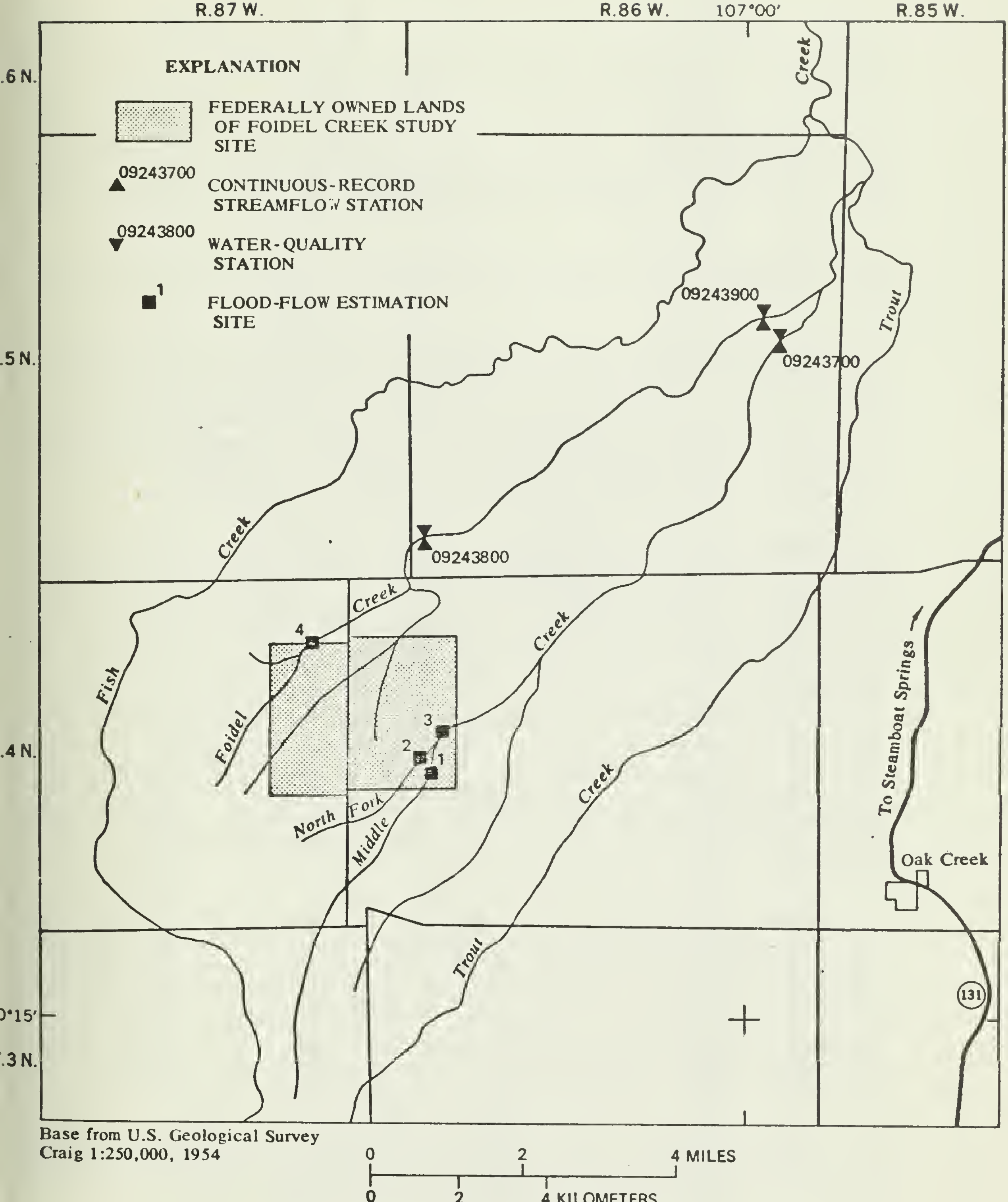


Figure 11--Location of Foidel Creek study site.

Stream discharges for water years 1976-1978 for stations 09243700 Middle Creek near Oak Creek, Colorado (drainage area, 23.5 mi^2), 09243800 Foidel Creek near Oak Creek, Colorado (drainage area, 8.61 mi^2), and 09243900 Foidel Creek at mouth, near Oak Creek, Colorado (drainage area, 17.5 mi^2) are shown on figures 12, 13, and 14, respectively. The average discharge for station 09243700 is 2.05 ft^3/s (1,480 acre-ft/yr), for station 09243800 is 0.332 ft^3/s (240 acre-ft/yr), and for station 09243900 is 1.21 ft^3/s (876 acre -ft/yr).

The extremely low discharges for water year 1977 are a reflection of the recent drought.

A flow-duration curve is a cumulative frequency curve that displays the percent of time a given discharge is equaled or exceeded during a given period. The flow-duration curves for the streamflow gaging stations on Foidel Creek and Middle Creek are shown in figure 15. The Middle Creek flow-duration curve is used to illustrate the use of the curve. A discharge of 1 ft^3/s would be equaled or exceeded 30 percent of the time, based on the 3 years of record.

The shape of the flow-duration curve indicates if the low flow character of a stream is sustaining or diminishing at the low flow endpoint. The curves for the three stations exhibit diminishing low flow characteristics. That is, the base flow at each station is zero much of the year. The Middle Creek curve plots to the right of the Foidel Creek curves, reflecting more runoff due to the larger drainage size, but all curves have the same basic shape. An analysis of these flow-duration curves was made to estimate the flow duration curves at the mining tract but proved inadequate. However, as there is less drainage area for the stream in the mining tract contributing to flow, the flow-duration curves would be shifted some unknown amount to the left reflecting lesser flows. That is, mean discharges would be equaled or exceeded a smaller percent of the time.

An estimate of floodflows for selected streams in the mining tract is included to evaluate the potential hazards near the streams. Floods may occur as a result of melting snowpack in the spring, as a result of convective-type cloudburst storms from late spring through fall, or a combination of both. Flood discharges for selected streams in the tract, estimated from the size of the drainage area, the mean annual precipitation, and site elevation (McCain and Jarrett, 1976), are given in table 20, page 103.

The potential flood hazards in the mining tract are minimal, except near the immediate channel, due to the small contributing drainage area which limits the size of the flood discharges.

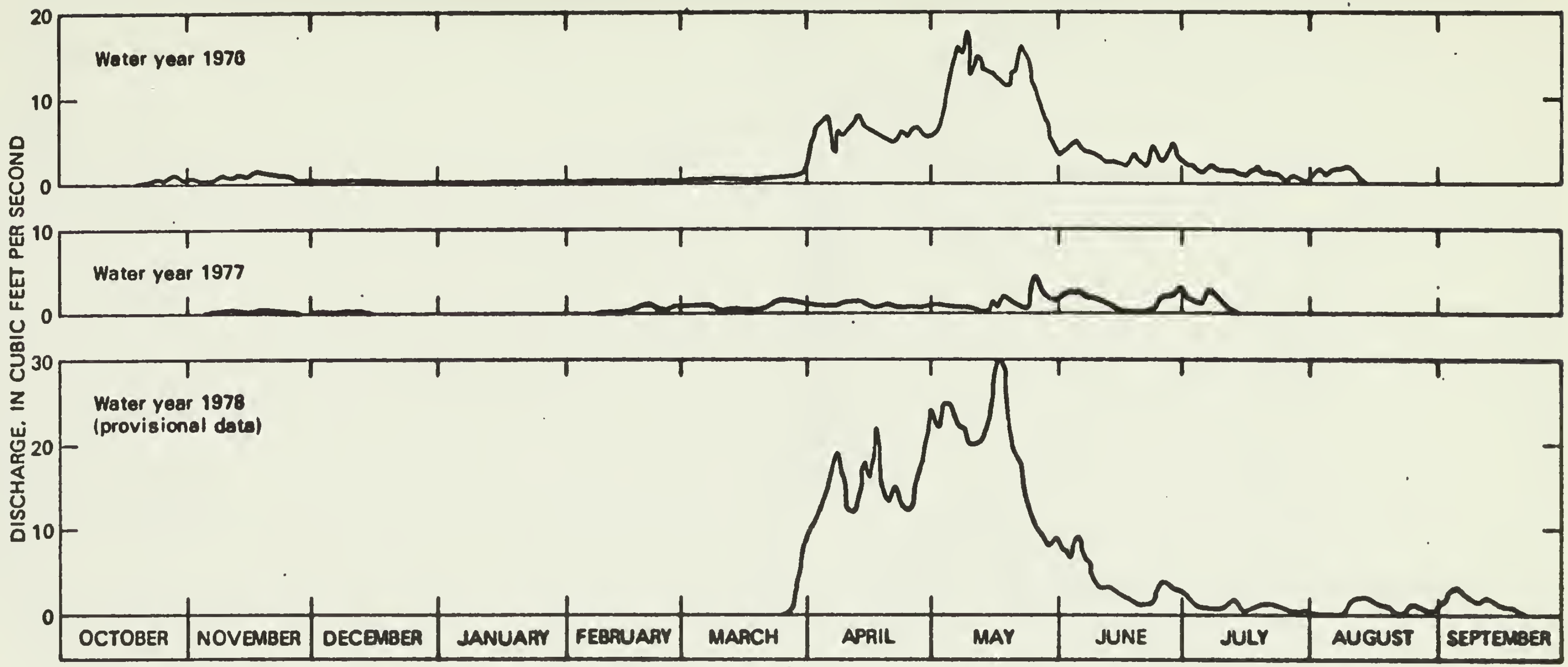


Figure 12--Hydrographs of daily mean flow, station 09243700 Middle Creek near Oak Creek, Colo., 1976-78.

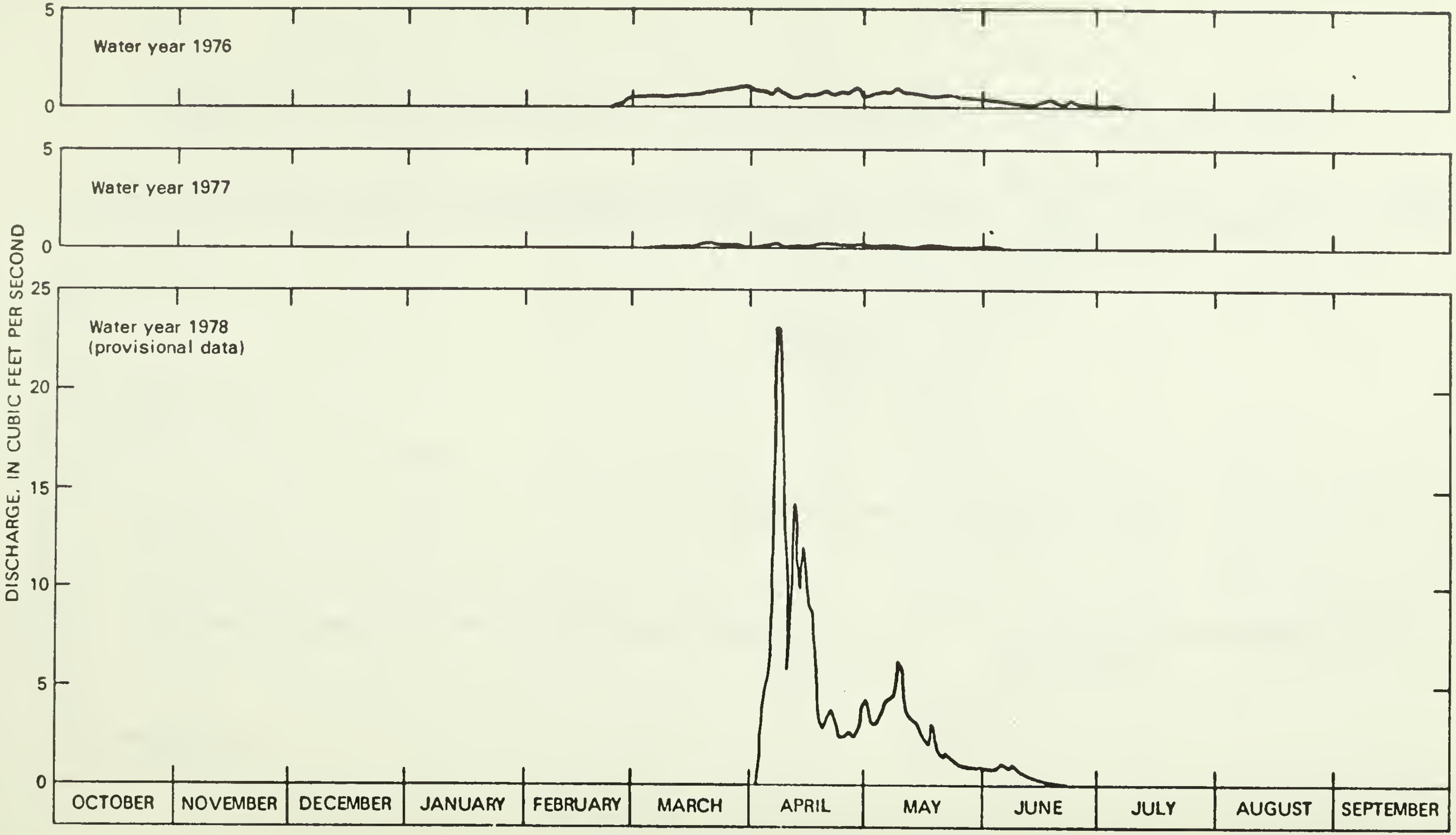


Figure 13--Hydrographs of daily mean flow, station 09243800 Foidel Creek near Oak Creek, Colo., 1976-78.

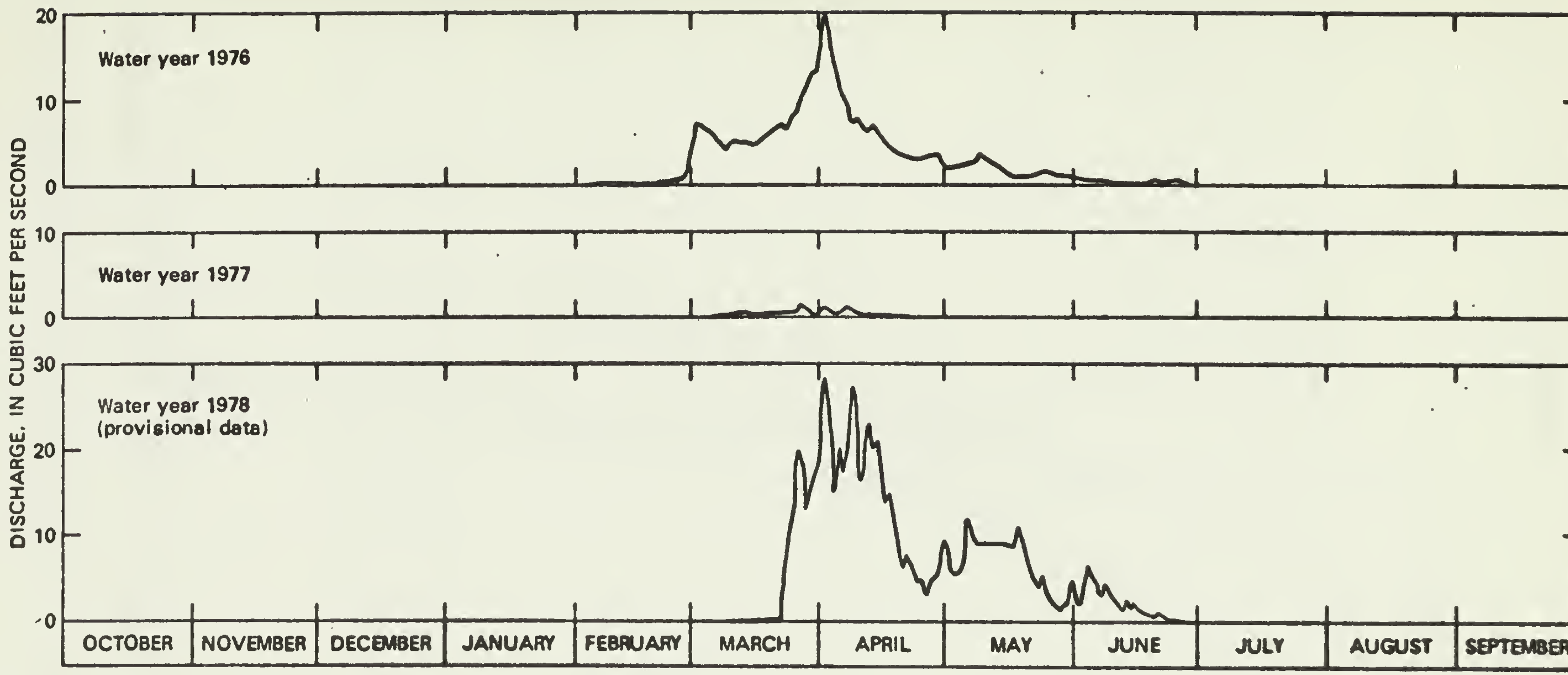


Figure 14--Hydrographs of daily mean flow, station 09243900 Foidel Creek at mouth, near Oak Creek, Colo., 1976-78.

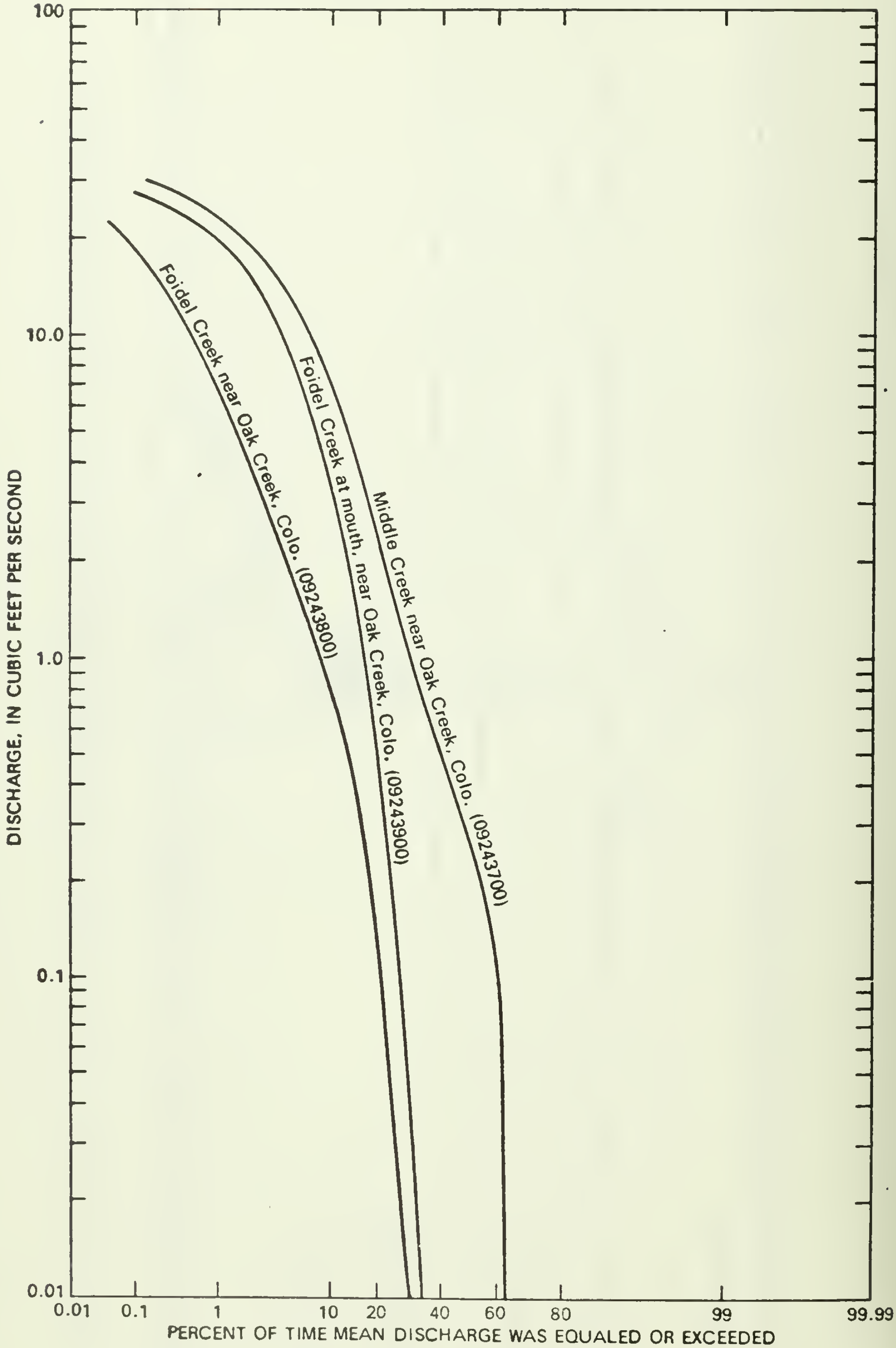


Figure 15--Flow duration curves of daily mean flow for Foidel and Middle Creeks near Oak Creek, Colo.

Table 20.--Estimated Flood Discharges for Selected Stream Sites

No.[1/]	Stream	Flood discharges, in cubic feet per second Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}
1	Middle Creek above confluence with North Fork Middle Creek---------	20	52	72	90	110
2	North Fork Middle Creek-----------	15	41	58	72	98
3	Middle Creek below confluence with North Fork Middle Creek---------	32	77	105	130	160
4	Foidel Creek at downstream end of study site----------------------	24	60	85	110	130

1/ Reference number for floodflow estimation site shown in figure 11.

Ground Water

Available ground-water data within the area of study (fig. 11) consist of five observation wells which were constructed in 1976, with the assistance of the Bureau of Reclamation. Pertinent construction data for these wells are shown in table 21. Data for observation wells adjacent to the study site are not given in table 21. Detailed geochemical data are not available for the study area. However, the Environmental Protection Agency, along with researchers from the Colorado School of Mines' Research Institute, have recently published a report, "Overburden Mineralogy as Related to Ground-water Chemical Changes in Coal Strip Mining," which lists pertinent geochemical information for the Energy Fuels and Edna Mines that is transferable to the Foidel Creek Study Site.

The Foidel Creek Study Site (fig. 11) lies within the Twentymile Park syncline in the southeastern part of the Yampa coalfield. The aquifer units in the area consist of sandstones within the Williams Fork and Iles Formations (fig. 9). The Williams Fork Formation ranges from 1,100 to 2,000 feet in thickness and contains three principal coals which have been previously described in this report.

Table 21.--Well-construction Data for Observation Wells Located Within the Foidel Creek Study Site

Well location	Casing I.D., in inches	Well depth	Top of first perforation	Water level	Date of last measurement
		in feet below land surface			
SB00408724BCB-1	2	145	105	84.50	7-78
SB00408724DBD-2	2	263	203	231.45	6-78
SB00408619BBD	2	111	71	72.40	6-78
SB00408618BDA	2	180	140	23.10	6-78
SB00408713DAA	2	173	133	+2.00	6-78

Principal ground-water withdrawal in areas adjacent to the study site areas is mainly from the alluvium or the unconfined part of the aquifers in the Williams Fork and Iles Formations. The unconfined part of the aquifer is that which is under atmospheric pressure; whereas the confined part is under greater than atmospheric pressure. There is no continuous boundary between the unconfined and confined parts of the aquifer because of the lenticular nature of the sandstones in the Williams Fork and Iles Formations.

Within the boundaries of the Foidel Creek Study Site there is currently no withdrawal from the ground-water system, except by natural discharge of ground water to Foidel Creek under the prevailing gaining conditions.

Recharge to the rock units within the Foidel Creek Study Site results from infiltration of precipitation and snowmelt. The amount of recharge is now known but is probably less than 1 percent of the annual precipitation. There is some recharge to the alluvium during periods of high discharge in Foidel Creek. This water, however, is immediately released as the stage decreases. Direct recharge to deeper aquifers may occur where streams cross the northwest-southwest trending faults. Small stock ponds within the study site probably do not contribute to recharge because of the high evaporation rates and silting of the pond bottoms.

The altitude of the potentiometric surface is shown in figure 16. Because of well construction methods and well measurement techniques, only a composite surface can be shown. One of the wells was flowing to about 2 ft above the land surface. Ground-water movement within the study site is shown by the arrows in figure 16. The direction of

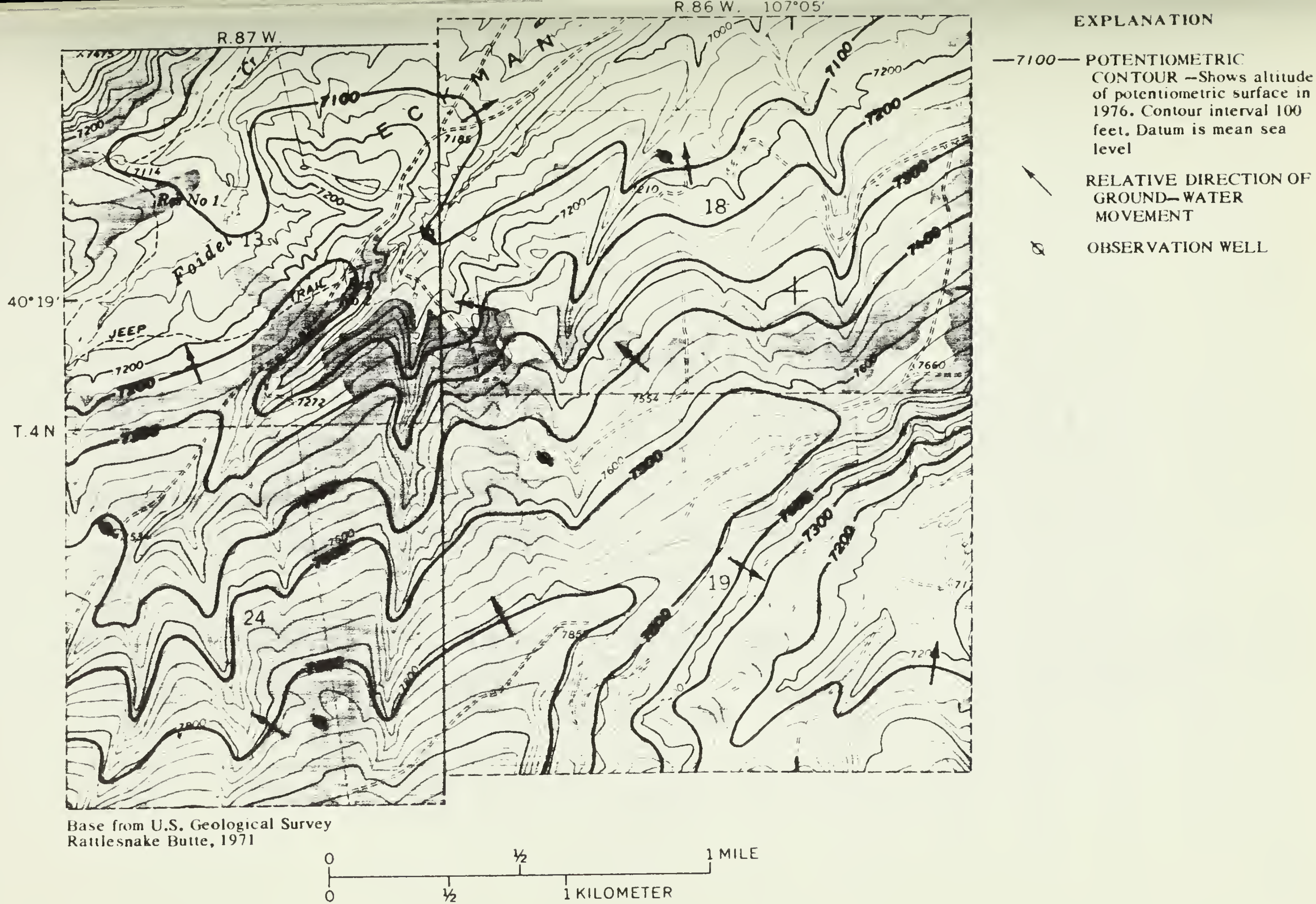


Figure 16--Potentiometric surface and the direction of ground-water movement in the Foidel Creek study site.

movement is essentially toward the northeast or towards the axis of the Twentymile Park syncline. Ground-water movement out of the area is towards the Yampa River. Aquifer tests made on wells outside of the study site show that the rate of movement is very small. Values of hydraulic conductivity range from about 0.1 ft/d to 0.01 ft/d.

Values for transmissivity usually vary from 5 to 10 ft^2/d. Some transmissivities have been reported to be less than 1 ft^2/d. Figure 17 shows a recovery test made on a well similarly constructed as those within the study site (see table 21). This test shows an extremely steep recovery curve. A discharge of about 10 gal/min for a small diameter well is probably the maximum for wells in this area.

Water Quality

All natural waters contain mineral constituents dissolved from the rocks and soils with which they have been in contact. The concentration of dissolved constituents depends primarily on the type of soil or rock, to some extent the length of contact time, solubility of the minerals, and pressure and temperature conditions. In addition to these natural conditions, man's activities, such as the mining of coal, can have a profound effect on the chemical quality of the water.

All of the data presented in tables 22 and 23 are from the Environmental Protection Agency publication (EPA-600/7-78-156) "Overburden Mineralogy as Related to Ground-water Chemical Changes in Coal Strip Mining." The location of all cores, ponds, springs, lysimeters, and wells listed in tables 22 and 23 can be found in the above-mentioned publication.

An interpretation of the data in tables 22 and 23 from Energy Fuels and Edna coal mines shows that the ground water in these adjacent geologically similar areas can be classified into three major groups: sodium bicarbonate waters, which occur in the lower part of the unconfined zones and in the confined zones; calcium-magnesium sulfate waters, which occur in the thicker shales; and calcium bicarbonate waters, which occur mostly in the alluvium. The origin of these three water types is given below:

Water Type 1 (Na-HCO_3). - The water most nearly representative of this end member is that of Sample D-9 (table 22) which is artesian in origin. The total dissolved solids content of this water type is approximately 600 mg/L. On this basis, the sodium bicarbonate water is unusual. Also it contains considerably less calcium and magnesium than is usually reported as occurring with the sodium. A possible explanation of the bicarbonate ground water is that it results from sulfate reduction. Where water and organic material are in contact,

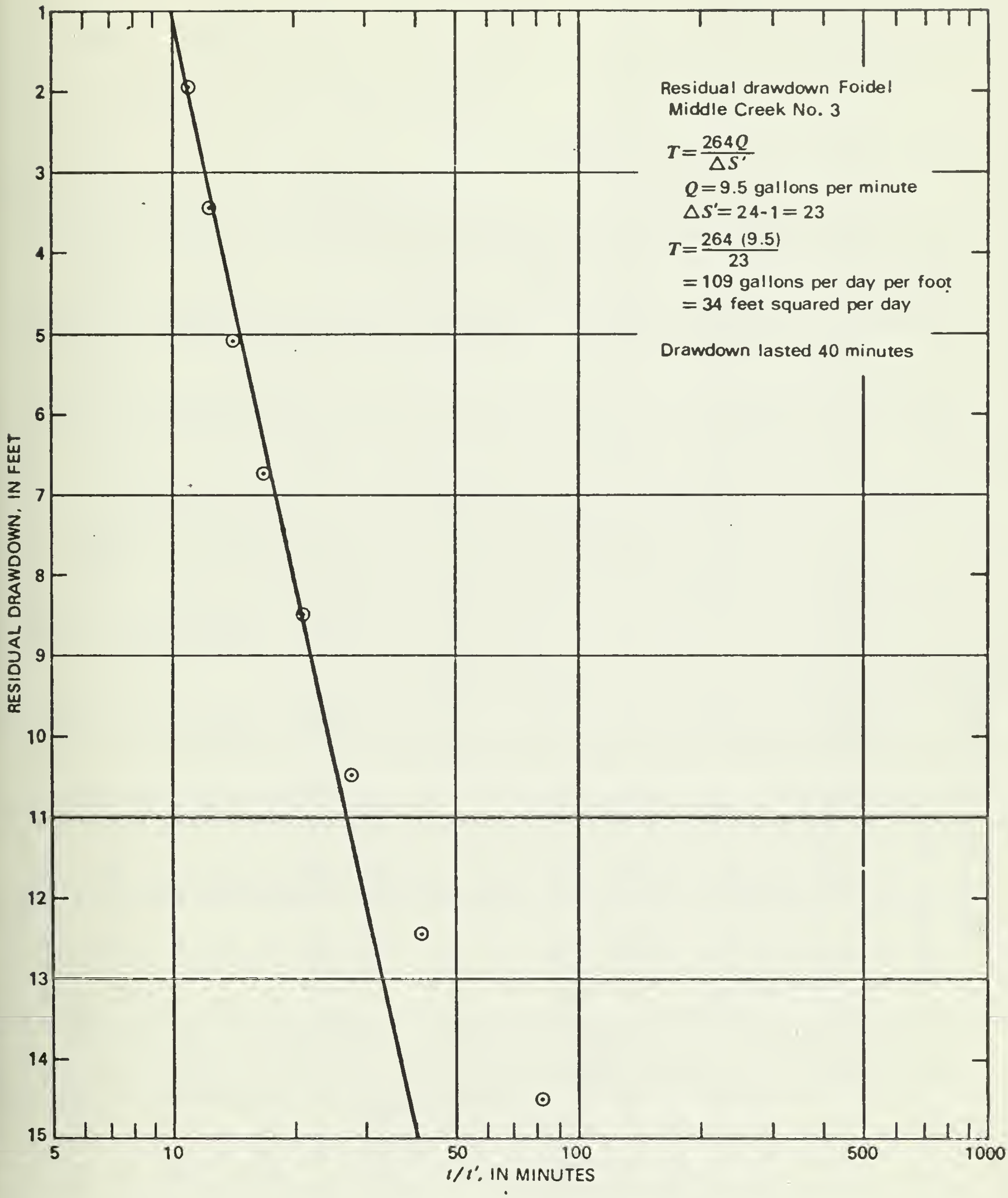


Figure 17 -- Recovery test made on a well adjacent to the Foidel Creek study site.

Table 22.--Water data from Energy Fuels Mine, Colo.

[From Hounslow, Fitzpatrick, Cerrillo, and Freeland, 1978, table C-1, p. 222]

Samples	Pond 1	Pond 2	Pond 3	Spoils Flume	Stream	Lysimeter SL-3	Lysimeter SL-4	Well S-6	Well S-9	Well S-10	Well D-6	Well CD-7	Well CD-8	Well D-9	Well D-14
Field Measurements															
Temperature (°C)	13.8	14	17	10.2	14.5	10	4	7.2	10.2	7.2	9.0	6.3	13.7	11.4	8.0
pH	9.2	8.1	6.2	8.4	8.0	7.7	6.5	7.4	7.2	7.6	7.9	10.0	7.7	9.6	6.5
Dissolved O_2 (mg/l)	14	21		16	10	3		14	11	8	14	13	9.1		
Conductivity (μmhos)	450	1,850	2,400	1,750	2,000	2,100	1,700	1,180	1,380	710	800	240	450	780	880
Salinity (°/oo)	0.8	1.8	2.3	1	1.8	2	2	0.5	0.7	0			0	0	1.2
Laboratory Determinations															
Organic															
Total Organic C (ppm)	20.5	3.5	10.9	2.4	14.7	81.2		5.6	6.4	5.9	6.0	4.4	3.0	115	4.8
Phenols (ppm)	<0.003	<0.001	<0.001	<0.001	0.003			0.012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tannin + Lignin (ppm)	0.84	<0.05	<0.05	<0.05	0.47			<0.02	<0.05	0.05	<0.005	0.08	<0.05	<0.09	0.09
Physical															
Total Alpha Activity (pCi/l)	6.0±2.7	11±6	24±8	8.7±5.1	19±7			6.4±1.2	6.8±3.9	3.1±1.3	2.0±2.3	2.7±1.1	2.8±1.6		17±5
Total Beta Activity (pCi/l)	0±16	8±19	0±21	0±8.5	5±22			17±10	0±13	0±8	10±6	28±10	0±7.2		38±19
Laboratory Determinations															
Inorganic (mg/l)															
HCO_3^{-1}	141	273	141	296	544	271	219	384	547	571	490	269	312	543	454
Br^{-1}	<0.02	0.25		0.65	<0.02			0.58	16		<0.1	0.26		<0.1	
CO_3^{-2}	53	2	0	0	0	0	0	0		0		5	0	48	0
Cl^{-1}	17	10	10	10	55	59	47	13	16	11	33	32	10	10	18
F^{-1}	1.0	2.1	0.9	0.5	3.2	1.1	0.9	0.7	0.6	0.9	0.46	0.7	0.5	0.2	4.7
$NO_2^{-1} + NO_3^{-1}$	0.2	2.7		1.0	0.5			0.4	0.8	0.3	5.1	0.3	0.7	0.4	<0.1
PO_4^{-3}				<0.1					2.1	<0.1	<0.1	<0.1	<0.1	<0.1	
SO_4^{-2}	68	1,450	1,750	1,440	1,540	1,650	1,450	735	800	176	263	1,393	70	100	500
SiO_2	4.2	6.3	<0.1	0.9	<0.1			9.6	1.9	7.5	11.5	13.3	1.6	85.8	9.6
Al	0.3	0.3	0.3	<1.0	0.3	0.5	0.5	<0.1	<1.0	0.3	<1.0	<0.1	<1.0	<2.0	1.2
As	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.003	<0.005	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005
Ba				<0.2					<0.2		<1.0		<0.2	<1.0	
B	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1
Cd	<0.04	<0.03	<0.01	<0.1	<0.04	0.01	0.01	<0.03	<0.1	<0.03		<0.03	<0.1		<0.04
Ca	36	365	429	400	250	407	229	242	153	41	14	28	36	5.4	79
Cr	<0.05	<0.03	<0.05	<0.1	<0.05	<0.005	<0.005	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.1	<0.05
Cu	<0.04	0.06	0.03	<0.1	<0.04	0.03	0.01	<0.04	<0.1	<0.04	<0.04	<0.04	<0.1	<0.04	<0.04
Fe	<0.1	0.3	0.4	0.1	0.1	0.50	0.10	0.2	0.5	0.4	<0.2	<0.1	0.1	1.3	0.7
Pb	<0.03	0.06	<0.01	<0.2	<0.03	0.02	0.09	0.05	<0.2	<0.03	<0.1	<0.03	<0.2	<0.1	0.03
Li				<0.1					0.1		0.1		0.1	<0.1	
Mg	37	127	151	187	229	176	122	105	106	20	8	15	19	1.2	24
Mn	<0.1	<0.1	<0.1	0.1	0.9	3.4	0.05	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hg	<0.0001	0.0001	0.009	0.0001	<0.0001			0.0003	0.0001	<0.0001		0.0001	0.0002		<0.0001
Mo	<0.01	0.02	<0.01	<0.02	0.10			<0.01	0.11	0.02	<0.01	<0.01	<0.02	0.03	0.02
Ni	<0.1	<0.1	<0.1	<0.1	<0.1	0.08	0.10	<0.1	<0.1	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1
K	2.2	2.9	5.2	3.7	2.6	22	6	1.4	3.9	3.3	2.0	25	2.6	2.7	3.0
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Na	33	30	30	38	134	200	371	59	223	200	286	18	108	271	237
Sr	0.3	3.1	4.3	3.5	1.8	5	2	1.4	2.0	0.7	0.6	0.35	1.6	0.1	1.5
Tl	2.09	0.56	0.65	0.53	1.46	0.0	<0.10	0.40	0.23	0.68	0.25	0.22	0.08	0.32	0.44
Zn	<0.1	<0.1	0.04	0.4	0.1	0.48	0.22	0.10	0.4	0.2	0.1	0.1	0.2	0.2	<0.1

Table 25.--Water data from Edna Mine, Utah.

[From Hounslow, Fitzpatrick, Cerrillo, and Freeland, 1978, table C-2, p. 223]

Samples	Pond 1	Pond 2	Pond 3	Spring 1	Spring 2	Spring 3	Spring 4	Lysimeter SL-3	Lysimeter SL-10	Lysimeter SL-12	Well S-5	Well S-7	Well S-8
Field Measurements													
Temperature (°C)	25	24	16.8	9.8	10.0	10.3	11.5	8.5	12	7	10	8	14
pH	8.2	8.3	7.3	7.2	7.1	7.6	7.4	6.8	6.9	8.4	7.0	7.3	7.1
Dissolved O_2 (mg/l)	9	14		15	17	15	15	4	2	2	3	5	8
Conductivity (µmhos)	2,380	2,170	2.180	1.625	1,640	1,810	2.000	1,940	2,400	4,050	1.220	140	560
Salinity (°/oo)	1	2.1	2.0	1.0	1.0	1.6	1.8	1.5	2	2.5	0.5	0	0
Laboratory Determinations													
Organic													
Total Organic C (ppm)	5.3	4.0	4.1	3.4	2.7	2.8	3.5	9.4	16.7	11.5	3.9	2.2	15.43
Phenols (ppm)	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	0.008	0.012
Tannin + Lignin (ppm)	<0.02	<0.02	0.05	<0.002	<0.002	<0.02	<0.02				<0.02		
Physical													
Total Alpha Activity (pCi/l)	6.4±4.9	3.1±3.8	11±5	4.5±2.1	4.5±3.5	8.7±5.5	0±3.5				12±4	3.0±1.4	0.4±1.2
Total Beta Activity (pCi/l)	11±22	4±21	26±19	0±16	0±23	0±22	11±22				20±12	0±9	12±10
Laboratory Determinations													
Inorganic (mg/l)													
HCO_3^{-1}	128	53	107	168	247	163	162	137	253	730	410	116	181
Br^{-1}	0.45	<0.02	0.07	0.30	0.36	0.34	0.49	<0.02		<0.02		0.41	
CO_3^{-2}	0	2	0	0	0	0	0	0	0	0	0	0	0
Cl^{-1}	13	14	13	10	10	10	12	11	47	22	14	4	14
F^{-1}	1.2	1.6	2.0	0.6	0.6	1.6	2.2	0.7	0.8	0.8	1.1	1.1	1.2
NO_2^{-1} + NO_3^{-1}	0.4	0.3	<0.1	1.0	0.4	0.4	0.4				0.7	0.4	2.2
PO_4^{-1}				<0.1	<0.1								
SO_4^{-2}	230	1,488	1.250	1.650	1,563	1,563	1.725	1,875	1,634	2,975	775	25	1,530
SiO_2	7.7	0.5	<0.1	0.7	3.7	10.5	10.1				5.8	11.2	5.8
Al	<0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.5	0.5	0.5	<0.1	<0.1	<0.1
As	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.003	<0.005
Ba				<0.2	<0.2								
B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				<0.1	<0.1	<0.1
Cd	<0.03	<0.03	<0.04	<0.1	<0.1	<0.03	<0.03	0.01	0.01	0.01	<0.03	<0.03	<0.03
Ca	500	386	415	407	415	472	486	440	420	170	276	26	276
Cr	0.14	<0.05	<0.05	<0.1	<0.1	<0.5	<0.05	<0.005	<0.005	<0.005	<0.05	<0.05	<0.05
Cu	<0.04	<0.04	<0.04	<0.1	<0.1	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fe	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	12	0.5	6.6	0.2	2.0
Pb	0.07	0.05	0.05	<0.1	<0.1	0.06	0.06	0.05	<0.01	0.20	0.05	<0.03	<0.03
Li				<0.1	<0.1								
Mg	150	113	151	169	150	178	157	182	111	158	92	10.7	29
Mn	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	7.5	0.2	0.1	0.2	0.8
Hg	0.0006	0.004	<0.0001	<0.0001	<0.0001	<0.0001	0.0001				<0.0001		0.0007
Mo	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01				<0.01	<0.01	<0.01
Ni	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	<0.1	<0.1	0.1
K	4.7	2.7	2.6	2.2	2.6	2.2	3.2	4.0	5.0	38	4.0	1.3	6.6
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.008	<0.005	<0.005	<0.005
Na	26	25	22	11.4	13.7	14	25	26	86	1,140	24	4.8	14
Sr	1.9	2.6	2.4	1.6	1.7	2.0	2.6	1.5	2.2	13	3.3	0.1	0.4
Ti	0.34	0.34	0.59	0.05	0.03	0.20	0.23		0.72	0.72	0.30	0.20	0.43
Zn	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	2.3	0.1	0.1	0.1	0.2

such as in coal seams, this reaction is catalyzed by anaerobic bacterial. The reaction generally proposed is:

$$SO_4^{=} + CH_4HS \;\overline{+}\; HCO_3\overline{+}\; H_2O \qquad (1)$$

The sulfide produced by this reaction leads to the precipitation of iron and some metals present in the original water.

Further, if calcium and mangesium were initially present in the water, these elements may have been absorbed by montmorillonite clay, releasing sodium into solution.

Water Type 2 (Ca-Mg-SO_4). - The samples representative of this water type are the four springs and three ponds from the Edna Mine (table 23) and two ponds from the Energy Fuels Mine (table 22). The water in these ponds either moved through the spoils material prior to emerging at the surface or was otherwise in direct contact with spoils material.

Possible mechanisms for the production of Water Type 2 chemistry include: (1) leaching of the gypsum and starkeyite from the spoils piles. This would be the most likely mechanism, assuming sufficient gypsum in the spoils; (2) bacterial or chemical decomposition of pyrite to sulfuric acid coupled with the solution of calcite and dolomite. This, again, is dependent upon the presence of pyrite; and (3) bacterial oxidation of the organic sulfur in the coal and the reaction of the sulfuric acid so formed with calcite and dolomite. The coal does contain about 0.5 percent organic sulfur, and the near-neutral pH is optimal for most sulfur bacterial. The questionable points are, first, whether sufficient coal remains in the spoils to account for the sulfate content of the water and, second, whether sulfur-oxidizing bacteria are present.

Water Type 3 (Ca-HCO_3 low total dissolved solids). - The water most representative of this type is that of Sample S-7 (table 23) from the Edna Mine, which is water from the shallow alluvial aquifer.

Four ground-water analyses are plotted on figure 18. Based on geology and well depth, the three-phase system is quite apparent. Depending upon the geology of the overburden, calcium and magnesium concentrations may not be critical. More detailed sampling will be necessary to map the chemical facies present in the study site.

Well number	Well depth (ft)	As (UG/L	Dissolved Fe (UG/L)	Mn (UG/L)	pH	Se (UG/L)	Specific conduc-tance (µmhos/cm)	Dissolved Zn (UG/L)
FM-3	122	--	20	10	8.7	0	900	10
BR-5	173	--	1,200	60	7.4	0	1,300	60
BR-10	198	0	250	20	8.1	0	3,400	--
BR-8	18	1	30	15	7.2	2	610	--

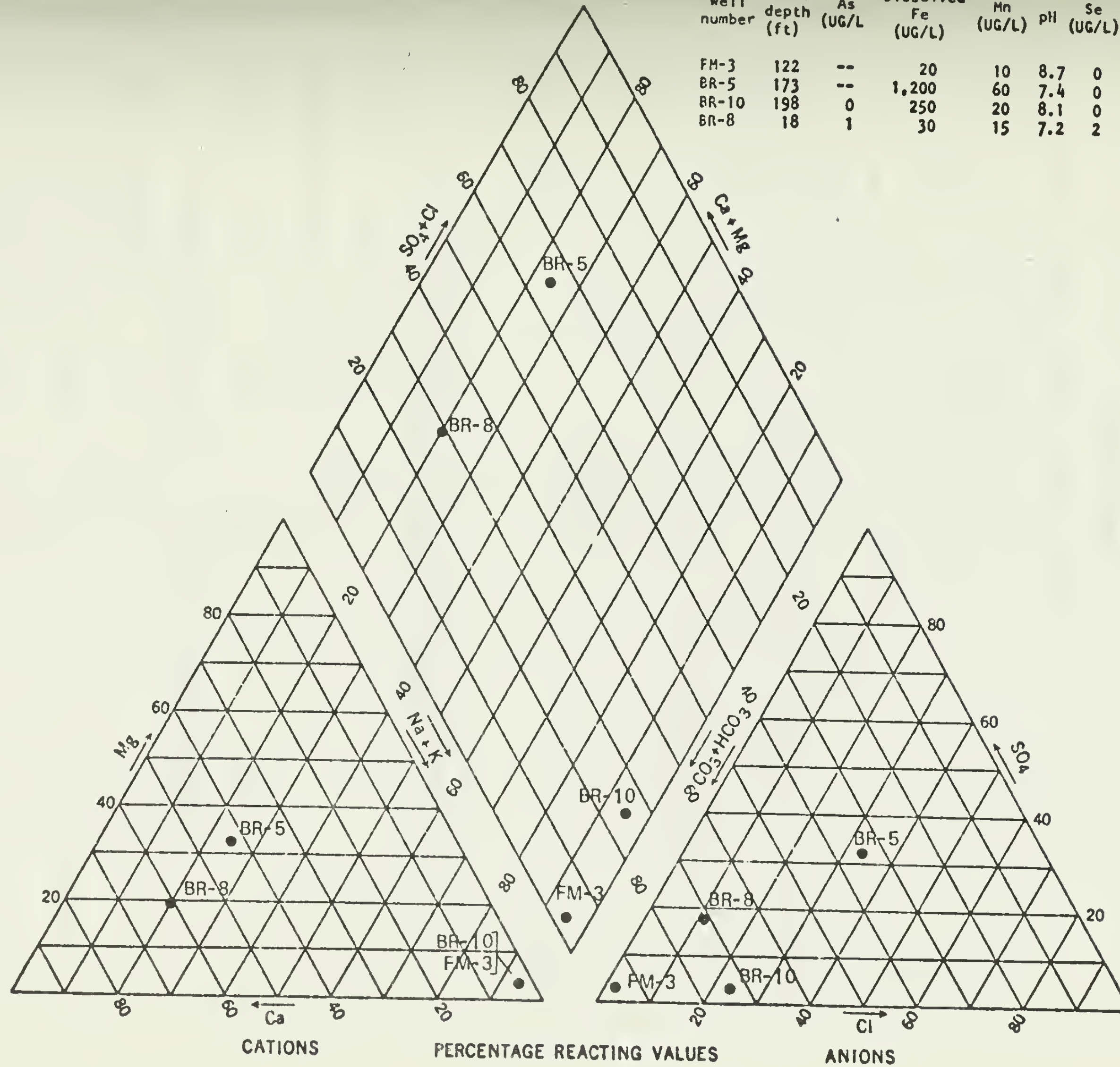


Figure 18--Water-analysis diagram showing ground-water variation in wells adjacent to the Foidel Creek study site, Colo.

A measure of the dissolved constituents in the surface water is expressed in terms of specific conductance. The relationship between water discharge and specific conductance is shown (figs. 19, 20, and 21) for the three surface-water stations identified in figure 11. The method of least squares was used to obtain a statistical relation between these two variables. Note the exponent in each equation, shown in figures 19 through 21, are very small. Therefore, from the results obtained from this data thus far, it appears that very little dilution occurs in the dissolved solids as discharge increases.

The primary constituents in the dissolved system at these three gaging stations are calcium, magnesium, bicarbonate, and sulfate. These major constituents for each of the gaging stations are shown in figures 22 through 24. These constituents are plotted against specific conductance in order that the relative magnitude of each constituent can be determined for a range of dissolved solids. Because the ratio of dissolved calcium to magnesium averages 2.3, only the values of dissolved calcium are plotted. The relations between specific conductance and these major constituents were obtained by the method of least squares and are given in table 24.

Table 24.--Least-squares Equations for Major Constituents Versus Specific Conductance for the Three Gaging Stations

Constituent	n	r^2	Standard error of estimate	Equation
9243700 Middle Creek near Oak Creek, Colorado				
Calcium (mg/L)	25	0.72	7.46	$C_{Ca} = 25.49 + 0.069SC$
Bicarbonate		0.61	39.49	$C_{HCO_3} = 99.69 + 0.289SC$
Sulfate	24	0.72	19.97	$C_{SO_4} = -5.49 + 0.186SC$
09243800 Foidel Creek near Oak Creek, Colorado				
Calcium (mg/L)	10	0.92	7.21	$C_{Ca} = -16.2 + 0.134SC$
Bicarbonate	10	0.67	47.50	$C_{HCO_3} = 36.6 + 0.36\ SC$
Sulfate	10	0.54	55.22	$C_{SO_4} = -90.3 + 0.32\ SC$

Table 24.--Least-squares Equations for Major Constituents Versus Specific Conductance for the Three Gaging Stations - (continued)

Constituent	n	r^2	Standard error of estimate	Equation
09243900 Foidel Creek at mouth, near Oak Creek, Colorado				
Calcium (mg/L)	8	0.95	4.93	$C_{Ca} = 15.2 + 0.09\ SC$
Bicarbonate	8	0.53	52.50	$C_{HCO_3} = 32.8 + 0.24\ SC$
Sulfate	8	0.81	38.40	$C_{SO_4} = -48.1 + 0.356SC$

Samples collected from Foidel Creek near Oak Creek from March 1976 through June 1978 were analyzed for major ions and selected trace constituents (Appendix D). Results of these analyses can be used to characterize the dissolved solids in the samples and estimate the constraints that may exist for minor or trace components. Table 25 lists the mean concentrations and standard deviations of the major ion analyses reported in Appendix D. The average concentrations listed in table 25 meet promulgated standards for both aquatic life and domestic drinking water supplies (Environmental Protection Agency, 1976).

Table 25.--Mean Concentration and Standard Deviations of the Concentration of Major Ions in Samples from Foidel Creek near Oak Creek

(In milligrams per liter)

Ion	Mean	Standard deviation
Calcium	89	7.2
Magnesium	40	3.3
Sodium	27	3.3
Potassium	3.4	.4
Bicarbonate	316	48
Sulfate	161	55
Chloride	5.2	.9

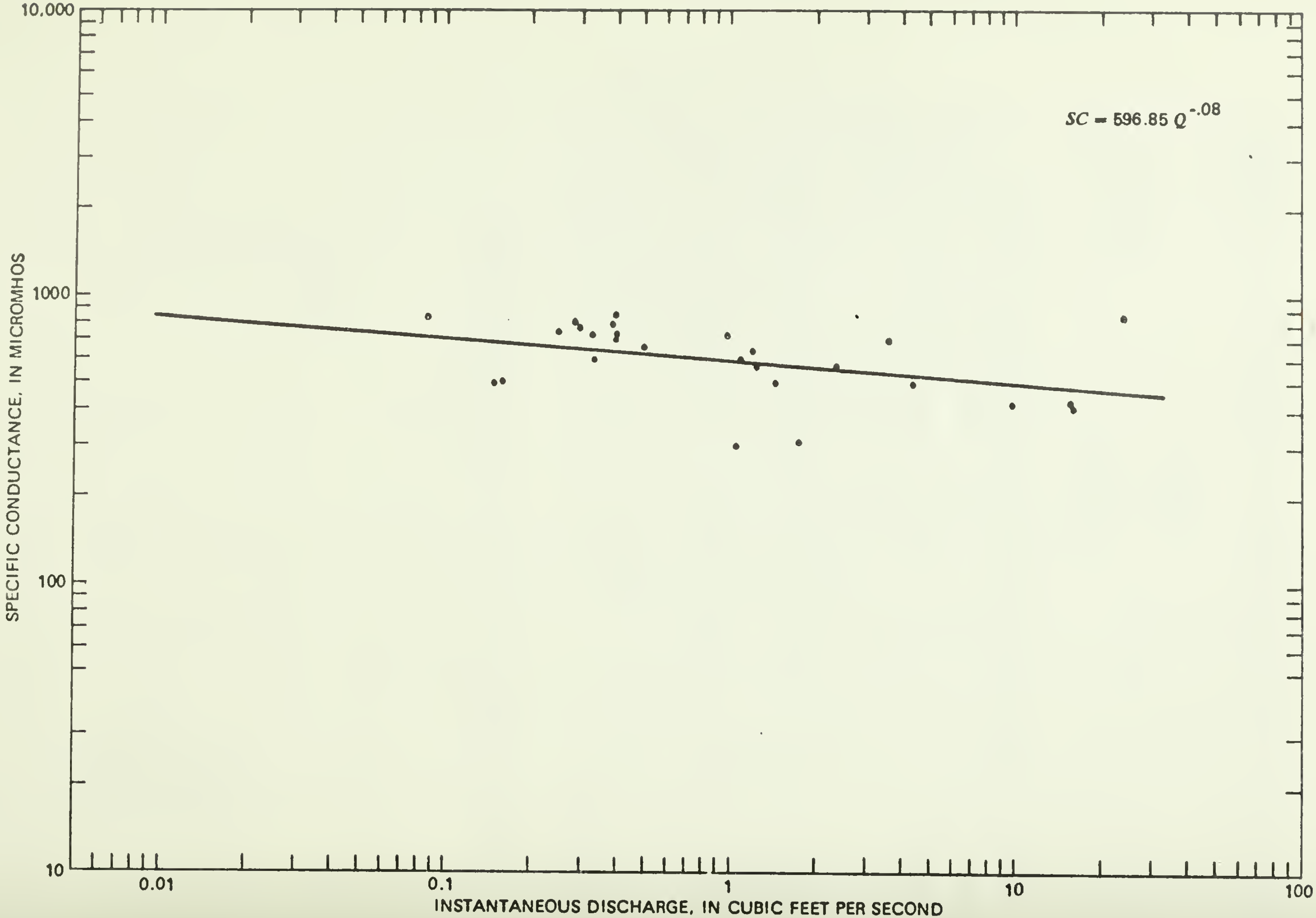


Figure 19--Instantaneous discharge versus specific conductance for Middle Creek near Oak Creek, Colo. (09243700).

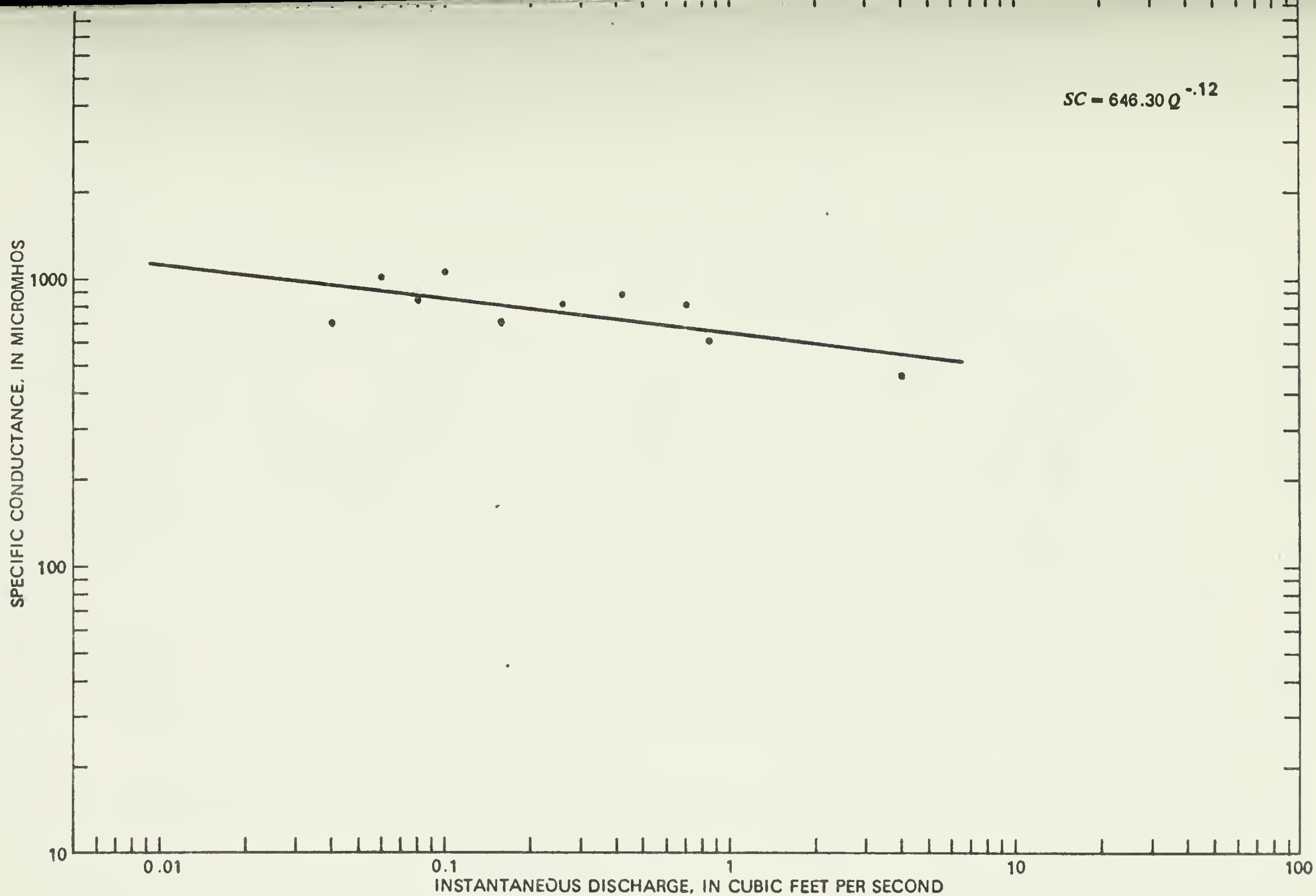


Figure 20.--Instantaneous discharge versus specific conductance for Foidel Creek near Oak Creek, Colo. (09243800).

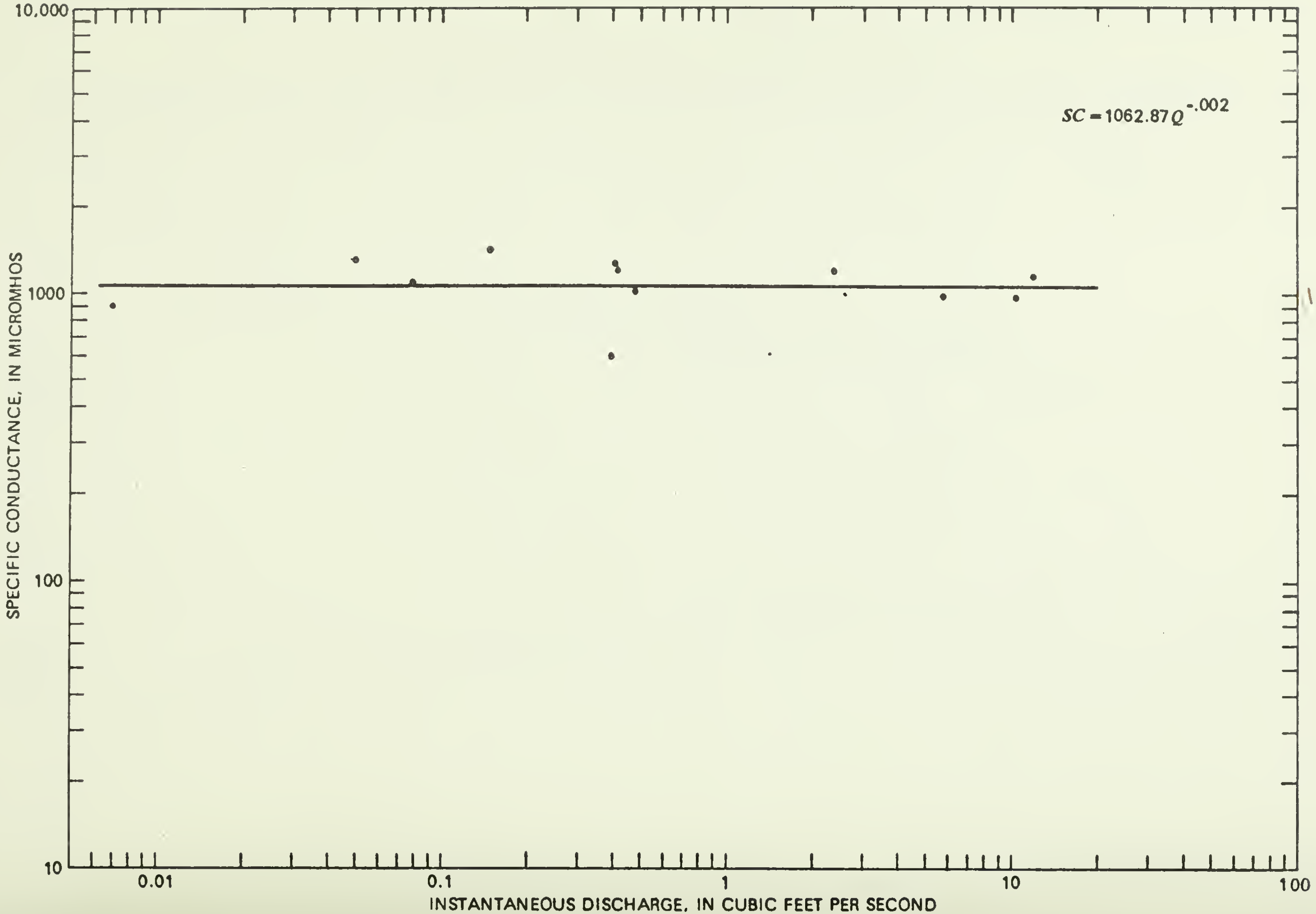


Figure 21.--Instantaneous discharge versus specific conductance for Foidel Creek at mouth, near Oak Creek, Colo. (09243900).

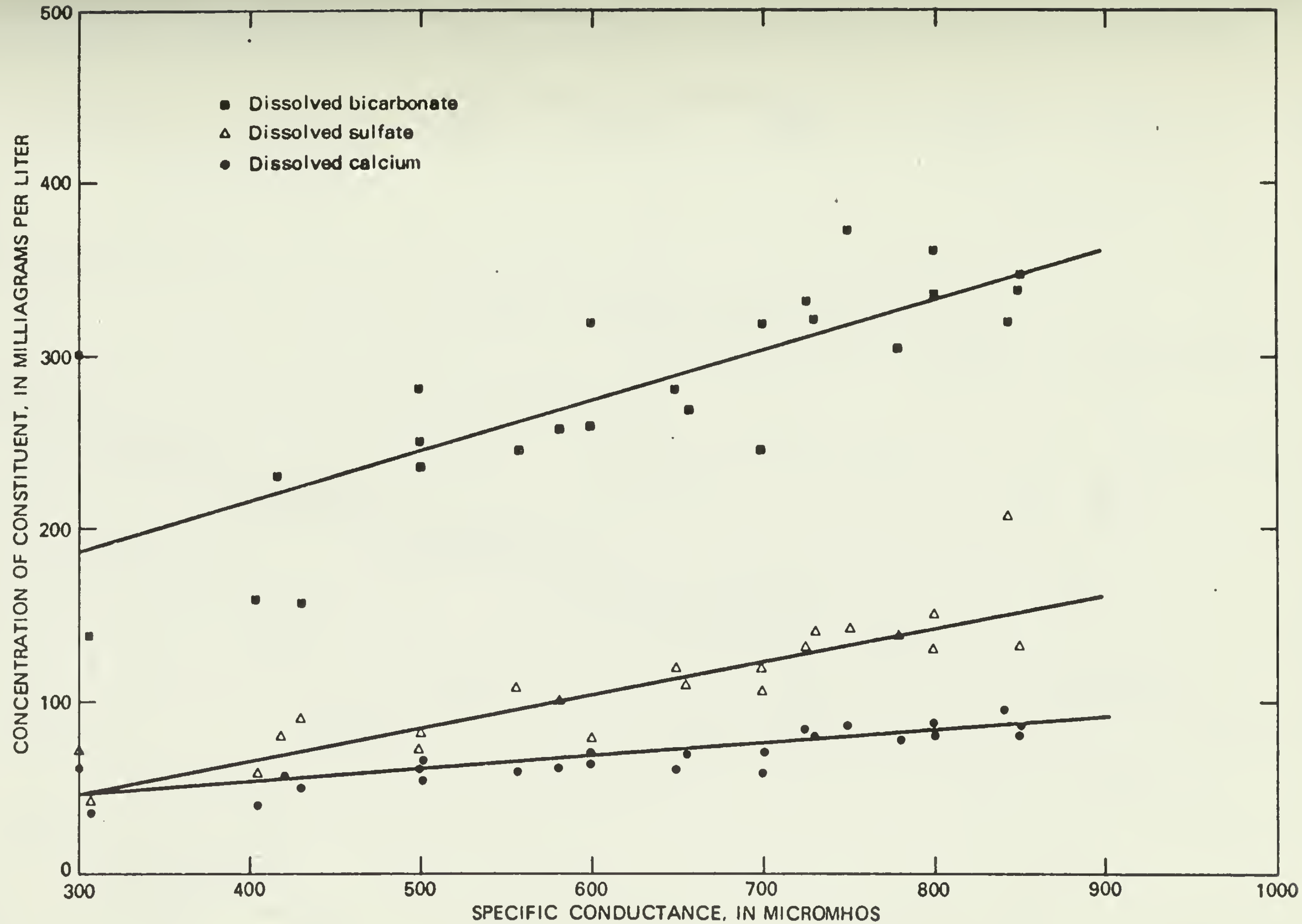


Figure 22--Major constituents versus specific conductance for Middle Creek near Oak Creek, Colo. (09243700).

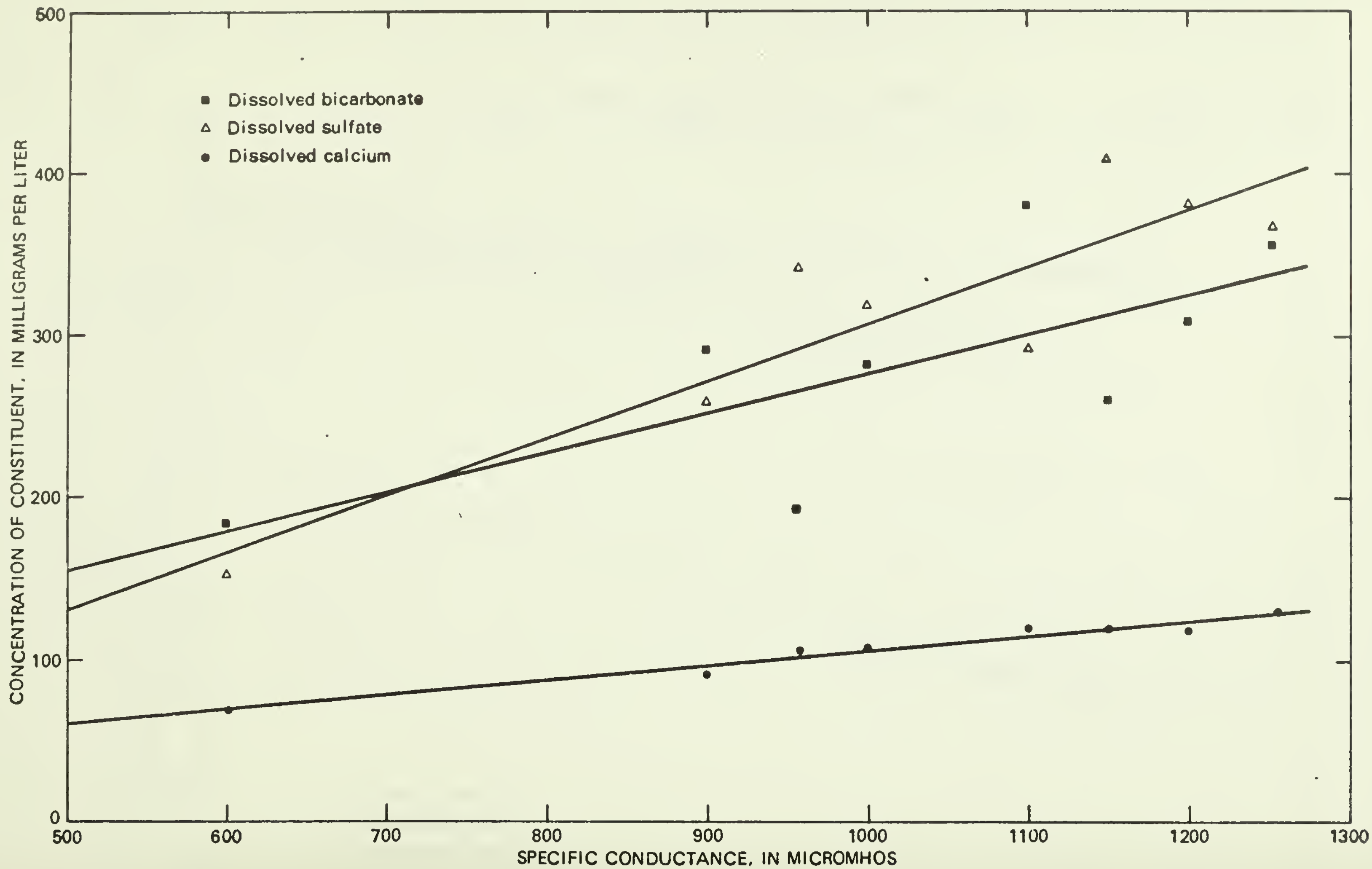


Figure 23.--Major constituents versus specific conductance for Foidel Creek near Oak Creek, Colo. (09243800).

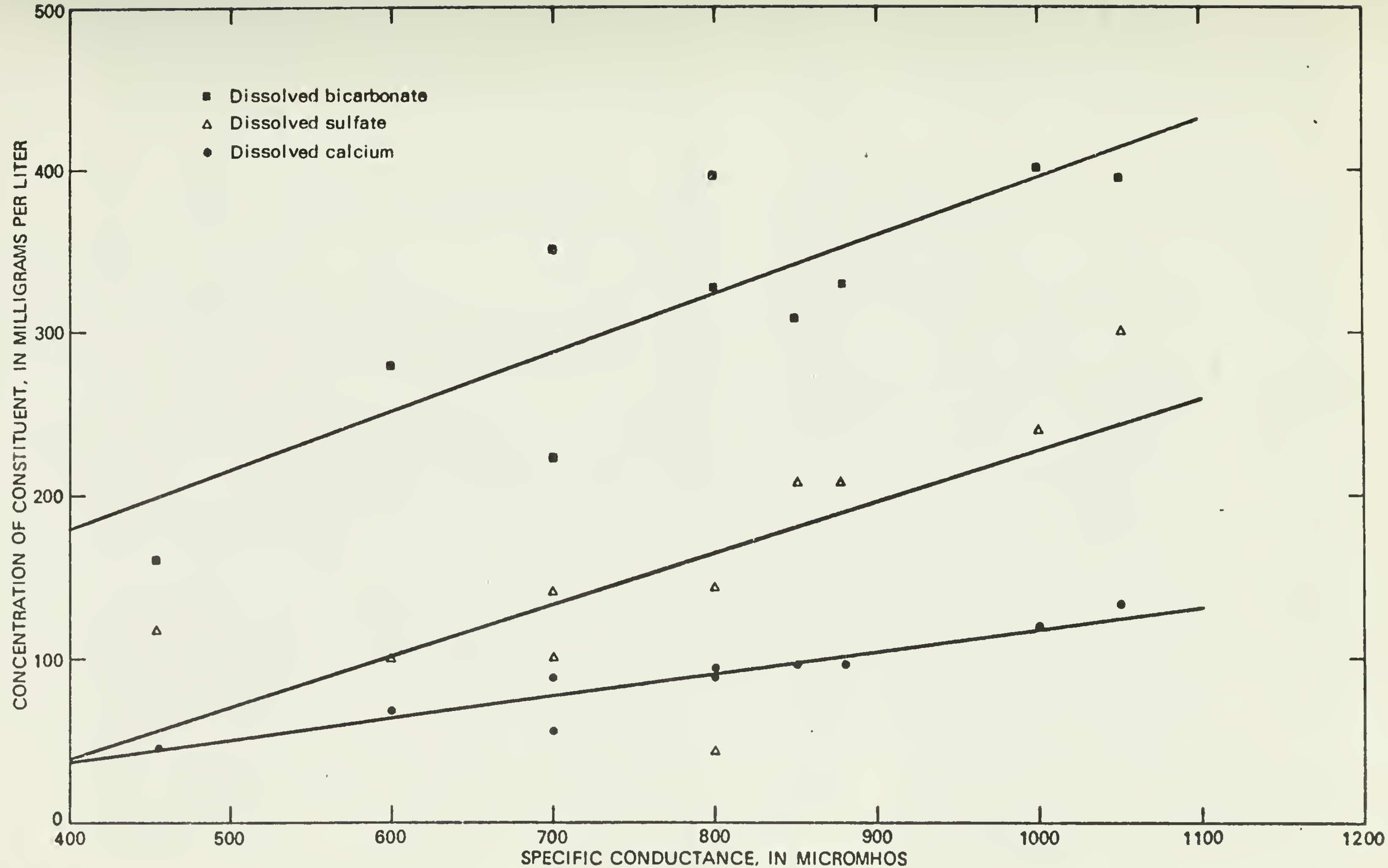


Figure 24.--Major constituents versus specific conductance for Foidel Creek at mouth, near Oak Creek, Colo. (09243900).

In addition to a comparison of analytical results with promulgated standards, the likelihood of sporadic high concentrations can be assessed by consideration of solubility limitations for many chemical constituents. For example, table 26 lists the logarithy (base 10) of the activity product divided by the solubility product for the analyses considered here. The Log_{10} of this ratio is a measure of the tendency of a mineral to dissolve into the solution or precipitate from it; positive values denote a tendency to precipitate from solution, while negative values denote a tendency to dissolve into solution, thereby increasing the concentrations of the appropriate ions in solution. For a detailed discussion of activity products and solubility products see Garrels and Christ (1965). The data in table 26 were calculated from the data in Appendix D by use of the computer program SOLMNEQ (Kharaka and Barnes, 1973). The data in table 26 indicate that the minerals calcite, dolomite, and magnesite ranged from supersaturated to undersaturated.

Table 26.--The Logarithm (Base 10) of the Activity-product to Solubility-product Ratio with Respect to Selected Minerals for Samples from Foidel Creek near Oak Creek

Sample date	Ratio, in dimensionless units		
	Calcite	Dolomite	Magnesite
76/03/05	0.23	0.50	-0.39
76/04/08	-0.02	0.03	-0.61
76/05/07	0.34	0.76	-0.22
76/06/04	0.24	0.59	-0.28
77/03/18	-0.19	-0.37	-0.84
77/04/14	-0.31	-0.58	-0.92
77/05/11	-0.23	-0.43	-0.84
78/04/18	0.21	0.54	-0.31
78/05/30	0.74	1.61	0.26
78/06/19	0.68	1.49	0.19

A likely explanation for this indicated change in water quality is that the ground water which seeps into Foidel Creek is approximately saturated with calcite, dolomite, and, perhaps, magnesite. Dilution by snowmelt causes the system to become undersaturated, while concentration by evaporation causes supersaturation. If the ground-water input to Foidel Creek is saturated with calcite and dolomite because of its contact with the country rock of the area, then the major ion chemistry of Foidel Creek will respond primarily to dilution and evaporation in the absence of direct inputs by man. Thus, concentrations of the major ions can be expected to approximate the ranges of concentration shown in Appendix D.

The capability of water from Foidel Creek reacting with dissolved trace metals and precipitating out these trace metals can be evaluated for selected trace metals and appropriate minerals. For example, in an oxidizing environment such as a surface-water stream, the solubility of iron can be expressed by equation 2 (Garrels and Christ, 1965, p. 185):

$$Log_{10}(Fe^{+3}) = -0.72 - 3pH \qquad (2)$$

In equation 2, Log_{10} denotes the logarithm base 10, Fe^{+3} denotes the activity of the ferric ion considered equal to the concentration in moles per liter, and pH denotes the solution pH. At a pH of 7.1, the lowest shown in appendix D, the solubility of ferric ion is only $10^{-22.0}$ moles per liter, or much less than a microgram per liter.

The solubility of some carbonates is sufficiently low to allow effective controls on the solubility of some trace metals. For example, equation 3 considers the solubility of lead carbonate at 25 °C:

$$Log_{10}(Pb^{+2}) = -13.45 - Log_{10}(CO_3^{=}) \qquad (3)$$

In equation 3, Pb^{+2} denotes divalent lead ion and $CO_3^{=}$ denotes carbonate ion. Using data from appendix D the carbonate ion activity can be shown to range from $10^{-4.6}$ to $10^{-5.7}$. The corresponding maximum solubility of divalent lead is 0.3 and 4 ug/L, respectively. Similar calculations for the zinc and copper carbonates show zinc solubility to range from 490 to 6,200, and copper solubility to range from 640 to 8,060 ug/L, respectively.

In summary, the major ion chemistry of Foidel Creek probably results from equilibration of ground-water seepage with calcite and dolomite, followed by varying degrees of dilution or concentration by evaporation. The carbonate ion resulting from this contact with carbonate rocks may limit soluble lead concentrations to a few micrograms per liter. The concentration of soluble copper and zinc, however, may range up to several thousand micrograms per liter if carbonate solubility is the only control. Dissolved iron concentrations will probably not be a long-lived problem in the oxidizing environment of the stream because of the small solubility of the ferric ion at the pH values encountered in this stream.

Suspended sediment concentrations have been sampled periodically at all three stations since 1975. Concentrations range from 16 to 75 mg/L. This larger concentration was obtained at a discharge of 16 ft^3/s, which yields an instantaneous suspended-sediment discharge of 32 tons/d.

It must be pointed out that sufficient sampling at the higher discharges and correlation with the automatic pumping sampler has not yet been done. Thus, the range of suspended sediment could be considerably higher.

The bed and banks of the Foidel Creek channel consist primarily of silts and clays, and the valley in which this stream flows is primarily fine grain material. Disruptions near the channel could, therefore, increase suspended-sediment concentrations dramatically. Once in suspension, this fine-grain material could travel great distances downstream.

Effects of Mining on Area Hydrology

The majority of annual runoff originates in the form of snowmelt during the spring months as reflected in the streamflow records for Foidel and Middle Creeks. As the streamflow records are of short duration and were not collected at the proposed site, the effects of mining on the hydrology can only be presented in relative terms.

The effects of mining on the quantity of runoff differs for each stream in the proposed mining tract because of the location of each stream channel through the mining tract. The majority of the contributing drainage of Foidel Creek tributary is within the proposed mining tract and would be most affected. As the contributing drainage from the mining tract to the remaining streams is small, the effects to streamflow should be minimal.

Whether the mining activities would increase or decrease flow would be determined by the extent and practices at the mining tract. If there are no water-conveyance channels in the mined area, the snowmelt would probably infiltrate into the ground and decrease the amount of surface runoff or change the time distribution of the surface runoff. As pointed out previously, disruptions of the alluvial valley floor or the channel proper could increase suspended-sediment concentrations. This fine-grained material could travel great distances downstream. If some buffer between the mine proper and the channel is established, little increase in suspended sediment should be noted.

Qualitative estimates of channel response to natural or imposed changes can be made using Lane's relation (Simons, 1976) which is $Q.S\ Q_s.d_{50}$. This relation states that the stream discharge (Q) times channel slope (S) is directly proportional to the sediment discharge (Q_s) times the mean bed-material size (d_{50}). This relation will be kept in balance. That is, man-induced changes in a variable on one side of the relation will result in a natural change in the variables on the other side of the relation to maintain a proportionality. As an example, if water discharge (Q) is increased from mining and if the size of material is unchanged (d_{50}), then the sediment discharge will increase (Q_s). This can occur from increased bed and bank erosion.

There is a possibility of about five ground-water overburden relationships. These relationships are: (1) overburden and coal seams are above the water table; (2) overburden and coal seams intercept the water table or overburden contains a confined aquifer above the coal; (3) overburden and coal occur above a confined aquifer; (4) overburden is within an unconfined aquifer, and coal seam is below; and (5) overburden that contains a confined aquifer is above the coal.

Within the study site, conditions (1), (2), and (4) exist. Where the overburden and coal seam occur above the water table or intersect it, very little difference can be expected between the composition of waters that pass through the overburden and the spoil overburden. This is probably true because the waters passing through undisturbed overburden come in contact with the same minerals before mining as after mining. The dissolved solids content of the spoil waters is always greater because of evaporation and increased surface area in the spoil material.

Where mining is carried out below the potentiometric surface (compare fig. 16 with table 8, main text), some dewatering will be necessary. The amount of withdrawal can only be determined after the mine plan is known. The permeability of the spoil differs drastically from undisturbed rocks. At first, permeability is greater than that of the undisturbed rocks, but as the spoil compacts, permeability is gradually reduced. This reduction in permeability will mean a decrease in the release of dissolved minerals.

Recommendations for Additional Study Needs

Existing streamflow gaging station records in northwestern Colorado reflect the hydrology of the higher mountains on the hydrology of the semiarid plateau. Much of the potential mining activity in northwestern Colorado is expected to occur in this transition area between the plateau and mountains, where minimal hydrologic information exists. The limited data that has been collected has been for a short time, and it would be unreliable to transfer this hydrology to an ungaged watershed without correlation-type studies on longer term hydrologic data.

Due to these reasons, McCain and Jarrett (1976) indicate the methods presented to determine flood characteristics in this transition region should only be used as an interim procedure until additional data can be collected and analyzed to define the hydrology of the transition region with more reliability. Christensen (1978) of USGS, in cooperation with several Federal and State water agencies, has initiated a hydrologic data-collection and analysis study to help define the flood hydrology in the transition region of Colorado.

Continued streamflow-data collection is imperative to: (1) define existing runoff conditions; (2) evaluate the effects of proposed mining tracts; (3) develop reliable techniques to transfer hydrologic information from gaged to ungaged watersheds; and (4) record changes due to mining of an area. Additional data on ground-water chemistry are needed to: (1) determine the mechanisms which presently control water quality, and (2) decide the nature of likely mining effects on these mechanisms.

CONCLUSION AND RECOMMENDATIONS FOR RECLAMATION

Legal Requirements of Mine-land Reclamation

Federal. - The legal requirements for reclamation of disturbed lands in the development of coal resources are covered principally by the following laws:

National Environmental Policy Act (Public Law 91-190)
Surface Mining Control and Reclamation Act (Public Law 95-87)
Federal Land Policy and Management Act (Public Law 94-529)

The following regulations enforce or have control of various aspects of surface mining and effect various phases of land reclamation:

Title 43 CFR 3041	(BLM)	Surface Management and Protection
Title 30 CFR 700	(OSM)	Surface Mining and Reclamation and Enforcement
Title 30 CFR 211	(USGS)	Operating Regulations for Coal Mining

The OSM (Office of Surface Mining) Regulations in 30 CFR 700 differ from previous Federal regulations in that they are more specific in certain areas to help mitigate the impacts on vegetation due to surface mining.

State Regulations. - In Colorado the surface-mined coal lands are governed by the "Colorado Open Mining Land Reclamation Act." The rules and regulations for this act are enforced by the Colorado

Mined Land Reclamation Board. A permit, bond, and filing fee are required from mine operators. This permit includes reclamation performance standards.

Local Regulations. - Local regulations are not as explicit regarding surface mining and reclamation as are State laws. Information to the extent and requirement of local regulations can be obtained from the Routt County Court House, Steamboat Springs, Colorado.

Resources and Land Use After Mining

Return to Present Land Use

The lands which overlie the coal seams of the Foidel Creek Study Site are primarily valuable and used for wildlife grazing and habitat, domestic livestock grazing, and watershed management. The objective will be to reclaim the area after mining to its present uses.

Livestock Grazing. - Livestock are grazed primarily during the spring, summer, and fall. To insure reestablishment of vegetation, livestock should be excluded from the area. Livestock grazing could be permitted after a suitable period of ecosystem stabilization and to the degree compatible with wildlife use.

Wildlife Habitat. - The objective should be to return the area to suitable big game habitat. Deer and elk use the study site in varying degrees yearlong.

Resident deer now inhabit the area yearlong and would be expected to return to the site after mining and reclamation are completed. Adequate food and cover species should be available for these animals.

Elk primarily use the study site in the winter and early spring. Elk migrate through the area and use portions of the site for calving grounds. Possibly the elk would use the area after reclamation provided cover is available. This would not occur until larger brush and trees have been reestablished.

Since small mammals, bird amphibian, and reptile habitat would be destroyed with surface mining, the repopulation of the reclaimed site would be fairly rapid due to the short reproduction cycle of these animals.

If wetlands are disturbed, then these wetlands should be restored and maintained to the original condition of those lands prior to mining to provide habitat for ducks, beaver, and possibly fish.

Noncommercial Timber. - Even though aspen trees occupy 75 percent at this time, they are not being harvested for any wood products. It is possible after reclamation that aspen could be harvested for fuelwood or pulpwood.

Watershed Management. - Watershed management, as an existing land use, includes such soil and water objectives as the maintenance or improvement of water quantity, quality, and timing, and the maintenance or improvement of soil productivity and stability. The reclamation objective for the study site includes returning the site's hydrologic condition back to the premining situation in terms of water quantity, quality, and timing of runoff. This applies both to surface and ground water. The existing water quality meets State and Federal water quality standards. The mining plan should include provisions to maintain water quality after mining at or above the water quality standards. Returning the site hydrology back to the original condition will be a time-dependent process; however, this can be achieved within a period of a few years. Current uses of water within the study site, primarily water for livestock and wildlife watering, will be restored or improved after mining. The reclamation objective also includes restoring soil productivity and stability to an equal or better condition than what existed before mining. Onsite soil erosion will gradually decrease during the reclamation period as vegetation succession and development progresses and watershed cover improves.

Visual Resources. - The objective of reclamation in order to consider the visual or scenic values shall be to implement land treatment techniques that meet the objectives of the premining VRM class.

Approach to Report

The reclamation recommendations written for this report are for the specific land uses on this site. Other uses may be possible as discussed in the alternative section. Some of the methods and practices suggested may be projected to similar areas.

Resource Problems to be Considered During Reclamation

Quantity of Plant Growth Media Available

A land suitability survey, discussed previously in this report, was made of the site. The intensity of this survey was not sufficient to accurately determine the quantity and location of available planting media; however, by using the detail of this survey it is expected that approximately 91 percent of the study site has adequate material for postmining reclamation purposes. The remaining 9 percent of the study site is Class 6 lands which have soil and topographic deficiencies and drainage characteristics which render them unsuitable as a planting medium.

Assuming an average minimum depth of 36 inches for Class 1 lands; 24 inches for Class 2 lands; and 6 inches for Class 3 lands; there would be approximately 6,000,000 cubic yards of topsoil available for stockpile in the total area. The Class 1 lands are the most desirable as a source of topsoil and would supply about 6.0 percent of highly suitable material. The Class 2s lands similar in respect to the Class 1 lands, except for having moderately fine and fine-textured soils (heavy clay loam, silty clays, and clay) which may somewhat impede water movement and depth of rooting, would supply about 9.0 percent of suitable topsoil material. The Class 2t, 3s, and 3st lands would yield the remaining 85 percent of topsoil material but are less well suited because of surface rock, soil deficiencies, and steep slopes. These classified lands and their approximate locations are identified on the composite land suitability map on page 68.

Physical and Chemical Characteristics of Available Plant Growth Media

Based on characterization of the surface and upper soil materials (5 ft) made in relation to the land suitability survey, these soils (which will be separated and stockpiled for planting media) reflect very few adverse physical and chemical conditions in their use as a plant growth medium. The majority of the surface soils are fine-sandy loams, sandy clay loams, and clay loams with adequate permeabilities and water-holding capacities and exhibit low levels of alkalinity and salinity.

The chemical and physical properties of the geologic overburden material (5 ft to bottom coal seam) were characterized for five deep hole locations on the site and it would be difficult to accurately project the type and quantity of this material between the five core locations. However, it is reasonable to assume these and similar geologic overburden materials that were identified as suitable (presented on the geologic logs as "suitability of overburden") are generally well suited for use as a planting medium. However, since sufficient topsoil is available, overburden material will not be considered as a source of planting media.

General Feasibility of Revegetation in Relation to Quantity and Quality of Planting Media

Successful revegetation is dependent on the proper selection of a planting media which effects stockpiling, shaping and placing of material, seedbed preparation, planting, and management of revegetated area after establishment of cover. If these factors, along with soil-water relationships and climate, are taken into consideration, successful revegetation should be achieved, based on the quality and quantity of planting media evaluated in the Foidel Creek study site.

Nutrient Deficiencies

Fertilizer analysis of the available planting media was not done; however, greenhouse studies indicate the use of fertilizer high in nitrogen and phosphorus enhances growth potential on similar soils and particularly overburden materials. More detailed fertility studies, such as plant uptake or onsite plot studies, should be made in this area before fertility recommendations are made.

Toxic Materials

Toxicity studies were not performed on the Foidel Creek soil or overburden samples other than salinity and alkalinity contents. Neither of these are of the magnitude to be toxic in the materials selected as planting media. More detailed studies should be conducted prior to preparing a mining plan to determine presence of toxic elements, such as boron, selenium, and heavy metals that would be detrimental to planting media, surface and ground-water supplies, and animal consumption. In event toxic materials are encountered, regulations in effect at the time will dictate handling and placement of disturbed overburden material.

Climate and Water

The study site has a montane climate with 15 to 20 inches of annual precipitation. Precipitation is adequate for spring and early summer revegetation efforts. Soil water in some years may be limiting to fall planting of trees and shrubs. Evaporation rates are moderately high throughout the growing season. Winter temperatures, when snow cover is absent, may be detrimental to recently established vegetation.

Little hydrologic impacts resulting from mining will occur in Middle Creek or the North Fork. However, much of the study site contributes water to Foidel Creek. Mining will result in increased suspended sediment concentrations at first, but these concentrations will decrease over time during the reclamation period. Erosion and sediment hazards are particularly high in and near valley alluvium and stream channel areas because of the fine-grain material found there. Direct disruption of channels will result in fine-grain sediment being transported considerable distances downstream. Where precipitation is transmitted through spoil material and into the ground-water system, dissolved solids concentrations will increase on the recession limb of the hydrograph. Baseflows will have higher TDS (total dissolved solids) loadings. TDS concentrations will decrease slightly over time as the permeability of spoils decreases.

Some dewatering may be necessary depending upon the exact location and design of the mine with respect to the potentiometric surface. Quantities of water are not expected to be great, and the existing channels should be able to handle the additional water.

Channels are relatively well incised and floodflows are mostly confined to the channels. Mining activities are not expected to significantly increase flood potential and/or damage.

Recommendations for Reclamation

Handling and Placement of Soil and Bedrock

Mining techniques and regulations in force at the time mining occurs will dictate whether the identified suitable topsoil will be stockpiled for later use or moved from the mining site to areas being rehabilitated in the Foidel Creek Study Site. Any suitable topsoil that is stockpiled should be identified and kept separated from unsuitable materials so that contamination can be kept to a minimum.

Bedrock materials that are identified unsuitable should be separated and later placed at a depth at least greater than 10 ft below the reconstructed surface soil profile. Primary consideration in the placement of the unsuitable bedrock material should be given to prevent pollution of ground waters or contamination of surface waters.

Hydrology and Erosion Control

Regulations will prevent any mining activities within the floodplain of Foidel or Middle Creeks. In addition, buffers should be installed between the mine and these main channels to prevent any sediment from reaching their waters. Tributary streams should be completely impounded above the mine site. It is likely that the first order tributaries to Foidel Creek within the study site would be mined. The reclamation plan should include returning these streams to their original hydraulic characteristics. The channels should be restored to their original width/depth ratio or to a slightly greater width/depth ratio. Bed material sizes should be the same or larger than before mining. The channel gradient should be returned to the premine gradient.

The use of water control structures is acceptable and recommended. They should not be used where water retention and subsequent percolation will increase TDS concentrations. Large sediment basins should be located below spoils piles rather than in them. All water and erosion control structures should be designed so as to limit their effective life to not greater than 10 years and not less than 5 years. Following the reclamation period, remaining water or sediment control structures should be removed.

Reconstructed slopes should resemble premining conditions. Long slope segments over 4 to 5 percent should be interrupted by terraces Slope segments between terraces should not exceed 50 to 100 ft in length depending on the slope steepness. Wherever possible, south exposures should be minimized and graded relatively flat so as to lessen the microclimate effects on revegetation.

To improve infiltration, chiseling of the topsoil prior to planting is recommended. Also, on slopes over 2 percent, gouger pitting and/or contour furrowing is recommended. Again, any erosion control structures should have an effective life between 5 and 10 years.

Selection of Species for Seeding

Regulations governing reclamation require a return of surface-mined lands to approximately their natural state and revegetating with principally native plants.

The following list of plant species represents the native potential vegetation for the study site. The list indicates the diversity of the study area. The plant community of a specific area is determined by the climate, soil, and topography.

Grasses	Forbs	Shrubs
Slender wheatgrass	Balsamroot	Bittersweet
Bearded wheatgrass	Eriogonum	Snowberry
Western wheatgrass	Paintbrush	Serviceberry
Thickspike wheatgrass	Geranium	Gamble Oak
Streambank wheatgrass	Mules ear	Chokecherry
Bluebunch wheatgrass	Aster	Rose
Letterman needlegrass	Lupine	Big sagebrush
Columbia needlegrass	Western yarrow	Fringed sagebrush
Green needlegrass	American vetch	Silver sagebrush
Pine needlegrass	Cow parsnip	Alkali sagebrush
Idaho fescue	Tall bluebells	Low rabbitbrush
Arizona fescue	Aspen peavine	Vasey rabbitbrush
Thurber fescue	Buchwheat	Green rabbitbrush
Mountain brome	Herbaceous sage	Aspen
Nodding brome	Native clovers	Douglas fir
Native bunch-bluegrass	Phlox	
Sandberg bluegrass	Pussytoes	
Nevada bluegrass	Onions	
June grass	Gilia	

Grasses	Forbes	Shrubs
Parry oatgrass	Bedstraw	
Basin wildrye	Tall bluebells	
Mountain muhly	Meadowrue	
Squirreltail		
Sedges		
Rushes		

There are no identified endangered or threatened plant species on the study site or surrounding area.

Total annual potential production of plant growth on fairly deep soils having a good water holding capacity and a large percent of the soil moisture available for plant growth, ranges from 1,800 lbs/acre Air Dry in favorable years to 1,200 lbs/acre Air Dry in unfavorable years. Optimum ground cover is 35 percent.

Total annual potential production of plant growth on very favorable soil ranges from 3,000 lbs/acre Air Dry in favorable years to 1,500 lbs/acre Air Dry in unfavorable years. Optimum ground cover is 60 percent.

Total annual potential production of plant growth, having limiting soil characteristics, ranges from 800 lbs/acre Air Dry in favorable years to 300 lbs/acre Air Dry in unfavorable years. Optimum ground cover is 35 percent.

Total annual potential production of woodland soils is not available.

Introduced species which have shown adaptation to the area include:

- Siberian wheatgrass
- Crested wheatgrass
- Pubescent wheatgrass
- Intermediate wheatgrass
- Smooth brome
- Russian wildrye
- Fescue
- Penstemon
- Vetch
- Aster
- Alfalfa

Reclamation efforts should be directed toward the development of diverse and self-perpetuating plant communities. When selecting a mixture of grass, shrub, and tree species for revegetation several considerations should influence the selection. (1) Their natural adapation for the area's topography, soil, and climate, (2) their ability to provide cover and soil stability, (3) their nutritional value and palatability for domestic livestock and wildlife, (4) their drought resistant, (5) their susceptibility to disease, and (6) their ability to establish.

Seeding Methods

Surface mulching for improvement of soil characteristics as well as surface stabilization should be considered in the revegetation plan. If a mulch is applied for improvement of soil characteristics it should be incorporated into the soil before seeding. Adequate nitrogen must be available for the breakdown. Mulching for surface stability can be accomplished by applying a grass or straw mulch and crimping after seeding or seeding into a standing mulch of annuals. Annuals used as a cover crop (standing mulch) should either be a hybrid or not allowed to set viable seed. This will eliminate their competing with the seeded mixture the next year.

Compaction of the soil should be avoided. Following placement of the soil and subsoil with heavy equipment, it should be ripped or subsoiled in some manner to enhance water infiltration. The soil surface should be even and firm enough to allow regulation of uniform planting depth. Grass seed should be drilled on the contour or parallel with the slope at a depth of 1/2 to 3/4 of an inch. Small seed such as clovers or alfalfa should be broadcast behind the grass seed with the minimal amount of cover provided by the drill drags. Larger seed such as brush, having long germination periods, should be seeded deeply enough to ensure a moisture supply during germination.

The depth placement of a seed is roughly proportional to its size. To enhance germination and obtain an established stand of grass, fall seeding is recommended.

This practice is normally followed in local mine reclamation work and has proven superior to spring seeding. If fertilizers are used they should be incorporated into the soil before or during seeding.

For a quick establishment of trees and shrubs for wildlife cover, give first priority to transplanting mature healthy stock. This can be accomplished with the use of a front-end loader or tree spade. The second priority should be the use of bare-root stock or container grown trees and shrubs planted in the early spring. The use of bare-root or container stock should be in conjuntion with rodent and wilflife protection. To enhance vegetative growth of shrubs and trees select pockets, north aspects, or areas of snow accumulation where moisture accumulates during the wet seasons or where evapotranspiration ratio is low.

Postmining Land Management During Reclamation

Proper postmanagement of the reclaimed area is essential if reclamation is to be successful. In the event weed growth prevents the likely survival of the seeded species during establishment, acceptable methods of weed control should be used. The reseeded area should be protected from grazing until vegetation is sufficiently developed and established to withstand grazing use without damaging the vegetative cover. Once established, a planned grazing system should be used to graze the area. Corrective measures should be taken to stop any erosion.

If noxious weeds invade the rehabilitation site, acceptable methods of removal should be used. Water must be provided for wildlife and livestock.

It may be necessary to reintroduce shrub and tree transplants for additional wildlife cover and food.

Alternatives for Reclamation

Although it is assumed that the entire area will be reclaimed for wildlife grazing and habitat, domestic livestock grazing, and watershed management use following mining, the possibility of dryland wheat production should be mentioned. Areas within the reclamation site could be adapted to farming if the final land shape is sufficiently leveled to permit farm machinery use and topsoil plus subsoil are restored. Such use would produce more food for human comsumption than is possible from native vegetation.

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APPENDICES

A. GEOLOGY

B. COAL

C. SOIL

D. STUDY AREA [illegible]

-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET ..1.. OF ....

FEATURE ... Foidel Creek Site ... PROJECT ... EMRIA-BLM ... STATE ... Colorado

HOLE NO. .. DH-1 .... LOCATION ... See Location Map ... GROUND ELEV. ... 7520* ... DIP (ANGLE FROM HORIZ.) ... Vertical

COORDS. N. ... E. ...

BEGUN . 9-5-75 .... FINISHED . 9-15-75 ... DEPTH OF OVERBURDEN .... 0.6 ... TOTAL DEPTH . 422.0 ... BEARING ... ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED ... 111.2 ... 9-19-75 ... LOGGED BY .. N. B. Bennett, III .. LOG REVIEWED BY .. N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Longyear 34 truck mounted drill rig.	Rock bit (0-10)	0 (RB)						7519.4	0.6			0-0.6 - SOIL: Brown. No recovery.
Lost 30 percent of drill water return .6 to 85.6; 40 percent 85.6-422.	Nx	73			Suitable 10-50							0.6-409.9 WILLIAMS FORK FM., MESA VERDE GROUP
Hole rockbitted 0-10. Nx core 10-422.		100					Unsuitable 50-85					0.6-94.1 - SHALE: Clayey. Noncalcar[eous] except at 26.5 where there are 1/8" calcite stringers. Gypsum at 36.4 [and] 44.7. Fe stains along bedding and joint planes. Fossil shell at 81.8 Hardness 5-6. Desiccates rapidly i[nto] 1/16" to 1/2" thick discs. Some bl[ocky] structure. Less desiccation starti[ng] at 57' but breaks into discs with m[ed]ium hammer blow. More cemented and less clayey below 57'. Bedding dip 23°. Few joints near vertical to 7[...] Grades in and out of siltstone with depth. Gray to black.
Water used as drilling fluid 0-422.		46										
Hole cased 0-11.		57										
*Elevation taken from Rattlesnake Butte Quadrangle.		84										
		100										
		92			Suitable 85-			7425.9	94.1			94.1-141.1 - SANDSTONE: Very fine gr[ained]. Banded with black siltstone and carb[on]aceous layers. Slight to moderatel[y] calcareous. Siltstone with fine co[...]
		100										

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx – 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

A-1

GEOLOGIC LOG OF DRILL HOLE

FEATURE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

HOLE NO. DH-1 LOCATION See Location Map COORDS. N. E. GROUND ELEV. 7520± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9-5-75 FINISHED 9-15-75 DEPTH OF OVERBURDEN 0.6 TOTAL DEPTH 422.0 BEARING -------

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 111.2 9/19/75 LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Nx	100			~113.5	113.5–129						113.5 and 113.9. Increasing siltst[c] 132.5-141.1. Hardness 6-7. Banding dips 8°. Mode length 6". Gray-whit[e]
					129–162.1			7378.9	141.1			141.1-145.6 - SANDSTONE: Nonbanded. [F]i[ne] grained. Friable and rusty 141.1-14[5] Calcareous 143.4-144.1. Near verti[cal] joints 141.1-141.5 and 143.2-143.7 (stained). Few carbonaceous specks a[nd] bands. Gray.
								7374.4	145.6			145.6-162.1 - SANDSTONE: Banded, simi[lar] to 94.1-141.1 interval. Moderately calcareous. Hardness 4-5. Increasi[ng] carbonaceous bands with depth. Car[bon]aceous 161.9-162.1. Black with lig[ht] sandstone bands.
							162.1–162.9	7357.9	162.1			162.1-162.9 - COAL: Sample taken.
					162.9–180.9			7357.1	162.9			162.9-180.9 - SANDSTONE: Very fine grained. Carbonaceous and coaly ba[nd]ing. Slightly silty. Noncalcareous Carbonaceous bands increase with de[pth] and grades into carbonaceous materi[al] at 180.9. Hardness 5. Fractured a[long] near vertical joint 171.3-172.0. Ot[her] high angle joints 172-178.8. Bands dip 13°. Gray with dark gray to bl[ack] bands.
								7339.1	180.9			180.9-182.4 - SHALE: Slightly clayey cemented. Slightly calcareous. Bre[aks] into 1" flat pieces. Black.
							182.4–191.2	7337.6	182.4			182.4-191.2 - COAL: Sample taken. Wa[xy] bed.
						191.2–195.6		7328.8	191.2			191.2-191.6 - CARBONACEOUS MATERIAL: Slightly coaly. Black.
								7328.4	191.6			191.6-195.6 - SANDSTONE: Shaley to s[h]le with sandstone bands. Spotty calca[reous] Pyrite on high angle joint plane 19[-] 193.5. Very fine grained sandstone Gray, black.
							195.6–	7324.4	195.6			

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx - 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

(6-74) of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 5

FEATURE: Foidel Creek Site | PROJECT: EMRIA - BLM | STATE: Colorado

HOLE NO.: DH-1 | LOCATION: See Location Map | GROUND ELEV.: 7520± | DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9-5-75 | COORDS. N. E. | FINISHED: 9-15-75 | DEPTH OF OVERBURDEN: 0.6 | TOTAL DEPTH: 422.0 | BEARING: -------

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 111.2 9/19/75 | LOGGED BY: N.B. Bennett, III | LOG REVIEWED BY: N.B. Bennett, III

Column headings: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | DEPTH (FEET) FROM (P, Cs, or Cm) TO | SUITABILITY OF OVERBURDEN (SUITABLE, DOUBTFUL, UNSUITABLE) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Type and size of hole: Nx. Core recovery: 100.

Elevation (feet)	Depth (feet)	Suitability	Classification and physical condition
7317.7	202.3	Unsuitable	195.6-202.3 - COAL AND CARBONACEOUS MATERIAL: Coal sample taken 196.4-198.8.
7308.7	211.3	Suitable	202.3-211.3 - SANDSTONE: Black shale to carbonaceous bands. Slightly calcareous. Hardness 5-6. Bands dip 14°. Broken along near vertical joint 203.1-205.9. Becomes shalier with depth.
7299.0	221.0	Suitable	211.3-221.0 - SHALE: Sandy stringers, spotty calcareous. Fossiliferous. Hardness 4-5. Becomes harder with depth. No desiccation. Black, shiny.
7275.5	244.5	Doubtful	221.0-244.5 - SANDSTONE: With shaley black bands. Very fine grained. Non- to spotty calcareous. Increasing shale with depth. Slickensides on shale 241.7. Broken with slickensides 232.5. Minute pyrite crystals 244.5. Hardness 6. Light gray sandstone.
7274.5	245.5	Unsuitable	244.5-245.5 - COAL: Sample taken.
7273.3	246.7		245.5-246.7 - SILTSTONE: To very fine grained sandstone. Near vertical joint 245.7-246.6. Dark gray.
7266.1	253.9	Suitable	246.7-253.9 - SANDSTONE: With bands and swirls of dark siltstone, shale, and coal. Very fine grained. Noncalcareous. White.
7264.3	255.7		253.9-255.7 - COAL: Sample taken.
7248.4	271.6	Unsuitable	255.7-271.6 - SANDSTONE: With carbonaceous and thin coal layers to 257.1. Slightly friable. Hardness 5. 2' pieces. Gray with black stringers.
7247.9	272.1		271.6-272.1 - COAL: And black carbonaceous material.
7246.2	273.8	Suitable	272.1-273.8 - SILTSTONE: Broken along high angle joint 272.1-272.5. Hardness 6. Dark gray.
7234.7	285.3	Suitable / Doubtful	273.8-285.3 - SANDSTONE: With black carbonaceous and coaly seams and swirls. Highly calcareous. Hardness 6. Brownish siltstone 283.5-283.7. 2' pieces. White sandstone.
7222.1	297.9	Suitable	285.3-297.9 - SHALE: With sandstone and siltstone banding. Clayey to cemented. Spotty calcareous. Broken 286.9-287.3, and 292.5-293.5. Black with light gray to whitish bands.
		Suitable	297.9-309.8 - SANDSTONE: Very fine grained. Moderately calcareous. Slight

EXPLANATION

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

A-3

GEOLOGIC LOG OF DRILL HOLE

FEATURE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

HOLE NO. DH-1 LOCATION See Location Map COORDS. N. ... E. ... GROUND ELEV. 7520± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9-5-75 FINISHED 9-15-75 DEPTH OF OVERBURDEN 0.6 TOTAL DEPTH 422.0 BEARING ------

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 111.2 9/19/75 LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Nx	100			Suitable to 333.8	7210.2	309.8			banding to 302.7 then banded with si... and siltstone layers, layers increase to 309.8. 1/8" offset on banding at 308.6 (bioturbated?). Beds dip 11°. Near vertical joint 297.9-298.5. Gr... with white bands.
										309.8-333.8 - SHALE: To shaley siltst... Spotty calcareous. Fossiliferous. Mostly sandstone 326.8-333.5. Sligh... desiccation. Hardness 5. Near vert... joint 322.5-323. 36° dipping joints at 315.0 and 315.9. Broken 320.3-32... along high angle joint. Black with ... bands.
					Unsuitable 333.8-334.3	7185.2	333.8			333.8-334.3 - COAL: Sample taken.
					Suitable 334.3-350.2	7185.7	334.3			334.3-335.4 - SILTSTONE: Carbonaceous ... 334.8. Very slightly calcareous. Tw... parallel near vertical joints 334.8-335.3. Black.
						7184.6	335.4			335.4-350.2 - SANDSTONE: With black shaley to carbonaceous bands and swi... No banding 338.3-341.8. Moderately calcareous. Very fine grained. Hard... 5-6. Bands dip 9°. Shalier with de... Whitish to dark-gray with black band...
					Unsuitable 350.2-370.5	7169.8	350.2			350.2-370.5 - COAL: Sample taken. Wolfcreek bed.
					Doubtful 370.5-400	7149.5	370.5			370.5-371.3 - SANDSTONE: Very fine grained. Dark gray.
						7148.7	371.3			371.3-375.6 - SANDSTONE: With bands a... swirls of siltstone and carbonaceous material. Very fine grained. Bands dip 9°. Hardness 5-6. Light gray with black banding.
						7144.4	375.6			375.6-376.1 - SHALE: Cemented. Sligh... desiccated.
						7143.9	376.1			376.1-384.1 - SANDSTONE: Similar to 371.3-375.6 interval. Very thin coa... layering in shale 377.5-377.8. Broke... 378.8-379.5 along near vertical join... Bedding dips 12° at 384.1.
						7135.9	384.1			384.1-384.8 - SANDSTONE: With thin co... seam. Very fine grained.
						7135.2	384.8			384.8-393.0 - SILTSTONE: With scatter... sandstone banding and very thin coal... Sandstone increases with depth. Hardness 6. Dark gray to gray with whit...
						7127.0	393.0			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

RE... Foidel Creek Site ... PROJECT ... EMRIA - BLM ... STATE ... Colorado

O. ... DH-1 ... LOCATION ... See Location Map ... GROUND ELEV. ... 7520* ... DIP (ANGLE FROM HORIZ.) ... Vertical

COORDS. N. ... E. ...

... 9-5-75 ... FINISHED ... 9-15-75 ... DEPTH OF OVERBURDEN ... 0.6 ... TOTAL DEPTH ... 422.0 ... BEARING ... --

AND ELEV. OF WATER AND DATE MEASURED ... 111.2 ... 9-19-75 ... LOGGED BY ... N. B. Bennett, III ... LOG REVIEWED BY ... N. B. Bennett, III

ES ON WATER S AND LEVELS, G, CEMENTING, G, AND OTHER ING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Nx	100						7114.8	405.2			393.0-405.2 - SANDSTONE: With black siltstone, carbonaceous material, and coal bands and swirls. Scattered slickensides. Hardness 6. Very fine grained. Bands dip 19°.
								7112.4	407.6			405.2-407.6 - SHALE: Scattered thin coal seams (-1/8") and slickensides. Slight to no desiccation. Hardness 4-5. Dark gray to black.
								7112.0	408.0			407.6-408 - SANDSTONE: Very fine grained. Some carbonaceous material. Minute pyrite crystals. Slightly vuggy. Hard, light-green granular deposit on near vertical joint
								7111.4	408.6			408-408.6 - COAL
								7111.1	408.9			408.6-408.9 - SHALE: Carbonaceous and coaly. Slightly calcareous. Broken. Hardness 3.
								7110.1	409.9			408.9-409.9 - SANDSTONE: Fine grained. Thin coal seams.
		100						7098.0	422.0			409.9-422 TROUT CREEK SANDSTONE MEMBER ILES FM. 409.9-422 - SANDSTONE: Fine grained. Friable, massive, damp. Hardness 5. Predominately rounded quartz. No HCl reaction. White to light gray.

TOTAL DEPTH - 422 ft.

EXPLANATION

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

A-5

GPO 854-625

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Foidel Creek Site — PROJECT: EMRIA - BLM — STATE: Colorado

HOLE NO.: DH-2 — LOCATION: See location map — COORDS. N. ... E. ... — GROUND ELEV.: 7890* — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9-16-75 — FINISHED: 9-19-75 — DEPTH OF OVERBURDEN: 1.7' — TOTAL DEPTH: 263.1' — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 111.2' 9-19-75 — LOGGED BY: N. B. Bennett, III. — LOG REVIEWED BY: N. B. Bennett, I

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drilled with Longyear 34 truck mounted drill rig.

Rock bitted 0-8.7. Nx core 8.7-263.1.

Water used as drilling fluid 0-263.1.

100% water return 0-111.2. 0% return 111.2-263.1.

*Elevation taken from Rattlesnake Butte Quadrangle.

TYPE AND SIZE OF HOLE: Rock bit (0-8.7); Nx (8.7 on)

CORE RECOVERY (%): WS; 78; 100; 31; 100

SUITABILITY OF OVERBURDEN: Suitable 1.7-23.4; Unsuitable 23.4-32.2; Suitable 32.7-37.0; Unsuitable 37.0-39.4; Suitable 39.7-73.6; Doubtful 73.6-86.8; Suitable 86.8-91.3; Doubtful 91.3-

ELEVATION (FEET)	DEPTH (FEET)
7888.3	1.7
7876.4	13.6
7869.6	20.4
7866.6	23.4
7857.8	32.2
7857.3	32.7
7855.1	34.9
7853.0	37.0
7850.6	39.4
7850.3	39.7
7847.0	43.0
7846.2	43.8
7833.6	56.4
7823.6	66.4
7803.2	86.8
7798.7	91.3

CLASSIFICATION AND PHYSICAL CONDITION

0-1.7 SUPERFICIAL SOIL DEPOSITS

1.7-247.5 WILLIAMS FORK FM. OF THE M VERDE GROUP

1.7-13.6 - SHALE: Weathered, Fe stai slightly calcitic, partially desicc Black.

13.6-20.4 - SANDSTONE: With about 50 cent carbonaceous banding. Very fi grained. Moderately calcareous. F stained. Hardness 6. Black and wh

20.4-23.4 - SHALE: Weathered and Fe stained. Partly desiccated. Hardn 5. Breaks into flat pieces. Gray.

23.4-32.2 - COAL: Sample taken. Partl lost because of broken core spring. Wadge Bed.

32.2-32.7 - SHALE: Partly carbonaceo and coaly. Black.

32.7-34.9 - SANDSTONE: Very fine gra Black siltstone banding. Weathered Broken along vertical Fe stained jo White sandstone.

34.9-37.0 - SHALE: Cemented, partly desiccated. Gray.

37.0-39.4 - COAL: Sample taken.

39.4-39.7 - SHALE: Carbonaceous, min pyrite crystals. Black.

39.7-43.0 - SANDSTONE: Very fine gra Slightly weathered and Fe stained. siltstone bands. Hardness 6. 19° d ping bedding. 73° dipping joint at 40.4'. Gray.

43.0-43.8 - SHALE: Thin bedded, part desiccated. Hardness 4-5. Black.

43.8-56.4 - SANDSTONE: Similar to 39 43 interval. Banding increases wit depth. Fossiliferous. Spotty calc eous.

56.4-66.4 - SHALE: Fissile, spotty ca careous. Fresh. 74° dipping joint 61.9. Dark gray.

66.4-86.8 - SANDSTONE: With darker b of siltstone, carbonaceous material coal. Very fine grained and light to 74.5, then fine and dark gray in scattered layers. Dips 18°. Hardne Increasing banding with depth. Cro bedded(?).

86.8-91.3 - SHALE: And some siltston Carbonaceous and coaly. Slightly c on bedding planes. Bedding planes age about 3/4" apart. Some minute pyrite. Dark gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx – 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

RE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

O. DH-2 LOCATION See location map GROUND ELEV. 7890' DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

9-16-75 FINISHED 9-19-75 DEPTH OF OVERBURDEN 1.7' TOTAL DEPTH 263.1' BEARING --

AND ELEV. OF WATER AND DATE MEASURED 111.2' 9-19-75 LOGGED BY N. B. Bennett, III LOG REVIEWED BY N. B. Bennett, III

ES ON WATER S AND LEVELS, G, CEMENTING, IG, AND OTHER ING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	ELEVATION (FEET)	DEPTH (FEET)
	Nx	100			7789.6	100.4
					7788.0	102.0
					7787.2	102.8
					7772.4	117.6
					7771.1	118.9
					7754.7	135.3
					7748.7	141.3
					7739.8	150.2
					7736.3	153.7
					7729.7	160.3
					7713.9	176.1
					7710.0	180.0
					7708.3	181.7
					7707.6	182.4
					7694.2	195.8

CLASSIFICATION AND PHYSICAL CONDITION

91.3-100.4 - SANDSTONE: Very fine grained. Some dark banding. Scattered carbonaceous material. 9° bedding dip. Near vertical joint 96.3-97.4. Light gray.

100.4-102.0 - COAL: Sample taken.

102.0-102.8 - SHALE: Carbonaceous and coaly. Light weight. Pyritic. Black.

102.8-117.6 - SANDSTONE: Very fine. Some darker banding. Fe stained near vertical joints 106.1-113.1. Badly broken 109.2-113.1 (drill water loss zone) with heavy Fe stains. Light gray.

117.6-118.9 - SHALE: Coaly, pyritic, hardness 5. Gray to black.

118.9-135.3 - SANDSTONE: Fine to very fine. Scattered thin carbonaceous and coal seams with minute pyrite. Small sulfur crystals 118.9-123. Becomes shalier with depth. Near vertical joint 123.4-124.7. Light gray to 120.2, then dark gray.

135.3-141.3 - SHALE: Clayey. Thin bedded to laminated. Dark gray to black.

141.3-150.2 - SANDSTONE: Fine. Highly calcareous. Damp. Friable. 71° dipping joints 145.6-146.4. Brown when fresh, dries to light tan.

150.2-153.7 - SANDSTONE: With darker banding. Very fine. 10° bedding dip. Grades into siltstone.

153.7-160.3 - SILTSTONE: Slightly to highly calcareous. 12° dip. Hardness 5-6. Massive. 80° joint at 154.7. Gray.

160.3-176.1 - SHALE: Spotty calcareous. Fossiliferous. Hardness 5. Breaks into discs. Broken along intersecting near vertical joints 167.4-168.3. Black to dark gray.

176.1-180.0 - SANDSTONE: Very fine. Bands of fine carbonaceous material and coal (-1/16"). Light gray.

180-181.7 - COAL: Sample taken.

181.7-182.4 - CARBONACEOUS MATERIAL AND COAL

182.4-195.8 - SANDSTONE: Very fine. Highly calcareous. Slightly silty and friable. Faint banding. Dips 9°. 80° joints 185.4-187.1 and 187.9-189.5. Banding increases with depth. Siltstone 194.8-195.8. Light gray.

EXPLANATION

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx - 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Foidel Creek Site — PROJECT: EMRIA - BLM — STATE: Colorado

HOLE NO.: DH-2 — LOCATION: See location map — COORDS. N. … E. … — GROUND ELEV.: 7890± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9-16-75 — FINISHED: 9-19-75 — DEPTH OF OVERBURDEN: 1.7' — TOTAL DEPTH: 263.1' — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 111.2' 9-19-75 — LOGGED BY: N. B. Bennett, III — LOG REVIEWED BY: N. B. Bennett, I

Type and size of hole	Core recovery (%)	Suitability of overburden	Elevation (feet)	Depth (feet)
Nx	100	Unsuitable to 214.1	7675.9	214.1
		Doubtful 214.1–221	7675.5	214.5
		Suitable 221–244.9	7661.2	228.8
			7650.6	239.4
			7648.8	241.2
		Doubtful/Unsuitable 244.9–247.2	7645.1	244.9
			7643.6	246.4
		Suitable 247.2–263.1	7642.8	247.2
			7642.5	247.5
			7626.9	263.1

CLASSIFICATION AND PHYSICAL CONDITION

195.8-214.1 - COAL: Sample taken. Wol Creek bed.

214.1-214.5 - CARBONACEOUS SHALE

214.5-228.8 - SANDSTONE: Very fine grained. Banded with darker siltsto Black gyppy siltstone 216.3-219.7. Bands increase with depth. Bioturbat Broken along near vertical joint 217.2-218.7. Light gray.

228.8-239.4 - SHALE AND SILTSTONE: Mos the latter. Some sandstone bands. C carbonaceous material, and slickensi on some breaks. Hardness 5. Sandsto increases with depth. 50 percent sa stone and 50 percent siltstone 233.7 239.4.

239.4-241.2 - SANDSTONE: Very fine grained. Slightly friable and silty Hardness 5-6. Light gray.

241.2-244.9 - SANDSTONE AND SILTSTONE: With carbonaceous material, coal, an slickensides.

244.9-246.4 - SHALE: Platy, carbonace near lower contact. Black. Nearly pure montmorillonite 245.2-246: Lig green, soapy. Also contains illite and kaolinite.

246.4-247.2 - COAL: Sample taken.

247.2-247.5 - SHALE: Carbonaceous.

247.5-263.1 - SANDSTONE: Fine grained Noncalcareous to 260.1 then moderate so. Massive. Contact dips 29°. Qua crystals. Dark gray to 252.9 then white. Trout Creek sandstone, membe of the Iles Fm.

T.D. 263.1

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

(6-74) of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

TURE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

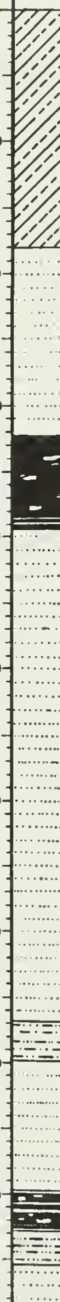
E NO. DH-3 LOCATION See Location Map GROUND ELEV. 7117± DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. .... E. ....

UN 9-24-75 FINISHED 9-26-75 DEPTH OF OVERBURDEN 18.0 TOTAL DEPTH 200.6 BEARING -----

TH AND ELEV. OF WATER VEL AND DATE MEASURED See Below LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER ...SSES AND LEVELS, ...SING, CEMENTING, ...VING, AND OTHER ...LLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
...lled with Long-...r 34 truck-...nted drill rig.	Rock bit	RB			0-2							0-18 - Superficial soil deposits of clay and silt. Sandy. Shaley structure near 15.0. Gray, light-brown.
...k bitted 0-2.	Nx	100				2-18		7099	18			18-200.6 WILLIAMS FORK FM. MESA VERDE GROUP
...core 2-200.6 ...med hole with ...k bit 0-22.5 ...installed 4" ...ing. Casing left ...hole.		50			18-32.4			7084.6	32.4			18-32.4 - SANDSTONE: Fine grained. Gray with black carbonaceous bands. Spotty calcareous. Massive. Weathered and broken 18-19.
		56					32.4-39.3	7078.7	38.3			32.4-38.3 - COAL: Sample taken.
		0						7077.7	39.3			38.3-39.3 - SHALE: Carbonaceous with thin coal and minute pyrite crystals. Black.
...artesian water ...ween 31.5 and ...5', about 3/4 ...per minute. ...increased to ...gpm with 25' ...71.5-81.5 with ...at 150.7, flow ...71 gpm with ...head.		94			39.3-52	52-60		7040.1	76.9			39.3-76.9 - SANDSTONE: Gray with dark carbonaceous banding. Very fine grained. Banding decreases to 74.9 then increases. Spotty calcareous. Mud with shale structure 40.5-41.5. Shale 82.2-83.6, fissile, black. 82° dipping joints 41.8-42.3. Other high angle joints at 49.8, 55.5, 56.2, 58-61.7 (broken here), 64.4, and 72.
...gpm with 40' ...when hole at ...6.								7037.1	79.9			76.9-79.9 - SILTSTONE: Moderately calcareous. Hardness 4-5. Slightly shaley.
...evation taken ...om Rattlesnake ...tte Quadrangle.		100			60-89.9			7027.1	89.9			79.9-89.9 - SANDSTONE: With dark carbonaceous banding. Very fine grained. Hardness 6. Light gray.
							89.9-92.3	7027.0	90			89.9-90 - CARBONACEOUS SHALE.
								7026.5	90.5			90-90.5 - COAL: Sample taken.
								7025.0	91.5			90.5-91.5 - CARBONACEOUS SHALE.
					92.3-92.9			7024.7	92.3			91.5-92.3 - COAL: Sample taken.
								7024.1	92.9			92.3-92.9 - CARBONACEOUS SHALE.
						92.9-		7021.7	95.3			92.9-95.3 - SILTSTONE: Slightly carbonaceous. Light green deposit on joint at 93.9. Hardness 5. Dark gray.
												95.3-104.7 - SANDSTONE: Very fine grained. Massive. Hardness 6. Vertical joint 103.5-104.1. Broken 95.3-96 and 96.8-97.8 along high angle joints. Light gray.



EXPLANATION

...RE ...SS

...RE ...ERY

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Foidel Creek Site PROJECT: EMRIA - BLM STATE: Colorado

HOLE NO.: DH-2 LOCATION: See location map COORDS. N. ... E. ... GROUND ELEV.: 7890± DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9-16-75 FINISHED: 9-19-75 DEPTH OF OVERBURDEN: 1.7' TOTAL DEPTH: 263.1' BEARING: ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 111.2' 9-19-75 LOGGED BY: N. B. Bennett, III LOG REVIEWED BY: N. B. Bennett, I

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Nx	100						7675.9	214.1			195.8-214.1 - COAL: Sample taken. Wol Creek bed.
								7675.5	214.5			214.1-214.5 - CARBONACEOUS SHALE
								7661.2	228.8			214.5-228.8 - SANDSTONE: Very fine grained. Banded with darker siltsto Black gyppy siltstone 216.3-219.7. Bands increase with depth. Bioturbat Broken along near vertical joint 217.2-218.7. Light gray.
								7650.6	239.4			228.8-239.4 - SHALE AND SILTSTONE: Mos the latter. Some sandstone bands. C carbonaceous material, and slickensi on some breaks. Hardness 5. Sandsto increases with depth. 50 percent sa stone and 50 percent siltstone 233.7 239.4.
								7648.8	241.2			239.4-241.2 - SANDSTONE: Very fine grained. Slightly friable and silty Hardness 5-6. Light gray.
								7645.1	244.9			241.2-244.9 - SANDSTONE AND SILTSTONE: With carbonaceous material, coal, ar slickensides.
								7643.6	246.4			244.9-246.4 - SHALE: Platy, carbonace near lower contact. Black. Nearly pure montmorillonite 245.2-246: Lig green, soapy. Also contains illite and kaolinite.
								7642.8	247.2			246.4-247.2 - COAL: Sample taken.
								7642.5	247.5			247.2-247.5 - SHALE: Carbonaceous.
								7626.9	263.1			247.5-263.1 - SANDSTONE: Fine grained Noncalcareous to 260.1 then moderate so. Massive. Contact dips 29°. Qua crystals. Dark gray to 252.9 then white. Trout Creek sandstone, membe of the Iles Fm.
												T.D. 263.1

Suitability of overburden: Unsuitable 195.8-214.1; Doubtful 214.1-221; Suitable 221-245; Doubtful 245-246.4; Unsuitable 246.4-247.2; Suitable 247.2-263.1.

Depth scale: 210, 220, 230, 240, 250, 260, 270, 280, 290

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx - 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

TURE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

E NO. DH-3 LOCATION See Location Map GROUND ELEV. 7117* DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

UN 9-24-75 FINISHED 9-26-75 DEPTH OF OVERBURDEN 18.0 TOTAL DEPTH 200.6 BEARING -----

TH AND ELEV. OF WATER VEL AND DATE MEASURED See Below LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

OTES ON WATER SSES AND LEVELS, SING, CEMENTING, VING, AND OTHER LLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SUITABILITY OF OVERBURDEN	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
lled with Long- r 34 truck- nted drill rig.	Rock bit	RB	Suitable (0–3)			0-18 - Superficial soil deposits of clay and silt. Sandy. Shaley structure near 15.0. Gray, light-brown.
k bitted 0-2.	Nx	100	Doubtful (3–18)			18-200.6 WILLIAMS FORK FM. MESA VERDE GROUP
core 2-200.6 med hole with k bit 0-22.5 installed 4" ing. Casing left hole.		50				
		56		7099	18	18-32.4 - SANDSTONE: Fine grained. Gray with black carbonaceous bands. Spotty calcareous. Massive. Weathered and broken 18-19.
artesian water ween 31.5 and 5', about 3/4 . per minute. w increased to gpm with 25' d 71.5-81.5 with e at 150.7, flow 71 gpm with head.		0	Suitable			
		94		7084.6	32.4	32.4-38.3 - COAL: Sample taken.
			Unsuitable	7078.7	38.3	38.3-39.3 - SHALE: Carbonaceous with thin coal and minute pyrite crystals. Black.
gpm with 40' l when hole at 6.			Suitable	7077.7	39.3	39.3-76.9 - SANDSTONE: Gray with dark carbonaceous banding. Very fine grained. Banding decreases to 74.9 then increases. Spotty calcareous. Mud with shale structure 40.5-41.5. Shale 82.2-83.6, fissile, black. 82° dipping joints 41.8-42.3. Other high angle joints at 49.8, 55.5, 56.2, 58-61.7 (broken here), 64.4, and 72.
evation taken om Rattlesnake tte Quadrangle.		100	Doubtful / Suitable			
			Suitable	7040.1	76.9	76.9-79.9 - SILTSTONE: Moderately calcareous. Hardness 4-5. Slightly shaley.
				7037.1	79.9	79.9-89.9 - SANDSTONE: With dark carbonaceous banding. Very fine grained. Hardness 6. Light gray.
				7027.1	89.9	89.9-90 - CARBONACEOUS SHALE.
			Unsuitable	7027.0	90	90-90.5 - COAL: Sample taken.
				7026.5	90.5	90.5-91.5 - CARBONACEOUS SHALE.
				7025.0	91.5	91.5-92.3 - COAL: Sample taken.
			Suitable	7024.7	92.3	92.3-92.9 - CARBONACEOUS SHALE.
				7024.1	92.9	92.9-95.3 - SILTSTONE: Slightly carbonaceous. Light green deposit on joint at 93.9. Hardness 5. Dark gray.
			Doubtful	7021.7	95.3	95.3-104.7 - SANDSTONE: Very fine grained. Massive. Hardness 6. Vertical joint 103.5-104.1. Broken 95.3-96 and 96.8-97.8 along high angle joints. Light gray.

EXPLANATION

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Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

FEATURE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

HOLE NO. DH-3 LOCATION See Location Map GROUND ELEV. 7117* DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

BEGUN 9-24-75 FINISHED 9-26-75 DEPTH OF OVERBURDEN 18.0 TOTAL DEPTH 200.6 BEARING ------

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Below LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	ELEVATION (FEET)	DEPTH (FEET)
	Nx	100	7012.3	104.7
			7010.3	106.7
			6999.2	117.8
			6997.1	119.9
			6995.1	121.9
			6994.7	122.3
			6992.7	124.3
			6986.0	131.0
			6952.5	164.5
* Elevation taken from Rattlesnake Butte Quadrangle.			6947.1	169.9
			6943.5	173.5
			6936.9	180.1
			6936.1	180.9
			6924.1	192.9
			6919.6	197.4
			6916.4	200.6

SUITABILITY OF OVERBURDEN: SUITABLE / DOUBTFUL / UNSUITABLE

CLASSIFICATION AND PHYSICAL CONDITION

104.7-106.7 - SILTSTONE AND SHALE: bedded to fissile. Hardness 5. D gray.

106.7-117.8 - COAL: Sample taken. Wadge bed.

117.8-119.9 - SILTSTONE: With thin stone layers. Light green deposit 119. Dark gray.

119.9-121.9 - COAL: Sample taken.

121.9-122.3 - CARBONACEOUS SHALE.

122.3-124.3 - SILTSTONE AND SANDSTON Thin bedded. Banded.

124.3-131 - SANDSTONE: Very fine gr ed. Increasing calcite with depth Banded. Hardness 6. Massive. Li gray.

131-164.5 - SILTSTONE: With sandsto bands. Intermixed with fissile sh Bioturbated 131.8. Massive siltst 12° bedding dip. Sandstone increa at 150. Broken into 1-2" pieces 1 154.6. Various gray shades.

164.5-169.9 - SANDSTONE: Very fine. Hardness 6. Moderately calcareous Banded with carbonaceous material. Light gray with dark gray bands.

169.9 - 173.5 -SILTSTONE: Scattered carbonaceous material. Gypsum and pyrite at 170.7. Massive. Hardne 5

173.5-180.1 - SANDSTONE: Very fine. Scattered carbonaceous material. tical joint 173.5-176.4. Light gr

180.1-180.9 - COAL: Sample taken.

180.9-192.9 - SANDSTONE: Very fine. Carbonaceous bands and pods. Vugg Light weight. Fossilferous. Ligh and dark gray.

192.9-197.4 - SILTSTONE: Carbonaceo and coaly. Dark gray to black.

197.4-200.6 - SANDSTONE: Fine to ve fine. High angle joint at 198.8. Hardness 6. Light gray.

T.D. 200.6

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

URE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

NO. DH-4 LOCATION See Location Map GROUND ELEV. 7160 DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

N 9/20/75 FINISHED 9/22/75 DEPTH OF OVERBURDEN 1.8' TOTAL DEPTH 172.9' BEARING --

H AND ELEV. OF WATER EL AND DATE MEASURED 44.3 9-23-75 LOGGED BY N. B. Bennett, III LOG REVIEWED BY N. B. Bennett, III

OTES ON WATER SES AND LEVELS, ING, CEMENTING, ING, AND OTHER LING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
lled with Long- 34 truck ted drill rig.	Rockbit	0 (RB)	7158.2	1.8	0-1.8 - SUPERFICIAL SOIL DEPOSITS: Clay, medium plasticity. 1.8-172.9 WILLIAMS FORK FM. 1.8-10.3 - SHALE: Highly weathered, black.
lled with rock 0-8.5. Nx core 172.9.		72	7149.7	10.3	10.3-49.9 - SANDSTONE: Very fine grained. Contains carbonaceous bands and stringers that increase from 48.6. Fe stained to 19'. Few siltstone and thin coal layers and stringers. No to spotty calcareous. Slightly friable and silty. Broken 19.6-26 along high angle joints. Hardness 5-6. Light gray and rusty.
r used as ling fluid 0- 9. No losses e drilling.	NX core				
alled 2" pvc to bottom of . 40' slotted.					
		100	7110.1	49.9	49.9-51.2 - SHALE: Fissile to blocky. Hardness 5. Mostly broken along a vertical joint. Dark gray.
			7108.8	51.2	51.2-55.4 - SANDSTONE: Very fine grained. Moderately calcareous. Hard green deposit on vertical joint 54.8-55.4. 8-16° bedding dips. Other scattered vertical joints. Gray with dark gray bands.
			7104.6	55.4	55.4-71.4 - SILTSTONE: With some shale layers and sandstone bands. Increasingly carbonaceous with depth. Slightly calcareous in sandstone bands. Massive where not banded. Broken in shaley and vertical joint zone 57-58. Gray.
			7088.6	71.4	71.4-71.8 - COAL: Sample taken.
			7088.2	71.8	71.8-74.1 - SILTSTONE: With carbonaceous material. Dark gray to black.
			7085.9	74.1	74.1-86.9 - SANDSTONE: Very fine. Very faint banding that increases with depth. Near vertical joints 74.1-75.1. Light gray.
			7073.1	86.9	86.9-88.3 - SILTSTONE: Carbonaceous, thin bedded. Black.
			7071.7	88.3	88.3-98.9 - COAL: Sample taken.
			7061.1	98.9	98.9-99.6 - SHALE: Carbonaceous and coaly. Black.
			7060.4	99.6	

Suitability of overburden: SUITABLE 0-1.8, 10.3-19.2, 25.8-31.8, 31.8-71.4, 71.8-88.3; DOUBTFUL 1.8-10.3, 15.0-21.4, 26.4-32.4; UNSUITABLE 71.4-71.8, 88.3-99.6 (as shown graphically).

EXPLANATION

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

FEATURE: Foidel Creek Site PROJECT: EMRIA - BLM STATE: Colorado

HOLE NO.: DH-4 LOCATION: See Location Map COORDS. N. ... E. ... GROUND ELEV.: 7160 DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9/20/75 FINISHED: 9/22/75 DEPTH OF OVERBURDEN: 1.8' TOTAL DEPTH: 172.9' BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 44.3 9-23-75 LOGGED BY: N. B. Bennett, III LOG REVIEWED BY: N. B. Bennett, I

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
	Nx	100								99.6-114.7 - SANDSTONE: Very fine grained. Spotty faint calcareous. Banded with darker carbonaceous ma- ial that increases with depth. Fe high angle joints. Light gray wit dark gray bands.
								7045.3	114.7	114.7-142.2 - SHALE: With sandstone bands decreasing with depth to 125 where they increase. Breaks along dipping bedding planes. Coal at l contact. Calcareous sandstone. Hi- ness 5. Black.
								7017.8	142.2	142.2-160.5 - SANDSTONE: Very fine grained. Few carbonaceous bands d 15°. Broken along high angle join 159.5-160.5. Massive. Light gray
								6999.5	160.5	160.5-161.9 - COAL: Sample taken.
								6998.1	161.9	161.9-162.2 - CARBONACEOUS SHALE
								6997.8	162.2	162.2 - 172.9 - SANDSTONE: Very fin grained. Carbonaceous banding. H calcareous to 168.7, then none. Ha- ness 6. Broken 167.4-168.7. Ligh gray with dark gray bands.
								6987.1	172.9	T.D. 172.9

Depth scale: 110, 120, 130, 140, 150, 160, 170, 80, 90

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

ATURE Foidel Creek Site | PROJECT EMRIA - BLM | STATE Colorado

LE NO. DH-5 | LOCATION See Location Map | COORDS. N. ... E. ... | GROUND ELEV. 7515+ | DIP (ANGLE FROM HORIZ.) Vertical

GUN 9-23-75 | FINISHED 9-24-75 | DEPTH OF OVERBURDEN 3.0 feet | TOTAL DEPTH 111.0' | BEARING --

PTH AND ELEV. OF WATER EVEL AND DATE MEASURED 34.1' 9-24-75 | LOGGED BY N. B. Bennett, III | LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER OSSES AND LEVELS, ASING, CEMENTING, AVING, AND OTHER RILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
lled with Long-r 34 truck mounted ll rig.	NX CORE	0			0-3 SOIL: With weathered shale fragments
er used as drill- fluid 0-111. No s 0-13, 10% loss 111.		100	7512.0	3.0	3-111.0 WILLIAMS FORK FM. OF THE MESA VERDE GROUP
kbitted 0-1.1. core 1.1-111.		98			
evation taken m Rattlesnake te Quadrangle.		48	7502.5	12.5	3-12.5 SHALE: Highly weathered. Clayey. Fe stains. Tan and rusty color.
		100	7490.0	25.0	12.5-25 SANDSTONE: Very fine to fine grained. Bands and swirls of carbonaceous material. Gypsum at 15.5. Fe stains on joint and bedding planes. Broken along 70° dipping joint 21.3-22. Slightly friable and silty. Light gray.
			7485.5	29.5	25-29.5 SILTSTONE: And carbonaceous materials. Very carbonaceous and coaly 25-25.3. Increasing carbonaceous materials with depth. Vertical joint 26.7-27.2. Gray, black.
			7482.5	32.5	29.5-32.5 COAL: Sample taken.
			7479.2	35.8	32.5-35.8 SILTSTONE: Very carbonaceous 32.5-33. Deep Fe stain at 35.7 on bedding plane. Broken 33-33.7.
		98			
		100	7420.0	95.0	35.8-95 SANDSTONE: With zones of carbonaceous banding and pods, and shale. Spotty calcareous. Banding increases with depth. Very fine grained. Slightly friable. Bioturbated zones. 10° bedding dip. Broken along high angle joints 53.7-56.4 and Fe stained. Gray and brown (from Fe staining).
					95-111 SILTSTONE: With sandstone, coal and carbonaceous layering. Carbonaceous shale 104-105 with coal, shale 105.9-107.8. Clayey shale. Massive siltstone. Laminated shale. Dark gray to black.
					T.D. 111.0

SUITABILITY OF OVERBURDEN (SUITABLE / DOUBTFUL / UNSUITABLE); DEPTH (FEET) FROM (P, Cs, or Cm) TO; GRAPHIC LOG; SAMPLES FOR TESTING

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

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EXPLANATION

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

IRE Foidel Creek Site | PROJECT EMRIA-BLM | STATE Colorado | SHEET 1 OF 2 | HOLE NO. DH-5

GPO 854-625

GEOLOGIC LOG OF DRILL HOLE

FEATURE Foidel Creek Site PROJECT EMRIA - BLM STATE Colorado

HOLE NO. DH-5 LOCATION See Location Map COORDS. N. E. GROUND ELEV. 7515± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9-23-75 FINISHED 9-24-75 DEPTH OF OVERBURDEN 3.0' TOTAL DEPTH 111.0' BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 34.1' 9-24-75 LOGGED BY N. B. Bennett, III LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	110	100						7404.0	111.0			
			B.O.H.-111.0									
	120								120			
	130								130			
	140								140			
	150								150			
	160								160			
	170								170			
	180								180			
	190								190			

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

A P P E N D I X B

COAL

Statement on the use of metric and English units of measure in this coal report.

Current policy calls for exclusive use of metric units in all reports of the U.S. Geological Survey; therefore, metric units were used throughout the text of the coal section in the report. However, because the detailed coal resource data presented in the tables in the report are expected to be of interest primarily to the engineers and geologists of mining companies, and because mining companies in the United States principally employ the English system of measure, the data in the tables are presented in English units. English-to-metric conversion factors may be found in the headings of the tables.

GEOLOGY AND COAL RESOURCES OF THE FOIDEL CREEK EMRIA SITE AND SURROUNDING AREA, ROUTT COUNTY, COLORADO

ABSTRACT

Terrigenous clastic sediments of the Upper Cretaceous Mesaverde Group (Campanian) in the southeastern part of the Yampa coal field in Routt County, northwestern Colorado, contain many beds of bituminous coal. Lower, middle, and upper coal groups are recognized. The middle coal group, in the lower coal-bearing member of the Williams Fork Formation, contains two thick, persistent coal beds in the Foidel Creek area. The Wadge coal bed, stratigraphically the higher of the two, reaches thicknesses of 3.7 meters, and is strippable beneath large areas on the south slope of Eckman Park. Coal resources of the Wadge bed in the Foidel Creek area--an area of 134 square kilometers, as defined in this study--are estimated to be 317 million metric tons. The Foidel Creek EMRIA reclamation study site--an area of 10.9 square kilometers--contains about 36.1 million metric tons of Wadge coal, as much as 28.1 million metric tons of which occur beneath overburden 61 meters or less in thickness. About 52 meters lower in the section, the Wolf Creek coal bed locally exceeds 6.1 meters in thickness. Coal resources of the Wolf Creek bed in the Foidel Creek area are estimated to be 434 million metric tons. The Foidel Creek EMRIA reclamation study site contains an estimated 49.7 million metric tons of Wolf Creek coal.

APPENDIX C

SOIL

NO. 2

Layers
FSL
SiCL
CL
Shale 40+

Location: NW1/4NE1/4

8-12% Slope

Remarks: Sage; unconsolidated shale 40"+

NO. 13

Left	Layers	Right
.34 / 35	CL	.05 / 6.5
55	C	.03 / 6.7
.20 / 65	C	.07 / 7.0
	Shale	

Location: NW1/4 NW1/4

12-15% Slope

Unconsolidated shale 40"+

NO. 3 (triangle) Deep Hole #3

Location: NE 1/4 SE 1/4

Remarks: Laborotory results are given in Soils Appendix

NO.

NO. 3

Layers
CL
C
Clay & Shale

Locotion: NE1/4 SE1/4

Parent material: Shale

10% Slope

Cloy & shale 20"+

NO. 14

Layers
L
CL
CL
Shale & SS

Location: SW 1/4 SW 1/4

Parent Material: Interbedded sandstone & shale

Remarks: Sage

NO.

NO.

NO. 12

Layers
L
L
SL

Location: SW 1/4 SE1/4

Parent moterial: Interbedded sandstone & Shale

Remarks: Ookbrush

NO. 23

Left	Layers	Right
.07 / 55	CL	.06 / 6.0
.16 / 35	C	.06 / 6.4
.12 / 40	CL & C	.11 / 6.6

Locotion: SE 1/4 NW 1/4

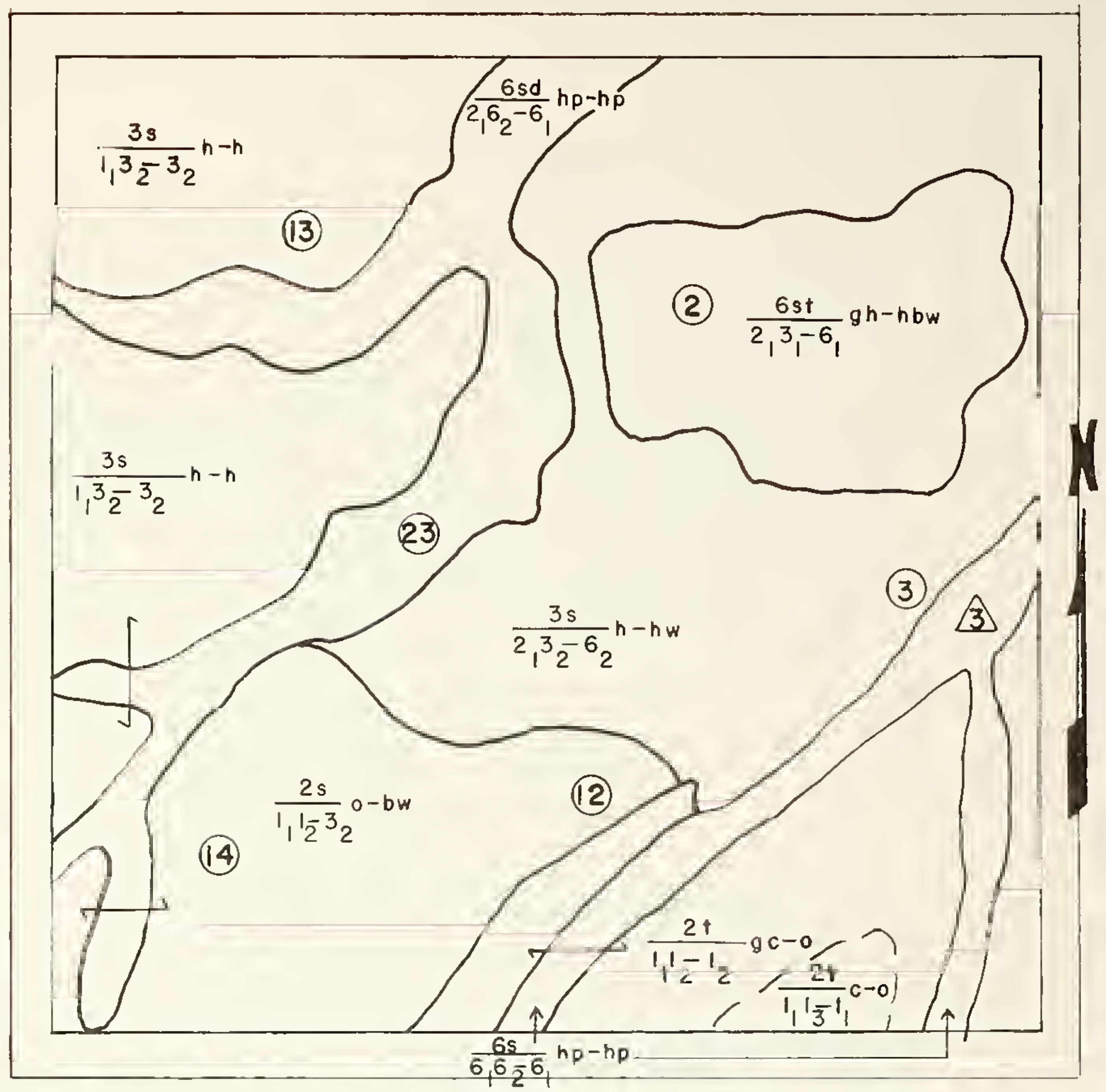
0-2% Slopes

Porent Moteriol: Alluvium

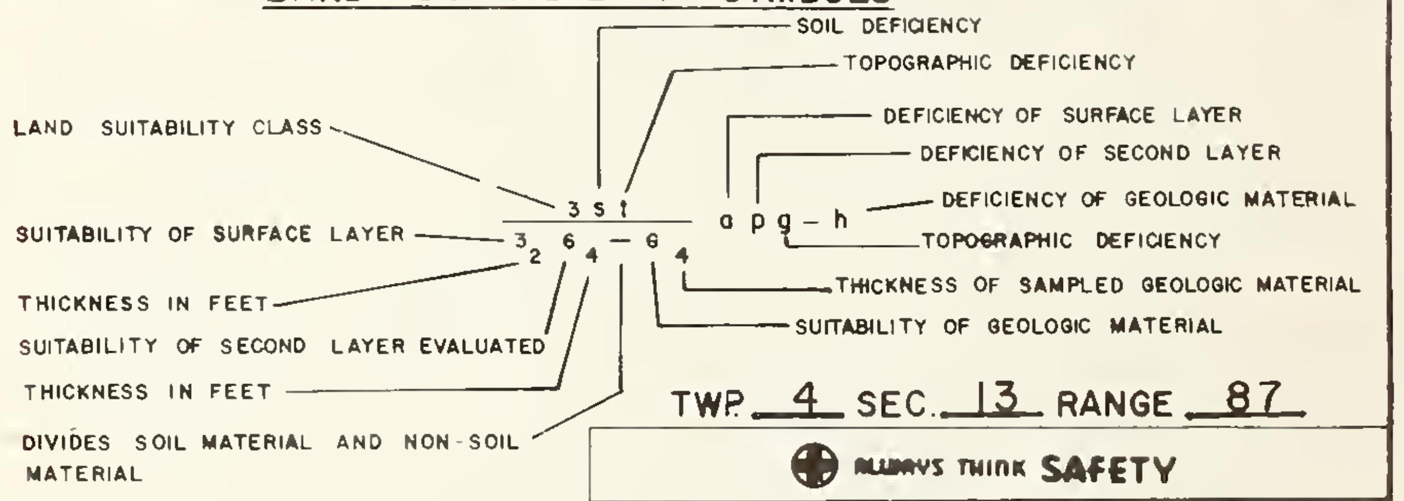
Remarks: CL and C stratified

NO.

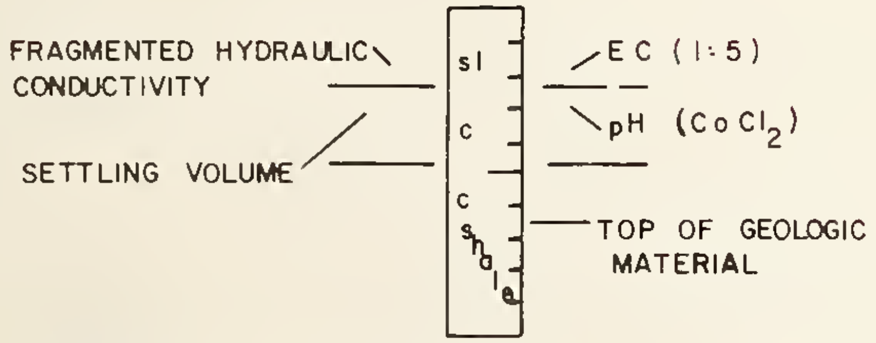
NO.



LAND SUITABILITY SYMBOLS



SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Symbol	Meaning	Symbol	Meaning
Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

- s SALINITY
- a SODICITY
- w WEATHERABILITY
- k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
- b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- o NO DEFICIENCY
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

1000 0 1000

SCALE OF FEET

FOIDEL CREEK STUDY AREA
COLORADO

TWP. 4 SEC. 13 RANGE 87

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY

LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED W.C. LAUBNER SUBMITTED
DRAWN W.C. LAUBNER RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. | Figure C-1

NO. 1

L | S CL | CL | Shale & Ss

Location: NW 1/4 NW 1/4

5-8% Slope

Parent Material: Shale

Remarks: Shale and sandstone 30"+

NO. 17

.12 / 50	CL	.07 / 6.3
.18 / 55	C	.04 / 6.3
.28 / 60	C	.10 / 6.8
	Shale Ss	

Location: SE 1/4 NW 1/4

8-10% Slope

Remarks: Soft shale and sandstone fragments

NO. [1]

.64 / 35	CL	.13 / 6.3
9.3 / 75	SiC	.05 / 6.1
.32 / 40	SiC	.04 / 6.2
.06 / 40	SiC	.04 / 6.5
.38 / 38	SiCL	.12 / 6.8
.09 / 38	SiCL	.16 / 7.3

Location: NW 1/4 NW 1/4

Parent Material: Shale

NO. ⚠4 Deep Hole #4

Location: SE 1/4 NE 1/4

Remarks: Laboratory results are given in Soils Appendix

NO. 4

L FSL | L CL | L | Ss

Location: SW 1/4 SW 1/4

10-20% Slope

Parent Material: Sandstone

Remarks: Unconsolidated Sandstone 30"+

NO. 18

FSL | FSL Ss | Soft Ss

Location: SE 1/4 SE 1/4

10% Slope

Parent Material: Sandstone

Remarks: Soft sandstone 30"+

NO. [3]

.50 / 29	UFSL	.07 / 5.8
	UFSL	
.58 / 29	FSL	.06 / 6.0
.70 / 28	Ss	.05 / 6.0
.80 / 20	Ss	.03 / 6.2

Location: SW 1/4 SW 1/4

Parent Material: Medium textured sandstone

NO.

NO. 11

L | CL | L | SCL CL | Shale

Location: SE 1/4 NE 1/4

Parent Material: Interbedded Sandstone and shale

NO. 19

40 / 25	FSL	.04 / 6.2
.32 / 25	L	.03 / 6.3
.36 / 33	FSL	.05 / 6.6
	Soft Ss Shale	

Location NW 1/4 SE 1/4

10% Slope

Parent Material: Sandstone and shale interbedded

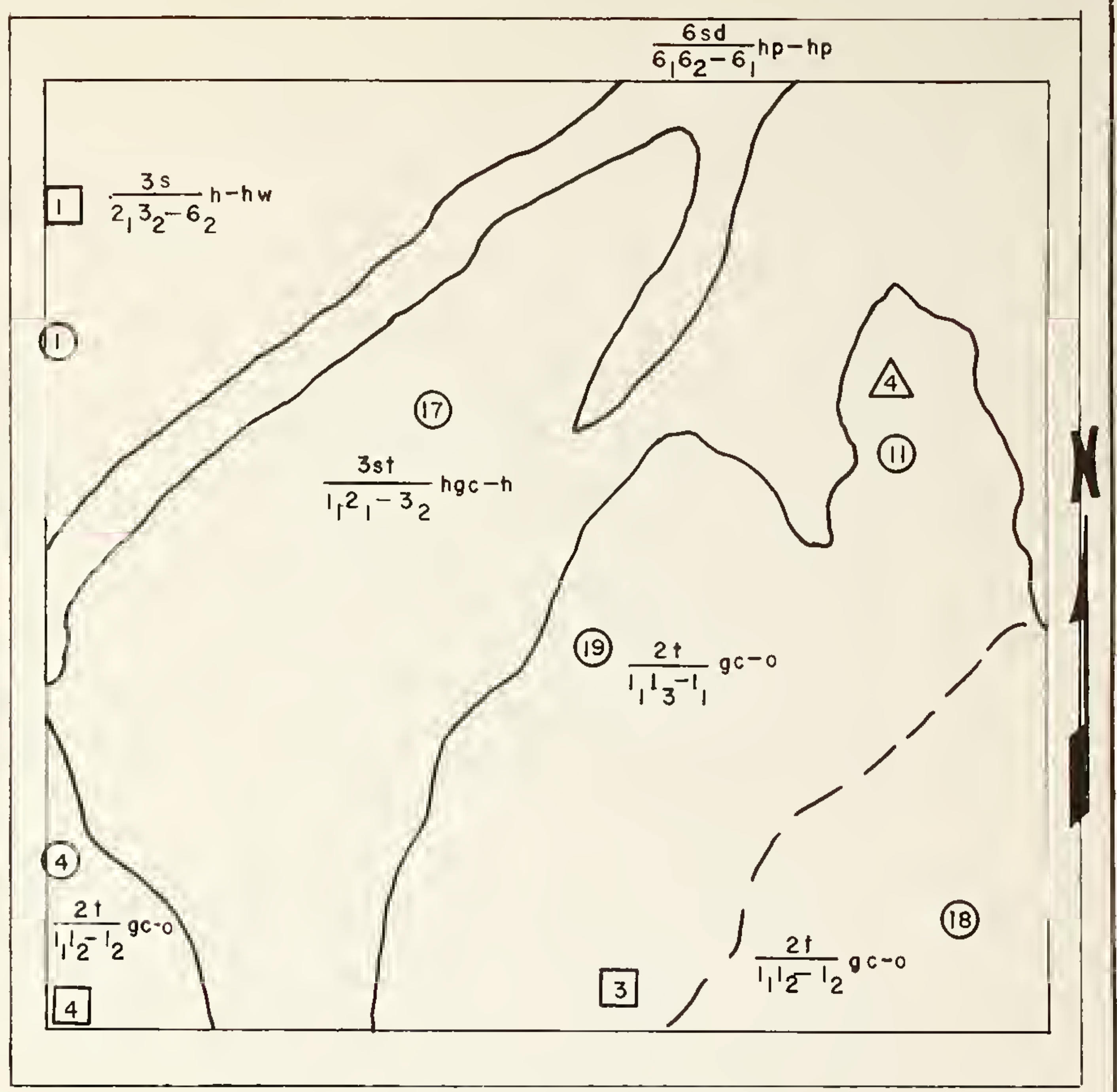
NO. [4]

1.34 / 30	L	.06 / 6.0
1.34 / 30	L	.05 / 6.1
1.20 / 31	CL	.05 / 6.1
1.36 / 31	CL	.03 / 6.1

Location: SW 1/4 SW 1/4

Parent Material: Fine textured sandstone

NO.



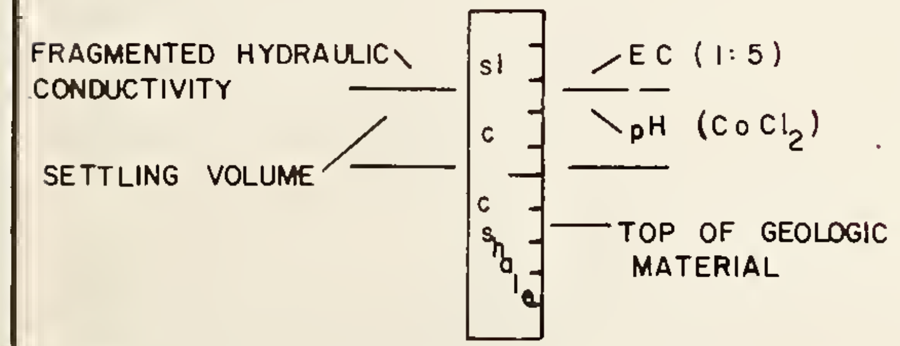
LAND SUITABILITY SYMBOLS

3 s t / 3₂ 6₄ — 6₄ a p g - h

- LAND SUITABILITY CLASS
- SOIL DEFICIENCY
- TOPOGRAPHIC DEFICIENCY
- DEFICIENCY OF SURFACE LAYER
- DEFICIENCY OF SECOND LAYER
- DEFICIENCY OF GEOLOGIC MATERIAL
- TOPOGRAPHIC DEFICIENCY
- THICKNESS OF SAMPLED GEOLOGIC MATERIAL
- SUITABILITY OF GEOLOGIC MATERIAL
- SUITABILITY OF SURFACE LAYER
- THICKNESS IN FEET
- SUITABILITY OF SECOND LAYER EVALUATED
- THICKNESS IN FEET
- DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

TWP. 4 SEC. 18 RANGE 86

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

- s SALINITY
- o SODICITY
- w WEATHERABILITY
- k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
- b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- o NO DEFICIENCY
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

1000 0 1000

SCALE OF FEET

FOIDEL CREEK STUDY AREA
COLORADO

ALWAYS THINK SAFETY

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CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. Figure C-2

NO. 5

CL / C / C / Shale

Location: NW1/4 NW1/4

Parent Material: Shale

Remarks: Unconsolidated Shale 18+, sage and shrubs

NO. 8

FSL / L / FSL & Ss

Location: NW1/4 SE1/4

Parent Material: Sandstone

Remark: FSL and Ss fragments 18"+

NO. 21

	Layer	
.28 / 32	FSL	.05 / 6.0
.68 / 33	L	.06 / 6.5
.60 / 30	CL	.05 / 6.6
.13 / 38	CL & Clay	.06 / 6.8

Location: SW 1/4 SE 1/4

0-2% slopes

Parent Material: alluvium

Remarks: Sage and meadowgrass

NO.

NO. 6

FSL / SL & Ss

Location: NE 1/4 NW 1/4

Parent Material: Sandstone

Remarks: Sandstone fragments 14"+

NO. 9

L / L / L / Ss & Shale

Location: NW1/4 SE 1/4

Parent Material: Sandstone

Remarks: Sandstone fragments and shale 40"+, sage oakbrush

NO. 2

	Layer	
.60 / 30	CL	.06 / 6.5
.38 / 27	CL	.06 / 6.3
.52 / 28	CL	.04 / 6.1
.62 / 75	C	.03 / 5.5
.16 / 85	S.C.	.04 / 4.3

Location: SW1/4 SW1/4

Parent Material: Interbedded sandstone & shale

NO.

NO. 7

FSL / Soft Ss

Location: SE1/4 NW1/4

Parent Material: Sandstone

Remarks: Soft sandstone 20"+, sage and gramma grass, no aspen

NO. 20

	Layer	
1.40 / 27	FSL	.06 / 6.1
1.02 / 26	L	.04 / 5.8
1.03 / 34	FSL & soft Ss	.03 / 5.6

Location: SW 1/4 SW 1/4

Parent Material: Sandstone

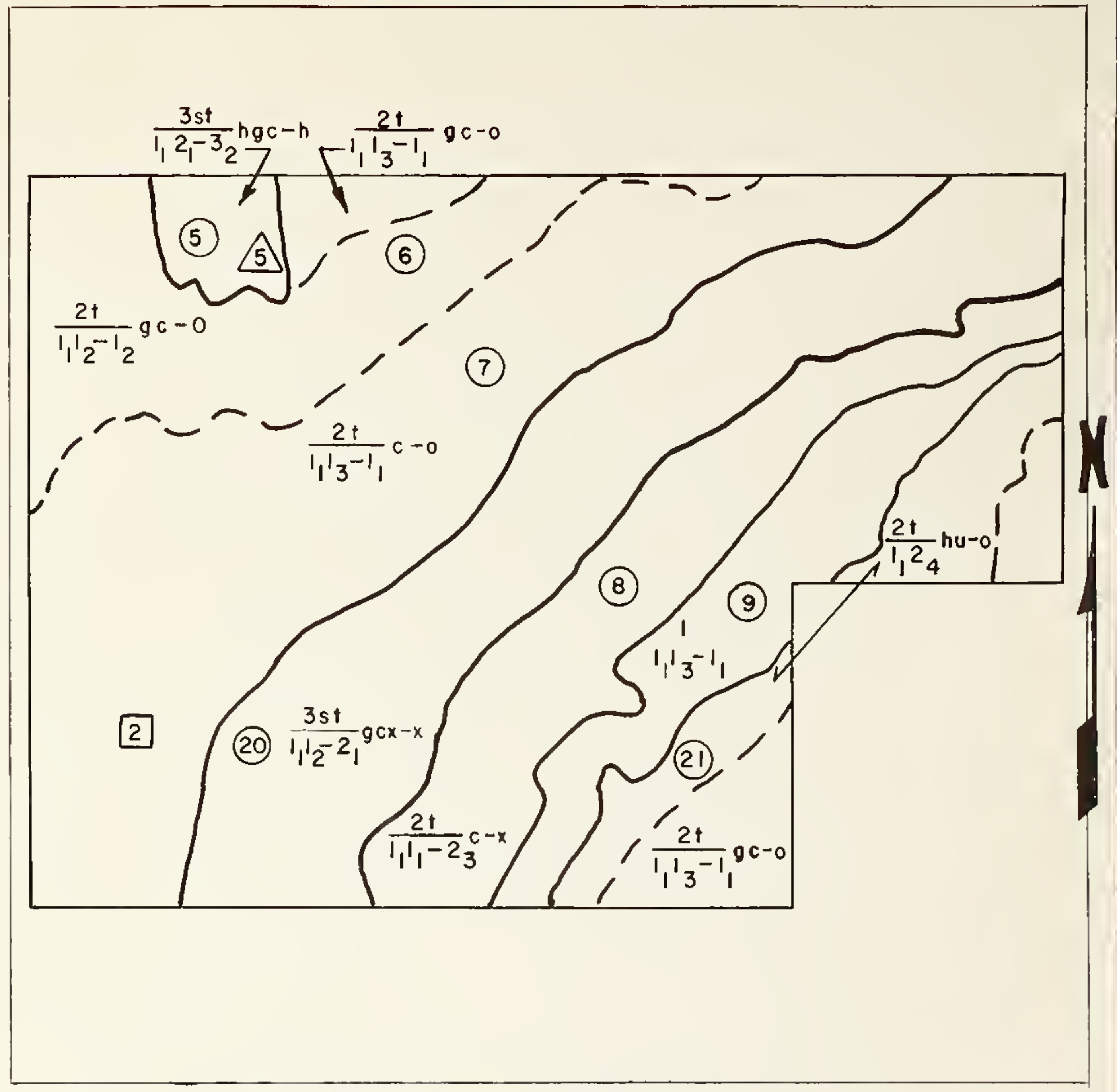
Remarks: Aspen and oakbrush

NO. 5 Deep Hole #5

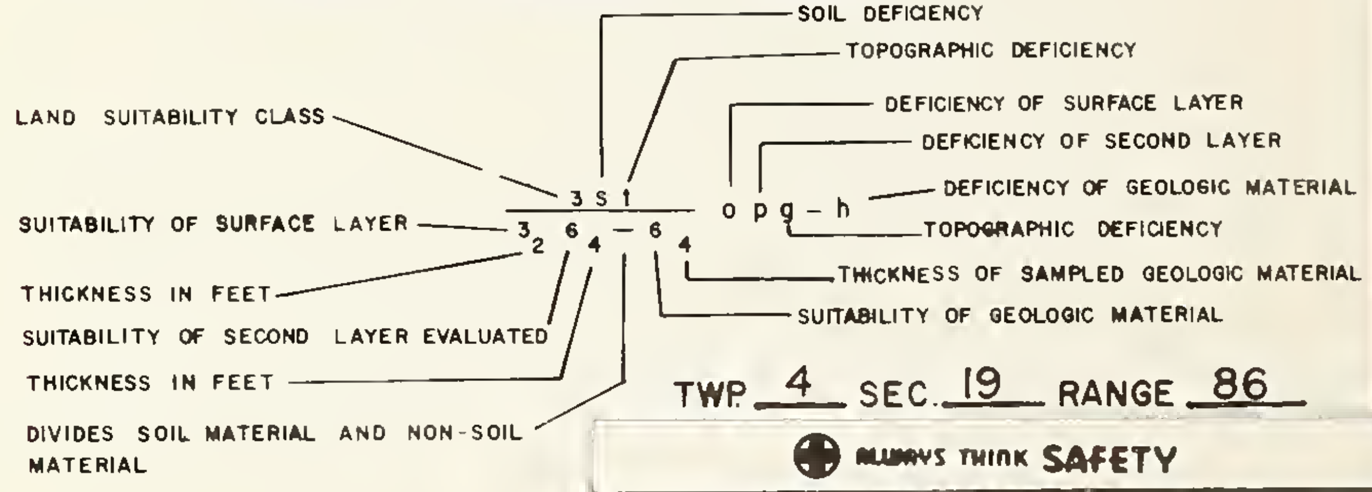
Location: NW 1/4 NW 1/4

Remarks: Laboratory results are given in Soils Appendix

NO.

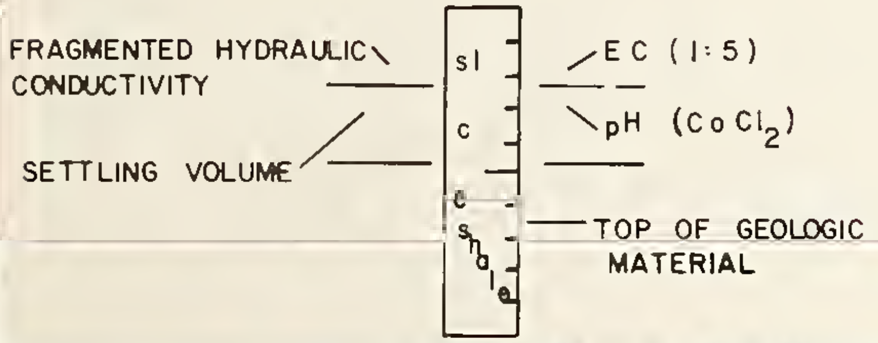


LAND SUITABILITY SYMBOLS



TWP. 4 SEC. 19 RANGE 86

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

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- a SODICITY
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- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- o NO DEFICIENCY
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

1500 750 0 1500

SCALE OF FEET

FOIDEL CREEK STUDY AREA
COLORADO

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DRAWN W.C LAUBNER — RECOMMENDED
CHECKED T. CAPPELLUCCI — APPROVED

LM REGION, DEN., COLO. | Figure C-3

NO. 15

CL
C
CL
L
Shale
SS

Location
SW 1/4 NW 1/4

15-20% Slope

Parent Material
Interbedded sandstone and shale 48+

NO. 1 Deep Hole #1

Location:
SW 1/4 NW 1/4

Remarks:
Laboratory results are given in Soils Appendix

NO.

NO.

NO. 16

.24 / 32	FSL	.05 / 6.2
.26 / 28	L	.03 / 6.1
.56 / 35	Ss	.03 / 6.1
	Ss	

Location:
NW 1/4 NE 1/4

Aspen and Oakbrush

Parent Material: Shale

Remarks: Unconsolidated SS (24-36")
Soft solid SS (36-60")

NO. 2 Deep Hole #2

Location:
SW 1/4 SE 1/4

Remarks:
Laboratory results are given in Soils Appendix

NO.

NO.

NO. 24

.18 / 25	FSL	.05 / 6.0
.28 / 25	L	.03 / 6.6
.62 / 27	SL & SS	.03 / 6.1
	Soft SS	

Location:
NW 1/4 NE 1/4

Aspen and Sage

Parent Material:
Sandstone

Remarks: SL and Ss fragments 24-40"

NO.

NO.

NO.

SOIL PROFILE KEY

FRAGMENTED HYDRAULIC CONDUCTIVITY — sl — EC (1:5)
SETTLING VOLUME — c — pH ($CaCl_2$)
c
shale — TOP OF GEOLOGIC MATERIAL

SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
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SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

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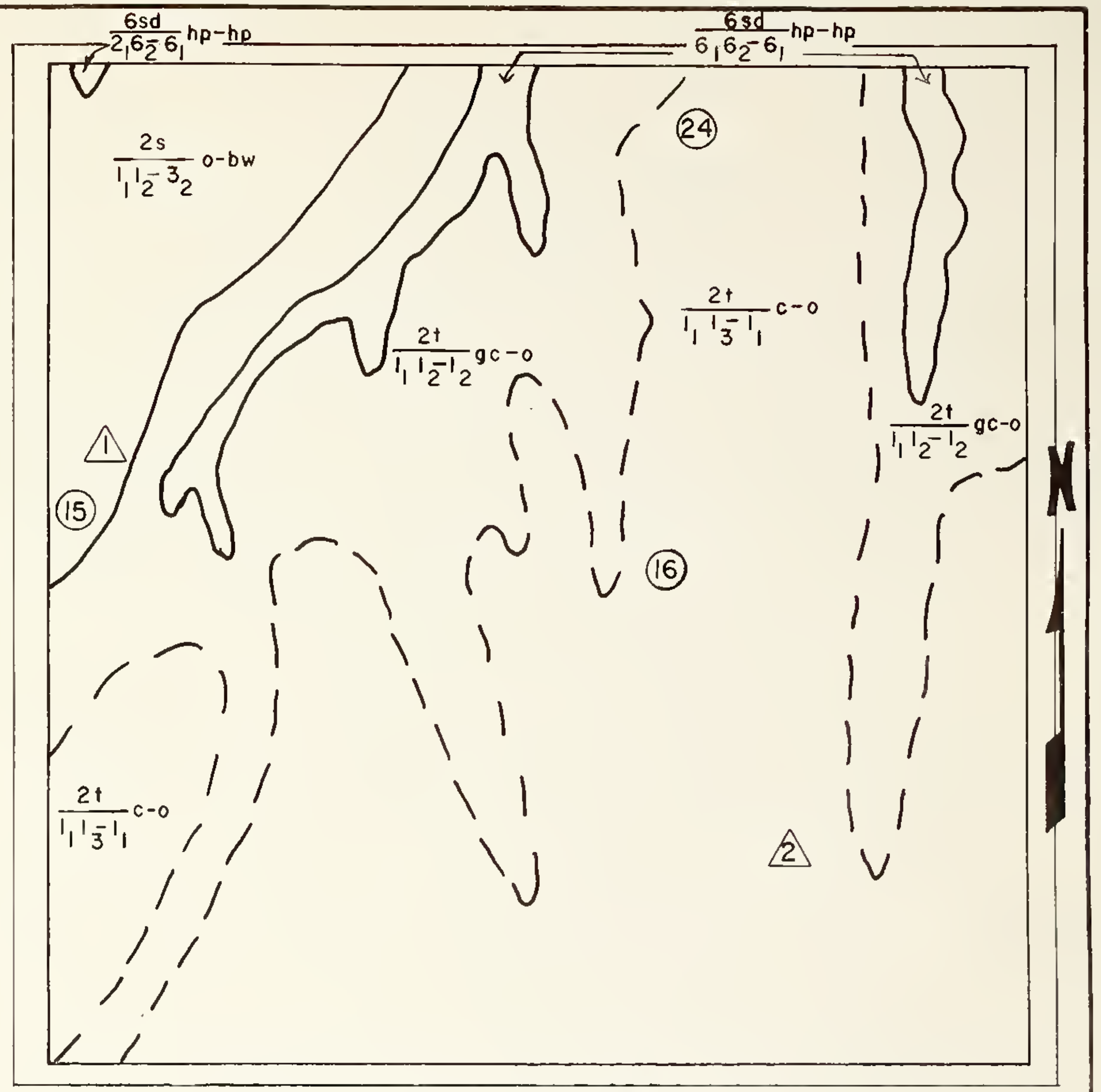
- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- o NO DEFICIENCY
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS



LAND SUITABILITY SYMBOLS

3 s t
3 6 — 6 a p g — h
2 4 4

- LAND SUITABILITY CLASS
- SOIL DEFICIENCY
- TOPOGRAPHIC DEFICIENCY
- DEFICIENCY OF SURFACE LAYER
- DEFICIENCY OF SECOND LAYER
- DEFICIENCY OF GEOLOGIC MATERIAL
- TOPOGRAPHIC DEFICIENCY
- SUITABILITY OF SURFACE LAYER
- THICKNESS IN FEET
- SUITABILITY OF SECOND LAYER EVALUATED
- THICKNESS IN FEET
- DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL
- THICKNESS OF SAMPLED GEOLOGIC MATERIAL
- SUITABILITY OF GEOLOGIC MATERIAL

TWP. 4 SEC. 24 RANGE 87

1000 0 1000
SCALE OF FEET

FOIDEL CREEK STUDY AREA
COLORADO

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LAND SUITABILITY

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DRAWN W.C. LAUBNER RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. Figure C-4

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

Lab Number	Site Number	Depth Inches	Hydraulic Conductivity Ins./hr. 6th Hr.	Hydraulic Conductivity Ins./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR	Saturation Extract Sat %	Saturation Extract Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	% of Moisture 15 Bars
S1	FCS-1-1	0-3	.62	.64	7.0	6.3	35			.13				.23	.38	2.54	.34	49.7	.13		.12	.10	46.0	.22		20.3
S2	2	3-7	1.30	9.28	7.0	6.1	45			.05				.38	.11	4.65	.07	57.1	.27		.10	.09	51.0	.18		17.5
S3	3	7-15	.30	.32	7.2	6.2	40			.04				.21	.13	2.67	.11	36.3	.10		.12	.11	58.0	.21		22.4
S4	4	15-32	.05	.06	7.4	6.5	40			.04				.48	.13	5.27	.08	50.9	.27		.14	.13	58.0	.22		16.0
S5	5	32-38	.30	.38	8.3	6.8	38			.12				.49	1.8	4.00	1.27	58.3	.23		.66	.56	49.0	1.14		14.7
S6	6	30+	.10	.09	7.8	7.3	38			.16				.36	.21	3.81	.15	40.4	.15		.70	.69	50.0	1.38		16.3
S7	FCS-2-1	2-0	.92	1.24	6.9	6.7	34			.09				.18	.19	1.92	.19	38.4	.08		.06	.05	48.0	.10		7.3
S8	2	0-8	.58	.60	6.9	6.5	30			.06				.52	.28	5.12	.18	58.3	.30		.06	.04	43.0	.09		20.5
S9	3	8-16	.42	.38	7.2	6.3	27			.06				.49	1.0	4.87	.64	53.2	.26		.06	.01	36.0	.03		11.9
S10	4	16-34	.54	.52	6.8	6.1	28			.04				.40	1.1	3.66	.78	54.0	.20		.10	.04	31.0	.13		11.8
S11	5	34-48	.42	.62	5.5	4.7	75			.03				.20	.43	2.20	.41	43.1	.09		.08	.06	30.0	.20		15.7
S12	6	48-60	.28	.16	5.6	4.3	85			.04				.28	.62	2.80	.52	42.5	.12		.08	.05	40.0	.13		11.4
S13	FCS-3-1	0-6	1.32	.50	6.7	5.8	29			.07				.38	1.1	3.16	.88	47.3	.15		.06	.01	39.0	.03		8.1
S14	2	6-10	1.28	.58	6.7	6.0	30			.06				.43	.50	5.12	.31	69.8	.36		.06	.03	41.0	.07		7.7
S15	3	10 14	1.32	.70	6.8	6.0	28			.05				.54	.09	5.95	.05	65.3	.39		.06	.05	32.0	.16		10.6
S16	4	14-20	2.76	.80	7.3	6.2	20			.03				.30	.09	3.47	.07	34.1	.12		.02	.01	24.0	.05		10.0
S17	FCS-4-1	0-9	2.46	1.84	6.7	6.0	30			.06				.25	.09	3.04	.07	35.4	.11		.04	.03	48.0	.08		14.3
S18	2	9-16	1.16	1.84	6.6	6.1	30			.05				.41	.15	4.85	.10	53.0	.26		.06	.05	44.0	.11		20.0
S19	FCS-4-3	16-22	2.82	1.20	6.6	6.1	31			.05				.43	.15	5.16	.09	48.9	.25		.04	.03	40.0	.08		13.5
S20	4	22-30	.84	1.36	7.0	6.1	31			.03				.33	.08	3.63	.06	37.4	.14		.06	.05	25.0	.24		10.4
S21	FCS-13-1	0-12	.32	.34	7.2	6.5	35			.05				.27	.05	3.29	.04	50.1	.16		.06	.05	36.0	.17		16.4
S22	2	12-30	.44	1.06	7.1	6.7	55			.03				.25	.33	3.00	.27	53.6	.16		.06	.04	46.0	.09		24.6
S23	3	30-40	.16	.20	7.9	7.0	65			.07				.42	.29	5.20	.18	60.2	.31		.06	.04	48.0	.08		20.3
S24	FCS-16-1	0-14	.26	.24	7.0	6.2	32			.05				.47	.08	5.32	.05	49.6	.26		.04	.03	34.0	.12		10.4
S25	2	14-24	.32	.26	7.0	6.1	28			.03				.33	.08	3.98	.06	34.9	.14		.04	.03	18.0	.22		5.7
S26	3	24-36	.54	.56	6.4	6.1	35			.03				.27	.11	3.13	.09	33.9	.11		.04	.03	14.0	.29		7.7
S27	FCS-17-1	0-10	.20	.12	6.6	6.3	50			.07				.39	.13	5.52	.08	64.3	.35		.04	.03	51.0	.06		21.4
S28	2	10-30	.18	.18	6.8	6.3	55			.04				.26	.30	3.60	.22	57.6	.21		.14	.12	51.0	.24		23.4
S29	3	30-48	.24	.28	8.1	6.8	60			.10				.39	.45	4.88	.29	58.8	.29		.04	.01	50.0	.02		20.3
S30	FCS-19-1	0-14	.60	.40	6.8	6.2	25			.04				.47	.10	5.88	.06	44.2	.26		.14	.13	30.0	.47		8.9
S31	2	14-30	.40	.32	7.4	6.3	25			.03				.35	.09	4.38	.06	37.1	.16		.04	.03	22.0	.18		5.7
S32	3	30-48	.34	.36	7.4	6.6	33			.05				.52	.15	6.51	.08	39.2	.26		.04	.03	14.0	.21		7.1
S33	FCS-20-1	0-18	1.12	1.40	7.0	6.1	27			.06				.48	.08	5.38	.05	45.2	.24		.04	.03	32.0	.13		9.2
S34	2	18-40	.92	1.02	6.8	5.8	26			.04				.41	.20	4.38	.13	30.9	.14		.04	.03	15.0	.20		7.1
S35	3	40-60	1.08	1.03	6.7	5.6	34			.03				.23	.20	2.82	.17	38.9	.11		.06	.05	26.0	.19		12.4
S36	FCS-21-1	0-14	.34	.28	7.0	6.0	32			.05				.36	.19	3.63	.14	51.7	.19		.14	.13	42.0	.31		16.0
S37	FCS-21-2	14-36	.52	.68	7.2	6.5	33			.06				.43	.99	3.91	.71	52.5	.21		.16	.11	38.0	.29		10.6
S38	3	36 50	.44	.60	7.2	6.6	30			.05				.38	1.1	3.44	.84	46.5	.16		.16	.11	32.0	.34		9.7
S39	4	50-60	.13	.13	7.4	6.8	38			.06				.36	1.0	2.97	.84	43.4	.13		.18	.14	34.0	.41		9.7
S40	FCS-23-1	0-12	.12	.07	6.9	6.0	55			.06				.60	.25	7.60	.13	70.9	.54		.06	.04	58.0	.07		16.2
S41	2	12-30	.20	.16	7.2	6.4	35			.06				.40	.45	4.63	.30	70.6	.33		.20	.17	74.0	.23		17.8
S42	3	30-60	.16	.12	7.3	6.6	40			.11				.80	2.5	7.12	1.33	66.9	.48		.54	.37	52.0	.71		19.2
S43	FCS-24-1	0-12	.20	.18	7.0	6.0	25			.05				.42	.08	4.63	.05	44.4	.21		.04	.03	38.0	.11		7.1
S44	2	12-24	.32	.28	7.1	6.6	25			.03				.24	.06	2.82	.05	33.2	.09		.06	.05	16.0	.38		6.2
S45	3		.50	.62	7.2	6.1	27			.03				.21	.07	2.25	.07	34.7	.08		.04	.03	16.0	.25		6.5

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr.		pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract				Saturation Extract						Gyp Me 100g	Na Me/100g		Cation Exchange Capacity	ESP %	% of Moisture	
			6th Hr.	24th Hr.						ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g		Total Na	Exch. Na				15 Bars
46	FC-1-1	0-10	.20	.32	8.1	7.2	45			.31											.70		36.0			13.0
47	2	10-18	.20	.26	8.2	7.5	48			.43				3.0	7.5	36.3	1.78	48.3	1.75		.76	.40	37.0	1.1		10.7
48	3	18-23	.16	.13	7.9	7.3	58			1.02				4.7	8.2	70.2	1.38	54.0	3.79		.76	.32	45.0	.71		15.6
49	4	23-28	.09	.12		7.4	50			1.88				8.0	27.0	112	3.59	55.0	6.16		2.66	1.17	38.0	3.1		14.6
50	5	28-33	.88	1.36		7.4	45			2.51				10.0	42.4	164	4.68	53.6	8.79		3.62	1.35	40.0	3.4		14.1
51	6	33-38	.11	.14		6.9	48			2.64				10.0	36.0	172	3.88	57.1	9.82		3.26	1.20	43.0	2.8		14.9
52	7	38-44.3	.10	.10		7.1	50			1.99				7.7	19.5	127	2.45	57.6	7.32		1.76	.64	30.0	2.1		16.3
53	FC-1-8	44.3-51.2	.10	.16		7.2	48			1.88				7.0	32.4	98.0	4.63	54.9	5.38		2.82	1.04	43.0	2.42		17.1
54	9	51.2-57	.04	.04	8.4	7.6	38			1.04				6.5	59.6	26.6	16.3	45.1	1.20		8.40	5.71	37.0	15.4		12.7
55	10	57-63			9.1	7.8	38			.58				3.7	37.6	8.00	18.8	43.6	.35		8.80	7.16	34.0	21.1		13.6
56	11	63-70.1			8.9	7.9	35			.51				4.3	38.0	12.0	15.5	39.8	.48		7.10	5.59	30.0	18.6		13.9
57	12	70.1-75	.03	.02	8.8	7.8	34			.49				3.7	30.0	10.6	13.0	36.4	.39		6.30	5.21	27.0	19.3		12.2
58	13	75-80.1	.15	.07	8.6	7.8	35			.51				3.8	30.0	10.9	12.9	36.1	.39		6.00	4.92	34.0	14.5		16.5
59	14	80.1-85.6			8.3	7.6	24			.34				3.3	25.0	14.6	9.25	26.1	.38		1.44	.79	7.8	10.1		3.7
60	15	85.6-90	.30	.50	8.0	7.5	25			.37											.80		8.0			5.2
61	16	90-94.1	.18	.12	7.8	7.3	28			.22											.96		18.6			7.2
62	17	94.1-100	.41	.26	8.0	7.4	27			.19				1.33	6.7	12.8	2.65	27.4	.35		.36	3.42	15.0	2.3		8.6
63	18	100-106	.51	.46	7.8	7.4				.23											.22		15.6			5.3
64	19	106-113.5	.58	.80	7.9	7.4	25			.27											.16		8.8			3.3
65	20	113.5-122.5	.28	.40	7.5	7.2	26			.40				3.1	1.3	48.8	.26	29.9	1.46		.12	.08	5.6	1.4		0.7
66	21	122.5-129	.86	.54		7.1	25			.47				3.2	.85	48.8	.17	30.5	1.49		.10	.07	1.8	.39		0.9
67	22	129-135	.36	.52	7.5	7.3	20			.36											.14		6.6			3.7
68	23	135-141.1	.80	.82	7.8	7.4	33			.30											.16		7.4			3.1
69	24	141.1-145.6	.44	.40	9.0	8.0	30			.13				.82	.50	9.64	.23	26.2	.25		.14	.13	8.1	1.1		4.8
70	25	145.6-154.5	.36	.32	8.4	7.6	20			.19											.14		9.0			4.9
71	26	154.5-162.1	.28	.20	8.0	7.0	25			.14											.12		7.6			4.9
72	27	162.9-171.9	.26	.30	8.2	7.3	24			.19											.16		8.6			3.8
73	28	171.9-180.9	.24	.30	8.2	7.4	24			.19											.10		8.0			4.8
74	29	180.9-182.4	.94	1.00	8.0	7.3	28			.24											.26		19.0			4.2
75	30	191.2-195.6	3.18	.62	8.0	7.3	29			.13											.12		4.4			3.7
76	31	198.8-202.3	.22	.20	8.5	7.6	25			.17											.16		12.8			6.5
77	32	202.3-205.9	.11	.20	8.4	7.6	28			.20											.16		4.8			4.9
78	33	205.9-211.3	.84	1.50	8.3	7.6	26			.19											.24		12.0			8.7
79	34	211.3-216	.78	.72	8.3	7.7	28			.20											.22		22.0			6.4
80	35	216-221	.80	.60	8.0	7.5	27			.30											.16		21.0			5.6
81	36	221-229	.02	0.80		6.8	21			.36				2.9	.92	44.2	.19	27.7	1.22		.12	.09	3.0	3.0		1.3
82	37	229-237	.98	.64	7.2	7.0	20			.26											.10		2.6			1.6
83	38	237-244.5	.72	1.30	6.9	6.7	22			.38				3.0	1.3	53.5	.25	27.4	1.47		.10	.06	5.8	1.03		2.4
84	39	245.5-253.9	.20	.10	7.5	7.2	20			.18											.30		10.0			3.8
85	40	255.7-263	5.46	.66	6.1	4.8	20			.24											.06		.10			0.1
86	41	263-271.6	.74	1.20	5.1	4.5	23			.33				3.0	.70	33.0	.17	29.1	.96		.06	.04	2.0	2.0		1.2
87	42	272.1-273.8	.66	.50	7.0	6.8	24			.26											.16		12.0			3.3
88	43	273.8-280	.32	.20	7.5	7.1	23			.18											.24		6.4			3.8
89	44	280-285.3	.80	.50	7.9	7.3	20			.16											.14		4.0			1.9
90	45	285.3-292	1.20	1.40	7.8	7.2	28			.28											.26		12.6			7.6
91	46	292-297.9	3.88	.84	7.9	7.2	28			.21											.20		18.0			4.1
92	47	297.9-303	.70	.50	8.0	7.6	22			.16											.14		6.4			3.6
93	48	303-309.8	.92	.40	8.3	7.5	24			.16											.22		4.0			2.5
94	49	309.8-317	1.08	.60	8.2	7.4	25			.19											.16		14.0			4.4
95	50	317-322.5	.74	.70	8.0	7.3	28			.16											.30		20.0			5.7
96	51	322.5-326.	.80	1.40	7.8	7.3	25			.24											.28		19.2			4.3
97	52	326.8-333.	.16	.30	7.4	6.9	23			.27											.12		6.0			3.1
98	53	334.3-342	.24	.20	8.1	7.5	24			.19				1.3	1.95	10.9	.84	27.4	.30		.14	.09	3.2	2.8		2.1
99	54	342-350.2	.32	.20	8.4	7.6	24			.19											.16		4.0			2.8
100	55	370.5-375.6	.28	.20	7.6	7.1	22			.18											.14		2.6			1.5
101	56	375.6-380	.52	.60		6.1	23			.24											.16		2.2			2.0
102	57	380-384.8	.44	.60		5.7	24			.30				2.7	1.55	31.1	.39	31.9	.99		.14	.09	9.8	.92		3.6
103	58	384.8-393	.12	.04		7.0	26			.10											.24		3.8			2.7
104	59	393-399	.36	.16	7.7	7.2	25			.12											.28		3.8			2.1
105	60	399-405.2	.76	.22	7.4	7.2	25			.14											.26		3.6			2.7
106	61	405.2-408	.40	.48	7.2	7.0	28			.32				3.0	16.3	27.1	4.4	34.7	.94		1.24	.67	16.0	4.2		8.1
107	62	408.6-415	3.68	.68		7.1	18			.04											.08		3.1			2.2
108	63	415-422	4.30	.21		7.2	20			.05											.10		3.0			1.9

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Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	Hydraulic Conductivity Ins./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR	Saturation Extract Sat %	Saturation Extract Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	% of Moisture 15 Bars
109	FC-2-1	0-5	1.02	1.06		7.3	38			.72											.74		24.0			16.2
110	2	5-13.6	.12	.08		7.4	53			.19											.22		27.0			17.0
111	3	13.6-20.4	.34	.38	7.7	7.0	28			.19											.18		12.0			6.9
112	4	20.4-23.4	.40	.42	7.5	7.1	38			.28											.16		19.0			11.5
113	5	32.2-37.0	.26	1.98	7.4	6.9	27			.15											.04		7.4			3.1
114	6	39.4-43.8	.60	.40	7.2	6.7	31			.26											.04		13.6			6.3
115	7	43.8-50	.44	.40	7.8	7.3	24			.16											.14		12.0			4.4
116	8	50-56.4	.34	.60	8.0	7.4	25			.18											.16		17.2			6.0
117	9	56.4-61	.64	.56	8.1	7.4	30			.21											.12		14.4			9.4
118	10	61-66.4	1.76	.54		7.3	28			.30				2.7	.75	44.2	.16	32.4	1.43		.04	.02	11.4	.18		8.5
119	11	66.4-73.7	.68	.64	7.7	7.0	22			.25											.04		6.6			3.8
120	12	73.7-80	.76	.68	7.5	7.0	22			.12											.04		3.1			2.0
121	13	80-86.8	.38	.24		6.6	24			.28											.04		4.4			3.4
122	14	86.8-91.3	.28	.22	7.1	6.8	25			.13											.06		12.4			6.8
123	15	91.3-100.4	.48	.38	7.4	7.2	24			.13											.04		2.9			1.2
124	16	102-110	.98	.16	7.3	7.0	23			.10											.04		2.5			1.8
125	17	110-117.6	.97	.36	6.0	5.3	23			.27				2.3	.55	28.6	.15	33.1	.95		.04	.02	1.9	1.9		1.9
126	18	117.6-123.7	.70	.62		6.3	22			.21											.04		3.7			1.2
127	19	123.7-130	.48	.52	7.3	6.9	25			.19											.06		6.0			3.3
128	20	130-135.3	.69	.60	7.6	7.2	23			.17											.16		6.8			4.3
129	21	135.3-141.3	.68	.76	7.9.	7.4	26			.19											.10		14.4			5.3
130	22	141.3-150.2	1.66	1.06	8.4	7.7	22			.09											.04		3.6			1.4
131	23	150.2-153.7			8.5	7.3	22			.15											.10		5.4			3.7
132	24	153.7-160.3	.34	.16	8.3	7.4	26			.18											.12		9.0			4.0
133	25	160.3-168	1.19	.76	7.8	7.3	30			.15											.12		14.8			8.8
134	26	168-176.1	1.58	.80	7.8	7.3	28			.18											.08		13.4			6.1
135	27	176.1-180	.43	.36		7.2	24			.23											.04		3.0			4.9
136	28	182.4-189	.58	.28	7.8	7.6	22			.20											.06		9.9			4.7
137	29	189-195.8	.30	.14	8.0	7.6	23			.23											.06		7.2			5.4
138	30	214.1-221	.32	.28	7.7	7.2	24			.20											.06		2.6			1.0
139	31	221-228.8	.38	.50	7.0	6.6	24			.23											.04		7.6			4.7
140	32	228.8-233.7	1.94	.66	7.7	7.5	28			.16											.22		14.6			9.0
141	33	233.7-239.4	.70	.50	7.2	7.0	28			.14											.16		15.4			11.2
142	34	239.4-244.9	.94	.44	7.3	7.1	29			.15											.12		13.7			6.3
143	35	244.9-246.4	1.26	.60	5.9	5.6	22			.13											.08		6.8			3.0
144	36	247.2-255.0	2.76	.42	6.6	6.5	25			.09				1.3	1.15	20.2	.36	32.8	.66		.05	.01	7.6	.19		4.6
145	37	255-263.1	3.50	.66	8.0	7.2	24			.10				.56	.89	9.33	.41	33.9	.32		.14	.11	8.4	1.3		3.5
146	FC-3-1	0-3	1.02	.60	7.1	6.3	30			.11											.12		45.8			23.0
147	2	3-7	.14	.26	6.7	6.8	45			1.53				4.1	12.5	58.5	2.31	59.7	3.49		1.18	.43	47.0	.91		16.8
148	3	7-10	.10	.12	7.3	7.1	42			.23											.18		28.8			14.3
149	4	10-15	.02	.22	7.6	7.2	45			.24											.58		54.0			19.5
150	5	15-18	.94	.62	7.8	7.1	35			.09											.12		14.2			5.6
151	6	18-25	2.14	.64		6.6	23			.34				3.0	1.6	43.5	.34	28.3	1.23		.06	.01	7.2	.28		3.8
152	7	25-32.4	1.08	.54		6.3	24			.55				3.6	2.5	55.1	.48	28.6	1.58		.14	.07	11.0	.32		4.4
153	8	38.3-45				7.0	25			.21											.04		6.8			3.4
154	9	45-52	.74	.70		7.0	24			.27											.04		7.0			4.0
155	10	52-60	.42	.64	7.3	7.1	25			.31				2.5	2.0	31.6	.50	34.5	1.09		.08	.01	2.6	.38		0.4
156	11	60-68	.34	.24	7.8	7.3	27			.21											.12		4.5			3.8
157	12	68-76.9	.26	.14	8.1	7.5	20			.20											.20		7.4			6.9
158	13	76.9-79.9	.52	.64	8.1	7.6	22			.25											.26		25.0			9.3
159	14	79.9-85	.28	.18	7.9	7.3	25			.12											.10		7.0			4.5
160	15	85-89.9	.24	.14	8.1	7.4	23			.15											.12		5.8			4.0
161	16	90.5-91.5	4.00	2.40	6.9	6.9	27			.12											.30		30.0			8.2
162	17	92.3-95.3	.42	.60	7.1	6.9	26			.14											.20		18.8			7.6
163	18	95.3-104.7	.22	.26	7.6	7.2	24			.17											.18		15.6			8.2
164	19	104.7-106.7	.84	.68	7.7	7.3	27			.17											.08		16.4			8.0
165	20	117.8-119.9	.24	.34	7.8	7.3	25			.14											.08		15.0			6.6
166	21	121.9-124.3	.20	.14	8.1	7.3	24			.19											.12		11.4			5.9
167	22	124.3-131	.16	.20	8.1	7.6	23			.16											.16		3.6			0.4
168	23	131-137	.44	.16	7.9	7.5	25			.19											.30		14.4			8.1
169	24	137-145	1.12	1.18	8.3	7.5	23			.23											.26		25.8			8.4
170	25	145-153	.30	.18	8.2	7.3	24			.17											.08		7.5			3.7
171	26	153-158	.68	.48	8.0	7.1	23			.18											.06		13.2			6.2

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
172	27	158-164.5	.52	.28	7.5	6.9	23			.20											.06		8.8			4.8
173	28	164.5-169.9	.20	.20	8.0	7.2	22			.16											.08		14.5			4.8
174	29	169.9-173.5	.24	.14	8.5	7.3	26			.17											.16		12.0			4.0
175	30	173.5-180.1	.14	.10	8.0	7.5	25			.14											.06		6.8			5.9
176	31	180.9-186	.76	.66		7.4	22			.20											.10		6.0			6.2
177	32	186-192.9	.90	.54		7.0	22			.33				2.9	1.9	42.9	.41	30.8	1.32		.10	.04	4.4	1.8		2.9
178	33	192.9-197.4	.26	.34	7.2	7.0	23			.37				3.3	3.5	47.7	.72	30.0	1.43		.12	.01	14.6			8.5
179	34	197.4-200.6	.64	.40	8.4	7.5	21			.12											.14		4.6			4.1
180	FC-4-1	0-1.8				6.4	26														.10		24.2			11.6
181	2	1.8-10.3	.40	.76	6.0	5.2	34			.05											.10		47.0			12.5
182	3	10.3-15	.68	.70	6.1	6.0	22			.13											.04		4.1			3.9
183	4	15-21	3.58	.66	6.5	6.5	22			.06											.04		2.2			1.8
184	5	21-26	1.38	.48	7.2	6.8	24			.11											.06		5.8			3.8
185	6	26-31	.90	.50	7.4	7.0	26			.13											.06		3.6			2.0
186	7	31-36	1.50	.66	7.3	7.1	22			.13											.06		6.4			4.9
187	8	36-41	.68	.38	7.5	7.2	22			.22											.12		8.4			3.8
188	9	41-46	.54	.48	7.8	7.2	23			.22											.06		6.6			4.5
189	10	46-49.9	.24	.16	8.0	7.3	25			.19											.10		13.2			7.9
190	11	49.9-51.2	1.06	.96	7.8	7.4	27			.24											.08		21.0			8.4
191	12	51.2-55.4	1.82	.34	8.7	7.4	22			.13											.10		6.0			3.5
192	13	55.4-60.4	2.28	1.00	8.5	7.4	24			.14											.12		9.4			4.5
193	14	60.4-65	4.98	1.04	8.6	7.4	23			.14											.12		7.7			4.1
194	15	65-71.4	2.60	.74	8.1	7.2	26			.23											.10		19.2			8.2
195	16	71.8-74.1	.26	.46	8.0	7.4	30			.13											.12		24.8			14.6
196	17	74.1-80.4	.14	.26	8.1	7.5	23			.12											.06		7.8			5.6
197	18	80.4-86.9	.16	.28	8.3	7.5	24			.12											.06		5.2			3.2
198	19	86.9-88.3	1.86	.24	8.1	7.5	26			.14											.06		8.0			7.8
199	20	99.6-105	.38	.36	7.9	7.6	22			.12											.14		6.0			4.0
200	21	105-110.4	.26	.20	8.6	7.7	23			.15											.16		2.4			2.3
201	22	110.4-114.7	1.64	1.66	7.4	6.9	23			.14											.24		6.8			6.5
202	23	114.7-120.4	.30	.24	8.0	7.4	24			.16											.22		19.6			3.8
203	24	120.4-130.4	.52	.72	7.8	7.3	25			.20											.12		22.2			5.2
204	25	130.4-135.6	.38	.28	8.1	7.3	24			.13											.04		8.2			3 7
205	26	135.6-142.2	.34	.22	7.5	7.2	25			.21											.04		5.2			5 0
206	27	142.2-147	.74	.66	7.8	7.3	22			.14											.06		3.6			3 4
207	28	147-152.9	.36	.38	8.0	7.5	22			.15											.06		6.2			6.9
208	29	152.9-160.5	.26	.06	8.1	7.5	22			.16											.04		3.4			3.5
209	30	161.9-162.2	.32	.18	8.0	7.3	23			.13											.04		6.5			3.9
210	31	162.2-167	.42	.16	8.2	7.4	21			.18											.08		4.0			4.1
211	32	167-172.9	.64	.14	7.7	7.1	22			.33											.02		4.2			3.8
212	FC-5-1	1-2	.92	1.32	7.9	7.2	44			.16											.12		51.0			15.8
213	2	2-4.2	3.90	2.24	8.7	7.5	44			.14											.52		42.0			16.7
214	3	4.2-6	.52	.66	7.6	7.4	44			1.13				4.1	21.0	53.2	4.07	54.7	2.91		1.2	.05	33.6			17.0
215	4	6-8.2	1.92	1.02	7.4	7.4	42			1.43				4.3	16.0	64.2	2.82	50.8	3.26		.82	.01	37.6			9.8
216	5	8.2-12.5	.58	.66	7.6	7.3	48			.75				4.1	6.5	64.2	1.15	52.0	3.34		.46	.12	34.0	.35		12 9
217	6	12.5-18.5	1.50	.64	7.5	7.2	38			1.06				3.4	3.0	58.5	.55	36.7	2.15		.12	.01	12.0			8.1
218	7	18.5-23	1.62	.62	7.2	6.6	25			.42				3.1	1.2	45.8	.25	29.7	1.36		.16	.12	5.4	2.2		3.2
219	8	23-29.5	.48	.56	7.1	6.9	27			.36				2.9	1.2	43.8	.26	29.4	1.29		.08	.04	6.9	.58		4.5
220	9	32.5-35.8	.24	.08	7.3	6.8	28			.21											.06		13.6			5.1
221	10	35.8-39	.38	.46	7.5	7.2	22			.11											.06		2.1			1.8
222	11	39-43	.34	.30	7.8	7.4	24			.13											.08		4.2			3.6
223	12	43-48	.24	.26	8.0	7.6	24			.12											.08		3.7			3.2
224	13	48-53	1.78	1.16	8.4	7.7	23			.09											.08		3.6			3.3
225	14	53-56.4	1.60	.80	8.4	7.6	22			.08											.12		5.5			5.2
226	15	56.4-63	.58	.44	8.5	7.7	23			.11											.10		5.8			3.6
227	16	63-68	.64	.28	8.2	7.7	24			.11											.08		5.2			3.6
228	17	68-73	2.34	.88	8.6	7.6	23			.09											.08		2.6			1.0
229	18	73-78	1.36	1.18	8.2	7.6	23			.13											.06		5.6			3.5
230	19	78-83	1.28	.80	8.3	7.4	24			.19											.08		6.6			5.9
231	20	83-88	1.26	.82	8.5	7.6	22			.13											.12		1.2			1.3
232	21	88-93	1.46	.66	8.5	7.7	23			.40				.99	.04	11.1	.02	36.6	.41		.06	.05	4.6	1 3		2.9
233	22	93-95	.62	.82	8.1	7.5	22			.23				1.8	.09	24.1	.02	35.8	.86		.10	.09	9.6	1.0		3.7
234	23	95-103	.16	.08	8.3	7.7	31			.15											.18		15.4			7.5
235	24	103-111	.28	.20	8.3	7.6	45			.17											.16		7.2			7.0

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By

William B. Peters, Luvern L. Resler, and Robert Vader 1/

Sil is characterized by laboratory methods to confirm judgment in field araisals. There is a tendency among most laboratory activities to "ver test"; i.e., perform too many or unnecessary tests on certain sils at the expense of not performing essential or critical testing on pticular samples. Also, laboratory activities tend to emphasize comphensive analyses of samples from master sites and neglect selection, squence, and quality control in mass testing performed on a screenable bsis. The latter-type testing is frequently handled as routine work ulizing the least dependable personnel and considered not worthy of cmpetent and close supervision. Thus, too often the screenable labor:ory testing becomes a liability rather than an asset in supporting lnd classification surveys. Because the screenable testing represents cverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it sould be administered for performance with respect to both quality and qntity commensurate with the goals and objectives of the investigation.

T: objective of characterizing soil and overburden will be to support jgment in estimating land reclamation potential. (Overburden refers t the material consolidated or unconsolidated overlying minable resources i relation to surface mining.) Thus, the laboratory analyses must be pformed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of t: soil and overburden be appraised in relation to edaphology; i.e., amedium suitable for the support of plant growth, rather than pedology.

B:ause the laboratory studies should serve to support field appraisals, al laboratory work should be closely coordinated with fieldwork. For fll effectiveness, laboratory studies must be preceded by field studies. T: number and type of studies will be determined by area conditions - p:ticularly variability, the controlling project specifications, and neds. There should be a joint plan between field and laboratory invest:ations prior to taking of samples if maximum utilization of data is

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to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

eenable testing, the characterization for moisture retentivity at ires less than 15 bars is not recommended unless a suitable use can ablished. Measurements of moisture retentivity at 15-bars pressure commended because water content at this potential is usually cor-d with several characteristics including amount and kind of clay, e area, and cation exchange capacity. Moisture percentages at otential would probably not be applicable in simulating water t at wilting for native vegetation.

tial screening, diluted soil-water suspensions may be substituted e time-consuming, saturated soil extracts in measuring electrical tance provided limitations are ascertained. The reliability of moisture contents even as a tool in screening depends on the kind ts present. For chloride salts, the results will be only slightly ed by the moisture content, but if sulfate or carbonate salts, have relatively low solubility, are present in appreciable quan-, the apparent amount of soluble salt will depend on the soil-water [Richards, 1954].

not concur in the practice of characterizing vast numbers of sam- or textural class through measurements of particle-size distribu- This blanket laboratory analysis for soil textural class is r required nor desired. Particle-size analysis should be limited ter site characterization, the occasional confirmation of field al appraisals, and the training of new employees.

screenable characterization of samples, a procedure for the ce of testing and screening of samples should encompass the fol- phases. Under Phase I of the scheme, all samples would be char-zed for (1) soil structure stability through measurement of lic conductivity on a fragmented sample basis during the 6th and ours and volume of wet settled floccules, (2) moisture retentivity bars pressure, (3) electrical conductivity of soil-water extract,) pH in water and in 0.01 molar calcium chloride solution.

second phase, <u>selected</u> samples suspected through the testing s of Phase 1 to be salt affected should be characterized for ical conductivity of the saturation extract and sodium adsorption

third phase, <u>selected</u> samples suspected through the testing s of Phases I and II to be salt affected with respect to sodium tested for either gypsum requirement or residual gypsum, depend- salinity levels and associated pH values. Residual gypsum will imated by measuring calcium plus magnesium in a 1:5 soil-water xtract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calciu plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for solubl aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Carbonate and bicarbonate were determined in saturation extract by titration with a weak acid solution and chloride was determined in saturation extract by Mohr volumetric method (Bower, C. A. and L. V. Wilcox, 1965. Soluble Salts. In C. A. Black, et al., Methods of Soil Analysis, Agronomy No. 9, American Society of Agronomy, 62-1.3.2.1, 62-3.4.2, and 62-3.5.2).

Cation-exchange capacity was measured at pH 8.2 by sodium saturation, washing with isopropyl alcohol, and extraction with ammonium acetate (Chapman, H. D., 1965. Cation Exchange Capacity. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 57-3).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Handbook No. 60, 22c:104).

Hydraulic conductivity was measured on fragmented samples in plastic permeameters of 1-inch inside diameter under conditions of 2:1 constant head (USDI Bureau of Reclamation Instructions, 517.7.3).

Soil pH in 1:5 soil-water ratio suspension was measured by glass electrode and transistor voltmeter (Peech, Michael, 1965. Soil pH by Glass Electrode pH Meter. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 60-3.4.

Neutral salt exchange acidity and exchangeable aluminum were determined by extraction with 1N KCl and double titration with strong base and strong acid, respectively (McLean, E. O., 1965. Aluminum. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 67-3.2, 67-3.5).

Particle-size analysis was by the sieve and pipette method without removal of organic matter and insoluble carbonates using sodium metaphosphate for attaining dispersion (Day, Paul R., 1965. Particle Fractionation and Particle-Size Analysis. In C. A. Black, et al., Methods of Soil Analysis, Part 1, Agronomy No. 9, American Society of Agronomy, 43-4.3.1, 43-4.3.3, 43-4.3.5, and 43-4.3.6).

Soil pH in 1:2 soil 0.01M $CaCl_2$ solution ratio was measured by glass electrode and transistor voltmeter (Peech, Michael, 1965. Soil pH by Glass Electrode pH Meters. In C. A. Black, et al., Methods of Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 60-3.5).

Soluble salts were estimated by measuring electrical conductivity of saturation extract (Bower, C. A. and L. V. Wilcox, 1965. Soluble Salts. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 62-1.3.2.1 and 62-2.2).

Water retentivity of soil was measured at 15 bars pressure using ceramic plate or plastic membrane (Richards, L. A., 1965. Physical Condition of Water in Soil. In C. A. Black, et al., Methods of Soil Analysis, Part 1, Agronomy No. 9, American Society of Agronomy, 8-2.3).

PROGRESS REPORT

Results of Weathering Tests Conducted on Core Samples from Coal-mined Areas

Objectives

Laboratory weathering tests were conducted on overburden core samples from Foidel Creek, Colorado, to determine which materials would break down sufficiently to allow for their possible use as a planting media in revegetation of strip-mined areas.

The number of core samples tested under each condition is as follows:

Test condition	Number of samples tested
Freeze-thaw	12
Wet-dry	12
Outdoor	7

Results of laboratory weathering tests conducted on core samples from other sites were reported previously in Applied Science Referral Memorandums No. 75-1-2, dated March 28, 1975, and 76-1-7, dated May 7, 1976.

Test Procedures

Specimens for the freeze-thaw, wet-dry, and outdoor tests were cut from core samples submitted by regional personnel.

The purpose of including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and the freeze-thaw and wet-dry conditions.

A freeze-thaw cycle consisted of the following conditions:

1. 8 hours at 23.9°C (75°F), 100 percent relative humidity (wetting/thawing)

2. 16 hours (64 hours on weekend) at -17.8°C (0°F) (freezing)

For the wet-dry tests, one cycle consisted of:

1. 8 hours at 23.9°C (75°F), 100 percent relative humidity (wetting)

2. 16 hours (64 hours on weekends) at 37.8°C (100°F), 10 percent relative humidity (drying)

For testing and handling the core specimens, about 5 cm (2 inches) in diameter by 5 cm (2 inches) in length, were placed on a No. 10 mesh screen in 400-ml plastic beakers.

Tests were started on April 23, 1976, and 30 laboratory weathering cycles were completed on June 8, 1976. For the outdoor exposure specimens, 7 weeks of testing were completed on June 10, 1976. During this 7-week period, the specimens were subjected to approximately 5 cm (2 inches) of precipitation. Because of the mild weather, no freeze-thaw cycles occurred during this period. The outdoor specimens will continue to be monitored, and a subsequent memorandum report will be prepared summarizing the results.

Test Results

The test specimens were visually examined about once a week to monitor changes, and the results of these examinations are summarized in table FC-1.

At the completion of the 30 weathering cycles, a percent breakdown value (%BD) was determined for a number of the specimens. This value listed under the remarks column in the table was derived as follows:

$$\%BD = \frac{TW-IW}{TW} = 100$$

Where

TW = Total specimen weight
IW = Weight of original specimen remaining intact after testing

Also, to provide a visual record of the tests, photographs, both black/white and 35-mm color slides were taken of several samples exhibiting the greatest breakdown. These results are shown in figures FC-1 through FC-3.

Based on the results of these tests, the following samples appeared to have broken down sufficiently for possible use as a planting media: shale, FC-1-11, depth 63.0 to 70.1 feet; shale, FC-1-46, depth 292.0 to 297.9 feet; and siltstone, FC-4-13, depth 55.4 to 60.4 feet.

Five sandstone samples exhibited little or no breakdown at all. These included FC-1-37, depth 29.0 to 237.0 feet; FC-1-54, depth 342.0 to 350.2 feet; FC-1-63, depth 415.0 to 422.0 feet; FC-2-22, depth 141.3 to 150.2 feet; and FC-3-18, depth 95.3 to 104.7 feet.

It should be noted that the use of a diamond saw was required to cut the test specimens from the submitted core samples and is indicative of their original condition.

A dry gradation analysis was obtained on several specimens and the results are listed in table FC-2.

Acknowledgement

Laboratory photographic work by W. M. Batts.

Table FC-1

WEATHERING TESTS
Core Samples from Foidel Creek, Colorado

Sample I.D.	Remarks
Shale FC-1-11 * Depth (ft) 63.0-70.1 (FC-1) **	(See figure FC-1) Freeze-thaw: Slight slaking at 3 cycles, slaking at 6 cycles, continued slaking at 30 cycles. %BD = 100. Wet-dry: Slaking at 3 cycles, continued slaking at 30 cycles. %BD = 100. Outdoor: No sample.
Sandstone FC-1-20 Depth (ft) 113.5-122.5 (FC-2)	Freeze-thaw: Sample broke into three pieces at 30 cycles. Wet-dry: No change at 30 cycles. Outdoor: No change at 7 weeks.
Sandstone FC-1-37 Depth (ft) 229.0-237.0 (FC-3)	Freeze-thaw: Slight cracking on bottom of sample at 30 cycles. Wet-dry: No change at 30 cycles. Outdoor: No sample.
Shale FC-1-46 Depth (ft) 292.0-297.9 (FC-4)	(See figure FC-2) Freeze-thaw: Slight cracking at 3 cycles, slight slaking at 6 cycles, slaking at 20 cycles, continued slaking at 30 cycles. %BD = 100. Wet-dry: Slaking at 3 cycles, continued slaking at 30 cycles. %BD = 100. Outdoor: Slaking at 1 week, continued slaking at 7 weeks.
Sandstone FC-1-54 Depth (ft) 342.0-350.2 (FC-5)	Freeze-thaw: No change at 30 cycles. Wet-dry: No change at 30 cycles. Outdoor: No change at 7 weeks.
Sandstone FC-1-63 Depth (ft) 415.0-422.0 (FC-6)	Freeze-thaw: No change at 30 cycles. Wet-dry: No change at 30 cycles. Outdoor: No change at 7 weeks.

* Field sample number.
** Laboratory sample number.

Table FC-1 - Continued

Sample I.D.	Remarks
Sandstone FC-3-18 Depth (ft) 95.3-104.7 (FC-7)	Freeze-thaw: No change at 30 cycles. Wet-dry: Very slight break on one edge at 30 cycles. Outdoor: No change at 7 weeks.
Sandstone FC-2-22 Depth (ft) 141.3-150.2 (FC-8)	Freeze-thaw: No change at 30 cycles. Wet-dry: No change at 30 cycles. Outdoor: No change at 7 weeks.
Siltstone FC-2-33 Depth (ft) 233.7-239.4 (FC-9)	(See figure FC-3) Freeze-thaw: Slight cracking at 3 cycles, slight slaking at 6 cycles, slaking at 26 cycles, slight swelling at 30 cycles, %BD = 17.8. Wet-dry: No change at 30 cycles. Outdoor: No sample.
Siltstone FC-3-27 Depth (ft) 158.0-164.5 (FC-10)	Freeze-thaw: Slight cracking at 15 cycles, slaking at 30 cycles. %BD = 41.7. Wet-dry: Slight cracking at 6 cycles, no appreciable change in sample at 30 cycles. Outdoor: No change at 7 weeks.
Siltstone FC-4-13 Depth (ft) 55.4-60.4 (FC-11)	Freeze-thaw: Slight cracking and slight slaking at 3 cycles, slaking and delamination at 30 cycles. %BD = 61.5. Wet-dry: Slight cracking at 3 cycles, slaking at 15 cycles, continued slaking at 30 cycles. %BD = 16.8. Outdoor: No sample
Shale FC-4-24 Depth (ft) 120.4-130.4 (FC-12)	Freeze-thaw: Slight cracking at 6 cycles, very slight slaking at 15 cycles. %BD = less than 1. Wet-dry: No change at 30 cycles. Outdoor: No sample.

Table FC-2

GRADATION ANALYSIS
Core Specimens Subjected to 30 Laboratory Weathering Cycles

Shale, FC-1-11, Depth 63.0 to 70.1 Feet

	Cumulative percent passing	
Sieve size	Freeze-thaw specimen	Wet-dry specimen
4	100.0	18.0
10	96.8	4.1
50	12.7	1.4
100	5.7	1.0
200	3.2	0.8

Shale, FC-1-46, Depth 292.0 to 297.9 Feet

	Cumulative percent passing	
Sieve Size	Freeze-thaw specimen	Wet-dry specimen
4	90.3	17.9
10	61.2	3.6
50	5.6	1.2
100	3.3	1.0
200	2.3	0.8

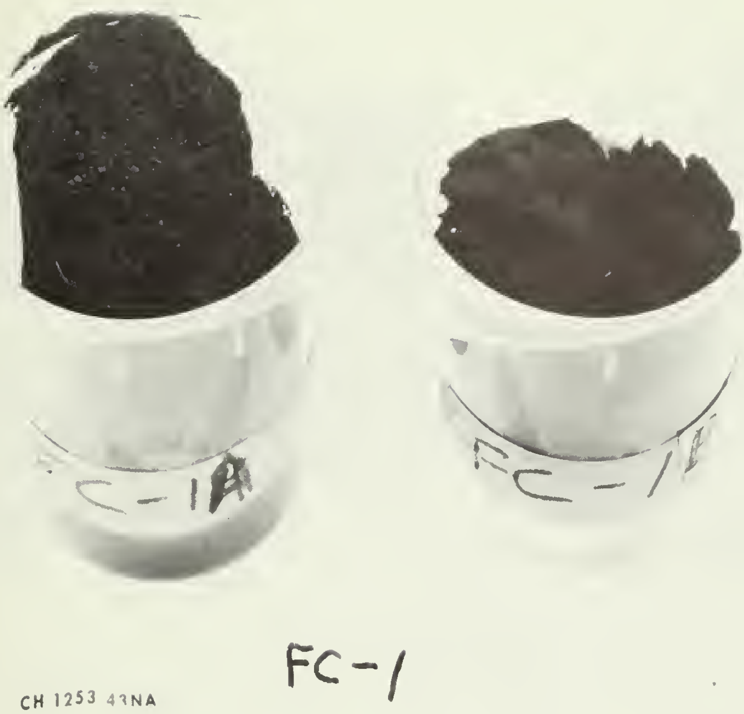


Figure FC-1. Results of laboratory weathering for shale sample from Foidel Creek, Colorado; FC-1-11, Depth 63.0' to 70.1'. Sample A on left was subjected to 30 freeze-thaw cycles; and Sample B on right was subjected to 30 wet-dry cycles.

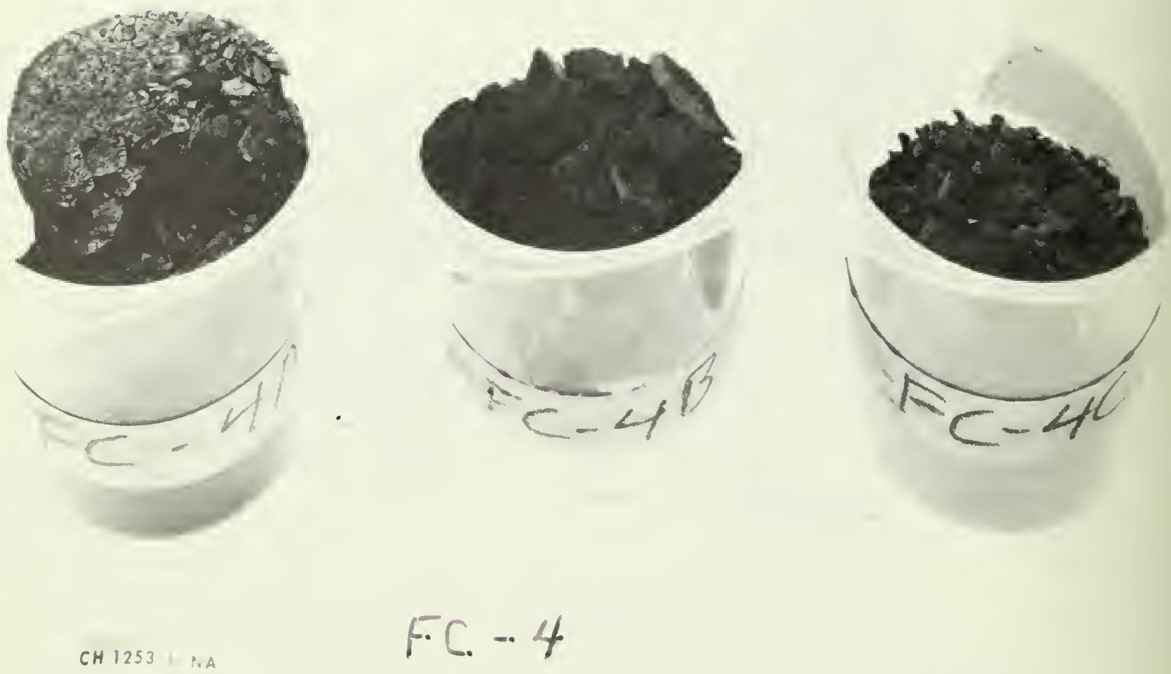


Figure FC-2. Results of laboratory weathering for shale sample from Foidel Creek, Colorado; FC-1-46, Depth 292.0' to 297.9'. Sample A on left was subjected to 30 freeze-thaw cycles; Sample B in center was subjected to 30 wet-dry cycles; and Sample C on right was subjected to 7 weeks of outdoor exposure.

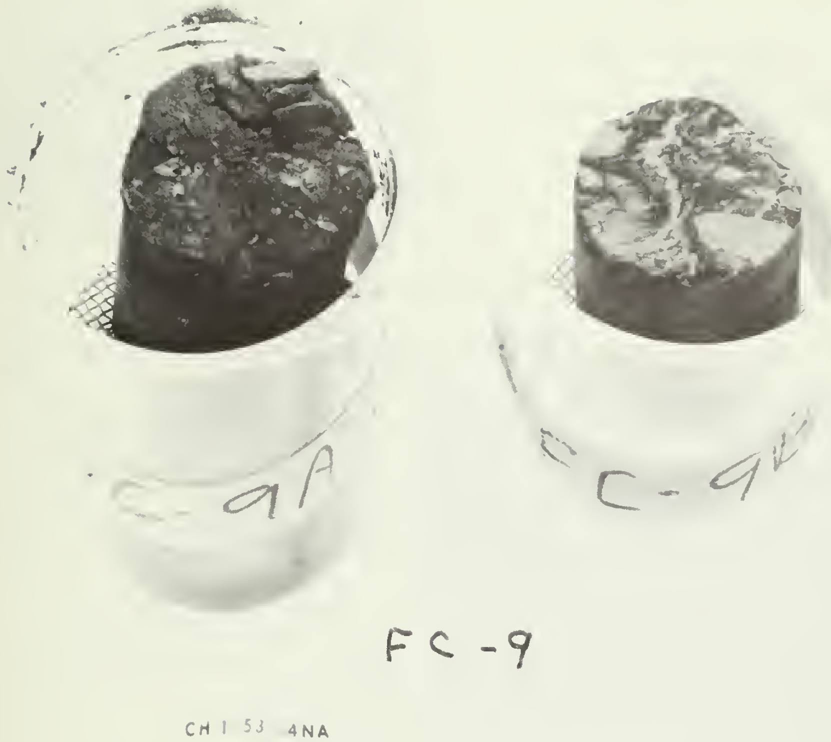


Figure FC-3. Results of laboratory weathering for siltstone sample from Foidel Creek, Colorado; FC-2-33, Depth 233.7' to 239.4'. Sample A on left was subjected to 30 freeze-thaw cycles; and Sample B on right was subjected to 30 wet-dry cycles.

INTRODUCTION

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations, the soil will be conserved and replaced. However, on some sites the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this study was to evaluate the suitability of overburden as plant growth media.

This greenhouse study was a portion of a larger study carried out by the Bureau of Reclamation in coring and characterizing overburden on potential federal coal lease sites. This report is on the Bear Creek, Horse Nose Butte, Red Rim, Bisti West, Foidel Creek, and White Tail Butte EMRIA sites. A previous report was on the Alton, Hanna Basin, Otter Creek, and Taylor Creek EMRIA sites.

Figure 2a. Range in growth on samples from Bisti West site in New Mexico.

Figure 2b. Range in growth on samples from Foidel Creek site in Colorado.

Figure 2c. Range in growth on samples from White Tail Butte site in Wyoming.

Figure 2. Range in Western wheatgrass growth on overburden and soil samples from the Bisti West, Foidel Creek, and White Tail Butte sites.

Bisti West, New Mexico (Kirtland, Fruitland, & Picture Cliffs formations)

Geologic samples from the Bisti West, New Mexico site generally yielded low to medium. Fifty-one percent of the samples yielded low, 47% medium, and one sample or 2% yielded high (Figures 11 and 12, Table 4). These overburden samples were generally sodic with a few being saline-sodic. These samples with a high sodium content were mostly fine-textured with swelling clays resulting in a large amount of surface cracking. Also, these samples had high pH values with 87% of the samples having a pH of 9.0 or greater and 20% with a pH of 10.0 or 10.1. The majority of the geologic samples from this site have physical and chemical characteristics which make them unsuitable as plant growth media.

Soil samples from the Bisti West site yielded much better than the geologic samples. Relative yields were 10% low, 58% medium, and 23% high (Figure 13, Table 4). The soil samples have better characteristics as plant growth media but some have sodium problems. In general, the surface soils showed the most favorable characteristics and generally yielded more than subsurface samples.

Foidel Creek, Colorado (Iles formation, Mesa Verde group).

Overburden samples from the Foidel Creek site in Colorado generally yielded from low to medium. Relative yields were 44% low (Figure 14, Table 5), 55% medium, and 1 sample or 1% high. These samples were mostly coarse-textured with low water-holding capacities. As a general rule those samples with the higher field capacity produced the highest yields.

There were no soil profile samples from the Foidel Creek used in the greenhouse trials.

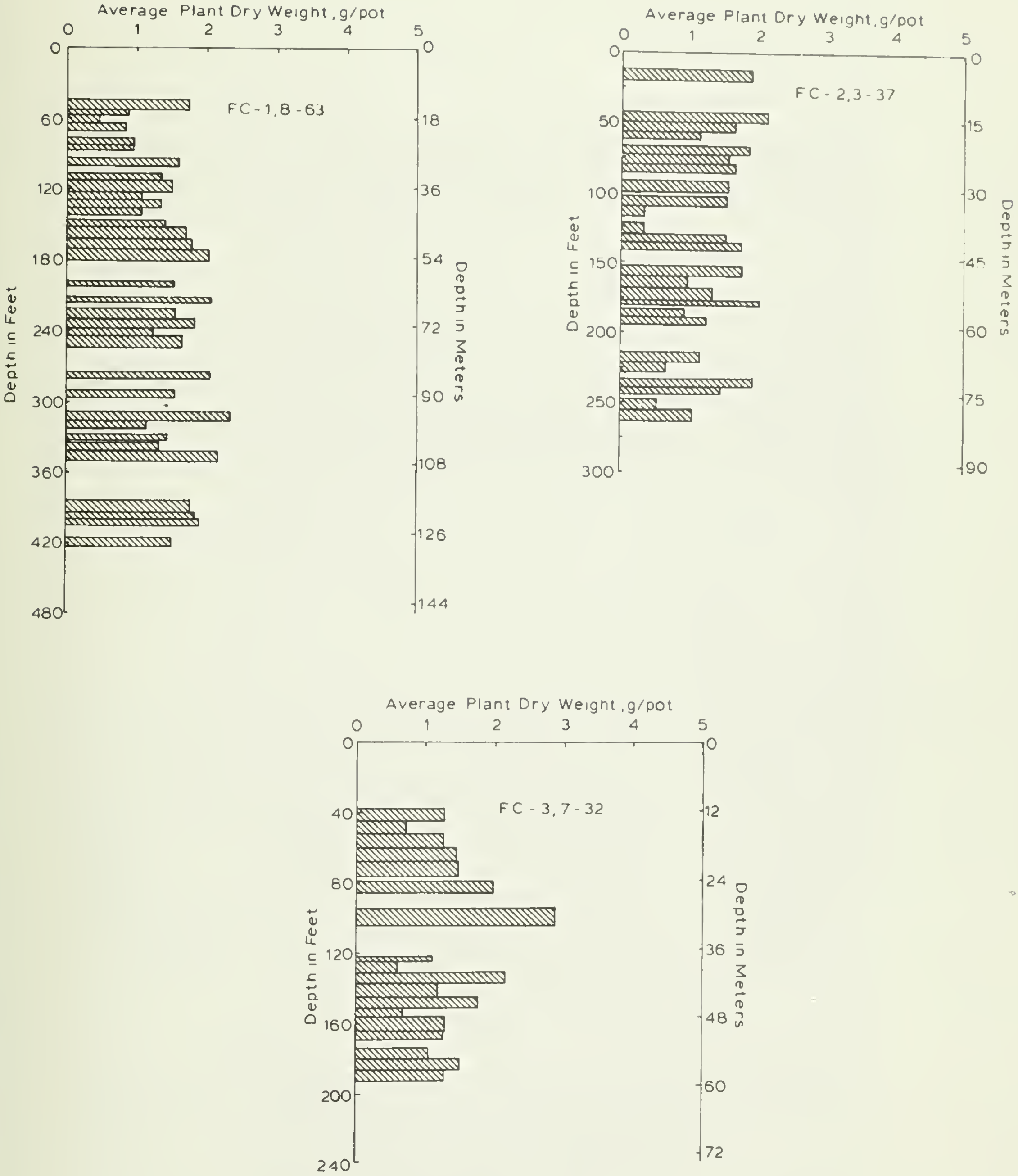


Figure 14. Yields of western wheatgrass on overburden samples from coreholes DH-1, DH-2, and DH-3, Foidel Creek site in Colorado.

Table 5. Foidel Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	Germination: Days After Seeding for Ten Plants to Emerge II	Germination: Number of Seeds Germinated I	Germination: Number of Seeds Germinated II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	Harvest: Plant Dry Weight (gm) II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	Harvest: Average Plant Height (cm) II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
FC-1- 8	44.3 - 51.2	2	8	8	33	35	1	0	1.67	1.80	41	27	29	0	0	15.89
FC-1- 9	51.2 - 57.0	2	9	11	23	26	1	1	1.14	0.65	21	22	21	0	0	14.90
FC-1-10	57.0 - 63.0	2	9	7	31	32	1	0	0.36	0.60	11	15	18	0	0	14.25
FC-1-11	63.0 - 70.1	2	8	10	34	34	1	0	0.94	0.71	20	23	24	1	0	13.43
FC-1-13	75.0 - 80.1	2	8	8	33	36	1	1	0.87	1.07	23	24	26	0	0	13.73
FC-1-14	80.1 - 85.6	2	8	10	39	36	1	0	0.97	0.93	23	23	19	1	0	8.54
FC-1-17	94.1 - 100.0	2	7	7	25	38	1	0	1.67	1.53	38	28	28	1	0	8.51
FC-1-19	106.0 - 113.5	2	8	10	29	28	1	0	1.69	1.06	33	28	26	1	0	7.96
FC-1-20	113.5 - 122.5	2	9	8	27	29	1	0	1.20	1.80	36	24	32	0	0	8.41
FC-1-21	122.5 - 129.0	2	10	10	35	20	1	0	1.13	1.02	26	27	23	0	0	8.59
FC-1-22	129.0 - 135.0	2	8	9	29	25	1	0	1.53	1.16	32	28	28	0	0	9.28
FC-1-23	135.0 - 141.1	2	8	8	40	25	1	1	0.88	1.30	26	21	26	0	0	6.91
FC-1-25	145.6 - 154.5	2	7	8	36	28	1	0	1.50	1.34	34	26	27	0	0	7.93
FC-1-26	154.5 - 162.1	2	7	7	36	33	1	0	1.57	1.83	41	28	29	0	0	8.20
FC-1-27	162.9 - 171.9	2	11	7	35	29	1	0	1.70	1.88	43	29	30	0	0	10.40
FC-1-28	171.9 - 180.9	2	8	8	31	36	1	0	1.74	2.32	49	31	35	0	0	8.79
FC-1-31	198.9 - 202.3	2	7	7	36	36	1	0	1.40	1.62	36	29	29	1	0	6.08
FC-1-34	211.3 - 216.0	2	7	7	32	38	1	1	1.73	2.38	49	29	33	0	0	8.88
FC-1-36	221.0 - 229.0	2	7	7	34	28	1	0	1.69	1.41	37	27	27	0	0	7.96
FC-1-37	229.0 - 237.0	2	7	8	33	35	1	0	1.94	1.72	44	30	34	0	0	8.04

Table 5. (cont.) Foidel Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
FC-1-38	237.0 - 244.5	2	8	8	38	30	1	1	1.14	1.30	29	24	27	0	0	7.64
FC-1-39	245.5 - 253.9	2	7	7	35	38	1	0	1.86	1.42	39	30	27	0	0	7.86
FC-1-41	263.0 - 271.6	2	12	13	23	16	1	1	Trace	Trace		0	0	0	0	7.71
FC-1-43	273.8 - 280.0	2	7	7	35	36	1	0	2.00	2.10	49	30	33	1	0	7.92
FC-1-46	292.0 - 297.9	2	6	7	33	36	2	1	1.60	1.49	37	26	26	0	0	7.26
FC-1-49	309.8 - 317.0	2	7	7	34	35	1	0	2.29	2.39	56	30	33	0	0	7.92
FC-1-50	317.0 - 322.5	2	8	7	38	37	1	1	1.25	1.08	28	26	21	1	0	6.15
FC-1-52	326.8 - 333.8	2	8	7	36	37	1	0	1.27	1.57	34	25	31	1	0	7.94
FC-1-53	334.3 - 342.0	2	8	7	28	36	1	0	1.03	1.59	31	23	29	0	0	7.51
FC-1-54	342.0 - 350.2	2	7	7	36	39	1	0	2.34	1.99	52	32	31	0	0	8.60
FC-1-58	384.8 - 393.0	2	7	7	38	34	1	1	1.75	1.81	43	28	28	0	0	7.57
FC-1-59	393.0 - 399.0	2	7	7	37	36	1	0	1.84	1.80	43	29	28	1	0	6.93
FC-1-60	399.0 - 405.0	2	9	7	36	37	1	0	1.87	1.93	45	30	30	0	0	7.52
FC-1-63	415.0 - 422.0	2	8	8	31	31	1	0	1.60	1.40	36	28	29	1	0	5.67
FC-2- 3	13.6 - 20.4	2	10	8	40	34	1	0	1.85	1.95	45	27	29	1	0	12.00
FC-2- 7	43.8 - 50.0	2	7	8	23	36	1	0	2.03	2.19	50	30	33	0	0	10.19
FC-2- 8	50.0 - 56.4	2	8	7	37	35	1	0	1.44	1.91	40	26	32	1	0	8.75
FC-2- 9	56.4 - 61.0	2	7	11	33	30	1	1	1.22	1.09	28	25	26	0	0	8.43
FC-2-11	66.4 - 73.7	2	7	8	28	32	1	0	2.01	1.76	45	27	30	0	0	9.00

Table 5. (cont.) Foidel Creek Greenhouse Data.

Sample No.	Depth(ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
FC-2-12	73.7 - 80.0	2	7	7	35	28	1	0	1.48	1.69	38	30	31	0	0	8.37
FC-2-13	80.0 - 86.8	2	9	8	36	35	1	1	1.91	1.43	40	30	28	0	0	10.03
FC-2-15	91.3 - 100.4	2	8	11	36	30	1	1	1.95	1.21	38	28	27	1	0	11.90
FC-2-16	102.0 - 110.0	2	9	11	26	16	1	1	1.75	1.35	37	29	29	1	0	8.09
FC-2-17	110.0 - 117.6	2	11	8	29	28	1	1	0.33	0.33	8	10	10	0	0	8.42
FC-2-19	123.7 - 130.0	2	7	11	30	28	1	1	0.46	0.16	7	13	11	0	0	7.43
FC-2-20	130.0 - 135.3	2	6	8	40	29	1	0	1.52	1.50	36	28	29	1	0	6.25
FC-2-21	135.3 - 141.3	2	7	6	31	33	1	1	1.73	1.82	42	27	29	0	0	9.62
FC-2-24	153.7 - 160.3	2	7	6	35	39	2	1	1.91	1.65	43	30	30	0	0	8.47
FC-2-25	160.3 - 168.0	2	7	7	35	34	1	1	1.22	0.76	24	23	21	0	0	9.23
FC-2-26	168.0 - 176.1	2	7	7	33	38	1	1	1.03	1.65	32	23	30	0	0	8.00
FC-2-27	176.1 - 180.0	2	10	8	32	34	1	0	1.82	2.23	48	31	36	0	0	12.03
FC-2-28	182.4 - 189.0	2	9	13	30	16	1	0	1.12	0.75	22	25	20	0	0	7.17
FC-2-29	189.0 - 195.8	2	8	8	32	36	1	0	1.13	1.37	30	24	26	0	0	8.72
FC-2-30	214.1 - 221.0	2	8	9	35	26	1	0	1.25	1.02	27	27	25	0	0	8.99
FC-2-31	221.0 - 228.8	2	12	12	33	30	1	0	0.49	0.89	16	16	22	0	0	8.05
FC-2-33	233.7 - 239.4	2	7	6	34	34	1	0	1.63	2.21	46	29	30	1	0	9.78
FC-2-34	239.4 - 244.9	2	8	8	33	26	1	0	1.63	1.53	38	27	28	0	0	8.14
FC-2-36	247.2 - 255.0	2	8	9	30	22	1	0	0.46	0.64	13	15	17	0	0	6.35
FC-2-37	255.0 - 263.1	2	10	11	30	36	1	0	1.17	0.95	23	24	24	2	0	6.36

Table 5. (cont.) Foidel Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
FC-3- 7	25.0 - 32.4	2	12	14	20	16	1	0	Trace	Trace		0	0	0	0	7.15
FC-3- 8	38.3 - 45.0	2	7	9	38	28	1	0	1.31	1.26	31	28	27	0	0	8.31
FC-3- 9	45.0 - 52.0	2	10	10	23	30	1	1	0.77	0.64	17	23	20	1	0	7.70
FC-3-10	52.0 - 60.0	2	10	8	24	40	1	0	1.24	1.29	30	21	28	0	0	7.57
FC-3-11	60.0 - 68.0	2	9	7	31	33	1	0	1.33	1.52	34	27	28	1	0	9.10
FC-3-12	68.0 - 76.9	2	8	7	32	34	1	0	1.26	1.65	35	27	29	0	0	8.48
FC-3-14	79.9 - 85.0	2	7	7	40	33	1	0	1.89	2.10	48	293	31	0	0	8.14
FC-3-18	95.3 - 104.7	2	7	7	34	37	1	0	2.82	2.83	68	35	34	0	0	13.93
FC-3-21	121.9 - 124.3	2	7	8	36	26	1	1	1.42	0.79	26	24	25	0	0	7.85
FC-3-22	124.3 - 131.0	2	11	7	17	25	1	0	0.52	0.69	14	22	27	0	0	7.38
FC-3-23	131.0 - 137.0	2	6	6	38	35	2	1	1.94	2.38	52	32	33	0	0	9.18
FC-3-24	137.0 - 145.0	2	7	7	32	38	1	1	1.11	1.25	28	27	25	0	0	7.86
FC-3-25	145.0 - 153.0	2	7	8	33	37	1	0	2.02	1.33	40	30	27	0	0	10.72
FC-3-26	153.0 - 158.0	2	12	9	28	28	1	0	0.46	0.92	16	19	25	0	0	7.77
FC-3-27	158.0 - 164.5	2	9	7	25	36	1	0	1.17	1.41	31	23	26	0	0	8.33
FC-3-28	164.5 - 169.9	2	9	9	33	30	1	0	0.93	1.62	30	24	29	0	0	10.10
FC-3-30	173.5 - 180.1	2	9	9	31	31	1	0	1.37	0.69	25	26	22	1	0	10.13
FC-3-31	180.9 - 186.0	2	8	7	32	32	1	0	1.40	1.60	36	33	33	0	0	14.99
FC-3-32	186.0 - 192.9	2	10	8	26	33	1	0	1.06	1.51	31	20	22	0	0	7.53

Table 5. (cont.) Foidel Creek Greenhouse Data.

Sample No.	Depth	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
STANDARD SOILS																
Platner																
Check	surface	2	6	6	40	35	0	0	3.83	4.54	100	37	39	0	0	15.2
Kimm	surface	2	6	6	38	37	0	0	4.57	4.92	113	38	43	0	0	20.6
R-438-26																
Control	surface	2	7	7	37	36	0	0	2.03	1.54	43	29	30	0	0	13.14
Red Rim																
Check	surface	2	7	7	39	37	0	0	4.80	4.41	110	39	41	1	0	18.4

ADDITIONAL DATA

Blackening of the leaf tips was observed on various samples. This blackening of the leaf tips was hypothesized to be boron toxicity, but work done by Bureau of Reclamation personnel in Billings, Montana showed that there was no correlation between the amount of hot water soluble boron and the amount of blackened leaf tips. This blackening of leaf tips was also noted in a previous greenhouse study on overburden from the Alton, Hanna Basin, Otter Creek, and Taylor Creek EMRIA sites.

In some cases, sufficient soil material was not available for a sample weight of 2.0 kg (Tables 2, 3, 4). It was not known whether significant yield decreases per pot would result if the sample weight was less than 2.0 kg so an experiment was conducted using three soils with five sample weights (2.0, 1.9, 1.8, 1.6, and 1.4 kg). The soils used were the Platner and Kimm standard soils and the C_{ca} horizon from the Kimm series which will be called Kimm C_{ca} in this report. All treatments were replicated 3 times, making a total of 45 pots. Western wheatgrass was grown on the soils for 56 days following seeding (January 17 to March 13, 1976). The samples were fertilized and seeded and the plants thinned and harvested following the previously mentioned procedures. An analysis of variance (AOV) was run on the data (Table 7) to determine if there were any significant differences in yields. The results showed that there were significant differences in yields between the sample weight (0.001 level). Since the AOV showed there were significant differences, a Duncans Multiple Range test was conducted.

These results showed that there were significant differences in yield at the 5% level between all sample weights except 2.0 versus 1.9 kg; 1.9 versus 1.6 kg; and 1.6 versus 1.4 kg. This shows that for statistical comparison purposes, a sample weight of 1.9 or 2.0 kg is needed for this study.

Table 7. Yields of western wheatgrass as a function of weight of soil per pot.

Soil Sample	Pot Wt. (Kg.)	Plant Dry Weight I	II	III
Platner	2.0	2.89	2.79	2.35
Platner	1.9	2.34	2.65	2.65
Platner	1.8	2.47	2.61	2.56
Platner	1.6	2.16	2.56	2.00
Platner	1.4	2.67	2.32	2.40
Kimm A_1	2.0	4.85	4.56	4.39
Kimm A_1	1.9	4.29	4.34	4.33
Kimm A_1	1.8	3.65	4.52	4.16
Kimm A_1	1.6	4.46	3.55	3.73
Kimm A_1	1.4	3.64	3.31	3.51
Kimm C_{ca}	2.0	2.83	2.86	2.56
Kimm C_{ca}	1.9	2.97	3.00	3.22
Kimm C_{ca}	1.8	2.42	2.29	2.35
Kimm C_{ca}	1.6	2.19	2.87	2.98
Kimm C_{ca}	1.4	2.24	2.38	2.15

Pot Weight (Kg)	Mean Plant Dry Weight (g)
2.0 a*	3.34
1.9 a	3.31
1.8 b	3.00
1.6 b, c	2.94
1.4 c	2.74

* Any two pot weights followed by the same letter are not significantly different at the 0.05 level.

NO. 2

Layers: FSL, SiCL, CL, Shale 40+

Location: NW¼NE¼

8-12% Slope

Remarks: Sage; unconsolidated shale 40"+

NO. 13

.34 / 35	CL	.05 / 6.5
55	C	.03 / 6.7
.20 / 65	C	.07 / 7.0
	Shale	

Location: NW¼NW¼

12-15% Slope

unconsolidated shale 40"+

NO. 3 Deep Hole #3

Location: NE¼SE¼

Remarks: Laboratory results are given in Soils Appendix

NO.

NO. 3

Layers: CL, C, Clay & Shale

Location: NE¼SE¼

Parent Material: Shale

10% Slope

Clay & shale 20"+

NO. 14

Layers: L, CL, CL, Shale & SS

Location: SW¼SW¼

Parent Material: Interbedded sandstone and shale

Remarks: Sage

NO.

NO.

NO. 12

Layers: L, L, SL

Location: SW¼SE¼

Parent material: Interbedded sandstone & shale

Remarks: Oakbrush

NO. 23

.07 / 55	CL	.06 / 6.0
.16 / 35	C	.06 / 6.4
.12 / 40	CL & C	.11 / 6.6

Location: SE¼NW¼

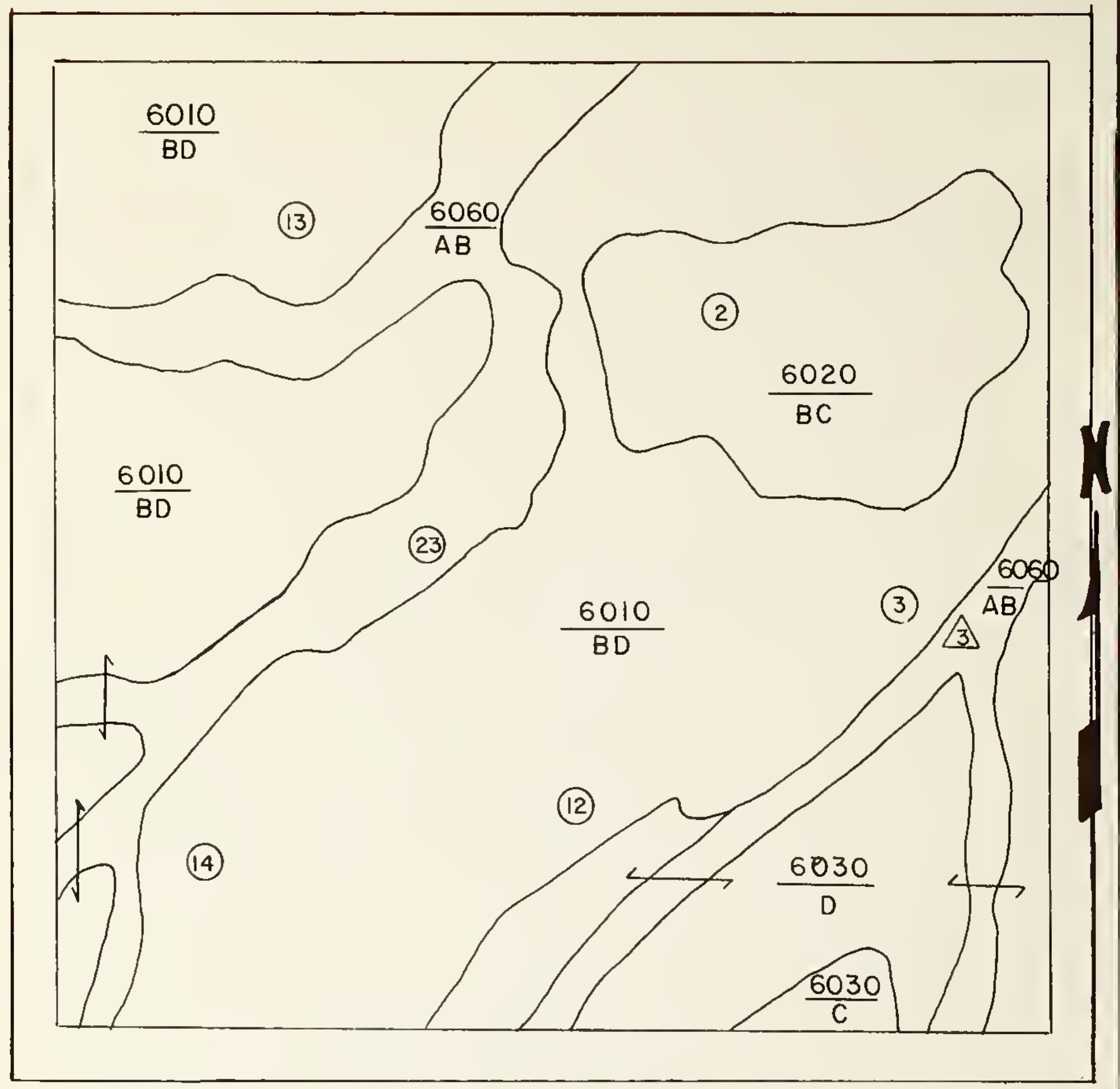
0-2% Slope

Parent Material: Allumium

Remarks: CL and C stratified

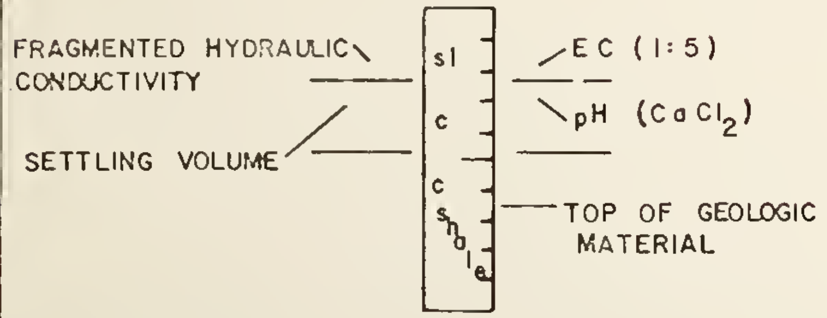
NO.

NO.



SCALE: 1"= 1000'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER NAME

6010 AABERG CLAY LOAM
- A - 0 to 3 percent
- B - 3 to 7 percent

6020 MOYERSON CLAY LOAM
- BC - 3 to 12 percent

NUMBER NAME

6030 HESPERUS LOAM
- B - 3 - 7 percent
- C - 7 to 12 percent
- D - 12 to 20 percent
- E - 20 to 40 percent

6040 UNNAMED FINE SANDY LOAM
- CD - 7 to 20 percent

NUMBER NAME

6050 SPLITRO FINE SANDY LOAM
- A - 0 to 3 percent
- D - 12 to 20 percent

6060 CUMULIC CRYAQUOLLS (alluvial stream bottoms)
- A - 0 to 3 percent
- AB - 0 to 7 percent

TWP 4 SEC 13 RANGE 87

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UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

SOIL INVENTORY

FOIDEL CREEK STUDY AREA-COLORADO

DESIGNED ________ TECH. APPROVAL ________
DRAWN L. SHANKLIN SUBMITTED ________
CHECKED T. CAPPELLUCCI ADMIN. APPROVED ________

LM REGION, DEN., COLO. | Figure C-5

NO. 1

Horizon
L
S.CL
CL
Shale & Ss

Location: NW¼NW¼

5-8% slope

Parent Material: Shale

Remarks: Shale and sandstone 30"+

NO. 17

Left values	Horizon	Right values
.12/50	CL	.07/6.3
.18/55	C	.04/6.3
.28/60	C	.10/6.8
	Shale Ss	

Location: SE¼NW¼

8-10% slope

Remarks: Soft shale and sandstone fragments

NO. [1]

Left values	Horizon	Right values
.64/35	CL	.13/6.3
	SiC	
9.3/75	SiC	.05/6.1
.32/40	SiC	.04/6.2
.06/40		.04/6.5
.38/38	S.CL	.12/6.8
.09/38	S.CL	.16/7.3

Location: NW¼NW¼

Parent Material: Shale

NO. △4 Deep Hole #4

Location: SE¼NE¼

Remarks: Laboratory results are given in Soils Appendix

NO. 4

Horizon
L FSL
L CL
L
Ss

Location: SW¼SW¼

10-20% Slope

Parent Material: Sandstone

Remarks: Unconsolidated sandstone 30"+

NO. 18

Horizon
FSL
FSL Ss
Soft Ss

Location SE¼SE¼

10% slope

Parent Material: Sandstone

Remarks: Soft sandstone 30"+

NO. [3]

Left values	Horizon	Right values
.50/29	UFSL	.07/5.8
	UFSL	
.58/29	FSL	.06/6.0
.70/28	Ss	.05/6.0
.80/20		.03/6.2
	Ss	

Location: SW¼SW¼

Parent Material: Medium textured sandstone

NO.

NO. 11

Horizon
L
CL
L
SCL CL
Shale

Location: SE¼NE¼

Parent Material: Interbedded sandstone and shale

NO. 19

Left values	Horizon	Right values
.40/25	FSL	.04/6.2
.32/25	L	.03/6.3
.36/33	FSL	.05/6.6
	Soft Ss Shale	

Location: NW¼SE¼

10% slope

Parent Material: Sandstone and shale interbedded

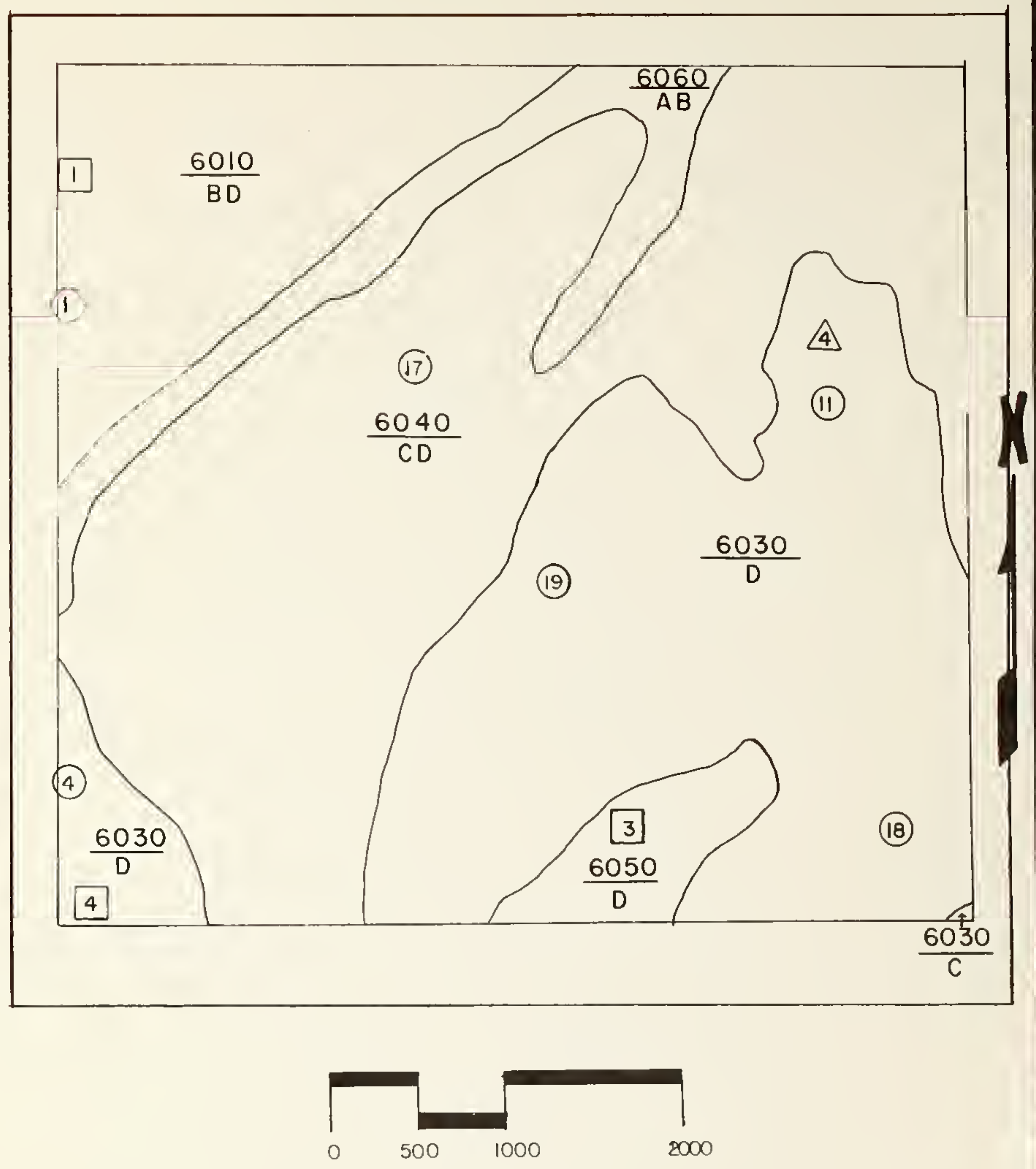
NO. [4]

Left values	Horizon	Right values
1.34/30	L	.06/6.0
1.34/30	L	.05/6.1
1.20/31	CL	.05/6.1
1.36/31	CL	.03/6.1

Location: SW¼SW¼

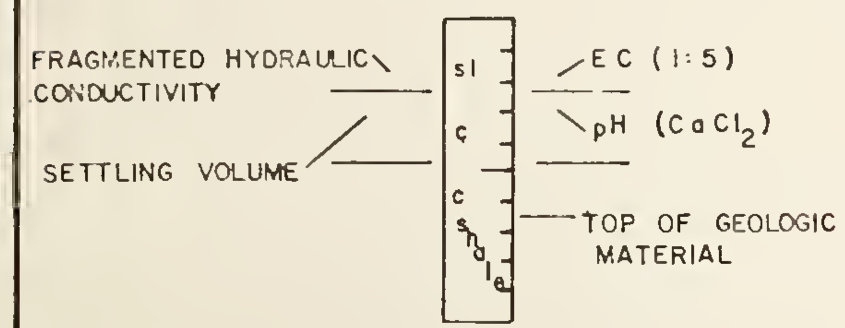
Parent Material: Fine textured Sandstone

NO.



SCALE: 1" = 1000'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Symbol	Name	Symbol	Name
Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
6010	AABERG CLAY LOAM A - 0 to 3 percent B - 3 to 7 percent
6020	MOYERSON CLAY LOAM BC - 3 to 12 percent
6030	HESPERUS LOAM B - 3 to 7 percent C - 7 to 12 percent D - 12 to 20 percent E - 20 to 40 percent
6040	UNNAMED FINE SANDY LOAM CD - 7 to 20 percent
6050	SPLITRO FINE SANDY LOAM A - 0 to 3 percent D - 12 to 20 percent
6060	CUMULIC CRYAQUOLLS (alluvial stream bottoms) A - 0 to 3 percent AB - 0 to 7 percent

TWP. 4 SEC. 18 RANGE 86

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL INVENTORY

FOIDEL CREEK STUDY AREA COLORADO

DESIGNED ______ TECH. APPROVAL ______
DRAWN L. SHANKLIN SUBMITTED ______
CHECKED T. CAPPELLUCCI ADMIN. APPROVED ______

LM REGION, DEN., COLO. Figure C-6

NO. 5

Layers: CL / C / C / Shale

Location: NW¼NW¼

Parent Material: Shale

Remarks: Unconsolidated Shale 18+, sage and shrubs

NO. 6

Layers: FSL / SL & Ss

Location: NE¼NW¼

Parent Material: Sandstone

Remarks: Sandstone fragments 14"+

NO. 7

Layers: FSL / Soft Ss

Location: SE¼NW¼

Parent Material: Sandstone

Remarks: Soft sandstone 20"+, sage and gramma grass, no aspen

NO. 8

Layers: FSL / L / FSL & Ss

Location: NW¼SE¼

Parent Material: Sandstone

Remarks: FSL and Ss fragments 18"+

NO. 9

Layers: L / L / L / Ss & Shale

Location: NW¼SE¼

Parent Material: Sandstone

Remarks: Sandstone fragments and shale 40"+, sage oakbrush

NO. 20

	Layer	
1.40 / 27	FSL	.06 / 6.1
1.02 / 26	L	.04 / 5.8
1.03 / 34	FSL & soft Ss	.03 / 5.6

Location: SW¼SW¼

Parent Material: Sandstone

Remarks: Aspen and oakbrush

NO. 21

	Layer	
.28 / 32	FSL	.05 / 6.0
.68 / 33	L	.06 / 6.5
.60 / 30	CL	.05 / 6.6
.13 / 38	CL & Clay	.06 / 6.8

Location: SW¼SE¼

0-2% slope

Parent Material: alluvium

Remarks: Sage and meadowgrass

NO. 2 (boxed)

	Layer	
.60 / 30	CL	.06 / 6.5
.38 / 27	CL	.06 / 6.3
.52 / 28	CL	.04 / 6.1
.62 / 75	C	.03 / 5.5
.16 / 85	S.C.	.04 / 4.3

Location: SW¼SW¼

Parent Material: Interbedded sandstone and shale

NO. 5 (triangle) Deep Hole #5

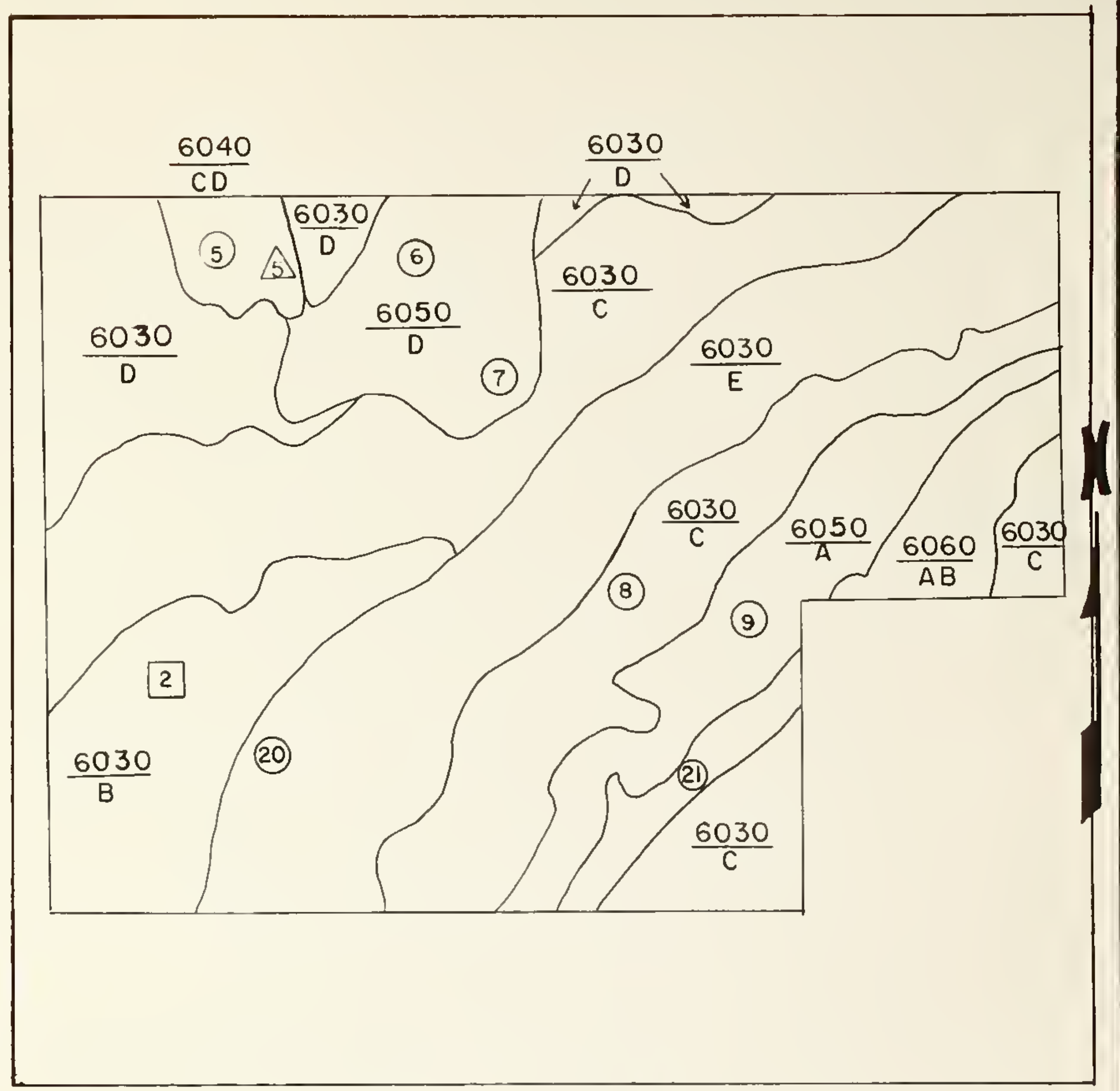
Location: NW¼NW¼

Remarks: Laboratory results are given in Soils Appendix

NO.

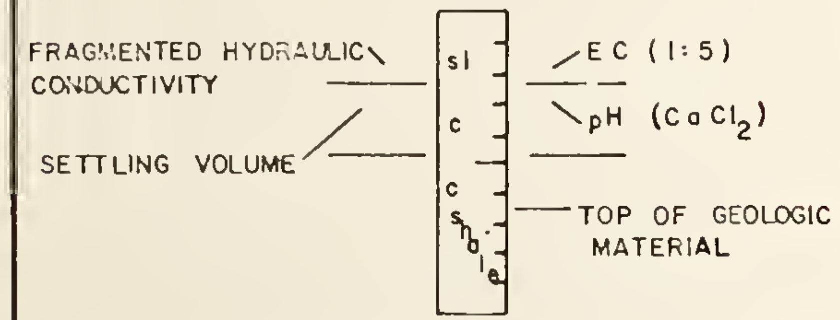
NO.

NO.



SCALE 1"= 1500'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Symbol	Name	Symbol	Name
Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	S C	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
6010	AABERG CLAY LOAM A - 0 to 3 percent B - 3 to 7 percent
6020	MOYERSON CLAY LOAM BC - 3 to 12 percent
6030	HESPERUS LOAM B - 3 to 7 percent C - 7 to 12 percent D - 12 to 20 percent E - 20 to 40 percent
6040	UNNAMED FINE SANDY LOAM CD - 7 to 20 percent
6050	SPLITRO FINE SANDY LOAM A - 0 to 3 percent D - 12 to 20 percent
6060	CUMULIC CRYAQUOLLS (alluvial stream bottoms) A - 0 to 3 percent AB - 0 to 7 percent

TWP. 4 SEC. 19 RANGE 86

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SOIL INVENTORY

FOIDEL CREEK STUDY AREA-COLORADO

DESIGNED ______ TECH. APPROVAL ______
DRAWN L SHANKLIN SUBMITTED ______
CHECKED T CAPPELLUCCI ADMIN. APPROVED ______

LM REGION, DEN., COLO. | Figure C-7

NO. 15

CL | C | CL | L | Shale SS

Location: SW¼NW¼

15-20% Slope

Parent Material: Interbedded sandstone and shale 48+

NO. 16

.24 / 32	FSL	.05 / 6.2		
.26 / 28	L	.03 / 6.1		
.56 / 35	Ss	.03 / 6.1		
	Ss			

Location: NW¼NE¼

Aspen and Oakbrush

Parent Material: Shale

Remarks: Unconsolidated SS (24-36") Soft solid SS (36-60")

NO. 24

.18 / 25	FSL	.05 / 6.0
.28 / 25	L	.03 / 6.6
.62 / 27	SL & SS	.03 / 6.1
	Soft SS	

Location: NW¼NE¼

Aspen and Sage

Parent Material: Sandstone

Remarks: SL and Ss fragments 24-40"

NO. 1 Deep Hole #1

Location: SW¼NW¼

Remarks: Laboratory results are given in Soils Appendix

NO. 2 Deep Hole #2

Location: SW¼SE¼

Remarks: Laboratory results are given in Soils Appendix

NO.

NO.

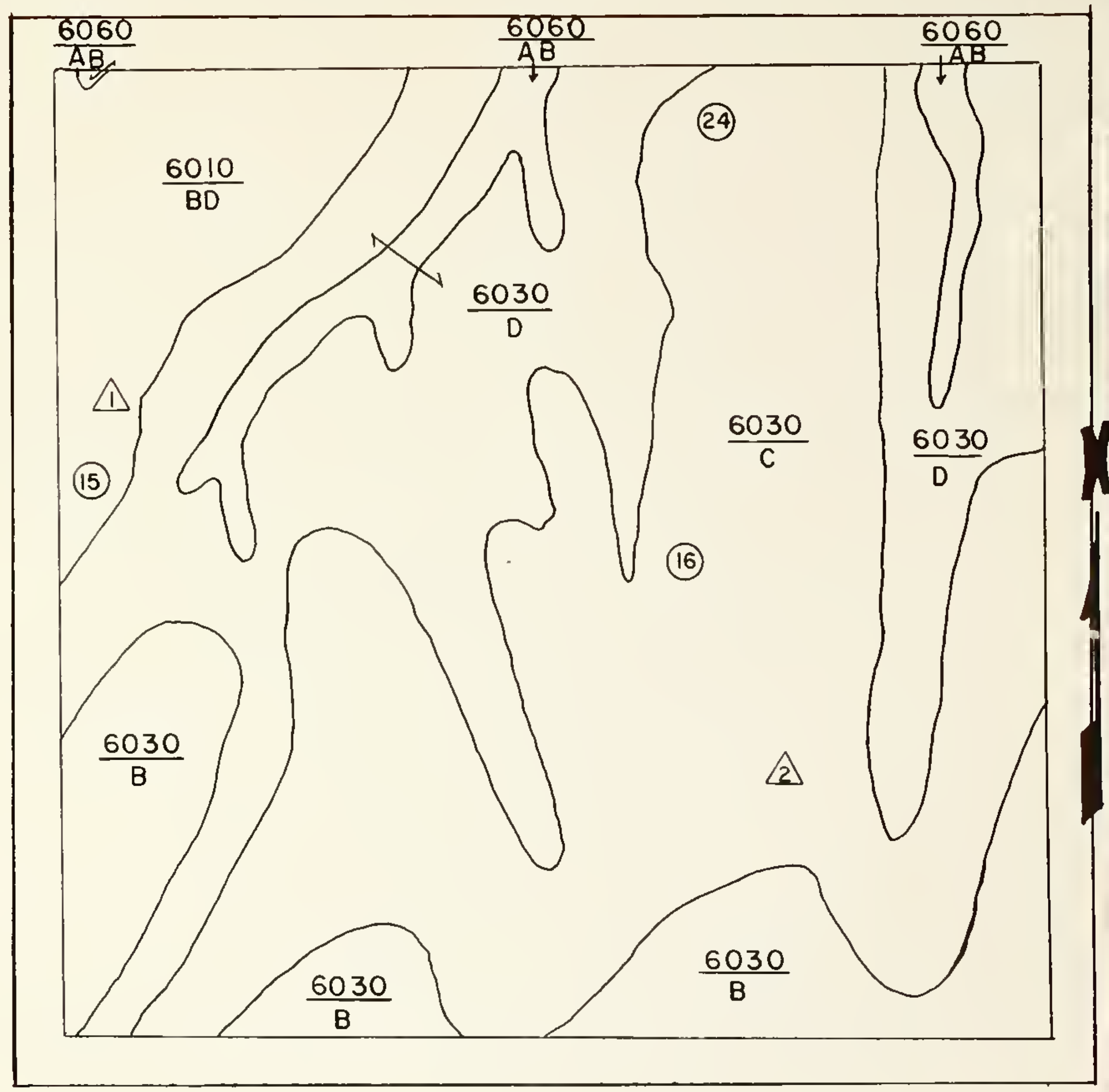
NO.

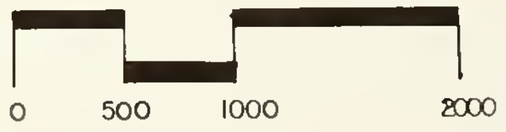
NO.

NO.

NO.

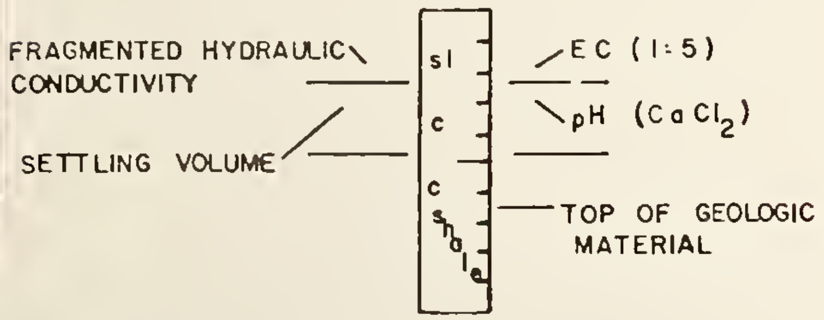
NO.





SCALE: 1" = 1000'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
6010	AABERG CLAY LOAM A - 0 to 3 percent B - 3 to 7 percent
6020	MOYERSON CLAY LOAM BC - 3 to 12 percent
6030	HESPERUS LOAM B - 3 to 7 percent C - 7 to 12 percent D - 12 to 20 percent E - 20 to 40 percent
6040	UNNAMED FINE SANDY LOAM CD - 7 to 20 percent
6050	SPLITRO FINE SANDY LOAM A - 0 to 3 percent D - 12 to 20 percent
6060	CUMULIC CRYAQUOLLS (alluvial stream bottoms) A - 0 to 3 percent AB - 0 to 7 percent

TWP 4 SEC. 24 RANGE 87

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SOIL INVENTORY

FOIDEL CREEK STUDY AREA-COLORADO

DESIGNED ______ TECH. APPROVAL ______
DRAWN L. SHANKLIN SUBMITTED ______
CHECKED T. CAPPELLUCCI ADMIN. APPROVED ______

L M REGION, DEN., COLO. | Figure C-8

Aaberg Series 6010

Borollic Vertic Camborthid, Fine Montic

A Q-3" - (10 yr 5/2) clay loam; (10 yr 3/2)

Moist; weak medium platey structure, breaking to weak medium crumb; soft, friable; noncalcareous; clear, smooth boundary.

B21 3-7" - (10 yr 5/3) silty clay: (10 yr 3.5/2)

Moist; moderate medium subangular blocky structure, breaking to strong fine subangular blocks; very hard when dry, moist firm; thin continuous clay filsm; noncalcareous; clear smooth boundary.

B22 7-15" - (10 yr 5/3) silty clay; (10 yr 3/2)

Moist; moderate, coarse subangular blocky structure breaking to moderate, medium subangular blocks; very hard when dry, moist firm; thin patchy clay films, mainly on vertical ped faces; noncalcareous; gradual smooth boundary.

B_3 15-32" - (10 yr 4/3) silty clay; (10 yr 3/2)

Moist; very weak coarse blocky structure breaking to weak to moderate medium blocks; very hard when dry, moist firm; thin patchy clay films, mainly on vertical ped faces; noncalcareous; gradual smooth boundary.

C_{ca} 32-38" - (10 yr 5/6) silty clay loam; (10 yr 4/4)

Moist; Massive to very weak fine blocky structure; friable; slightly calcareous; clear wavy boundary.

C_r 38" + - (10 yr 6/2) silty clay loam; (10 yr 4.5/3)

Moist; Massive; friable; slightly calcareous; small sandstone and shale fragments comprise about 15 to 25 percent of this material.

Hesperus Series 6030

Argic Pachic Cryoboroll, fine loamy, mixed

A_o 2-0" - (10 yr 6/2) loam;

(10 yr 2.5/2)

Moist; moderate medium crumb structures; soft, friable; noncalcareous; clear smooth boundary.

A 0-8" - (10 yr 4/3) clay loam;

(10 yr 2.5/2)

Moist; weak, fine subangular blocky structure breaking to moderate medium granules; slightly hard when dry, moist friable; noncalcareous; clear, smooth boundary.

B_2 8-16" - (10 yr 4/3) clay loam;

(10 yr 2.5/2)

Moist; moderate medium subangular blocky structure, breaking to moderate fine subangular blocks; slightly hard when dry, moist firm; thin continuous clay films on vertical faces; noncalcareous; wavy diffuse boundary.

B_3 16-34" - (10 yr 3/3) light clay loam;

(10 yr 4.5/3)

Moist; weak corase subangular blocky structure; slightly hard when dry, moist, firm; thin patchy clay films, mainly on vertical faces; noncalcareous; gradual wavy boundary.

C_1 34-48" - (7.5 yr 5/4) heavy clay loam to light silty clay;

(7.5 yr 4/3) Moist; massive; hard when dry, moist firm; sticky and plastic; noncalcareous; many sandstone and shale fragments; clear smooth boundary.

C_2 48-60" - (2.5 yr 5/4) silty clay;

(10 yr 4/3)

Moist; massive; hard when dry, moist firm; sticky and plastic; noncalcareous; many sandstone fragments.

Unnamed Series 6040

Pachic Cryoboroll, fine loamy, mixed

2-0" - (10 yr 6/2) loamy leaf litter; (10 yr 2.5/2)

Moist; structureless, partially decomposed organic material.

0-8" - (5 yr 4/2) very fine sandy loam; (5 yr 2.5/2)

Moist; weak, fine granular structure; soft, very friable; noncalcareous; clear, smooth boundary.

8-14" - (5 yr 3.5/2(very fine sandy loam; (2.5 yr 2/2)

Moist; weak medium subangular blocky structure, breaking to moderate, medium granules; soft, very friable; noncalcareous; gradual, smooth boundary.

B_2 14-22" - (7.5 yr 3.5/2) fine sandy loam; (5 yr 2/2)

Moist; moderate, medium subangular blocky structure, breaking to moderate, medium granules; very thin discontinuous clay films, mainly on vertical ped faces; soft, very friable; noncalcareous; clear smooth boundary. This horizon contains 5 to 10 percent by volume of soft sandstone fragments.

C_r 22-28" - Soft partially decomposed sandstone. Many fractures, 75 percent sandstone fragments by volume and 25 percent weathered soil material.

R 28" - Solid sandstone, soft and partially fractured.

Splitro Series 6050

Lithic Cryoboroll, loamy, mixed

A_o 2-0" - (10 yr 6/2) loamy leaf litter
(10 yr 2.5/2)

Moist; structureless, partially decomposed organic material.

A_{11} 0-6" - (5 yr 4/2) very fine sandy loam;
(5 yr 2.5/2)

Moist; weak, fine granular structure; soft, very friable; noncalcareous; clear smooth boundary.

A_{12} 6-10" - (5 yr 3.5/2) very fine sandy loam;
(2.5 yr 2/2)

Moist; weak, medium subangular blocky structure, breaking to moderate, medium granules; soft, very friable; noncalcareous; gradual, smooth boundary.

C 10-14" - (7.5 yr 3.5/2) fine sandy loam; (5 yr 2/2)

Moist; moderate, medium subangular blocky structure, breaking to moderate, medium granules; soft, very friable; noncalcareous; clear smooth boundary. This horizon contains about 5 percent by volume of soft sandstone fragments.

C_r 14-20" - Soft, partially decomposed sandstone. Many fractures, 75 percent sandstone fragments by volume, and 25 percent weathered soil material.

r 20" + - Solid sandstone, soft and partially fractured.

APPENDIX D

STUDY SITE HYDROLOGY

WATER QUALITY DATA, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976

DATE	TEMPERATURE (DEG C)	WEATHER (WMO CODE NUMBER)	STREAMFLOW (CFS)	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (MICROMHOS)	OXYGEN, DISSOLVED (MG/L)	PH (UNITS)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	ALKALINITY (MG/L AS CACO3)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)
MAR												
05...	.0	1	.42	.42	880	9.4	7.8	8.3	269	328	0	.11
APR												
08...	4.0	0	--	.16	700	8.2	7.8	5.7	184	224	0	.03
MAY												
07...	10.0	1	--	.71	800	5.5	7.8	8.3	267	326	0	.07
JUN												
04...	13.0	1	--	.26	800	5.5	7.5	20	326	397	0	.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FUIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976

D-1

DATE	PHOSPHATE, ORTHO, DISSOLVED (MG/L AS PO4)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DISSOLVED (MG/L AS C)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	SODIUM ADSORPTION RATIO	SODIUM PERCENT	POTASSIUM, DISSOLVED (MG/L AS K)
MAR												
05...	.09	.03	--	--	430	160	99	45	36	.8	15	3.8
APR												
08...	.06	.02	--	--	200	93	63	29	28	.7	18	3.5
MAY												
07...	.03	.01	--	--	360	95	84	37	25	.6	13	3.1
JUN												
04...	.31	.10	5.0	4.9	410	84	93	43	28	.6	13	2.8

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DATE	CHLORIDE, DIS-SOLVED (MG/L AS CL)	SULFATE DIS-SOLVED (MG/L AS SO4)	FLUORIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	ARSENIC DIS-SOLVED (UG/L AS AS)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM DIS-SOLVED (UG/L AS CD)	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGANESE, DIS-SOLVED (UG/L AS MN)	NICKEL, DIS-SOLVED (UG/L AS NI)
MAR 05...	6.0	210	.2	9.4	2	60	1	2	40	3	90	2
APR 08...	4.2	140	.2	7.8	--	60	--	--	120	--	40	--
MAY 07...	5.2	140	.3	7.4	--	50	--	--	40	--	90	--
JUN 04...	4.6	46	.4	8.8	1	--	0	0	60	0	290	0

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DATE	VANADIUM, DIS-SOLVED (UG/L AS V)	ZINC, DIS-SOLVED (UG/L AS ZN)	ANTIMONY, DIS-SOLVED (UG/L AS SB)	SELENIUM, DIS-SOLVED (UG/L AS SE)	ODOR, ATMOSPHERIC (SEVERITY)	SOLIDS, SUM OF CONSTITUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	SOLIDS, DIS-SOLVED (TONS PER AC-FT)	MERCURY DIS-SOLVED (UG/L AS HG)	SEDIMENT, SUS-PENDED (MG/L)	SEDIMENT DIS-CHARGE, SUS-PENDED (T/DAY)
MAR 05...	.6	10	0	0	0	572	.65	.78	.0	24	.03
APR 08...	--	--	--	--	0	387	.17	.53	--	102	.04
MAY 07...	--	--	--	--	0	463	.89	.63	--	54	.10
JUN 04...	2.1	10	0	0	0	423	.30	.58	.0	48	.03

WATER QUALITY DATA, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977

DATE	TEMPERATURE (DEG C)	WEATHER (WMO CODE NUMBER)	STREAMFLOW (CFS)	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (MICROMHOS)	OXYGEN, DISSOLVED (MG/L)	PH (UNITS)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	ALKALINITY (MG/L AS CACO3)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)
MAR 18...	1.0	1	.10	.10	1050	4.0	7.2	39	320	388	0
APR 14...	5.0	1	--	.08	850	6.5	7.2	31	250	310	0
MAY 11...	5.0	1	--	.06	1000	3.0	7.1	51	330	400	0

WATER QUALITY DATA, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977

DATE	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	PHOSPHATE, ORTHO, DISSOLVED (MG/L AS PO4)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DISSOLVED (MG/L AS C)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	SODIUM ADSORPTION RATIO
MAR 18...	.24	.06	.02	11	8.6	550	230	130	54	33	.6
APR 14...	.04	.03	.01	--	--	410	160	98	41	30	.6
MAY 11...	.02	.37	.12	--	--	510	180	120	51	35	.7

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DATE	SODIUM PERCENT	POTASSIUM, DISSOLVED (MG/L AS K)	CHLORIDE, DISSOLVED (MG/L AS CL)	SULFATE DISSOLVED (MG/L AS SO4)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	COPPER, DISSOLVED (UG/L AS CU)	IRON, DISSOLVED (UG/L AS FE)	LEAD, DISSOLVED (UG/L AS PB)
MAR											
18...	12	4.4	6.5	300	.2	9.6	80	1	4	180	1
APR											
14...	13	3.9	6.9	210	.3	8.3	70	--	--	140	--
MAY											
11...	13	3.8	7.8	240	.2	9.4	100	--	--	100	--

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DATE	MANGANESE, DISSOLVED (UG/L AS MN)	NICKEL, DISSOLVED (UG/L AS NI)	VANADIUM, DISSOLVED (UG/L AS V)	ZINC, DISSOLVED (UG/L AS ZN)	SELENIUM, DISSOLVED (UG/L AS SE)	ODOR, ATMOSPHERIC (SEVERITY)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, DISSOLVED (TONS PER AC-FT)	SEDIMENT, SUSPENDED (MG/L)	SEDIMENT DISCHARGE, SUSPENDED (T/DAY)
MAR											
18...	1100	13	.0	20	1	0	732	.20	1.00	50	.01
APR											
14...	70	--	--	--	--	0	552	.12	.75	7	.00
MAY											
11...	570	--	--	--	--	0	666	.11	.91	46	.01

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DATE	TEMPERATURE (DEG C)	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	ALKALINITY (MG/L AS CACO3)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	PHOSPHATE, ORTHO, DISSOLVED (MG/L AS PO4)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
APR											
18...	9.0	4.0	459	8.2	1.6	130	160	0	.46	.09	.03
MAY											
30...	18.5	.85	600	8.2	2.8	230	280	0	.35	.03	.01
JUN											
19...	17.0	.04	700	8.0	5.6	290	350	0	.01	.03	.01

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DATE	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DISSOLVED (MG/L AS C)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	SODIUM ADSORPTION RATIO	SODIUM PERCENT	POTASSIUM, DISSOLVED (MG/L AS K)
APR										
18...	--	--	220	87	48	24	15	.4	13	2.9
MAY										
30...	--	--	310	84	71	33	17	.4	10	2.6
JUN										
19...	9.2	11	370	86	85	39	21	.5	11	3.1

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WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	CHLORIDE, DISSOLVED (MG/L AS CL)	SULFATE DISSOLVED (MG/L AS SO4)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	ARSENIC DISSOLVED (UG/L AS AS)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	COPPER, DISSOLVED (UG/L AS CU)	IRON, DISSOLVED (UG/L AS FE)	LEAD, DISSOLVED (UG/L AS PB)
APR										
18...	3.9	120	.2	6.7	--	80	--	--	50	--
MAY										
30...	3.8	100	.3	9.4	--	70	--	--	280	--
JUN										
19...	3.4	100	.3	11	2	90	2	4	320	8

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DATE	MANGANESE, DISSOLVED (UG/L AS MN)	NICKEL, DISSOLVED (UG/L AS NI)	VANADIUM, DISSOLVED (UG/L AS V)	ZINC, DISSOLVED (UG/L AS ZN)	ANTIMONY, DISSOLVED (UG/L AS SB)	SELENIUM, DISSOLVED (UG/L AS SE)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, DISSOLVED (TONS PER AC-FT)	MERCURY DISSOLVED (UG/L AS HG)
APR										
18...	10	--	--	--	--	--	302	3.28	.41	--
MAY										
30...	70	--	--	--	--	--	377	.37	.51	--
JUN										
19...	230	0	.0	20	0	0	436	.05	.59	.0