RESOURCE & POTENTIAL RECLAMATION EVALUATION

McCALLUM STUDY AREA

Report No. 26

1979

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

7-2090 (4-81)
Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. BLM-YA-551-PHI-2	2. GOVERNMENT ACCESSION NO.
3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE McCallum Study Area: Resource and Potential Reclamation Evaluation	5. REPORT DATE September 1983
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Bureau of Reclamation Bureau of Land Management U.S. Geological Survey	8. PERFORMING ORGANIZATION REPORT NO. 26-79
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bureau of Reclamation Lower Missouri Region DFC, Bldg. 20 Denver, CO 80225	10. WORK UNIT NO.
	11. CONTRACT OR GRANT NO. 52500 - AG5 - 1
12. SPONSORING AGENCY NAME AND ADDRESS Bureau of Land Management Denver Service Center DFC, Bldg. 50, D-450 Denver, CO 80225	13. TYPE OF REPORT AND PERIOD COVERED Final
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This report was proposed through the efforts of the Bureau of Land Management, Bureau of Reclamation, and Geologic Survey as part of the Federal Coal Management Program.

16. ABSTRACT

The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The report includes data on climate, biological and cultural resources, physiography, geology, coal resources, soil overburden, vegetation, and hydrology. The study area is within Moffat County in Colorado. The site climate is highland continental. Average annual precipitation is less than 16 inches. The area is composed of seven ecological subdivisions or range sites as follows: mountain loam, dry mountain loam, drainage bottom, clay pan, valley bench, dry exposure, and salt flat. The Coalmont Formation which occurs within the Study Area is a maximum of 12,000 feet thick and consists of micaceous and arkosic sandstone, minor conglomerate, mudstone, claystone, carbonaceous shale, and coal. The Sudduth coalbed, occurring 50 to 250 feet above the base of the Coalmont Formation, contains significantly thick coal deposits. Results of the land suitability survey show that approximately 87 percent of the Study Area has adequate material for postmining reclamation purpose. Approximately 67 percent of the Study Area is class 1. Class 2 and 3 land comprise about 10 percent each. The remaining 13 percent of the Study Area was Class 6. The overall effect of mining on hydrology of the area should be minimal, primarily because only small areas of the basins will be mined.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS--

0510 Environmental Surveys
0807 Coal Deposits
1407 Reclamation

b. IDENTIFIERS-- Reclamation potential, surface mined lands Colorado

c. COSATI Field/Group *COWRR:* *SRIM:*

18. DISTRIBUTION STATEMENT *Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161.*	19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PAGES
	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. PRICE

CONTENTS

CONTENTS - Continued

CONTENTS - Continued

APPENDIXES

CONTENTS - Continued

TABLES

FIGURES

CONTENTS - Continued

FIGURES - Continued

CONTENTS - Continued

FIGURES - Continued

FIGURES - Continued

INTRODUCTION

Recent energy demands focused attention on coal sources existing primarily in the Rocky Mountain and the Northern Great Plains Provinces of the Western States. The BLM (Bureau of Land Management) has responsibility for encouraging and assisting in meeting these energy demands and for ensuring sound reclamation of surface-mined public lands to return them to a productive and useful state.

Purpose

The purpose of this study is to determine the reclamation potential of the McCallum area near Walden, Colorado, problems involved in reclaiming the area, and measures required to return the area to the land form and vegetative cover existing prior to mining.

Objectives

The overall objectives of the Federal Coal Management Program are to:

- Evaluate environmental effects of surface mining of areas under consideration for coal development.

- Provide resource and reclamation information for the leasing area selection procedures as set forth by the Secretary of the Interior.

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

- Provide resource, impact, and reclamation information to support State and local regional development and land-use planning efforts.

- Determine the present and potential capability of the surface soil and subsurface resources to support vegetation in areas of coal deposits.

- Provide physical and chemical data from which realistic stipulations may be prepared for coal exploration, mining, and reclamation plans.

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

Authority

This study was authorized by the Public Land Administration Act of July 14, 1969 (74 Stat. 506), the Federal Land Policy and Management Act of 1976 (Public Law 94-579), and the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87).

Responsibility

The BLM, Reclamation (Bureau of Reclamation), and USGS (U.S. Geological Survey) participated in this program.

Bureau of Land Management

BLM was responsible for:

- Selection of reclamation study areas for coordinated investigation of vegetation, soil, geological structure, surface water, and ground water.
- Preparation, coordination, issuance, and monitoring execution of work orders.
- Review and consolidation of work order and field office data and preparation of input to reports published by Reclamation.
- Procurement of easements and rights-of-way to conduct the studies.
- Distribution of technical data, reports, reclamation, and rehabilitation recommendations to field offices.

Bureau of Reclamation

Reclamation was responsible for:

- Conduct of land studies, including a land suitability classification and laboratory characterization program.
- Conduct of drilling operations for core samples used in analysis of geological strata and overburden materials.
- Mapping of surface geology.
- Preparation of geologic logs on drill holes.
- Collection of coal samples.
- Installation of casing in holes selected for ground-water observation wells.
- Characterization and interpretation of data available on soils and overburden materials and substrata immediately below the coal resources in relation to reclamation and revegetation.
- Advise and recommendation of suitable plant species for use in areas to be reclaimed.
- Advise and recommendation of reclamation techniques.
- Coordination, assembling, and printing the final report.

U.S. Geological Survey

USGS was responsible for:

- Conducting soil/vegetation and sediment studies resulting in soil/vegetation maps, hydrologic properties of soils, and sediment data.
- Assessing reclamation potential based on water availability.
- Preparing sediment yield maps.
- Preparing erodibility illustrations.
- Determining rainfall-runoff relationships and analyzing surface and subsurface waters for chemical quality.
- Evaluating coal sections and preparing well logs.
- Preparing coalbed maps showing coal resources.
- Tabulation of coal resources estimates.
- Preparation of a table of analytical results on coal resources.
- Graphic presentation of analytical results including vertical (plotted against well logs) and horizontal (plan view if significant).
- Evaluation of the effects of mining on the area hydrology and downstream.

GENERAL DESCRIPTION

Location and Setting

The McCallum Study Area, as shown on figure 1, is located approximately 8 miles east of Walden, Colorado. The lands studied lie within Jackson County and include T. 9 N., R. 78 W., sec. 22 - all, sec. 23 - all except W1/2 of the NE1/4 and the NE1/4 of the NW1/4, sec. 26 - all except E1/2 of the SE1/4 and the SW1/4 of the SE1/4, sec. 27 - all, and sec. 28 - all.

The surface ownership in the study area is public lands administered by BLM. These lands occur at an elevation between 8550 and 8100 feet. The coal minerals are owned by the Federal Government.

Present Land Use

The present resource in the Study Area is used for cattle grazing, wildlife, and as a watershed that provides forage for cattle. Livestock utilize the allotments in the spring and early summer, when 400 head of cattle graze on the public lands. Allotment evaluations indicated that the range condition within those allotments was fair, with a static or upward trend.

Watershed management, an existing land use, includes soil and water objectives for maintenance or improvement of water quantity, quality, and timing, and soil productivity and stability.

The area presently provides important habitat for sage grouse, antelope, mule deer, various raptors, rodents, and songbirds. The sage grouse strutting grounds, nesting areas, and wintering habitat are of particular importance. The 1978 DOW (Division of Wildlife) count showed there were 160 grouse on the two strutting grounds within or adjacent to the study area.

The DOW also counted 150 to 200 antelope using the study area and surrounding vicinity. Mule deer use the area on their transition from summer ranges at higher elevations to their winter range along the Michigan River north of Walden, Colorado. No inventory data for the number of mule deer are available.

Raptors use the site as hunting habitat for rodents. Important raptor species include the bald and golden eagles and the red-tailed and marsh hawks.

The major recreational use of the area is hunting, primarily for sage grouse and antelope. No accurate use figures are available.

Reclamation Objectives for the Study Area

The reclamation objectives for the McCallum Study Area in North Park are to return it, as nearly as possible, to the landform and vegetative cover that existed prior to mining. The area is native rangeland with livestock

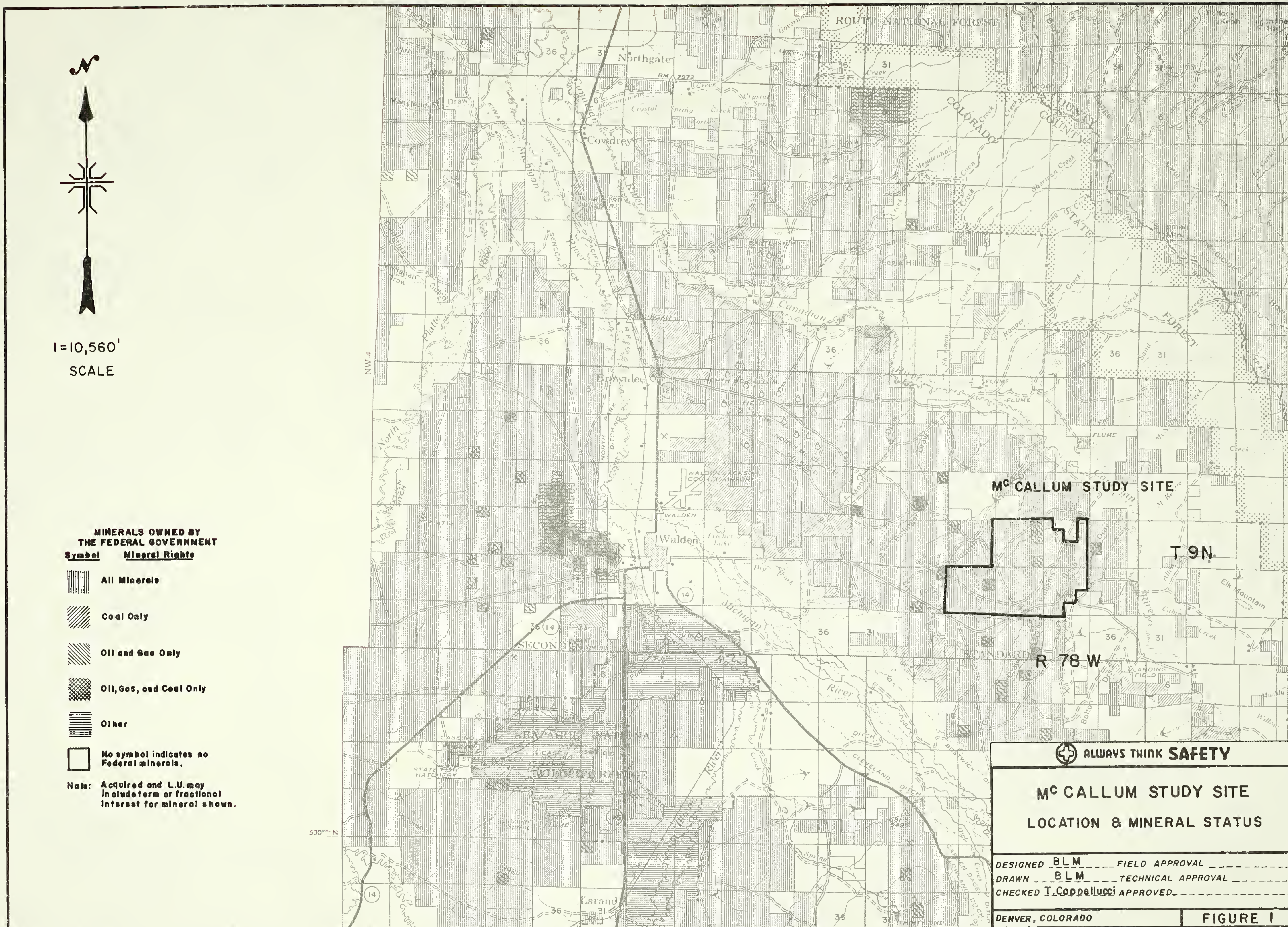


Figure 1. - McCallum Study Area location and mineral status.

grazing, wildlife use, and watershed management as the major land uses. Postmining reclamation should ensure the continuance of these uses at their present capabilities, or improve upon them.

Opportunities exist to improve livestock forage production by increasing the composition and density of native grass species preferred by cattle, such as blue-bunch wheatgrass.

Postmined Land Use

The postmined land use for the McCallum Study Area should be the same as present land use. Multiple use management will be applied to all federally owned surface land.

Postmining reclamation should ensure the return of air and water quality to or above the quality it was prior to mining. The existing air and water quality meets State and Federal standards. Both surface- and ground-water quantity, quality, and timing of runoff will return to the premining condition. Current uses of water within the study area, primarily water for livestock and wildlife, will be replaced or improved after mining.

To ensure postmining visual resources conform to premining visual resources, landform must be returned to existing contours or recommended landforms in the area. Reclamation efforts should utilize native species.

Reclamation Alternatives

There were no alternatives planned for postmine use because there is no current land use plan for the area. Additional alternatives may be identified later in a Resource Management Plan which is being prepared.

CLIMATE

Temperature

Large-scale geographical features have a pronounced effect on the climate of North Park and the McCallum area. Because of its midlatitude and continental location, seasonal variations in temperature are well pronounced. Monthly average maximum, minimum, and mean temperatures along with daily temperature extremes for Walden are shown on figure 2. Walden experiences a large seasonal range in temperature ranging from a mean January temperature of 15 °F to a monthly mean temperature of 59 °F in July. Day to night (diurnal) temperature variations are also large because of the high elevation of the area and the interior mountain-valley location. During the winter months the diurnal temperature range averages 25 °F, increasing to nearly 40° in midsummer to early fall.

Extremely cold nighttime temperatures occur with regularity. Temperatures of -20 °F and colder occur every year at Walden. The coldest temperatures usually occur in January and February. Figure 3 shows the average number of days each year when temperatures are at or below certain levels. Temperatures of 0 °F and below have occurred in all months except May through August. Even in midsummer below freezing temperatures can occur. The average freeze-free period for Walden, shown in table 1, is 33 days with July and early August being the least likely period for experiencing subfreezing temperatures. However, daytime temperatures stay well above freezing throughout the summer season, and daily maximum temperatures of 32 °F and below occur on an average of 75 days per year. Due to its high elevation location, extremely warm temperatures are very rare. The all-time highest temperature ever recorded was 96 °F, and temperatures above 85 °F are quite unusual.

Elevations within the interior of North Park generally vary by a few hundred feet, but terrain features do have a pronounced effect on temperature. Lower elevation valley bottom locations, such as Walden, experience colder winter temperatures, larger diurnal temperature variations, higher daytime temperatures in the summer, and a shorter growing season than the higher lands between rivers. For example, the Spicer Weather Station southwest of Walden is 265 feet higher than the Walden Station. The growing season is a few days longer at Spicer. Nighttime temperatures at Walden are cooler throughout the year and average 3 °F less than Spicer during midwinter. Extremely cold temperatures occur much more frequently at Walden. However, high temperatures at Walden average about 2 °F warmer than Spicer during the summer. This same type of temperature variation can be expected to occur even in very local areas over a distance of only a few hundred feet. Therefore, temperature variations are likely to be encountered from one area to another in the McCallum area.

Precipitation

North Park is a semiarid area. The entire interior of North Park averages less than 16 inches of precipitation annually. Measurements at Walden indicate that the annual average precipitation (1938-1979), including the

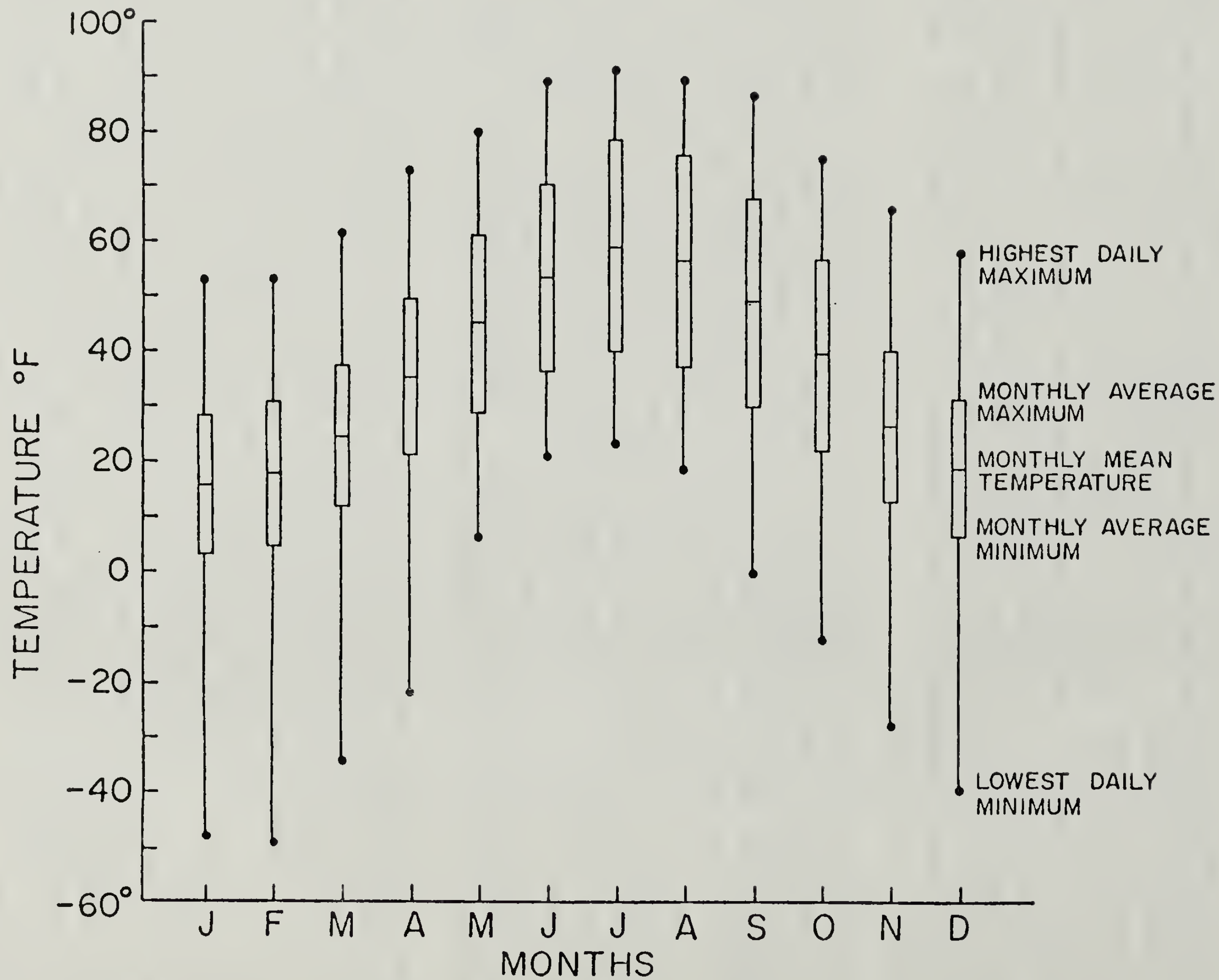


Figure 2. - Monthly average maximum, minimum, and mean temperatures and daily extremes for Walden, Colorado, 1938-1979.

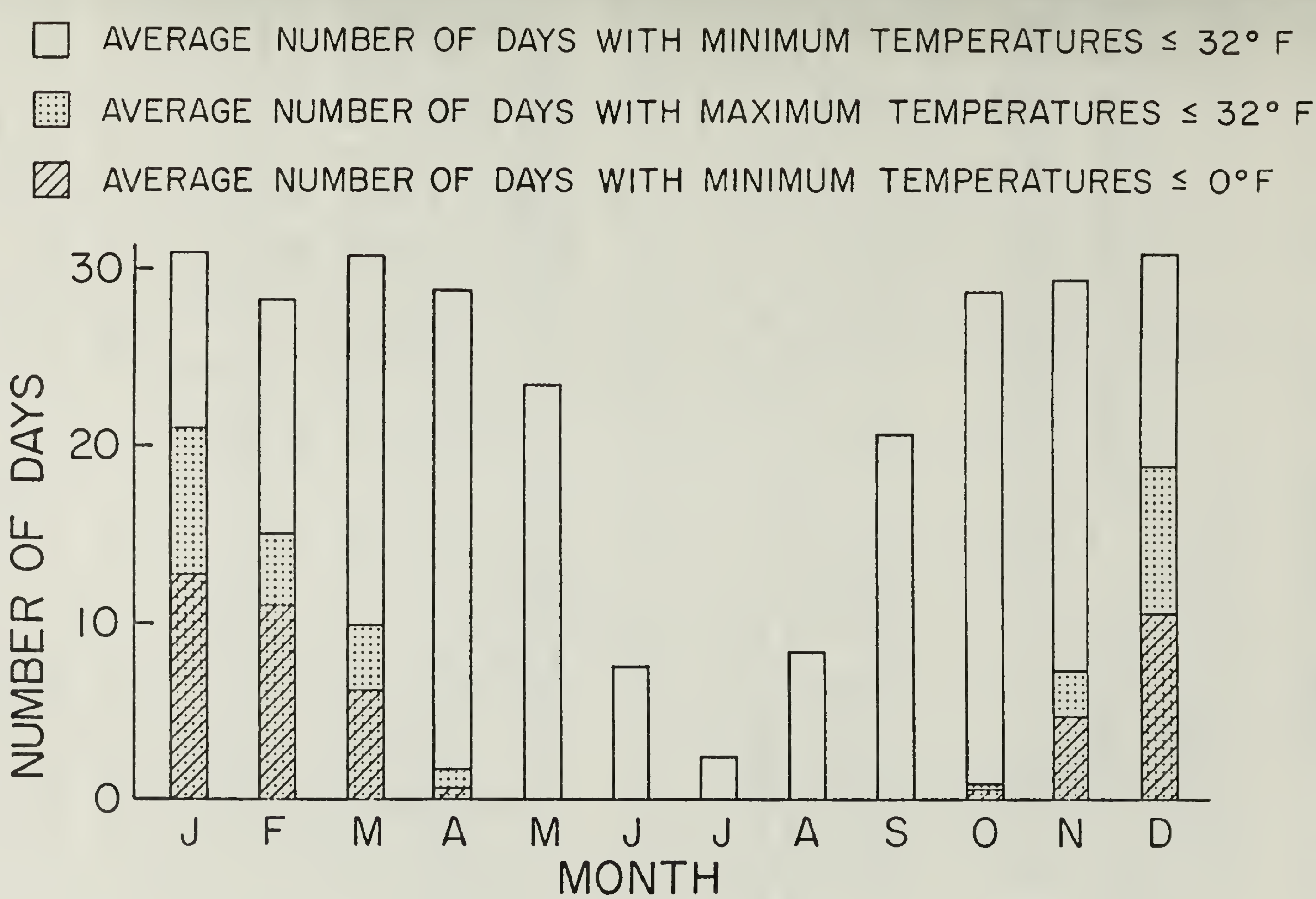


Figure 3. - Average number of days with temperatures equal or below specified threshold values for Walden, Colorado, 1948-1975.

Table 1. - Spring and fall freeze statistics and freeze-free periods for Walden, Colorado [1]*

		SPRING FREEZE			FALL FREEZE			FREEZE-FREE PERIOD (DAYS)			
Station	T°F	Mean Date	SD*	Last Date	Mean Date	SD*	First Date	Mean	SD*	Max.	Min.
Walden	32	7-05	12.1	7-20	8-07	11.9	7-21	33.	18.7	58.	1.
	28	6-16	14.7	7-09	8-22	13.1	7-28	67.	19.8	117.	40.
	24	5-29	12.8	7-01	9-06	9.2	8-22	100.	15.3	122.	60.
	20	5-14	7.3	5-28	9-11	11.5	8-22	120.	11.5	147.	103.
	16	5-04	10.6	5-19	9-26	10.2	9-09	145.	9.7	161.	127.

SD* = Standard Deviation

		SPRING Probability That Last Spring Freeze Will Occur On or After Date					FALL Probability That First Fall Freeze Will Occur On or Before Date				
Station	T°F	90	80	50	20	10	90	80	50	20	10
Walden	32	6-20	6-25	7-05	7-16	7-21	8-23	8-18	8-08	7-29	7-24
	28	5-28	6-04	6-16	6-29	7-05	9-08	9-03	8-23	8-12	8-06
	24	5-13	5-19	5-30	6-10	6-15	9-19	9-15	9-07	8-30	8-26
	20	5-05	5-08	5-14	5-21	5-24	9-27	9-22	9-12	9-02	8-28
	16	4-21	4-26	5-05	5-13	5-18	10-10	10-05	9-27	9-18	9-14

* Brackets refer to items in the bibliography.

water equivalent of winter snowfall, is only 9.67 inches. Since 1937, annual precipitation totals at Walden ranged from a low of 5.92 inches in 1964 to a high of 13.56 inches in 1951.

Precipitation in the area is produced by three basic mechanisms: (1) large-scale organized storm systems, (2) orographic lifting caused by moist air rising over mountain ranges, and (3) convective thundershower activity. Strong large-scale storm systems generally occur during the winter and spring seasons. Orographic lifting is a dominant factor during that same period when the westerly flow aloft over the midlatitudes is strongest. Convective activity becomes the dominant precipitation mechanism during midsummer when the large-scale atmospheric circulation is weak but solar insolation and heating are strong.

Winter Precipitation

Winter (usually defined as October through April) is the driest time of the year in the center of North Park, even though the same period is the wettest season in many of the surrounding mountains. Winter water-equivalent precipitation in excess of 40 inches is common in parts of the Park Range west of Walden. However, as the westerly flow crosses the mountain barrier, the air descends over the park causing the air to warm and clouds and precipitation to decrease before ascending the next mountain range. Thus, precipitation is minimized over the center of North Park. Monthly precipitation information for Walden is shown on figure 4. Walden averages only about 4 inches of precipitation for the October through April period.

Practically all winter precipitation in the North Park region falls as snow. Most winter precipitation is associated with large-scale storm systems which generate widespread upward motion and precipitation. The topography again plays an important role. Even in major storm situations, heavy precipitation is not likely in the interior portions of North Park because the low-level moisture sources necessary to produce heavy precipitation are blocked by the surrounding mountains. As a result, occurrences of daily precipitation amounts of 0.50 inch or greater rarely occur during the winter.

Monthly average snowfall for Walden and the average number of days with 1 inch or more of snow on the ground are shown on figure 5. Snowfall is not particularly heavy, averaging only 51 inches per year, but snow usually stays on the ground throughout the midwinter months. The snowmelt usually is complete by early April, and the snow that falls in April, May, and June usually melts quickly. Typical midwinter snowdepths at Walden are 1 foot or less although maximum depths up to nearly 3 feet have been recorded.

Snowfall and snowdepth increases usually are noted approaching the mountains surrounding Walden. The Spicer Station, for example, averages 125 inches of snowfall annually, experiences snowdepths as great as 4 feet, and averages 151 days per year with 1 inch or more of snow on the ground (41 days more than Walden). Eyewitness reports indicate that the McCallum Study Area also receives more winter snowfall than Walden; however, these increases are not excessive. Generally, snowfall seems to change little from Walden eastward to the McCallum Study Area, but then increases rapidly from there eastward across the Canadian River to the Medicine Bow Mountains.

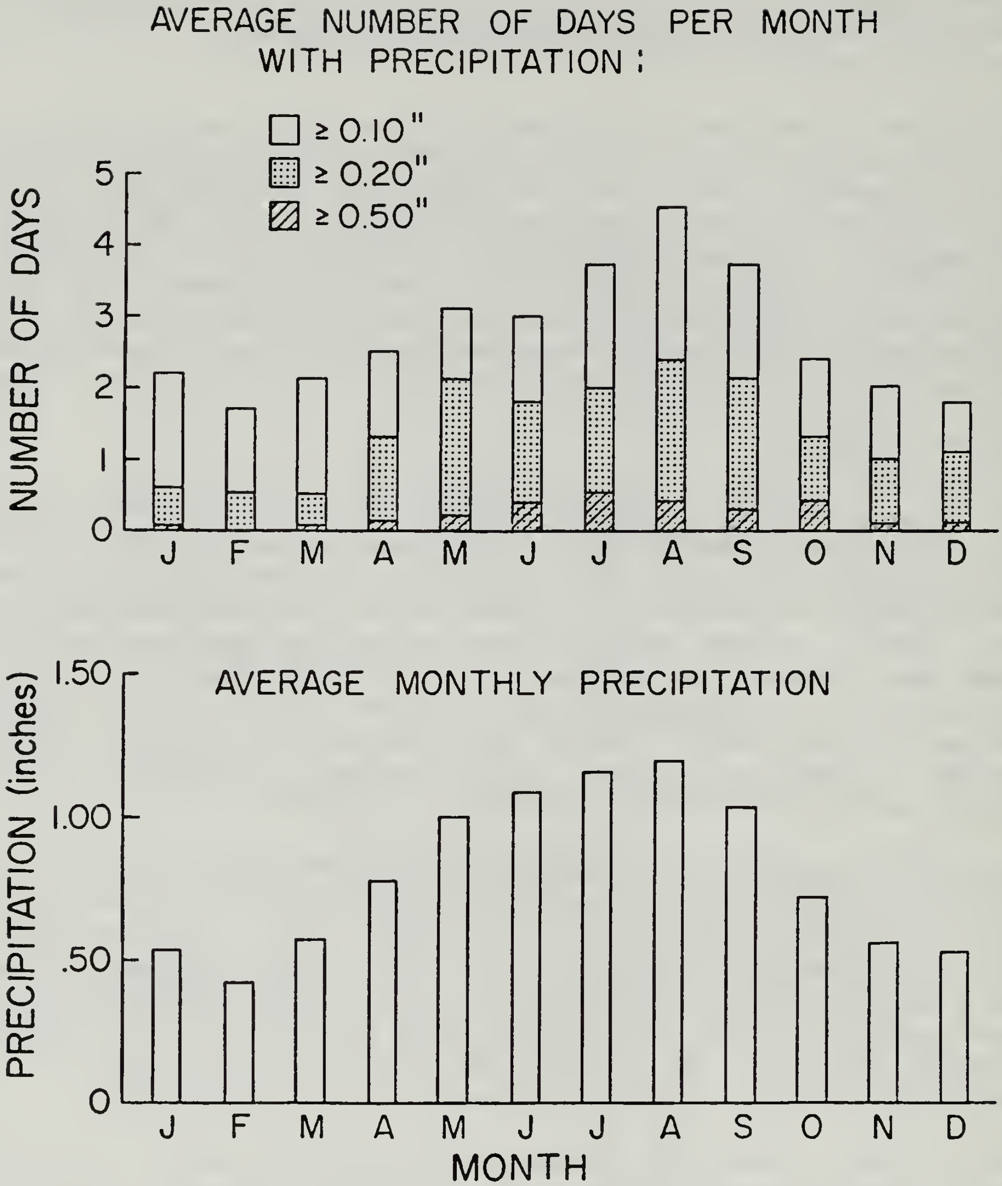


Figure 4. - Monthly precipitation climatologies for Walden, Colorado, 1938-1975.

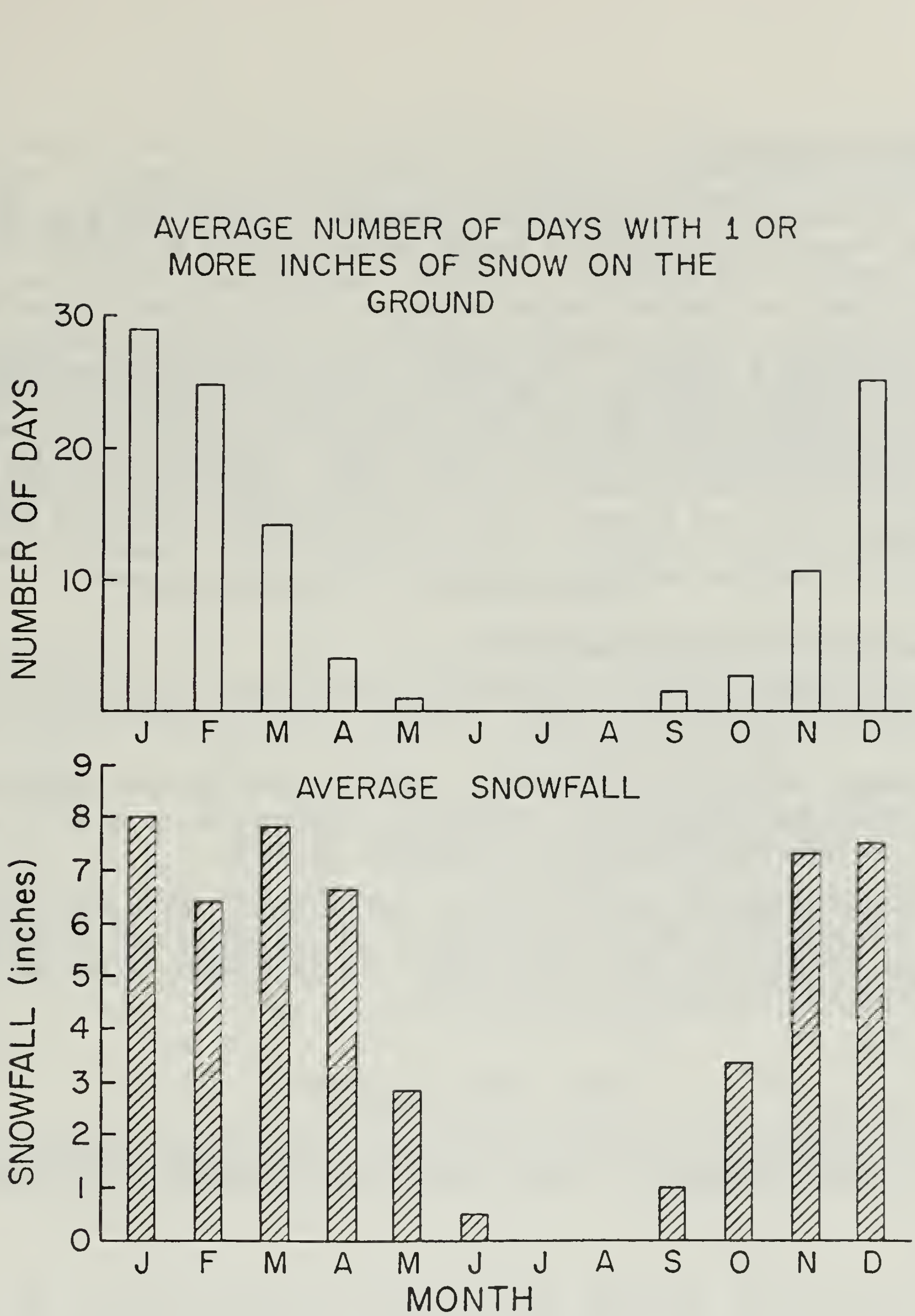


Figure 5. - Average monthly snowfall (inches) and average number of days with snow on the ground for Walden, Colorado, 1938-1975.

Summer Precipitation

The five summer months, May through September, account for about 60 percent of the annual precipitation in the Walden area (about 6 inches). From late June through early September, afternoon thundershower activity occurs frequently both over the surrounding mountains and across the center of North Park. However, rainfall amounts are usually light because the storms have limited moisture sources. The abundant, low level moisture necessary to generate severe thunderstorms and occasional heavy precipitation (characteristics of eastern Colorado and other Great Plains locations) is unable to cross the mountain barrier east of North Park. The greatest 1-day precipitation total recorded at Walden was 2.19 inches; however, daily amounts in excess of 1 inch are extremely rare. Daily rainfall amounts of 0.50 inch or greater occur an average of two times each summer. Rainfall amounts of 0.10 inch or greater on the average occur 18 days each summer.

Areal Distribution of Precipitation

The basic characteristics of the distribution of precipitation in the park are:

- Summer precipitation, on the average, is quite uniform across the entire North Park area. Significant increases occur only as you rise into the higher mountains surrounding the park.

- Winter precipitation is lowest in the center of North Park but increases with elevation and increases rapidly as you get closer to the surrounding mountain barriers, particularly the Park Range to the west and the Medicine Bow Mountains to the east.

Other Climatic Elements

Data are presently lacking in North Park to support detailed descriptions of other climatic elements. However, some general comments can be made.

Wind

North Park and the immediate McCallum area experience frequent and strong winds during winter and spring. The prevailing wind direction is from the southwest, and wind gusts in excess of 40 mi/h are not uncommon during the winter months. The result is considerable blowing snow which frequently causes very low visibilities and ground blizzard conditions. The blowing snow tends to pile up in huge drifts in protected areas while exposed areas are sometimes blown completely clear. Winds are more gentle and wind directions are dominated by local topography during the summer and early fall.

Solar Radiation

Little is known about the winter solar radiation averages and variations in North Park. However, during the summer months cloudiness and, hence, solar radiation is very similar across all of Colorado [2]. During the midsummer period, a typical daily solar radiation total should equal about 60 percent of the extraterrestrial radiation (the amount of energy that would be received at the surface if there was no atmosphere to reflect, scatter, and absorb the sun's energy). For June 21, this would equal about 2300 Btu/ft^2 per day of solar energy reaching a horizontal surface in North Park.

Evaporation

Maximum evaporation rates occur in midsummer when temperatures are highest. Estimates suggest that the May through September Class A pan evaporation total should average about 35 inches in the Walden and central North Park area. This is consistent with actual pan evaporation measurements taken near Grand Lake and at Green Mountain Dam, which are weather stations south of Walden and North Park but at similar elevations.

Climate Analyses for Reclamation

A variety of climate analyses were performed. These analyses are intended to assist and support the planning and decisionmaking processes leading to a comprehensive reclamation strategy. However, these analyses cannot necessarily stand alone. They must be viewed and interpreted in context with available biologic, hydrologic, geologic, and edaphic information.

Critical climatic elements related to vegetation selection are shown in table 2. Where analyses have been completed, values of these critical climatic parameters have been filled in for the McCallum Study Area. More detailed information concerning some of these analyses is given in the following discussion. Corresponding information of plant species for revegetation generally is not available. If plant specific requirements relating to climate constraints could be obtained, vegetation selection would be a straightforward task and table 2 could be used as a guide. In the absence of detailed plant information, alternative ways of using climatic information can be used. The first step is to consider the local native plant populations. While detailed quantitative information may not be available for these plants and conditions may not always be favorable for easy germination and establishment of these species, they clearly are adapted to the local climate and have proven their ability to survive. Local experience in plant selection can be provided by reclamation specialists, seed suppliers, State extension agents, or others who have succeeded in establishing vegetation on nearby sites. Site-specific experimental field studies also can be carried out in order to provide information on plant selection and methods of establishment.

Many of the climate analyses are presented in terms of probability. This is by far the most realistic way to view climate since climate is not a static element of the environment. Natural climate variations are sufficently great that it is not possible to precisely anticipate climatic conditions for a given time and place (as suggested by climatic averages or normals). However, from the historical record it is possible to accurately estimate the most likely range and distribution of these climatic conditions and to determine the frequency of occurrence of adverse conditions which could be detrimental to reclamation success.

Table 2. - Critical climatic elements related to vegetation selection.

Climatic element	Units	Climatic profile for McCallum Study Area*
Elevation above sea level	ft	8,300
Long-term mean annual air temperature	F°	36
High temperature extreme	F°	96
Hottest temperature experienced every year	F°	83
Low temperature extreme	F°	-49
Coldest temperature experienced every year	F°	-20
Freeze-free period	days	35
Potential thermal growing season (probability = 0.5)	days	156
Annual precipitation	inches	11.0
Driest years (probability = 0.10)	inches	8.0
May-September total precipitation	inches	6.0
Driest summer (probability = 0.10)	inches	3.5
October-April total precipitation	inches	5.0
Driest winter (probability = 0.10)	inches	3.0
May-September potential evapotranspiration	inches	22

*Estimates made for the McCallum Study Area based on Walden and other North Park data.

Temperature Analyses

Several specific climate analyses of temperature are presented here. Results of these analyses are described along with comments on how these results pertain to reclamation and revegetation problems and opportunities.

Freeze-free period. - The freeze-free periods for Walden (table 1) are presented graphically on figure 6 which shows average dates for the last spring occurrence and first fall occurrence of temperatures ≤ 32, 28, 24, 20, and 16 °F. Also shown are the latest spring occurrence and earliest fall occurrence as well as standard deviations to indicate how these dates are climatically distributed.

The average number of days between last spring and first fall occurrence of ≤ 32 °F is 33 days with an observed range from 1 to 58 days. If the threshold of 28 °F is used, the average period between occurrences is 67 days with a range from 40 to 117 days. This type of information applies to the vegetation selection step of reclamation. Only plants which can tolerate short growing seasons have a chance for survival and

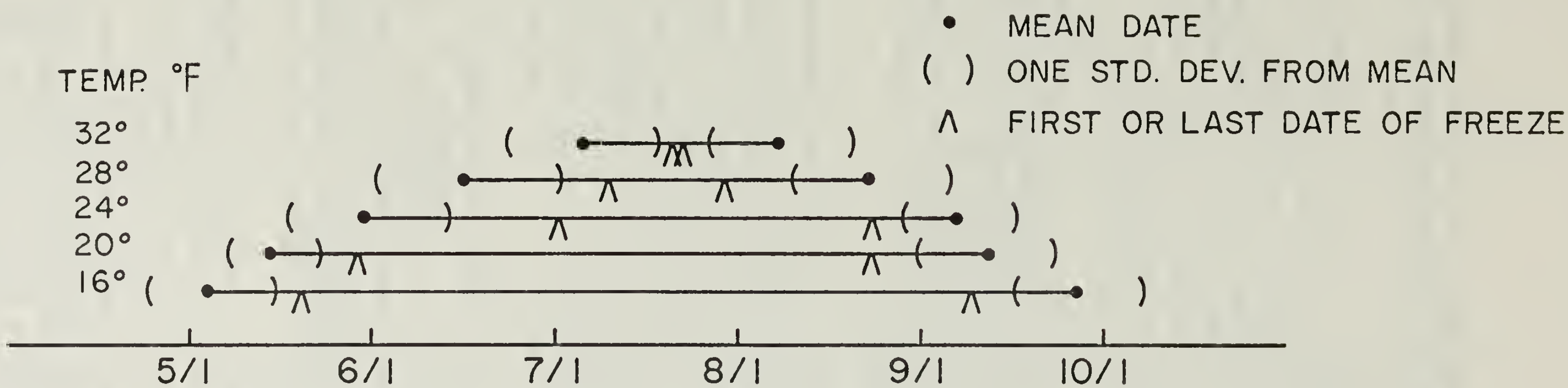


Figure 6. - Freeze-free periods at Walden, Colorado, 1951-1970 [1].

establishment in the McCallum Study Area. Different temperature thresholds are used in addition to the 32 °F value because the temperature of a "killing frost" varies a great deal from one plant species to another.

This information is shown on figure 7 in terms of probabilities. The distributions of the last spring occurrence and first fall occurrence of minimum temperatures of $\leq$ 32, 24, and 16 °F are plotted. The distance between related curves at a given probability is the maximum freeze-free period for that probability. For example, there is a 90 percent likelihood (0.90) that the last spring occurrence of $\leq$ 32 °F will occur on or after June 20, the first fall occurrence will occur on or before August 23, and the freeze-free period will be $\leq$ 62 days.

Growing Season. - Freeze-free periods as described are often used to define growing season. However, the freeze-free period does not always correlate well with actual plant response because it is difficult to: (1) establish the air temperature for defining the "killing frost" and (2) establish the duration of time during which the air temperature remains below the threshold air temperature. Also, frost can occur when measured air temperature is above 32 °F.

Many plants (particularly cool-season grasses) can "green-up" and remain green when air temperatures are below freezing. Although the plants are green, they are not actively growing. The synthesis of many studies suggests that the potential period of active growth for many temperate plants occurs when the average air temperature remains above 40 °F. Since the first warm spring day does not necessarily ensure that the growing season has begun, an end-element running mean air temperature is used to establish the beginning (and ending) of what is called the "potential thermal growing season." This information is important in selecting vegetation and estimating the success potential of revegetation activities.

In the usual calculation of a running mean, the average air temperature replaces the middle element in the run. For example, for a 7-day running mean, the average value replaces the 4th element in the run. If the running mean was used to define the growing season, it would imply that the plants know the temperatures for the next 3 days in advance. To solve this problem, the running mean average replaces the end-element in the run when it is used to define the potential thermal growing season.

Using the 1938-1979 weather record for Walden, the end-element 7-day running mean air temperature above 40 °F was calculated for each year. The probability that the 7-day running mean air temperature would be above 40 °F was calculated. This curve is shown on figure 8. This graph indicates that a potential thermal growing season of about 100 days is virtually certain. The median growing season length is about 150 days (probability of 0.50). Longer and longer growing seasons become less and less frequent, with a 200-day growing season occurring with a probability less than 0.01. These growing seasons are much longer than indicated in the freeze-free analysis. Also the season is shifted more towards the fall, because the final day of the 7-day running mean is used rather than

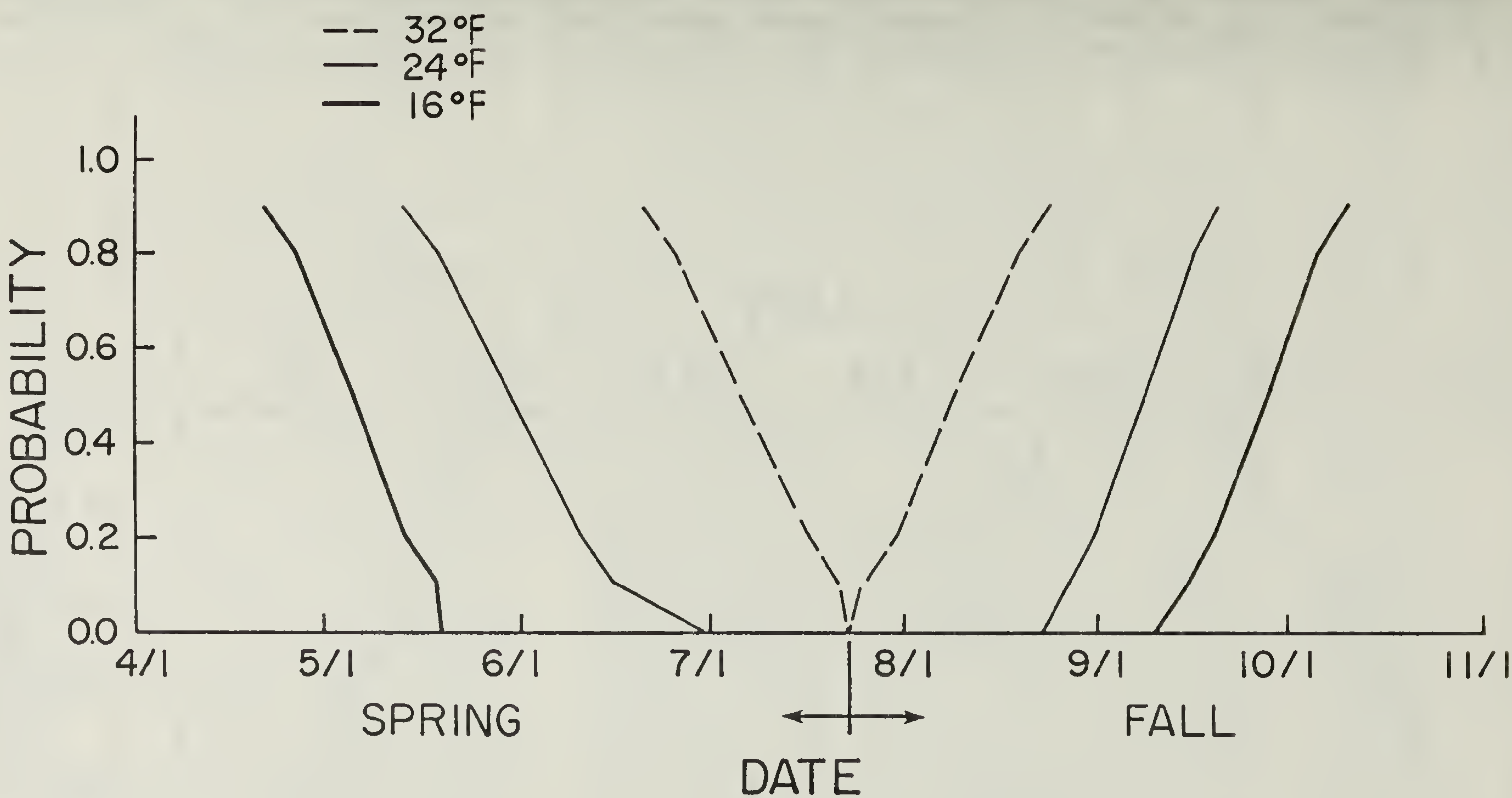


Figure 7. - Probability that the freeze-free period at Walden, Colorado, is equal to or shorter than the corresponding intervals between the spring and fall curves for 32, 24, and 16 °F. Spring curves show the probability distributions of the last occurrence each spring of temperatures ≤ each threshold. Fall curves show similar distributions of the first occurrence each fall of temperatures ≤ the same thresholds for the period 1951-1970.

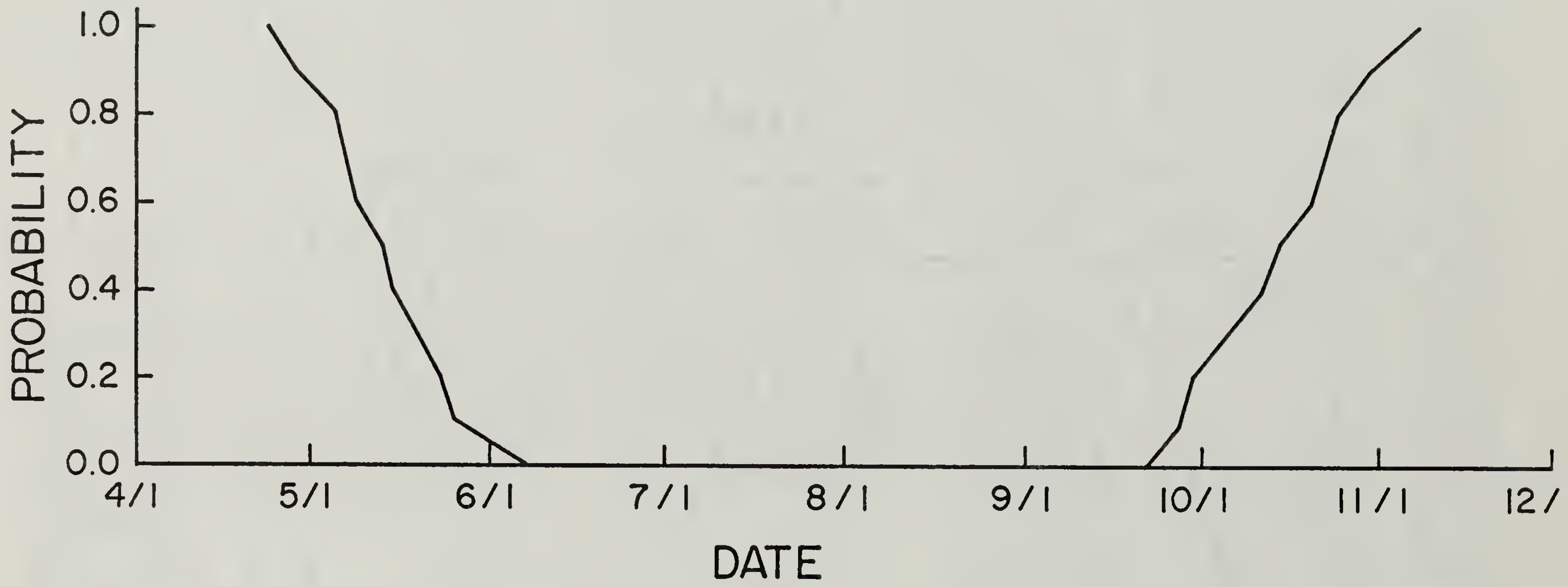


Figure 8. - Probability that the potential thermal growing season (the period of time that the end-element 7-day running mean air temperature remains continuously above 40 °F) is equal to or shorter than the corresponding interval between the spring and fall curves at Walden, Colorado, based on 1938-1979 data.

the midpoint and daytime temperatures, later in the season, continue to stay warm while nighttime readings drop quickly. Thus, the 7-day running mean temperature stays above 40 °F long after subfreezing nighttime temperatures begin to occur.

Late warm periods. - Figure 9 shows the probability of having at least one occurrence of a 3-, 5-, or 7-day period having a mean temperature > 40 °F at Walden after specified dates. These warm periods can lead to premature germination of fall-planted seed if moisture is available.

An example of the interpretation of this graph is: 50 percent of the time there is at least one occurrence of a 7-day period with a mean temperature > 40 °F after October 1. For a 3-day period, the equivalent 50 percent date is much later, October 18. There have been occurrences of 3-day periods with a mean temperature > 40 °F as late as December 1.

Extreme temperatures. - The probability that the daily minimum temperature will drop to various cold temperature thresholds on any day during the winter months at Walden is shown on figure 10. Temperatures of 0 °F or colder can occur at any time from October through April. From late November to early March there is at least a one in four chance on each day that the minimum temperature will fall to 0 °F or below. The first 10 days of January is the period most likely to experience severe cold.

Temperatures below 0 °F indicate a high probability of human discomfort. Of greater importance, in terms of reclamation, are the potential effects of extremely cold temperatures on vegetation. Temperatures < -20 °F have occurred from early November to early April but are most likely in January and February. While the probability on any given day of experiencing such intense cold never exceeds 0.10 for the winter as a whole, temperatures below -20 °F occur every year, and temperatures ≤ -40 °F occur about 1 year in 8. In the absence of snowcover, these cold temperatures can lead to winterkill of tender plants.

Probabilities of experiencing daily summer temperatures above various warm thresholds are shown on figure 11. Extreme heat is not a problem in North Park; however, temperatures above 75 °F occur regularly from June through September. Temperatures in excess of 85 °F occur relatively infrequently (maximum probability of only 0.05) and are most likely in mid- to late July and early August. These warm temperature extremes are not a severe hazard; however, they lead to rapid drying of topsoil and can contribute to moisture stress, especially in young plants. The period of highest probability of very warm temperatures thus must be accompanied by adequate precipitation (or supplemental water must be applied) in order to assure survival of new plant life in the reclamation area.

Precipitation Analyses

Several aspects of precipitation in North Park are described here. Emphasis is placed on areal distribution and seasonal variations of total precipitation along with frequency and intensity of heavy rain and snow events.

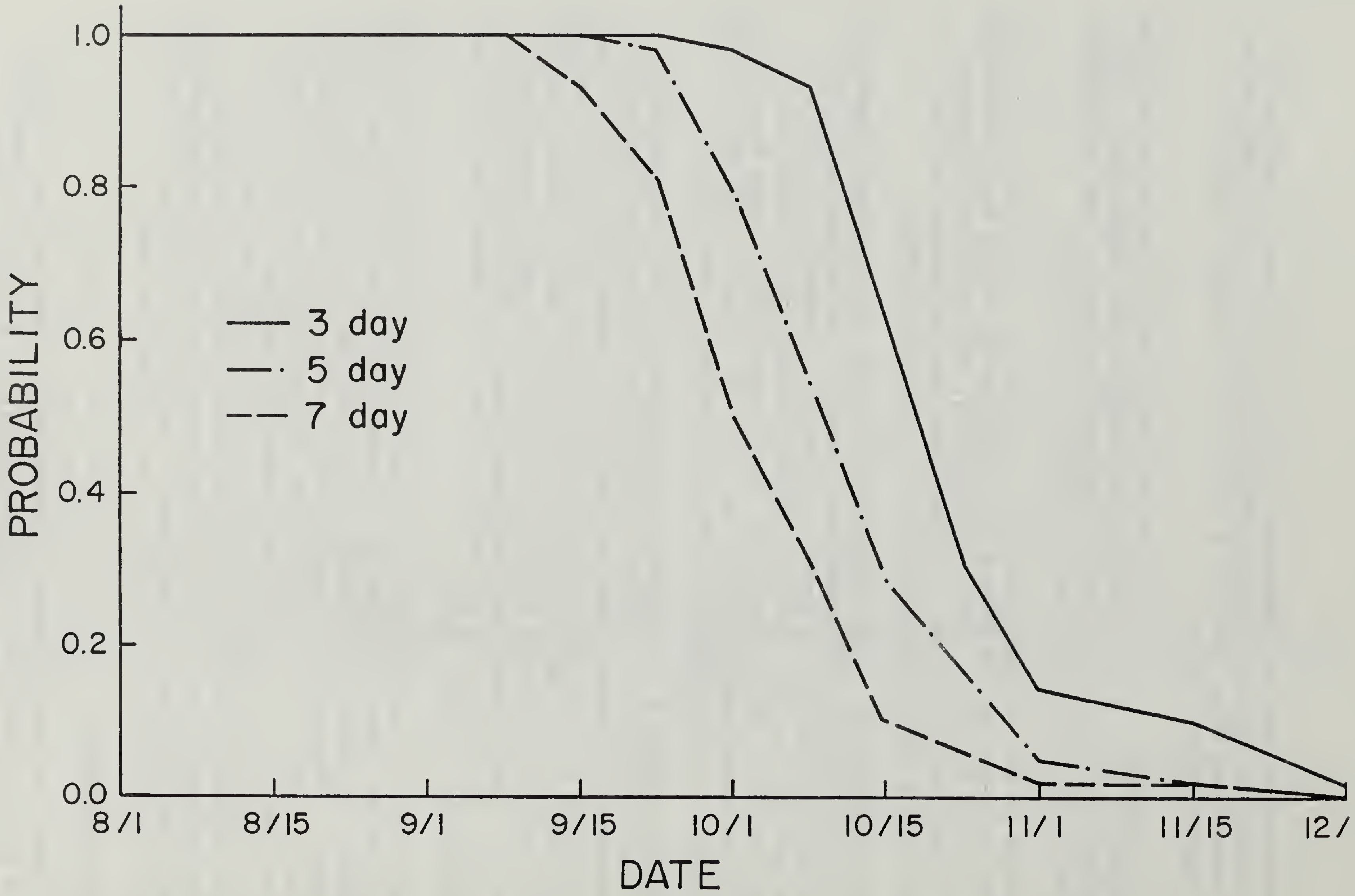


Figure 9. - Probability of at least one occurrence of an N-day period with

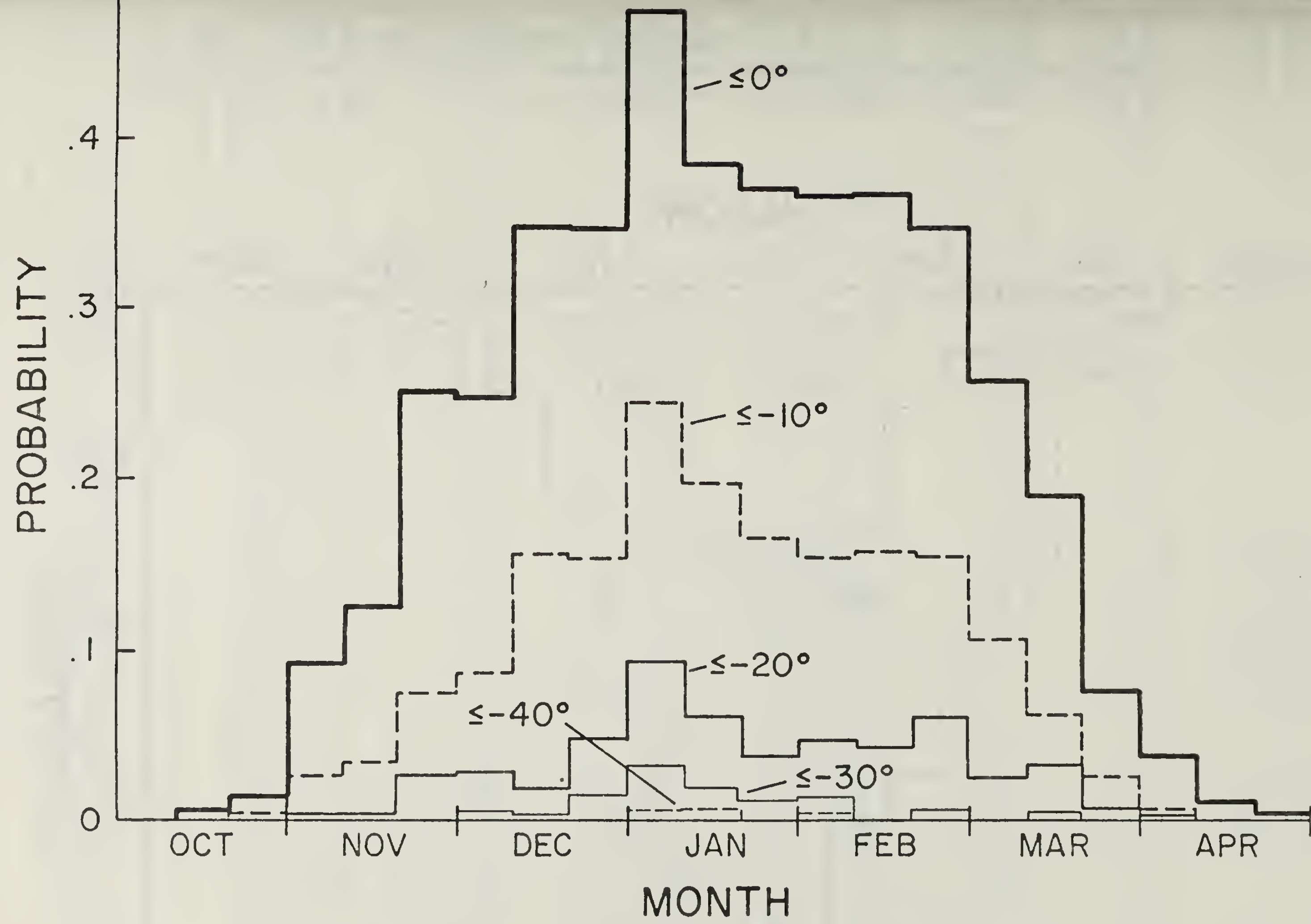


Figure 10. - Probability of daily minimum temperatures dropping to (a) ≤ 0 °F, (b) ≤ -10 °F, (c) ≤ -20 °F, (d) ≤ -30 °F, and (e) ≤ -40 °F. Probabilities averaged over one-third month intervals at Walden, Colorado, 1938-1980.

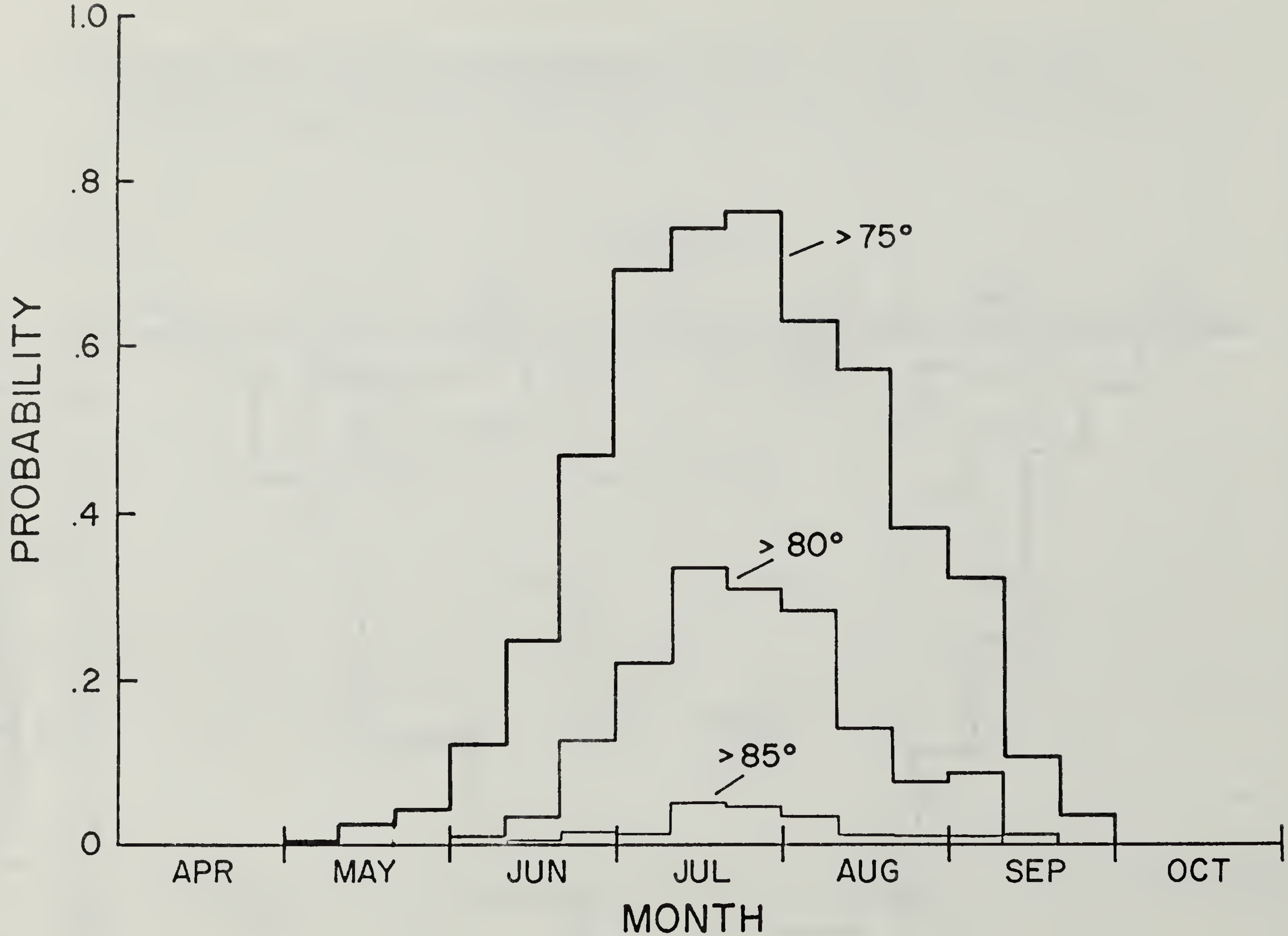


Figure 11. - Probability of daily maximum temperature exceeding (a) 75 °F, (b) 80 °F, and (c) 85 °F. Probabilities averaged over one-third month intervals at Walden, Colorado, 1937-1980.

McCallum Study Area precipitation. - The Walden Weather Station is the only long-term precipitation station near the McCallum Study Area. However, the McCallum Study Area is much closer to the Medicine Bow Mountains east of North Park. Data from available stations indicate summer averages ranging from 5.49 inches at Walden and 6.41 inches at Spicer to 8.36 inches at Gould. A good estimate for average summer precipitation in the McCallum Study Area is about 6 inches.

Combining estimates for winter and summer precipitation, average annual precipitation in the McCallum study is approximately 11 to 12 inches. Additional data collected in the area in the months and years to come will help evaluate this estimate.

Annual and seasonal variability. - Considerable year-to-year variability of both annual and seasonal precipitation occurs. This is highly significant in terms of vegetation selection and assessment of potential success for reclamation strategies.

A probability distribution of annual and seasonal precipitation for Walden is shown in figure 12. (Adjustments to these curves could be made to reflect the expected differences in average precipitation between Walden and McCallum Study Area.) Winter precipitation at Walden has ranged from 1.91 to 6.94 inches with a median value of 4.12. Fifty percent of the years the winter precipitation remains within 1 inch of the median.

The shape of the distribution of summer precipitation is similar to winter except near both ends of the distribution. This is because greater extremes relative to the median value occur during the summer. Summer totals have ranged from 2.40 to 10.18 inches, with a median value of 4.91. Sixty percent of all summers receive less than the average precipitation.

Since vegetation is limited by the driest years and seasons, it is important to examine the low ends of each distribution. Summer precipitation at Walden, less than 3.50 inches, occurs about 1 year in 10. In winter, 1 year in 10 receives less than 2.60 inches of precipitation. Plants chosen for revegetation must be able to tolerate these extreme conditions.

Some plants can survive water shortages but require considerably more water to become established initially. Therefore, there are only certain years when these plants can naturally germinate and become established. For example, if a plant species requires at least 7 inches of summer season precipitation to become established, the local climate will meet these demands only 1 year in 5.

Frequency and intensity probabilities. - The number and size of precipitation events are important in various aspects of reclamation. Since the only long-term precipitation records available in North Park are daily totals, this discussion is limited to precipitation events defined as 24-hour amounts.

The frequency and intensity of daily precipitation for a yearly period are presented on figure 13. The ordinate is probability, and the abscissa is number of days (N). Individual points on the graph are the probability

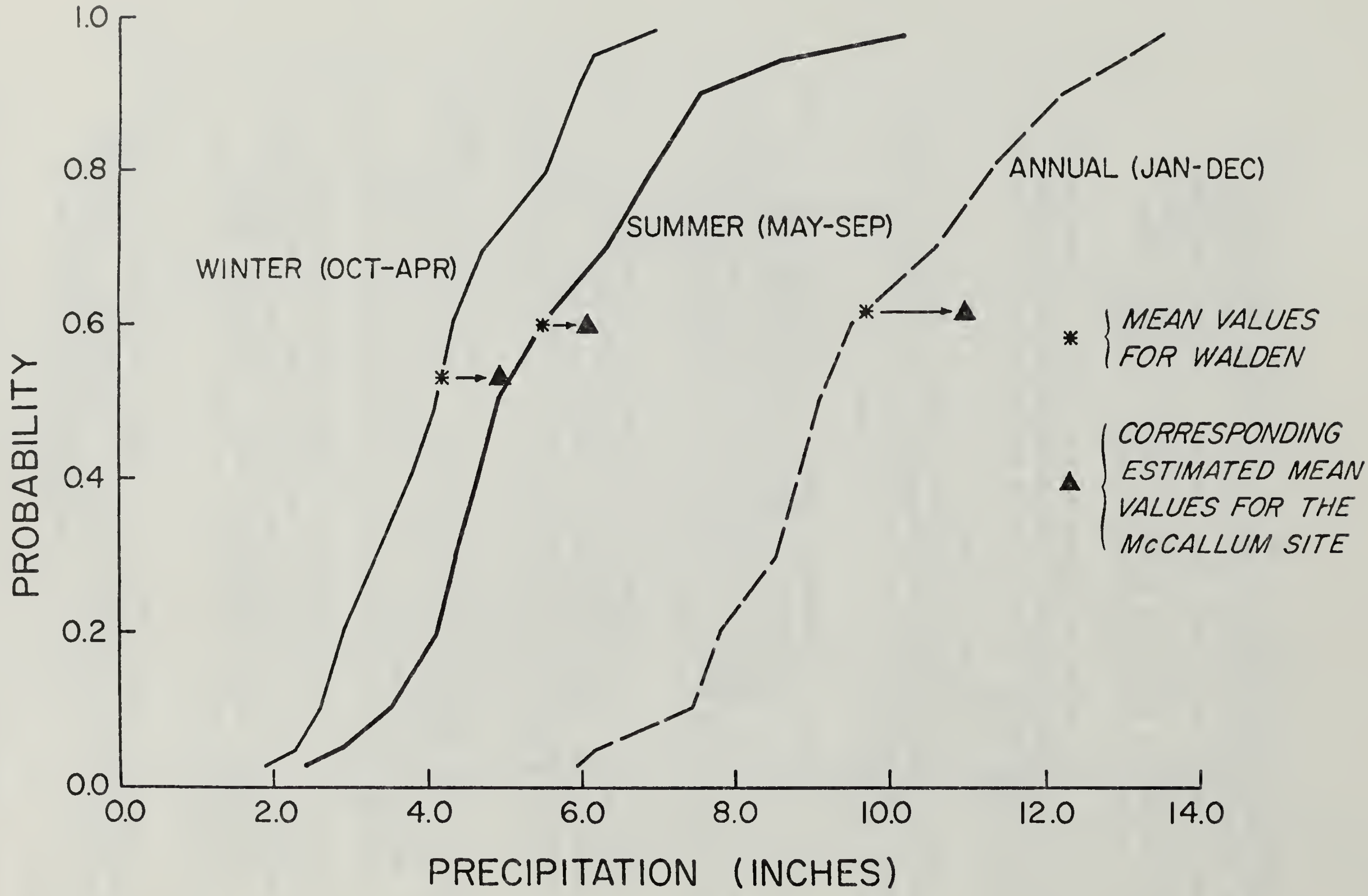


Figure 12. - Probability of receiving X inches or less of precipitation during winter, summer, and annually at Walden, Colorado, 1938-1980. Mean seasonal and annual values for Walden are shown with estimated mean values for the McCallum Study Area.

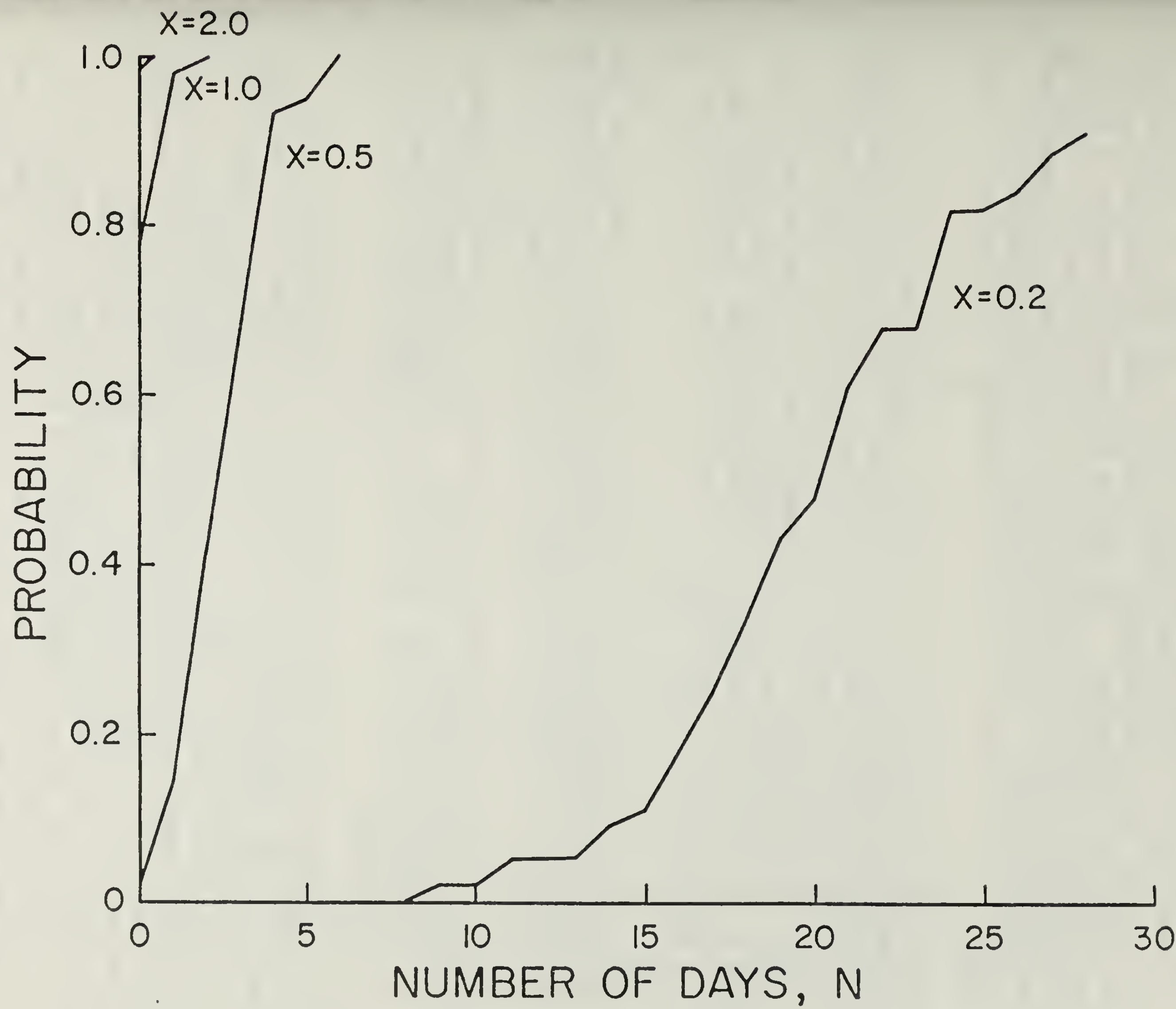


Figure 13. - Probability that year has N days or less of precipitation equal to or greater than X inches for Walden, Colorado, 1938-1979.

that a given year will have less than n days with precipitation greater than X, where X is the threshold value of precipitation for each separate line on the graph. The graph shows that for a threshold of 1.00 inch there is a 77 percent probability that no days will occur with greater than 1.00 inch of precipitation. There is a 98 percent probability that no more than 1 day will occur with greater than 1.00 inch of precipitation. It is not until the threshold is lowered to 0.20 inch that a significant number of days appear. The median (50 percent) number of days with precipitation equaling or exceeding 0.20 inch is about 20. There is a 10 percent chance that 15 days will occur and a 10 percent chance that more than 27 will occur. Thus, 80 percent of the years studied will have between 15 and 27 days with precipitation equal to or greater than 0.20 inch.

The implication of this graph for successful revegetation is striking. Significant precipitation events are required to substantially contribute to soil moisture content. However, in dry years, daily precipitation totals of 0.50 inch or greater may occur only one time or less. This would place severe moisture stress on young plants. In wetter years as many as four or five occurrences of precipitation events equaling or exceeding 0.50 inch can be expected. In such years, the likelihood for establishing vegetation is much higher. Typically three or less large storms ($\geq$ 0.50 inch) occur in a year.

These data indicate that the climate is so dry that it is likely that more than one attempt to revegetate will be required. Mulching, increasing the depth of topsoil, and/or providing supplemental water would significantly raise the chances of revegetation success on the first attempt.

The second implication from figure 13 is that large rain events capable of causing major erosion problems rarely occur. The low probabilities for 0.50- and 1.00-inch precipitation events have already been described. There is a 98 percent chance that no 1-day rain greater than 2 inches will occur in a given year.

Snowfall frequency and intensity. - Probability of daily snowfall at Walden is shown in Figure 14 in a form identical to figure 13. The only difference is that the X threshold values are in inches of snowfall. An immediate conclusion is that large daily snowfalls are very rare. In fact, a 6-inch daily snowfall has only occurred a maximum of three times in one winter. There is a 41 percent chance that a 6-inch daily snowfall will not occur at all. Figure 15 displays the same information for snowstorms instead of daily snowfall. A snowstorm is defined as the snowfall total for all consecutive days when daily snowfall equals or exceeds 1 inch. The change of definition has a small but noticeable effect on probabilities. For example, there is a 22 percent chance of not getting a 6-inch storm in a given winter, and there have been as many as four 6-inch storms in one winter.

These snowfall statistics require some modification for use in the McCallum Study Area. Since winter precipitation is likely to be higher than at Walden by about 15 to 25 percent, both the number and size of storms are

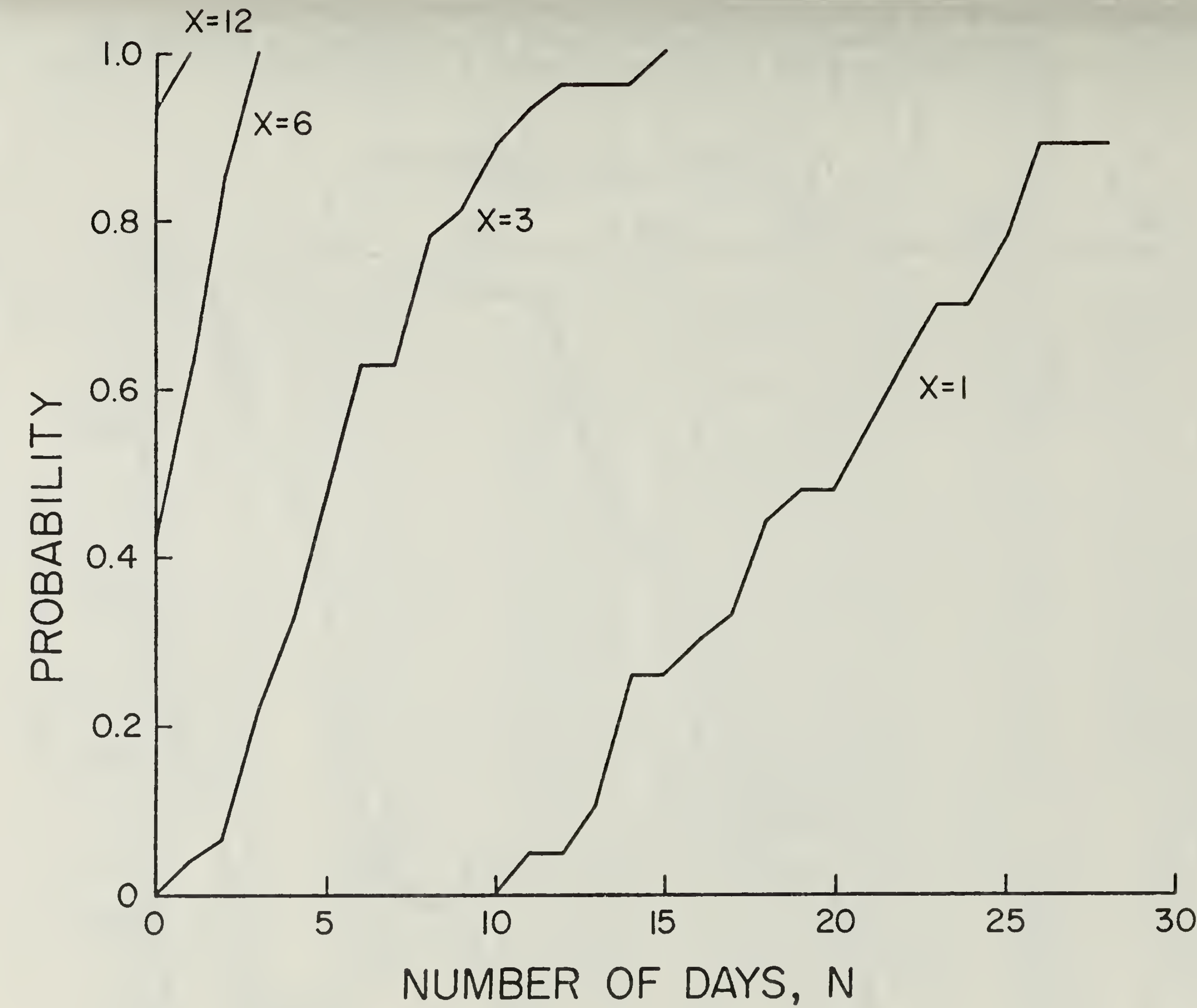


Figure 14. - Probability that a winter season has N days or less of snowfall equal to or greater than X inches for Walden, Colorado, 1938-1980.

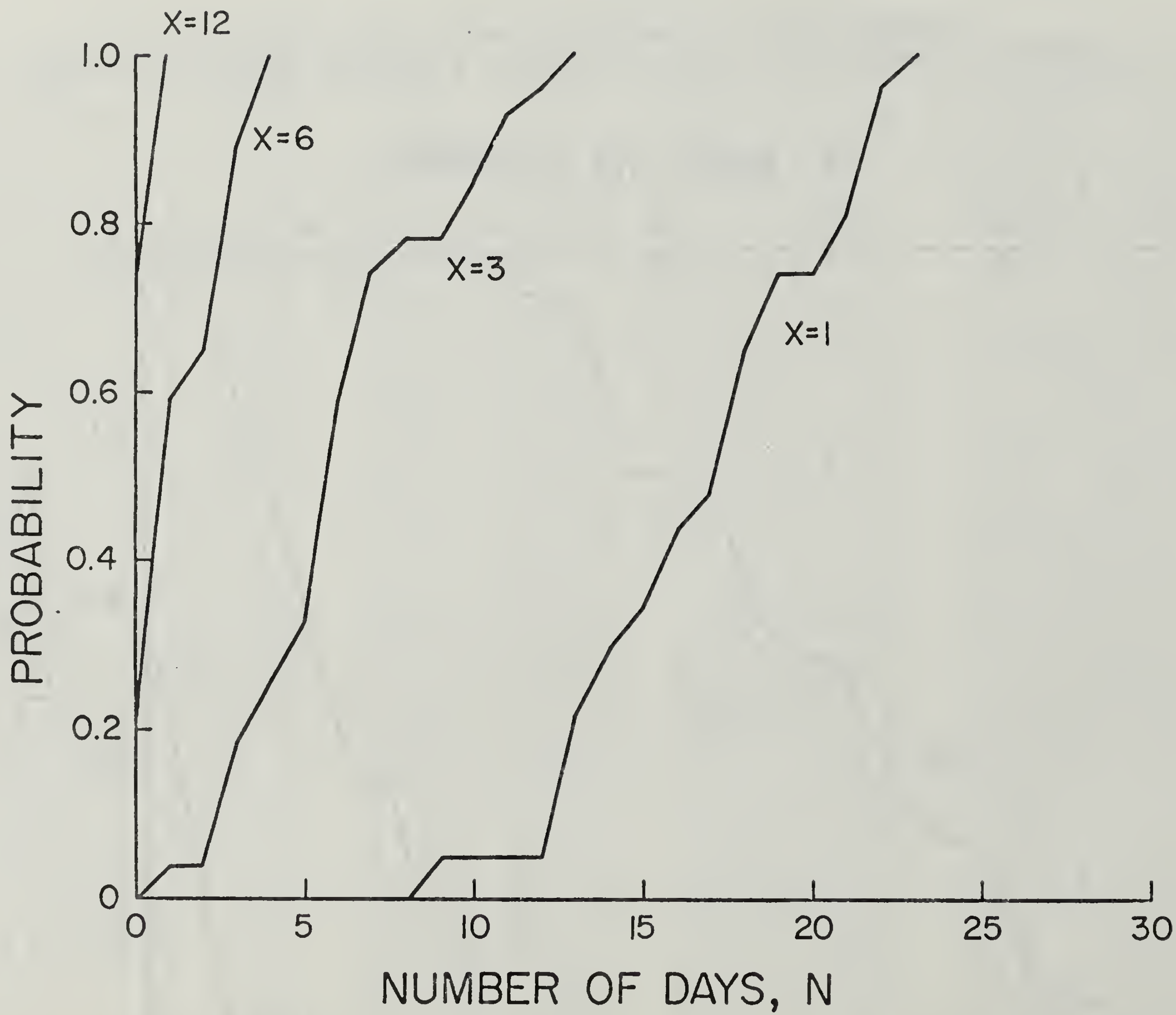


Figure 15. - Probability that a winter season has N storms or less of snowfall equal to or greater than X inches for Walden, Colorado, 1938-1980.

probably increased. Without data it is difficult to make any confident estimates of these differences, however, general conclusions are the same. Snowfall is not excessive and can be very light in some years. Because single storm snowfall totals are not large, driving conditions and mobility should not be greatly restricted bv snowfall alone throughout the winter. The worst problems will be caused by blowing and drifting of the existing snow by the strong winds which buffet the area.

Snow accumulation and snowmelt. - The amount of snow on the ground during the winter months is significant from several perspectives. Snow affects surface mobility, acts as an insulating blanket to protect plants from extreme cold, and contributes to the soil moisture as it melts.

The probability of having snow on the ground on any given day at Walden exceeding the thresholds of 0, 4, and 10 inches is shown on figure 16. (Again, it should be remembered that somewhat greater snowfall, and hence snowdepth, is expected in the McCallum Study Area compared to Walden.) Measurable snow may stay on the ground anytime from September through May. From late November until mid-May there is a greater than 50 percent probability that at least an inch of snow will be on the ground on any given day. However, even in midwinter when temperatures tend to be coldest, there is a 1 in 10 chance that very cold temperatures will occur when there is little snow on the ground to protect vegetation.

Snowdepths in excess of 4 inches at Walden never achieve a probability in excess of 0.50. The windy conditions of North Park can easily blow 4 inches of snow off areas, leaving smooth, exposed surfaces. As a result, topsoil erosion as well as winterkill of plants may be a problem. Increasing surface roughness and/or constructing snow fences may be required to reduce these problems.

There can be extreme variability of snowdepth throughout the winter and from one year to the next. The most likely periods to experience deep snow are in early January and again during late January and most of February. However, the probability of having more than 10 inches of snow on the ground on any given day never exceeds 0.20.

The period of maximum snowmelt in the Walden-McCallum area occurs during March. (Note the rapid decrease in snowdepth probabilities on figure 16.) This has a bearing on surface moisture, access, and erosion. Extremely muddy conditions can be expected until well into April and May following wet winters. However, the water content of the snowpack is generally not excessive. Daytime temperatures during March and April rise above freezing regularly, but nighttime temperatures generally fall back below freezing. As a result, the snowmelt rate is retarded and significant erosion usually is not a problem.

int Analyses of Temperature and Precipitation

ants respond not solely to temperature or precipitation but to a combination of all climatic elements.

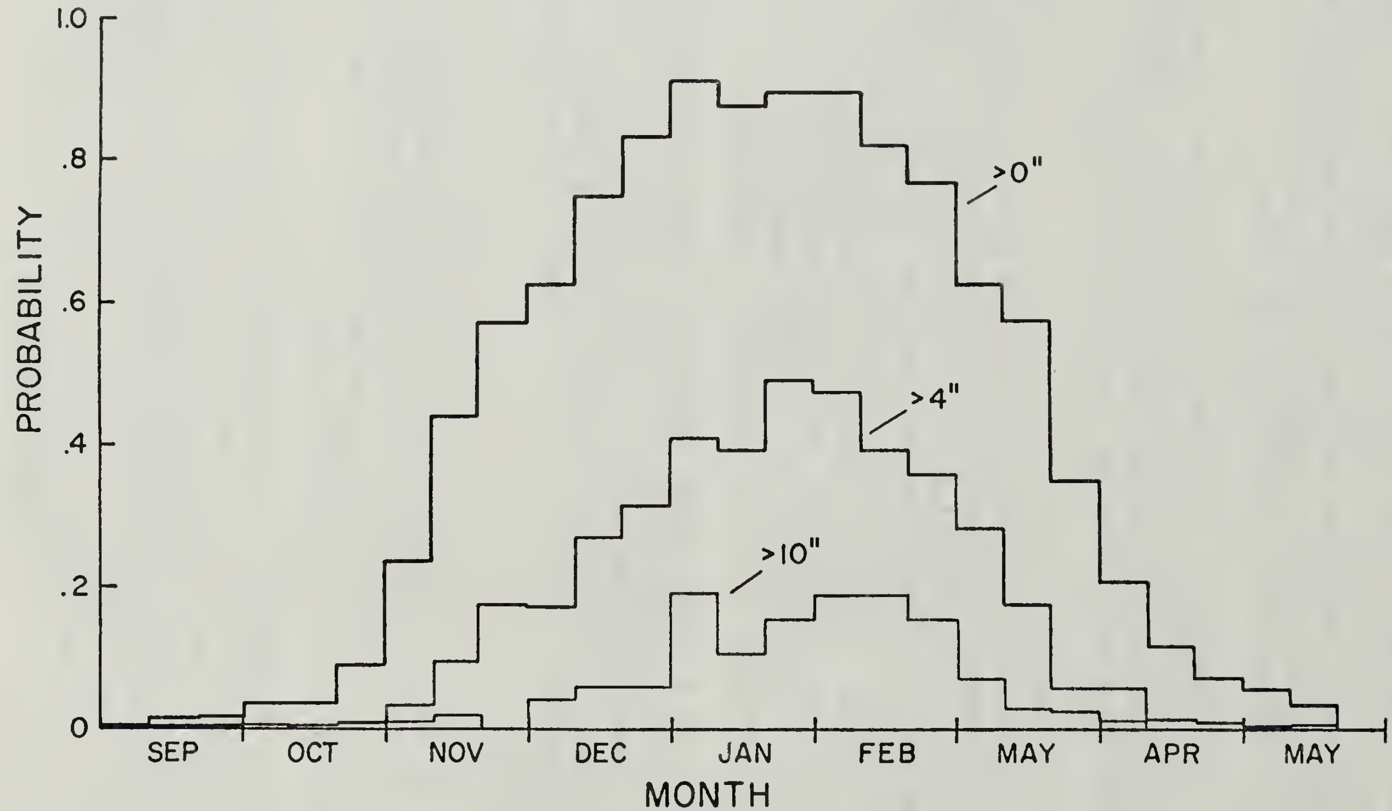


Figure 16. - Probability of having snowdepth on the ground exceeding (a) 0 inch, (b) 4 inches, and (c) 10 inches. Probabilities averaged over one-third month intervals at Walden, Colorado, 1938-1980.

Growing season - joint probablility. - The potential thermal growing season is "potential" in that active plant growth could potentially occur during this period if soil water were continuously available. To calculate the occurrence of favorable periods of both air temperature and soil water would require determining a complete soil water balance. Unfortunately, the necessary data are unavailable for virtually all revegetation sites. However, rainfall amounts above a reasonable threshold over a period of a few days can be used as a surrogate for the soil water balance of the surface layer. Once the probabilities of the rainfall amount above a given threshold for a given time period are determined, the joint probability of both air temperature and rainfall can be calculated.

For the Walden data the probability of at least 0.20 inch of rain occurring within a 3-day period was used to represent the minimum requirements for growth for newly established plants.

Figure 17 illustrates the joint probability of at least 0.20 inch of rain within a 3-day period and a 7-day end-element running mean air temperature above 40 °F (potential thermal growing season). The potential thermal growing season influences the joint temperature-rainfall probability for the first 45 days in the spring and the last 50 days in the fall. Between the first of June and mid-September, the rainfall probability alone determines opportunities for active growth. As temperatures warm in the spring, the joint probability gradually rises to above 0.20 in early June. The joint probability then decreases from about the first week in June to a minimum in the first week in July and again increases to a high in the last week in July. Thereafter, the joint probability erratically decreases until temperature again becomes the primary control.

The joint probability analysis has direct implications for plant growth and survival. Although the exact significance of probability thresholds are not known, some periods are clearly better suited for plant growth than others. For example, if one examines the 0.25 joint probability level across the graph (fig. 17), four short periods occur that might be especially favorable for active growth once every 4 years. Considering the 0.10 (1 year in 10) joint probability level, two long periods favorable for active growth can be expected. However, note the low probability for rain between late June and early July. This dip in the joint probability suggests a low survival rate for new vegetation without the help of irrigation during this high stress period. This example serves to illustrate the uncertainties of favorable periods for active growth. The probabilities are average and bear no significance for any individual year of interest. The joint probability simply illustrates the harsh conditions that newly established plants would encounter.

Growing season potential evapotranspiration minus total precipitation. - Potential evapotranspiration at Walden, calculated by the Blaney-Criddle method [3], is approximately 23 inches between April and September as seen on figure 18. The average rainfall for the same period is about 7 inches resulting in a moisture deficit of 16 inches. Figure 18 dramatically illustrates the limitations for optimum growth on a revegetated site near Walden. This, however, is not of direct practical use since

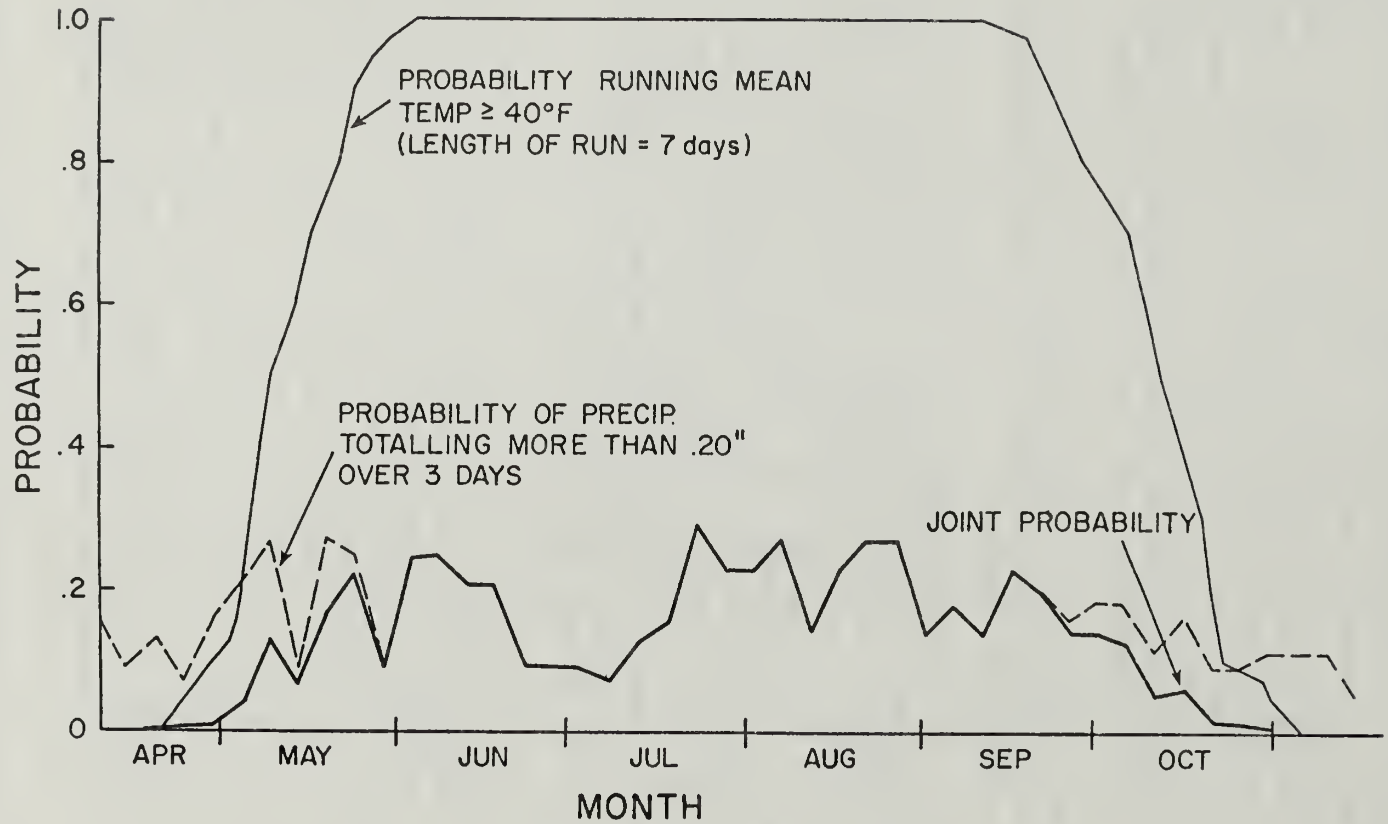


Figure 17. - Probability of receiving significant precipitation during the growing season at Walden, Colorado, 1938-1979. Thin solid curve is the probability of being in the thermal growing season. Dashed curve is the probability of receiving more then 0.1-inch precipitation in 3 days. Thick solid curves are the joint probability of the other two curves.

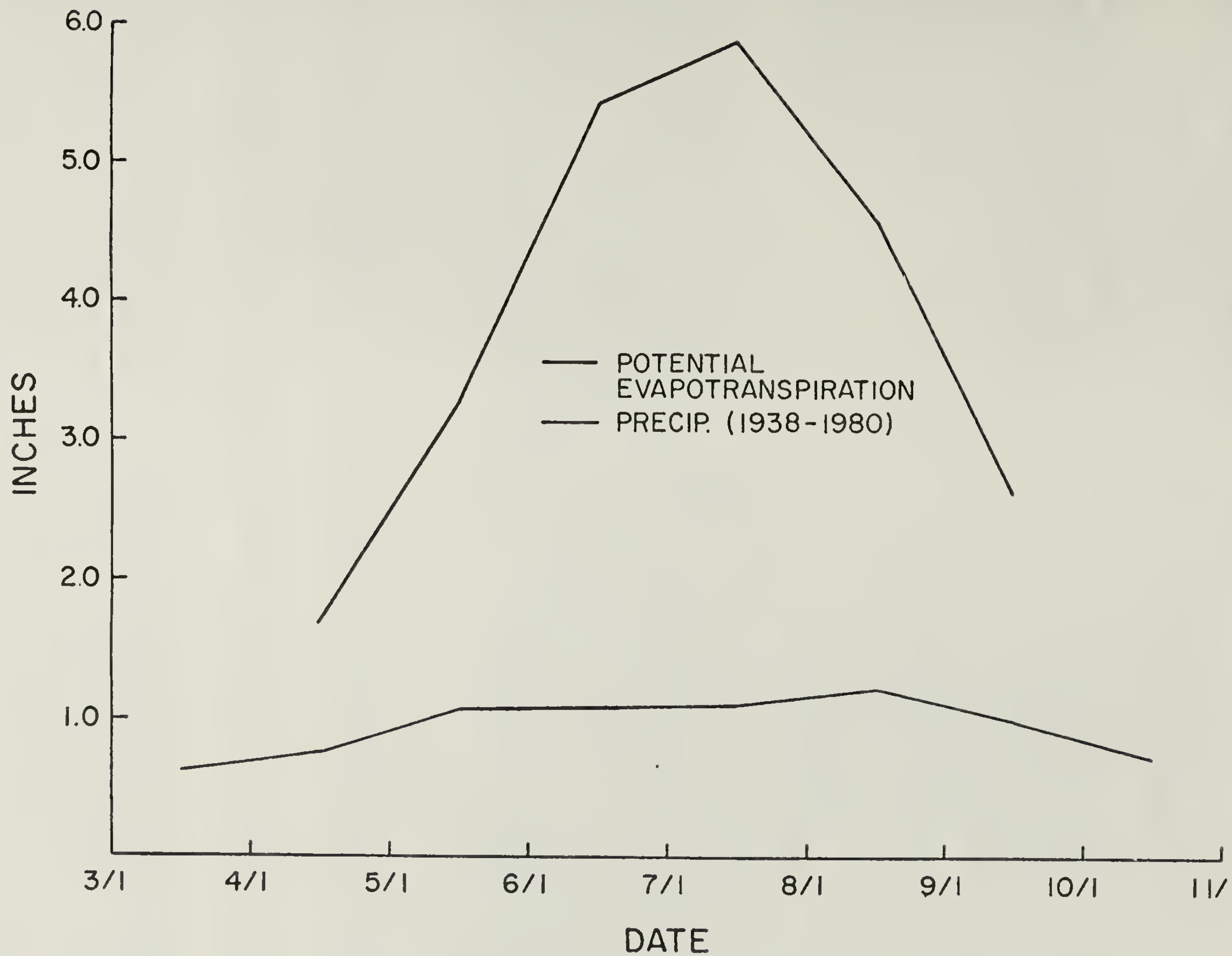


Figure 18. - Monthly evapotranspiration (calculated by the Blaney-Criddle Method) and average monthly precipitation for Walden, Colorado, 1938-1979.

water deficits calculated from potential evapotranspiration estimates apply only when the concern is for optimum conditions for maximum production. This high level of production need not be reached since regulations only require revegetation sites to be restored to production levels equivalent to native plant productivity.

ENVIRONMENTAL PROFILE

Biological Resources

The McCallum Study Area provides habitat for a variety of wildlife species associated with the sagebrush-grassland ecosystem. The more common species expected to inhabit the area are:

Possible mammals	Possible/probable birds
White-tailed jackrabbit	Marsh hawk
Cottontail rabbit	Red-tailed hawk
Richardson's ground squirrel	Swainson's hawk
Sagebrush vole	Golden eagle
Coyote	Prairie falcon
Red fox	Sage grouse
Badger	Mourning dove
Striped skunk	Horned lark
Mule deer	Sage thrasher
Pronghorn	Sage sparrow
	Brewer's sparrow

Some 60 to 70 antelope utilize the Study Area during at least part of the year. This group of antelope is a segment of a herd unit estimated at 100 to 150 in number and inhabit the area bounded by Cameron Pass on the south, Colorado State Highways No. 125 and 14 on the west, the foot of the Medicine Bow Mountains on the east, and the Wyoming State line on the north. The Colorado Division of Wildlife has designated this area as Antelope Unit A8. Antelope does and fawns were observed within the Study Area. The succulent grasses and forbs available in Brush Draw in spring and early summer provide highly nutritious forage and may attract lactating does to the area.

Mule deer migrate through the area en route to lower elevational winter ranges between Walden and Cowdrey. Some deer winter on the south-facing ridges and slopes west of the Study Area.

Elk are not known to use the site, but have been observed north in the McCallum oil field in past winters.

Small mammal and songbird data are lacking in the McCallum Study Area. Those species listed in the North Park URA (Unit Resource Analysis) associated with the sagebrush ecosystem can be expected to inhabit the site. The few species of songbird and small mammals listed earlier are known to inhabit the Study Area and adjacent similar habitat; however, biological factors such as population numbers, distribution, habitat requirements, etc., for these species are unknown at this time.

The raptors listed, excepting the bald eagle, are common users of the area. Hunting for prey food species is the most important raptor use of the area. Prey species available for raptors in the Study Area include those small birds and mammals listed. Isolated patches of quaking aspen located northwest of the Study Area provide perching, roosting, and nesting habitat for raptors. An active golden eagle nest located 1 mile northwest of the Study Area produced two eagles during the 1979 nesting season. Prairie falcons, marsh hawks, red-tailed hawks, and Swainson's hawks are commonly observed hunting in the study area. Nests of these species have not been documented in the Study Area.

There are no aquatic wildlife or wild horses using the Study Area.

Sage grouse are known inhabitants of the McCallum Study Area and nearly all of the remaining sagebrush habitat in North Park as well. Most of the study area provides suitable sage grouse nesting habitat and at least one lek. The lek, located adjacent to Williams Draw in section 23, was the focal point of the Federal Coal Management Program funded Sage Grouse Study which was contracted to the Colorado DOW. The Sage Grouse Study was initiated as an attempt to assess the potential impacts of strip mining on sage grouse in North Park.

To assess these impacts, the study identified critical seasonal ranges and specific habitat preferences of sage grouse in areas to be disturbed by mining. A copy of the final Sage Grouse Study Report is on file in the BLM District Office at Kremmling, Colorado.

Results of the study indicate that sage grouse select winter, breeding, nesting, and brood-rearing habitats on the basis of suitable vegetative structure and probably sagebrush species and subspecies composition. Also, sage grouse do not necessarily move elsewhere and maintain the same populations present prior to disturbance of preferred habitats. If populations of sage grouse are to be maintained, mitigation and rehabilitation must be developed to provide year-round habitats for sage grouse.

Several mitigation techniques should be considered. Among methods of reducing and mitigating impacts on sage grouse resulting from mining are:

- Maintainence or protection of preferred habitats where possible.

- Limiting disturbance adjacent to and on winter concentration areas impacted by mining.

- Limiting disturbance adjacent to leks and on preferred FL (feeding-loafing) areas used by males around leks. Avoidance of road construction and placement of overburden piles adjacent to leks, preferred FL areas, and in flight paths of males moving from the lek to FL sites.

- Curtailing explosions during the mating period (1 hour before to 1 hour after sunrise) from March 15 to June 1.

- Reducing or eliminating grazing in areas around leks.

- Fertilization of undisturbed preferred habitat and areas adjacent to coal mines may be useful, but needs further documentation.

- Obtaining financial support from coal companies to monitor sage grouse movements and habitat use prior to and throughout the mining period and developing better techniques to reestablish the sagebrush community on reclaimed areas.

Sage grouse require a diversity of habitat types throughout the year. Therefore, rehabilitation of sage grouse habitats must concentrate on restoring the diverse habitat structure present before mining.

Possible rehabilitation techniques include:

- Creating topographic diversity in habitat. Flatter, open areas (less than 10 percent slope) are used extensively during the breeding season whereas draws and swales with high sagebrush canopy cover and large plants are important in winters with heavy snowfall. Windswept south-facing ridges and hilltops also are important in winter. Draws where lush herbaceous growth dominates rather than sagebrush are important for broods in early summer and also are used by unsuccessful hens and cocks.

- Transplanting and/or seeding of native grasses, forbs, and especially sagebrush. Special consideration should be given to species and subspecies of sagebrush preferred by sage grouse. Big sagebrush (Artemisia tridentata) is preferred over alkali sagebrush (A. longiloba) in the Study Area. Wyoming big sagebrush (A. t. wyomingensis) is preferred over mountain big sagebrush (A. t. vaseyana).

- Transplanting and/or seeding of sagebrush throughout reclaimed areas and creation of "patchy" areas with denser stands of sagebrush in draws and swales where greater moisture can support better sagebrush cover. Sagebrush density (average) should be at least three plants/m^2.

- Fertilization of reclaimed areas should be periodically done until sagebrush, forbs, and grasses are well established.

- Irrigation of reclaimed areas to provide ample moisture during the growing season and building of snow fencing to hold snow on reclaimed areas for additional early spring moisture.

- Strive to create a diversity in sagebrush structural types to meet sage grouse habitat requirements during all seasons. Preferred FL habitats are those between 25 to 50 percent sagebrush canopy cover and 25 to 41 cm sagebrush height. Large plants and high canopy cover are preferred at FL sites during winters with heavy snowfall. Nesting hens also prefer excellent cover and larger plants. Small plants and lower canopy cover are preferred at FL sites during the breeding season and low canopy cover (11 percent) and sagebrush height (10 cm) are found at leks. Sage grouse prefer vigorous stands of sagebrush with an average of 75 percent foliation of sagebrush plants.

Cultural Resources

Presently, about 72 percent of the Study Area is inventoried for cultural resources. Nine cultural sites are identified (see table 3). Seven prehistoric sites are identified as open lithic scatters or areas exhibiting the by-products and waste products of stone tool manufacture. One prehistoric site has a subsurface deposition of cultural remains. The single historic site is the relatively recent Conrad Coal Mine.

The prehistoric sites are located either on higher vantage points or on the adjacent flatter sage-covered areas, especially close to intermittent water sources. Previous cultural resource studies in North Park have reinforced the location of these sites in that the high ground was important for game or people spotting and the proximity to water as an incentive to camp and work area location.

The historic site is located relative to coal outcrops in the area. Historic sites also tend to occur in relatively flatter areas, especially in proximity to water sources and ease of access.

As the remainder of uninventoried portions within the Study Area may contain these types of locations, the potential for locating further sites is correspondingly high. Contact BLM Area Archeologist or District Archeologist if additional site-specific information is necessary.

The BLM's CR (Cultural Resource) responsibility for coal leasing is effective through the memorandum of agreement between BLM, USGS, and OSM (Office of Surface Mining) for the Federal Coal Management Program.

Upon lease application, the BLM enters into an EA (Environmental Assessment) which assesses existing CR data and recommends complete inventory and evaluation for the entire tract prior to mine plan approval through the EA and Unsuitability Criteria Application. OSM requires complete inventory and evaluation of all CR prior to mine plan approval. Once coal is leased in approved areas, Standard Coal Lease Stipulation 14 covers CR located as a result of construction operations.

Table 3. - Cultural resource site summary

Site No.	Legal	Description	Significance	Recommended action
			Professional judgment rendered by contract Archeologist and/or BLM Archeologist National Register of Historic Places - eligibility	All Sites: determine eligibility to NRHP. Determine effect for NRHP-eligible sites. Protect/ mitigate in consultation w/SHPO and ACHP
5JA171*	9 N., 78 W., sec. 28, NW1/4	Open lithic scatter - possible lookout	Not eligible	No further action
5JA195*	9 N., 78 W., sec. 28, NW1/4	Open lithic scatter	Not eligible	No further action
5JA196*	9 N., 78 W., sec. 28, NW1/4	Open lithic scatter	Not eligible	No further action
5JA200*	9 N., 78 W., sec. 23, SE1/4	Open lithic scatter	Not eligible	No further action
5JA201*	9 N., 78 W., sec. 23, SE1/4	Open lithic scatter	Not eligible	No further action
5JA213**	9 N., 78 W., Sec 22, SW1/4	Open lithic scatter	Not eligible	No further action
5JA415***	9 N., 78 W., sec. 27, NE1/4	Exposed subsurface cultural deposition	Need more information	Test to determine NRHP eligibility if to be impacted
5JA416***	9 N., 78 W., sec. 26, SW1/4	Open lithic scatter	Not eligible	No further action
Conrad Coal Mine (historic site)	9 N., 78 W., sec 27, SE1/4	Historic coal mine	Not eligible	No further action

* Preliminary Report of a Class III Cultural Resources Inventory of BLM coal lease tracts in N.P., Jackson County, Colorado; Lischka-Miller, 1978, C.U., Boulder.
** An archeological reconnaissance of a pipeline alinement and three oil well locations, Jackson County, Colorado; McNamara-Jennings, 1979, C.S.U./L.O.P.A. Report No. 31.
*** Powers Elevation Company for Kerr Coal Colorado, October 1979 (personal communication PEC).

Visual Resources

The visual resources of the McCallum Study Area are similar to those of the surrounding North Park Area. The VRM (Visual Resource Management) Class for the area is designated as Class III and Class IV (see fig. 19).

In VRM III areas, management activities may cause visual contrasts that are evident and may begin to attract attention but should remain overall subordinate to the existing landscape. In Class IV areas visual contrasts from management activities may attract attention and be a dominant feature within the landscape in terms of scale (of importance vs. surrounding landscape) or size, but should borrow from or blend in with the elements of the surrounding landscape (form, line, color, texture).

The primary purpose for assigning VRM classes is to determine the allowable range of contrasts of a proposed project or action [4]. We arrive at these VRM classes by overlaying an area's scenic quality, distance zones, and visual sensitivity levels through use of a combination matrix [4].

A proposed management activity may create contrasts greater than the allowable limit. In this case mitigating measures are implemented to reduce this impact. Examples of these measures include, but are not limited to, screening with natural or artificial materials, revegetation, recontouring, feathering sharp lines, contouring road alinements and erosion control.

Environmental design skills should be called upon to determine the appropriate techniques.

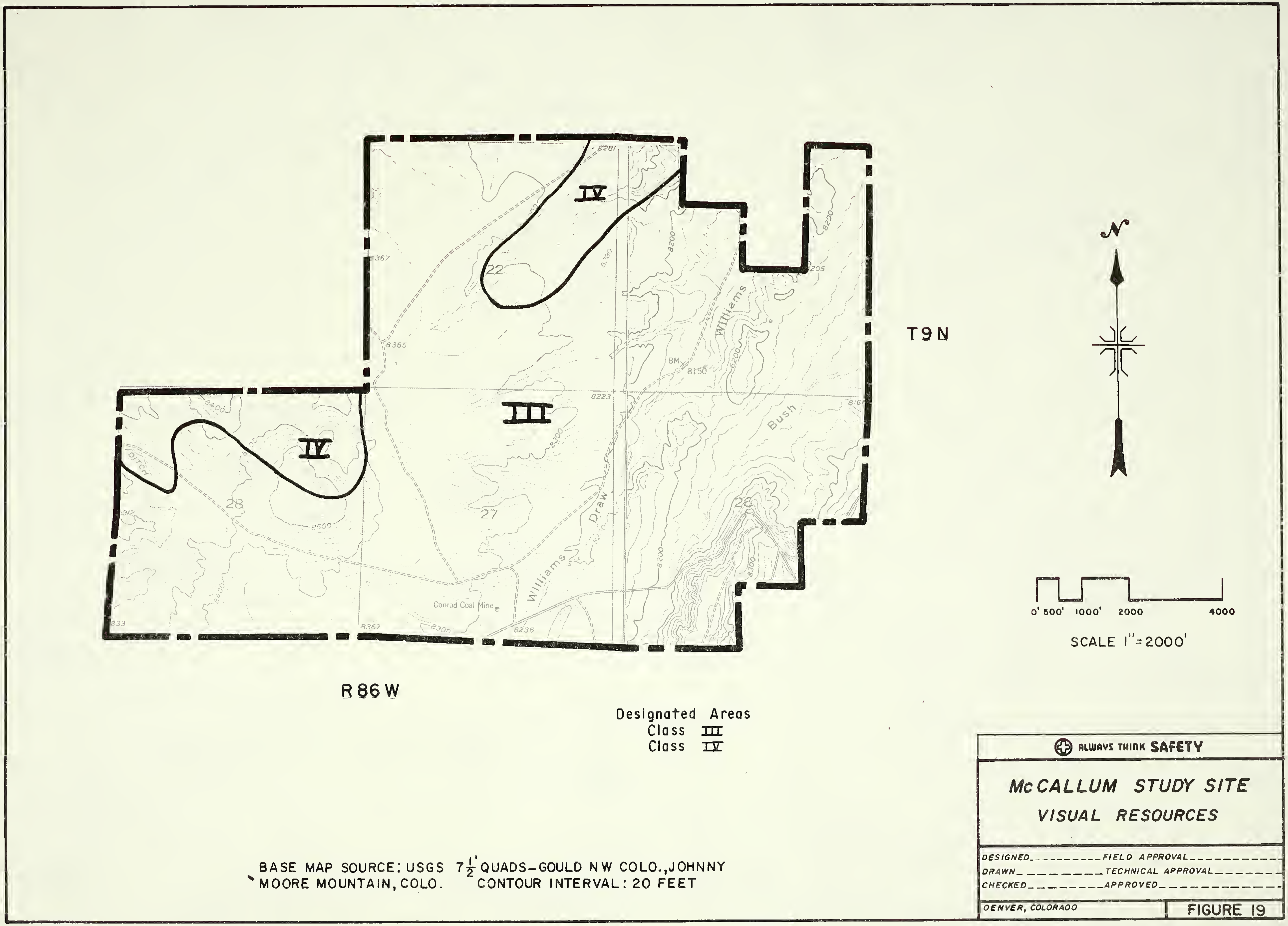


Figure 19. - Visual resources designated areas.

PHYSICAL PROFILE

Geology

Area Geology

The McCallum Study Area is located approximately 8 miles east of Walden, Colorado, in Jackson County. The area lies in the northeastern portion of an intermontane basin known as North Park which is located at the north end of the Southern Rocky Mountains physiographic province [5]. North Park is bounded on the northeast by mountains of the Medicine Bow Range; on the southeast by mountains of the Front Range; on the south by mountains by the Rabbit Bars Range; and on the west by mountains of the Park Range. These mountains rise to altitudes of 11,000 to 13,000 feet, while the floor of the park is characterized by a rolling topography averaging 8,100 to 8,300 feet above sea level [6].

North Park is drained by the North Platte River which flows northward into Wyoming. The Platte is fed by tributaries having headwaters in the mountains surrounding the park. The streams are fed primarily by meltwater from snow and ice found on the slopes and in cirques at high altitude. The major tributaries are the Canadian River, Michigan River, Illinois Creek, Grizzly Creek, and Rock Fort [7].

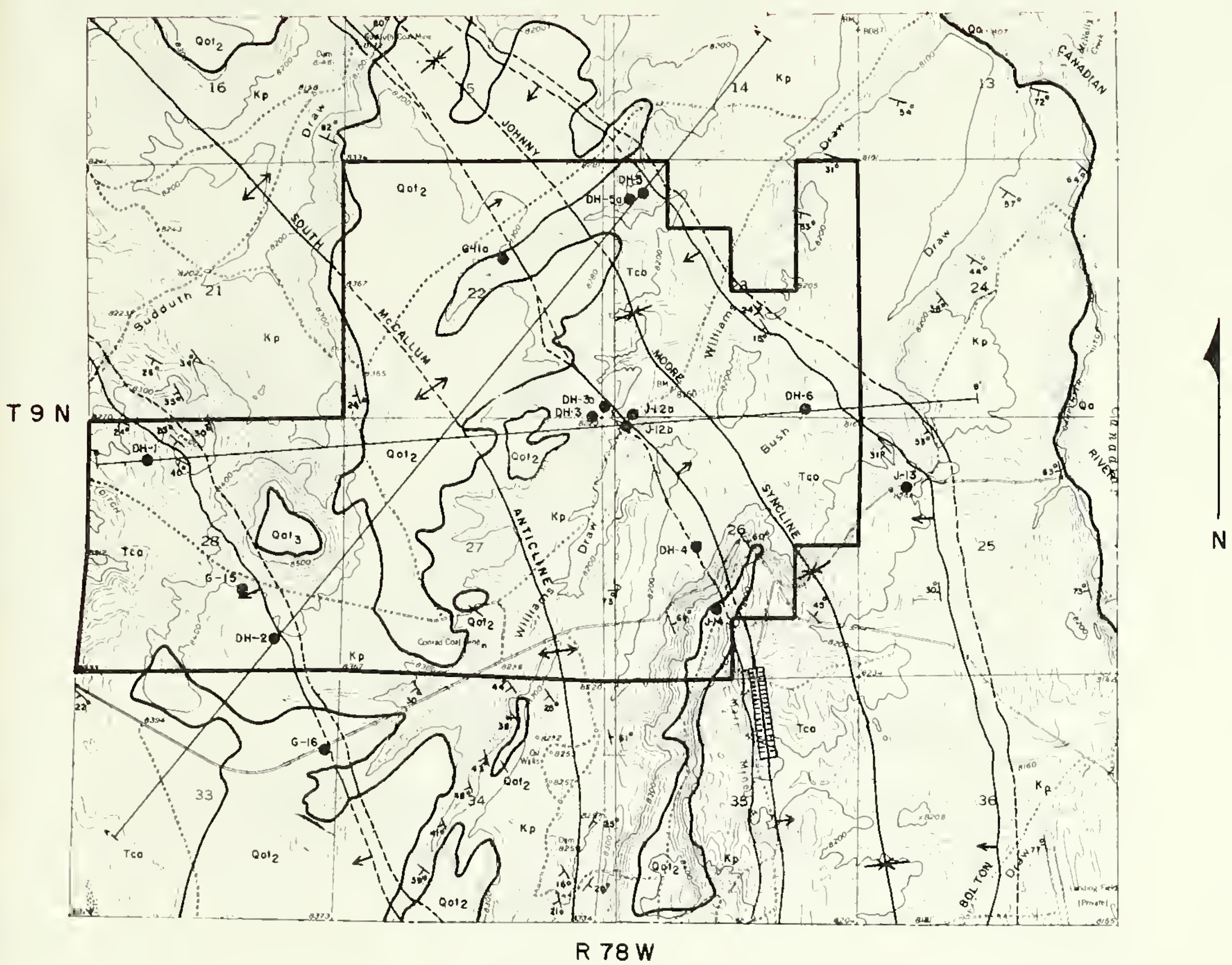
The Canadian River has its headwaters in the Medicine Bow Mountains about 10 miles southeast of the Study Area, and flows in a northwest direction and joins the North Platte River about 11 miles northwest of Walden. The tributaries on the east side of the Canadian River are small but have a constant flow. They have their source in the timbered slopes of the Medicine Bow Mountains. Tributaries on the west are intermittent streams that flow only after rainy periods [7]. This condition typifies the Study Area.

The Study Area is drained by a series of northeast-flowing intermittent streams (fig. 20). The two major streams are Williams Draw and Bush Draw which flow into the Canadian River about 1 mile northeast of the Study Area. Drainage patterns in the area are primarily dendritic.

The land surface in the Study Area is gently rolling and dissected by the intermittent streams. The highest point in the area is a hilltop in Section 28 with an elevation just over 8540 feet. The lowest point is 8,100 feet where Williams Draw leaves the Study Area in Section 23. Maximum relief in the area is about 440 feet. Slopes in the Study Area range from about 2 percent in the north to about 23 percent in the southeast. Figure 21 shows the McCallum Study Area topography.

Regional Geology

North Park is a large structural and topographic basin formed by the uplift of the Park Range and Medicine Bow Range, and possible depression of the park floor [7]. This tectonic activity took place during the Laramide Orogeny [8]. The surrounding mountain ranges are composed of Pre-Cambrian granites, gneiss, and schists, while the park floor is made up of sedimentary rocks ranging in age from Permian to Recent.



EXPLANATION

QUATERNARY	HOLOCENE		Qa	ALLUVIUM — FLOOD-PLAIN CLAY, SILT, SAND, AND GRAVEL DEPOSITS ALONG PRESENT STREAMS.
	PLEISTOCENE		Qot2	OLDER TERRACE DEPOSITS — SAND AND GRAVEL DEPOSITS ON SURFACES 120 FT. ABOVE PRESENT, STREAM LEVELS.
			Qot3	OLDER TERRACE DEPOSITS — SAND AND GRAVEL DEPOSITS ON SURFACES 180 FT. ABOVE PRESENT, STREAM LEVELS.
TERTIARY	EOCENE AND PALEOCENE		Tca	COALMONT FORMATION — FINE-GRAINED MICACEOUS SANDSTONE, TUFFACEOUS SILTSTONE, SANDSTONE, CONGLOMERATE, AND CARBONACEOUS CLAYSTONE OR MUDSTONE. SUDDUTH COAL ZONE OF BEEKLY (1915) AT BASE OF COALMONT.
CRETACEOUS	UPPER CRETACEOUS		Kp	PIERRE SHALE — INTERBEDDED BROWN TO GREY CALCAREOUS SANDSTONE, SILTSTONE AND GREY SILTY, TO SANDY SHALE.

CONTACT OF LITHOLOGIC UNITS — DASHED WHERE APPROXIMATE.

COAL SEAM — DASHED WHERE APPROXIMATE (ARROW IN DIRECTION OF DIP).

TREND OF AXIS OF JOHNNY MOORE SYNCLINE — DASHED WHERE APPROXIMATE.

TREND OF AXIS OF SOUTH McCALLUM ANTICLINE — DASHED WHERE APPROXIMATE.

10° STRIKE AND DIP OF BEDS.

● DH-2 DRILL HOLE LOCATION AND IDENTIFICATION NUMBER. HOLES DESIGNATED WITH "G" OR "J" ARE, USGS DRILL HOLES.

ACTIVE COAL STRIP MINE.

A — A' LINE OF GEOLOGIC CROSS SECTION.

10° OVERTURNED BED

BOUNDARY OF STUDY AREA.

2000 0 2000 4000 6000
SCALE OF FEET

NOTE: GEOLOGY FROM KINNEY (1970), USGS OPEN FILE NO. 70-182.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

McCALLUM SITE

GEOLOGIC MAP

GEOLOGY ________ TECHNICAL APPROVAL L.K. WESTON
DRAWN ________ SUBMITTED ________
CHECKED ________ ADMIN APPROVED ________
DENVER, COLORADO MARCH 20, 1980 FIGURE 20

Figure 20. - Geologic map.

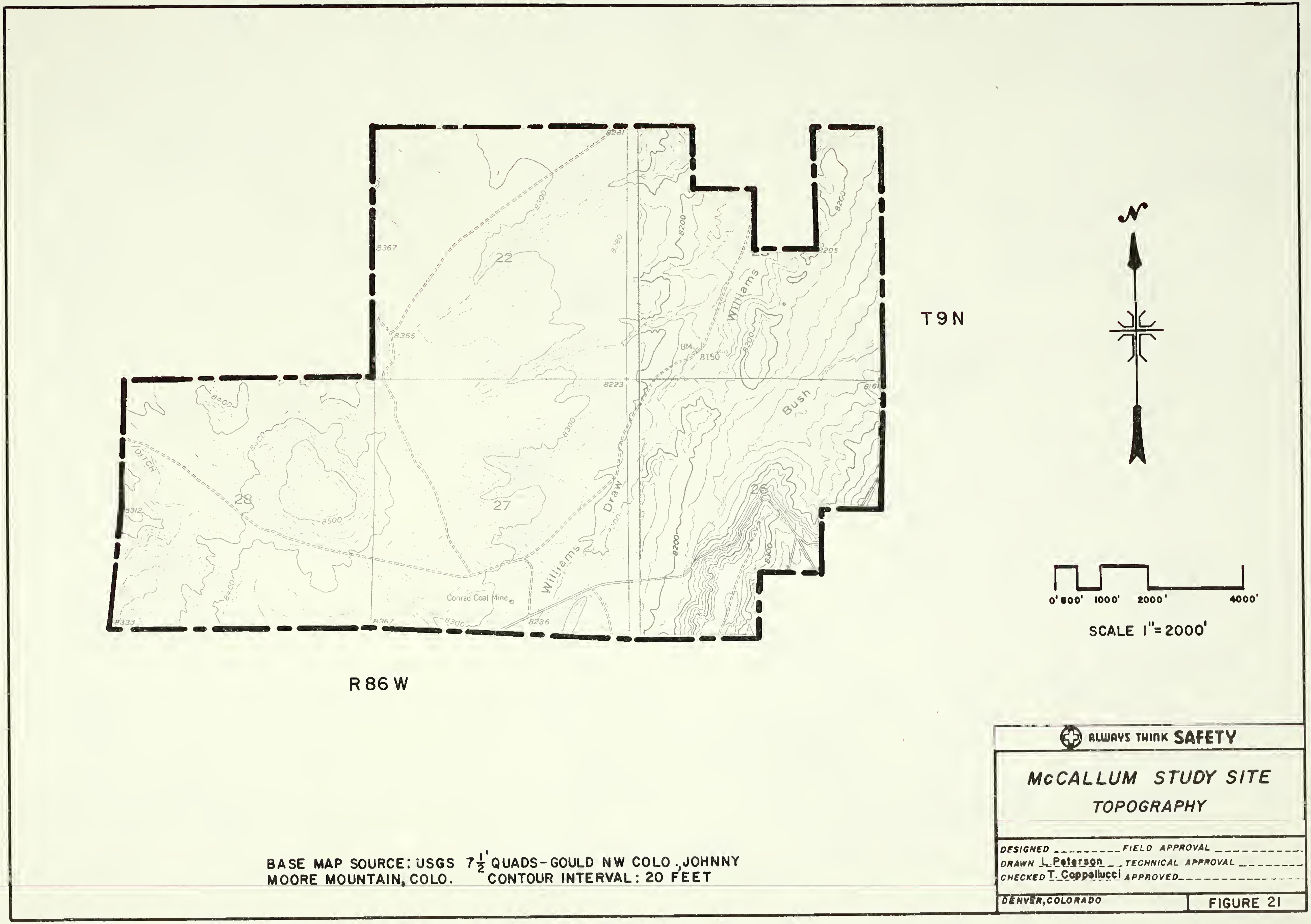


Figure 21. - McCallum Study Area topography.

The sedimentary beds are tilted upwards around the basin boundary on the east, south, and west with dips toward the center of the basin ranging from 20 to 50°, 7 to 15°, and 15 to 90°, respectively. The north end of the basin is bounded by the Independence Mountain fault where the crystalline rocks of Independence and Watson Mountains were thrust over the sedimentary sequence at right angles to the strike of the beds.

In the northwestern part of the park, Sheep Mountain and Delaney Butte are major features composed of crystalline rock that has been exposed by thrust faulting [8]. A large north-northwest trending ridge was formed in the process which extends from Sheep Mountain to the northern park boundary.

Another major structure is the North Park syncline that trends northwest from the southeastern portion of the park to Delaney Butte. The smaller Johnny Moore syncline and McCallum anticline are found in the northeastern portion of the park east of Walden. This anticlinal-synclinal sequence also trends north-northwest. McCallum anticline is important locally because of the exposed coalbeds along the eroded limbs of the anticline.

The lower eastern slopes of the Park Range are locally covered by glacial moraine deposits. These deposits range in thickness from a few feet to several hundred feet.

Site Geology

Techniques and procedures used. - During the months of June through September 1979, eight holes were drilled in the Study Area by a Reclamation drill crew. The drilling aided geologic interpretation of the area and provided coal and formation samples for further analyses. Coal samples were delivered to USGS for study, and overburden samples were supplied to Reclamation's Regional Soil-Water Laboratory in Denver for determination of suitability as a plant growing medium.

Drilling was accomplished with a S&H 142C skid-mounted rig with the exception of DH 4 which was drilled with a Sulliven 22 skid-mounted rig. Core was taken with NQ wireline, and a combination of water and water with Rivert additive was used as the drilling fluid. Water was hauled to the site from the Canadian River as far as 6 miles from the drilling location. A 5,000-gallon tractor-trailer rig was used to haul water for most of the operation. Near the end of the program, a 1,500-gallon U.S. Army water truck was purchased and used.

The drill holes were located to statistically sample the coal and overburden materials. Locations of the holes are shown on figure 20. Four of the drill holes penetrated coal and four did not. Two holes, DH 3 and DK 5, were offset and redrilled in an unsuccessful attempt to encounter coal. Elevations of the drill holes were estimated from USGS quadrangle maps with a contour interval of 20 feet. The drill core from DH 3 and DH 5 was given to USGS, while the core from DH 1, DH 2, DH 3a, DH 4, and DH 5a was retained by Reclamation. The geologic logs are contained in appendix A.

The USGS drilled some holes in the Study Area in 1977. The holes were logged by geophysical methods, and include natural gamma spontaneous potential, resistivity, and density logging [9]. The coal zone in some of the holes was core drilled. The narrative information from the USGS drilling program was used to supplement the data from the Reclamation program. In addition, a number of reports and other published information was accessed during this study.

Stratigraph and geologic logs. - The geologic formations encountered in the drilling program within the Study Area are the Upper Cretaceous Pierre Shale, the Tertiary Coalmont Formation, and the Quaternary Terrance Deposits.

The Pierre Shale is a marine deposit made up of a sandy member and a shaley member [10]. The shaley member is a gray shale that is silty to sandy in the upper part. The sandy member comprises the upper part of the formation, and is made up of brown to gray calcareous sandstones, siltstones, and shales. The upper sandstones are abundantly fossiliferous [7]. Thickness of the formation is about 4,500 feet [6] in the North Park area, and is exposed in the eroded core of the McCallum anticline.

The Pierre Shale was encountered in two drill holes, DH 3a and DH 5a. In DH 3a, the Pierre Shale was near the surface at a depth of 2 feet and an elevation of 8228 feet. In DH 5a, the Pierre Shale was encountered at a depth of 84 feet and elevation of 8086 feet. In both cases, the Pierre Shale was identified as basically a sandy siltstone. The siltstone had a tendency to disintegrate in place to fragments about 0.5 inch thick. There was a slight to moderate tendency for the siltstone particles to break down in water. Brachiopod fossils were found in core from DH 5a.

Lying unconformably on the Pierre Shale is the nonmarine Coalmont Formation of Paleocene-Eocene age. The Coalmont is composed of fine-grained micaceous sandstones, tuffaceous siltstones, conglomerate, and carbonaceous claystones and mudstones [10]. The Sudduth Coal zone appears near the base of the formation and is separated from the underlying Pierre Shale by 30 to 40 feet of white sugary sandstone. The sandstone is made up of white quartz and black, cherty grains. Maximum thickness of the Coalmont is about 3,500 feet east of Walden [7]. The Coalmont forms both limbs of the McCallum anticline. Erosion has exposed the coalbeds near the base of the formation.

The Coalmont Formation was encounted in drill holes DH 1, DH 2, DH 4, DH 5a, and DH 6 at depths of 18.0, 4.5, 22.5, 12.4, and 13.0 feet, and at elevations of 8322.0, 8400.5, and 8137.5, 8157.6, and 8107.0 feet, respectively. The Coalmont was identified as a series of sandstones and siltstones. The sandstones were light gray to white in color and silty in places. The white sandstones were composed of quartz grains with biotite flakes. Most of the sandstone broke down slow to moderately fast in water. The siltstones were gray to brownish gray in color, and sandy in many places. In several instances, the siltstone had a tendency to disintegrate in place to fragments about 0.5 inch thick. Breakdown of the siltstone in water ranged from very slow to rapid.

Coal was encountered in DH 1, DH 2, DH 5a, and DH 6 at depths of 66.2, 145.2, 12.4, and 123.9 feet, respectively. Beneath the coal in DH 2, a 10.5-foot thickness of igneous intrusive rock was encountered. The rock had a porphyritic texture with light colored areas up to 0.1-inch diameter scattered throughout a gray, fine-grained ground mass. Numerous small biotite flakes were present.

Overlying the Pierre Shale and Coalmont Formation in the Study Area are Quaternary age terrace depoists. Two deposits in the Study Area are designated as older terrace deposits [10] (fig. 20). The deposits are composed of sand and gravel laid down by streams at elevations 120 feet (Qot_2) and 180 feet (Qot_3) above present stream levels. The terrace deposits were not encountered in any of the drill holes.

Figure 20 gives the geologic map of the Study Area showing the geologic formations and general structure of the study site. Drill hole information was used in conjunction with the map to construct geologic cross section (fig. 22).

Structure. - The major structure in the Study Area is the north-northwest trending McCallum anticline. Actually, this structure is made up of two anticlines and are referred to as the North McCallum anticline and the South McCallum Aaticline [11]. The entire structure encompasses an area of about 2 miles wide and 17 miles long (fig. 23). The folds are asymmetrical with the steep flanks on the east side. Dips of the east limb of the North McCallum fold range from 50 to 75°, while dips of the west limb range from 25 to 40°. Mapped closure is about 1,400 feet.

For the South McCallum fold, dips of the east limb range from 35 to 90°, while dips of the west limb range from 20 to 40°. Mapped closure is about 2,000 feet. Numerous oil and gas wells penetrate the folds and are producing from the Dakota Formation.

Pierre Shale outcrops in the center of the structure, and the Coalmont Formation forms the limbs of the fold. Coalbeds of the lower portion of the Coalmont surround the structure.

Geomorphology

Discussion of the geomorphology of the McCallum Study Area is based on an analysis of the Williams Draw Study watershed, monitored by the USGS, with gaging station located in the SW1/4, NE1/4 sec. 23, T. 9 N., R. 78 W., USGS 7.5-minute quadrangle, Johnny Moore Mountain, Colorado. This watershed is taken as representative of the Study Area.

Williams Draw is a fourth-order basin (using a liberal augmentation of the blue line streams of USGS 7.5 minute, 1:24000 quadrangles) draining northeast to the Canadian River, see figure 24. The maximum elevation in the watershed is about 8550 feet (2610 m) and it enters the Canadian River at about 8050 feet (2455 m). The Williams Draw gage is at about 8150-ft (2485-m) elevation. The

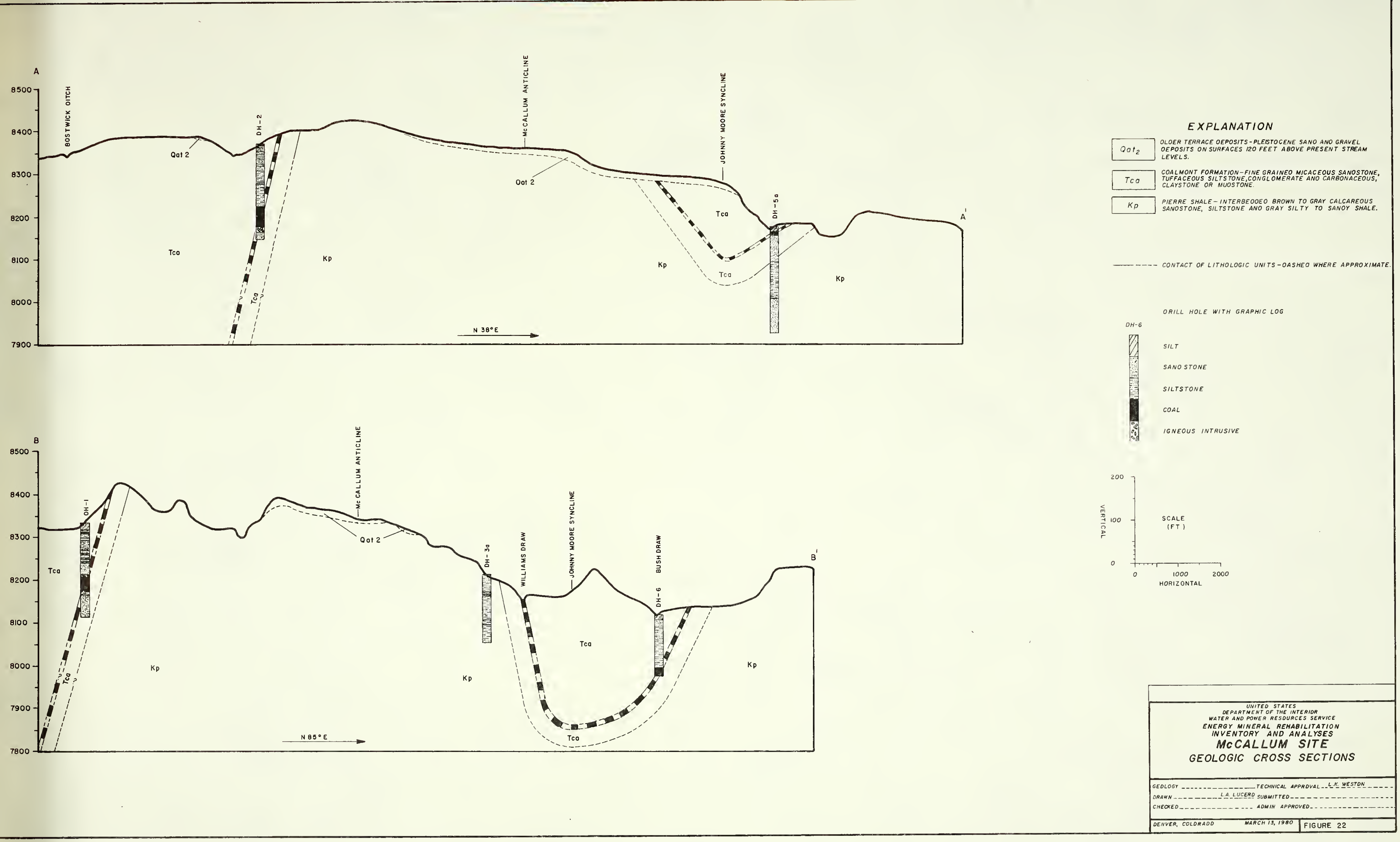


Figure 22. - McCallum Study Area geologic cross sections.

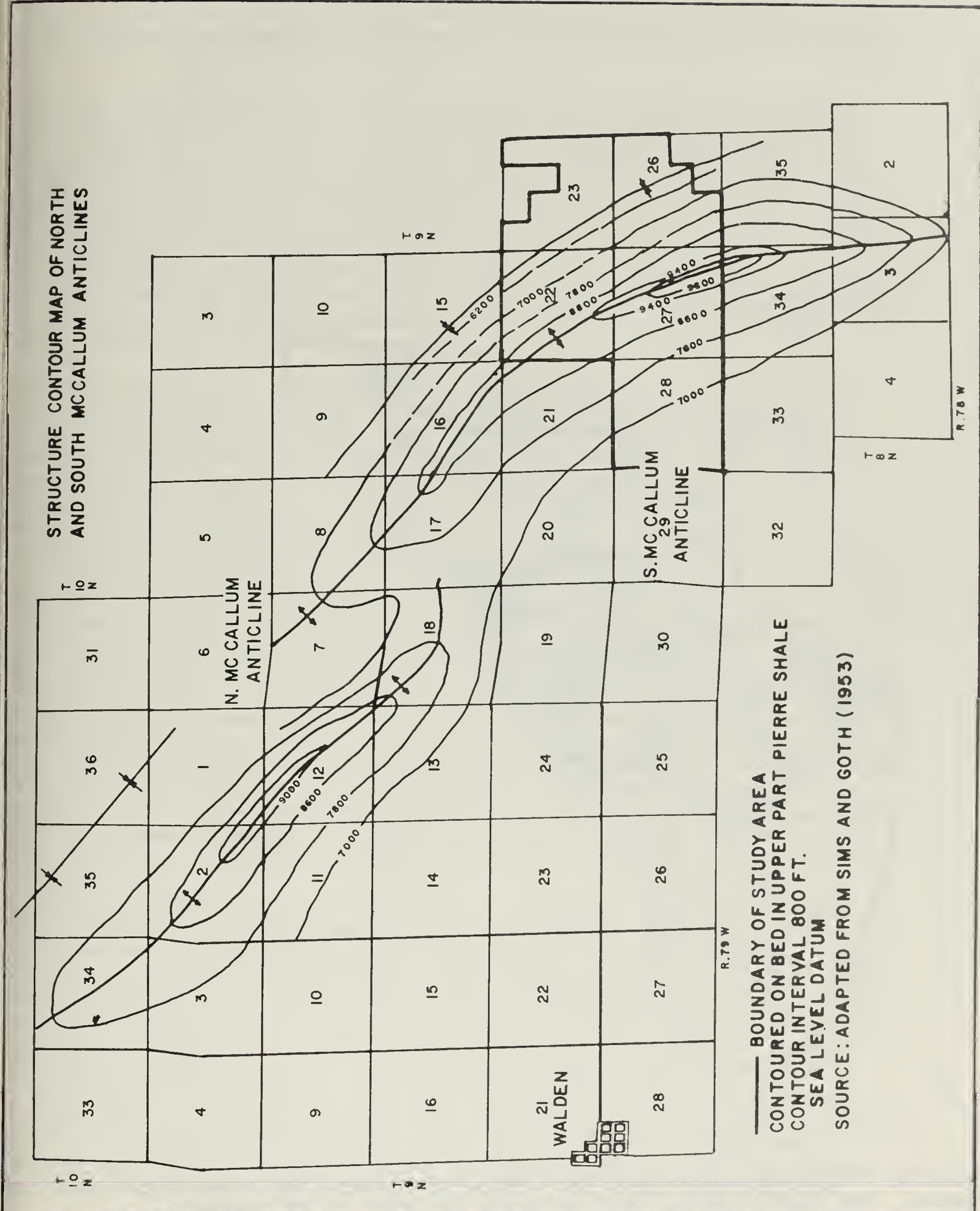


Figure 23. - Structure contour map of north and south McCallum anticlines.

Figure 24. - Tributary basin map of Williams Draw. Heavy lines bound subbasins. The identification label indicates the order of the subbasin.

drainage area above the gaging station is 3.44 mi^2 (8.90 km^2). The mean slope gradient for the entire watershed is 0.09 foot (9.0 percent), calculated by the line intersection method [12].

A generalized cross section of the watershed shows a pronounced asymmetry (fig. 25). The slopes from along the southeastern divide down to the main channel are shorter, steeper, and more finely dissected than those on the western part of the basin. The southeastern basins are dominantly first and small second order, draining directly into the main channel. Along these northwest-facing slopes are outcrops of resistant arkosic sandstone - beds of the Cretaceous Pierre Formation, upthrown by a normal fault striking azimuth 30° (dip unknown; see fig. 26), probably directly beneath the main channel of Williams Draw. The only prominent rilling or gullying on the basin slopes are associated with these sandstone outcrops; no other outcrops of sandstone were found elsewhere in the basin.

The western portion of the watershed is dominated by slopewash soils developed to varying degrees and eolian and outwash terrace gravel materials probably associated with past glacial activity in the nearby Medicine Bow Mountains. The channels here are longer, with up to third-order basins, and generally lower channel and slope gradients than northwest-facing slopes across the main channel. Analysis of aerial photography indicates some bedrock control, less pronounced than on the eastern side of the Williams Draw fault. The topographic effect is subtle, though it is strongly reflected in vegetation. This less extreme bedrock control is probably due to several factors. This faulting may have been along a plane dipping to the east. The main channel exploited this fault zone along this plane and left a low relief surface in the western part while eroding toward the east. This could explain the differing topographics on each side of the fault with essentially identical bedrock. The terrace gravels found on upper elevations throughout the area have a greater armoring effect on gentler slopes and channels than on the nearby escarped slopes southeast of the fault. Gravels enhance infiltration, provide surface roughness, and require greater flow depths and velocities to transport, making a more erosion-resistant terrain. This is the case in the western portion of the basin. On a steep slope, the combination of increase colluvial transport and shorter residence times of surface water and higher velocities diminishes the armoring effect of the gravels.

In the southeastern portion of the basin, the erosion resistant capacities of the gravels are overshadowed by those of sandstone. The beds, both sandstone and shale, strike roughly perpendicular to the main channel and the fault. An anticline-syncline pair produce steeply dipping beds parallel to their trend (fig. 26). The larger tributary channels have exploited the less resistant shale beds in the east. Their steep valley side slopes are underlain by sandstone (see fig. 27). While rills and gullies are not abundant in Williams Draw, those which do occur are found almost exclusively on steep slopes underlain by sandstone. The surface material being eroded in the rilling process is often a well-sorted, fine-grained, unconsolidated sediment that appears to be local accumulations of windblown silts. (Sand dunes, existing to the north across the Canadian River at the foot of the Medicine Bow Mountains, support the existence of sources and sinks form windblown

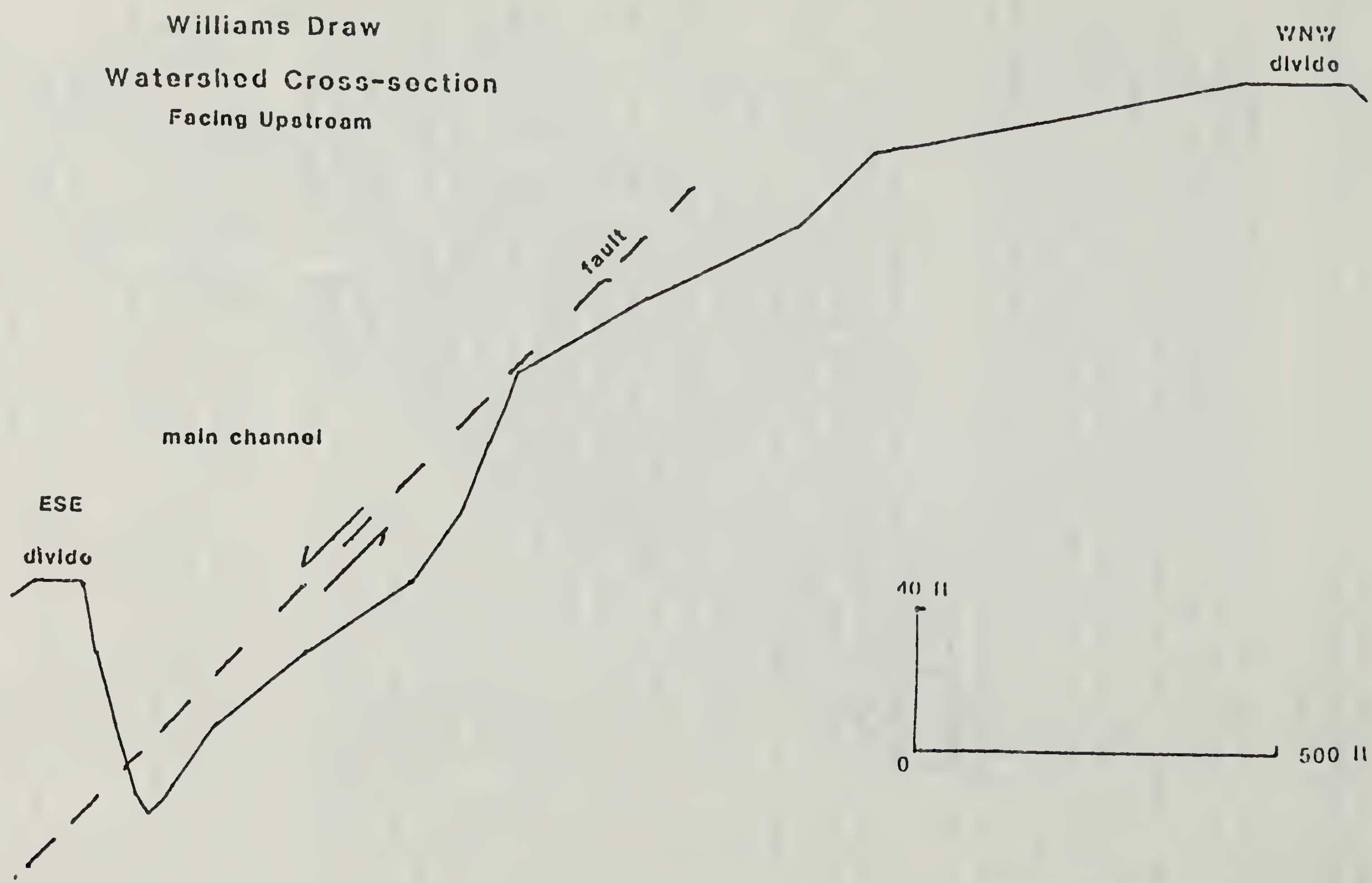
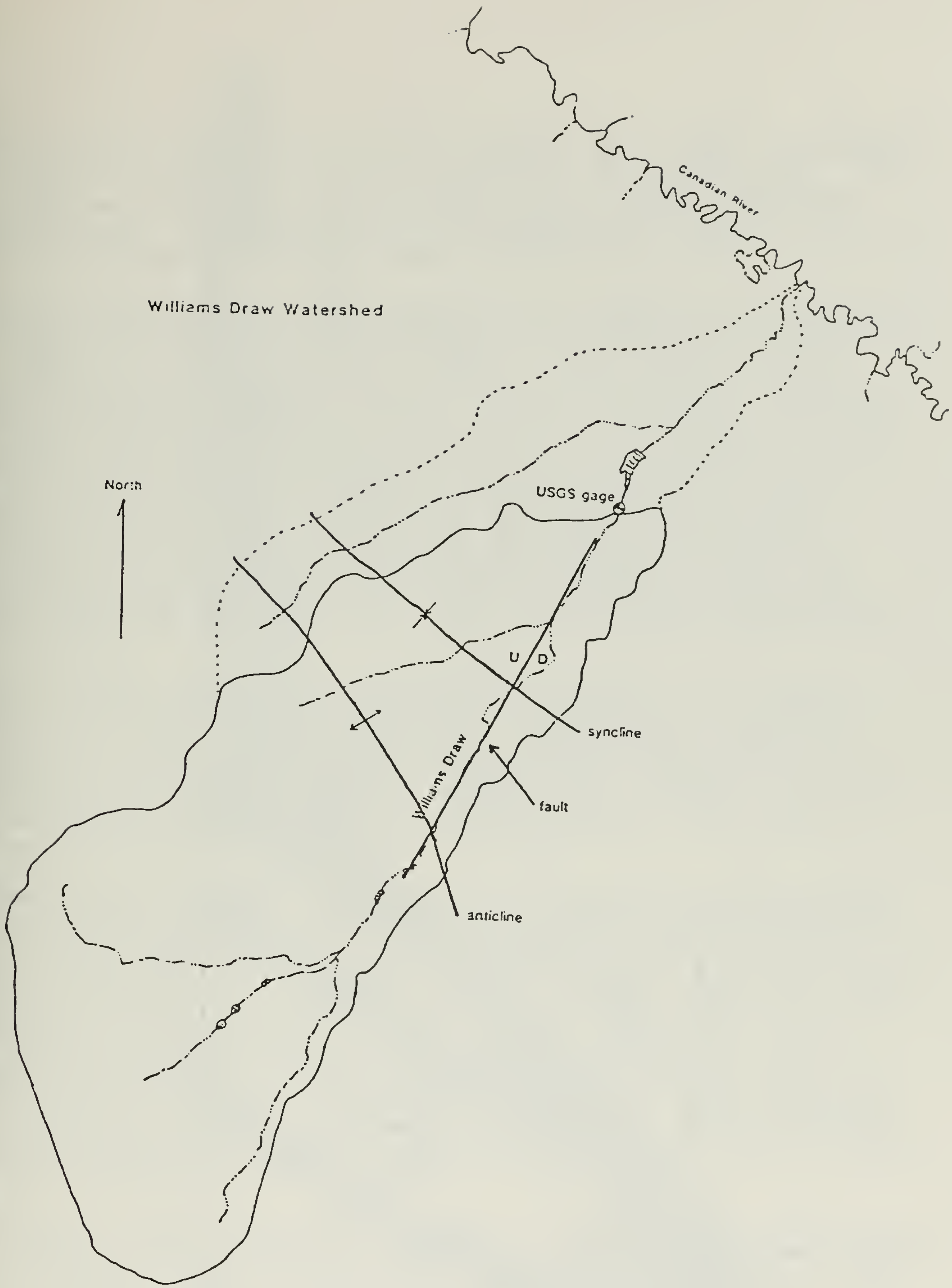


Figure 25. - A typical watershed cross section for Williams Draw, showing fault plane location relative to side slope and channel. Exact location and dip of fualt plane (or zone) are not known.



igure 26. - Location map of Williams Draw, showing extent of blue line channels from USGS 7.5-minute quadrangle, location and relative motion of a normal fault, and the location of an anticline-syncline pair found in the basin. Fault location was provided by Kerr Coal Company.

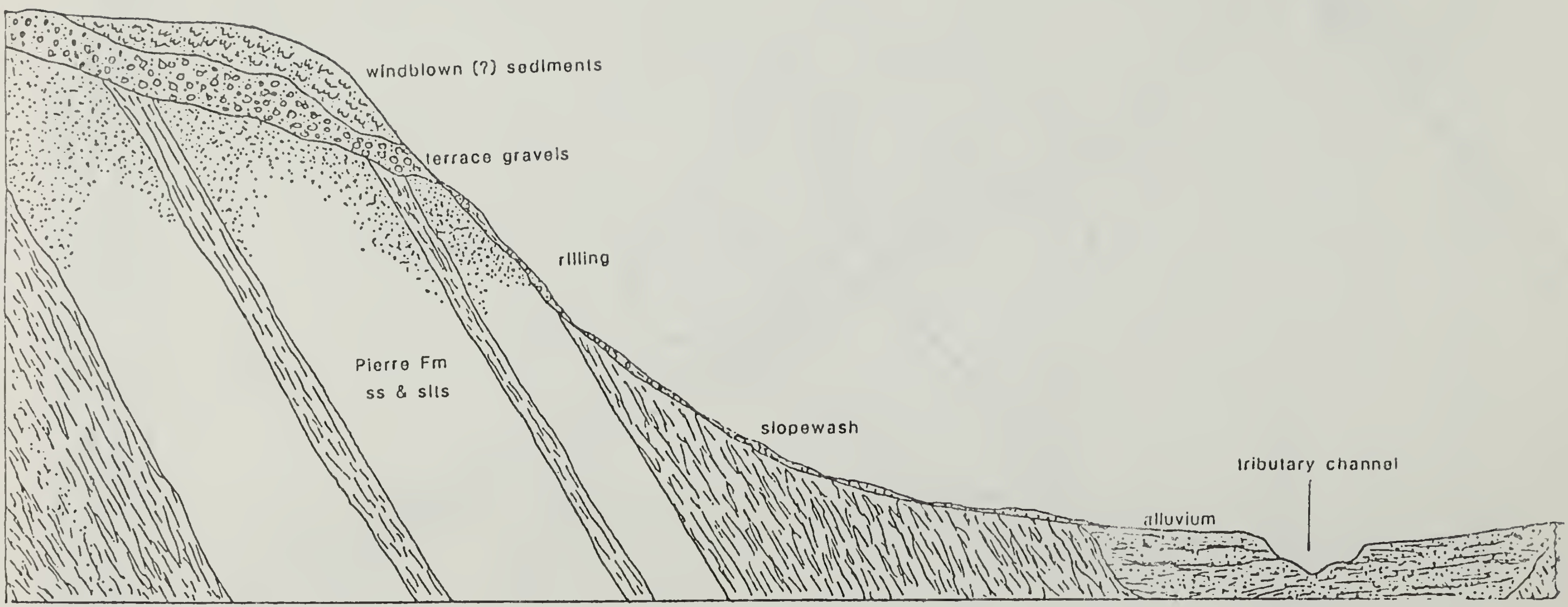


Figure 27. - Schematic of hillslope controlled by resistant bedrock, as in the southeast portion of Williams Draw.

sediment.) This material has a low shear strength and is erodible. (The only landslide features found in the basin were several small slumps, occurring in this material, though probably not associated with the sandstone beds. This landsliding was found on north-facing steep slopes downslope from poorly developed swales. This suggests that the slumping may be related to high soil moistures during spring melting of snow. No bedrock was seen.)

The aspect and gradient of the hillslopes and the direction of streamflow in Williams Draw are controlled by the structural and bedrock geology underlying it. Figure 28 is a polar plot of the aspect or facing direction versus frequency of occurrence of a sampling of about 140 hillslopes. The heavy lines are the general strike of the fault plane(s) and bedrock in the basin. The dominant hillslope facing directions are ESE and NE, perpendicular to the strike of the plane of the fault and bedding. It is common for streams to erode preferentially along faults and less resistant beds, forming a dominance of valleys parallel to these geologic features (see fig. 29). Hillslope aspect tends to be perpendicular to stream valley direction. The degree of geologic control can be estimated by degree to which hillslope aspect alines perpendicularly to bedding, faulting (fig. 28), and stream valley orientation (fig. 29). These plots indicate a high degree of geologic control.

Bedrock lithology and structure also control the gradient of hillslopes. Figure 30 is a plot of hillslope aspect (facing direction) versus mean gradient of a random sampling of hillslope. Clearly the W- to WNW-facing slopes are the steepest in the basin. These are the hillslopes to the southeast of the main channel; though they represent a limited areal extent, they are critical because they are the likely location of slope stability problems, both rilling and slumping.

Williams Draw is an elongate basin with short, steep basins joining the main channel from the southeast, and with larger more dendritic basins draining from the west (fig. 24 and table 4). The southeast portion of the basin has a high drainage density, 8.25 km/km^2, relative to the rest of the basin. The remaining portion has a drainage density of 5.13 km/km^2. Physically, drainage density is a measure of the length of channel, in kilometers, that 1 km^2 of drainage area will "support." Inversely, the reciprocal of drainage density is the drainage area (km^2) required to support 1 km of channel. The western portion of the basin requires nearly twice as much area to support 1 km of channel as does the southeastern part (table 4). This suggests that a greater proportion of rainfall runs off with more energy from the southeast part than the western part of the basin.

The asymmetry of Williams Draw is a product of bedrock lithology and structure. Using a method described by Hadley [13], the ratio of the mean distance from the channel to the divide of a basin was calculated, producing a value of 5.72, which is the ratio of the length southeast (i.e., northeast-facing) to northwest (i.e., southeast-facing) slopes. This asymmetry dictates the differential in slope gradients from southeast to northwest and west.

The channel geometry of Williams Draw varies from well-defined, somewhat incised channel flowing through sagebrush-covered flood plain to a broad, shallow, grassy channel. A series of stock ponds, intact and failed, along

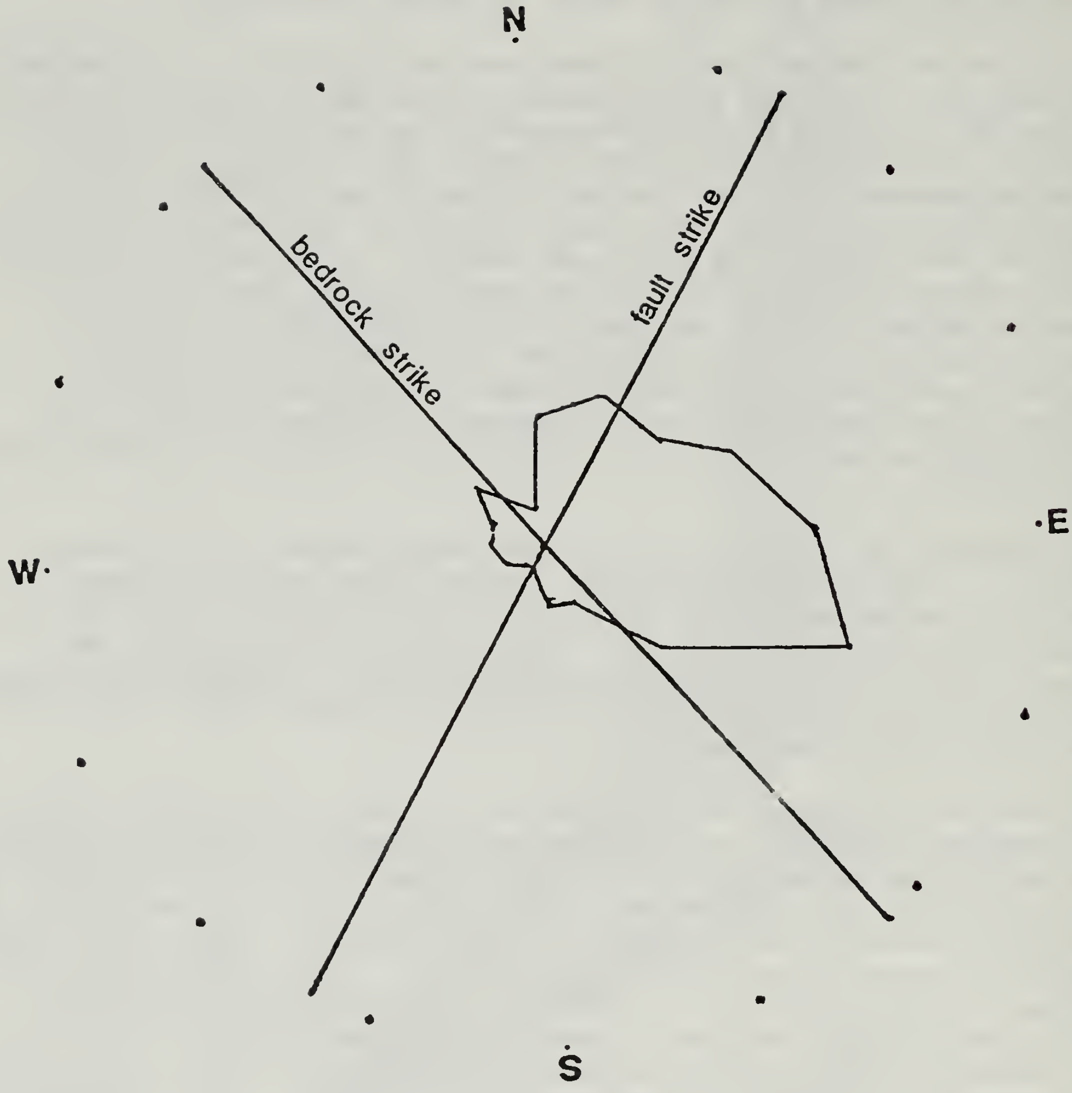


Figure 28. - Polar plot of the aspect, or facing direction, versus frequency of occurrence of sampling of approximately 140 hillslopes. Heavy lines are general strike of fault planes and bedrock in basin.

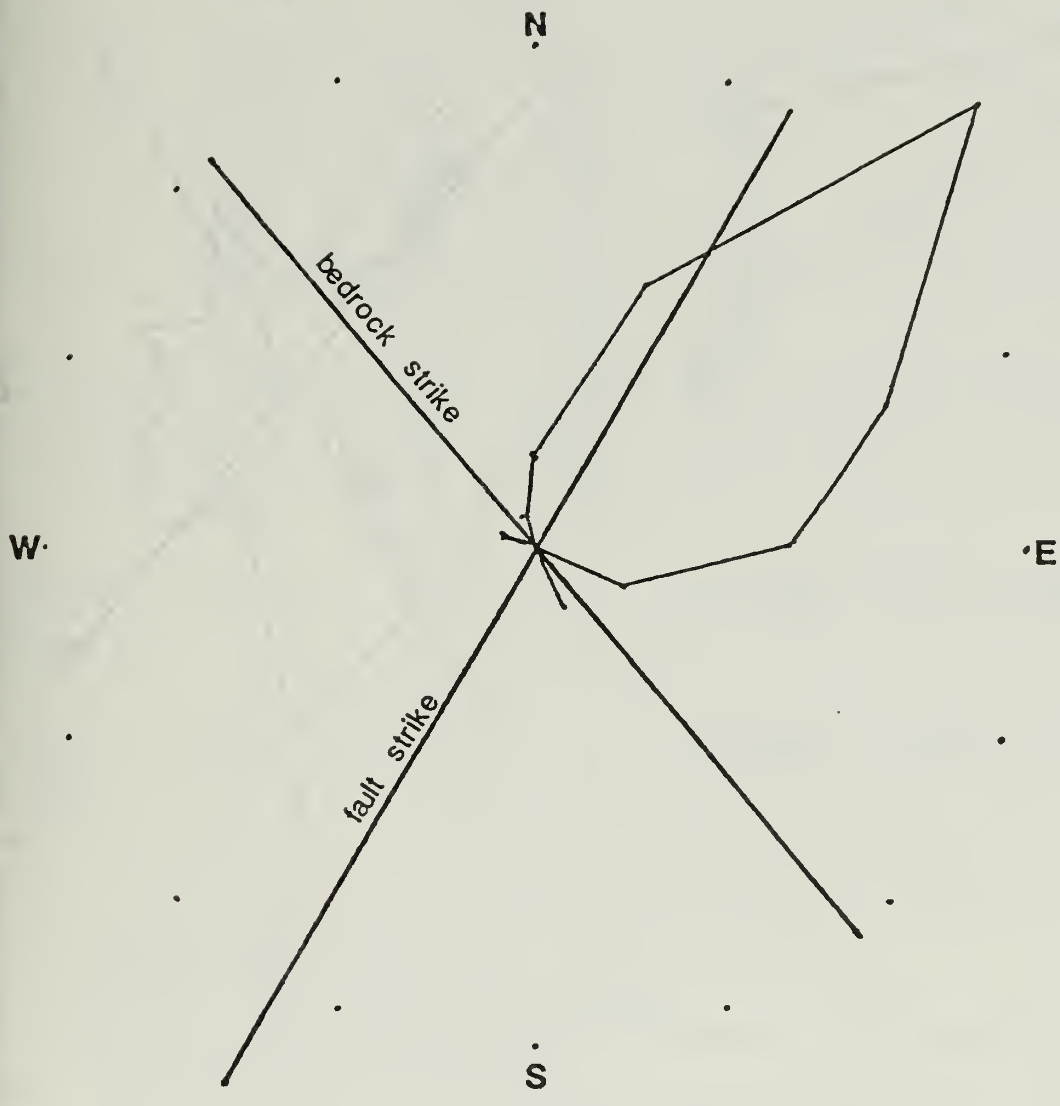


Figure 29. - Polar plot showing valleys parallel to geologic features.

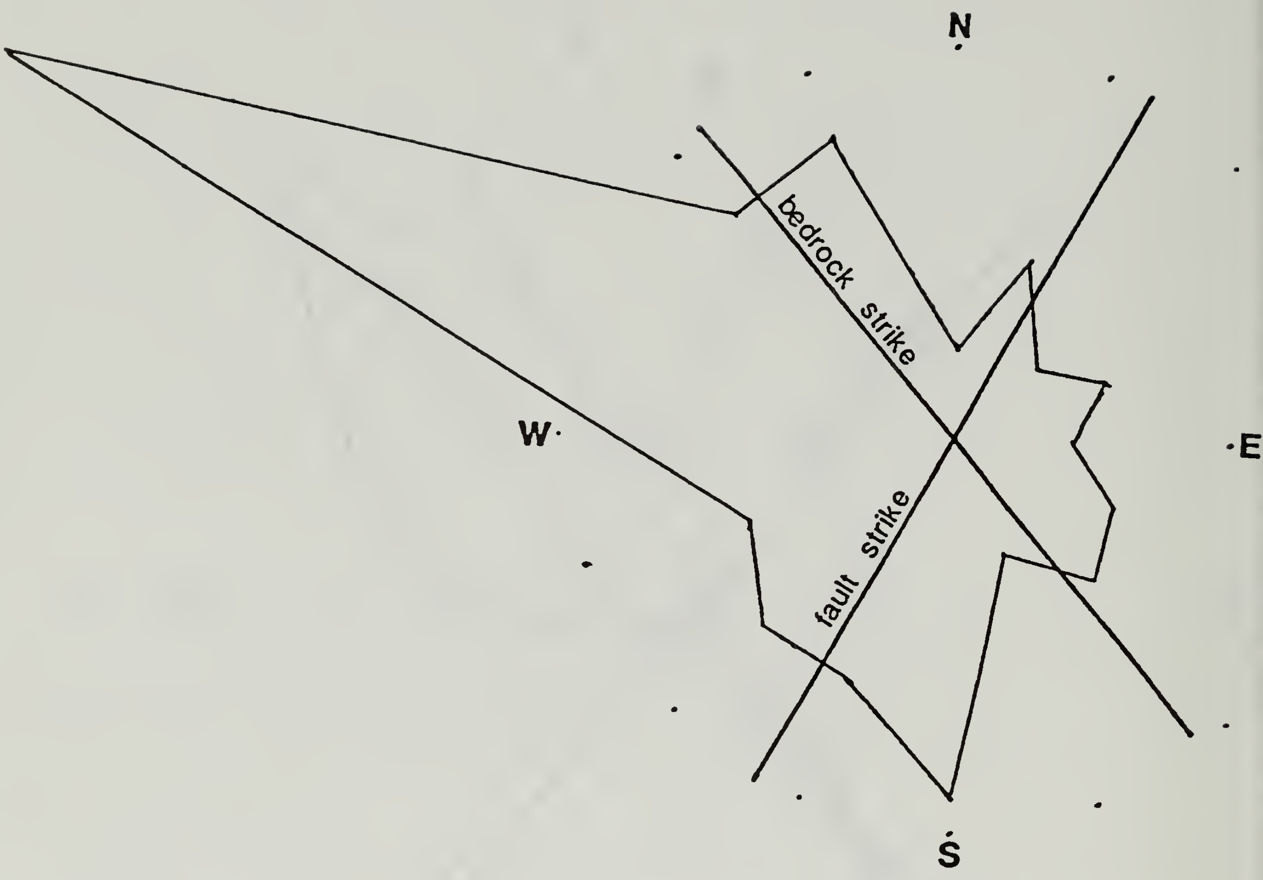


Figure 30. - Plot of hillslope aspect versus mean gradient of random sampling of hillslope.

Table 4. - Drainage basin parameters for Williams Draw and its tributaries

Basin	$A(km^2)$	P(km)	$L_m(km)$	$D_d(\frac{km}{km^2})$	
4a	8.90	14.46	6.16	5.34	Williams Draw
3a	1.50	5.72	2.81	6.06	
3b	1.07	3.84	1.74	3.65	
2a	1.06	5.92	2.44	3.77	
2b	1.80	6.83	2.32	3.76	
2c	0.78	4.39	1.71	6.49	
2d	1.05	4.94	2.14	5.55	
2e	0.31	2.38	0.88	6.20	
2f	0.22	2.07	0.92	4.99	
2g	0.12	1.28	0.55	8.64	
2h	0.23	2.03	0.79	--	
2i	0.39	3.14	1.21	--	
2j	0.41	3.27	1.49	--	
2k	0.13	1.34	0.57	--	
2l	0.16	1.37	0.54	--	
Southeast part of Williams Draw	0.86	--	--	8.25	(ΣL = 7.08 km); $1/D_d$ = 0.12
Western part of Williams Draw	8.04	--	--	5.03	(ΣL = 41.25 km); $1/D_d$ = 0.20

A = Drainage area (km^2).
P = Basin perimeter length (km).
L_m = Length of main channel to divide (km).
D_d = Drainage density equal to the total length of all channels (L) divided by the drainage area (km/km^2).
Basin = The subbasin described. The number in the identification refers to the stream order of the subbasin. (Horton, 1932).
ΣL = Total length of all channels (km).

the channel make it difficult to determine the natural geometry of the channels. The broad, shallow, grassy channels seem to be found downstream of the stock ponds, as in the middle fork of the three major upper tributaries (fig.26). There are three intact stock ponds on this fork; from this point downstream, the channel is broad and grassy (with the exception of channel incision associated with failed dams). The eastern fork has a well-defined slightly incised channel with a sagebrush flood plain. The west fork is intermediate to the two, but it flows through a road culvert above its junction with the middle fork. It may be hypothesized that the stock ponds increased the soil moisture in the alluvium below the dams and brought salts to the surface to the point where the native vegetation could no longer survive. This decrease in shrubby vegetation may have led to a change in channel cross section geometry, i.e., toward an increased width/depth ratio. There also appears to be an increase in salt efflorescence in the channel and on the flood plain and terraces below these dams. The relationship of these dams to the channel geometry, salt budget, and moisture in the alluvium is unclear.

For the most part, the channels of Williams Draw are stable, with the exception of short reaches of channel gullying associated with failed dams. Apparently these dams were not constructed under the supervision of BLM or SCS and their history is unknown. Inspection showed two modes of failure - overtopping of the dam and gullying of the spillway. Aside from these dams, the channels do not appear to be a problem.

The physiography of the McCallum Study Area, which is substantially composed of Williams Draw, is a product of bedrock lithology and structure. An east-dipping fault or fault zone underlying the main channel of Williams Draw may be an explanation for the symmetry of the valleys in the area. Coarse terrace gravels, found on the divide areas and as slope wash and lag deposits on side slopes provide resistance to erosion. Well-sorted, fine-grained sediments, probably windblown, locally overlie these coarse gravels and bedrock. The steepest slopes are underlain by arkosic sandstones, and when these steep slopes are mantled with the windblown material, are prone to rilling and slumping. Stock ponds appear to have had a major influence on the geometry of channels in the basin. The channels below dams are broad, shallow, and vegetated except for limited gullying associated with failed dams. The channels of Williams Draw are stable and are probably not very sensitive to small hydrologic changes.

Coal

USGS in cooperation with BLM and Reclamation, collected and analyzed representative coal samples from the McCallum Study Area. Twenty-eight samples (24 coal and 4 coal-associated rock) were analyzed for the area. At about the same time, 16 samples (12 coal and 4 coal-associated rock) were collected and analyzed from the nearby Coalmont area. Several previous investigations of the coal geology of North Park have been made. Reports on these investigations range from 1915 to 1978 and are referenced in appendix A, Coal.

The Coalmont Formation is the most widespread unit in the two coal areas and is the only formation containing significantly thick coal deposits. The formation is a maximum of 12,000 feet thick and consists of micaceous and arkosic sandstone, minor conglomerate, mudstone, claystone, carbonaceous shale, and coal.

The two major coalbeds in the Coalmont Formation are the Sudduth, occurring 50 to 250 feet above the base of the Coalmont Formation, and the Riach, occurring approximately 3,000 feet above the base. The two coalbeds never have been found together in one section. The Sudduth bed occurs only in the McCallum Study Area in northeastern North Park, and the Riach coalbed occurs only in the Coalmont area in southwestern North Park.

During the months of June through September 1979, eight holes were drilled in the Study Area by a Reclamation drill crew. Samples from all coalbeds encountered were delivered to the USGS for study.

A detailed report prepared by USGS, including information about the coal resources in the McCallum and Coalmont Study Areas of North Park, Jackson County, and data for the coal samples collected by Reclamation are in appendix A of this report.

INTERPRETATIONS FOR SOIL AND BEDROCK MATERIAL

Major Soil Bodies

The major physiographic units of the McCallum Study Area are: (1) gently sloping outwash fans and terraces; (2) hills, ridges, and valley side slopes, and (3) narrow smoothly incised ephemeral stream valleys. Following are general descriptions of the soils and topography associated with these physiographic units.

Gently Sloping Outwash Fans and Terraces

This physiographic unit comprises 50 percent of the Study Area and is the most important unit from the standpoint of quality and quantity of material suitable for use as a revegetation media. The west one-half of sections 22 and 23 is almost exclusively comprised of outwash fans.

The soils of this physiographic unit are formed in outwash and alluvium on fans and terraces. They support a relatively productive plant cover of mixed short grasses and forbs. The land is used for grazing. The soil depth usually is greater than 60 inches to bedrock. Medium and moderately fine textures are dominant and include sandy loams, fine sandy loams, sandy clay loams, and clay loams.

Slopes generally range from 3 to 6 percent, but include those from 2 to 15 percent for fans and terraces within the Study Area. The depth of solum (the A and B horizons) is quite variable ranging from 10 to 24 inches in thickness. The surface layer is most often a pale brown or brown sandy loam, 6 to 14 inches thick. The dark brown subsoil has textures of sandy clay loam and clay loam and is 8 to 14 inches thick. The underlying soil material (C horizon) is generally light in color (light gray or very pale brown), and textúres include gravelly sandy loam, sandy loam, and sandy clay loam. The size of the gravels ranges from pea size to 2-inch diameter.

In many areas it was not practical to bore below 36 to 48 inches because of the quantity and size of the rock fragments.

Water readily infiltrates these soils and percolates freely through the soil profile. Penetration of roots usually is more than 20 inches, but if the soil mantle is thin, root penetration is more restricted.

Hills, Ridges, and Valley Side Slopes

This physiographic component occupies about 47 percent of the Study Area. The soils were developed from weathered sandstone, siltstone, and shale. Slopes are variable within these landforms, ranging from 6 to 35 percent. Generally, the soils display weakly developed solum or no development. The major factor which impeded solum development was steep slopes. Thickness of soil material ranges from very thin to deep. The shallow soils (less than 20 inches to geologic material) are located on ridge tops, steeply sloping hillsides, and on upper stems of drainageways. The deeper soils generally are confined to colluvial slopes and alluvial deposits along drainageways.

The surface layer of these soils is commonly hard, grayish brown to dark brown, and is noncalcareous. Textures range from loam to silty clay. The surface layer is underlain by dark platey shales or yellowish brown sandstone. Water infiltration rates are moderate to moderately slow. Downward movement is generally restricted throughout the profile.

The more gently sloping and rounded drainages which are associated with large outwash fans, have soils which are dark brown, friable loam or sandy clay loam, and are noncalcareous. Water moves freely in and through these soils which are generally more than 60 inches to geologic material.

Range is the primary land use in this physiographic unit. The steeper hillsides and angular ridges support only a sparse cover of short grasses and forbs.

Smoothly Incised Ephemeral Stream Valleys

Soils of this physiographic unit comprise about 3 percent of the Study Area. They occur along Bush and Williams Draw and generally are classed as unsuitable as topsoiling material. These soils are more than 4 feet in thickness.

The soils are stratified, and colors of the layers range from dark brown or brown to yellowish brown. Texture includes loam, clay loam, and silty clay and consistence is hard. These soils have appreciable amounts of sodium. Because of the sodium and clay content, water movement through the soil mass is very restricted. Normally the water table is within 72 inches of the surface during some period of the year. Land use is primarily range, with a fair cover of salt- and sodium-tolerant grasses and shrubs.

Land Suitability

A detailed land suitability survey was made of the Study Area to characterize and evaluate the surface and underlying material, to a depth of 10 feet, in relation to its suitability as a source of planting media for resurfacing shaped spoils following surface mining. The survey provided data on the quality and quantity of surface material for revegetation and the ease of stripping and stockpiling. Basic data such as present physical and chemical properties in the upper 10 feet of soil material are also provided by the study.

Land classification specifications were developed specifically for this Study Area to establish ranges of land suitability as a source of planting media. Soil factors included in the specifications for quality consideration were: texture, salinity, sodicity, permeability, available water-holding capacity, and erosion hazard. Quantity considerations were primarily assessed by evaluating the depth and geographic extent of suitable material. Excessive slope and depth to bedrock outcrops were factors considered in relation to ease of stripping and stockpiling of material. The land classification specifications for the McCallum Study Area are given in table 5.

Table 5. - Land classification specifications 1/
McCallum Study Area - Colorado

	Land class		
	1	2	3
Soils 2/			
Texture	Fine sandy loam to clay loam.	Loamy fine sand to clay (friable).	Fine sand to clay.
Available water-holding capacity	>1.5 in/ft	>0.8 in/ft	>0.6 in/ft
Hydraulic conductivity (internal drainage)	Adequate to provide a well-drained and aerated root zone and infiltration rate adequate to prevent serious erosion.	May be slightly restricted resulting in decreased drainage and aeration in the root zone and at a 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 equilbrium)	<10 ESP (exchangeable sodium percentage) - 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.
Weatherability 3/	Breaks down rapidly upon exposure to normal weathering in the surface environment	May require short to moderate period to break down upon exposure.	May require an extended period to breakdown into optimum particle size distribution.

Table 5. - Land classification specifications 1/
McCallum Study Area - Colorado - continued

	Land class		
	1	2	3
Depth	>36 inches of usable and strippable material.	>24 inches of usable and strippable material.	>6 inches of usable 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 sand-stone and/or shale	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5-inches 5%; 2.5-10-inches <5%	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5-inches 10%; 2.5-10 inches <10%	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-25-inches 25%; 2.5-10-inches <15%
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 appreciably and to 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 Limitations.		

Table 5. - Land classification specifications 1/
McCallum Study Area - Colorado - continued

	Land class		
	1	2	3
Class 6	All areas not meeting requirements for classes 1, 2, or 3. These materials are unsuited as a source of material for revegetation. One or a combination of deficiencies may result in the use of this class.		

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

Four land suitability classes (1, 2, 3, and 6) were developed which closely correspond with the class numbers used in the Reclamation Land Classification System. Class 1 lands are the most desirable as a source of topsoil for surfacing shaped spoils. Based on the criteria established for class 1, these lands will supply a large quantity of highly suitable material. This material can be easily stripped and stockpiled for postmining use on the lands they occupy and possibly for use on adjacent areas where topsoiling material is inadequate. Class 2 lands have adequate resurfacing material, but may require special placement practices to meet such requirements. These lands are less desirable in quality or are more difficult to strip and stockpile than class 1 lands. Class 3 lands are marginal in their suitability for reclaiming mined areas because of poorer quality soil material and/or lesser available quantities. With good procedures for stripping and stockpiling, land in this class will meet quantity and quality requirements for shaping and revegetating. Class 6 lands generally do not have adequate quantity or suitable quality material for topsoil use and should not be stripped and stockpiled. If class 6 lands are disturbed by surface mining, it will be necessary to either borrow suitable material or improve the available material for revegetation to be successful.

Many of the observable characteristics such as texture, structure, consistency, salinity, and sodicity were directed toward estimating soil-moisture relationships of the material. The tentative land suitability classes were assigned by using these basic soil characteristics combined with observations of other land features such as stones, exposed indurated bedrock, and slope. The final land class was determined after evaluating the laboratory data along with the observational information.

Results of the land suitability survey show that approximately 87 percent of the Study Area has adequate material for postmining reclamation purpose. Deficiencies observed during the survey were fine textures, steep slopes, sodicity, and areas having insufficient quantities of strippable material.

The land suitability survey provides adequate data for developing lease stipulations regarding 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. It may be desirable to obtain more detailed information through additional soil borings, observations, and supporting laboratory data. A procedure similar to that used in the land classification could then be used to determine the quantity, quality, and locations of the available material suitable to be stockpiled for planting media. Following is a description of the major land classes in the land suitability survey:

Class 1. - Lands in this class have a minimum depth of 36 inches of good quality soil suitable for plant media. These soils are forming generally in residuum. The dominant textures are loam, sandy clay loam, and silt loam. Aggregate stability in the soil solum is strong, 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 generally noncalcareous in the upper 36 inches of the soil profile and only slightly calcareous from 3 to 5 feet. Approximately 67 percent of the Study Area is in class 1.

Class 1 lands in the Study Area include: (1) gently sloping upland fans, terraces, and other upland areas; and, (2) gently sloping drainageways.

Class 2. - Approximately 10 percent of the Study Area was classified as class 2. The only limitations in this class were soil-related deficiencies. Thus, only the subclass "s" was used.

Subclass 2s. - Lands in subclass 2s have the following deficiencies: (1) moderately fine textured soils with restricted permeabilities, (2) moderately coarse textured soils which have a relatively high erosion hazard, and (3) soils having impervious bedrock or cobble within 24 inches of the surface. Levels of sodium and salinity are low and pose no serious problems.

Subclass 2s lands are minor in extent. Three distinct types exist: (1) knobs, (2) steep eroded hillsides, and (3) long narrow areas between edges of uplifts, east of Bush Draw.

Class 3. - All lands classified as class 3 were on the basis of soil deficiencies; thus, only the subclass "s" was used. About 10 percent of the Study Area is comprised of class 3 lands.

Subclass 3s. - Lands in this subclass are primarily fine textured (silty clay and clay). Also, a few small areas occur which have an average minimum depth of 12 inches of moderately coarse or medium textured soil material overlying impervious shale. These soils are generally nonsodic and nonsaline.

The primary land feature consists of side slopes along drainages, and to a minor extent old eroded surfaces consisting mainly of geologic material. These old surfaces are in transition area between fans and upland hills, or on ridges between dendritic drainages sourcing from shales.

Class 6. - Lands in this class are unsuitable for use as a source of planting media. Two subclasses, one having a soils deficiency and the other a soils and topography deficiency, are recognized. About 13 percent of the Study Area is class 6 lands.

Subclass 6s. - These lands basically are along Bush and Williams Draw. Soils of these lands are not suited in their present condition for use as a plant growth medium because of sodicity and restricted permeability rates. In most profiles, the ESP exceeds 15 percent. Because these soils are water deposited, the profiles are highly stratified. Soil textures are generally sandy clay loam or clay loam in the upper 6 inches, and grade to silty clay and clay below this depth.

The lands within the Study Area are nearly level flood plains of intermittent drainages in the Study Area.

Subclass 6st. - Within this subclass are lands which have: (1) no soil material or less than 6 inches of soil overlying hard sandstone or shale, and (2) very hard clay soils underlain by resistant shales at depths of less than 24 inches. Both soil conditions are on slopes of more than 25 percent.

The lands occur as steep barren escarpments along Williams Draw or are on actively eroding hillsides between upland ridges and intermittent drainages.

Table 6 gives the acreage and percentage of each represented land subclass for the entire study area and also by individual section. Figure 31 is a composite land suitability map for the area.

Table 6. - Composite land suitability

Class	Township 9 North, Range 78 West					Total acres	Percent of Study Area
	Section No.						
	22	23	26	27	28		
1	594.2	336.9	191.7	555.5	313.6	1,991.9	67.3
2s	32.6	48.9	168.5	6.9	41.9	298.8	10.1
3s	-	14.1	36.0	50.8	199.3	300.2	10.2
6t	-	-	-	-	-	-	-
6s	-	53.1	79.6	10.8	-	143.5	4.8
6st	13.2	67.0	44.2	16.0	85.2	225.6	7.6
Totals	640.0	520.0	520.0	640.0	640.0	2,960.0	100.0

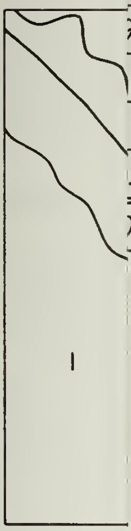
Overburden Suitability

The land suitability survey classified lands for their suitability as a source of planting media taking into consideration many factors including soil depth up to at least 10 feet. A quality evaluation of the overburden from a depth of 10 feet to bottom of coal seam was made, based on data derived from chemical and physical laboratory tests on core taken from six deep-hole borings drilled on the site. In the event adequate topsoil or suitable soils are unavailable, suitable overburden may be considered. Greenhouse studies are presented in appendix D of this report and were considered in evaluating the core material.

The quality evaluations apply to the specific core site. Because of the limited number of holes drilled and the nature of the geologic material, the quantity and quality evaluations of the core overburden should not be projected between drill hole locations.

ABILITY

ST	TOTAL ACRES	PERCENT OF STUDY AREA
3		
6	1991.9	67.3
.9	298.8	10.1
.3	300.2	10.2
	143.5	4.8
.2	225.6	7.6
.0	2960.0	100.0



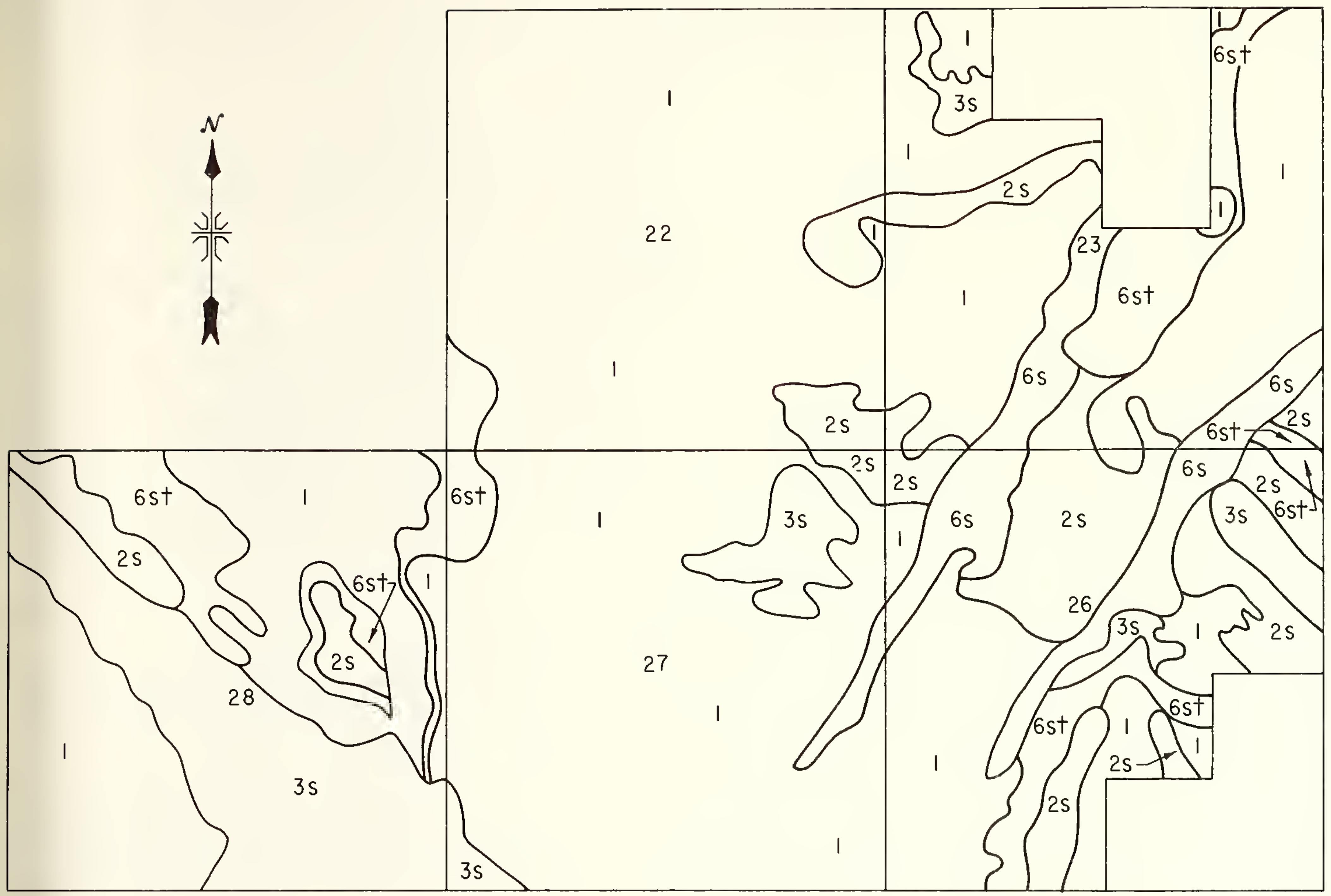
ALWAYS THINK SAFETY

McCALLUM STUDY SITE
COMPOSITE LAND SUITABILITY MAP

DESIGNED ____________ TECH. APPROVAL ______________
DRAWN ______________ SUBMITTED ________________
CHECKED ____________ APPROVED _________________

DENVER, COLORADO | FIGURE 31

Figure 31. - Composite land suitability map.



COMPOSITE LAND SUITABILITY

CLASS	TOWNSHIP 9 NORTH, RANGE 78 WEST					TOTAL ACRES	PERCENT OF STUDY AREA
	SECTION NUMBERS						
	22	23	26	27	28		
1	594.2	336.9	191.7	555.5	313.6	1991.9	67.3
2s	32.6	48.9	168.5	6.9	41.9	298.8	10.1
3s		14.1	36.0	50.8	199.3	300.2	10.2
6s		53.1	79.6	10.8		143.5	4.8
6st	13.2	67.0	44.2	16.0	85.2	225.6	7.6
TOTALS	640.0	520.0	520.0	640.0	640.0	2960.0	100.0

ALWAYS THINK SAFETY

McCALLUM STUDY SITE

COMPOSITE LAND SUITABILITY MAP

DESIGNED ____ TECH. APPROVAL ____
DRAWN ____ SUBMITTED ____
CHECKED ____ APPROVED ____

DENVER, COLORADO | FIGURE 31

Figure 31. - Composite land suitability map.

The suitability evaluations were rated on a broad scale as suitable, limited, or unsuitable. Applicable parts of the specifications used for the land suitability survey were used to provide criteria for the ratings. The suitable rating is equivalent to class 1 and the best of class 2. The limited rating is equivalent to the lower part of class 2 and class 3. The unsuitable rating is equivalent to class 6.

Results of the core evaluations are:

Deep hole No. 1

Depth (ft)	Material	Evaluation	Remarks
0.0-2.0	Silt	Unsuitable	Low pH - coaly
2.0-18.0	Silt	Suitable	
18.0-22.0	Siltstone	Limited	Coaly
22.0-26.0	Coal	Unsuitable	
26.0-36.4	Siltstone	Limited	Coaly
36.4-41.0	Sandstone	Limited	Coarse textured 1/
41.0-66.2	Siltstone	Suitable	
66.2-122.0	Sandstone	Limited	Coarse textured 1/
122.0-127.7	Siltstone	Limited	Coaly
127.7-158.5	Coal	Unsuitable	
158.5-168.3	Siltstone	Unsuitable	High SAR (sodium adsorption ratio) - low permeability
168.3-221.0	Sandstone	Unsuitable	High ESP - coarse textured 1/

1/ Coarse textured indicates low cation exchange capacity, high or excessive permeability, and limited available water-holding capacity.

There are fine coal particles throughout 0-2.0 feet. The siltstone layers 18.0-22.0 feet above and 26.0-36.4 feet below the coal at 22.0-26.0 feet also contained coaly particles. The sandstone material from 168.3-221.0 feet were coarse in texture having low cation exchange and moisture-holding capacities. These materials exhibited restricted disturbed hydraulic conductivities and high ESP values.

Deep hole No. 2

Depth (ft)	Material	Evaluation	Remarks
0.0-4.5	Silt	Limited	Saline and moderate SAR values
4.5-8.0	Siltstone	Limited	Moderate SAR values
8.0-16.2	Sandstone	Limited	Moderate SAR values
16.2-23.0	Siltstone	Limited	Fine-textured 1/ moderate SAR and ESP
23.0-26.5	Sandstone	Limited	Moderate SAR values
26-5-33.7	Siltstone	Limited	Moderate SAR values
33.7-50.7	Sandstone	Limited	Moderate SAR values
50.7-60.8	Sandstone (fine)	Unsuitable	High ESP
60.8-145.2	Siltstone	Unsuitable	High SAR and ESP
145.2-193.2	Coal		
193.2-203.7	Igneous intrusive	Unsuitable	High SAR and ESP
203.7-221.7	Sandstone	Unsuitable	High SAR and ESP

1/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

The materials below 50.7 feet had restricted permeabilities and high SAR (10.8-27.8) and high ESP (14.5-43.1) values.

Deep hole No. 3a

Depth (ft)	Material	Evaluation	Remarks
0.0-2.0	Silt	Suitable	
2.0-4.1	Siltstone	Suitable	
4.1-41.5	Siltstone	Suitable	
41.5-47.0	Siltstone	Suitable	
47.0-50.4	Sandstone	Limited	Coarse textured 1/
50.4-88.8	Siltstone	Suitable	
88.8-106.3	Siltstone	Limited	Moderate SAR values
106.3-160.0	Siltstone	Unsuitable	High SAR and ESP

1/ Coarse textured indicates low cation exchange capacity, high or excessive permeability, and limited available water-holding capacity.

Most of the materials tested below 88.8 feet showed an increase in SAR and ESP values with depth.

Deep hole No. 3a

Depth (ft)	Material	Evaluation	Remarks
0.0-2.0	Silt	Suitable	
2.0-4.1	Siltstone	Suitable	
4.1-41.5	Siltstone	Suitable	
41.5-47.0	Siltstone	Suitable	
47.0-50.4	Sandstone	Limited	Coarse textured 1/
50.4-88.8	Siltstone	Suitable	
88.8-106.3	Siltstone	Limited	Moderate SAR values
106.3-160.0	Siltstone	Unsuitable	High SAR and ESP

1/ Coarse textured indicates low cation exchange capacity, high or excessive permeability, and limited available water-holding capacity.

Most of the materials tested below 88.8 feet showed an increase in SAR and ESP values with depth.

Deep hole No. 4

Depth (ft)	Material	Evaluation	Remarks
0.0-8.0	Silt	Suitable	
8.0-12.0	Silt	Suitable	
12.0-20.5	Sand	Suitable	
20.5-22.5	Silt	Suitable	
22.5-50.0	Siltstone	Suitable	
50.0-144.0	Siltstone	Unsuitable	Restricted disturbed hydraulic conductivity and high SAR and ESP values
144.0-253.0	Sandstone	Unsuitable	High SAR and ESP values

The geologic sand material 12.0-20.5 feet was described as sand, but was very silty in physical condition.

Deep hole No. 5a

Depth (ft)	Material	Evaluation	Remarks
0.0-3.2	Silt	Suitable	
3.5-12.4	Silt and clay	Suitable	
12.4-19.5	Coal	Unsuitable	
19.5-70.5	Sandstone	Suitable	
70.5-84.0	Sandstone	Limited	Moderate SAR
84.0-169.5	Siltstone	Unsuitable	High SAR and ESP values
169.5-250.5	Sandstone	Unsuitable	High SAR and ESP values

The 19.5-20.5-foot horizon was siltstone with slickensides and had a high carbonaceous content; this layer would be limited in suitability. Chemically the sandstone from 20.5-70.5 feet met the suitability criteria, but physically exhibited very little breakdown and may cause some problems due to lack of weatherability. At 84.0 feet the geologic materials increase in sodium content yielding high SAR and ESP values.

Deep hole No. 6

Depth (ft)	Material	Evaluation	Remarks
0.0-2.0	Silt	Limited	Gravel
2.0-8.0	Silt	Unsuitable	High SAR and ESP, salinity
8.0-13.0	Gravel		No sample
13.0-19.8	Sandstone	Limited	Moderate SAR values
19.8-29.8	Sandstone	Limited	Restricted hydraulic conductivity indicative of high SAR potential
29.8-123.9	Siltstone	Unsuitable	High SAR and ESP values
123.9-144.5	Coal		

All of the materials tested below 29.8 feet had high SAR and ESP values throughout to 123.9 feet.

VEGETATION

Significant variations in species, proportion of species, and total annual production, due largely to the differences in soil, topography, and other environmental factors, causes vegetative dissimilarities within the plant community at the McCallum Study Area. Based on these factors, seven ecological subdivisions or range sites are found within the 2,960-acre area: mountain loam, dry mountain loam, drainage bottom, clay pan, valley bench, dry exposure, and salt flat.

No suitable habitat for threatened and endangered plant species was observed, and no threatened and endangered species were found within the Study Area.

The vegetation of the Study Area is mapped according to the various range sites, figure 32, and described in this section. Total annual production and plant composition of the range sites are found in table 7. Species frequency and percent areal cover are found in table 8.

Mountain Loam (228)

The mountain loam range site (fig. 33) mainly occupies the alluvial slopes. The soils are fairly deep and moderately fine to moderately coarse textured with high to low holding capacities. A large percent of this soil moisture is available for plant growth.

This range site is the most productive site within the Study Area in terms of total annual vegetative production. The site is dominated by big sagebrush, which accounts for 67 percent of the total air-dry weight composition (table 7) and approximately 26 percent of the cover (table 8). Associated dominant understory vegetation includes some of the more moisture demanding grasses, such as Idaho fescue and mutton bluegrass, along with various wheatgrasses.

The present vegetative composition, based on percent of air dry weight, computes to be approximately 21 percent grass and grass-like species, 1 percent forbs, and 78 percent shrub.

The SCS range productivity and composition information indicates the sites potential composition (by weight) as:

15 percent Idaho fescue	*Festuca idahoenis*
15 percent wheatgrasses	*Agropyron* Spp.
10 percent big sagebrush	*Artemisia tridentata*
10 percent sandberg bluegrass	*Poa secunda*
5 percent needlegrass	*Stipa* Spp.
5 percent sedges	*Carex* Spp.
5 percent prarie junegrass	*Koeleria cristata*
5 percent bottlebrush squirreltail	*Sitanion hystrix*
5 percent native brome	*Bromus* Spp.
3 percent snowberry	*Symphoricarpous* Spp.
3 percent antelope bitterbrush	*Purshia tridentata*
2 percent low rabbitbrush	*Chrysothamnus* Spp.
17 percent unknowns	

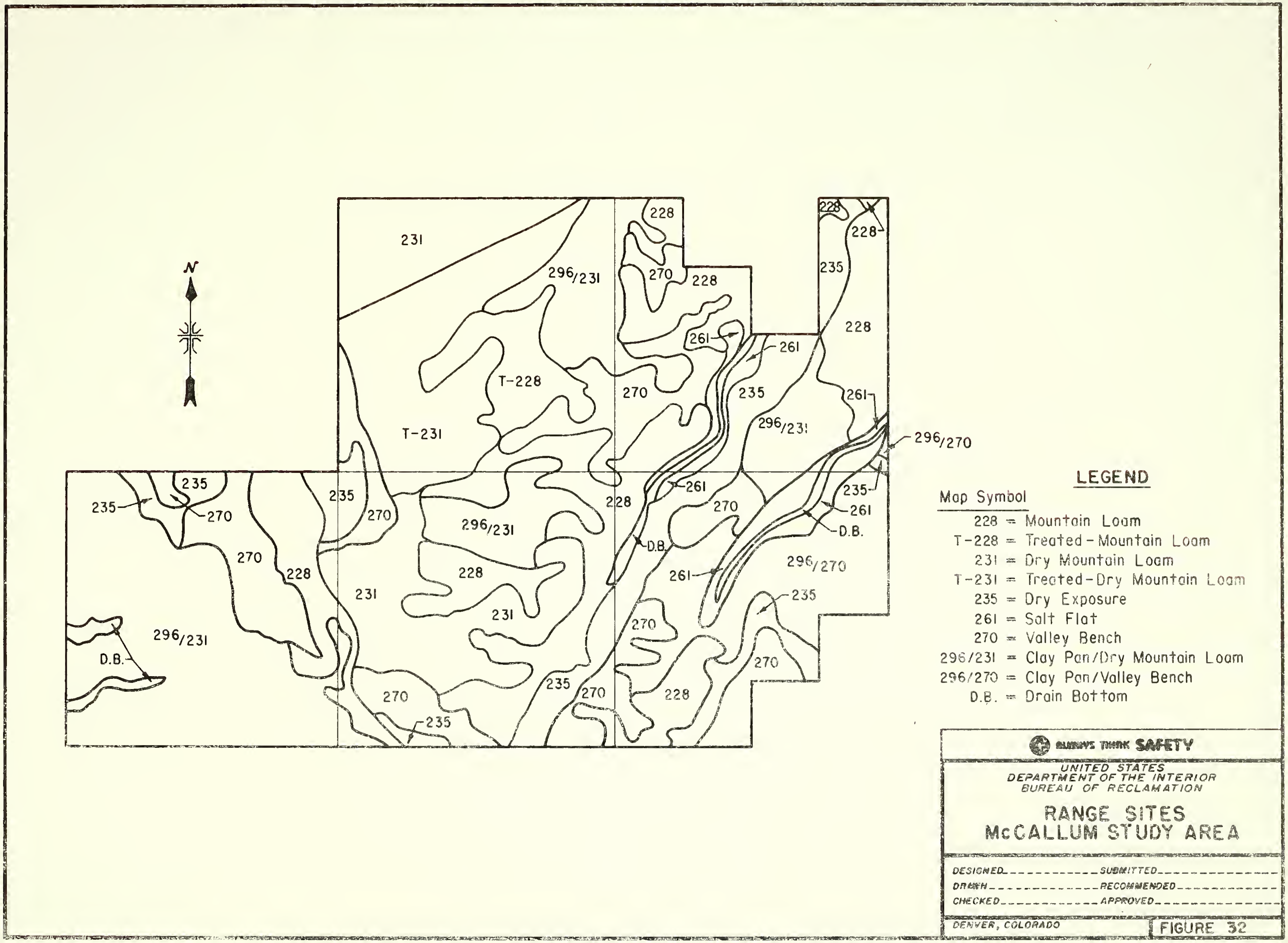


Figure 32. - Range sites.

Table 7. - Production per range site as pounds per acre (air dry) plant composition expressed as percent on dry weight basis by species 1/

	Range sites								
	Mtn. loam (untreated)	Dry mtn. loam (treated)	Drainage bottom	Dry mtn. loam (untreated)	Mtn. loam (treated)	Clay pan	Valley bench	Dry exposure	Salt flat
tal production -	660	537	529	460	382	364	303	216	142
Species				Plant composition					
asses									
*Agsp		5.5		5.2			31.0	11.6	
Agsm	0.15				2.1	2.5			9.8
Agrop	6.0	14.3	4.91	4.3	19.1	4.9	2.3	20.9	
Pofe	5.3	16.2	0.37	5.0	5.0		15.8		
Pose						2.5		2.3	
Stpi	2.7	2.8		3.2	13.6	6.0	2.6	0.5	0.7
Stco2			1.32						
Stco		0.35							
Feid	4.65	6.3		12.6	53.0				
Sihy	0.3	0.2		0.2	1.3	2.7	1.3		0.8
Kocr	0.9	3.7		1.9	0.5	1.4	3.9	2.3	2.1
Orhy								0.9	
Hoju			1.03						
Deca			10.96						
Muhle			4.91						
Spai									14.0
Total	20.00	49.35	23.50	32.40	94.60	20.00	56.90	38.50	27.40
rass-like									
Juba			12.0						
Carex	0.9		8.1	0.8			T		
Cane			43.85						
Total	0.9		63.95	0.8			T		
orbs									
Phbr	0.15	2.9		0.8	1.0	0.8	6.6	8.8	2.8
Poan			0.56						
Irmi			1.7						
Arfr							7.5	2.8	
Sedum						1.9	1.9		3.5
Eriog	0.3			0.2					
Astra							T	4.6	
Anten		T	4.5						
Aster									8.4
Cirsi			2.64						
Erige			0.94						
Ranum			0.75						
Af	0.75		0.94					3.2	
Total	1.20	2.90	12.03	1.00	1.00	2.70	16.00	19.40	14.70
hrubs									
Artr	67.0	19.9	0.56	55.0	4.4	63.0	14.6		4.7
Arar								11.7	
Arlo									26.0
Cela									8.9
Save									2.8
Chrys	10.9	27.4		10.8		14.3	12.5	30.5	14.8
Opunt		T					T		0.7
Total	77.90	47.30	0.56	65.80	4.4	77.30	27.10	42.20	57.90

1/ See list of Symbols, Scientific Names, and Common Names of Plant Species following table 8.

Table 8. - Species frequency and percentage areal cover, mulch, bare soil, and rock for range sites

	Range sites																	
	Mtn. loam (untreated)		Dry mtn. loam (treated)		Orainage bottom		Dry mtn. loam (untreated)		Mtn. loam (treated)		Clay pan		Valley bench		Dry exposure		Salt flat	
Species	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq	Percent cover	Freq
Grasses																		
*Agsp	1.24	10	6.0	10			3.0	40					13.0	90	14.0	70		
Agsm	0.5	10							3.0	30	1.0	10					8.0	80
Agrop	12.13	90	200	100	0.5	40	11.5	80	20.5	100	4.0	70			15.5	80		
Pofe	5.45	90	8.0	90	0.5	10	3.0	50	2.5	20			4.0	80				
Pose											0.5	70			1.5	30		
Stpt	4.7	70	8.0	80			5.5	60	15.0	100	12.0	80	3.0	40			0.5	10
Stco2					4.0	40												
Stco			0.5	10														
Feid	2.72	60	3.0	10			8.0	50	26.5	90								
Sihy	0.25	15	0.5	10			0.5	10	0.5	30	1.5	50					0.5	10
Kocr			3.5	90			0.5	70	0.5	20	0.5	30	3.5	40	1.0	40	1.5	20
Orhy															2.0	20		
Hoju					1.0	30												
Deca					6.0	40												
Muhle					11.0	40												
Spai																	2.5	100
Grass-like																		
Juba					11.0	80												
Carex	0.99	20	0.5		14.0	70	0.5	10										
Cane					12.0	30												
Forbs																		
Phbr	0.25	10	1.5	50					1.0	30	1.0	20	3.0	90	1.0	60	0.25	10
Poan					2.0	20												
Irmi					1.0	10												
Arfr											0.5	10	3.5	40	1.5	40		
Sedum																	0.75	20
Erlog	0.25	15					0.5	20										
Astra															1.5	10		
Anten	0.25	10			4.0	50												
Aster																	1.5	70
Cirsi					1.0	70												
Erige					3.5	60												
Ranun					0.5	10												
Af	0.24	5			0.5	10									0.5	60		
Shrubs																		
Artr	25.74	100	4.5	50	1.0	10	18.5	100	2.5	30			13.5	90			6.0	30
Arar															2.0	20		
Arlo											36.0	100					8.0	60
Cela																	1.0	30
Save																	3.5	30
Chrys	7.18	60	9.0	90			4.5	70			2.5	50	6.0	90	9.0	80	4.5	60
Mulch																		
P	12.13		6.5		2.0		16.0		6.0		6.5		2.0		0.5		0.5	
N	10.4		13.5		14.0		7.0		12.0		12.5		11.5		3.5		5.0	
B	14.85		14.5		10.5		16.5		10.0		17.0		11.0		34.5		54.5	
Rock																		
G	0.74		0.5				3.5				4.0		25.5		9.5		1.5	
C							1.0				0.5		0.5		2.5			

1/ See list of Symbols, Scientific Names, and Common Names of Plant Species following this table.

Symbols, Scientific Names, and Common Names of Plant Species

Grasses

Agsp	*Agropyron spicatum*	Bluebunch wheatgrass
Agsm	*Agropyron smithii*	Western wheatgrass
Agrop	*Agropyron* Spp.	Wheatgrass
Arfr	*Artemisia frigida*	Fringed sagebrush
Deca	*Deschampsia caespitosa*	Tufted hairgrass
Feid	*Festuca idahoensis*	Idaho fescue
Hoju	*Hordeum jubatum*	Foxtail barley
Kocr	*Koeleria cristata*	Prairie junegrass
Muhle	*Muhlenbergia* Spp.	Muhly
Orhy	*Oryzopsis hymenoides*	Indian ricegrass
Pofe	*Poa fendleriana*	Mutton bluegrass
Pose	*Poa secunda*	Sandberg bluegrass
Sihy	*Sitanion hystrix*	Bottlebrush squirreltail
Spai	*Sporobolus airoides*	Alkali sacaton
Stco2	*Stipa columbiana*	Subalpine needlegrass
Stco	*Stipa comata*	Needle-and-thread-grass
Stpi	*Stipa pinetorum*	Pine needlegrass

Grass-Like

Cane	*Carex nebraskensis*	Nebraska sedge
Carex	*Carex* Spp.	Sedge
Juba	*Juncus balticus*	Baltic rush

Forbs

Anten	*Antennaria* Spp.	Pussytoes
Aster	*Aster* Spp.	Aster
Astra	*Astragalus* Spp.	Locoweed
Cirsi	*Cirsium* Spp.	Thistle
Erige	*Erigeron* Spp.	Daisy
Eriog	*Eriogonum* Spp.	Buckwheat
Irmi	*Iris missouriensis*	Rocky Mountain iris
Phbr	*Phlox bryoides*	Phlox
Poan	*Potentilla answerina*	Silverweed cinquefoil
Ranun	*Ranunculus* Spp.	Buttercup
Sedum	*Sedum* Spp.	Stonecrop
Af	*Unidentified*	Annual forb
T	Trace species	

Symbols, Scientific Names, and Common Names of Plant Species - Continued

Shrubs

Arar	Artemisia arbuscula	Low sagebrush
Arlo	Artemisia longiloba	Alkali sagebrush
Artr	Artemisia tridentata	Big sagebrush
Cela	Ceratoides lanata	Winterfat
Chrys	Chrysothamnus Spp.	Rabbitbrush
Save	Sarcobatus vermiculatus	Greasewood
Opunt	Opuntia Spp.	Prickly pear

Mulch

P	Persistent litter	Large animal droppings and woody material
N	Nonperisitent litter lasting less than 2 years	

Rock

G	Gravel < 3 inches
C	Cobble 3 to 10 inches
B	Bare ground

Figure 33. - Vegetation typical of the untreated mountain loam range site (228)

Figure 34. - Vegetation typical of the treated mountain loam range site (T228)

Potential production (air-dry weight) ranges from 1,200 pounds per acre during unfavorable years to 1,800 pounds per acre during favorable years. Optimum ground cover is 35 percent.

Mountain Loam - Treated (T228)

This site (fig. 34) contains the same soil, topography, and environmental factors and has the same potential as described under mountain loam. The difference between the areas is the significant variation of total annual production and proportion of species from one site to the other. This variation is due to the fact that this portion of the mountain loam site falls within an area that was chemically treated for sagebrush control in 1963.

This site is fifth in terms of total annual production within the Study Area. The vegetative composition of this area is predominately grasses with more than 50 percent of the composition being Idaho fescue along with various wheatgrasses, muttongrass, and pine needlegrass, which account for 39 percent of the vegetative composition. The present vegetative composition, based on percent air-dry weight, computes to be approximately 95 percent grass, 1 percent forb, and 4 percent shrub in contrast to 21 percent grass, 1 percent forb, and 78 percent shrub within the untreated mountain loam site.

Dry Mountain Loam (231)

The dry mountain loam site (fig. 35) occupies gently sloping to steeper hillsides of the Study Area. The soils are gritty loams to sandy loams with a depth of topsoil of about 7 inches. Exposure and wind limit plant growth on areas within this site.

This range site is fourth in terms of total annual vegetative production within the Study Area. The site is dominated by the shrub component. Big sagebrush and rabbitbrush contribute approximately 66 percent to the total annual production. Bluebunch wheatgrass, muttongrass, and Idaho fescue are the dominant grass components.

The SCS range productivity and composition information indicates the site's potential composition (by weight) as:

30 percent big sagebrush	Artemisia tridentata
10 percent pine needlegrass	Stipa columbiana
10 percent streambank wheatgrass	Agropyron riparium
10 percent sheep fescue	Festuca ovina
10 percent muttongrass	Poa fendleriana
10 percent low rabbitbrush	Chrysothamnus Spp.
5 percent junegrass	Koeleria cristata
3 percent buckwheat	Eriogonum Spp.
3 percent bluebunch wheatgrass	Agropyron spicatum
2 percent squirreltail	Sitanion hystrix
2 percent low phlox	Phlox Spp.
5 percent unknowns	

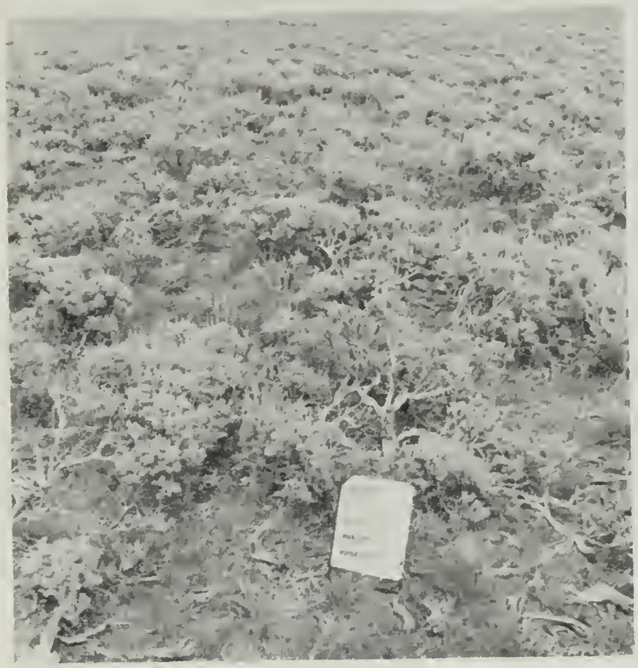


Figure 35. - Vegetation typical of the untreated dry mountain loam range site (231).

Figure 36. - Vegetation typical of the treated dry mountain loam range site (T231).

Potential production (air-dry weight) ranges from 500 pounds per acre during unfavorable years to 1,000 pounds per acre during favorable years. Optimum ground cover is 35 percent.

The present vegetative composition on an air-dry weight basis is approximately 33 percent grass, 1 percent forb, and 66 percent shrub.

Dry Mountain Loam - Treated (T231)

This portion of the dry mountain loam site (fig. 36) falls within the area sprayed in 1963. This alteration of the vegetative community causes significant variations in the proportions of species and a slight variation in total annual production between this area and the untreated dry mountain loam site.

This treated area is second in terms of total annual production within the Study Area. Muttongrass, various wheatgrasses, and Idaho fescue contribute 16.3 percent, 19.8 percent, and 6.3 percent, respectively, to this production. Pine needlegrass and junegrass also form a significant part of the understory. Big sagebrush and rabbitbrush contribute 19.9 percent and 27.4 percent, respectively, as opposed to 55 percent and 10.8 percent in the untreated dry mountain loam area.

Dry Exposure (235)

The dry exposure range site (fig. 37) occupies the steep slopes, ridges, and hilltops within the Study Area.

Soils within this site are gravelly sandy loams to gravelly loams. Soils have a droughty desert appearance with fine- to medium-sized gravel on the surface. Topsoil is thin and low in fertility. These factors coupled with sharply reduced moisture affectiveness due to slopes, soils, snow removal by wind, and high evaporative rates contribute to restrictions in plant growth.

This site is eighth in total annual production within the area having a predominately grass and cushion-type forb plant community. The wheatgrasses dominate the grass production, while phlox, fringed sage, and loco are the major forb producing species. Low sage and low rabbitbrush comprise the shrub composition.

The present vegetative composition on an air-dry weight basis computes to be approximately 38 percent grass, 19 percent forb, and 42 percent shrub.

The SCS range productivity and composition information indicates the site's potential composition (by weight) as:

15 percent bluebunch wheatgrass	*Agropyron spicatum*
10 percent Indian ricegrass	*Oryzopsis hymenoides*
10 percent rabbitbrush	*Chrysothamnus* Spp.
10 percent other perennial grasses	
10 percent junegrass	*Koeleria cristata*
10 percent fringed sage	*Artemisia frigi*
5 percent needle-and-thread grass	*Stipa comata*

Figure 37. - Vegetation typical of the dry exposure range site (235).

Figure 38. - Vegetation typical of the salt flat range site (261).

5 percent buckwheat	Eriogonum Spp.
5 percent pussytoes	Antennaria Spp.
5 percent streambank wheatgrass	Agropyron riparium
5 percent blue grama	Bouteloua graci
5 percent globe mallow	Sphaeralcea coccinea
5 percent nailwort	Paronychia Spp.

Potential production (air-dry weight) ranges from 200 pounds per acre during unfavorable years to 500 pounds per acre during favorable years. Ground cover is approximately 25 percent.

Salt Flats (261)

The salt flat range site (fig. 38) occupies the flat to gently sloping swales at the eastern portion of the Study Area.

Soils within this site are moderately well-developed natric soils developing in strongly alkali sediments. The texture varies from a sandy clay loam to a clay through the profile. The combination of heavy soils and sodium salts restrict plant growth.

This site is the lowest in terms of annual vegetation production within the Study Area. The site has a salt tolerant shrub-grassland plant community. Western wheatgrass and alkali sacaton are the dominant grass species totaling approximately 24 percent of the annual production, while phlox, stonecrop, and aster comprise the forb composition producing nearly 15 percent of the annual production. Sagebrush, winterfat, rabbitbrush, and greasewood comprise the majority of the shrub composition which totals approximately 57 percent of the total annual production.

The SCS range productivity and composition information indicates the site's potential composition (by weight) as:

15 percent western wheatgrass	Agropyron smithii
15 percent saltgrass	Distichlis stricta
10 percent alkali bluegrass	Pos juncifolia
10 percent squirreltail	Sitanion hystrix
10 percent alkaligrass	Sporobolus airoides
10 percent big sagebrush	Artemisia tridentata
5 percent Indian ricegrass	Oryzopsis hymenoides
5 percent greasewood	Sarcobatus vermiculatus
5 percent winterfat	Ceratoides lanata
5 percent mat saltbush	Atriplex Spp.
10 percent unknowns	

Potential production (air-dry weight) ranges from 500 pounds per acre during unfavorable years to 900 pounds per acre during favorable years. Optimum ground cover is 25 percent.

Valley Bench (270)

The valley bench range site (fig. 39) occupies the broad-sweeping benchlands within the Study Area.

Figure 39. - Vegetation typical of the valley bench range site (270).

Figure 40. - Vegetation typical of the clay pan range site (296/231).

The soils are light-colored sandy loam with fine to medium gravel to cobble on the surface. Moisture intake rate is rapid with moderate waterholding capacity.

This site is seventh in total annual production within the Study Area and contains a grassland-sagebrush plant community. Bluebunch wheatgrass, muttongrass, and junegrass are the most frequently occurring grasses totaling approximately 51 percent of the total annual production. Big sagebrush and low rabbitbrush account for 27 percent of the production, while fringed sage, phlox, and stonecrop make up the forb composition totaling approximately 16 percent of the total annual production.

The SCS range productivity and composition information indicates the site's potential composition (by weight) as:

30 percent big sagebrush	Artemisia tridentata
10 percent junegrass	Koeleria cristata
10 percent streambank wheatgrass	Agropyron riparium
10 percent pine needlegrass	Stipa columbiana
10 percent muttongrass	Poa fendleriana
5 percent squirreltail	Sitanion hystrix
5 percent bluebunch wheatgrass	Agropyron spicatum
5 percent needle-and-thread grass	Stripa comata
5 percent blue grama	Bouteloua gracili
5 percent low rabbitbrush	Chrysothamnus Spp.
3 percent buckwheat	Eriogonum Spp.
2 percent unknowns	

Potential production (air-dry weight) ranges from 500 pounds per acre during unfavorable years to 1,000 pounds per acre during favorable years. Ground cover is approximately 30 percent.

Clay Pan (296/231)

Ths clay-pan range site (fig. 40) is found mainly in the western portion of the Study Area on the nearly level to gentle slopes. The effective precipitation is limited by the low water intake rate of the soil. The subsoil is strongly structured and fine textured. The subsoil clays restrict water permeability and plant moisture availability due to the high swelling clays. The topsoil ranges in thickness from 1 to 8, inches and the texture may be fine sandy clay loam or silty clay.

The area supports a sparse, low appearing, shrub-dominated community. Alkali sagebrush is the dominant shrub species accounting for 63 percent of the total annual production. Low rabbitbrush is also quite prevalent. Pine needlegrass, Sandberg bluegrass, squirreltail, and various wheatgrasses are the principal grass species.

This site is sixth in total annual production of the sites, sampled with approximately 77 percent shrub, 3 percent forb, and 20 percent grass species production.

The SCS range productivity and composition information indicates the site's potential composition (by weight) as:

35 percent	alkali sagebrush	*Artemisia longiloba*
10 percent	pine needlegrass	*Stipa columbiana*
10 percent	streambank wheatgrass	*Agropyron riparium*
10 percent	muttongrass	*Poa fendleriana*
5 percent	low rabbitbrush	*Chrysothamnus* Spp.
5 percent	junegrass	*Koeleria cristata*
5 percent	squirreltail	*Sitanion hystrix*
5 percent	winterfat	*Ceratoides lanata*
5 percent	bluebunch wheatgrass	*Agropyron spicatum*
5 percent	stonecrop	*Sedum* Spp.
5 percent	unknowns	

Potential production (air-dry weight) ranges from 300 pounds per acre during unfavorable years to 800 pounds per acre during favorable years. Optimum ground cover is 35 percent.

Drainage Bottom (D.B.)

The drainage bottom area (fig. 41) is found mainly in the eastern portion of the Study Area along Bush and Williams Draw. The hydrologic characteristics of this area are what delineates this area from the other sites within the Study Area. Runoff and a high water table provide the medium for a plant community dominated by sedge and rush Spp. These two comprise approximately 64 percent of the total annual production. Wheatgrass Spp., tufted hairgrass, and Muhly Spp. are also important components of the annual grass production. Of the nine sites sampled, this area has the greatest diversity in terms of forb composition. Rocky Mountain iris, pussytoes Spp., and thistle Spp. are the principal producers. This site is third in total annual production, but no information on yield potential or composition potential is available for this site.

Figure 41. - Vegetation typical of the drainage bottom areas (D.B.).

HYDROLOGY

In order to determine potential effects of surface mining on the environment of the McCallum Study Area, it is necessary to understand its hydrology. Surface-water data have been obtained for the McCallum Study Area since 1979, primarily in the Williams Draw basin. These data have provided a basic understanding of the runoff and water-quality characteristics of the basin. Recent data observed for runoff and water-quality characteristics on Williams and Bush Draws were used to improve and verify the interpretations provided in this section.

Ground-water data for the McCallum Study Area are practically nonexistent; therefore, the conclusions on that subject are tentative. Additional data are needed for a basic understanding of the ground-water hydrology.

Surface Water

Streamflow

The gently rolling topography of the McCallum Study Area is drained by two ephemeral streams, Williams Draw and Bush Draw, which are northeast-flowing tributaries of the Canadian River (fig. 42). The Canadian River, northeast of the McCallum Study Area and the only major perennial stream nearby, flows northwesterly out of the Medicine Bow Mountains and across the eastern portion of North Park, where it has developed a flood plain one-fourth to one-half mile wide.

As part of a larger ongoing study, two continuous-record streamflow and water-quality monitoring stations were installed on the Canadian River in April 1978, one upstream (station 06619400 near Lindland, Colorado) and one downstream (station 06619450 near Brownlee, Colorado) from the proposed coal developments in the McCallum Study Area (fig. 42). Hydrographs for the 1978 and 1979 water years for these two stations are shown in figures 43 and 44.

The hydrographs shown in figures 43 and 44 represent less than 2 years of streamflow; however, the flow characteristics can be described in general terms on the basis of comparison with annual hydrographs of other stations in Jackson County with longer periods of record. The water year in the North Park area can be divided into two phases in which the streamflow characteristics are markedly different. Phase 1 begins in early spring when ice breakup and snow melting at low elevations cause sharp increases in stream discharge. Flows recede somewhat after this period, then increase in May and June due to snow melting at higher elevations. Temperature and the amount of solar radiation and precipitation affect the magnitude, timing, and number of streamflow peaks due to snowmelt. Streamflow during this phase is a variable mix of ground-water discharge and snowmelt runoff.

Phase 2 begins in late June, when snowmelt floods subside. In July and August, rainstorms cause moderate increases in streamflow. In September, base flow conditions are established and prevail throughout the winter except

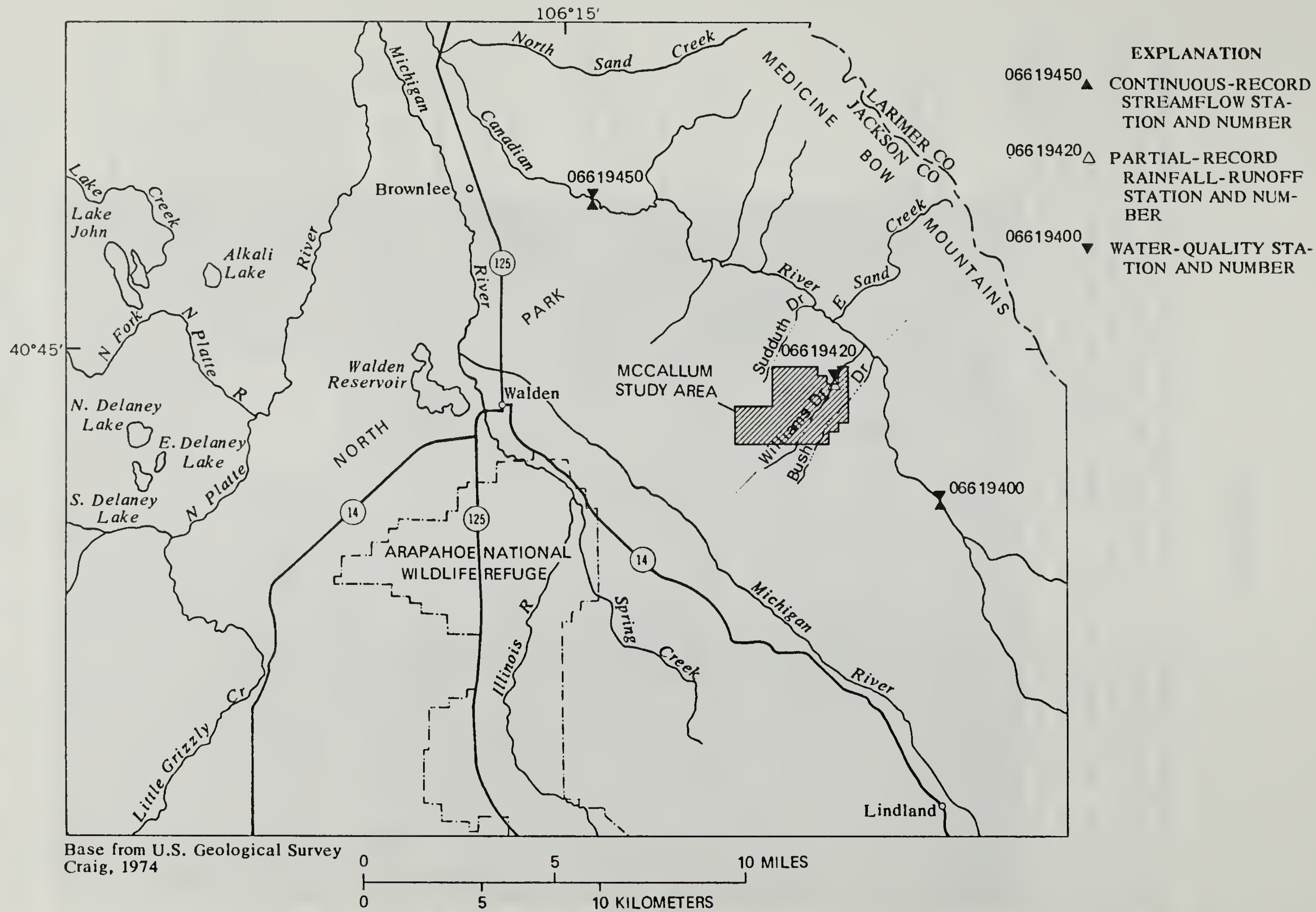


Figure 42. - Tributaries of the Canadian River located in the McCallum Study Area.

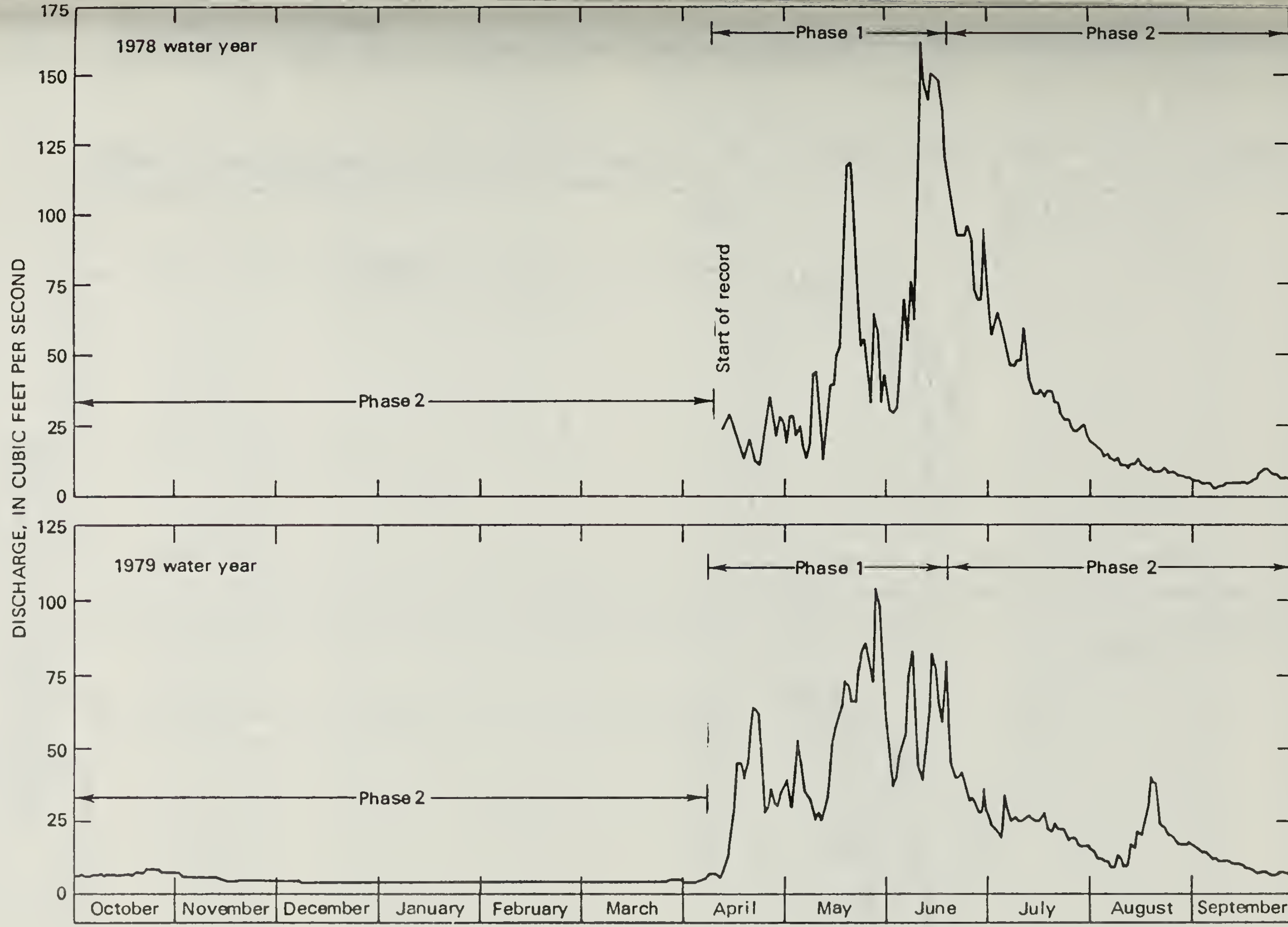


Figure 43. - Mean daily streamflow at station 06619400, Canadian River near Lindland, Colorado.

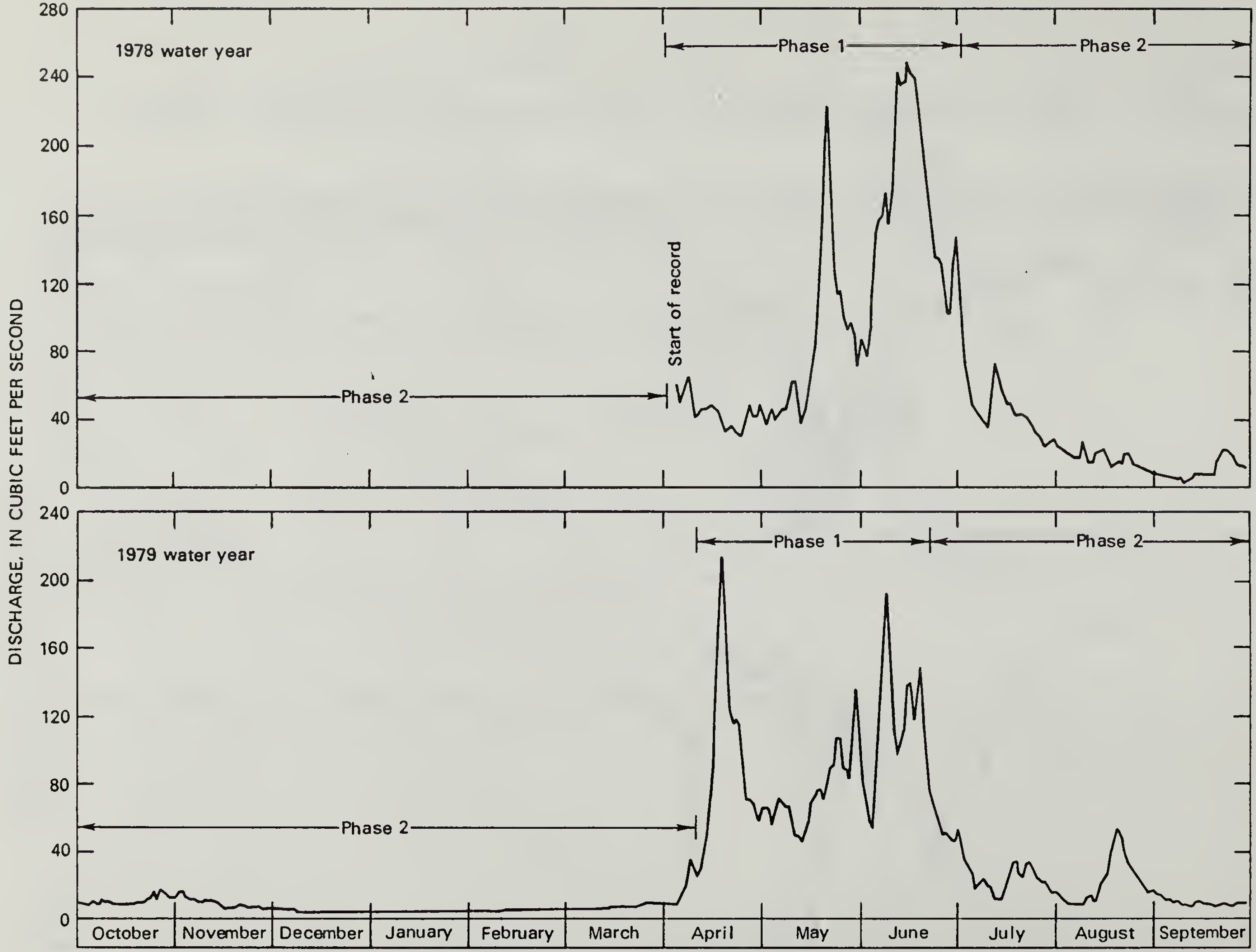


Figure 44. - Mean daily streamflow at station 06619450, Canadian River near Brownlee, Colorado.

for minor fluctuations in streamflow caused by precipitation and variations in temperature. Base flow is sustained primarily by ground-water discharge to the stream from the alluvial aquifer adjoining the river channel.

A partial-record, rainfall-runoff station (06619420) was installed in Williams Draw in July 1979 to gather streamflow records downstream from the McCallum Study Area (fig. 42). Hydrographs for this station for the 1980 and 1982 runoff seasons are shown in figure 45; there was no flow during the 1981 season. The large peak in April 1980 was the result of rapid melting of a significant amount of snow which accumulated the preceding winter. Additional snowfall in May resulted in lesser snowmelt peaks. Snow accumulation during 1982 was not significant, but two spring snowstorms resulted in some runoff in April and May (fig. 45).

Significant runoff in Williams Draw due to rainfall has not been recorded through the 1982 water year. For example, two continuous-record precipitation gages (fig. 46) in the Williams Draw basin recorded an average of 1.18 inches of rain during August 15-20, 1979. A maximum 1-day total of 0.55 inch and a maximum 1-hour total of 0.32 inch were recorded on August 18 at the upper site. None of this precipitation produced runoff at the gage. However, the two Canadian River gages recorded significant increases in streamflow during this period (figs. 43 and 44). A similar type of rainstorm in September 1982 resulted in a very small amount of runoff in Williams Draw (fig. 45). To date, all significant runoff in Williams Draw was the result of snowmelt.

Use

During the growing season, generally extending from May through August in North Park, a considerable demand is placed upon surface water for flood-type irrigation of hay meadows within and adjacent to the flood plains of the Canadian River and its tributaries. These diversions, together with the associated return flows, greatly affect the natural flow of the river and its tributaries. However, because streamflow records were not collected prior to the start of irrigation in this area, the effects of irrigation on streamflow cannot be determined. During years of low to moderate snowmelt runoff, the effects of irrigation will be much more evident than during years of high snowmelt runoff.

Although no irrigation of hay meadows takes place in the McCallum Study Area, the use of water for livestock and wildlife watering is of some importance. Water for this use is provided by several stock ponds in the Bush and Williams Draw basins and a small, developed spring in the SW1/4 sec. 22 (fig. 46).

Chemical Quality

A sampling program to determine the water quality of the Canadian River was begun in November 1977 in anticipation of the establishment of two monitoring stations the following April. Summaries of the water-quality data obtained at these two stations are given in tables 9 and 10. Water samples for Williams Draw were collected whenever runoff conditions existed and personnel were at the station. The results of these anlayses are shown in table 11. With the

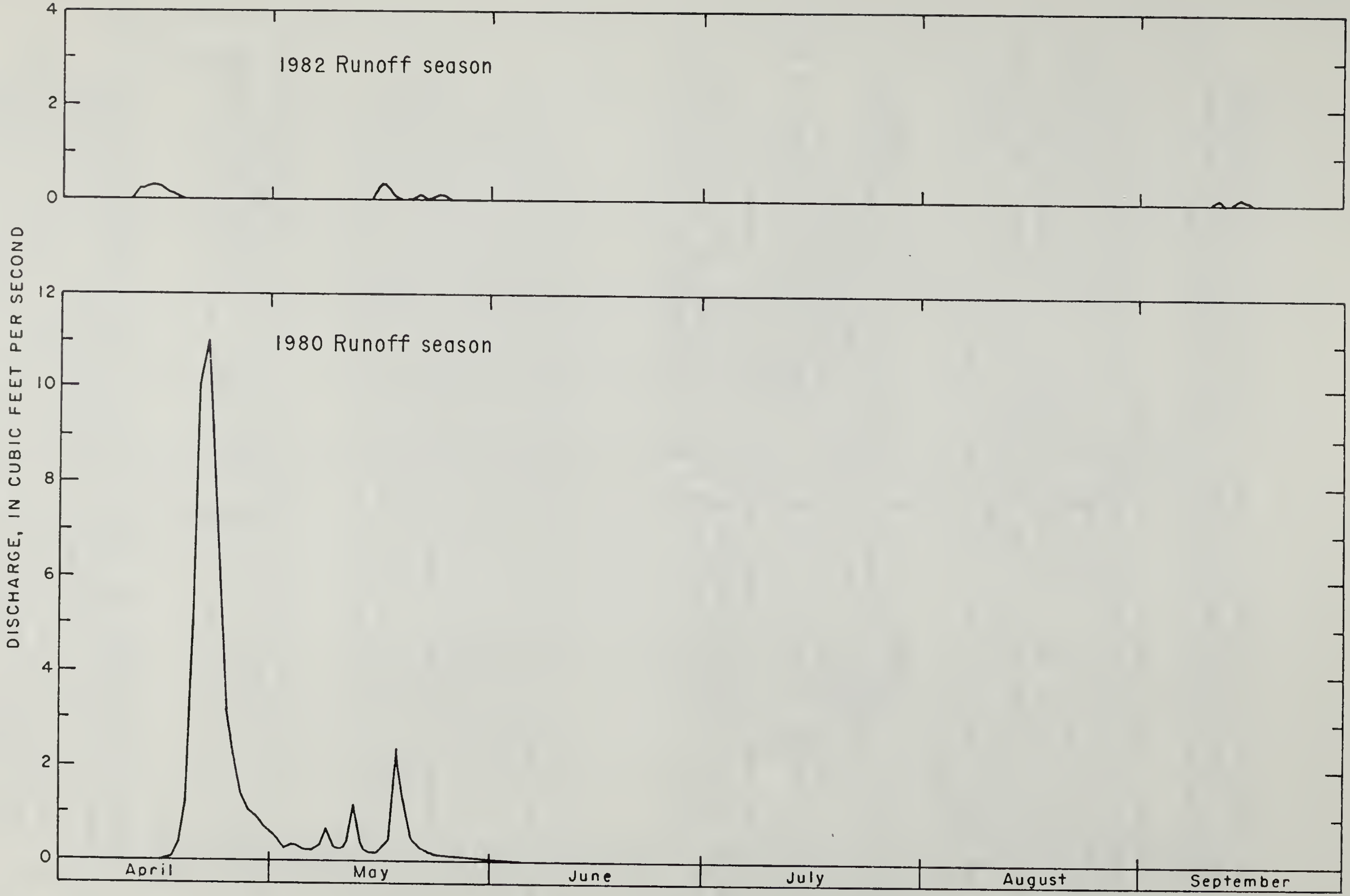


Figure 45. - Mean daily streamflow at station 06619420, Williams Draw near Walden, Colorado.

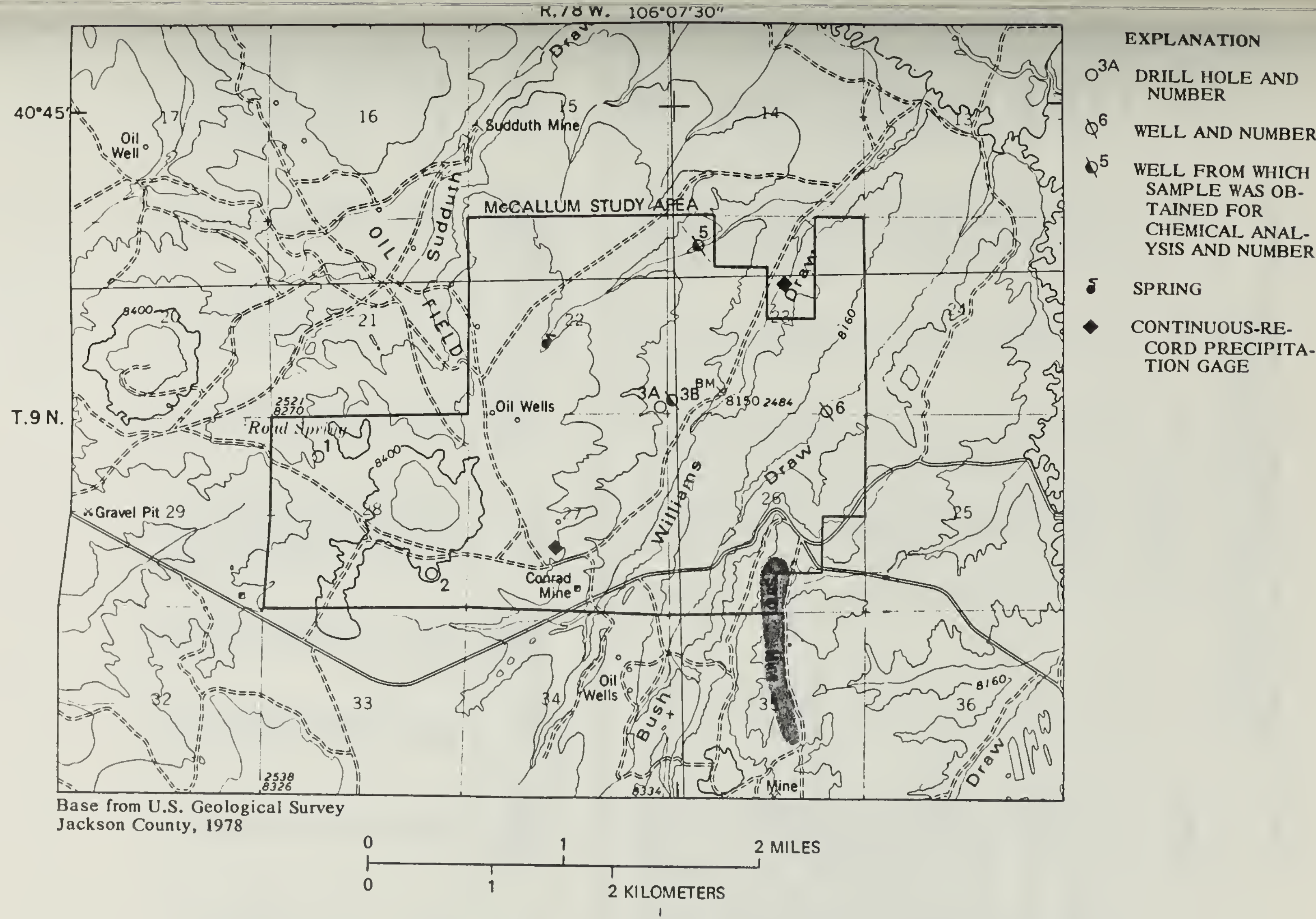


Figure 46. - Location of drill holes, wells, spring, and precipitation gages in the McCallum Study Area.

Table 9. - Summary of water-quality data for station 06619400, Canadian River near Lindland, Colorado

Property	No. of analyses	Mean	Median	Range	Units
Discharge	105	28.7	16.2	4.0-119	ft^3/s
Dissolved oxygen	40	9.2	9.2	6.6-12.4	mg/L
pH	40		7.6	6.8-8.4	units
Specific conductance (at 25 °C)	42	172	185	80-290	µmho/cm
Temperature	106	9.6	10.8	0.0-22.0	°C
Alkalinity (as $CaCO_3$)	40	54	57	19-74	mg/L
Calcium, dissolved	39	23	23	10-37	mg/L
Carbon, organic, dissolved as C	15	6.8	6.6	2.2-14	mg/L
Carbon, organic, total as C	13	7.3	7.3	3.7-13	mg/L
Chloride, dissolved	40	1.3	0.7	0.1-13	mg/L
Fluoride, dissolved	40	0.1	0.1	0-0.20	mg/L
Magnesium, dissolved	39	5.1	5.6	2.3-7.9	mg/L
Potassium, dissolved	40	1.4	1.1	0.5-5.8	mg/L
Nitrogen, NO_2 + NO_3, dissolved as N	40	0.09	0.08	0-0.70	mg/L
Phosphate, ortho, dissolved as PO_4	38	0.08	0.03	0-0.43	mg/L
Phosphorus, ortho, dissolved as P	39	0.03	0.01	0-0.14	mg/L
Silica, dissolved	39	8.1	8.4	0.7-10	mg/L
Sodium, dissolved	39	4.8	4.6	1.7-12	mg/L
SAR	39	0.25	0.23	0.11-0.59	
Sulfate, dissolved	40	31	36	0.9-56	mg/L
Solids, sum of dissolved constituents	38	107	114	48-160	mg/L
Solids, dissolved load	37	6.7	3.6	1.5-22	t/acre-ft

Property	Dissolved				Total recoverable			
	No. of analyses	Mean (µg/L)	Median (µg/L)	Range (µg/L)	No. of analyses	Mean (µg/L)	Median (µg/L)	Range (µg/L)
Aluminum	13	48	30	1.0-200	13	389	300	100-1200
Arsenic	10	0.8	1.0	0-1.0	8	0.9	1.0	0-2.0
Boron	40	26	20	0-70				
Cadmium	10	1.5	1.5	0-3.0	8	0.4	0.0	0-1.0
Copper	10	1.2	1.5	0-3.0	9	3.7	3.0	0-13
Iron	38	352	325	40-610	31	1066	880	500-3100
Lead	15	6.9	3.0	0-62	13	7.9	4.0	0-61
Maganese	39	45	40	10-140	31	66	50	20-220
Mercury	10	0.07	0.1	0-0.1	7	0.09	0.1	0-0.3
Molybdenum	8	5.5	5.5	1.0-10	8	0.9	0.5	0-3.0
Nickel	10	4.9	2.0	0-37	8	2.9	2.5	0-6.0
Selenium	10	0.6	1.0	0-1.0	7	0.4	0.0	0-1.0
Zinc	15	8.9	4.0	0-30	13	18	20	0-50

Table 10. - Summary of water-quality data for station 06619450, Canadian River near Brownlee, Colorado

Property	No. of analyses	Mean	Median	Range	Units
Discharge	123	40	18	2.4-322	ft^3/s
Dissolved oxygen	39	7.7	7.7	3.4-10.9	mg/L
pH	39		7.8	7.1-8.7	units
Specific conductance (at 25 °C)	40	288	291	200-445	µmho/cm
Temperature	124	12.6	14.0	0-26.5	°C
Alkalinity (as $CaCO_3$)	39	106	110	74-150	mg/L
Calcium, dissolved	39	36	36	24-50	mg/L
Carbon, organic, dissolved as C	14	9.2	8.4	3.3-16	mg/L
Carbon, organic, total as C	14	10	9.7	3.2-17	mg/L
Chloride, dissolved	39	1.8	1.4	0.5-11	mg/L
Fluoride, dissolved	39	0.2	0.2	0.1-0.2	mg/L
Magnesium, dissolved	39	9.3	9.4	6-13	mg/L
Potassium, dissolved	39	2.0	1.7	1.1-5.0	mg/L
Nitrogen, $NO_2 + NO_3$, dissolved as N	39	0.09	0.09	0.01-0.47	mg/L
Phosphate, ortho, dissolved as PO_4	38	0.06	0.03	0-0.30	mg/L
Phosphorus, ortho, dissolved as P	38	0.02	0.01	0-0.10	mg/L
Silica, dissolved	38	10	10	6.2-14	mg/L
Sodium, dissolved	39	11	10	6.6-21	mg/L
SAR	39	0.43	0.40	0.31-0.83	
Sulfate, dissolved	39	41	44	3-110	mg/L
Solids, sum of dissolved constituents	37	175	179	109-282	mg/L
Solids, dissolved load	36	22	7.1	1.5-148	t/acre-ft

Property	Dissolved				Total recoverable			
	No. of analyses	Mean (µg/L)	Median (µg/L)	Range (µg/L)	No. of analyses	Mean (µg/L)	Median (µg/L)	Range (µg/L)
Aluminum	13	44	40	0-140	13	335	220	0-1800
Arsenic	10	1.1	1.0	0-3.0	8	1.1	1.0	1.0-2.0
Boron	39	40	40	20-80				
Cadmium	10	1.4	1.0	0-3.0	8	0.6	0.5	0-2.0
Copper	10	1.6	2.0	0-3.0	9	29	3.0	0-5.0
Iron	39	190	170	30-520	30	784	645	290-2600
Lead	15	5.0	2.0	0-24	13	11	3.0	0-80
Maganese	39	41	30	10-240	30	64	50	20-300
Mercury	10	0.1	0.1	0.0-0.4	7	0.1	0.1	0.0-0.4
Molybdenum	8	5.5	5.5	1.0-10	8	1.5	1.5	0-4.0
Nickel	10	3.7	2.5	0-13	8	3.9	3.5	0-9.0
Selenium	10	0.6	1.0	0-1.0	7	0.4	0.0	0-1.0
Zinc	15	8.1	4.0	0-37	13	18	20	0-60

Table 11. - Summary of water-quality data for station 06619420, Williams Draw near Walden, Colorado

Property	No. of analyses	Mean	Median	Range	Units
Discharge	10	3.3	0.8	0.08-16	ft^3/s
Dissolved oxygen	5	8.6	8.8	7.0-9.6	mg/L
pH	8		7.8	7.2-8.3	units
Specific conductance (at 25 °C)	10	430	287	95-1300	µmho/cm
Temperature	9	8.1	8.5	0.5-23	°C
Alkalinity (as $CaCO_3$)	10	142	87	40-420	mg/L
Calcium, dissolved	10	34	22	9.4-9.7	mg/L
Carbon, organic, dissolved as C	3	13	13	13-14	mg/L
Carbon, organic, total as C	3	12	13	11-13	mg/L
Chloride, dissolved	10	3.5	2.8	1.2-7.9	mg/L
Fluoride, dissolved	10	0.4	0.4	0.1-0.8	mg/L
Magnesium, dissolved	10	18	11	3.2-58	mg/L
Potassium, dissolved	10	3.9	3.6	2.7-6.4	mg/L
Nitrogen, $NO_2 + NO_3$, dissolved as N	9	0.3	0.1	0.01-2.2	mg/L
Phosphate, ortho, dissolved as PO_4	9	0.5	0.6	0.1-0.9	mg/L
Phosphorus, ortho, dissolved as P	9	0.2	0.2	0.04-0.3	mg/L
Silica, dissolved	10	8.7	8.6	4.3-17	mg/L
Sodium, dissolved	10	37	20	46-120	mg/L
SAR	10	1.13	0.90	0.34-2.53	
Sulfate, dissolved	10	85	34	10-310	mg/L
Solids, sum of dissolved constituents	7	253	186	80-809	mg/L
Solids, dissolved load	7	0.84	0.50	0.07-3.5	t/acre-ft

Property	Dissolved				Total recoverable			
	No. of analyses	Mean (µg/L)	Median (µg/L)	Range (µg/L)	No. of analyses	Mean (µg/L)	Median (µg/L)	Range (µg/L)
Aluminum	8	472	60	10-3100	8	1655	880	80-6900
Arsenic	5	1.2	1.0	1.0-2.0	6	1.8	2.0	1.0-2.0
Boron	10	93	75	10-290				
Cadmium	5	1.2	1.0	1.0-2.0	5	1.0	1.0	0-2.0
Copper	5	2.8	3.0	1.0-5.0	6	6.7	5.0	2.0-20
Iron	10	209	130	20-520	10	1993	1400	230-5100
Lead	8	1.8	1.5	0-4.0	8	15	7.5	1.0-64
Maganese	10	51	28	7-250	10	87	65	20-230
Mercury	5	0.12	0.1	0-0.2	5	0.04	0.0	0-0.1
Molybdenum	5	8.2	10	1.0-10	5	0.8	1.0	0-2.0
Nickel	5	4.8	1.0	0-20	5	6.0	6.0	3.0-9.0
Selenium	5	0.4	0.0	0-1.0	5	0.6	1.0	0-1.0
Zinc	8	22	14	4-89	8	28	20	10-60

exceptions of iron, lead, and manganese, the range of values of the constituents reported in the analyses met the promulgated standards for both aquatic life and domestic drinking water supplies [14, 15].

A difficult goal in water-quality studies is to derive a simple relation between discharge and dissolved-solids concentration, or specific conductance [16, p. 271-280]. This relation is complex for the Canadian River stations. The discharge during phase 1 (figs. 43 and 44) may come from as many as four different sources. Ice buildup in the Canadian River often achieves a bank-full condition; this ice is derived from winter flows which generally have larger specific conductances. Rapid melting of this large volume of ice produces a large discharge having a large specific conductance. Direct overland runoff from the melting of low-elevation snows may also contribute to large conductance readings relative to discharge during this period. Another source is the rapid runoff from snows at high elevations in the granitic Medicine Bow Mountains. Because this runoff has little opportunity to dissolve minerals, large flow could have a smaller specific conductance than a similar discharge during ice breakup. A fourth possible source is ground-water discharge. Because streamflow during this period (phase 1) may come from so many different sources, a specific conductance-discharge relation for the Canadian River stations generally cannot be defined.

During phase 2, the specific conductance-discharge relation is better defined because the flow is more uniform. However, the general dilution relation using specific conductance and discharge is not a satisfactory model for defining the water quality of this region.

The relation between major constituents and specific conductance is more useful for defining water quality. The major constituents in the surface waters of the Canadian River and Williams Draw are bicarbonate, sulfate, calcium, magnesium, and sodium. Bicarbonate concentration is not routinely determined in laboratory analyses as it is largely controlled by a complex equilibrium system [16]. Concentration of bicarbonate generally is expressed in terms of an equivalent concentration of calcium carbonate ($CaCO_3$). Alkalinity, as $CaCO_3$, can easily be converted to bicarbonate concentration by dividing the former by 0.8202 [16, p. 84]. Further discussions in this section reference to alkalinity in milligrams per liter as $CaCO_3$.

Regression plots for the five major constituents and dissolved solids on specific conductance are illustrated in figure 47 for purposes of general comparison among the two Canadian River stations and Williams Draw. More detailed plots of these regressions, showing data points, are included in appendix C. The regression equations and statistics are presented in table 12. These equations are updates of those previously presented by Kuhn [17].

When comparing the regression equations for the two Canadian River stations (06619400 and 06619450), remember that for a given point in time the downstream station (06619450) generally has a greater specific conductance than the upstream station (06619400). Analysis of published values of specific conductance for these stations [18] verifies this and shows that a somewhat

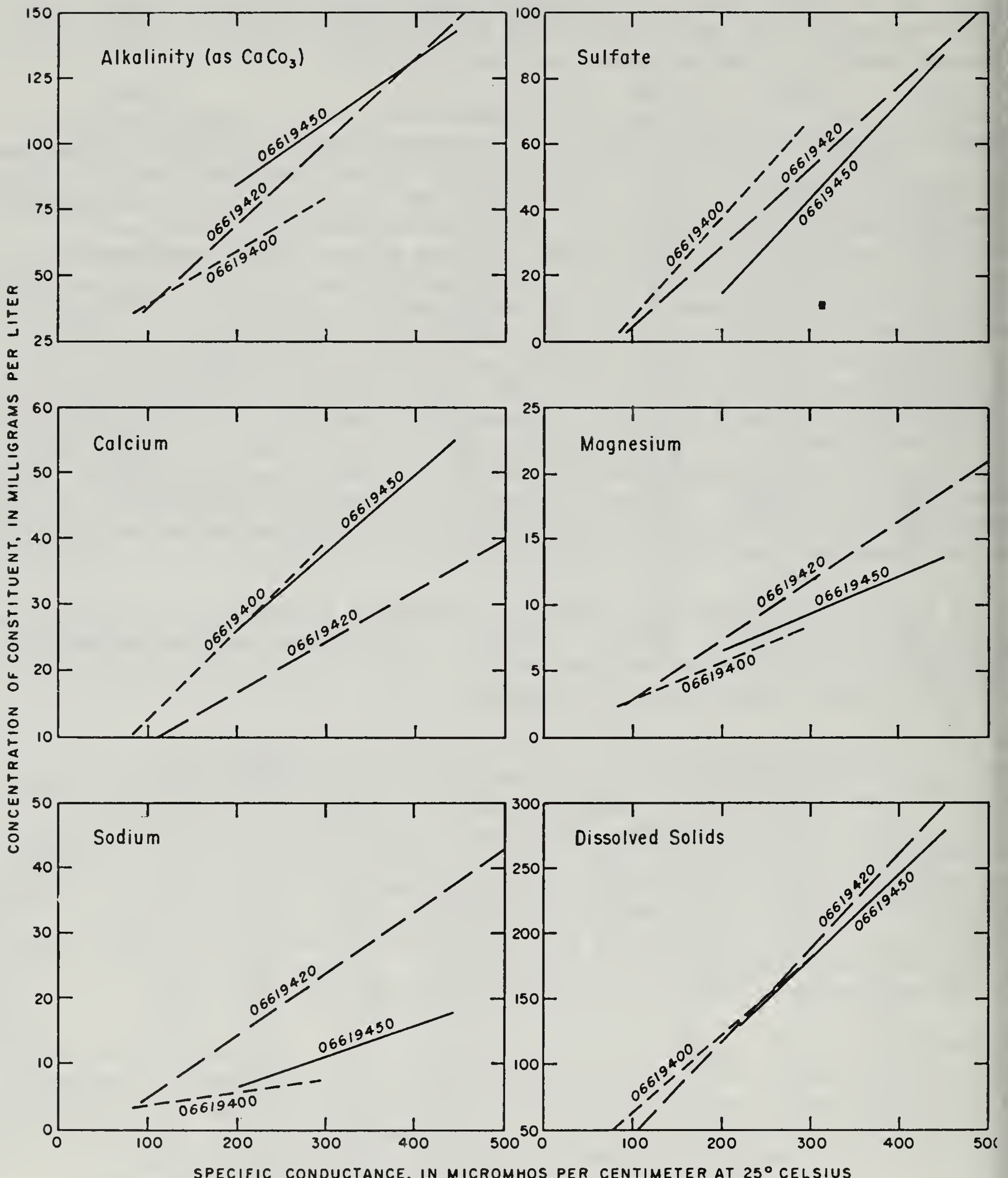


Figure 47. - Comparison of the regressions of five major constituents and dissolved solids on specific conductance for stations 06619400, 06619420, and 06619450.

Table 12. - Regression equations for each of five major constituents and sum of constituents (dissolved solids) for stations 06619400, 06619450, and 06619420

Constituent	No. of samples	Coefficient of determination (R^2)	Standard error of estimate (mg/L)	Equation
		Canadian River near Lindland (06619400)		
Alkalinity (as $CaCO^3$)	40	0.66	7.1	C(alk) = 0.193 x SC + 20
Sulfate	40	0.79	7.7	$C(SO_4^{-2})$ = 0.293 x SC - 20
Calcium	39	0.82	3.2	$C(Ca^{+2})$ = 0.133 x SC
Magnesium	39	0.84	0.6	$C(Mg^{+2})$ = 0.028 x SC + 0.2
Sodium	39	0.25	1.7	$C(Na^{+1})$ = 0.020 x SC + 1.4
Dissolved solids	38	0.86	13	C(DS) = 0.607 x SC + 2.2
		Range of SC = 80-290		
		Canadian River near Brownlee (06619450)		
Alkalinity (as $CaCO^3$)	38	0.47	13	C(alk) = 0.237 x SC +38
Sulfate	38	0.62	12	$C(SO_4^{-1})$ = 0.295 x SC - 44
Calcium	38	0.78	3.2	$C(Ca^{+2})$ = 0.118 x SC + 2.4
Magnesium	38	0.84	0.7	$C(Mg^{+2})$ = 0.029 x SC + 0.8
Sodium	39	0.57	2.1	$C(Na^{+1})$ = 0.048 x SC - 3.1
Dissolved solids	36	0.93	9.2	C(DS) = 0.657 x SC - 13
		Range of SC = 200-445		
		Williams Draw near Walden (06119420)		
Alkalinity (as $CaCO^3$)	10	0.97	24	C(alk) = 0.319 x SC + 53
Sulfate	10	0.98	15	$C(SO_4^{-2})$ = 0.245 x SC - 20
Calcium	10	0.98	4.8	$C(Ca^{+2})$ = 0.076 x SC + 1.5
Magnesium	10	0.98	3.3	$C(Mg^{+2})$ = 0.046 x SC - 1.9
Sodium	10	0.99	2.7	$C(Na^{+1})$ = 0.097 x SC - 5
Dissolved solids	7	0.99	24	C(DS) = 0.720 x SC - 2
		Range of SC = 95-1300		

C = concentration in mg/L.
SC = specific conductance.
DS = dissolved solids.

reasonable situation would be a specific conductance of 200 mho at station 06619400 and a conductance of 300 mho at station 06619450. The observed values show considerable variation; the values of 200 and 300 were chosen for illustration purposes. For the above conductance values, 200 mho at station 06619400 and 300 mho at station 06619450, the regressions (fig. 47) show that alkalinity concentration is significantly larger at station 06619450, whereas sulfate concentration is about the same at both stations. Alkalinity (mostly in the form of bicarbonate), then, readily enters the stream system between the two stations, however, sulfate does not. Time correlation cannot be made between specific conductance on Williams Draw and the Canadian River; however, within the ranges of specific conductance observed on the Canadian River, the concentrations of alkalinity and sulfate on Williams Draw (predicted from the regressions for these two constituents) generally are within the concentration ranges predicted for the Canadian River stations.

The regressions for calcium, magnesium, and sodium on specific conductance show that the relation between these constituents is fairly constant from station 06619400 to station 06619450, except that the sodium regression slope is slightly greater at station 06619450. However, the regression slope for these constituents at station 06619420 is considerably different than at the Canadian River stations. Thus, calcium is less available and magnesium and sodium are more available in Williams Draw than in the Canadian River.

The regression positions and slopes for dissolved solids at all three stations are similar; station 06619420 has a somewhat steeper slope. Within the range of specific conductances observed at the Canadian River stations, dissolved-solids concentration on Williams Draw is similar to that at the former two stations. The maximum specific conductance observed at station 06619420 is much greater than that observed at either stations 06619400 or 06619450; corresponding dissolved solids or individual constituent concentrations also will be much larger at station 06619420. However, these large conductances coincide with very small discharges, and these large concentrations are readily diluted by the Canadian River.

The relation of the major ions to one another can be better understood by converting concentration in milligrams per liter to milliequivalents per liter. In an analysis expressed milliequivalents per liter, unit concentrations of all ions are chemically equivalent [16, p. 82]. The bar graphs in figure 48 show the percentage mean concentrations of the ions in milliequivalents per lit for the samples collected during the 1978 and 1979 water years. The mean concentrations are expressed as a percentage of the cation or anion concentrati The actual average concentration of all the ions considered, however, is 1.6 times greater at the downstream station than at the upstream station. The percentage difference between the mean concentrations of the individual ions at the two stations is shown in the rightmost bar graph in figure 48. Comparis of the average milliequivalents per liter concentration of major constituents at the Canadian River and Williams Draw stations during April and May is shown in figure 49. Whereas the water at both Canadian River stations is a calcium bicarbonate type, the water in Williams Draw is nearly a calcium sodium magnesium type.

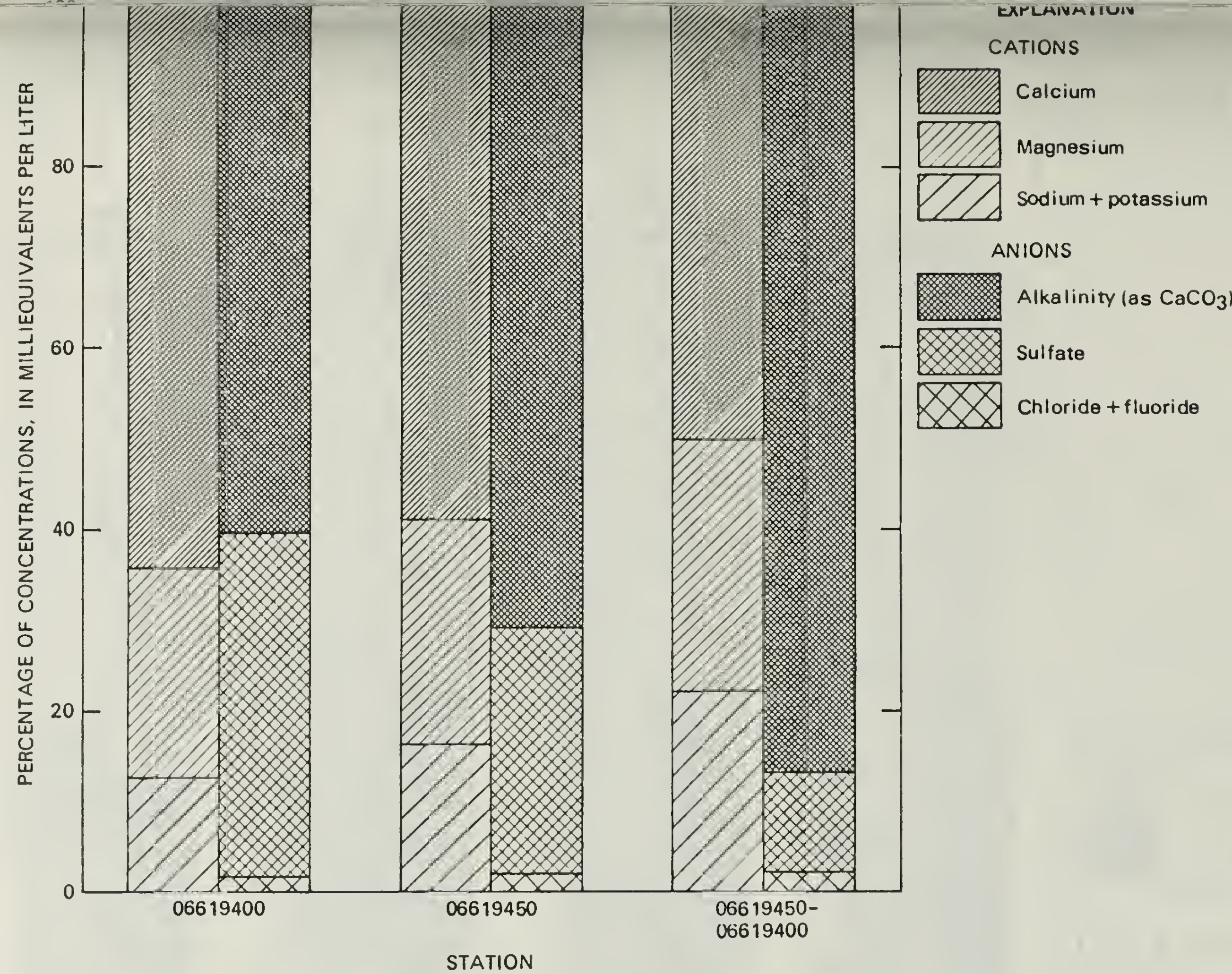


Figure 48. - Percentage mean concentration of ions in water samples taken at stations 06619400 and 06619450 and the differences between the mean concentrations at the two stations for the 1978 and 1979 water years.

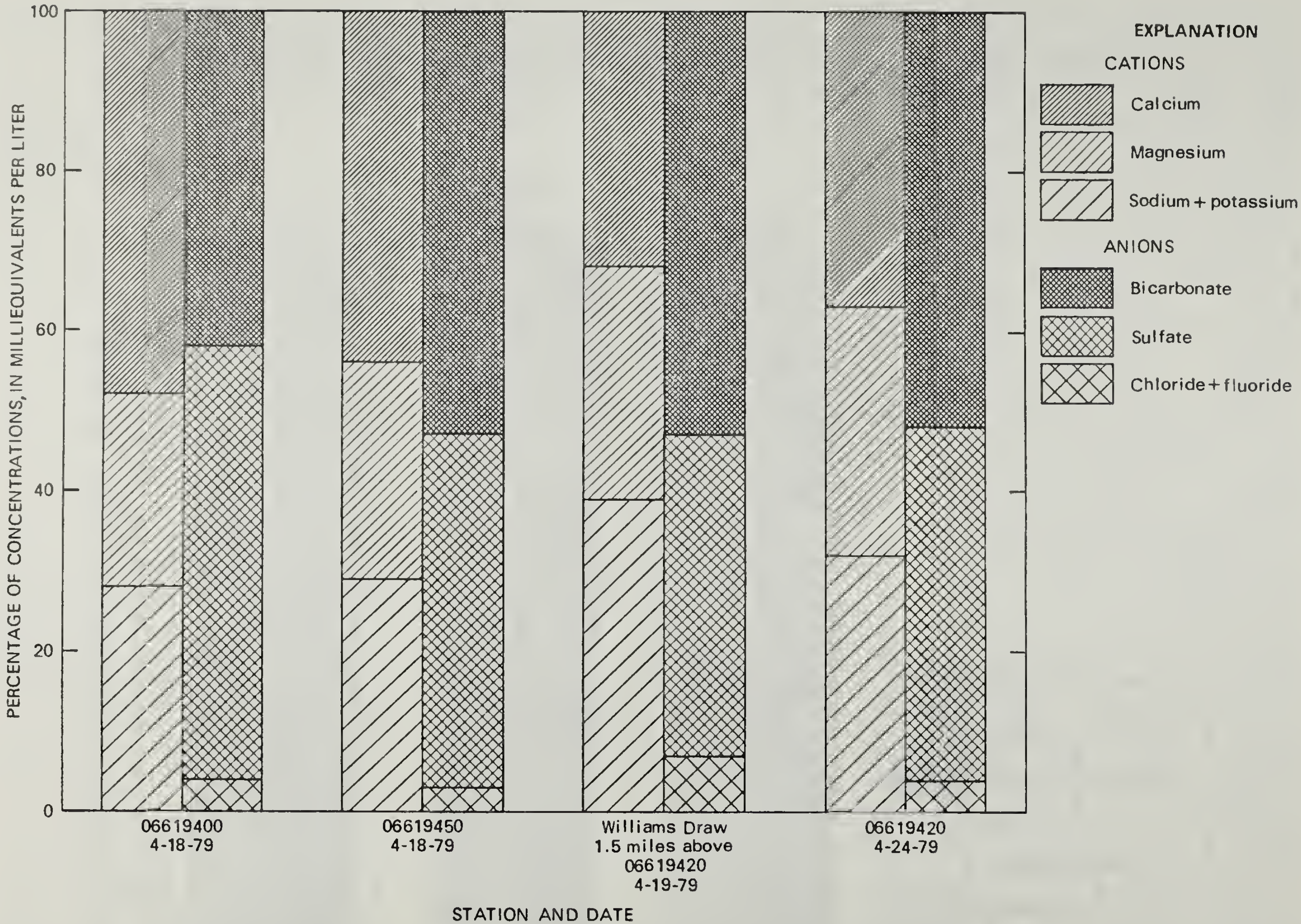


Figure 49. - Average percentage concentration of ions in water samples from Canadian River near Lindland (06619400), Canadian River near Brownlee (06619450),

The load of constituents, in units of weight per time, can be computed from discharge-weighted concentrations. The percent of the annual load contributed by each of the major ions for the two Canadian River stations for the 1979 water year is shown in figure 50. As additional years of data become available, the percentages of the annual ionic loads contributed by each ion should vary only slightly, while the actual load in tons per year may show considerable variation. The annual runoff is highly variable; thus, the annual dissolved-solids load will be variable since it is dependent on the amount of runoff. The dissolved-solids load for Williams Draw cannot be determined from available data; however, since the annual discharge is very small compared to the Canadian River, the load also will be small.

The annual loads shown at the top of the bar charts in figure 50 are approximate values and should not be accepted as the absolute load values for the 1979 water year. These values were determined by weighting the ion concentrations of individual analyses by the mean discharge during the time periods adjacent to the sampling. This indirect method was used to compute the loads because, as previously discussed, the general dilution model is not easily defined for this system since discharge and ion concentration do not always have a direct relation.

Although the values are approximate, they do illustrate that the load of all ions at the downstream station, 06619450, is three times the load at the upstream station, 06619400. The increase in load can be attributed to factors such as ground- and surface-water inflow and continued solution of ions not at saturation with respect to minerals which are contributing the ions.

Suspended Sediment

Automatic-pumping sediment samplers were installed at both Canadian River stations in 1978; annual sediment load data for these stations for the 1979 through 1982 water years are presented in table 13. The data show that about three to five times more sediment passed the downstream station, whereas the discharge was only about 1.2 to 1.9 times greater. Although data for 1981 and 1982 are only for partial years and station 06619400 has some missing data in 1981, it is evident that most of the sediment passes these stations during the 3-month snowmelt period of April, May, and June.

Daily suspended-sediment concentration at either Canadian River station is not large. The maximum mean daily concentration at station 06619400 was 199 milligrams per liter; the corresponding load was 23 tons per day. The maximum daily load, however, was 32 tons. At station 06619450, the maximum daily concentration was 282 milligrams per liter, with a corresponding load of 126 tons per day; the maximum load was 176 tons per day.

Suspended-sediment data for Williams Draw (table 14) show that the concentrations observed are generally less than the daily concentrations at either Canadian River station during snowmelt. The loads for station 06619420 are instantaneous loads and would be daily loads only if the concentrations and discharges at the time of sampling were equal to the mean daily values. These instantaneous load values indicate that loads at station 06619420 are much less than at stations 06619400 and 06619450.

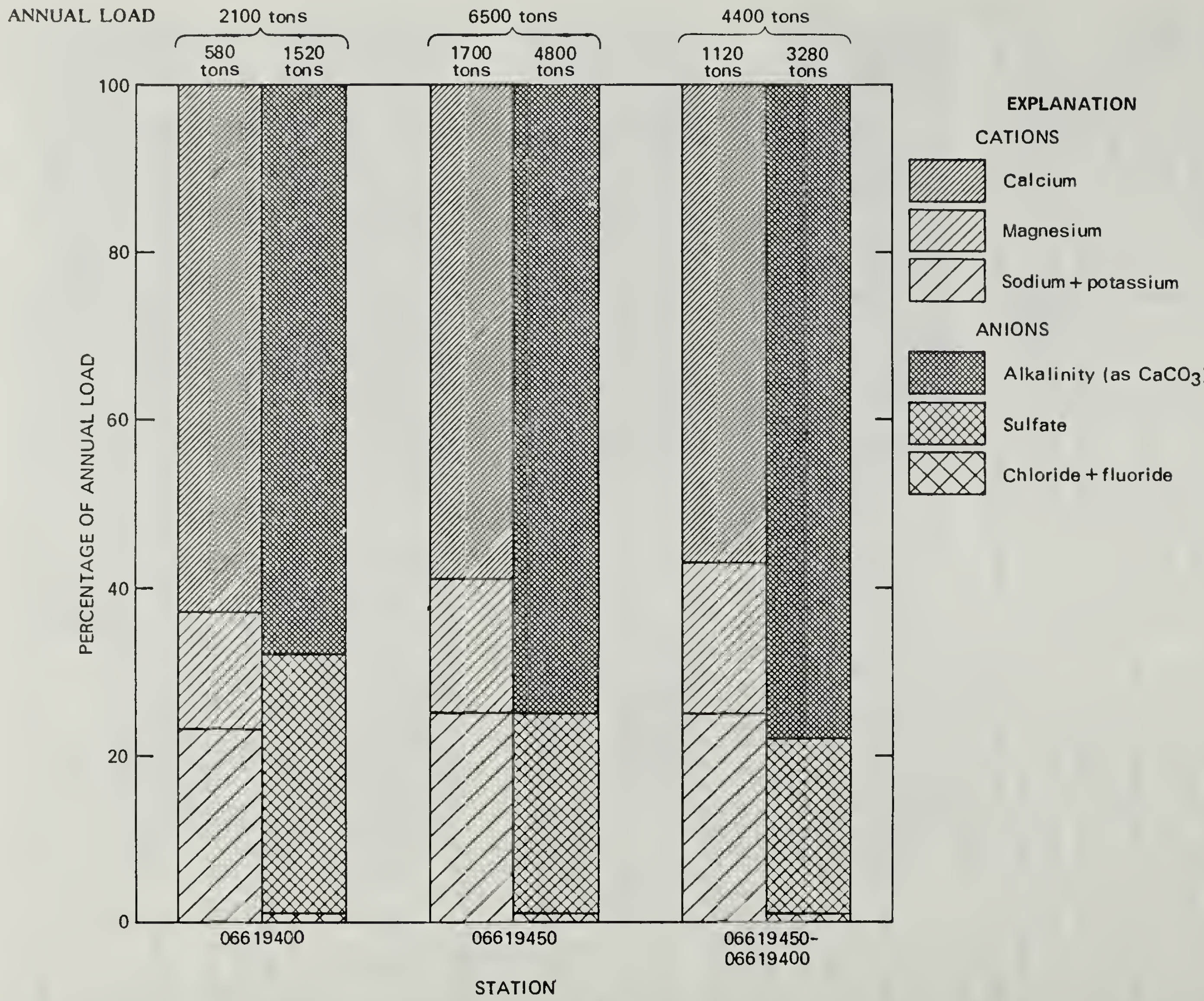


Figure 50. - Percentages of ions in the annual ionic loads of major ions at stations 06619400 and 06619450 and the percentage difference between the annual ionic loads at the two stations for the [illegible] water year.

Table 13. - Summary of annual suspended-sediment loads and runoff for stations 06619400, Canadian River near Lindland, Colorado, and 06619450, Canadian River near Brownlee, Colorado

ater ear	Annual suspended-sediment load tons	April-June suspended-sediment load tons	Percent of annual load in April-June tons	Annual runoff acre-feet	Percent of annual runoff in April-June
		06619400			
979	533	419	79	12,660	62
980	522	469	90	13,060	68
981	1/ 2/ 311	2/ 244	78	10,750	58
982	1/ 437	1/ 326	75	15,690	51
		06619450			
979	2,094	1.905	91	20,560	71
980	2,889	2,802	97	24,540	78
981	1/ 528	412	78	12,480	50
982	1/ 1,398	1,142	82	23,480	53

/ Annual load is for period April to September only.
/ Values include some missing data.

Table 14. - Suspended sediment data for station 06619420, Williams Draw near Walden, Colorado, compared to data for stations 06619400, Canadian River near Lindland, Colorado, and 06619450, Canadian River near Brownlee, Colorado

Date of uspended-sediment sample	Station					
	1/ 06619420		2/ 06619400		2/ 06619450	
	concentration mg/L	load tons	concentration mg/L	load tons	concentration mg/L	load tons
4-24-79	29	0.06	77	14	179	57
4-24-80	35	0.23	80	17	216	176
4-29-80	14	0.03	110	19	-	70
4-13-82	65	0.15	-	1.1	-	5.0
4-26-83	76	2.0				
5- 5-83	63	0.37				

/ Concentration and load are instantaneous values.
/ Concentration is mean daily value, load is for load for day.

Total runoff at the Williams Draw station in 1980 was 123 acre-feet; this represents a mere 0.5 percent of the 1980 water-year runoff at station 0661945 (table 13). If the average concentration (47 mg/L) of the six sediment sample (for station 06619420) is applied to the total 1980 runoff of Williams Draw, the total suspended-sediment load would be 7.7 tons. If the maximum observed concentration, 76 milligrams per liter, were used, the total load would be 13 ns this, in turn, would represent only 0.5 percent of the annual sediment load at station 06619450. Although these are hypothetical situations, they do demonstrate that the amount of sediment contributed to the Canadian River by Williams Draw is small.

Between stations 06619400 and 06619450 are several other ephemeral tributaries to the Canadian River in addition to Williams Draw. The amount of streamflow or sediment contributed by these tributaries is not known, but it is improbabl that the amount of streamflow is significantly different from that observed at station 06619420. Therefore, even if suspended-sediment concentration in these ephemeral tributaries were significantly greater than in Williams Draw, the total sediment contributed by these streams could not begin to account for the increase in sediment load between the two Canadian River stations.

One likely source of additional sediment is the perennial tributary of the Canadian River, East Sand Creek (fig. 42). This stream drains an area of extensive deposits of Quaternary sand, including a dune area known as the East Sand Hills. Although no streamflow or sediment data are available for this stream, observation of this stream indicates a large amount of sand being transported. Above the confluence of Sand Creek with the Canadian River, the riverbed is principally gravel; below the confluence the riverbed is principally sand. Size analysis of suspended sediment indicates that, during April, May, and June about 60 percent of the sediment at station 06619400 is finer than sand size (0.062 millimeter), whereas at station 06619450 only about 34 percent of the sediment is finer than sand.

The average percent finer than sand for three of the sediment samples from Williams Draw was 94 percent; the lowest percentage was 88 percent. In summary then, sediment contribution by Williams Draw to the Canadian River appears to be minor; a source other than the several ephemeral tributaries of the Canadian River has not been verified.

Ground Water

Occurrence

Small to very small amounts of water may be found under favorable conditions in the Pierre Shale, Coalmont Formation, alluvium, and older terrace deposits in the McCallum Study Area. Although generally considered impervious in North Park [19], the Pierre Shale may yield small quantities of water from sandstones and siltstones in the Study Area. Ground water in the Pierre Shale is most likely to be found at shallow depths because the water is transmitted primarily by fractures, which are wider and more numerous near the surface.

Permeable sandstones are the principal aquifers in the Coalmont Formation. Studies in the Coalmont area, about 15 miles southwest of Walden, Colorado, indicate that under certain conditions shaley beds in the Coalmont Formation may confine water in the sandstones [20]. The principal coal seam in the McCallum Study Area, the Suddeth Coal, lies in the Coalmont Formation and is an aquifer in parts of the area.

The older terrace deposits in North Park are generally 6 feet less in thickness, and yield water to springs and seeps in only a few places [19]. The spring in the unnamed draw in section 22 of the McCallum Study Area (fig. 46) probably originates in these terrace deposits where they overlie the relatively impermeable Pierre Shale.

Alluvial deposits, consisting of sand and gravel in a matrix of silt and other fine-grained material, are the principal source of readily developed ground water in North Park [19]. However, the intermittent and ephemeral streams of the McCallum Study Area are smaller than many streams in North Park. Although the alluvial deposits are wide, compared with the size of the streams, they are probably less than 25 feet thick and are composed mostly of fine-grained material. The potential yield of these deposits in the McCallum Study Area is not known, but they do furnish some of the water to stock ponds along Williams Draw and Bush Draw.

<u>Hydraulic Properties of Aquifers</u>

Information on the hydraulic properties of aquifers in the McCallum Study Area is available only for the Pierre Shale and Coalmont Formation. Laboratory tests of core samples from four drill holes and wells (table 15, fig. 46) were used to estimate the hydraulic conductivity and porosity of these two formations. Horizontal hydraulic conductivities of the siltstones and sandstones tested ranged from <0.000024 to 0.352 foot per day. Vertical hydraulic conductivities ranged from <0.000024 to 0.347 foot per day. Because strata penetrated by the drill holes dip from 25 to 75°, both the horizontal and vertical hydraulic conductivities of the laboratory samples were measured at an angle to the bedding. This probably accounts for the low ratios of horizontal to vertical hydraulic conductivity listed in table 15. Had the samples been taken parallel and perpendicular to the bedding instead of at an angle to it, the measured hydraulic conductivities would be larger and smaller, respectively, than those listed in table 15. This is true because fluids in unfractured rock tend to move most readily parallel to the preferred grain orientation and least readily perpendicular to it. Porosity of the samples ranged from 2.8 to about 27 percent.

The laboratory tests indicate that although most of the rock contain significant amounts of pore space, their hydraulic conductivities generally are so low that they would yield only small amounts of water to wells or to mines unless the rocks contained secondary openings such as joints. Joints undoubtedly increase the rate at which the Pierre Shale and Coalmont Formation yield water. Although no field studies were made of the size, opening, and orientation of joints, they are visible in outcrops and were reported in all of the test holes drilled.

Table 15. - Core analyses
(Analyses by Core Laboratory, Inc. [1], K_h = horizontal hydraulic conductivity, in feet per day; K_v = vertical hydraulic conductivity, in feet per day)

Drill hole or well	Lithology from log	Depth (feet)	Porosity (percent)	K_h	K_v	$\frac{K_h}{K_v}$
1	Sandstone, very fine to fine	92	18	0.0010	0.0019	0.5
	Siltstone, coarse	108	8.4	0.00012	0.00015	0.8
	Sandstone, very fine to fine	185	12.4	0.00061	0.00022	2.8
	Sandstone, fine	210	19.9	0.010	0.0092	1.1
2	Siltstone, very fine to siltstnne, muddy	220	16.4	0.00090	0.00075	1.2
3A	Siltstone, fine to coarse	18-19	20.5	0.020	0.012	1.7
	Siltstone, fine to coarse	19-20		0.011	0.012	0.9
	Siltstone, fine to coarse	20-21		0.019	0.016	1.2
	Siltstone, fine to coarse	21-24.6	18.4	0.012	0.0092	1.3
	Siltstone, coarse, and sandstone, very fine	24.6-31	18.8	0.0085	0.0060	1.4
	Siltstone, fine to medium	31-41	18.5	0.020	0.026	0.7
	Siltstone, medium	51-61	15.5	0.049	0.0061	8.0
	Siltstone, medium	61-65	2.8	<0.000024	<0.000024	
	Siltstone, coarse, and sandstone, very fine	71-81	17-7	0.0073	0.0075	0.9
	Siltstone, coarse, and sandstone, very fine	81-82		0.0046	0.0046	1.0
	Siltstone, coarse, and sandstone, very fine	82-83		0.0080	0.0058	1.4
	Siltstone, coarse, and sandstone, very fine	83-84		0.0034	0.0039	0.8
	Siltstone, coarse and sandstone, very fine	84-85		0.0023	0.0020	1.2

Table 15. - Core analyses - Continued
(Analyses by Core Laboratory, Inc. 1/, K_h = horizontal hydraulic conductivity, in feet per day; K_v = vertical hydraulic conductivity, in feet per day)

Drill hole or well	Lithology from log	Depth (feet)	Porosity (percent)	K_h	K_v	$\frac{K_h}{v}$
3A	Siltstone, medium to coarse	85-86	17.4	0.00039	0.00039	1.0
	Siltstone, medium to coarse	86-87		0.00051	0.00044	1.2
	Siltstone, medium to coarse	87-88		0.0029	0.0027	1.1
	Siltstone, medium to coarse	88-89		0.0034	0.0029	1.2
	Siltstone, medium to coarse	89-90		0.0011	0.0011	1.0
	Siltstone, medium to coarse	90-91	15.0	0.0051	0.0019	2.7
	Sandstone, fine	91-92		0.0010	0.0010	1.0
	Sandstone, fine	92-93		0.001	0.001	1.3
	Sandstone, fine	93-94		0.00090	0.00068	0.75
	Sandstone, fine	94-94.8		0.20	0.092	2.2
	Sandstone, fine	96-97	20.4	0.016	0.0095	1.7
	Sandstone, fine	97-98		0.039	0.019	2.1
	Sandstone, fine	98-99		0.085	0.070	1.2
	Sandstone, fine	100-101		0.352	0.347	1.01
	Sandstone, fine	101-109.4	22.8	0.070	0.046	1.5
5	Siltstone, very fine					
	Sandstone, very fine to fine	69	20.4	0.0051	0.0039	1.3
	Sandstone, very fine to fine	83	19.1	0.0053	0.0039	1.4
	Sandstone, very fine	148.5	9.9	0.0041	0.0023	1.8
	Sandstone, medium to coarse	178.8	20.4	0.034	0.021	1.6
	Sandstone, medium to coarse	180	24.2	0.12	0.075	1.6
	Sandstone, fine	228	15.4	0.0020	0.0014	1.4
	Sandstone, very fine	238.6	26.6	0.019	0.022	0.86

1/ The use of the company name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Transmissivity tests on the aquifers penetrated by the drill holes would ha provided additional useful information on the hydraulic properties of the aquifers, but the holes were too small to be used for the tests. However, aquifer test conducted on a well in the Coalmont Formation, 3.5 miles east Walden, indicated a transmissivity of 120 feet squared per day [19]. The thickness of the aquifer is unknown.

Yield of Wells

Although drill holes 3B and 5 in the McCallum Study Area encountered water the Pierre Shale and were completed as observations wells, the Pierre Shale does not generally yield water to wells in North Park. However, wells in t Coalmont Formation yield quantities of water adequate for domestic and stoc use in some areas of North Park. In other areas, yields are poor. Yields wells are generally less than 10 gallons per minute [19].

Drill hole 6 in the McCallum Study Area flowed for about an hour from a zon at 28 feet in the Coalmont Formation. The yield was not measured, however, report on three wells, drilled in the upper part of the Coalmont Formation the Coalmont area, indicates they flowed 3, 0.9, and 0.8 gallons per minute

Observation Wells

Observation wells were installed by setting perforated casings in three of the drill holes. The bottoms of the casings were set on the bottoms of the drill holes, and the annuli between the casings and the top 3 to 5 feet of e holes were filled with concrete. The casings were perforated opposite permeable beds. In drill hole 3B, the casing was perforated in the lowest part of the hole from 140 to 160 feet opposite fine- to medium-grained siltstone and sandy siltstone, probably in the Pierre Shale. The casing in drill hole 5 was perforated in the lowest part of the hole from 200 to 250 feet opposite fine- to medium-grained sandstone in the Pierre Shale. Wer levels in the wells, when completed, were about 100 feet above the perforatns. Although hole 6 was drilled to 140 feet, difficulties in well construction made it necessary to perforate the casing in the upper part of the hole fro 24 to 30 feet. The perforations were made opposite a medium- to coarse-graed sandstone in the Coalmont Formation. Because of open-hole well completions the aquifers penetrated are probably interconnected, and water entering the wells may not come solely from the permeable bed opposite the perforations.

Recharge

Although no estimate was made of the quantity of recharge to the Pierre Shale, Coalmont Formation, or older terrace deposits in this area, the recharge is probably directly related to the amount of precipitation. The alluvial deposits are probably recharged principally by water from the streams, precipitation, and terrace deposits.

Use

The only use of ground water in the area is to water stock. Ground water a streamflow furnish water to stock ponds in Williams Draw and Bush Draw duri wet weather, but ground water is the only source of replenishment during dr periods. Seeps in the bottoms of these draws also form shallow pools that are a source of water for livestock and wildlife. A spring was developed in the unnamed draw in section 22 to supply a watering trough, but the improvements were no longer in use in 1981.

Quality

Two water samples from the bedrock aquifers were obtained for chemical analysis, one from well 3B and one from well 5. The results of the analyses are given in table 16. The water in well 3B probably comes from the Pierre Shale and is a calcium sodium bicarbonate type. The water in well 5 probably comes from the Pierre Shale but may be mixed with water from the Coalmont Formation. The small number of samples taken makes it impossible to draw any conclusions regarding the chemical character of the water from the different formations or its changes with depth.

Only those trace elements that are known to be associated with coals in the Rocky Mountains are listed in the analyses. The trace-elements concentrations of both samples are within the standards established for drinking water by the U.S. Environmental Protection Agency [14], except for iron and manganese. The high values of these constituents are not dangerous to health but are objectionable from an aesthetic standpoint.

Reclamation determined the mineralogy of the cores but found no minerals containing heavy metals. X-ray analyses of the cores by Indiana University substantiated the core descriptions made by Reclamation.

The dissolved-solids content of the ground water is generally greater than that of the surface water. The dissolved-solids content of the water sample from well 3B (table 16) is about two or three times greater than the average content of samples from the Canadian River stations (tables 9 and 10), and about 1.5 times the average content of samples from Williams Draw (table 11). The dissolved-solids content of the sample from well 5 is greater by several times than the maximum content of either Canadian River station, but only about 1.5 times greater than the maximum content at the Williams Draw station. The larger dissolved-solids content in ground water generally results from the long contact time which the water has with soluble rocks and minerals in the aquifers.

Table 16. - Water Quality Analyses

Data type	Well 3B	Well 5
Physical properties		
Depth, in feet below land surface	180	250
pH, in units	6.9	6.1
Specific conductance, in micromhos per centimeter at 25 °C	504	2,332
Water temperature, in °C	9.0	9.0
Major consituents, dissolved, in milligrams per liter		
Alkalinity, as $CaCO_3$	260	1,100
Calcium	52	410
Chloride	3.4	8.8
Fluoride	0.4	0.2
Magnesium	13	76
Potassium	3.0	8.6
Sodium	60	85
Sulfate	17	13
Total hardness, as $CaCO_3$	180	1,300
Sum of constituents (dissolved solids)	367	1,350
Trace elements, dissolved, in micrograms per liter		
Aluminum	40	
Arsenic	3	1
Boron	110	150
Bromide	0	100
Cadmium	10	23
Iron	50,000	50,000
Lead	2	0
Manganese	950	8,300
Molybdenum	1	2
Phosphorus	10	50

CONCLUSIONS AND RECOMMENDATIONS FOR RECLAMATION

This section presents the conclusions and recommendations for reclamation at the McCallum Study Area based on study findings. For more detailed information on any subject or base data used in making these conclusions and recommendations, refer to the specific sections within the report.

Legal Requirements of Mined Land Reclamation

General

The overlaying principal of coal reclamation for surface mines is to return the mined lands to approximate original contour at a level and quality of productivity of noncoal resources equal to or greater than that which existed prior to mining. This task is distributed, over time to various Federal and State agencies, as discussed below.

Federal

The legal requirements for the reclamation of surface-mined coal lands are principally covered by Surface Mining Control and Reclamation Act (Public Law 95-87), Federal Coal Leasing Amendments Act of 1976, and Federal Land Policy and Management Act (Public Law 94-529). The following regulations enforce or control various aspects of surface mining and affect various phases of land reclamation:

Title 43 CFR 3041 (BLM) Surface Management and Protection
Title 43 CFR 3400 (BLM) Coal Leasing
Title 30 CFR 700 (OSM) Surface Mining Reclamation Enforcement
Title 30 CFR 211 (USGS) Operation Regulations for Coal Mining

State

Reclamation of surface-mined coal lands are governed by the Colorado Surface Coal Mining Reclamation Act of 1973, as amended.

The rules and regulations for this act are enforced by the MLRB (Colorado Mined Land Reclamation Board). A permit bond and filing fee are required from mine operators and includes reclamation performance standards. By agreement, the MLRB has assumed the Office of Surface Mining's authority to review and permit operations in Colorado. This program delegation is under review in the Federal courts.

Several other State agencies which enforce or control various aspects of surface mining in Colorado which can impact phases of land reclamation are:

State Health Department:

Air Quality CRS (1973) 25-7-101 et seq.
Water quality CRS (1973) 25-8-101 et seq.
Waste Disposal CRS (1973) 30-20-101 et seq.

State Engineers Office

Water Wells CRS (1973) 37-90-137
Water Impoundments CRS (1973) 37-87-101 et seq.

Local

Local regulations are not as explicit as State laws regarding surface minin and reclamation. In general, MLRB has primacy in the development of reclama- tion standards over local government. Information on local regulations can be obtained from the Jackson County Court House, Walden, Colorado.

Because of modification of statutes and regulations on the reclamation of surface-mined coal lands, only the most current literature on roles and responsibilities of participating entities should be used.

There is considerable overlap in Federal-Federal, Federal-State, and State-State responsibility concerning coal regulation. In order to understand th limits of each agency's program, it may be necessary to review existing agreements between agencies in each level of Government and between levels Government. At the present time, the existing BLM, OSM, and USGS Agreement is being rewritten to include the Forest Service, incorporate recent regula- tory changes by OSM and BLM, incorporate OSM delegations to the MLRB, and recognize the reorganization of BLM and USGS.

Postmining Land Use Recommendations

The McCallum Study Area, if mined, should be returned to its approximate original land form with quantities and quality of vegetation necessary to promote the three primary postmining land uses - livestock grazing, watersh cover protection, and wildlife habitat. In general, postmining reclamation should ensure the continued present primary resource uses, as discussed earlier in this report, at approximately the same base levels. Reclamation should also ensure the return of air and water quality to premining base levels.

Livestock Grazing

The Study Area is within a grazing allotment that provides forage for catt during spring and early summer. Postmining reclamation efforts should recognize this primary resource use. The BLM range conservationist should recognize that proper management of the reclaimed area is essential if the reclamation treatment is to be successful.

tershed Management

e Study Area's watershed management should include reclamation provisions r returning the area's hydrologic condition to the premining situation in rms of water quantity, quality, and timing of runoff, for both surface and ound-water conditions.

e existing water quality in the Study Area meets State and Federal water ality standards. The mining plan should include provisions to maintain ter quality after mining at or above the water quality standards. Returning e site hydrology to the original condition is a time-dependent process; wever, it should be achieved prior to bond release.

il productivity and stability should be returned to an equal or better ndition than existed before mining. On-site soil erosion will gradually crease during the reclamation period as vegetation succession and development progresses and watershed cover improves.

ldlife

e entire Study Area is comprised of native range (excluding present roads d stock trails). This native range serves as habitat for antelope, migrating le deer, sage grouse, and a host of small mammals and song birds and must returned to its original condition. Reclamation recommendations as scussed later in this report should be addressed when developing the clamation plan for the Study Area.

Resource Relationships to Reclamation Practices

anting Media

Quantity. - A land suitability survey was made of the Study Area to determine the quantity and availability of topsoil in the area. The intensity of the survey and a description of the soils are discussed in this report. Utilizing this information, it is expected that approximately 87 percent of the soils surveyed, class 1, 2, and 3, would be suitable for stockpiling for future use as a plant growth media. The remaining 13 percent of the study site, class 6 lands, have soils and/or topographic characteristics which do not meet the requirements of suitable material for stockpiling and reclaiming purposes.

Based on the land suitability specifications, the class 1 lands, comprising about 67 percent of the area, would be most desirable as a source of revegetation material for surfacing shaped spoils. These lands provide highly suitable material which is easily stripped and stockpiled for postmining use. The class 2 lands, which make up about 10 percent of the area, provide adequate stockpiling material, but the fine textured soil found in this class may require good placement practices and be more difficult to strip and stockpile. The class 3 lands comprise about 10 percent of the area, but are marginal in their suitability because of poorer quality soil material.

Quality. - The Class 1, 2, and 3 lands (and particularly the class 1 lands which should be identified and stockpiled for planting media) reflect very few adverse chemical conditions based on laboratory evaluations of the surface and upper soil materials (10 ft) taken relative to the land suitability surveys.

Physically, the class 2 lands and especially the class 3 lands have fine textured soils (clay, silty clay, and clay loam). Once disturbed, these soils lose the amount of natural structure they have, and water movement will be impeded. Wind erosion is likely, and additional land treatment will be necessary during reclamation revegetation. Some areas of class 2 lands have moderately coarse textured soils and have relatively high erosion potential. Some soils having impervious bedrock or cobble within 24 inches of the surface are also restricted to class 2. A few small areas have been placed in class 3 which have an average depth of 12 inches of moderately coarse or medium textured soil material overlying impervious shale.

Soils which have been classed as class 1, 2, and 3 have no serious chemical problems stemming from high levels of sodium or other salts in the depths considered for stripping.

The chemical and physical characterizations of the overburden material (10 ft to bottom of coal seam) were characterized for six deep-hole locations on the site. A summation of the laboratory data from these six deep core profiles indicated that about 19 percent of the overburden material was suitable for use as plant growth media, 21 percent had limited suitability and 60 percent was evaluated as unsuitable. Coarse textures, moderate sodium levels, and fine textures were the main reasons for the limited suitability rating. High sodium levels as indicated by high SAR and ESP values, high salinity levels, and restricted disturbed hydraulic conductivity in combinations were responsible for the unsuitable ratings.

These quality evaluations were based on the six specific drill sites. Because of the limited number of holes drilled and the variable nature of the geologic material, the quantity and quality of the overburden should not be projected extensively among drill hole locations.

The quality data for each specific site was discussed earlier in the section on overburden suitability.

Nutrient Deficiencies. - Laboratory and greenhouse studies indicate that phosphorous deficiencies are common for most soil and all geologic material studies. Some potential micronutrient deficiencies occur on both soil and geologic samples. Deficiencies in zinc and copper were the most common. However, it is important to point out that the criteria used for evaluating micronutrient deficiencies were observed on agromonic crops sensitive to these elements.

More detailed fertility studies, such as onsite plot studies, should be made in this area before fertility recommendations are made.

Toxic Materials. - Toxicity studies were not performed on the McCallum Study Area soil or overburden samples other than determining salinity and alkalinity contents. Sodium is a major problem common to a large percentage, approximately 60 percent, of the geologic materials studied and portions of the soil material studied in the areas designated as class 6. The sodium problem offers reduced plant growth, reduced physical quality of the material, and potential reduced water quality in the Study Area. Neither alkalinity or salinity are of the magnitude to be toxic in the material evaluated as suitable for 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.

Availability. - The soil quantity and quality evaluations of the McCallum Study Area indicate that a successful revegetation program is feasible when the topsoil or similar soils identified as suitable in the land suitability survey are used as a planting media. In the Study Area there are approximately 2,591 acres of class 1, 2, and 3 lands. These lands include 1,992 acres (class 1) having a minimum of 36 inches of highly suitable strippable material; 299 acres (class 2) having a minimum of 24 inches of usable strippable material; and 300 acres (class 3) having a minimum of 6 of inches usable strippable material. The land suitability survey should be intensified when accurately establishing cut stakes for topdressing material.

Sections 22, 27, and portions of 28 appear to have more than adequate highly suitable strippable material available for stockpile or for direct use from the mining area to other areas being rehabilitated in the McCallum Study Area. Sections 23 and 26 have adequate strippable material; however, the draws in these sections are comprised of saline and sodic soils, and these class 6 soils should not be used for topdressing but added to the spoil pile.

The fine textured subsoils, particularly clays, in the class 2 areas should be separated from the topsoil in the stripping operation. A double lift method of removing topdressing should be used where these subsoils are encountered to ensure proper placement practices.

Cimate

Lck of precipitation during the growing season is the factor most limiting t revegetation efforts. The combination of extreme cold, high winds, very dy air, warm daytime temperatures, and lack of snow cover will cause winterkll for some young plants. Temporal distribution of the estimated 11 to 1 inches of precipitation that falls at the Study Area will determine the sccess of plant species at progressive developmental stages.

Fall seeding (for spring germination) is preferred because it allows the new seedlings to take full advantage of spring precipitation for plant establishment. The available data indicates that the last week in October is generally the best time for seeding. Seeding at this time helps avoid premature germination resulting from late warm periods and allows for seeding prior to major snowfalls. It also promotes early spring germination and maximizes use of available moisture.

The reclamation plan should provide resources for multiple seeding attempts, since the establishment of vegetation is likely to fail frequently. If this is unacceptable, the application of supplemental water should be considered.

Treatments to increase optimum conditions for productive growth should include mulching, land surface shaping and/or contouring, enhancement of snow accumulation, and distribution by the use of snow fences or windbreaks. High wind conditions occur several times each winter. Snow fences can be used to protect ridges and lee slopes from wind erosion and desiccation. Also, increasing the surface roughness will enhance snow accumulations, reduce wind erosion, and minimize the winterkill problem. Critical climatic elements related to vegetation selection are shown in table 2. The estimates in this table are based on data for Walden and other North Park areas.

Precipitation observations should be continued at the McCallum Study Area to establish the local precipitation climate. Collection of other data on site, such as daily maximum and minimum temperatures, wind speed and direction, and humidity is also desirable.

Hydrology

Restoration of water resources.- The overall effect of mining on the hydrology of the area should be minimal, primarily because only small areas of the basins would be mined. The type of mining and reclamation practices used are the major factors involved in maintaining the hydrologic balance of the area.

The loss of water in stock ponds and springs is a potential effect of mining due to the dewatering of aquifer systems. If this occurs, alternate sources of water for livestock and wildlife should be provided.

Mining should not cause significant increases in sediment concentrations and load if natural buffer zones are maintained between the disrupted areas and the stream channel. Proper design of any roads, stream crossings, and water-conveyance channels would also help keep sediment-discharge increases to a minimum. The loss of riparian vegetation in Williams or Bush Draws because of dewatering of alluvial aquifers could result in increased erosion; thus, increased sediment is possible in these streams.

Surface Water. - Mining could possibly affect stream discharge, quality, or sediment concentration. Generally, only small areas of the basins would be mined, so the effect on runoff because of increased infiltration or decreased snowmelt should be minimal. Pumpage of water from mine pits, if necessary, could provide additional surface-water flow at any time of the year, unless retention ponds are established for sediment traps or other purposes.

The quality of surface water could be affected by the addition of ground water pumped from the strip-mine pits. However, the location and extent of the more permeable aquifers in the area to be mined are not accurately known. Observations of strip mines just outside the area suggest that little or no ground water would flow into the pits. The chemical analyses of the two ground-water samples show that the ground water has a much greater dissolved-solids concentration than the surface water. However, ground water pumped from the mine pits may or may not be chemically similar to that of the two ground-water samples. The effect of this ground water on the surface water depends on the quantity of mine-pit effluent, the amount of surface water available for dilution, and the material the ground water comes in contact with before reaching the stream. The water chemistry of the Williams Draw runoff, could be changed quite dramatically by the addition of mine-pit effluent. However, the Canadian River has a large dilution capacity, and the water entering from Williams Draw may have little effect on the overall surface-water quality. During base-flow periods, however, this dilution capacity would be considerably reduced.

Runoff waters originating above the mine areas should be stored and diverted into natural channels below the mine areas. This minimizes undesirable changes of water quality and helps maintain the downstream ephemeral draws. Some changes in slope and alinement of the main tributary channels undoubtedly occurs during reclamation; however, these changes can be used advantageously to retain moisture for revegetation and prevent excessive erosion. The reclaimed mainstem active channels should be seeded or sodded with species comparable to premining conditions.

The quality of water pumped out of the mine pits or runoff from the mine area and spoils should be monitored. If the quality of these waters is below State standards, evaporation ponds should be established.

Ground Water. - Mining in the valleys of Bush and Williams Draws or other alluvial valleys could result in some dewatering of the alluvial aquifers adjacent to the mine pits. A decrease or loss of the riparian vegetation in the drainages could result. This dense grass cover helps keep channel erosion at a minimum as well as providing browse for wildlife and livestock. Mining could cause the water levels in nearby stock ponds to decline if the ponds are supplied entirely or in part by ground water. The flow of the small developed spring in section 22 (fig. 45) could be reduced or interrupted by the mining.

Present knowledge about both the alluvial aquifers and bedrock aquifers of the Coalmont Formation is limited. Therfore, a network of ground-water observation wells should be established on the Canadian River side of the potential leasing area [KRCRA (Known Recovery Coals Resource Area)] as soon as possible. Present water quality and water levels could be determined and monitored during mining operations. If undesirable changes of ground-water quality are observed, a moratorium should be placed on further leasing. The alluvial draws should be reconstructed after mining with the original alluvial overburden in order to maintain the same hydrologic balance as existed before mining. A prompt reconstruction of the alluvial valleys will further help to minimize the adverse effects of dewatering.

Reclamation Procedures

Spoils Shaping and Recontouring

The success of erosion control, establishment of vegetation, and results of postmined land reclamation can be enhanced with techniques of spoil shaping and recontouring. This phase of the reclamation effort must be addressed in the reclamation plan and would be completed prior to redistributing topsoil. An opportunity exists to increase productivity of the McCallum Study Area by modifying the postmined landscape and improving some physical properties associated with vegetative growth. The postmined landscape should appear as it did prior to surface mining, except that we recommend limiting slopes to less than or equal to 10 percent and constructing contour terraces or furrows.

A moderate slope gradient (less than or equal to 10 percent) will reduce the erosion potential on reclaimed areas initially and in the long term by reducing the energy of surface-water runoff. Reducing the potential energy of surface water flow reduces the sediment load carried downslope and increases infiltration on the slope. Also, equipment can work more efficiently on a slope of 10 percent or less. This applies to shaping and recontouring operations, seedbed preparation, seeding, and management operations after vegetative establishment. Because runoff will be less on these more moderate slopes, infiltration will be higher, and hence productivity will be enhanced.

Contour terracing should be considered in the reclamation plan for the McCallum Study Area to further alleviate erosion and enhance the retention of water on the slope. Moisture either as snow or rain will accumulate on the terraces, providing additional time for infiltration and percolation of water into and through the soil. Terracing is especially important on north and east facing slopes. The prevailing winds are southwesterly and deposit windblown snow on the leeward side of ridges. Snow on the north and east aspects initially is deposited during events, then deposited by the wind and presists longer between events and through the winter season because solar radiation is less intense on these aspects. Terraces should be constructed along the countour of the slopes. Terraces may not be justified on south and west aspects.

An alternate method of trapping moisture on south and west facing slopes would be to construct contour furrows. However, periodic maintenance is required to sustain the effectiveness of furrows. Contour furrows are not recommended as a substitute for terraces on north and east facing slopes, since furrows would fill and break, causing severe gullying as the snowmelt drains downslope.

Handling and Placement of Topsoil Dressing

Before topsoil is placed on the overburden, an undulating interface should be created between the two surfaces. A chisel plow or ripper can be used to breakup the overburden, alleviating compaction from grading operations and eliminating a potential barrier to water percolation and penetration of roots. In addition, an undulating interface between topsoil and overburden stabilizes topsoil redistributed on slopes, reducing the possibility of water piping or slippage of the topsoil. Ripping operations on overburden should occur along the contour of slopes.

Use of freshly stripped topsoil for redistribution on overburden is preferable. This procedure would eliminate stockpiling and maintain a viable population of microorganisms in the seedbed. Researchers have studied the microbial populations from stockpiled topsoil and their evidence suggests the viability decreases with the time of stockpiling. Microbial populations are an important component of the seedbed because they initiate decomposition, nutrient cycling, and nutrient uptake by plants.

The topsoil should be separated at the removal stage in two lifts and redistributed in the same manner. The objective is separation of the "A" horizon and possibly some of the "B" horizon material from the heavier textured "B" horizon, facilitating a successional process in soil development. Medium textures, organic material, microbial populations, and root stock and seed from native plants concentrated in the upper topsoil layer should result from this process. The lower topsoil layer could be composed of the heavier textured "B" horizon or nontoxic overburden material, if sufficient good "B" horizon material is not available. If overburden is used for the lower topsoil layer, it must not have any chemical or physical properties that would inhibit water movement through the profile or inhibit the growth of plant roots.

Seedbed Preparation

Seedbed preparation includes the proper techniques of applying the topsoil dressing. After topsoil is distributed, it requires some additional cultivating before a suitable seedbed is achieved. Nutrient deficiencies should be corrected and the compaction of topsoil alleviated. Temporary provisions for the protection of the seedbed prior to establishment of the postmined plant community should be applied. These concepts establish and protect the seedbed through the first growing season of the perennial plants and can be achieved with fertilization, chisel plowing, and/or disking and mulching.

Redistributed topsoil or overburden suitable as a plant growth medium invariably has inherent nutrient deficiencies. Analysis of natural soils indicates that phosphorus and nitrogen are limiting. More extensive soil analysis is recommended after redistribution to identify other deficiencies if they occur. Phosphorus fertilization, critical for seedling establishment, should be accomplished prior to disking. Nitrogen is more mobile in the soil water and does not need to be applied prior to disking. However, nitrogen is critical if either a nurse crop or applied straw or grass hay mulch is used to protect the seedbed. If an organic mulch is not used, it may suffice to eliminate nitrogen for the first growing season of the perennial plants, but should be applied prior to the second growing season. Large quantities of phosphorus and nitrogen fertilizers should not be applied because the establishment of plants may be inhibited.

Chisel plowing and disking alleviates the compaction of the topsoil and incorporates phosphorous fertilizer into the rooting zone of the plants. If compaction is not severe, disking may be all that is required to prepare the seedbed. These operations should be performed along the contour of slopes or on level areas, perpendicular to the wind.

A standing stubble mulch is recommended for the McCallum Study Area to reduce the influence of wind on evaporation and windblown snow. A standing stubble mulch can be attained in two ways. Using grass hay or straw, mulch can be spread at a rate of 2 tons per acre over a planted seedbed and tucked or crimped into the seedbed. A standing stubble mulch will be evident after crimping. However, mulching must follow seeding if the above method is utilized to achieve a standing stubble. Otherwise, seeding disrupts the standing stubble when a drill is pulled through the seedbed.

An alternative method of attaining a standing stubble is to grow an annual cover crop in place. Late fall (October) seeding is recommended for North Park. Therefore, a cover crop should be seeded in the fall after the seedbed has been prepared. During the growing season, the annual crop produces necessary forage to protect the seedbed from erosion and fulfills the recommendation of a standing stubble. However, measures must be taken to cut or remove the seed head before the crop produces viable seed. In years of below normal temperatures, a cover crop may fail or produce only a marginal crop. In this instance, the perennial seeding would not need to be delayed if mulch was spread and crimped to provide an effective standing stubble. The cover crop should be drilled along the contour of slopes or on level areas, perpendicular to the wind. Mulch that has been spread should be crimped in the same directions as a cover crop would be drilled.

Selection of Species for Seeding

Regulations specify that plant species used in revegetation must support the postmined land use and that the postmined plant community has as good or better potential than the existing plant community. Therefore, plant species diversity, cover, and forage production must be as good or better than the premined plant community. Additionally, regulations specify the use of a predominately native seed mix to establish a postmined plant community exhibiting similar characteristics to the naturally occurring community in terms of the overall phenology cycle, color and contrast, and shrub density. The goal is to establish a stable, productive, diverse, self-perpetuating plant community.

Several plant communities exist within the McCallum Study Area due to different soil types, management techniques, and microenvironments, including aspect. Assumptions are made at the time of seeding that the topsoils after application will have different chemical and physical properties than existed prior to mining, and different properties will be characteristic in the reapplied topsoil at different locations. However, these differences cannot be controlled. Management practices (herbicide use for sagebrush control and different grazing intensity) cause differences in the natural premined plant communities. However, management following plant establishment probably is more consistent from location to location, unless situations arise from establishment failures or transplanting shrubbery materials in mesic areas is feasible. The microenvironments change as a result of mining, except on the larger scale inferred by aspect. It can be expected that these conditions controlling the development of different plant communities prior to mining either are uncontrollable or consistent during the establishment of a postmined plant community, except for aspect.

The aspect in the McCallum Study Area greatly determines the species composition of a particular plant community. The growing season is short, cool temperatures and slightly windy conditions are characteristic. The prevailing wind is southwesterly and can be quite strong occasionally, especially in the winter. Snow that has fallen is relocated from southern aspects and ridgetops to northern aspects. During the spring thaw, snow persists longer, the growing season is shorter, soil temperatures are cooler, and soil moisture is greater on northern aspects. The southern aspects and ridge tops are warmer and have less soil moisture. Plant growth is initially accelerated in the spring. These characteristics of temperatures and moisture, compounded by the drying influence of the wind, especially on ridgetops, persist through the summer.

Therefore, the aspect, specifically north and south aspects and ridgetops, should be delineated by acreage in the reclamation plan. Different seed mixtures, especially adapted to each aspect, should then be used initially to avoid unnecessary competition by unadapted plant species. Establishment of a self-perpetuating, diverse, stable plant community could be accelerated by the selection of plant species for a given aspect.

Table 17 represents some plant species that are naturally occurring in the McCallum Study Area, other native species that should be considered and introduced species that are adaptable. Included in table 18 are the aspects that are suited for each species.

<u>Seeding and Transplanting Methods</u>

A perennial plant community can be established after mining by drill seeding, broadcast seeding, transplanting containerized or bare root materials, and transplanting mature plants with a specially designed front-end loader bucket. The transplanting methods are not suited for reestablishing a large area, but are useful to accomplish desired goals on specially suited sites. Late fall is the appropriate time to seed and the preferred time to transplant. However, bare root and containerized materials may survive well if planted very early in the spring.

Drill seeding is preferred over broadcast seeding. The drill can place the seed at a desired depth, drop seed at a uniform rate into furrows, and compact the soil around the seed to enhance germination. Seed should be drilled on

Table 17. - Recommended plant species that could be used for seed mixtures in the McCallum Study Area of North Park, Colorado.

Species	Suited variety	Native introduced	Aspect North	Aspect South	Aspect Ridge
Grasses					
Streambank wheatgrass	"Sodar"	N	X	X	
Western wheatgrass	"Arriba"	N	X	X	
Thickspike wheatgrass	"Critana"	N	X	X	X
Blue bunch wheatgrass		N		X	X
Beardless wheatgrass	"Whitmar"	N		X	
Siberian wheatgrass		I			X
Pubescent wheatgrass	"Luna"	I	X	X	
Junegrass		N		X	X
Needle-and-thread grass		N		X	X
Pine needlegrass		N	X	X	
Indian ricegrass	"Nezpar"	N			X
Meadow brome	"Regar"	I	X		
Blue gramma		N			X
Mountain muhly		N	X	X	
Mutton grass		N	X	X	
Sandberg bluegrass		N		X	X
Idaho fescue		N	X		
Sheep fescur		N		X	
Hard fescue	"Durar"	I	X	X	
Forbs					
Cicer milkvetch		I	X		
Rocky mountain penstemon		N	X		
Common dandelion		N	X		
Blue bell spp.		N	X	X	
Buckwheat spp.		N			X
Daisy spp.		N			X
Scarlet globemallow		N			X
Hoods phlox		N			X
Fringed sage		N		X	X
Louisiana sagewort		N		X	
Western yarrow		N			
Arrowleaf balsamroot		N	X	X	
Shrubs					
Wyoming big sage		N	X	X	
Snowberry		N	X		
Winterfat		N		X	X
Low rabbitbrush		N			X
Bitterbrush		N	X		
Service berry		N	X		

the contour of slopes or on level areas perpendicular to the prevailing wind. Separate seed boxes are useful for separating large seed from smaller seed. However, seeding depth is critical when small seed and large seed is mixed. Generally, grass seed can be planted one-quarter to one-half inch deep. Smaller seed should not be planted greater than one-quarter inch in depth.

Broadcast seeding can be accomplished by many methods and would depend on the acreage treated as to which method was used. Regardless of the method used, the seed must be covered with soil. On small areas that failed to establish initially, broadcasting with a hand seeder and using a few well-adapted plant species could prevent future problems of site erosion. Since the configuration of the postmined landscape will be accessible for drilling, large-scale broadcast seedings should not be required in the Study Area if slopes are minimized.

The seeding rate should be calculated by examining the characteristics of individual plant seeds and designing the density of individual plant species desired in the plant community. The characteristics which should be examined are: germination, pure seed, and number of seeds per pound. The seed mixture then can be designed to estimate the number of grass, forb, and shrub seedlings that are expected to germinate per square foot. When the seed is drilled on north and east aspects, the drilling rate should be calculated to apply 20 to 25 pure live seeds per square foot; incuded in this recommended rate is 3 to 5 forb seeds and 1 to 2 shrub seeds. If west aspects seedings, the appropriate rate for drilling and broadcasting should be increased by 50 percent. Ridgetop seedings may require a doubling of the recommended rate for north slopes.

If shrubs fail to establish from seed, then containerized or bare root stocks could be used to introduce these species into the plant community. It would be necessary to scrape an area of established vegetation and reduce plant competition at the time of transplanting. Some shrub species are not adapted to fall transplanting.

A tree spade of special front-end loader bucket can be used to transplant individual trees and shrubs, respectively. It would be desirable to plant mature shrub materials on mosic sites, such as draws and northern aspects; provide quick cover for upland game birds, and provide a seed source of adaptable native seed.

Erosion Control and Conservation Methods

Material such as the fine fextured subsoils found in the area should be mixed with gravel or coarse fragments (1- to 6-inch diameter) and placed in drainage channels to provide better growth medium, increase physical fertility, and act as anchor material. Channel width-depth ratio must be increased with uniform shaping of slope. These channels should be lined with boulders or other appropriate material at point of entry on mined land in order to reduce velocity and dissipate erosive energy flow.

Sodding of these drainageways should be accomplished to provide a stable channel. Sodding species should be selected for revegetation that are adapted to placement areas as upland species resodded into flood plains wi not adapt. Rhizomatous species should be used, including prairie sand reec western wheatgrass, and green needle. These should be adapted species as identified in the species selection recommendations. If cost of resodding cannot be justified, smooth brome, alfalfa brome, and oats could be plantec

Maintenance of all terraces constructed should continue for 5 years to ensure effectiveness and to repair damage by livestock, wildlife, and any subsidence that might occur.

Snow fences should be used to protect ridges and slopes subject to wind erio and desiccation. Snow fences placed next to any transplanted shrubs provic protection and enhance snow buildup for the transplants.

Postmining Land Use Management

Specific postmining land use management of the primary resources is discuss below.

Livestock Grazing. - The reseeded area should be protected from grazing until vegetation is sufficiently developed and established to withstand grazing use without damaging the vegetation (watershed) cover. Once established, a planned grazing system should be implemented. The result from the mined land reclamation grazing study presently being conducted the Colorado Yampa Coal Company study site may be of assistance in develoin proper grazing management for the reclaimed area.

Watershed Management. - A final reclamation plan for the area might require modification of the land form, such as terracing slopes which ha been discussed, thus reducing its gradient. This practice, as well as other slope modification techniques, would be desirable practices in controlling sediment runoff, as well as providing the opportunity to create microhabitats, if necessary.

Past and ongoing studies at the Kerr Mine (in the vicinity of the Study Area) indicate that moisture conservation practices, such as distributic of snow fences or planting natural barriers, will enchance revegetation the area. These practices should also be considered in a potential reclamation plan for the areas they would complement, all three primary postmining land uses.

Wildlife. - Reclamation practices should strive to meet the wildlife habitat needs of the area. Potential Impacts of Strip Mining in North Park, Colorado, No. YA-512-CT9-35, provides several recommendations for potential reclamation plan, and also contains baseline records which coul be utilized to evaluate the success of reclamation practices at mitigati potential impacts to sage grouse habitat.

The recommended seed mixture should suffice for most habitat requirements; however, due to the harsh growing conditions prevalent at the site, it may be difficult to establish some of the woody stem species desirable for wildlife habitat. Special revegetation techniques, such as planting containerized seedlings, or use of the "sod bucket" may prove advantageous in obtaining successful reclamation in the area.

REFERENCES

[ ] Benci, J. F., and T. B. McKee, "Colorado Growing Season," Climatology Report No. 77-3, Department of Atmospheric Science, Colorado State University, Fort Collins, Colo., 1977.

[ ] Doesken, N. J., T. B. McKee, S. B. Seagraves, W. C. Hume, and P. Wrenn, Colorado Solar Radiation Data, Colorado Climatology Office and Colorado Office of Energy Conservation, Department of Atmospheric Science, Colorado State University, Fort Collins, Colo., 1979.

[ ] Toy, T. J., "Potential Evapotranspiration and Surface-Mine Rehabilitation in the Powder River Basin, Wyoming and Montana," Journal of Range Management, 32(4), July 1979.

[ ] BLM Manual 8400, Bureau of Land Management.

[ ] Howard, Arthur D., John W. Williams, and Irwin Raisz, "Physiography," Geologic Atlas of the Rocky Mountain Region, Rocky Mountain Association of Geologists, Denver, Colo., 331 pp., 1972.

[ ] Miller, J. C., Geology of the North and South McCallum Anticlines, Jackson County, Colorado, with Special Reference to Petroleum and Carbon Dioxide, U.S. Geological Survey Cirular No. 5, 27 pp., 1934.

[ ] Beekly, A. L., Geology and Coal Resources of North Park, Colorado, U.S. Geological Survey Bulletin 596, 121 pp., 1915.

[ ] Hail, William J. Jr., Geology of Northwestern North Park, Colorado, U.S. Geological Survey Bulletin 1188, 133 pp., 1964.

[ ] Madden, Dawn H., Exploratory Drilling in the McCallum Coal Field, Jackson County, Colorado, U.S. Geological Survey Open-File Report 77-888, August-November 1977.

[ ] Kinney, Douglas M., Preliminary Geologic Map of the Gould Quadrangle, North Park, Jackson County, Colorado, U.S. Geological Survey Quadrangle Map, Open-File No. 70-182, 1970.

[ ] Sims, Frank C. and Joseph H. Goth, Jr., "McCallum Field, Jackson County Colorado," Wyoming Geological Association and University of Wyoming Guidebook - Eighth Annual Field Conference, Laramie Basin, Wyoming, and North Park, Colorado, pp. 156-158, 1953.

[ ] Horton, R. E., "Drainage Basin Characteristics," Trans. Amer. Geophys. Union, vol. 13, pp. 350-361, 1932.

[ ] Hadley, R. F., "Some Effects of Microclimate on Slope Morphology and Drainage Basin Development," USGS Research 1961 - USGS Prof. Paper 424-B, 1961.

[14] U.S. Environmental Protection Agency, National Interim Primary Drinking Water Regulations, U.S. Environmental Protection Agency 570/9-76-003, 159 pp., 1976a.

[15] Quality Criteria for Water, U.S. Government Printing Office, Washington, D.C., 256 pp., 1976b (1977).

[16] Hem, J. D., Study and Interpretation of The Chemical Characteristics of Natural Water, U.S. Geological Survey Water-Supply Paper 1473, 2d Ed., 363 p., 1970.

[17] Kuhn, Gerhard, Statistical Summaries of Water-Quality Data for Two Coal Areas of Jackson County, Colorado, U.S. Geological Survey Open-File Report 82-121, 23 pp., 1982.

[18] U.S. Geological Survey, Water Resources Data for Colorado - Water Year 1978, vol. 1, Missouri River, Arkansas River, and Rio Grande Basins, U.S. Geological Survey Water-Data Report CO-78-1, 1979, U.S. Department of Commerce National Technical Information Service, Springifled, Va., No. PB80-119 944. 1979.

__________ "Water Resources Data for Colorado - Water Year 1979, vol. 1, Missouri River, Arkansas River, and Rio Grande Basins," U.S. Geological Survey Water-Data Report CO-79-1, 1980, U.S. Department of Commerce, National Technical Information Service, Springfield, Va., No. PB-81-124 922, 1980.

__________ "Water Resources Data for Colorado - Water Year 1980, vol. 1, Missouri River, Arkansas River, and Rio Grande Basins," U.S. Geological Survey Water-Data Report CO-80-1, 1981, U.S. Department of Commerce, National Technical Information Service, Springfield, Va., 1981.

__________ "Water Resources Data for Colorado - Water Year 1981, Vol. 1, Missouri River, Arkansas River, and Rio Grande Basins: U.S. Geological Survey Water-Data Report CO-81-1, U.S. Department of Commerce, National Technical Information Service, Springfield, Va., 1982.

[19] Voegeli, P. T., Sr., Ground-Water Resources of North Park and Middle Park, Colorado - A Reconnaissance, U.S. Geological Survey Water-Supply Paper 1809-G, 54 pp., 1965.

General references not specifically cited:

EPA, National Secondary Drinking Water Regulations, Federal Register, vol. 42, No. 62, Thursday, March 31, 1977, part 1, pp. 17143-17147.

Hatch, J. R., D. H. Madden, and R. H. Affolter, Chemical Analyses of Coal and Coal-Associated Rock Samples from the Coalmont Formation, McCallum and Coalmont Areas, North Park, Jackson County, Colorado, U.S. Geological Survey Open-File Report 79-1099, 43 pp., 1979.

endricks, M. L., Stratigraphy of the Coalmont Formation Near Coalmont, Jackson County, Colorado, Colorado School of Mines, unpublished thesis, 1977.

:Kee, Thomas B., and N. J. Doeoken, F. M. Smith, J. D. Kleist, Climate Profile for the McCallum EMRIA Study.

rea, Climatology Report No. 81-1, Colorado Climate Center, Department of Atmospheric Service, Colorado State University, Ft. Collins, Colorado, March 1981.

veto, Ogden, Geological Map of Colorado, U.S. Geological Survey, 1979.

APPENDIX A
Geology and Coal

GEOLOGIC LOG OF DRILL HOLE

FEATURE: EMRIA PROJECT: BLM - MCCALLUM SITE STATE: Colorado

HOLE NO.: DH-1 LOCATION: See Location Map COORDS. N. ... E. ... GROUND ELEV.: 8340+ DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6-11-79 FINISHED: 6-21-79 DEPTH OF OVERBURDEN: 18.0 TOTAL DEPTH: 221.0 BEARING: ...

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

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

Hole drilled with S&H Drill 142C skid-mounted rig.

Push samples 0.0-13.0. NQ wireline 13.0-221.0. Drilled with water 0.0-13.0 and 71.0-221.0. Drilled with Revert 13.0-71.0.

Water Levels

Level	Date	Hole Depth
6.0	6-13	18.0
17.2	6-14	41.0
22.0	6-15	61.0
22.0	6-18	101.0
35.5	6-19	121.0
37.0	6-20	158.5
22.5	6-21	211.0
12.0	6-22	221.0

Gray color water return.

Water Loss

Percent	Interval
5	18.0-26.0
100	At 31.0
50	33.1-41.0
60	41.0-51.0
30	61.0-131.0
30	141.0-158.5
25	158.5-221.0

CORE RECOVERY (%)

50, 100, 40, 100, 66, 87, 64, 70, 0, 73, 52, 100, 71, 70, 71, 61

SUITABILITY OF OVERBURDEN

Depth (feet)	Suitability
0.0-2.0	Unsuitable
2.0-18.0	Suitable
18.0-22.0	Limited
22.0-26.0	Unsuitable
26.0-41.0	Limited
41.0-66.2	Suitable
66.2-100	Limited

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
8322.0	18.0
8318.0	22.0
8314.0	26.0
8303.6	36.4
8299.0	41.0
8273.8	66.2
8268.0	72.0
8265.5	74.5
8256.7	83.3
8255.0	85.0
8249.0	91.0
8247.0	93.0

CLASSIFICATION AND PHYSICAL CONDITION

0.0-18.0 Overburden.

0.0-18.0 - Silt. - Sandy. Largest size fraction is coarse sand. Fine coal particles disseminated throughout 0.0-2.0. Organic material and fine roots near top. Highly fragmented in some places (muddy looking). Few slickensides. Fe stain throughout. Calcareous 4.0-4.5. White calcareous zone at 7.0. Hardness 3-4. Brown, tan and gray.

18.0-221.0 Coalmont Formation.

18.0-22.0 - Siltstone. - No HCl reaction. Few joints dipping about 25°. Fe stain on joints and fracture surfaces. Slickensides near 18.0. Light gray to gray. Darker gray near 22.0. Rapidly breaks up in water (swelling clays?). Hardness 3-4.

22.0-26.0 - Coal. - Sample taken.

26.0-36.4 - Siltstone. - Sandy near 36.4. Few slickensides. HCl reaction 29.4-30.4. Uneven fracture. Rapid breakdown in water.

36.4-41.0 - Sandstone. - Silty. Quartz grains. Fine to medium grained. White to gray. Poorly cemented. Rapid breakdown in water. Hardness 3-4.

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"

GEOLOGIC LOG OF DRILL HOLE

FEATURE: EMRIA — PROJECT: BLM - McCALLUM SITE — STATE: Colorado

HOLE NO.: DH-1 — LOCATION: See Location Map — COORDS. N. ... E. ... — GROUND ELEV.: 8340+ — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6-11-79 — FINISHED: 6-21-79 — DEPTH OF OVERBURDEN: 18.0 — TOTAL DEPTH: 221.0 — BEARING: ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Below — LOGGED BY: L. K. Weston — 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	LIMITED	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING
		69									
		40									
		28						8218.0	122.0		
		88						8212.2	127.7		
		79									
		91									
		73						8181.2	158.5		
		96									
		100						8171.7	168.3		
		99									
		87									
		99									

CLASSIFICATION AND PHYSICAL CONDITION

41.0-66.2 - Siltstone. - Sandy 41.0-51.0 and 55.0-66.2. Shaley 51.0-55.0. Impure coal seam (1"-2") at 50.0. Fine grained sandstone 0.5 feet thick at 64.9, and thin sandstone stringers at 61.0 and 62.3. Calcareous 55.5-56.5. Core disentegrating in shaley interval. Breakage along surfaces dipping 20°-30° (bedding planes?) 55.0-66.2. Shaley interval breaks down rapidly in water. Silty intervals break down slow to moderately fast in water. Light to dark gray. Hardness 4-5.

66.2-122.0 - Sandstone. - Very fine to fine grained. Silty. Medium grained sandstone 71.0-72.0, 90.2-91.0, 100.7-101.0, and 121.0-122.0. Sandy siltstone 72.0-74.5, 83.3-85.0, and 91.0-93.0. Calcareous 66.2-71.0, 74.5-81.0, 102.8-108.2, and 113.0-114.5. Light gray with white and darker gray stringers dipping 20°-30°, more pronounced 114.0-121.0. Impure coal at 122.0. Coarser grained sands break down readily in water, finer grained sands break down very slow to slow. Good core this interval with pieces up to 1.0 feet in length. Hardness 4-7.

122.0-127.7 - Siltstone. - Thin impure coal at top of interval. Gradation to coal at 127.7. Grayish brown. Slickensided along break surfaces (from drilling?). No HCl reaction. Slow break down in water. Hardness 5.

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"

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE EMRIA PROJECT BLM - MCCALLUM SITE STATE Colorado

HOLE NO. DH-1 LOCATION See Location Map GROUND ELEV. 8340± DIP (ANGLE FROM HORIZ.) Vertical

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

BEGUN 6-11-79 FINISHED 6-21-79 DEPTH OF OVERBURDEN 18.0 TOTAL DEPTH 221.0 BEARING ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Below LOGGED BY L. K. Weston 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	LIMITED	UNSUIT-ABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		67										127.7-158.5 - Coal. - Sample taken.
									210			158.5-168.3 - Siltstone. - Sandy. High carbonaceous content upper 1.0 feet. Uneven breaks along surfaces dipping 20°-30°. No HCl reaction. Brownish gray to light gray. Very slow break down in water. Hardness 5.
		32							220			168.3-221.0 - Sandstone. - Very fine to fine grained. Silty. Coarser grained 191.0-221.0. Good core up to 1.5 feet long. No HCl reaction. Light gray to white. Very slow break down in water. Hardness 4-5.
								8119.0	221.0			Total depth 221.0.
									230			
									240			NOTE: The core was logged on 9-19-79, consequently, all of the samples were dry and the reported hardness is greater than would have been observed immediately after drilling. All reported dips have been corrected to true dips from the horizontal.
									250			
									260			
									270			
									280			
									290			

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

FEATURE: EMRIA PROJECT: BLM - MCCALLUM SITE STATE: Colorado

HOLE NO.: DH-2 LOCATION: See Location Map COORDS. N. ... E. ... GROUND ELEV.: 8360+ DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6-26-79 FINISHED: 7-5-79 DEPTH OF OVERBURDEN: 4.5 TOTAL DEPTH: 221.7 BEARING: ...

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

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

Hole drilled with S&H Drill 142C skid-mounted rig.

Push samples 0.0-4.5. NQ core 4.5-20.7. NQ Wireline 20.7-221.7. Drilled with water 0.0-4.5 and 61.7-221.7.

Drilled with Revert 4.5-61.7.

Water Levels

Level	Date	Hole Depth
7.0	6/28	31.7
7.0	6/29	61.7
20.1	7/2	91.7
30.0	7/3	171.7
8.4	7/5	201.7
8.4	7/6	221.7
8.5	7/9	221.7

Water Loss

Percent	Interval
30	31.7-91.7
20	91.7-221.7

Gray and brown color water return.

CORE RECOVERY (%) (top to bottom): 77, 100, 80, 52, 5, 64, 85, 100, 87, 100, 100, 43, 100, 80, 100, 66, 100, 89

SUITABILITY OF OVERBURDEN: Limited 0.0-61.7; Unsuitable 61.7 to bottom of sheet.

ELEVATION (FEET)	DEPTH (FEET)
8400.5	4.5
8397.0	8.0
8388.8	16.2
8382.0	23.0
8378.5	26.5
8371.3	33.7
8361.1	43.9
8354.3	50.7
8344.2	60.8
8317.4	87.6
8313.8	91.2

CLASSIFICATION AND PHYSICAL CONDITION

0.0-4.5 - Overburden.

0.0-4.5 - Silt. - Sandy. Largest size fraction is coarse sand. Roots and other organic material 0.0-2.0. Slight overall HCl reaction. Occasional light colored calcareous zones. Muddy appearance. Light to medium brown. Hardness 3-4.

4.5-221.7 - Coalmont Formation.

4.5-8.0 - Siltstone. - Sandy near 4.5 and 8.0. Calcareous 4.5-5.5. Poorly cemented (muddy looking). Fe stains throughout. Light brown to light gray. Slow to rapid breakdown in water. Hardness 3-4.

8.0-16.2 - Sandstone. - Silty. Poorly cemented. Calcareous near 12.0. Fe stains throughout. Tan to light brown. Moderately fast breakdown in water. Hardness 4-5.

16.2-23.0 - Siltstone. - Sandy near 23.0. Poorly cemented. Fe stains throughout. Few slickensides near 16.2. Tan to light brown. Rapid breakdown in water. Hardness 4-5.

23.0-26.5 - Sandstone. - Silty. Fine grained. Fe stains throughout. Slight HCl reaction. Light gray to tan. Slow to moderately fast breakdown in water. Hardness 4-5.

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

FEATURE: EMRIA — PROJECT: BLM - MCCALLUM SITE — STATE: Colorado

HOLE NO.: DH-2 — LOCATION: See Location Map — COORDS. N. ... E. ... — GROUND ELEV.: 8360± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6-26-79 — FINISHED: 7-5-79 — DEPTH OF OVERBURDEN: 4.5 — TOTAL DEPTH: 221.7 — BEARING: ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Below — LOGGED BY: L. K. Weston — 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	LIMITED	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100					//////					
	10	100					//////		110			
	20	100					//////		120			
	30	100					//////		130			
	40	100					//////	8259.8	140 / 145.2			
	50	65					//////		150			
	60	95					//////		160			
	70	76					//////		170			
	80	75					//////		180			
	90	33					//////		190			
		60					//////	8211.8	193.2			
		100					//////					

26.5-33.7 - Siltstone. - Sandy near 26.5 and through interval 31.7-33.7. Fe stains throughout. HCl reaction near 33.7. Some breakage along uneven surfaces dipping about 10°. Brownish gray to gray. Moderately fast to rapid breakdown in water. Hardness 4-5.

33.7-60.8 - Sandstone. - Silty. Poorly cemented. Fine grained 33.7-39.2, medium grained to coarse grained 39.2-43.9, sandy siltstone 43.9-50.7, very fine to fine grained 50.7-60.8. White quartz grains and biotite flakes. Fe stain throughout. Calcareous 42.3-43.7. Slightly calcareous 51.0-52.0. Calcareous 58.5-59.3. Disentegration of core in place 53.7-60.8. Breakage along uneven surfaces dipping 10°-55°. Light gray. Rapid breakdown in water, particularly coarser grained material. Hardness 4-5.

60.8-145.2 - Siltstone. - Sandy 60.8-63.4, 68.2-72.2, 84.4-87.6, 91.2-94.2, 102.7-129.7. Very fine grained silty sandstone 87-6-91.2. HCl reaction 62.7-63.2, 71.7-72.3, 88.3-91.2, 122.5-123.6, 126.5-128.9, and at 137.0. Much breakage along surfaces and joints dipping 20°-25°. Much light colored banding dipping at same angles. Core disentegrating in many places. Light gray to dark gray. Black carbonaceous material 145.2. Slickensides 150.0-150.7. Moderate to rapid breakdown in water. Hardness 4-5.

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"

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: EMRIA — PROJECT: BLM - MCCALLUM SITE — STATE: Colorado

HOLE NO.: DH-2 — LOCATION: See Location Map — COORDS. N. ... E. ... — GROUND ELEV.: 8360± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6-26-79 — FINISHED: 7-5-79 — DEPTH OF OVERBURDEN: 4.5 — TOTAL DEPTH: 221.7 — BEARING: ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Below — LOGGED BY: L. K. Weston — 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	LIMITED	UNSUIT-ABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
								8201.3	203.7			145.2-193.2 - Coal. - Sample taken.
		92										193.2-203.7 - Igneous Intrusive(?). - Porphyritic. Light colored areas up to 0.1" diameter throughout gray, fine grained ground mass. Numerous small biotite flakes. Tests with Benzidine for HCl indicate that whitish mineral is illite(?). Porous. Grades from fine grained texture near the coal to coarser grained near the sandstone. Does not readily break-down in water. HCl reaction 199.0-199.8. Dark gray to gray. Hardness 5-6.
		86						8183.3	221.7			203.7-221.7 - Sandstone. - Silty. Fine grained. Numerous dark gray to black carboniferous seams. Some breakage along surfaces dipping 30°-40°. HCl reaction 203.7-205.2 and at 209.0. Some Fe stain and greenish coloration near 221.7 (alteration products?). Good core with up to 1.0 feet long pieces. None to slow breakdown in water. Gray. Hardness 5.
												Total depth 221.7.
												NOTE: The core was logged on 9/24/79, consequently, all of the samples were dry and the reported hardness is greater than would have been observed immediately after drilling. All dips have been corrected to true dips from the horizontal.

Scale: 10, 20, 30, 40, 50, 60, 70, 80, 90 / 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"

GEOLOGIC LOG OF DRILL HOLE

FEATURE: EMRIA — PROJECT: BLM - MCCALLUM SITE — STATE: Colorado

HOLE NO.: DH-3a — LOCATION: See Location Map — COORDS. N. ... E. ... — GROUND ELEV.: 8230± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 7-16-79 — FINISHED: 7-23-79 — DEPTH OF OVERBURDEN: 2.0 — TOTAL DEPTH: 160.0 — BEARING: ...

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

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	CORE RECOVERY (%)	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
Hole drilled with S&H Drill 142C skid-mounted rig.	60	8228.0	2.0	0.0-2.0 Overburden.
Push sample 0.0-2.0.	100			0.0-2.0 - Silt. - Some sand. Largest size fraction is coarse sand. Organic material 0.0-1.5. Calcareous 1.5-2.0. Brown 0.0-1.5, tan to whitish 1.5-2.0. Bentonite(?) at 1.5. Hardness 3-4.
NW Coring 2.0-20.0. NQ wireline 20.0-160.0.	100			2.0-160.0 Pierre Shale (?).
Drilled with water 0.0-4.1 and 30.0-160.0. Drilled with Revert 4.1-30.0.	32			2.0-41.5 - Siltstone. - Sandy. Very fine to fine grained sand with coarser sand near top of interval Fe stain 2.0-3.0. Fe stain and hematite nodules 3.0-4.1 and at 8.4. HCl reaction 2.0-4.1. Tendency of core to part along joints dipping 40°-70° especially 20.0-28.0. Joints have Fe stain. Tan to light gray. Slow to fast breakdown in water. Hardness ranges from 3-5.
	92	8188.5	41.5	41.5-47.0 - Siltstone. - Shaley. Sandy at 42.7. Tendency to part in 0.5" layers. Slight HCl reaction 43.5-47.0. Slight tendency to breakdown in water. Light gray. Hardness 5-6.
	54	8183.0	47.0	
Brown and gray color water return. No reported water loss.	89	8179.6	50.4	47.0-50.4 - Sandstone and Siltstone. - Fine grained silty sandstone 47.0-48.6 and 49.6-50.4. Quartz grains with biotite flakes. Friable. Siltstone 48.6-49.6. Slight HCl reaction throughout interval. Gray. Moderately fast to rapid breakdown in water. Hardness 4-5.
	77			
	80			
	99			
	84			
	73			
	96			
	96			
	100			

Water Levels

Level	Date '79	Hole Depth
0	7/18	30.0
12.0	7/19	60.0
22.0	7/20	120.0
10.7	7/23	128.5
8.5	7/24	160.0
8.5	7/26	160.0

Suitability of overburden: Suitable 0.0-47.0 and 50.4-89.0; Limited 47.0-50.4 and 89.0-100.0.

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"

GEOLOGIC LOG OF DRILL HOLE

FEATURE EMR1A PROJECT BLM - MCCALLUM SITE STATE Colorado

HOLE NO. DH-3a LOCATION See Location Map COORDS. N. ... E. ... GROUND ELEV. 8230± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-16-79 FINISHED 7-23-79 DEPTH OF OVERBURDEN 2.0 TOTAL DEPTH 160.0 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Below LOGGED BY L. K. Weston 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	LIMITED	UNSUIT-ABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100						8123.7	106.3			50.4-106.3 - Siltstone. - Shaley. HCl reaction (slight) 50.4-53.5, 70.0-72.4, 80.3-90.0, 94.7-99.5, and 100.5-103.3. Breakage along joints dipping from 25°-65°. Much of the core is disentegrating in place. Slight to rapid breakdown in water. Light gray to gray. Hardness 3-5.
		72						8112.3	117.7			106.3-117.7 - Siltstone. - Highly calcareous. Core has rough exterior appearance. Joints ranging from near vertical to 35° dip. Little or no breakdown in water. Gray. Hardness 4-5.
		76										
		100										
		100										117.7-160.0 - Siltstone. - Shaley. Calcareous 124.4-128.5, at 136.5, 142.6-144.1, and 158.0-160.0. Irregular fracturing and decomposition of core in place. Joints and light colored laminae dipping 25°-80°. Slow to rapid breakdown in water. Gray. Hardness 3-4.
		100										
		100						8070.0	160			Total depth 160.0.

NOTE: The core was logged on 9/19/79, consequently, all of the samples were dry and the reported hardness is greater than would have been observed immediately after drilling. All reported dips have been corrected to true dips from the horizontal.

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

SHEET 1 OF 3

[Fe]ature: EMRIA — Project: BLM - McCallum Site — State: Colorado

[Ho]le No.: DH-4 — Location: See Location Map — Coords. N. ... E. ... — Ground Elev.: 8160+ — Dip (angle from horiz.): Vertical

[Be]gun: 8-30-79 — Finished: 9-24-79 — Depth of Overburden: 22.5 — Total Depth: 253.0 — Bearing: ...

[De]pth and elev. of water [l]evel and date measured: See below — Logged by: L. K. Weston — 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	Limited	Unsuitable	Elevation (feet)	Depth (feet)	Graphic log	Samples for testing	Classification and physical condition
Hole drilled with Sullivan skid-mounted rig.		45			0.0–50.0 (hatched)		50.0–bottom of sheet (hatched)					0.0-22.5 Overburden
NQ Wireline 0.0-253.0. Drilled with Revert 0.0-12.0 and 153.0-233.0. Drilled with water 12.0-153.0 and 233.0-253.0.		0										0.0-12.0 - Silt. - Roots and organic material 0.0-8.0. Scattered Fe stains. Calcareous 8.0-12.0. Igneous cobble at 12.0. Grayish brown. Hardness 3.
		73						8148.0	12.0			12.0-20.5 - Sand. - Fine to very fine grained. Silty. Fe stains throughout. Few hematite nodules. Highly calcareous upper half of interval. Tan to buff color grading to gray near 20.5. Hardness 3.
		53						8139.5	20.5			20.5-22.5 - Silt. - Sandy. Very coarse igneous gravel 22.2-22.5 (up to 1.5" diameter). No HCl reaction. Hardness 3-4.
		28						8137.5	22.5			22.5-253.0 Coalmont Formation
Gray color water return. Brown color near top.		59										22.5-144.0 - Siltstone. - Sandy. Increasing sand content near 144.0. Several joints dipping at angles ranging from 20° to 65°. Light colored calcareous zones scattered throughout. Good core with pieces up to 1.0 foot long. Breaks up slowly in water. Gray. Hardness 4-5.
No reported water loss.		98										144.0-253.0 - Sandstone. - Silty 144.0-163.0 and gray color. Medium grained 163.0-167.0. Fine grained and light gray 167.0-253.0. Unconsolidated 151.0-153.0. White and gray quartz grains with green mineral scattered throughout (alteration products?). Few biotite flakes. Few joint surfaces dipping at angles from 20° to 60°. Calcareous 151.0-153.0, at 161.0, 163.0-167.0, 172.3-175.0, and 233.0-240.0. Very slow break down in water. Gray to light gray. Hardness 5-6.
		93										
		100										
		90										
		100										
		95										
		100										

Water Levels

Level	Date	Hole Depth
10.0	8/31	20.5
8.5	9/12	20.5
9.5	9/13	43.0
8.3	9/14	83.0
6.6	9/17	133.0
8.5	9/18	153.0
8.5	9/20	153.0
6.6	9/21	163.0
8.4	9/24	233.0
6.6	9/25	253.0

EXPLANATION

CORE LOSS (open) — CORE RECOVERY (solid)

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

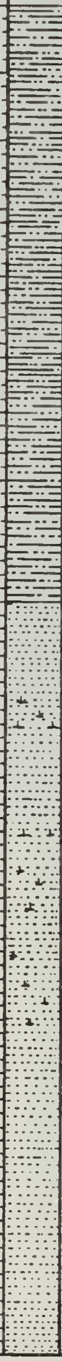
FEATURE: EMRIA — PROJECT: BLM - McCallum Site — STATE: Colorado

HOLE NO.: DH-4 — LOCATION: See Location Map — COORDS. N. ... E. ... — GROUND ELEV.: 8160± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 8/30/79 — FINISHED: 9/24/79 — DEPTH OF OVERBURDEN: 22.5 — TOTAL DEPTH: 253.0 — BEARING: ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Below — LOGGED BY: L. K. Weston — 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	LIMITED	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100										
	10	95							110			
	20	100							120			
	30	100							130			
	40	100						8016.0	140; 144.0			
	50	78							150			
		100										
	60	100							160			
	70	100							170			
	80	97							180			
	90	99							190			
		100										



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"

GEOLOGIC LOG OF DRILL HOLE

...TE: EMRIA	PROJECT: BLM - McCallum Site		STATE: Colorado
...LE ...: DH-4	LOCATION: See Location Map; COORDS. N. ... E. ...	GROUND ELEV.: 8160±	DIP (ANGLE FROM HORIZ.): Vertical
...GU...: 8/30/79	FINISHED: 9/24/79	DEPTH OF OVERBURDEN: 22.5	TOTAL DEPTH: 253.0; BEARING:
...PT AND ELEV. OF WATER ...EV AND DATE MEASURED: See Below	LOGGED BY: L. K. Weston		LOG REVIEWED BY: N.B. Bennett, III

...ES ON WATER ...S AND LEVELS, ...ASG, CEMENTING, ...G, AND OTHER ...NG CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	LIMITED	UNSUIT-ABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100										
	10	96							210			
	20	96							220			
	30	97							230			
	40	94							240			
	50	84						7907.0	250 / 253.0			Total Depth - 253.0
	60								260			NOTE: The core was logged on 10/18/79. Consequently, all of the samples were dry and the reported hardness is greater than would have been observed immediately after drilling. All reported dips have been corrected to true dips from the horizontal.
	70								270			
	80								280			
	90								290			

EXPLANATION

C..E ..S

C..E ..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

SHEET 1 OF 3

FEATURE: EMRIA | PROJECT: BLM - MCCALLUM SITE | STATE: Colorado

HOLE NO.: DH-5a | LOCATION: See Location Map | COORDS. N. ... E. ... | GROUND ELEV.: 8170± | DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 7-26-79 | FINISHED: 7-31-79 | DEPTH OF OVERBURDEN: 12.4 | TOTAL DEPTH: 250.5 | BEARING: ...

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

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

Hole drilled with S&H Drill 142C skid-mounted rig.

Push samples 0.0-7.5. NX coring 7.5-20.5. NQ wireline 20.5-250.5. Drilled with water 0.0-12.0 and 30.5-250.5. Drilled with Revert 12.0-30.5.

Water Levels

Level	Date	Hole Depth
27.1	7/30	70.5
30.6	7/31	140.5
29.4	8/1	250.5

Water Loss

Percent	Interval
100	At 55.0
100	At 60.0
40	At 62.0

Black, gray, and brown color water return.

CORE RECOVERY (%) (top to bottom): 44, 54, 0, 90, 100, 80, 54, 95, 79, 96, 100, 100, 94, 100

SUITABILITY OF OVERBURDEN: Suitable 0.0-12.4; Unsuitable 12.4-20.5; Suitable 20.5-70.5; Limited 70.5-85.5; Unsuitable 85.5-bottom of sheet

ELEVATION (FEET)	DEPTH (FEET)
8166.8	3.2
8157.6	12.4
8150.5	19.5
8149.5	20.5
8086.0	84.0

CLASSIFICATION AND PHYSICAL CONDITION

0.0-12.4 - Overburden.

0.0-3.2 - Silt. - Sandy. Roots and vegetative material throughout. Dark gray to black color. Almost a coaly appearance. Some Fe stain. No HCl reaction.

3.2-12.4 - Silt and Clay. - Muddy appearance. Increasing carbonaceous content and dark coloration near 12.4. HCl reaction in light colored areas. Tan, white, gray, and dark gray.

12.4-84.0 - Coalmont Formation.

12.4-19.5 - Coal. - Sample taken.

19.5-20.5 - Siltstone. - Slickensides. Fe stains. High carbonaceous content. No HCl reaction. Brown with purplish cast.

20.5-84.0 - Sandstone. - Silty. Fine grained. Grades into a sandy siltstone at 84.0. White to light gray at top of interval grading to gray. Hematite in cracks and joints upper 1.0 feet. Fe staining throughout to 53.0. Joints dipping 35°-50°, many "healed" with hematite. Good core with pieces up to 1.5 feet long. Light carbonaceous banding 66.5-70.5 and 76.2-82.0. Little or no breakdown in water. Hardness 5-6.

84.0-250.5 - Pierre Shale.

84.0-169.5 - Siltstone. - Sandy. Shaley in many places particularly 160.5-163.4. Uneven breakage along surfaces dipping at angles from 15° to 40°. Some evidence of banding (bedding planes?) dipping at same angles. Mostly good core up to 1.5 foot lengths. Fossiliferous 141.5-155.0. Small brachiopods at 144.0 and 145.0. Calcareous near fossil zones and 84.0-118.0. Gray. Little to no breakdown in water. Hardness 4-5.

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"

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

ATURE EMRIA ... PROJECT BLM - MCCALLUM SITE ... STATE Colorado

LE NO. DH-5a LOCATION See Location Map ... GROUND ELEV. 8170+ ... DIP (ANGLE FROM HORIZ.) Vertical

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

GUN 7-26-79 FINISHED 7-31-79 DEPTH OF OVERBURDEN 12.4 TOTAL DEPTH 250.5 BEARING ...

PTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Below ... LOGGED BY L. K. Weston ... 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	LIMITED	UNSUIT-ABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100							110			169.5-250.5 - Sandstone. - Silty. Very fine to fine grained. Excellent core up to 3.7 feet long. Some disentegration of core at 181.5 and 211.5. Uneven fracturing at no particular angle. Fairly uniform texture throughout. Fossiliferous 169.5-180.5 and 240.5-250.5. Calcareous near fossil zones and 218.1-222.4. Gray. Does not break down in water. Hardness 5-6.
		100							120			
		100							130			
		95							140			
		98							150			
		95							160			
		95						8000.5	169.5			
		100							170			
		100							180			
		99							190			

Depth scale (type and size of hole column): 10, 20, 30, 40, 50, 60, 70, 80, 90

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

FEATURE: EMRIA PROJECT: BLM - MCCALLUM SITE STATE: Colorado

HOLE NO.: DH-5a LOCATION: See Location Map COORDS. N. ... E. ... GROUND ELEV.: 8170± DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 7-26-79 FINISHED: 7-31-79 DEPTH OF OVERBURDEN: 12.4 TOTAL DEPTH: 250.5 BEARING: ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Below LOGGED BY: L. K. Weston 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	LIMITED	UNSUIT-ABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100										
		100										
		100										
		100										
		100										
								7919.5	250.5			Total depth 250.5.
												NOTE: The core was logged on 9/24/79, consequently, all of the samples were dry and reported hardness is greater than would have been observed immediately after drilling. All reported dips have been corrected to true dips from the horizontal.

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"

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: EMRIA — PROJECT: BLM - MCCALLUM SITE — STATE: Colorado

HOLE NO.: DH-6 — LOCATION: See Location Map — COORDS. N. ... E. ... — GROUND ELEV.: 8120± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 8-3-79 — FINISHED: 8-22-79 — DEPTH OF OVERBURDEN: 13.0 — TOTAL DEPTH: 144.5 — BEARING: ...

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

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

Hole drilled with S&H Drill 142C skid-mounted rig.

Push samples 0.0-7.7. NW coring 7.7-13.0. NQ wire-line 13.0-144.5. Drilled with water 7.7-144.5.

Water Levels

Level	Date	Hole Depth
7.7	8/7	34.8
5.7	8/8	100.0
7.2	8/9	120.0
8.0	8/13	144.5
8.0	8/14	144.5
8.0	8/15	144.5
8.0	8/16	144.5
8.0	8/17	144.5
8.0	8/20	144.5
8.0	8/21	144.5
8.0	8/22	144.5
7.5	8/23	144.5

No reported water loss. Gray and brown color water return.

CORE RECOVERY (%): 100, 100, 100, 100, 35, 35, 20, 3, 0, 91, 44, 100, 100, 100, 90, 100, 80, 100, 100

DEPTH (FEET) FROM: 100

SUITABILITY OF OVERBURDEN (Suitable / Limited / Unsuitable): NO SAMPLE

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
8107.0	13.0
8090.2	29.8

CLASSIFICATION AND PHYSICAL CONDITION

0.0-13.0 - Overburden.

0.0-13.0 - Silt. - Sandy. Coarse gravel 7.7-13.0 (igneous). Roots and organic material 0.0-2.0. Some Fe stains. HCl reaction 4.0-10.0. Tan to brown.

13.0-144.5 - Coalmont Formation.

13.0-29.8 - Sandstone. - Silty. Fine grained and poorly consolidated (wash samples) 13.0-24.3. Consolidated and fine to coarse grained 24.3-29.8. Subrounded quartz grains and biotite flakes in a silty matrix. Unconsolidated sand is highly calcareous. Consolidated sand is slightly calcareous in places. Slow to rapid breakdown in water. Tan to light gray. Hardness 3-4.

29.8-123.9 - Siltstone. - Sandy 48.0-65.5, 88.0-96.0. Shaley 104.2-123.9. Core has strong tendency to disentegrate in place. Much uneven fracturing along rough angular surfaces dipping 20°-30°. Few joint surfaces at same angle. HCl reaction at 70.0 and 88.0-90.0. Damp spot near 100.0. Slow breakdown in water. Light gray grading to dark gray to black near 123.9. Hardness 4-5.

123.9-144.5 - Coal. - Sample taken.

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"

GEOLOGIC LOG OF DRILL HOLE

FEATURE EMRIA PROJECT BLM - MCCALLUM SITE STATE Colorado

HOLE NO. DH-6 LOCATION See Location Map GROUND ELEV. 8120± DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

BEGUN 8-3-79 FINISHED 8-22-79 DEPTH OF OVERBURDEN 13.0 TOTAL DEPTH 144.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Below LOGGED BY L. K. Weston 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	LIMITED	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100										
		100							110			
		100						7996.1	123.9			
		100							130			
		100						7975.5	144.5			Total depth 144.5.

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90 / 110, 120, 130, 140, 150, 160, 170, 180, 190

NOTE: The core was logged on 9/25/79, consequently, all of the samples were dry and the recorded hardness is greater than would have been observed immediately after drilling. All reported dips have been corrected to true dips from the horizontal.

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"

Introduction

As part of a continuing program by the U.S. Geological Survey to collect nd chemically analyze representative samples of U.S. coals, 44 coal and oa-associated rock samples were collected from the Paleocene and Eocene, oalmont Formation in the McCallum and Coalmont areas, North Park, Jackson unty, Colorado. Twenty-eight samples (24 coal and 4 coal-associated rock) re from the McCallum area and 16 samples (12 coal and 4 coal-associated rock) re from the Coalmont area. Locations of ten core holes and three mines where he samples were collected, and an outline of North Park are shown on figure 1. he 44 samples are briefly described in table 1.

Previous Investigations

The coal geology of North Park, Jackson County, Colo., has been discussed r mentioned in a number of reports. Beekly (1915) mapped the geology of ackson County; Erdman (1941) mapped coal occurrences near the former town of oalmont to determine the extent of a burning coal bed; Hail (1965, 1968) apped the geology of western Jackson County; and Kinney (1970, 1971), Kinney nd Hail (1970a, b) and Kinney and others (1970) mapped eastern Jackson County adden (1977a,b) carried out an exploratory drilling program in the McCallum n Coalmont areas and delineated a leasable coal area (Madden and others 983). Hendricks (1977, 1978) studied the stratigraphy of the Coalmont ormation in the Coalmont, Colo. area.

The Coalmont Formation is the most widespread unit in the two coal areas nd is the only formation containing significantly thick coal deposits. The ormation is a maximum of 12,000 ft thick and consists of micaceous and rkosic sandstone, minor conglomerate, mudstone, claystone, carbonaceous shale, nd coal (Hail, 1968).

The sedimentary rocks of the Coalmont Formation in the Coalmont area fig. 1) consist of braided stream, overbank, and swamp deposits in the lower part and meandering channel, crevasse splay, levee, and swamp deposits in the

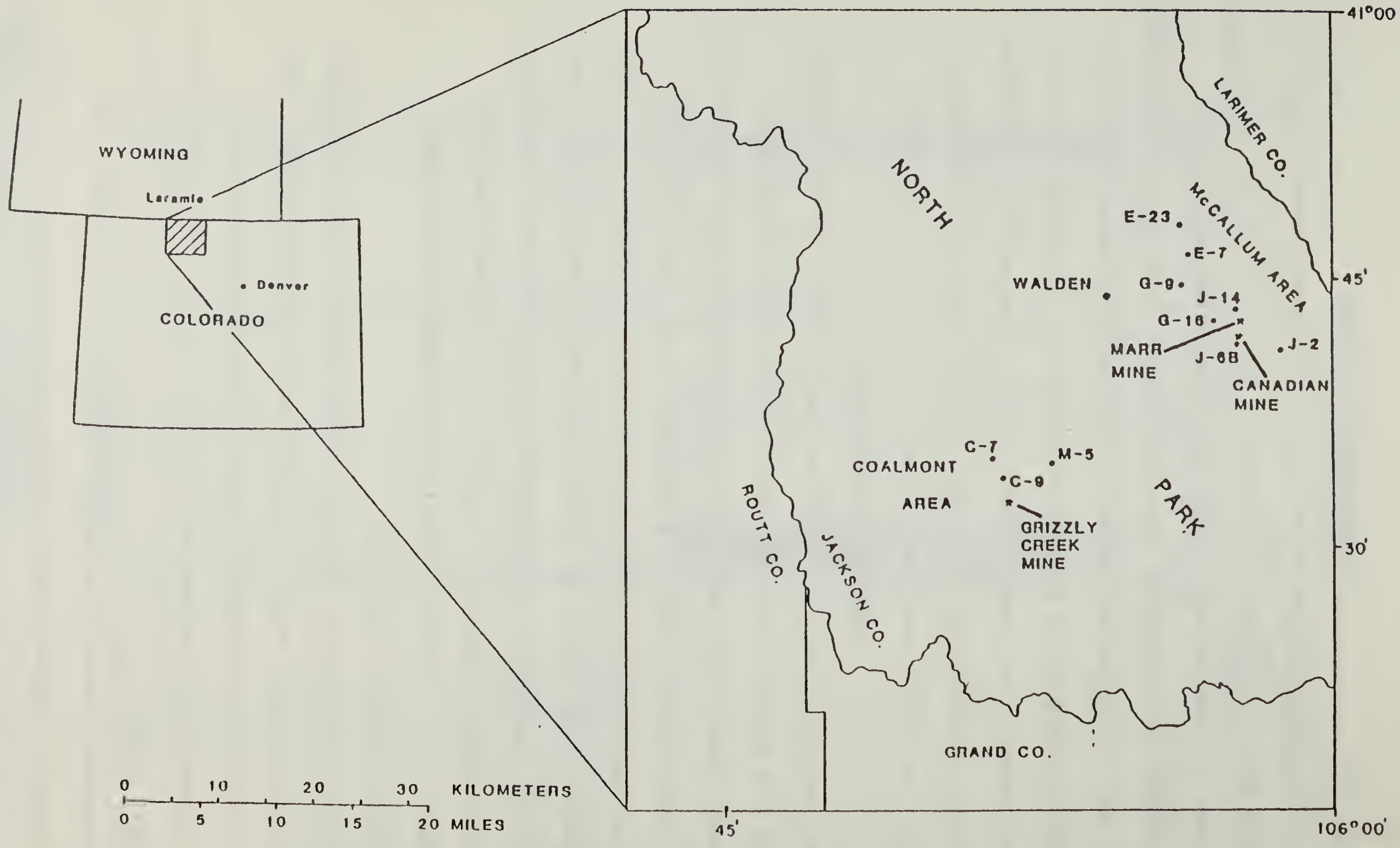


Figure 1.--Index map of part of north-central Colorado showing locations of core holes (•) and mines (⚒) in North Park, Jackson County, Colorado. The margins of North Park coincide with the Jackson County

Table 1.—USGS sample number, mine name or hole number, location, sample thickness or depth interval and coal bed name or description for 44 coal and coal-associated rock samples from the Coalmont Formation, McCallum and Coalmont areas, North Park, Jackson County, Colo.

[McCallum area samples are of Paleocene age; Coalmont area samples are of Eocene age. One foot = 0.305 meters]

USGS sample number	Mine name or core hole number	Location	Sample thickness or depth interval in feet	Coal bed name or description
		McCallum area channel samples		
D170627	Canadian strip mine	NE¼SW¼ sec. 2, T. 8 N., R. 78 W.	top 5.0	Sudduth.
D170628	———do———	———————do———————	next 5.0	Do.
D170629	———do———	———————do———————	———do———	Do.
D170630	———do———	———————do———————	———do———	Do.
D170631	———do———	———————do———————	bottom 4.5	Do.
D172059	———do———	———————do———————	2.0	Unnamed 32 ft below Sudduth.
D172052	Marr strip mine	SW¼SE¼ sec. 26, T. 9 N., R. 78 W.	top 10.0	Sudduth.
D172053	———do———	———————do———————	———do———	Do.
D172054	———do———	———————do———————	———do———	Do.
D172055	———do———	———————do———————	———do———	Do.
D172056	———do———	———————do———————	———do———	Do.
D172057	———do———	———————do———————	———do———	Do.
D172058	———do———	———————do———————	bottom 10.0	Do.
		McCallum area core samples		
D196200	G-9	NE¼NE¼ sec. 19, T. 9 N., R. 78 W.	94.0-141.0	Sudduth.
D196201	———do———	———————do———————	142.2-148.5	Do.
D196202	J-6B	NW¼NW¼ sec. 11, T. 8 N., R. 78 W.	57.4- 71.3	Do.
D196203	J-14	NE¼SW¼ sec. 26, T. 9 N., R. 78 W.	72.9-116.0	Do.
D196204	———do———	———————do———————	116.0-153.1	Do.
D196205	E-7	C NW¼ sec. 8, T. 9 N., R. 78 W.	1641.-206.0	Do.
D196206	G-16	SE¼NE¼ sec. 33, T. 9 N., R. 78 W.	143.8-167.9	Do.
D196441	———do———	———————do———————	167.9-170.0	Mudstone, carbonaceous.
D196442	J-2	SW¼NW¼ sec. 8, T. 8 N., R. 77 W.	57.8- 61.2	Mudstone.
D196443	———do———	———————do———————	61.2- 61.8	Shale, carbonaceous.
D196207	———do———	———————do———————	61.8- 83.1	Sudduth.
D196444	———do———	———————do———————	83.1- 87.0	Mudstone.

Table 1.—USGS sample number, mine name or hole number, location, sample thickness or depth interval and coal bed name or description for 44 coal and coal-associated rock samples from the Coalmont Formation, McCallum and Coalmont areas, North Park, Jackson County, Colo.—Continued

USGS sample number	Mine name or core hole number	Location	Sample thickness or depth interval in feet	Coal bed name or description
McCallum area core samples—Continued				
D196208	E-23	NW¼NE¼ sec. 31, T. 10 N., R. 78 W.	189.0-190.0	Unnamed rider coal, shaley.
D196209	——do——	——do——	198.7-217.0	Sudduth.
D196210	——do——	——do——	218.4-218.9	Lower split of Sudduth, shaley.
Coalmont area channel samples				
D174481	Grizzly Creek strip mine	SE¼NW¼ sec. 32, T. 7 N., R. 80 W.	Top 5.0	Riach.
D174483	——do——	——do——	next 5.0	Do.
D174484	——do——	——do——	——do——	Do.
D174485	——do——	——do——	——do——	Do.
D174486	——do——	——do——	bottom 3.0	Do.
Coalmont area core samples				
D194458	C-9	SW¼SE¼ sec. 19, T. 7 N., R. 80 W.	410.0-423.0	Riach.
D194485	——do——	——do——	423.0-431.0	Clay.
D194486	C-7	NW¼SW¼ sec. 18, T. 7 N., R. 80 W.	300.0-308.5	Mudstone, carbonaceous.
D194459	——do——	——do——	308.5-312.6	Riach.
D194460	——do——	——do——	312.6-319.6	Do.
D194461	——do——	——do——	319.6-329.0	Do.
D194462	——do——	——do——	329.0-337.5	Do.
D194487	——do——	——do——	337.5-338.6	Shale, coaly.
D194463	M-5	SE¼SE¼ sec. 15, T. 7 N., R. 80 W.	710.0-723.5	Riach.
D194488	——do——	——do——	723.5-724.3	Mudstone, carbonaceous.
D194464	——do——	——do——	724.3-732.5	Riach.

per member (Hendricks, 1977).

The two major coal beds in the Coalmont Formation are the Sudduth, which curs 50-250 ft above the base of the Coalmont Formation, and the Riach, which curs approximately 3,000 ft above the base. The Sudduth coal bed occurs in iney's (1970) arkosic member (5,500 ft thick) where the member overlies the 'irre Shale; and the Riach coal bed occurs in Hail's (1968) upper member 5500 ft thick (fig. 2)). The two coal beds have never been found together none section. The Sudduth bed occurs only in the McCallum area in northeastern cth Park and the Riach coal bed occurs only in the Coalmont area in south-etern North Park. The two areas are separated by a major east-northeast-nnding fault, the Spring Creek Fault, which has 4,900 ft of displacement (Ehrendt and others, 1969; Madden and others, 1978).

In the Coalmont area the Riach coal bed dips from 5° to 26° east or ctheast toward the center of the basin. Numerous northwest-trending faults ocur in the Coalmont area where they generally show less than 500 ft of satigraphic displacement (Hail, 1968) and repeat the poorly exposed "outcrop" o the Riach bed in a number of places (Madden and others, 1978). In the Mcallum area the Sudduth coal bed is folded into synclines and anticlines and ds range from 20° to vertical. Only minor faults cut the Sudduth bed.

According to Beekly (1915) the Sudduth bed has a maximum thickness of 58 f though in 1977 a thickness of 80 ft was reported in the Marr mine. The kown areal extent of the coal bed (including eroded areas along anticlinal ces) is approximately 140 mi^2. The Riach bed is a maximum of 80 ft thick (dmann, 1941). Its known areal extent is approximately 50 mi^2. However, a suggested by subsurface data from one drill hole approximately 4 mi northeast o the immediate Coalmont area (Madden and others 1978), this areal extent may b greater.

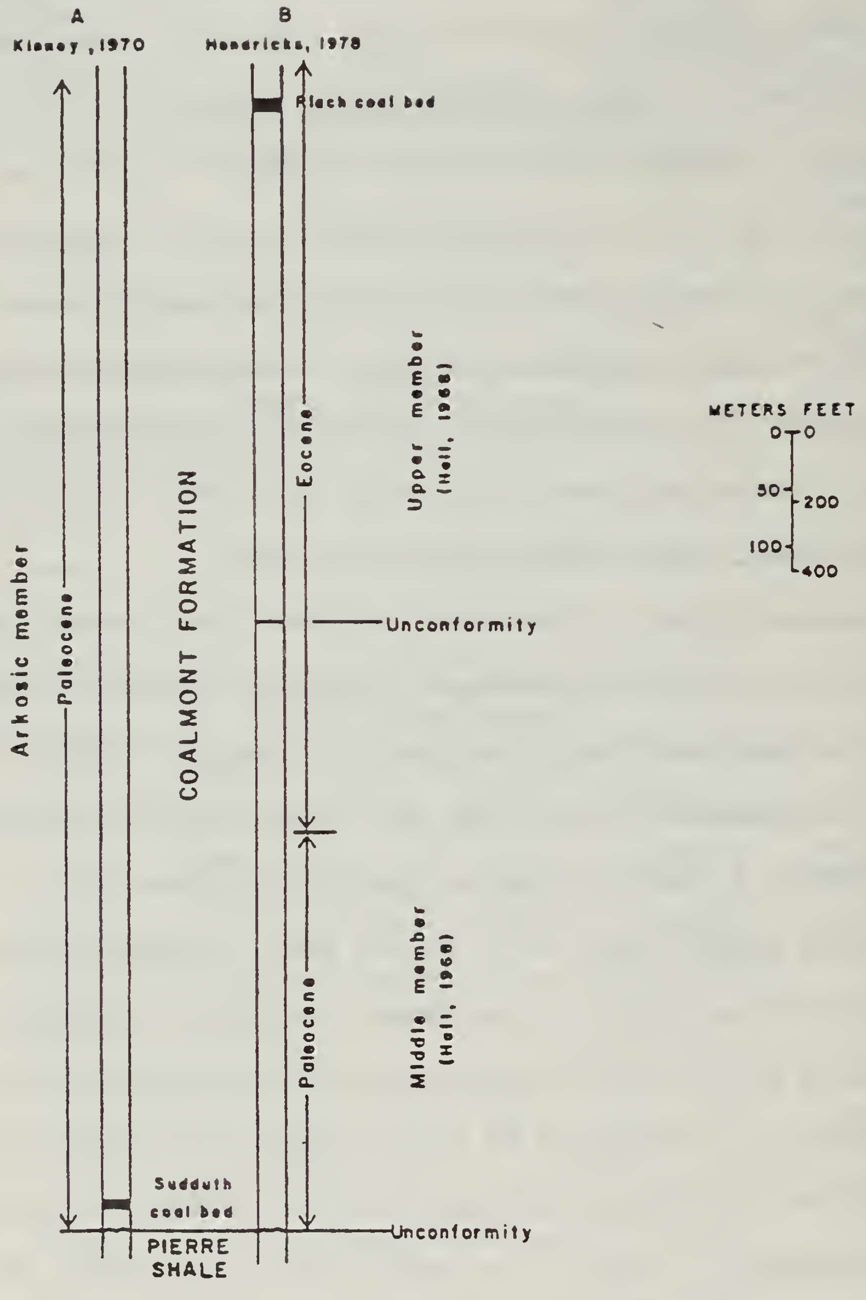


Figure 2.--Generalized columnar sections of the Coalmont Formation showing stratigraphic positions of the two major coal beds in Jackson County, Colorado. A, Sudduth coal bed in McCallum area; B, Riach coal bed in Coalmont area.

Explanation of data and summary tables

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations on 22 McCallum area coal samples are listed in table 2. Similar analyses for 16 Coalmont area coal samples are listed in table 6. These analyses were provided by the U.S. Department of Energy, Pittsburgh, Pa. Analyses for ash content and contents of 33 major and minor oxides and trace elements in the laboratory ash (table 3) and analyses for contents of seven trace elements in whole coal and coal-associated rock (table 4) for 28 McCallum area samples were provided by the U.S. Geological Survey, Denver, Colo. Similar analyses for the 16 Coalmont area samples are listed in tables 7 and 8. Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976). Table 5 contains the data listed in table 3 converted to a whole-coal and whole-rock basis plus the analyses listed in table 4; table 9 contains the data listed in table 7 converted to a whole-coal and whole-rock basis plus the analyses listed in table 8. Twenty-five additional elements not listed in tables 3 through 9 were looked for in all samples, but not found in amounts greater than their lower limits of detection (table 10). Unweighted statistical summaries of analytical data for the 21 Sudduth bed coal samples listed in tables 2, 3, and 5, are listed in tables 11, 12, and 13, respectively; unweighted statistical summaries of analytical data for the 12 Riach bed coal samples listed in tables 6, 7, and 9 are listed in tables 14, 15, and 16, respectively. Data summaries for Cd were not included in tables 13 and 16 because this element was not detected in a sufficient number of samples to calculate meaningful statistics. Data summaries for P_2O_5 content in the Riach bed ash (table 15) and P content in coal from the Riach bed (table 16) were also not included as statistics because of the variable lower detection limits.

Arsenic content of samples summarized in this report have been determine by two different analytical methods: samples D170627 through D170637, D17205 through D172059, D174481, and D174483 through D174486 were analyzed spectrophotometrically (lower detection limit 1.0 ppm); the other 26 samples were analyzed by instrumental neutron activation analysis (lower detection limit 0.1 ppm).

Thorium contents of the samples were determined by two methods: Samples D170627 through D170631, D172052 through D172059, D174481, and D174483 throug D174486 were analyzed by delayed neutron activation analysis (lower detection limit 3.0 ppm); the other 26 samples were analyzed by instrumental neutron activation analysis (lower detection limit 0.1 ppm).

P_2O_5 contents for all samples were determined by X-ray fluorescence spectroscopy. However, due to changes in technique, the lower detection limi for samples D170627 through D170631, D172052 through D172059, D174481, and D174483 through D174486 is 0.1 percent in the ash; for samples D194452 through D194464 and D194485 through D194488 it is 1.0 percent in the ash; and for samples D196200 through D196210 and D196441 through D196444 it is 0.01 percent in whole coal.

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of elements determine by this method are reported as the midpoint of the enclosing six-step brackets (see subtitle of table 3, or Swanson and Huffman, 1976, p. 6 for an explanati of six-step brackets.)

Analyses of 18 coal samples (D170627 through D170631, D172052 through D172059, D174481, and D174483 through D174486) listed in this report have been previously published in Swanson and others (1976, tables 37b, c, d and e) and in Boreck and others (1977, tables 2, 3, 4, 5, and 6). We have included the analyses here in order to provide a more complete data listing.

Explanation of statistical terms used in summary tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the estimated range of the central two-thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to GM·GD. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to GM/GD^2 and an upper limit equal to $GM \cdot GD^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's *t* statistic (Miesch, 1967).

A common problem in statistical summaries of trace-element data arises when the element content of one or more of the samples is below the limit of analytical detection. This results in a "censored" distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation, and arithmetic mean when the data are censored.

Discussion

The apparent ranks of all coal samples from the Coalmont Formation, McCallum and Coalmont areas, were calculated using the data in tables 2 and 6 and the formulas in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). Apparent rank for samples from the McCallum area range from subbituminous B (seven samples) to subbituminous A coal (15 samples). The samples of subbituminous A coal are from the southern part of the area and include all samples from the Marr and Canadian strip mines and cores J-14 and J-6B. Apparent rank for samples from the Coalmont area ranges from subbituminous C (one sample) to subbituminous B coal (11 samples).

A statistical comparison (student's t test 95-percent confidence level) of the data for the Sudduth and Riach beds summarized in tables 11 and 14, respectively, shows that the Sudduth bed has significantly higher contents of fixed carbon and carbon, a significantly higher heat of combustion; and significantly lower contents of moisture, ash, oxygen, and total, sulfate, pyritic and organic sulfur. The ash-fusion-temperature determinations and the contents of volatile matter, hydrogen and nitrogen are not significantly different. When compared at the 99-percent confidence level the contents of oxygen and sulfate sulfur are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and the geometric mean contents of nine major and minor oxides in the ash from the Sudduth bed with the Riach bed show that the Sudduth bed ash has a significantly higher content of CaO and significantly lower ash content and contents of MgO, K_2O, and Fe_2O_3 in ash. The contents of SiO_2, Al_2O_3, Na_2O, TiO_2, and SO_3 in ash are not significantly different. When compared at the 99-percent confidence level the contents of CaO are not significantly differe

A statistical comparison of the geometric mean contents of 36 elements in the Sudduth bed with the Riach bed shows that the Sudduth bed has significantly lower contents of Si, Al, Mg, Na, K, Fe, Ti, Ba, Be, Co, Cr, Cu, F, Ga, La, Mn, Mo, Nb, Ni, Pb, Sc, Sr, Th, U, V, Y, Yb, and Zn. The contents of Ca, As, B, Hg, Li, Sb, Se and Zr are not significantly different. When compared at the 99 percent confidence level the contents of Si, Na, Ti, Ga, Nb, and Pb are not significantly different.

Differences in the oxide composition of coal ashes and the elemental contents of coal result from differences in the total and relative amounts of the various inorganic minerals, the elemental composition of these minerals, and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geologic history of the coal bed. A partial listing of the geologic factors that influence element distributions would include chemical composition of original plants; amounts and compositions of the various detrital, diagenetic, and epigenetic minerals; chemical characteristics of the ground waters that come in contact with the bed; temperatures and pressures during burial; and extent of weathering. No evaluation of these factors has been made for coal from the Sudduth and Riach beds.

Acknowledgments

Fundamental to this paper is the contribution of the team of chemical laboratory personnel in the U.S. Geological Survey under the direction of Claude Huffman, Jr. and Joseph H. Christie: James W. Baker, Ardith J. Bartel David A. Bickford, Candy Bliss, Leon A. Bradley, George T. Burrow, James G. Crock, Andrew F. Drenick, Celeste M. Ellis, Jerry A. England, Edward J. Fennelly, Johnnie M. Gardner, Patricia G. Guest, John C. Hamilton, Raymond G. Havens, Jessie O. Johnson, Roy J. Knight, Cindy McFee, Robert E. McGregor, Violet M. Merritt, Hugh T. Millard, Jr., Harriet G. Neiman, George O. Riddle, Gaylord D. Shipley, James A. Thomas, Michele L. Tuttle, Richard E. VanLoenen, James S. Wahlberg, and Robert J. Young. In connection with the acknowledgmen to the above staff of chemical analysts, the invaluable contribution of the chemists in the Coal Analysis Section (Forrest E. Walker, Chemist in Charge), U.S. Department of Energy, Pittsburgh, Pa., is also gratefully acknowledged. We also appreciate Rick T. Hildebrand's help in preparing the data tables, Roger R. Trengrove's and Mary K. Queen's help in drafting the illustrations, and Ann M. Kramer's, Vernon E. Swanson's, and D. Keith Murray's help in collecting samples.

References cited

ican Society for Testing and Materials, 1978, Standard specifications for classification of coals by rank (ASTM designation D-388-77): 1978 Annual book of ASTM standards, pt. 26, p. 220-224.

ly, A. L., 1915, Geology and coal resources of North Park, Colorado: U.S. Geological Survey Bulletin 596, 121 p.

endt, J. C., Popenoe, Peter, and Mattick, R. E., 1969, A geophysical study of North Park and the surrounding ranges, Colorado: Geological Society of America Bulletin, v. 80, no. 10, p. 1523-1538.

ck, D. L., Jones, D. C., Murray, D. K., Schultz, J. E. and Suek, D. C., 1977, Colorado coal analyses, 1975, Colorado Geological Survey Information Series No. 7, 112 p.

n, A. C., 1959, Simplified estimators for the normal distribution when samples are singly censored or truncated: Technometrics, v. 1, no. 3, p. 217-237.

or, J. J., Keith, J. R., and Anderson, B. M., 1976, Trace-metal variation in soils and sagebrush in the Powder River basin, Wyoming and Montana: U.S. Geological Survey Journal of Research, v. 4, no. 1, p. 49-59.

man, C. E., 1941, Preliminary report on the geology of the Coalmont district, Jackson County, Colo.: U.S. Geological Survey Open-File report, 207 p., including appendix.

al, W. J., Jr., 1965, Geology of northwestern North Park, Colorado: U.S. Geological Survey Bulletin 1188, 133 p.

al, W. J., Jr., 1968, Geology of southwestern North Park and vicinity, Colorado: U.S. Geological Survey Bulletin 1257, 119 p.

Hedricks, M. L., 1977, Stratigraphy of the Coalmont Formation near Coalmont, Jackson County, Colorado: MS Thesis, Colorado School of Mines, 112 p.

Hendricks, M. L., 1978, Stratigraphy of the Coalmont Formation near Coalmont Jackson County, Colorado, in Hodgson, H. E., ed., Proceedings of the second symposium on the geology of Rocky Mountain coal - 1977: Colorado Geological Survey Resource Series 4, p. 35-48.

Kinney, D. M., 1970, Preliminary geologic map of the Gould quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey Open-File Report 1 map (2 sheets), 1:48,000.

Kinney, D. M., 1971, Preliminary geologic map of "southwest third" of Kings Canyon quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey Open-File Report, 1 sheet, scale 1:48,000.

Kinney, D. M., and Hail, W. J., Jr., 1970a, Preliminary geologic map of the Walden quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey Open-File Map, scale 1:48,000, 2 sheets, explanation.

______1970b, Preliminary geologic map of the Hyannis Peak quadrangle, North and Middle Parks, Jackson and Grand Counties, Colorado: U.S. Geological Survey Open-File Report, 1 map (2 sheets) 1:48,000.

Kinney, D. M., Hail, W. J., Jr., Steven, T. A., Johnson, R. B., Bush, A. L., Weir, G. W., 1970, Preliminary geologic map of Cowdrey quadrangle, North Park, Jackson County, Colorado: U.S. Geological Survey, Open-File. Map scale 1:48,000, 2 sheets, explanation.

Madden, D. H., 1977a, Exploratory drilling in the Coalmont coal field, Jackson County, Colorado, June-November 1977: U.S. Geological Survey Open-File Report 77-887, 138 p.

Madden, D. H., 1977b, Exploratory drilling in the McCallum coal field, Jackson County, Colorado, August-November 1977: U.S. Geological Survey Open-File Report 77-888, 80 p.

Madden, D. H., Jobin, D. A., and Storrs, P. J., 1978, Revision of the McCallum Known Recoverable Coal Resource Area, Jackson County, Colorado, 12 p., U.S. Geological Survey Administrative report.

iech, A. T., 1967, Methods of computation for estimating geochemical abundances: U.S. Geological Survey Professional Paper 574-B, 15 p.

wason, V. E., and Huffman, Claude, Jr., 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geological Survey Circular 735, 11 p.

wason, V. E., Medlin, J. H., Hatch, J. R., Coleman, S. L., Wood, G. H., Jr., Woodruff, S. D., and Hildebrand, R. T., 1976, Collection, chemical analysis, and evaluations of coal samples in 1975: U.S. Geological Survey Open-File Report 76-468, 503 p.

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index; and ash-fusion-temperature determinations for 22 coal samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.

[All analyses except heat-of-combustion, free-swelling index, and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Department of Energy, Pittsburgh, Pa. °F = (°C x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb). L, less than the value shown]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D170627	14.5	31.9	47.2	6.4	5.8	61.5	1.0	25.1	0.2	5,960	10,730
	---	37.3	55.2	7.5	4.9	71.9	1.2	14.3	.2	6,970	12,550
	---	40.3	59.7	---	5.3	77.7	1.3	15.4	.3	7,540	13,570
D170628	15.4	32.9	48.5	3.2	5.9	63.5	1.0	26.2	.2	6,110	10,990
	---	38.9	57.3	3.8	5.0	75.1	1.2	14.8	.2	7,220	12,990
	---	40.4	59.6	---	5.1	78.0	1.2	15.4	.2	7,500	13,500
D170629	16.1	31.4	43.0	9.5	5.7	57.0	.8	26.8	.2	5,500	9,900
	---	37.4	51.3	11.3	4.7	67.9	1.0	14.9	.2	6,560	11,800
	---	42.2	57.8	---	5.3	76.6	1.1	16.8	.3	7,390	13,310
D170630	14.6	32.6	49.1	3.7	5.8	63.1	.9	26.3	.2	6,050	10,890
	---	38.2	57.5	4.3	4.9	73.9	1.1	15.6	.2	7,080	12,750
	---	39.9	60.1	---	5.1	77.2	1.1	16.3	.2	7,410	13,330
D170631	14.5	27.4	38.9	19.2	5.0	49.9	.6	25.1	.2	4,770	8,580
	---	32.0	45.5	22.5	4.0	58.4	.7	14.3	.2	5,580	10,040
	---	41.3	58.7	---	5.1	75.3	.9	18.4	.3	7,190	12,940
D172059	12.8	37.3	44.8	5.1	5.9	62.9	1.0	24.4	.7	6,200	11,160
	---	42.8	51.4	5.8	5.1	72.1	1.1	14.9	.8	7,110	12,800
	---	45.4	54.6	---	5.5	76.6	1.2	15.9	.9	7,550	13,590
D172052	14.2	35.4	48.3	2.1	5.9	64.3	1.0	26.5	.2	6,270	11,280
	---	41.3	56.3	2.4	5.0	74.9	1.2	16.2	.2	7,300	13,150
	---	42.3	57.7	---	5.2	76.8	1.2	16.6	.2	7,490	13,480
D172053	14.4	34.4	47.9	3.3	5.8	62.8	.9	27.0	.2	6,020	10,830
	---	40.2	56.0	3.9	4.9	73.4	1.1	16.6	.2	7,030	12,650
	---	41.8	58.2	---	5.1	76.3	1.1	17.3	.2	7,310	13,160
D172054	13.0	35.0	47.8	4.2	5.7	63.1	.8	25.9	.3	6,060	10,900
	---	40.2	54.9	4.8	4.9	72.5	.9	16.5	.3	6,960	12,530
	---	42.3	57.7	---	5.1	76.2	1.0	17.3	.4	7,310	13,160
D172055	12.4	34.9	41.9	10.8	5.5	58.0	.7	24.8	.2	5,580	10,040
	---	39.8	47.8	12.3	4.7	66.2	.8	15.7	.2	6,370	11,460
	---	45.4	54.6	---	5.4	75.5	.9	17.9	.3	7,260	13,070
D172056	11.0	37.1	41.5	10.4	5.6	59.1	.8	23.9	.2	5,720	10,290
	---	41.7	46.6	11.7	4.9	66.4	.9	15.9	.2	6,420	11,560
	---	47.2	52.8	---	5.6	75.2	1.0	18.0	.3	7,270	13,090
D172057	12.0	36.0	45.5	6.5	5.7	61.7	.9	24.9	.3	5,990	10,790
	---	40.9	51.7	7.4	5.0	70.1	1.0	16.2	.3	6,810	12,260

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index; and ash-fusion-temperature determinations for 22 coal samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D170627	7.6	0.01	0.08	0.16	0.0	1,165	1,195	1,255
	---	.01	.09	.19				
	---	.01	.10	.20				
D170628	7.5	.01	.09	.06	.0	1,155	1,180	1,245
	---	.01	.11	.07				
	---	.01	.11	.07				
D170629	9.6	.02	.05	.09	.0	1,490	1,515	1,550
	---	.02	.06	.11				
	---	.03	.07	.12				
D170630	6.9	.01L	.04	.16	.0	1,195	1,220	1,290
	---	.01L	.05	.19				
	---	.01L	.05	.20				
D170631	8.4	.01L	.07	.10	.0	1,600+	1,600+	1,600+
	---	.01L	.08	.12				
	---	.02L	.11	.15				
D172059	6.5	.02	.21	.43	.0	1,230	1,260	1,305
	---	.02	.24	.49				
	---	.02	.26	.52				
D172052	6.9	.01L	.08	.13	.0	1,120	1,150	1,175
	---	.01L	.09	.15				
	---	.01L	.10	.16				
D172053	7.5	.01L	.13	.08	.0	1,120	1,150	1,175
	---	.01L	.15	.09				
	---	.01L	.16	.10				
D172054	6.4	.01L	.16	.11	.0	1,325	1,355	1,380
	---	.01L	.18	.13				
	---	.01L	.19	.13				
D172055	5.0	.01L	.09	.12	.0	1,600+	1,600+	1,600+
	---	.01L	.10	.14				
	---	.01L	.12	.16				
D172056	4.3	.01L	.09	.13	.0	1,600+	1,600+	1,600+
	---	.01L	.10	.15				
	---	.01L	.11	.17				
D172057	4.6	.02	.10	.14	.0	1,270	1,295	1,315
	---	.02	.11	.16				
	---	.02	.12	.17				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index; and ash-fusion-temperature determinations for 22 coal samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D172038	12.0	38.3	46.0	3.7	5.9	63.8	0.9	25.4	0.3	6,200	11,160
	---	43.5	52.3	4.2	5.2	72.5	1.0	16.7	.3	7,050	12,680
	---	45.4	54.6	---	5.4	75.7	1.1	17.5	.4	7,350	13,240
D196200	20.4	29.9	43.2	6.5	5.9	55.2	.9	31.3	.2	5,210	9,380
	---	37.6	54.3	8.2	4.6	69.3	1.1	16.5	.3	6,550	11,790
	---	40.9	59.1	---	5.0	75.5	1.2	18.0	.3	7,130	12,840
D196201	16.4	30.4	37.1	16.1	5.5	49.3	.9	27.6	.6	4,790	8,620
	---	36.4	44.4	19.3	4.4	59.0	1.1	15.6	.7	5,730	10,310
	---	45.0	55.0	---	5.4	73.0	1.3	19.3	.9	7,100	12,770
D196202	14.8	32.2	46.6	6.4	5.7	60.6	1.1	26.0	.2	5,840	10,510
	---	37.8	54.7	7.5	4.8	71.1	1.3	15.1	.2	6,850	12,330
	---	40.9	59.1	---	5.1	76.9	1.4	16.3	.3	7,410	13,340
D196203	14.0	33.3	47.2	5.5	5.7	61.3	.9	26.3	.3	5,810	10,460
	---	38.7	54.9	6.4	4.8	71.3	1.0	16.1	.3	6,760	12,170
	---	41.4	58.6	---	5.1	76.1	1.1	17.2	.4	7,220	13,000
D196204	12.9	34.4	45.7	7.0	5.6	60.5	.8	25.8	.3	5,770	10,380
	---	39.5	52.5	8.0	4.8	69.5	.9	16.5	.3	6,620	11,920
	---	42.9	57.1	---	5.2	75.5	1.0	17.9	.4	7,200	12,960
D196205	18.1	31.5	42.5	7.9	5.9	54.9	.8	30.2	.3	5,290	9,520
	---	38.5	51.9	9.6	4.7	67.0	1.0	17.2	.4	6,460	11,630
	---	42.6	57.4	---	5.3	74.2	1.1	19.1	.4	7,150	12,870
D196206	17.9	28.7	41.8	11.6	5.4	53.3	.8	28.5	.3	5,040	9,070
	---	35.0	50.9	14.1	4.2	64.9	1.0	15.3	.4	6,140	11,050
	---	40.7	59.3	---	4.8	75.6	1.1	17.9	.4	7,150	12,870
D196207	14.9	30.6	42.4	12.1	5.3	55.3	.9	26.0	.3	5,250	9,450
	---	36.0	49.8	14.2	4.3	65.0	1.1	15.0	.4	6,170	11,110
	---	41.9	58.1	---	5.0	75.8	1.2	17.5	.4	7,190	12,950
D196209	20.7	31.8	38.1	9.4	5.9	51.5	1.5	31.2	.5	5,000	8,990
	---	40.1	48.0	11.9	4.5	64.9	1.9	16.1	.6	6,300	11,340
	---	45.5	54.5	---	5.2	73.7	2.1	18.3	.7	7,150	12,870

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index; and ash-fusion-temperature determinations for 22 coal samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D172058	4.6	0.02	0.08	0.19	0.0	1,205	1,240	1,295
	---	.02	.09	.22				
	---	.02	.09	.23				
D196200	3.2	.03	.04	.12	.0	1,145	1,165	1,230
	---	.04	.05	.15				
	---	.04	.05	.16				
D196201	2.5	.01L	.04	.59	.0	1,600+	1,600+	1,600+
	---	.01L	.05	.71				
	---	.01L	.06	.87				
D196202	2.8	.01L	.06	.18	.0	1,205	1,225	1,330
	---	.01L	.07	.21				
	---	.01L	.08	.23				
D196203	2.2	.03	.07	.17	.0	1,230	1,290	1,330
	---	.03	.08	.20				
	---	.04	.09	.21				
D196204	.9	.03	.07	.20	.0	1,315	1,340	1,355
	---	.03	.08	.23				
	---	.04	.09	.25				
D196205	3.3	.01L	.07	.22	.0	1,290	1,315	1,340
	---	.01L	.09	.27				
	---	.01L	.09	.30				
D196206	3.2	.04	.09	.20	.0	1,165	1.195	1,310
	---	.05	.11	.24				
	---	.06	.13	.29				
D196207	3.4	.05	.05	.24	.0	1,260	1,290	1,345
	---	.06	.06	.28				
	---	.07	.07	.33				
D196209	3.1	.01	.08	.37	.0	1,170	1,200	1,315
	---	.01	.10	.47				
	---	.01	.11	.53				

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.

[Values in percent or parts per million. Coal and shale ashed at 525°C. L, less than the value shown; N, not detected. S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc. but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level]

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D170627	8.0	47	22	5.5	0.63	0.12	0.39	6.4	0.59	1.6	D170627
D170628	3.8	43	17	9.6	1.03	.15	.090	12	1.1	1.4	D170628
D170629	11.4	54	27	3.0	.93	.16	1.4	3.7	.83	.48	D170629
D170630	4.1	47	18	8.7	1.48	.11	.10	7.9	.86	.31	D170630
D170631	9.8	51	26	4.2	.93	.16	1.1	5.1	.57	1.1	D170631
D172059	6.1	34	24	8.3	1.19	.27	.15	7.5	.85	.10L	D172059
D172052	2.7	26	15	21	1.39	.20	.13	7.1	.81	1.6	D172052
D172053	2.7	16	18	22	1.81	.27	.22	7.0	.74	.53	D172053
D172054	5.4	25	26	13	1.28	.18	.16	4.6	1.6	1.1	D172054
D172055	9.5	41	30	7.3	.56	.11	.14	2.7	1.6	.93	D172055
D172056	9.2	46	24	7.4	.76	.09	.13	3.2	1.8	.53	D172056
D172057	8.1	44	26	8.3	.78	.14	.31	3.7	1.4	.35	D172057
D172058	3.9	30	18	15	1.19	.16	.13	6.9	.98	.13	D172058
D196200	7.4	33	23	12	1.82	5.10	.10	6.0	1.6	.41	D196200
D196201	19.1	54	28	3.2	.46	2.12	.10	1.6	1.2	.050	D196201
D196202	8.2	51	21	6.3	.92	.25	.80	6.5	1.0	1.1	D196202
D196203	6.4	41	21	11	1.32	.27	.70	3.9	1.1	1.1	D196203
D196204	8.7	49	24	7.8	.73	.16	.20	2.1	1.1	1.0	D196204
D196205	9.7	40	22	10	2.24	1.21	.30	4.7	1.1	.72	D196205
D196206	13.1	56	18	9.6	1.00	1.34	.60	3.2	1.0	.38	D196206
D196441	57.3	67	21	1.0	1.50	.98	2.5	2.9	.80	.12	D196441
D196442	92.8	75	19	.80	1.01	.48	2.7	2.3	.70	.080	D196442
D196443	70.2	67	28	.80	.89	.23	1.8	1.9	1.0	.060	D196443
D196207	13.2	56	22	5.4	.72	.31	.40	2.8	1.5	.38	D196207
D196444	89.3	81	17	.30	.69	.18	1.6	1.1	1.2	.060	D196444
D196208	45.3	51	25	1.5	.86	.28	1.3	11	1.2	.070	D196208
D196209	10.5	38	17	12	2.46	1.80	.30	4.4	1.0	1.9	D196209
D196210	40.8	52	21	1.7	.44	.62	.30	12	.80	.020	D196210

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	SO3 (percent)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Ga-S (ppm)	La-S (ppm)	Sample number
D170627	3.5	500	3,000	N	1.0L	7	15	44	20	N	D170627
D170628	7.1	700	5,000	N	1.0L	7	20	98	15	N	D170628
D170629	2.5	300	2,000	N	1.0L	10	30	76	15	N	D170629
D170630	7.2	1,000	5,000	3	1.0L	15	20	112	15	70	D170630
D170631	3.2	500	2,000	N	1.0L	7	10	33	15	N	D170631
D172059	8.5	1,000	1,500	7	1.0L	10	30	132	30	100	D172059
D172052	14	1,000	7,000	N	1.0L	15	30	150	20	100L	D172052
D172053	8.1	700	5,000	3	1.0L	15	20	110	30	150	D172053
D172054	5.4	300	3,000	3	1.0L	15	20	126	30	100	D172054
D172055	5.2	200	1,500	3	1.0L	15	15	68	50	100	D172055
D172056	5.1	200	1,000	N	1.0L	10L	15	106	30	100L	D172056
D172057	6.0	300	1,500	N	1.0L	15	15	102	50	100L	D172057
D172058	11	700	3,000	3	1.0L	20	30	176	30	100L	D172058
D196200	9.8	1,500	3,000	5	1.0L	10	30	96	70	150	D196200
D196201	5.2	700	1,000	10	1.0	20	70	188	100	100	D196201
D196202	7.0	1,500	3,000	3	1.0L	15	30	100	70	70	D196202
D196203	9.0	500	2,000	N	1.0L	10	30	82	70	70	D196203
D196204	8.0	500	2,000	5	1.0L	10	30	80	50	100	D196204
D196205	9.5	2,000	1,000	7	1.0L	30	50	103	70	100	D196205
D196206	6.0	700	1,500	3	1.0L	10L	20	44	50	N	D196206
D196441	.70	150	700	N	1.0L	10L	500	47	50	N	D196441
D196442	.30	100	2,000	N	1.0L	10	70	47	50	70	D196442
D196443	.90	70	2,000	5	1.0L	N	15	29	70	N	D196443
D196207	6.0	700	1,500	3	1.0L	10L	30	96	50	N	D196207
D196444	.080L	70	1,000	N	1.0L	N	50	24	50	N	D196444
D196208	3.2	300	300	5	1.0L	10L	30	58	100	70	D196208
D196209	12	1,500	1,500	7	1.0L	15	50	114	70	70	D196209
D196210	3.5	300	200	15	4.0	20	30	138	70	N	D196210

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Sample number
D170627	38	150L	5	N	15	25	10	2,000	50	20	D170627
D170628	34	740	5	N	15	25	10	2,000	70	30	D170628
D170629	32	150	5	N	10	65	10	700	100	20	D170629
D170630	29	220	10	7	20	40	15	1,500	100	30	D170630
D170631	20	150L	7	7	7	55	7	1,000	50	30	D170631
D172059	37	150L	20	20	30	50	15	500	150	50	D172059
D172052	34	150L	10	20	30	35	15	1,500	100	50	D172052
D172053	70	620	7	20L	30	40	15	1,000	100	30	D172053
D172054	138	150L	7	20L	15	50	15	700	70	30	D172054
D172055	175	150L	7	30	10L	60	15	1,000	100	30	D172055
D172056	68	150L	7	30	10L	50	10	700	150	20	D172056
D172057	69	150L	7	50	15	35	15	1,000	100	30	D172057
D172058	37	770	7	20L	30	40	15	700	150	30	D172058
D196200	145	310	15	20	15	65	20	3,000	150	70	D196200
D196201	132	80	15	20	20	65	20	1,000	150	70	D196201
D196202	44	360	15	30	30	55	15	1,500	150	50	D196202
D196203	109	480	N	20	15	40	15	1,000	150	30	D196203
D196204	170	480	7	30	15	75	20	1,000	150	50	D196204
D196205	105	420	15	20	30	45	15	1,500	150	50	D196205
D196206	42	540	N	30	10	45	10	1,000	70	30	D196206
D196441	33	230	7	30	20	55	15	500	100	30	D196441
D196442	39	150	N	20L	30	25L	15	300	150	30	D196442
D196443	84	185	N	20	N	60	15	300	70	30	D196443
D196207	105	420	N	20	20	35	15	1,000	100	30	D196207
D196444	45	82	N	20	10	25L	15	200	100	30	D196444
D196208	56	210	30	30	15	30	15	300	70	30	D196208
D196209	79	650	20	30	30	40	30	3,000	150	70	D196209
D196210	130	115	15	30	50	60	15	300	100	50	D196210

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D170627	2	60	150
D170628	3	90	200
D170629	2	62	150
D170630	3	94	200
D170631	2	80	150
D172059	3	34	N
D172052	3	70	200
D172053	3	70	N
D172054	3	52	N
D172055	3	44	N
D172056	2	46	N
D172057	3	58	N
D172058	3	92	N
D196200	5	105	500
D196201	5	106	500
D196202	5	131	300
D196203	3	131	200
D196204	5	158	300
D196205	5	225	300
D196206	3	119	200
D196441	3	166	150
D196442	3	167	150
D196443	2	201	300
D196207	3	176	150
D196444	3	61	300
D196208	3	43	200
D196209	7	85	300
D196210	5	590	200

Table 4.--Content of nine trace elements in 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.

[Analyses on air-dried (32°C) coal and shale. L, less than the value shown]

Sample number	As (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D170627	1.0	115	0.04	0.1	0.5	3.0L	0.6	D170627
D170628	1.0	40	.04	.1L	.3	3.0L	.4	D170628
D170629	3.0	80	.07	.2	1.3	3.3	1.0	D170629
D170630	1.0	30	.04	.1	.3	3.0L	.4	D170630
D170631	2.0	130	.04	.1L	.3	3.0L	1.1	D170631
D172059	1.0	30	.06	.3	.4	3.4	.6	D172059
D172052	2.0	30	.02	.2	1.9	3.0L	.2L	D172052
D172053	2.0	25	.02	.2	.8	3.0L	.3	D172053
D172054	2.0	30	.01	.1	.3	3.0L	.6	D172054
D172055	2.0	35	.02	.2	1.0	4.4	.8	D172055
D172056	2.0	30	.06	.2	1.0	3.8	1.0	D172056
D172057	2.0	30	.03	.5	.4	4.6	1.3	D172057
D172058	2.0	25	.02	.2	.2	3.0L	.2L	D172058
D196200	2.7	20L	.10	.2	1.0	2.4	.5	D196200
D196201	1.9	40	.28	.3	2.7	7.7	2.7	D196201
D196202	1.9	95	.02	.1	.8	1.7	.3	D196202
D196203	1.7	50	.02	.1L	.4	1.5	.1	D196203
D196204	2.3	35	.04	.2	.1L	2.5	.5	D196204
D196205	3.0	45	.18	.2	1.1	2.5	.4	D196205
D196206	1.5	65	.03	.5	2.0	2.8	.7	D196206
D196441	10	450	.02	1.5	2.1	9.7	4.4	D196441
D196442	40	485	.04	1.6	2.3	8.6	5.3	D196442
D196443	2.1	390	.03	1.8	2.7	13	6.7	D196443
D196207	.9	60	.04	.3	1.0	3.1	.7	D196207
D196444	2.7	390	.01L	1.5	.9	10	4.6	D196444
D196208	93	120	1.20	.5	.1L	7.2	2.2	D196208
D196209	.8	50	.1C	.4	1.3	2.8	.5	D196209
D196210	110	85	8.00	.9	9.6	5.8	1.4	D196210

Table 5.--Major-, minor-, and trace-element composition of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.

[Values in percent or parts per million. As, Co, Cr, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal and shale; all other values calculated from analyses of ash. S means analysis by emission spectrography; L, less than the value shown; N, not detected]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	As (ppm)	B-S (ppm)	Sample number
D170627	1.8	0.95	0.32	0.030	0.007	0.026	0.36	0.028	1.0	50	D170627
D170628	.77	.34	.26	.024	.004	.003	.32	.025	1.0	30	D170628
D170629	2.9	1.6	.24	.064	.014	.14	.29	.057	3.0	30	D170629
D170630	.90	.40	.25	.037	.003	.003	.23	.021	1.0	50	D170630
D170631	2.3	1.4	.29	.055	.012	.089	.35	.033	2.0	50	D170631
D172059	.97	.76	.36	.044	.012	.008	.32	.031	1.0	70	D172059
D172052	.33	.21	.40	.023	.004	.003	.13	.013	2.0	30	D172052
D172053	.20	.26	.42	.029	.005	.005	.13	.012	2.0	20	D172053
D172054	.63	.74	.51	.042	.007	.007	.17	.052	2.0	15	D172054
D172055	1.8	1.5	.50	.032	.008	.011	.14	.089	2.0	20	D172055
D172056	2.0	1.2	.48	.042	.006	.010	.20	.099	2.0	20	D172056
D172057	1.6	1.1	.48	.038	.008	.021	.21	.066	2.0	20	D172057
D172058	.55	.37	.42	.028	.005	.004	.19	.023	2.0	30	D172058
D196200	1.1	.90	.63	.081	.28	.006	.31	.071	2.7	100	D196200
D196201	4.8	2.8	.44	.053	.30	.048	.21	.14	1.9	150	D196201
D196202	2.0	.91	.37	.045	.015	.055	.37	.049	1.9	150	D196202
D196203	1.2	.71	.50	.051	.013	.037	.17	.042	1.7	30	D196203
D196204	2.0	1.1	.48	.038	.010	.014	.13	.057	2.3	50	D196204
D196205	1.8	1.1	.69	.13	.087	.024	.32	.064	3.0	200	D196205
D196206	3.4	1.2	.90	.079	.13	.065	.29	.078	1.5	100	D196206
D196441	18	6.4	.41	.52	.42	1.2	1.2	.27	10	100	D196441
D196442	33	9.3	.53	.56	.33	2.1	1.5	.39	40	100	D196442
D196443	22	10	.40	.38	.12	1.1	.93	.42	2.1	50	D196443
D196207	3.5	1.5	.51	.057	.030	.044	.26	.12	.9	100	D196207
D196444	34	8.0	.19	.37	.12	1.2	.69	.64	2.7	70	D196444
D196208	11	6.0	.49	.23	.094	.49	3.5	.33	93	150	D196208
D196209	1.9	.94	.90	.16	.14	.026	.32	.063	.8	150	D196209
D196210	9.9	4.5	.50	.11	.19	.10	3.4	.20	110	150	D196210

Table 5.--Major-, minor-, and trace-element composition of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Hg (ppm)	La-S (ppm)	Sample number
D170627	200	N	0.08L	0.5	1	3.5	115	1.5	0.04	N	D170627
D170628	200	N	.04L	.3	.7	3.7	40	.7	.04	N	D170628
D170629	200	N	.11L	1	3	8.7	80	1.5	.07	N	D170629
D170630	200	.15	.04L	.7	.7	4.6	30	.7	.04	3	D170630
D170631	200	N	.10L	.7	1	3.2	130	1.5	.04	N	D170631
D172059	100	.5	.06L	.7	2	8.1	30	2	.06	7	D172059
D172052	200	N	.03L	.5	.7	4.1	30	.5	.02	3L	D172052
D172053	150	.07	.03L	.5	.5	3.0	25	.7	.02	5	D172053
D172054	150	.15	.05L	.7	1	6.8	30	1.5	.01	5	D172054
D172055	150	.3	.10L	1.5	1.5	6.5	35	5	.02	10	D172055
D172056	100	N	.09L	1L	1.5	9.8	30	3	.06	10L	D172056
D172057	150	N	.08L	1.5	1.5	8.3	30	5	.03	7L	D172057
D172058	100	.1	.04L	.7	1	6.9	25	1	.02	5L	D172058
D196200	200	.3	.07L	.7	2	7.1	20L	5	.10	10	D196200
D196201	200	2	.19	3	15	36	40	20	.28	20	D196201
D196202	200	.2	.08L	1.5	2	8.2	95	7	.02	7	D196202
D196203	150	N	.06L	.7	2	5.2	50	5	.02	5	D196203
D196204	150	.5	.09L	1	2	7.0	35	5	.04	10	D196204
D196205	100	.7	.10L	3	5	10	45	7	.18	10	D196205
D196206	200	.5	.13L	1.5L	3	5.8	65	7	.03	N	D196206
D196441	500	N	.57L	7L	300	27	450	30	.02	N	D196441
D196442	2,000	N	.93L	10	70	44	485	50	.04	70	D196442
D196443	1,500	3	.70L	N	10	20	390	50	.03	N	D196443
D196207	200	.5	.13L	1.5L	5	13	60	7	.04	N	D196207
D196444	1,000	N	.89L	N	50	21	390	50	.01L	N	D196444
D196208	150	2	.45L	5L	15	26	120	50	1.2	30	D196208
D196209	150	.7	.11L	1.5	5	12	50	7	.10	7	D196209
D196210	70	7	1.6	7	15	56	85	30	8.0	N	D196210

Table 5.--Major-, minor-, and trace-element composition of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sample number
D170627	3.0	12L	0.5	N	1	570	2.0	0.1	0.7	0.5	D170627
D170628	1.3	28	.2	N	.7	230	1.0	.1L	.3	.3	D170628
D170629	3.6	17	.7	N	1	240	7.4	.2	1	1.3	D170629
D170630	1.2	9.0	.5	.3	.7	56	1.6	.1	.7	.3	D170630
D170631	2.0	15L	.7	.7	.7	450	5.4	.1L	.7	.3	D170631
D172059	2.3	9.2L	1.5	1.5	2	27L	3.1	.3	1	.4	D172059
D172052	.9	4.1L	.3	.5	.7	190	.9	.2	.5	1.9	D172052
D172053	1.9	17	.2	.5L	.7	63	1.1	.2	.5	.8	D172053
D172054	7.5	8.1L	.3	1L	.7	260	2.7	.1	.7	.3	D172054
D172055	17	14L	.7	3	1L	390	5.7	.2	1.5	1.0	D172055
D172056	6.3	14L	.7	3	1L	210	4.6	.2	1	1.0	D172056
D172057	5.6	12L	.7	5	1.5	120	2.8	.5	1.5	.4	D172057
D172058	1.4	30	.3	.7L	1	22	1.6	.2	.7	.2	D172058
D196200	11	23	1	1.5	1	130	4.8	.2	1.5	1.0	D196200
D196201	25	15	3	3	3	42	12	.3	3	2.7	D196201
D196202	3.6	30	1.5	2	2	390	4.5	.1	1.5	.8	D196202
D196203	7.0	31	N	1.5	1	310	2.6	.1L	1	.4	D196203
D196204	15	42	.7	2	1.5	380	6.5	.2	1.5	.1L	D196204
D196205	10	41	1.5	2	3	310	4.4	.2	1.5	1.1	D196205
D196206	5.5	71	N	5	1.5	220	5.9	.5	1.5	2.0	D196206
D196441	19	130	5	15	10	300	32	1.5	10	2.1	D196441
D196442	36	140	N	20L	30	320	23L	1.6	15	2.3	D196442
D196443	59	130	N	15	N	180	42	1.8	10	2.7	D196443
D196207	14	55	N	3	3	220	4.6	.3	2	1.0	D196207
D196444	40	73	N	20	10	230	22L	1.5	15	.9	D196444
D196208	25	95	15	15	7	140	14	.5	7	.1L	D196208
D196209	8.3	68	2	3	3	870	4.2	.4	3	1.3	D196209
D196210	53	47	7	15	20	36	24	.9	7	9.6	D196210

Table 5.--Major-, minor-, and trace-element composition of 28 coal and shale samples from the Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.--Continued

Sample number	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D170627	150	3.0L	0.6	5	1.5	0.15	4.8	10	D170627
D170628	70	3.0L	.4	3	1	.1	3.4	7	D170628
D170629	70	3.3	1.0	10	2	.2	7.1	15	D170629
D170630	70	3.0L	.4	5	1.5	.15	3.9	7	D170630
D170631	100	3.0L	1.1	5	3	.2	7.8	15	D170631
D172059	30	3.4	.6	10	3	.2	2.1	N	D172059
D172052	50	3.0L	.2L	3	1.5	.07	1.9	5	D172052
D172053	30	3.0L	.3	3	.7	.07	1.9	N	D172053
D172054	30	3.0L	.6	3	1.5	.15	2.8	N	D172054
D172055	100	4.4	.8	10	3	.3	4.2	N	D172055
D172056	70	3.8	1.0	15	2	.2	4.2	N	D172056
D172057	70	4.6	1.3	7	2	.2	4.7	N	D172057
D172058	30	3.0L	.2L	7	1	.1	3.6	N	D172058
D196200	200	2.4	.5	10	5	.3	7.8	30	D196200
D196201	200	7.7	2.7	30	15	1	20	100	D196201
D196202	150	1.7	.3	15	5	.5	11	20	D196202
D196203	70	1.5	.1	10	2	.2	8.4	15	D196203
D196204	100	2.5	.5	15	5	.5	14	20	D196204
D196205	150	2.5	.4	15	5	.5	22	30	D196205
D196206	150	2.8	.7	10	5	.5	16	30	D196206
D196441	300	9.7	4.4	70	15	1.5	95	100	D196441
D196442	300	8.6	5.3	150	30	3	150	150	D196442
D196443	200	13.0	6.7	50	20	1.5	140	200	D196443
D196207	150	3.1	.7	15	5	.5	23	20	D196207
D196444	200	10.0	4.6	100	30	3	54	300	D196444
D196208	150	7.2	2.2	30	15	1.5	19	100	D196208
D196209	300	2.8	.5	15	7	.7	8.9	30	D196209
D196210	150	5.8	3.4	50	20	2	240	70	D196210

[illegible] determinations for 12 coal samples from the Rinch bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[All analyses except heat-of-combustion, free-swelling index, and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Department of Energy, Pittsburgh, Pa. °F = (°C x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb), L, less the value shown]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D174481	14.5	29.3	24.7	31.5	4.6	37.8	0.5	25.0	0.6	3,620	6,520
	---	34.3	28.9	36.8	3.5	44.2	.6	14.2	.7	4,240	7,630
	---	54.3	45.7	---	5.5	70.0	.9	22.4	1.1	6,710	12,070
D174483	17.2	37.3	36.9	8.6	6.0	54.3	.7	29.8	.6	5,290	9,520
	---	45.0	44.6	10.4	4.9	65.6	.8	17.5	.7	6,390	11,500
	---	50.3	49.7	---	5.5	73.2	.9	19.6	.8	7,130	12,830
D174484	17.8	32.0	37.1	13.1	5.6	50.0	.7	29.6	1.0	4,780	8,600
	---	38.9	45.1	15.9	4.4	60.8	.9	16.8	1.2	5,810	10,460
	---	46.3	53.7	---	5.2	72.4	1.0	19.9	1.4	6,910	12,450
D174485	19.4	33.7	41.4	5.5	6.0	55.3	.8	31.7	.7	5,320	9,570
	---	41.8	51.4	6.8	4.8	68.6	1.0	17.9	.9	6,600	11,870
	---	44.9	55.1	---	5.1	73.6	1.1	19.2	.9	7,080	12,740
D174486	20.2	34.5	34.1	11.2	5.8	49.8	.8	31.5	.9	4,790	8,630
	---	43.2	42.7	14.0	4.5	62.4	1.0	17.0	1.1	6,010	10,810
	---	50.3	49.7	---	5.2	72.6	1.2	19.7	1.3	6,990	12,580
D194458	18.5	30.4	35.0	16.1	5.6	46.7	.9	29.4	1.2	4,480	8,060
	---	37.3	42.9	19.8	4.3	57.3	1.1	15.9	1.5	5,490	9,890
	---	46.5	53.5	---	5.4	71.4	1.4	19.8	1.8	6,840	12,320
D194459	14.7	28.0	28.7	28.6	5.2	41.9	.9	23.0	.4	4,120	7,420
	---	32.8	33.6	33.5	4.2	49.1	1.1	11.6	.5	4,830	8,700
	---	49.4	50.6	---	6.3	73.9	1.6	17.5	.7	7,270	13,090
D194460	17.3	31.8	36.9	14.0	5.7	50.1	1.2	28.7	.3	4,760	8,560
	---	38.5	44.6	16.9	4.6	60.6	1.5	16.1	.4	5,750	10,350
	---	46.3	53.7	---	5.5	72.9	1.7	19.4	.4	6,920	12,460
D194461	18.2	32.2	40.4	9.2	5.8	52.6	1.3	30.4	.7	5,030	9,060
	---	39.4	49.4	11.2	4.6	64.3	1.6	17.4	.9	6,150	11,070
	---	44.4	55.6	---	5.2	72.5	1.8	19.6	1.0	6,930	12,480
D194462	19.1	31.9	43.9	5.1	5.9	55.2	1.4	31.8	.5	5,260	9,480
	---	39.4	54.3	6.3	4.7	68.2	1.7	18.3	.6	6,510	11,710
	---	42.1	57.9	---	5.0	72.8	1.8	19.6	.7	6,950	12,500
D194463	15.7	24.5	22.8	37.0	4.3	32.2	.4	25.4	.6	3,060	5,500
	---	29.1	27.0	43.9	3.0	38.2	.5	13.6	.7	3,630	6,530
	---	51.8	48.2	---	5.4	68.1	.8	24.2	1.3	6,460	11,630
D194464	18.5	29.6	32.8	19.1	5.4	43.7	.6	29.7	1.4	4,160	7,490
	---	36.3	40.2	23.4	4.1	53.6	.7	16.3	1.7	5,110	9,190
	---	47.4	52.6	---	5.4	70.0	1.0	21.2	2.2	6,670	12,010

Table 6.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 12 coal samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D174481	2.7	0.03	0.16	0.39	0.0	1,600+	1,600+	1,600+
	---	.04	.19	.46				
	---	.06	.30	.72				
D174483	2.5	.01	.15	.42	.0	1,230	1,290	1,345
	---	.01	.18	.51				
	---	.01	.20	.57				
D174484	2.4	.09	.36	.52	.0	1,350	1,380	1,410
	---	.11	.44	.63				
	---	.13	.52	.75				
D174485	3.8	.04	.24	.46	.0	1,125	1,150	1,170
	---	.05	.30	.57				
	---	.05	.32	.61				
D174486	4.8	.07	.39	.44	.0	1,250	1,270	1,295
	---	.09	.49	.55				
	---	.10	.57	.64				
D194458	11.0	.04	.54	.64	.0	1,180	1,215	1,2[illegible]
	---	.05	.66	.79				
	---	.06	.83	.98				
D194459	9.9	.02	.11	.31	.0	1,540	1,540	1,540
	---	.02	.13	.36				
	---	.04	.19	.55				
D194460	7.7	.01	.02	.25	.0	1,380	1,410	1,530
	---	.01	.02	.30				
	---	.01	.03	.36				
D194461	5.7	.08	.28	.37	.0	1,170	1,230	1,350
	---	.10	.34	.45				
	---	.11	.39	.51				
D194462	7.4	.01	.07	.38	.0	1,145	1,175	1,280
	---	.01	.09	.47				
	---	.01	.09	.50				
D194463	6.4	.06	.18	.32	.0	1,600+	1,600+	1,600+
	---	.07	.21	.38				
	---	.13	.38	.68				
D194464	7.0	.26	.58	.60	.0	1,165	1,230	1,[illegible]

Table 7.--Major- and minor-oxide and trace-element composition of the laboratory ash of 16 coal and shale samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[Values in percent or parts per million. Coal and shale ashed at 525°C. L, less than the value shown; N, not detected. S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 1.2, etc. but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level]

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D174481	21.5	48	26	3.1	1.18	0.11	1.8	5.4	1.0	0.22	D174481
D174483	8.9	32	22	11	1.53	.12	.91	6.3	.96	.58	D174483
D174484	12.9	37	22	7.0	1.09	.09	.66	9.5	.93	.25	D174484
D174485	6.2	21	15	16	2.12	.11	.40	12	.72	.31	D174485
D174486	12.9	32	22	7.8	1.49	.12	1.2	11	.95	.16	D174486
D194458	20.5	46	24	4.4	1.56	1.80	1.4	9.1	1.0	1.0L	D194458
D194485	86.7	60	20	.91	1.70	.64	2.4	10	.84	1.0L	D194485
D194486	78.2	63	27	.43	1.40	.56	1.9	4.5	1.2	1.0L	D194486
D194459	13.8	46	26	4.0	2.08	2.62	1.2	8.7	1.3	1.0L	D194459
D194460	15.6	46	26	3.3	1.04	2.25	1.0	7.7	1.5	1.0	D194460
D194461	12.6	45	25	3.8	2.16	2.66	.90	9.6	1.3	1.0	D194461
D194462	6.5	32	20	5.6	3.42	5.40	.60	11	1.0	2.0	D194462
D194487	54.7	61	29	.64	1.11	.65	1.6	4.3	1.3	1.0L	D194487
D194463	40.0	57	30	2.1	2.42	1.01	1.8	5.9	1.3	1.0L	D194463
D194488	87.1	64	30	.41	.95	.34	1.7	2.9	1.2	1.0L	D194488
D194464	22.0	44	22	4.2	2.04	2.00	1.0	9.7	1.1	1.0L	D194464

Sample number	SO3 (percent)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Ga-S (ppm)	La-S (ppm)	Sample number
D174481	4.8	300	1,500	7	1.0L	30	150	216	50	100L	D174481
D174483	14	500	5,000	7	1.0L	30	150	246	30	100	D174483
D174484	11	300	1,500	5	1.0L	30	100	214	30	100L	D174484
D174485	24	700	2,000	7	1.0L	30	150	284	30	100	D174485
D174486	13	300	1,000	7	2.5	30	150	386	30	100	D174486
D194458	8.2	200	2,000	5	1.0L	50	150	310	30	100	D194458
D194485	1.2	N	500	3	1.0L	30	100	99	70	100L	D194485
D194486	.082	50L	500	N	2.0	10	100	108	30	100L	D194486
D194459	6.5	200	3,000	3	1.0L	50	200	191	70	100	D194459
D194460	3.8	150	3,000	3	1.0L	20	150	161	70	70	D194460
D194461	7.8	150	2,000	3	1.0L	50	150	182	50	150	D194461
D194462	12	300	5,000	5	1.0	50	150	215	50	150	D194462
D194487	1.1	50L	1,000	3	2.0	30	150	203	70	100	D194487
D194463	3.2	100	1,000	3	1.0L	30	150	173	50	70	D194463
D194488	.15	50L	500	3	1.0	10L	100	96	50	100L	D194488
D194464	8.2	200	1,500	7	1.0L	50	150	404	70	150	D194464

Table 7.--Major- and minor-oxide and trace-element composition of the laboratory ash of 16 coal and shale samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.--Continued

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Sample number
D174481	72	270	30	30	150L	50	40	20	1,000	300	D174481
D174483	50	1,100	50	20	150	70	30	30	3,000	300	D174483
D174484	66	550	30	20L	150L	100	30	20	1,500	200	D174484
D174485	20	1,100	70	20	150	70	40	30	3,000	300	D174485
D174486	50	850	70	20	150	70	45	30	1,000	300	D174486
D194458	75	260	50	20	N	100	65	30	1,000	300	D194458
D194485	68	1,190	7	30	150	50	40	30	150	150	D194485
D194486	72	225	7	30	150	30	25L	30	100	150	D194486
D194459	61	830	30	20	N	100	50	30	1,500	300	D194459
D194460	79	1,320	30	30	N	50	55	30	2,000	200	D194460
D194461	69	315	30	30	150	100	25	30	1,500	200	D194461
D194462	52	790	70	20	150	100	55	30	2,000	300	D194462
D194487	88	110	30	30	150	50	25	30	500	300	D194487
D194463	94	190	20	20	N	50	40	30	700	200	D194463
D194488	96	100	N	30	150	20	30	30	150	150	D194488
D194464	69	290	50	20	150	100	55	30	2,000	300	D194464

Sample number	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D174481	50	5	150	70
D174483	70	7	100	70
D174484	30	5	55	70
D174485	70	7	97	70
D174486	70	7	304	70
D194458	70	7	247	70
D194485	50	7	191	100
D194486	50	3	165	100
D194459	70	7	126	70
D194460	50	7	126	70
D194461	70	7	129	100
D194462	100	10	163	100
D194487	70	7	132	100
D194463	70	7	170	70
D194488	30	3	85	70
D194464	100	7	208	70

Table 8.--Content of seven trace elements in 16 coal and shale samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[Analyses on air-dried (32°C) coal and shale. L, less than the value shown]

Sample number	As (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D174481	2.0	185	0.04	0.2	2.4	16	13	D174481
D174483	1.0	75	.03	.2	.7	3.0L	5.8	D174483
D174484	4.0	65	.21	.2	5.7	9.9	4.6	D174484
D174485	2.0	35	.04	.1	1.6	9.0	3.5	D174485
D174486	3.0	55	.09	.2	2.4	3.0L	10	D174486
D194458	3.0	85	.16	.1L	3.6	7.5	13	D194458
D194485	5.4	605	.12	.6	1.7	19	14	D194485
D194486	1.4	445	.08	.6	1.0	26	12	D194486
D194459	1.4	90	.09	.2	.1L	4.3	4.1	D194459
D194460	.6	90	.01	.1	.5	3.9	3.5	D194460
D194461	2.0	65	.17	.2	3.1	4.2	3.7	D194461
D194462	.8	35	.04	.1L	.7	2.0	2.2	D194462
D194487	2.4	185	.17	.9	1.9	25	18	D194487
D194463	1.2	275	.07	.2	.1L	8.9	14	D194463
D194488	.8	440	.04	.5	1.9	23	20	D194488
D194464	2.1	105	.19	.3	.1L	5.8	12	D194464

Table 9.--Major-, minor-, and trace-element composition of 16 coal and shale samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[Values in percent or parts per million. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal and shale; all other values calculated from analyses of ash. S means analysis by emission spectrography; L, less than the value shown; N, not detected]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	As (ppm)	B-S (ppm)	Sample number
D174481	4.8	2.9	0.48	0.15	0.018	0.33	0.81	0.13	2.0	70	D174481
D174483	1.3	1.0	.69	.082	.008	.067	.39	.051	1.0	50	D174483
D174484	2.2	1.5	.64	.085	.009	.071	.86	.072	4.0	50	D174484
D174485	.61	.48	.69	.079	.005	.021	.53	.027	2.0	50	D174485
D174486	1.9	1.5	.72	.12	.011	.13	.96	.073	3.0	50	D174486
D194458	4.4	2.6	.64	.19	.27	.24	1.3	.12	3.0	50	D194458
D194485	24	9.2	.56	.89	.41	1.7	6.1	.44	5.4	N	D194485
D194486	23	11	.24	.66	.32	1.2	2.5	.56	1.4	50L	D194486
D194459	3.0	1.9	.39	.17	.27	.14	.84	.11	1.4	30	D194459
D194460	3.4	2.1	.37	.17	.26	.13	.84	.14	.6	20	D194460
D194461	2.6	1.7	.34	.16	.25	.094	.85	.098	2.0	20	D194461
D194462	.97	.69	.26	.13	.26	.032	.50	.039	.8	20	D194462
D194487	16	8.4	.25	.37	.26	.73	1.6	.43	2.4	30L	D194487
D194463	11	6.3	.60	.58	.30	.60	1.6	.31	1.2	50	D194463
D194488	26	14	.25	.50	.22	1.2	1.8	.63	.8	50L	D194488
D194464	4.5	2.6	.66	.27	.33	.18	1.5	.14	2.1	50	D194464

Sample number	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Hg (ppm)	La-S (ppm)	Sample number
D174481	300	1.5	0.22L	7	30	46	185	10	0.04	20L	D174481
D174483	500	.7	.09L	3	15	22	75	3	.03	10	D174483
D174484	200	.7	.13L	5	15	28	65	5	.21	15L	D174484
D174485	150	.5	.06L	2	10	18	35	2	.04	7	D174485
D174486	150	1	.32	5	20	50	55	5	.09	15	D174486
D194458	500	1	.21L	10	30	64	85	7	.16	20	D194458
D194485	500	2	.87L	20	100	86	605	70	.12	100L	D194485
D194486	500	N	1.6	7	70	84	445	20	.08	70L	D194486
D194459	500	.5	.14L	7	30	26	90	10	.09	15	D194459
D194460	500	.5	.16L	3	20	25	90	10	.01	10	D194460
D194461	200	.3	.13L	7	20	23	65	7	.17	20	D194461
D194462	300	.3	.07	3	10	14	35	3	.04	10	D194462
D194487	500	1.5	1.1	15	70	110	185	30	.17	50	D194487
D194463	500	1	.40L	10	70	69	275	20	.07	30	D194463
D194488	500	3	.87	10L	100	84	440	50	.04	100L	D194488
D194464	300	1.5	.22L	10	30	89	105	15	.19	30	D194464

Table 9.--Major-, minor-, and trace-element composition of 16 coal and shale samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.--Continued

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Sample number
D174481	15	58	7	7	30L	10	210	8.6	0.2	5	D174481
D174483	4.5	98	5	2	15	7	230	2.7	.2	3	D174483
D174484	8.5	71	5	2L	20L	15	140	3.9	.2	2	D174484
D174485	1.2	68	5	1.5	10	5	84	2.5	.1	2	D174485
D174486	6.5	110	10	2	20	10	90	5.8	.2	5	D174486
D194458	15	53	10	5	N	20	900L	13	.1L	7	D194458
D194485	59	1,000	7	20	150	50	3,800L	35	.6	20	D194485
D194486	56	180	5	20	100	20	3,400L	20L	.6	20	D194486
D194459	8.4	110	5	3	N	15	600L	6.9	.2	5	D194459
D194460	12	210	5	5	N	7	680	8.6	.1	5	D194460
D194461	8.7	40	3	3	20	15	550	3.2	.2	3	D194461
D194462	3.4	51	5	1.5	10	7	570	3.6	.1L	2	D194462
D194487	48	60	15	15	70	30	2,400L	14	.9	15	D194487
D194463	38	76	7	7	N	20	1,700L	16	.2	10	D194463
D194488	84	87	N	30	150	15	3,800L	26	.5	30	D194488
D194464	15	64	10	5	30	20	960L	12	.3	7	D194464

Sample number	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D174481	2.4	200	16.1	13	70	10	1	32	15	D174481
D174483	.7	300	3.0L	5.8	30	7	.7	8.9	7	D174483
D174484	5.7	200	9.9	4.6	20	5	.7	7.1	10	D174484
D174485	1.6	200	9.0	3.5	20	5	.5	6.0	5	D174485
D174486	2.4	150	3.0L	10	50	10	1	39	10	D174486
D194458	3.6	200	7.5	13	70	15	1.5	51	15	D194458
D194485	1.7	150	18.8	14	150	50	7	170	100	D194485
D194486	1.0	70	26.1	12	100	50	2	130	70	D194486
D194459	.1L	200	4.3	4.1	50	10	1	17	10	D194459
D194460	.5	300	3.9	3.5	30	7	1	20	10	D194460
D194461	3.1	200	4.2	3.7	20	10	1	16	15	D194461
D194462	.7	150	2.0	2.2	20	7	.7	11	7	D194462
D194487	1.9	300	25.0	18	150	30	3	72	50	D194487
D194463	.1L	300	8.9	14	70	30	3	68	30	D194463
D194488	1.9	150	23.1	20	150	30	3	74	70	D194488
D194464	.1L	500	5.8	12	70	20	1.5	46	15	D194464

Table 10.—Elements looked for, but not detected in coal and coal associated shale samples from the Coalmont Formation, McCallum and Coalmont areas, North Park, Jackson County, Colo.

[Approximate lower detection limits for these elements in ash, by the six-step spectrographic method of the U.S. Geological Survey, are included]

Element name	Symbol	Lower limit of detection (ppm) in ash
Silver	Ag	1
Gold	Au	50
Bismuth	Bi	20
Cerium	Ce	500
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Germanium	Ge	20
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lutetium	Lu	70
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellurium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

Table 11.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, and ash-fusion temperatures of 21 coal samples from the Sudduth bed, Coalmont Formation, McCallum area, North Park, Jackson County, Colo.

[All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviation and are reported on the as-received basis. °F = (°C x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb)]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	15.0	11.0	20.7	14.8	1.2
Volatile matter	32.9	27.4	38.3	32.8	1.1
Fixed carbon	44.3	37.1	49.1	44.2	1.1
Ash	8.0	2.1	19.2	6.8	1.8
Hydrogen	5.7	5.0	5.9	5.7	1.0
Carbon	58.6	49.3	64.3	58.4	1.1
Nitrogen	.9	.6	1.5	.9	1.2
Oxygen	26.7	23.9	31.3	26.6	1.1
Sulfur	.3	.2	.6	.3	1.4
Heat of combustion					
Kcal/kg	5,635	4,770	6,270	5,615	1.7
Btu/lb	10,135	8,580	11,280	10,100	1.1
Forms of sulfur					
Sulfate	0.03	0.01L	0.05	0.02	1.7
Pyritic	.08	.04	.16	.07	1.4
Organic	.18	.06	.59	.16	1.7
Ash-fusion temperatures, °C					
Initial deformation	1,295	1,120	1,600 +	1,285	1.1
Softening temperature	1,320	1,150	1,600 +	1,310	1.1
Fluid temperature	1,365	1,175	1,600 +	1,355	1.1

Table 12.—Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 21 coal samples from the Sudduth bed, Coalmont Formation in the McCallum area, North Park, Jackson County, Colo.

[All samples were ashed at 525°C; all analyses except geometric deviation are in percent]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
(Ash)	8.5	2.7	19.1	7.4	1.7
SiO_2	43	16	56	41	1.4
Al_2O_3	22	15	30	22	1.2
CaO	9.7	3.0	22	8.5	1.7
MgO	1.17	.46	2.46	1.06	1.6
Na_2O	.58	.09	5.1	.30	3.2
K_2O	.38	.09	1.4	.27	2.3
Fe_2O_3	5.0	1.6	12	4.5	1.6
TiO_2	1.1	.57	1.8	1.1	1.4
So_3	7.3	2.5	14	6.6	1.5
P_2O_5	.81	.05	1.9	.62	2.4

ate 13.--Arthimetic mean, observed range, geometric mean, and geometric deviation c 37 elements in 21 coal samples from the Sudduth bed, Coalmont Formation in the Callum area, North Park, Jackson County, Colo.

[Al analyses are in percent or parts per million and are reported on a whole-coal asis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were etermined directly on whole coal. All other values used were calculated from eterminations made on coal ash. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
		Percent			
i	1.9	0.20	4.8	1.4	2.2
l	1.1	.21	2.8	.85	1.9
a	.48	.24	.90	.45	1.4
g	.053	.023	.16	.047	1.7
a	.045	.003	.30	.016	4.2
	.033	.003	.14	.017	3.3
e	.25	.13	.37	.23	1.4
i	.059	.012	.14	.047	2.0
		Parts per million			
s	1.9	0.8	3.0	1.7	1.5
	70	15	200	50	2.2
a	150	100	200	150	1.3
e	.3	.1L	2	.15	4.6
o	1	.3	3	.7	2.2
r	2	.5	15	1.5	2.3
u	8.0	3.0	36	6.8	1.8
	50	20L	130	44	1.7
a	5	.5	20	3	2.8
g	.06	.01	.28	.04	2.3
a	5	3L	20	3	2.7
i	7.6	.9	25	4.8	2.6
n	27	9.0	71	16	2.8
o	.7	.2L	3	.5	2.5
b	2	.3L	5	1	4.2
i	1.5	.7	3	1	1.8
	270	22	870	200	2.5
b	4.3	.9	12	3.3	2.0
Sb	.2	.1L	.5	.2	1.8
Sc	1.5	.3	3	1	1.8
Se	.9	.1L	2.7	.7	2.3
Sr	100	30	300	100	1.9
Th	2.4	1.5	7.7	1.9	2.0
U	.8	.2L	2.7	.4	2.9
V	10	3	30	7	1.9
Y	3	.7	15	3	2.1
Yb	.3	.07	1	.2	2.1
Zn	8.7	1.9	23	6.5	2.1
Zr	20	5L	100	10	3.1

Table 14.—Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, and ash-fusion temperatures of 12 coal samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviation and are reported on the as-received basis. °F = (C° x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb)]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	17.6	14.5	20.2	17.5	1.1
Volatile matter	31.3	24.5	37.3	31.1	1.1
Fixed carbon	34.6	22.8	43.9	33.9	1.2
Ash	16.9	5.1	37.0	13.8	1.9
Hydrogen	5.5	4.3	6.0	5.5	1.1
Carbon	47.6	32.2	55.3	46.9	1.2
Nitrogen	.9	.4	1.4	.8	1.5
Oxygen	28.9	23.0	31.8	28.7	1.1
Sulfur	.7	.3	1.4	.7	1.6
Heat of combustion					
Kcal/kg	4,570	3,060	5,320	4,505	1.2
Btu/lb	8,220	5,500	9,570	8,100	1.2
Forms of sulfur					
Sulfate	0.06	0.01	0.26	0.04	2.8
Pyritic	.29	.02	.58	.19	2.6
Organic	.43	.25	.64	.41	1.3
Ash-fusion temperatures, °C					
Initial deformation	1,310	1,125	1,600+	1,300	1.1
Softening temperature	1,335	1,150	1,600+	1,325	1.1
Fluid temperature	1,395	1,170	1,600+	1,390	1.1

Table 15.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 9 major and minor oxides in the laboratory ash of 12 coal samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[All samples were ashed at 525°C; all analyses except geometric deviation are in percent]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
(Ash)	16.3	6.2	40.0	14.1	1.7
SiO_2	41	21	51	39	1.3
Al_2O_3	23	15	30	23	1.2
CaO	6.0	2.1	16	5.1	1.8
MgO	1.92	1.09	3.42	1.82	1.4
Na_2O	2.10	.09	5.40	.64	4.9
K_2O	1.1	.40	1.8	.99	1.6
Fe_2O_3	8.8	5.4	12	8.6	1.3
TiO_2	1.1	.72	1.5	1.1	1.2
SO_3	9.9	3.2	24	8.3	1.8

Table 16.--Arithmetic mean, observed range, geometric mean and geometric deviation of 37 elements in 12 coal samples from the Riach bed, Coalmont Formation in the Coalmont area, North Park, Jackson County, Colo.

[All analyses are in percent or parts per million and are reported on a whole-coal basis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, less than the value shown. Leaders (---) indicate means could not be calculated owing to an insufficient number of analyses above the lower detection limit]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
		Percent			
Si	3.5	0.61	11	2.6	2.2
Al	2.2	.48	6.3	1.7	2.0
Ca	.55	.26	.72	.52	1.4
Mg	.18	.079	.058	.16	1.8
Na	.27	.005	.33	.067	5.9
K	.18	.021	.60	.12	2.6
Fe	.93	.39	1.6	.84	1.5
Ti	.11	.027	.31	.091	1.9
		Parts per million			
As	2.0	0.6	4.0	1.7	1.8
B	50	20	70	50	1.6
Ba	300	150	500	300	1.6
Be	.7	.3	1.5	.7	1.7
Co	7	2	10	5	1.7
Cr	20	10	70	20	1.7
Cu	40	14	89	34	1.8
F	96	35	275	81	1.8
Ga	10	2	20	7	2.0
Hg	.10	.01	.21	.07	2.5
La	15	7	30	15	1.9
Li	12	1.2	38	8.4	2.4
Mn	84	40	210	76	1.6
Mo	7	3	10	7	1.4
Nb	3	1.5	7	3	1.9
Ni	15	5	20	10	1.6
P	---	84	680	---	---
Pb	7.4	2.5	16	6.0	1.9
Sb	.2	.1L	.3	.2	1.6
Sc	5	2	10	5	1.7
Se	2.0	.1L	5.7	1.1	3.2
Sr	200	150	500	200	1.4
Th	6.5	2.0	16	4.7	2.2
U	7.6	2.2	14	6.2	1.9
V	50	20	70	30	1.7
Y	10	5	30	10	1.7
Yb	1	.5	3	1	1.6
Zn	28	6.0	68	20	2.3
Zr	15	5	30	10	1.6

APPENDIX B
Soils

LAB #	Site Number	Depth Feet	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./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 CaMg Me/L	1:5 Extract SAR Est.	1:5 Extract CaMg Me/100g	Saturation Extract $ecx10^3$ @ 25 c	Saturation Extract Na Me/L	Saturation Extract CaMg Me/L	Saturation Extract SAR	Saturation Extract Sat %	Saturation Extract CaMg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture 1/3 bars	% of Moisture 15 bars
1	DH-1	0-2	.39	.18	5.2	4.1	20			.060				.611	1.67	3.96	1.19	27.1			.28	.23	60	.38	—	6.5
2	"	2-4	.96	1.7	7.2	6.4	22			.296				1.58	6.9	13.46	2.11	48.7			1.34	1.00	54.8	1.81	27.4	9.0
3	"	4-11.5	.02	.01	7.6	6.4	31			.363				2.74	10.3	30.68	2.63	71.1			2.42	1.69	42	4.02	43.9	13.8
4	"	11.5-18	.02	.01	7.3	6.3	30			.312				2.20	7.8	20.20	2.45	76.1			2.06	1.47	55.6	2.6	41.6	13.1
5	"	18.-21	.32	.62	7.1	6.2	24			.192				2.55	8.1	31.78	2.03	47.7			1.18	.79	48	1.7	30.4	9.0
6	"	26-36.4	.24	.34	8.4	6.4	28			.169				.724	2.3	4.06	1.61	61.7			.84	.70	44.2	1.6	30.7	2.6
7	"	36.4-41	1.2	.62	8.5	6.5	20			.147				1.44	2.3	14.5	.85	33.1			.44	.36	17.6	2.1	15.8	4.0
8	"	41-55	.13	.12	8.5	6.5	25			.149				.806	1.6	5.35	.97	44.7			.46	.39	30.6	1.3	27.7	7.3
9	"	55-66.2	.46	.50	8.7	6.6	22			.133				.710	1.55	4.95	.98	40.3			.46	.40	34.4	1.2	25.6	6.8
10	"	66.2-72	1.3	.84	8.8	6.5	18			.114				1.27	1.57	12.28	.63	30.9			.38	.33	9	3.7	19.6	3.4
11	"	72-83.3	1.1	.64	8.7	6.5	20			.111				.543	1.05	3.76	.77	32.8			.44	.41	17.6	2.3	19.9	4.8
12	"	83.3-90.2	1.2	.70	8.5	6.5	20			.108				.767	1.25	5.35	.76	36.5			.24	.19	12.6	1.5	23.8	5.7
13	"	90.2-101	1.1	.84	8.4	6.5	20			.107				.808	1.4	5.25	.87	36.3			.28	.23	13.2	1.7	19.4	4.5
14	"	101-106	1.2	.82	8.8	6.4	17			.096				.591	1.15	4.16	.79	31.7			.36	.32	12.4	2.6	15.6	3.4
15	"	106-122	.42	.44	8.6	6.4	22			.125				.942	.88	8.42	.43	35.9			.26	.23	11.6	2.0	17.9	3.5
16	"	122-128	.78	.82	8.3	6.4	18			.125				.985	.89	8.91	.42	41.2			.26	.22	35.6	.62	24.2	6.8
17	"	128.5-138		-	9.4	6.4	27			.102				.853	7.6	.79	12.1	35.1			3.0	2.81	92.6	12.1	20.5	2.1

LAB #	Site Number	Depth Feet	Hydraulic Conductivity In./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 1/3 bar	15 Bars
18	DH-1	168.3-173.5	–	–	9.5	6.9	26			.076			–	.686	7.50	.91	11.1	22.7			1.98	1.81	16	11.3	16.8	5.1
19	"	173.5-188.7	–	–	9.4	6.9	25			.063				.532	4.6	.50	9.2	22.7			1.62	1.52	8.4	18.0	14.4	3.4
20	"	188.7-200.0	.11	.26	9.5	6.9	30			.071			–	.867	9.50	.79	15.1	20.3			1.46	1.27	8.4	15.1	11.7	2.8
21	"	200-205	.05	.11	9.1	5.9	24			.076				.733	3.4	.59	6.3	21.8			1.3	1.21	6.0	20.2	11.7	2.0
22	"	205-221	.12	.48	9.2	6.0	26			.064				.668	5.3	.20	16.8	21.8			1.38	1.25	8.2	15.2	12.5	2.5
23	DH-2	0-3	2.8	2.3	8.4	6.2	21.5			.211				1.48	12.0	3.56	8.99	42.9			3.36	2.85	47.8	6.0	28.3	6.2
24	"	3-4.5	.60	.98	7.1	6.4	21			.939			–	5.11	34.0	30.92	7.81	49.1			3.9	2.23	39.8	5.6	30.0	6.9
25	"	4.5-8	.07	.07	7.2	6.5	29.5			.756			–	4.77	32.0	32.37	7.95	49.8			4.6	2.40	29	8.3	39.4	10.4
26	"	8-16.2	.54	1.2	9.1	6.7	24.5			.251				1.75	14.3	3.96	10.16	11.6			2.42	1.75	12.8	13.7	38.2	14.9
27	"	16.2-23	–	–	9.0	6.7	28			.217				1.18	9.9	1.78	10.5	61.0			5.1	4.50	36	12.8	40.1	10.5
28	"	23-26.5	.03	.04	9.3	6.7	25			.156				.898	7.5	.89	11.2	56.7			4.2	3.77	32	11.8	35.6	9.2
29	"	26.5-33.7	–	–	9.2	6.9	34.5			.221				.814	7.6	.99	10.8	73.5			5.9	5.34	38	14.1	48.3	12.5
30	"	33.7-43.9	.40	2.4	9.5	6.8	24			.142				.722	6.5	.59	12.0	41.6			3.54	3.25	25.8	12.6	24.5	6.3
31	"	43.9-50.7	–	–	9.4	7.6	34			.311				.910	7.9	.99	11.2	74.0			6.6	6.02	43	14.0	56.5	13.1
32	"	50.7-60.8	–	–	9.4	7.5	32			.313				.988	8.3	1.19	10.8	55.9			4.8	4.34	27	16.1	32.6	8.1
33	"	60.8-71.7	–	–	9.1	7.7	35			.357				1.72	13.6	2.57	12.1	72.3			6.3	5.30	35.6	14.9	45.2	13.1
34	"	71.7-87.6	–	–	9.2	7.6	30			.327				1.50	11.9	1.78	12.6	59.8			5.2	4.49	31	14.5	42.6	9.3

LAB #	Site Number	Depth Feet	Hydraulic Conductivity In./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 %	% Moisture 1/3 bar	15 Bar
35	D11-2	87.6-91.2	—	—	9.2	7.6	22			.278				1.38	19.9	1.78	13.7	71.6			3.12	2.118	13.6	18.2	31.3	6.7
36	"	91.2-101.7	—	—	9.2	7.7	30			.291				1.28	16.3	1.39	19.4	60.1			5.1	4.12	25.8	16.0	38.3	10.1
37	"	101.7-108.2	—	—	9.1	7.8	32			.385				1.51	15.5	2.97	12.7	61.7			5.4	4.44	26.4	16.8	38.4	11.2
38	"	108.2-111.7	—	—	9.1	7.8	30			.357				1.73	16.5	2.67	14.3	60.3			5.3	4.31	24	18.0	36.8	11.0
39	"	111.7-121.7	—	—	9.2	7.8	31			.385				1.36	13.1	1.58	14.7	63.9			5.26	4.42	23.6	18.7	39.8	10.6
40	"	121.7-126	—	—	9.2	7.8	27.5			.385				1.38	11.5	1.39	13.8	66.9			5.3	4.43	20	22.2	40.2	10.2
41	"	126-131.7	—	—	9.0	6.3	27.5			.397				1.50	13.8	1.68	15.1	62.4			5.1	4.24	22	19.0	36.7	9.8
42	"	131.7-145.2	—	—	9.2	6.6	35.5			.334				1.26	10.5	1.39	12.6	63.2			4.8	4.14	22.4	18.5	42.0	10.8
43	"	193.2-203.7	—	—	10.0	7.5	150			.620				.634	5.3	.10	23.7	298.5			19.6	18.3	42.6	43.1	118.0	37.9
44	"	203.7-209	—	—	9.9	7.0	19			.262				2.24	24.3	.59	14.[illegible]	34.1			3.12	2.29	6.25	36.6	23.1	9.8
45	"	209-221.7	—	—	9.2	6.8	18			.147				1.77	16.3	.69	27.6	25.9			1.62	1.20	3.5	34.3	12.9	6.2
46	D11-3	0-2	1.4	1.2	8.6	6.8	20			.159				.687	.82	7.49	.42	47.0			.30	.26	21	1.2	27.1	14.2
47	"	2-4.1	1.2	.80	8.6	6.8	20			.221				1.06	5.7	6.30	3.2	46.0			1.06	.80	13	6.1	25.8	14.1
48	"	4.1-10.5	1.1	.70	8.9	6.9	22			.110				.512	2.8	2.46	2.5	33.5			.28	.19	4.4	4.2	16.0	9.0
49	"	10.5-18.3	1.1	.70	8.7	6.8	17.5			.071				.413	1.2	3.45	.91	30.7			.22	.19	6.1	3.0	11.4	7.1
50	"	18.3-30	.98	.62	8.5	6.8	18.5			.044				.324	.99	2.36	.91	27.8			.16	.13	6.2	1.1	13.2	7.4
51	"	30-36	.88	.56	8.2	6.7	18.0			.067				.441	1.17	3.55	.88	29.4			.20	.17	4.8	3.5	22.2	6.1

LAB #	Site Number	Depth Feet	Hydraulic Conductivity In./hr. 6th Hr.	Hydraulic Conductivity In./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 1/3 BARS	% of Moisture 15 Bars
52	D113	36-41.5	1.0	.68	8.1	6.7	16.			.064				.487	1.19	4.14	.83	22.2			.16	.13	4.9	2.7	9.5	5.4
53	"	41.5-47	2.0	1.1	8.5	6.8	16			.102				.414	1.09	3.25	.86	21.8			.22	.19	5.4	3.5	8.8	4.9
54	"	47-50.4	5.3	3.1	8.8	6.8	15			.097				.624	1.35	5.42	.82	27.3			.20	.16	6.2	2.6	7.0	3.2
55	"	50.4-60	1.5	.94	8.6	6.8	17			.111				.635	1.6	5.32	.98	29.7			.18	.13	6.4	2.0	11.4	6.2
56	"	60-70	.34	.50	8.6	6.8	19			.130				.559	1.65	4.14	1.15	36.4			.24	.18	12.4	1.5	19.9	9.0
57	"	70-80	1.4	.54	8.4	6.8	18			.232				1.47	3.8	14.78	1.4	33.1			.34	.21	9.8	2.1	18.5	7.3
58	"	80-88.8	.70	.54	8.4	6.9	20			.281				1.69	6.3	15.3	2.3	41.9			.76	.50	17.4	2.9	24.5	9.2
59	"	88.8-100	.64	.44	9.1	6.9	18			.220				1.32	9.0	5.52	5.4	36.1			1.62	1.3	17.0	7.6	20.2	8.3
60	"	100-106.3	.08	.08	9.0	7.0	22			.314				1.61	14.5	5.71	8.6	46.0			2.9	2.28	20.6	11.1	29.8	11.6
61	"	106.3-117.7	0.0	0.0	9.6	6.8	21			.247				1.70	15.9	2.17	15.3	39.3			3.8	3.18	18.8	16.9	28.1	11.7
62	"	117.7-128.5	—	—	9.5	6.8	20			.278				1.77	18.5	2.17	17.8	39.1			4.8	4.08	19.2	21.3	28.8	10.6
63	"	128.5-138.1	—	—	9.7	6.9	24			.334													23.0		34.2	14.4
64	"	138.1-150	—	—	9.7	7.1	24			.358													23.8		36.0	12.0
65	"	150-160	—	—	9.8	7.1	23			.380				1.59	15.6	.99	22.2	63.6			8.2	7.21	22.4	32.2	35.3	16.9
66	D114	0-8	4.2	2.0	8.5	7.0	22			.111													31.4		34.1	18.5
67	"	8-12	1.3	1.4	8.3	7.3	25			.630				4.92	23.0	54.8	4.4	63.3			2.7	1.24	32.6	3.8	33.7	18.4
68	"	12-20.5	2.0	1.4	8.6	7.3	20			.158													12.2		22.9	9.0

LAB #	Site Number	Depth Feet	Hydraulic Conductivity In./hr. 6th Hr.	Hydraulic Conductivity In./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 1/3 BARS	% of Moisture 15 Bars
69	DH-4	20.6-22.5	2.2	1.6	8.3	7.3	20			.242															27.6	8.7
70	"	22.5-34.9	2.5	1.7	8.5	7.3	19			.221													12.8		20.0	8.2
71	"	34.9-43	.66	.72	8.7	7.3	20			.226													14.2		21.4	10.5
72	"	43-50	.40	.80	9.1	7.3	21			.272													18.2		23.4	10.6
73	"	50-64.2	-	-	9.6	7.5	20			.353													21.2		31.0	13.0
74	"	64.2-72	-	-	9.9	8.2	27			.372													24.6		41.4	20.4
75	"	72-79.8	-	-	9.9	8.2	27			.430				1.40	13.1	.99	18.6	85			11.0	10.01	28.6	32.0	43.0	23.9
76	"	79.8-100	-	-	9.8	8.1	27			.375				1.14	10.7	.95	15.5	85.5			8.6	7.79	18.0	43.3	41.0	21.9
77	"	100-109.3	-	-	9.9	8.3	32			.376				1.18	11.9	.78	19.1	84.9			10.0	8.99	20.8	43.2	46.4	29.9
78	"	109.3-124.9	-	-	10.1	8.4	30			.425				.938	8.5	.71	14.3	84.5			10.0	9.28	19.8	46.9	45.1	28.7
79	"	124.9-133	-	-	10.1	8.5	32			.319				.966	9.2	.67	15.9	87.1			10.8	10.0	20.6	49.5	45.7	30.4
80	"	133-144	-	-	10.0	8.5	30			.365				1.21	12.2	1.47	14.2	80.4			11.0	10.02	21.8	46.0	43.9	29.0
81	"	144-151	-	-	10.0	6.4	28			.458				1.18	12.9	.79	20.5	87.0			10.6	9.48	20.2	46.9	47.0	30.8
82	"	151-153	1.4	1.1	8.0	6.1	18			.327													12.6		13.9	6.1
83	"	153-159	-	-	10.0	8.4	32			.416				1.17	12.2	.59	22.5	90.1			9.8	8.7	18.8	46.3	45.2	26.7
84	"	159-163	-	-	9.9	8.4	28			.423				1.23	12.6	.79	20.1	84.4			9.2	8.14	16.8	48.?	41.3	24.9
85	"	163-171.9	-	-	10.0	8.3	24			.450				.809	8.0	.67	13.8	102.7			9.7	8.88	17.6	50.5	45.3	23.6

LAB #	Site Number	Depth / Feet	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ec$\times10^3$ @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract BAH Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ec$\times10^3$ @ 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 1/3 BARS	% of Moisture 15 Bars
86	DH-4	171.9-185.6	—	—	10.1	8.3	24			.446				.676	6.9	.99	9.8	74.0			9.8	9.29	17.6	52.8	41.4	23.6
87	"	185.6-200	—	—	10.0	8.0	23			.302													9.4		37.0	11.5
88	"	200-216.4	—	—	10.1	8.1	24			.330													11.6		37.5	14.5
89	"	216.4-231.6	—	—	10.1	8.3	23			.386				.919	9.9	.75	16.2	70.0			8.7	8.01	13.8	58.1	40.4	15.3
90	"	231.6-243	—	—	10.1	8.5	27			.462				.672	6.8	.67	11.8	86.2			11.0	10.41	17.2	60.5	46.6	29.7
91	"	243-253	—	—	10.0	8.4	26			.450				.837	7.9	1.31	9.8	81.5			11.2	10.56	18.8	56.2	46.8	25.1
92	DH-5	0-3.2	1.5	.88	7.8	7.1	23			.078													61.0		34.7	20.2
93	"	3.2-19.4	.38	.88	7.8	7.2	26			.177													38.2		28.1	17.7
94	"	19.5-30.5	.11	.07	8.1	6.8	18			.028													3.5		10.7	5.1
95	"	30.5-40.5	.34	.48	7.8	6.9	15.5			.039													3.4		11.6	5.9
96	"	40.5-50.5	.52	.48	7.7	6.9	16			.053													3.0		10.6	5.5
97	"	50.5-59.2	.78	.66	6.7	4.7	18			.273													3.8		15.6	6.2
98	"	59.2-70.5	.96	.72	7.7	6.3	20			.247													8.2		20.9	8.0
99	"	70.5-84	—	—	8.6	6.4	21			.423				2.53	22.4	5.94	13.0	56.0			3.8	2.55	14.4	17.7	25.3	9.1
100	"	84-100	—	—	9.6	6.8	22			.412				1.39	13.2	1.39	15.9	76.5			8.0	6.99	19.6	35.7	30.9	14.0
101	"	100-110.5	—	—	9.9	8.1	24			.426				2.12	20.5	1.18	26.7	79.3			11.2	9.57	29.6	32.3	46.5	17.0
102	"	110.5-120.5	—	—	9.8	8.0	28			.480				1.82	21.0	.98	29.8	76.1			9.5	7.9	21.0	37.4	43.3	20.4

Lab #	Site Number	Depth Feet	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./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.	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 %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture 1/3 Bars	% of Moisture 15 Bars
103	DH-5	120.5-133.7	–	–	9.6	8.0	26			.386											1'		19.6		42.1	17.5
104	"	133.7-140.5	–	–	9.9	8.0	26			.515				2.34	21.5	.78	34.4	70.9			12.6	11.08	23.0	46.6	42.1	19.0
105	"	140.5-149	–	–	10.0	8.1	23			.450				1.95	18.7	.59	31.4	63.7			11.2	10.01	21.8	45.9	40.4	15.8
106	"	149-160.5	–	–	10.0	8.2	25			.505				2.04	18.5	.59	34.1	67.9			11.2	9.94	21.6	46.0	42.0	18.3
107	"	160.5-169.5	–	–	9.7	8.3	25			.549				2.57	23.0	1.06	31.6	72.2			11.0	9.34	16.4	57.0	44.5	19.1
108	"	169.5-179.3	–	–	10.2	8.3	24			.279				1.69	18.4	.59	33.9	63.0			8.6	7.44	21.8	34.1	38.6	13.0
109	"	179.3-190.5	–	–	9.9	8.1	23			.393				1.95	19.0	.59	35.0	54.6			9.0	7.96	15.0	53.1	32.9	12.1
110	"	190.5-200	–	–	10.1	8.1	24			.300				.872	8.2	.51	16.2	77.9			8.8	8.16	15.4	53.0	43.7	27.8
111	"	200-220.5	–	–	10.0	8.1	23			.334				1.04	12.1	.29	31.8	63.5			10.0	9.23	15.6	59.2	38.1	18.1
112	"	220.5-236.5	.03	.04	11.0	8.2	22			.300				1.02	12.5	.79	12.9	49.8			9.8	9.18	18.2	50.4	20.3	8.6
113	"	236.5-252.5	.02	.02	10.0	8.1	22			.364				1.93	22.5	.59	41.4	48.4			10.75	9.66	18.6	51.9		14.5
114	DH-6	0-2	.54	.74	8.4	7.8	19			.951				3.66	12.0	37.8	9.4	43.8			4.2	3.38	16.8	20.1		12.7
115	"	2-4	.18	.24	8.2	7.8	26			2.67				12.1	115	51.4	26.3	51.9			13.2	2.23	15.8	15.8		15.1
116	"	4-8	.24	.24	9.1	7.9	18			1.71				13.1	130	47.5	26.7	44.4			10.8	5.03	11.6	43.4		8.3
117	"	8-13	1.9	.92	8.9	7.9	18			.496				4.83	33.5	29.50	8.7	31.5			1.42	.36	5.0	7.2		4.4
118	"	13-19.8	.02	.01	9.8	7.8	22			.236													26.2			7.8
119	"	19.8-24.5	.01	–	9.7	7.9	22			.247													24.2			7.8

LAB #	Site Number	Depth Feet	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./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
120	DH-6	29.8-40	—	—	9.6	7.9	29			.339													36.4			19.4
121	"	40-50	—	—	9.8	7.2	36			.447				1.14	12.0	.59	27.1	70.3			8.8	7.6	39.4	19.3		23.1
122	"	50-56.7	—	—	9.7	8.0	80			.549				.737	7.3	.50	14.6	165.6			15.0	13.8	45.8	30.1		52.9
123	"	56.7-65	—	—	9.9	8.2	40			.490				.710	7.4	.50	14.8	127.9			9.8	8.85	27.6	32.1		32.9
124	"	65-72.3	—	—	9.8	8.0	36			.490				1.42	16.0	.69	27.2	89.3			10.2	8.8	29.2	30.1		27.8
125	"	72.3-80	—	—	9.7	8.0	37			.514				1.51	17.5	.99	24.9	99.1			9.4	8.17	30.6	26.7		30.3
126	"	80-90	—	—	9.6	8.0	48			.585				1.27	13.1	.69	22.3	112.0			10.8	9.33	28.6	32.1		28.7
127	"	90-100	—	—	9.6	8.0	40			.572				1.09	13.1	.79	20.8	111.3			8.9	7.44	33.6	22.1		11.4
128	"	100-110	—	—	9.6	8.0	45			.531				1.12	10.8	1.09	14.6	92.2			10.4	9.35	32.2	29.0		49.9
129	"	110-120	—	—	9.5	8.0	40			.525				1.39	13.8	.59	25.4	96.1			9.4	8.07	30.2	26.7		35.5
130	"	120-122.8	—	—	9.4	7.9	40			.464				1.47	18.1	.79	28.8	81.3			7.5	6.03	28.2	21.4		29.3
131	"	122.8-123.9	—	—	9.5	7.7	34			.207											6.4		31.0			31.5
	★★	INCHES	★★																							
132	1	0-12	1.5	.98	9.1	7.5	18			.049				.283	.12	3.37	.09	34.2			.08	.08	12.4	.65	14.5	7.6
133	"	12-20	1.5	1.7	8.2	7.4	14.5			.050				.505	.52	4.77	.33	37.5			.10		15.2		18.2	9.6
134	"	20-30	1.1	1.5	8.1	7.4	20			.187				.426	.51	4.28	.34	32.7			.14		19.2		23.9	11.0
135	"	31-40	.36	.42	9.2	7.4	19.5			.134				.435	2.15	2.69	1.85	40.9			.48		18.2		27.2	13.6
136	"	40-44	.24	.30	8.5	7.3	20			.127				.521	3.8	2.24	3.67	37.2			.86		18.6		26.4	12.9

LAB #	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ec×10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ec×10^3 @ 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 1/3 Bar	15 Bars
137	2	0-10	4.0	1.3	8.9	7.1	20			.089				.334	.15	4.16	.105	43.7			.12	.11	17.2	.64	16.8	9.6
138	"	10-18	5.8	2.8	8.4	7.1	20.5			.049				.319	.40	3.31	.351	42.0			.16		19.8		22.5	11.0
139	"	18-36	1.7	1.2	8.6	7.2	18			.086				.273	.53	2.10	.517	38.1			.16		15.6		17.1	7.8
140	"	36-54	4.6	1.3	8.8	7.2	17			.093				.184	.49	1.88	.51	35.9			.24	.22	13.4	1.6	12.9	7.3
141	"	54-60	.70	.96	9.0	6.5	20			.117				.228	1.1	1.68	1.20	36.9			.42	.38	16.8	2.3	24.3	10.5
142	3	0-6	5.1	2.3	8.6	6.4	21			.089				.383	.32	2.98	.261	46.6			.14		21.6		21.5	9.9
143	"	6-14	6.1	2.9	8.6	6.5	23			.101				.430	.68	4.08	.475	51.7			.24		32.2		27.2	12.5
144	"	14-26	1.1	.82	8.5	6.6	17.5			.145				.510	.70	5.30	.430	31.2			.24		20.2		18.2	7.8
145	"	26-34	5.1	1.8	8.7	6.6	14.5			.117				.805	1.65	7.26	.864	19.2			.08		8.0		5.8	2.8
146	4	0-6	2.2	.88	8.2	6.4	19			.085				.448	.22	4.30	.150	43.6			.10		12.8		18.2	7.1
147	"	6-32	6.0	1.2	8.2	6.4	19			.057				.241	.22	2.12	.215	31.1			.10		13.4		14.1	6.9
148	"	32-36	2.3	.94	8.3	6.4	18			.066				.314	.30	3.55	.227	35.3			.10		4.2		13.8	5.9
149	5	0-2	3.3	1.6	8.0	6.3	20			.077				.528	.30	4.49	.200	36.3			.86		14.4		12.9	8.4
150	"	2-22	.12	.09	7.9	6.4	21			.188				1.591	4.75	8.77	2.26	51.9			.88		26.6		30.0	14.6
151	"	22-28	.34	.38	7.8	6.3	20			.258				2.000	6.4	4.48	2.38	50.5			.98		25.4		29.9	12.8
152	10	0-8	2.3	1.1	8.0	6.5	18.5			.063				.425	.53	3.79	.384	32.8			.10		11.0		14.7	6.1
153	"	8-22	3.0	1.2	8.1	6.4	18.5			.058				.282	.31	2.61		35.1			.12		13.6		17.5	7.4

LAB #	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH CaCl2 .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10³ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10³ @ 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 1/3 BAR	15 Bars
154	10	22-36	1.2	1.1	8.1	6.4	18.0			.113				.286	.37	2.45	.311	38.2			.18		12.6		19.3	8.0
155	11	0-3	.82	.88	8.0	6.5	17.5			.066				.456	.32	4.51	.211	41.2			.08		14.0		15.7	7.9
156	"	3-14	2.6	1.3	8.2	6.7	19			.079				.410	.38	4.90	.243	41.2			.14		19.6		20.6	10.3
157	"	14-30	2.7	1.7	8.2	6.8	20			.128				.316	.35	2.45	.21	41.2			.42		17.4		24.0	13.0
158	12	0-9	3.2	1.6	8.1	6.6	19.5			.056				.278	1.32	1.51	1.52	38.3			.32		14.0		20.2	9.4
159	"	2-18	—	—	8.5	6.6	24.5			.147				.755	6.9	1.47	4.91	54.1			3.70		35.2		38.3	21.3
160	"	18-26	.13	.14	7.6	6.5	26			1.87				5.98	33.0	51.48	6.5	61.3			4.40	4.08	39.8	10.3	35.8	24.2
161	14	0-8	4.0	2.2	6.8	6.1	28			.260				.956	.68	10.81	.293	81.5			.28		54.6		38.0	25.0
162	"	8-26	.08	.05	8.4	6.2	26			.204				.648	4.2	3.79	3.16	61.3			1.6		25.0		40.4	27.2
163	"	26-58	.63	.02	8.9	6.3	22.5			.192				0.60	3.7	2.28	3.5	40.7			1.96	1.81	14.2	12.7	26.6	12.7
164	"	58-64	.64	.84	8.7	6.4	18			.143				.433	2.4	2.12	2.31	35.4			.68		13.8		21.1	9.3
165	16	0-5	1.5	.96	8.3	6.3	19			.094				.521	.46	5.26	.283	47.9			.16		18.8		19.1	8.7
166	"	5-18	.78	.90	8.3	6.4	20			.076				.320	.59	4.31	.309	43.0			.18		22.0		26.7	11.7
167	"	18-36	1.3	1.7	8.3	6.4	20			.140				.313	.81	2.53	.721	41.7			.40		19.2		27.0	12.1
168	17	0-20	2.0	1.3	8.3	6.4	19.5			.092				.325	.48	3.30	.374	40.0			.18		19.6		18.6	9.6
169	"	20-26	.02	.14	8.3	6.5	18			.022				.175	1.1	.94	1.01	53.0			.66		34.2		31.2	18.2
170	18	0-18	.70	1.0	7.8	6.3	19.5			.091				.230	.15	1.63	.168	44.1			.15		4.8		25.2	11.8

LAB #	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./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 1/3 BARS	% of Moisture 15 Bars
171	18	18-26	.38	.56	7.8	6.3	19			.075				.172	.20	1.06	.270	40.9			.18		14.6		24.1	11.1
172	"	26-60	.36	.50	8.1	6.4	20			.121				.344	.36	3.06	.289	47.2			.18		13.4		25.0	11.5
173	19	0-4	.96	.72	7.8	6.3	20.5			.086				.464	.19	4.28	.129	50.6			.12		15.6		21.3	8.9
174	"	4-18	1.5	1.4	7.9	6.3	21			.068				.194	.31	1.63	.317	45.9			.22		21.0		31.0	14.7
175	"	18-24	3.0	1.6	8.0	6.4	20			.107				.344	.38	3.06	.305	44.4			.22		22.0		23.2	12.2
176	"	24-40	2.8	1.6	8.4	6.5	19.5			.121				.245	.50	1.55	.577	37.7			.26		14.8		23.9	11.5
177	20	0-7	2.0	1.2	8.3	6.4	18			.084				.288	.22	2.37	.201	42.6			.20		13.8		17.2	8.2
178	"	7-16	1.3	1.4	8.3	6.5	22			.088				.377	.73	2.86	.606	51.1			.24		27.0		30.2	15.9
179	"	16-30	2.8	1.5	8.4	6.6	22			.134				.319	1.09	2.04	1.09	50.1			.40		27.2		30.9	15.3
180	"	30-40	.88	1.3	8.7	6.6	21.5			.150				.345	1.83	1.43	2.19	46.8			.80		22.8		32.4	14.4
181	22	0-12	2.3	1.5	8.8	5.1	22			.128				.404	0.1	4.36	.068	49.7			.18	.18	14.8	1.2	22.7	10.9
182	"	12-20	.58	.76	8.4	5.4	20.5			.089				.384	.50	2.53	.447	40.7			.18		14.8		25.7	11.1
183	"	20-30	.07	.05	8.2	5.7	21.5			.106				.472	.80	3.18	.632	47.9			.22		17.2		30.2	14.9
184	"	30-40	.11	.10	8.4	6.0	22			.129				.367	.82	2.24	.782	51.9			.36		20.2		31.0	14.8
185	23	0-12	2.4	1.4	8.2	5.9	19.5			.085				.521	.25	4.49	.167	40.3			.16		13.3		17.1	8.3
186	"	12-30	2.9	1.3	8.2	5.9	19			.077				.208	.27	.94	.402	42.1			.20		16.3		19.8	9.5
187	24	0-12	1.4	1.0	7.6	5.8	19.5			.082				.644	.26	6.53	.144	44.8			.16		13.2		18.4	7.5

Mc Callum

LAB #	Site Number	Depth inches	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH CaCl2 .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10³ @ 25 c	Ca+Mg Me/L	BAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10³ @ 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 1/3 BAR	15 Bars
188	24	12-24	2.7	1.3	7.7	5.9	19			.074				.301	.29	2.19	.259	36.9			.20		14.6		20.6	9.3
189	"	24-36	2.3	1.3	7.7	6.2	20			.068				.190	.31	1.39	.370	35.7			.20		16.5		19.7	9.9
190	25	0-12	1.4	.86	7.7	6.0	19.5			.077				.377	.20	3.51	.151	31.5			.18		14.5		19.7	9.0
191	"	12-26	1.3	.84	7.8	6.1	19			.060				.174	.34	1.18	.431	32.9			.20		13.4		16.5	7.9
192	26	0-12	1.6	1.1	7.5	5.7	16.5			.077				.512	.21	5.02	.133	47.9			.16		16.2		26.1	9.4
193	"	12-24	1.9	1.2	7.5	5.7	18.5			.064				.209	.30	1.35	.372	32.7			.14		13.6		15.9	7.3
194	"	24-60	.58	.78	7.5	6.0	19.5			.060				.139	.21	1.10	.283	36.9			.18		15.4		23.3	10.9
195	27	0-12	1.1	1.0	7.6	6.3	20			.074				.451	.28	4.4	.53	46.1			.22	.18	17.4	1.0	29.0	12.1
196	"	12-24	.11	.08	7.7	6.6	20.5			.085				.371	1.7	2.32	1.59	51.1			.60	.51	22.0	2.3	29.9	14.8
197	"	24-48	.12	.09	8.1	6.7	22			.252				1.25	5.0	8.0	2.5	52.2			1.2	.94	19.2	4.9	29.4	15.0
198	28	0-12	1.4	1.0	7.8	6.3	21			.101				.300	.19	2.65	.167	31.8			.18		13.2		19.6	8.1
199	"	12-36	.52	.98	7.9	6.5	21			.060				.120	.20	.82	.316	38.1			.22		15.2		27.8	10.6
200	"	36-48	2.3	1.3	7.8	6.7	19			.096				.231	.35	5.08	.312	34.3			.24		12.8		17.5	7.2
201	29	0-12	1.6	1.0	7.0	6.0	19			.120				.591	.30	7.38	.197	48.8			.20		17.2		18.1	9.2
202	"	12-24	1.6	.88	7.5	6.3	20			.137											.42		12.6		21.6	10.5
203	"	24-30	1.5	.9	8.3	6.6	21.5			.184											.84		17.6		24.1	10.8
204	49	0-18	3.4	1.7	7.6	6.3	19.5			.080				.317	.15	2.3	.14	38.9			.10	.09	14.6	.6	21.0	8.3

LAB #	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ec x 10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ec x 10^3 @ 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 1/3 BAR	% of Moisture 15 Bars
205	49	18-26	2.8	1.5	7.7	6.4	19.5			.070											1 .20		15.6		26.3	11.1
206	"	26-36	4.2	2.1	7.8	6.5	20			.126											.28		18.0		21.2	10.8
207	"	36-45	2.3	1.2	8.2	6.7	21			.123											.24		15.4		28.3	11.2
208	"	45-55	.26	1.4	8.3	6.9	19.5			.111											.28		15.2		13.1	9.5
209	50	0-10	.92	.98	8.1	6.7	21.5			.068											.22		8.4		24.9	5.1
210	"	10-24	.01	.02	8.4	6.7	23			.098											2.9		27.6		36.3	20.0
211	"	24-34	.03	.03	8.9	6.9	19.5			.346				1.71	14.0	4.85	9.0	62.7			3.4	2.45	32.6	7.5	40.1	24.7
212	52	0-4	2.3	1.4	8.2	6.9	17.5			.171				1.23	.28	12.0	.11	34.5			.16	.15	17.0	.88	15.3	7.1
213	"	4-12	5.7	1.6	8.3	6.8	20.5			.068				.227	.25	2.21	.24	32.0			.18	.17	21.0	.81	23.5	12.8
214	"	12-27	.74	.68	8.4	7.2	20			.145											.26		14.8		24.5	15.3
215	53	0-4	3.9	1.8	7.0	6.4	18.5			.503				2.73	.26	25.06	.071	72.0			.16	.13	21.0	.62	23.7	12.3
216	"	4-10	2.7	3.1	7.5	6.4	18			.109				.304	.17	2.28	.16	44.4			.16	.15	12.4	1.21	15.9	8.6
217	"	10-16	4.2	1.4	7.7	6.4	19			.068				.261	.25	4.48		48.6			.14	.13	17.0	.76	20.3	10.6
218	"	16-27	3.3	1.3	7.7	6.5	18			.084											.16		12.6		17.8	8.7
219	54	0-6	1.1	.84	7.6	6.5	18			.096				.511	.22	2.04		34.3			.10	.09	12.0	.75	18.1	8.3
220	"	6-20	6.4	1.7	7.8	6.5	17.5			.063				.180	.40	1.60	.45	36.3			.16	.15	11.6	1.3	16.9	8.0
221	"	20-30	.84	.82	7.5	6.3	19			1.42											.52		13.2		20.2	10.0

LAB #	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 ec$\times10^3$ @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ec$\times10^3$ @ 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 %	1/3 BAR	15 Bars
222	54	30-44	.02	.02	8.6	6.7	23			.517				2.08	15.0	7.23	7.9	56.2			2.8	1.96	23.4	8.4	29.0	17.2
223	55	0-20	8.3	3.9	8.0	6.3	21			.143											.10		19.2		19.7	9.4
224	"	20-30	8.3	3.3	8.0	6.2	16			.103											.08		9.75		11.9	5.6
225	"	30-44	2.1	1.0	7.9	6.1	16.5			.102											.10		12.4		14.3	5.9
226	"	44-60	4.7	2.9	7.9	6.1	16			.090											.08		12.0		11.3	5.2
227	56	0-12	2.3	1.1	7.9	6.3	18.5			.187											.16		17.4		16.2	8.2
228	"	12-22	1.8	.98	8.0	6.6	19.5			.194											.20		14.0		13.8	6.9
229	"	22-36	1.0	.76	8.4	6.9	19			.180											.24		15.0		19.1	8.0
230		36-46	1.2	.70	8.8	7.1	19			.231				.357	2.1	2.38	1.9	39.9			.82	.74	15.0	4.9	16.2	7.8
231	57	0-6	1.5	.94	7.9	6.9	16.5			.211											.12		12.8		10.6	4.9
232	"	6-14	2.5	1.3	8.2	6.8	18.5			.119											.16		16.8		12.7	5.7
233	"	14-36	3.2	1.4	8.1	6.8	15.5			.112											.14		10.0		6.5	3.1
234	58	0-6	2.3	1.5	7.7	6.3	18.5			.119				.635	.90	4.60	.59	42.4			.15	.11	16.8	[illegible]	19.9	7.7
235	"	6-22	.96	1.8	8.1	6.2	18			.099				.152	1.35	.42	2.95	39.4			.80	.76	19.4	39	20.4	10.1
236	"	22-28		[illegible]	8.5	6.7	24			.360											3.2		33.0		35.9	18.9
237	"	28-34	.18	.30	8.4	6.9	19.5			.568				1.88	14.0	6.93	7.5	61.5			4.0	3.14	37.0	[illegible]	34.5	19.4
238	"	34+	.36	.62	8.1	6.9	22.5			.934				4.55	23.7	36.13	5.5	50.5			3.4	[illegible]	27.4	80	[illegible]	[illegible]

LAB No	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ec x 10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ec x 10^3 @ 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 1/3 BAR	15 Bars
239	59	0-6	2.6	1.4	7.3	6.2	20			.139											.12		18.8		19.2	9.4
240	"	6-24	.30	.64	7.6	6.2	19.5			.095											.18		30.2		36.2	20.2
241	"	24-36	.94	1.1	7.7	6.3	25			.111											.24		32.2		34.4	18.9
242	"	36-54	1.3	.76	8.0	6.5	20			.095											.26		20.0		23.7	10.7
243	"	54-60	1.1	1.2	8.1	6.7	22			.108											.40		28.2		30.3	16.4
244	60	0-4	3.1	1.6	7.9	6.7	24			.131											.86		32.0		37.9	19.7
245	"	4-24	.14	.32	8.5	6.9	25			.233											2.66		30.6		40.6	20.0
246	"	24-28	.06	.04	7.6	7.0	25			1.89											4.3		34.6		36.3	20.9
247	61	0-6	1.7	1.0	8.1	6.4	18			.142											.64		13.4		22.4	7.7
248	"	6-24	.04	.02	8.5	6.7	26			.350											3.4		29.6		36.1	18.5
249	"	24-38	.66	1.4	7.6	6.8	24			2.22											5.3		32.4		36.0	7.9
250	62	0-10	3.9	1.5	8.0	6.8	20			.025											.08		20.2		23.0	9.4
251	"	10-24	3.1	1.5	8.1	6.7	19.5			.042											.20		19.4		21.5	8.3
252	"	24-32	.34	.58	8.0	6.7	22			.084											.58		30.0		32.4	16.1
253	63	0-6	3.0	1.7	7.9	6.7	23.5			.067											.12		22.8		32.8	11.8
254	"	6-12	.28	.44	8.0	6.7	23			.045											.16		32.6		33.8	15.4
255	"	12-20	1.8	.92	8.0	6.7	20			.060											.16		23.2		24.8	10.0

LAB #	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH CaCl2 .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 1/3 BAR	15 Bars
239	59	0-6	2.6	1.4	7.3	6.2	20			.139											.12		18.8		19.2	9.4
240	"	6-24	.30	.64	7.6	6.2	19.5			.095											.18		30.2		36.7	20.2
241	"	24-36	.94	1.1	7.7	6.3	25			.111											.24		32.2		34.4	18.9
242	"	36-54	1.3	.76	8.0	6.5	20			.095											.26		20.0		23.7	10.7
243	"	54-60	1.1	1.2	8.1	6.7	22			.108											.40		28.2		30.3	16.4
244	60	0-4	3.1	1.6	7.9	6.7	24			.131											.86		32.0		37.9	19.7
245	"	4-24	.14	.32	8.5	6.9	25			.233											2.66		30.6		40.6	20.0
246	"	24-28	.06	.04	7.6	7.0	25			1.89											4.3		34.6		36.3	20.9
247	61	0-6	1.7	1.0	8.1	6.4	18			.142											.64		13.4		22.4	7.7
248	"	6-24	.04	.02	8.5	6.7	26			.350											3.4		29.6		36.1	18.5
249	"	24-38	.66	1.4	7.6	6.8	24			2.22											5.3		32.4		36.0	7.9
250	62	0-10	3.9	1.5	8.0	6.8	20			.025											.08		20.2		23.0	9.4
251	"	10-24	3.1	1.5	8.1	6.7	19.5			.042											.20		19.4		21.5	8.3
252	"	24-32	.34	.58	8.0	6.7	22			.084											.58		30.0		32.4	16.1
253	63	6-6	3.0	1.7	7.9	6.7	23.5			.067											.12		22.8		32.8	11.8
254	"	6-12	.28	.44	8.0	6.7	23			.045											.16		32.6		33.8	15.4
255	"	12-20	1.8	.92	8.0	6.7	20			.060											.16		23.2		24.6	10.0

Mc Callum

Lab #	Site Number	Depth Inches	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ec \times 10^3$ @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Tat.	1:5 Extract Ca+Mg Me/100g	Saturation Extract $ec \times 10^3$ @ 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 1/3 BAR	% of Moisture 15 Bars
256	63	20-30	2.0	.98	8.0	6.8	19.5			.104											.30		21.4		23.2	9.0
257	64	0-10	3.0	1.4	7.6	6.6	21			.130											.08		16.8		25.0	7.8
258	"	10-24	3.8	1.7	7.9	6.6	20			.055											.10		15.0		21.6	7.2
259	"	24-36	1.5	.86	7.9	6.6	21			.042											.14		17.4		24.6	9.4
260	"	36-54	.72	.56	7.9	6.6	17.5			.050											.10		11.8		12.7	5.8
261	"	54-60	1.1	.74	7.2	5.2	17			.067											.18		10.2		11.4	5.0
262	65	0-10	3.5	5.7	6.6	5.1	19.5			.118											.08		16.0		12.0	7.9
263	"	10-28	3.6	3.4	7.1	5.3	20.5			.034											.22		21.0		23.7	11.4
264	"	28-44	1.2	.80	7.1	5.3	20			.038											.32		20.8		25.5	2.3
265	66	0-20	.48	.58	7.1	6.0	24			.174				.668	3.95	3.22	3.12	60.8			1.4	1.2	33.8	3.6	34.1	20.0
266	"	20-26	.17	.18	6.7	6.1	29			1.20											2.7		37.6		35.8	21.2
267	"	26-32	.04	.04	6.7	6.1	27			1.05											2.8		28.0		34.5	21.3
268	67	0-6	6.9	5.7	7.3	6.3	20			.065											.18		19.0		12.1	9.6
269	"	6-24	.16	.11	7.5	6.2	21.5			.039											.40		31.6		27.6	15.7
270	"	24-30	.19	.21	7.4	6.2	21			.184											.60		26.8		25.1	13.3
271	68	0-18	3.7	1.7	7.5	6.3	21			.112											.16		26.6		21.0	13.6
272	"	18-24	2.3	1.8	7.9	6.3	21.5			.104											.18		21.8		25.6	14.0

LAB NO.	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ec \times 10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract $ec \times 10^3$ @ 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 1/3 BAR	15 Bar
273	68	24-48	1.0	.78	8.4	6.3	21			.127											1.0		18.5		26.2	11.9
274	69	0-12	2.6	1.4	8.2	6.3	19.5			.060											.10		17.0		19.2	8.8
275	"	12-24	4.0	3.8	8.2	6.3	19.5			.036											.14		23.8		20.3	10.4
276	"	24-36	2.5	2.5	8.2	6.3	18			.041											.14		17.8		16.1	8.2
277	"	36-48	1.3	.84	8.2	6.4	19			.112											.28		19.6		21.0	8.5
278	70	0-12	4.9	5.5	8.0	6.3	22			.077											.12		20.5		23.4	9.7
279	"	12-24	1.4	.80	8.2	6.4	20			.108											.20		25.4		19.0	8.3
280	"	24-36	1.8	1.2	8.3	6.5	19			.106											.20		19.0		15.9	7.2
281	71	0-16	6.1	6.7	7.5	5.8	20			.061				.469	.25	5.22	.15	43.7			.12	.11	23.8	.46	20.9	9.6
282	"	16-36	3.7	5.6	7.5	7.1	20			.101				.334	.70	3.56	.53	42.3			.26	.23	20.0	1.15	24.4	11.9
283	72	0-16	5.0	5.7	7.4	6.2	19			.046											.12		22.8		20.4	9.6
284	"	16-26	4.1	2.2	7.6	6.6	20			.092											.34		24.2		23.1	11.7
285	"	26-52	1.9	5.7	7.6	7.0	19			.303											1.3		21.6		26.1	10.9
286	73	0-18	3.0	5.6	7.9	7.0	19			.051				.442	.25	5.02	.15	42.0			.16	.15	23.8	.63	20.4	9.2
287	"	18-36	1.7	3.4	8.3	7.3	19			.095											.24		21.0		24.8	11.4
288	74	0-12	.54	.40	8.2	6.7	19			.034											.10		21.4		26.7	10.1
289	"	12-30	3.5	3.6	8.1	6.9	20			.048											.14		22.6		25.7	11.1

LAB #	Site Number	Depth INCHES	Hydraulic Conductivity Inc./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
290	74	30-42	4.0	4.7	8.2	7.1	21			.082											.20		21.8		26.8	11.8
291	"	42-56	4.0	3.3	8.5	7.2	16			.052											.20		11.4		12.0	5.3
292	75	0-12	2.5	1.6	7.6	6.4	21			.107											.08		16.8		17.1	8.2
293	"	12-24	1.2	.83	8.0	6.4	22			.029											.12		20.4		26.8	11.2
294	"	24-38	7.7	5.7	8.1	6.5	13			.019											.10		5.0		5.1	2.3
295	76	0-12	.66	1.2	7.3	6.0	21			.120											.10		17.2		20.9	8.8
296	"	12-24	1.8	1.3	7.7	6.2	20			.037											.10		16.2		28.6	11.0
297	"	24-36	1.4	.98	7.8	6.3	19			.029											.14		16.8		23.7	12.2
298	77	0-24	1.9	1.3	8.2	6.7	21			.049											.26		16.8		21.5	9.0
299	"	24-45	1.1	.82	7.9	7.2	22			.866											1.98		20.2		27.1	11.0
300	"	45-74	1.0	.80	8.3	7.3	20			.980											1.98		17.0		24.3	10.2
301	78	0-24	—	—	7.9	6.4	26			.188				.463	5.4	5.2	3.3	70.7			1.7	1.32	37.2	3.6	37.0	17.2
302	"	24-60	.04	.02	7.5	6.4	28			.444											2.14		40.0		35.7	19.8
303	79	0-18	5.0	5.6	8.0	6.4	20			.055				.294	.80	2.8	.67	29.6			.20	.17	17.4	.98	19.0	8.9
304	"	18-30	.63	.60	8.0	6.8	23			.119											.64		31.4		33.5	15.7
305	"	30-48	.02	.01	8.4	7.4	23.5			.302											2.2		35.8		35.2	20.3
306	"	48-52	.02	.02	8.3	7.6	24			.405											2.5		37.0		34.3	19.1

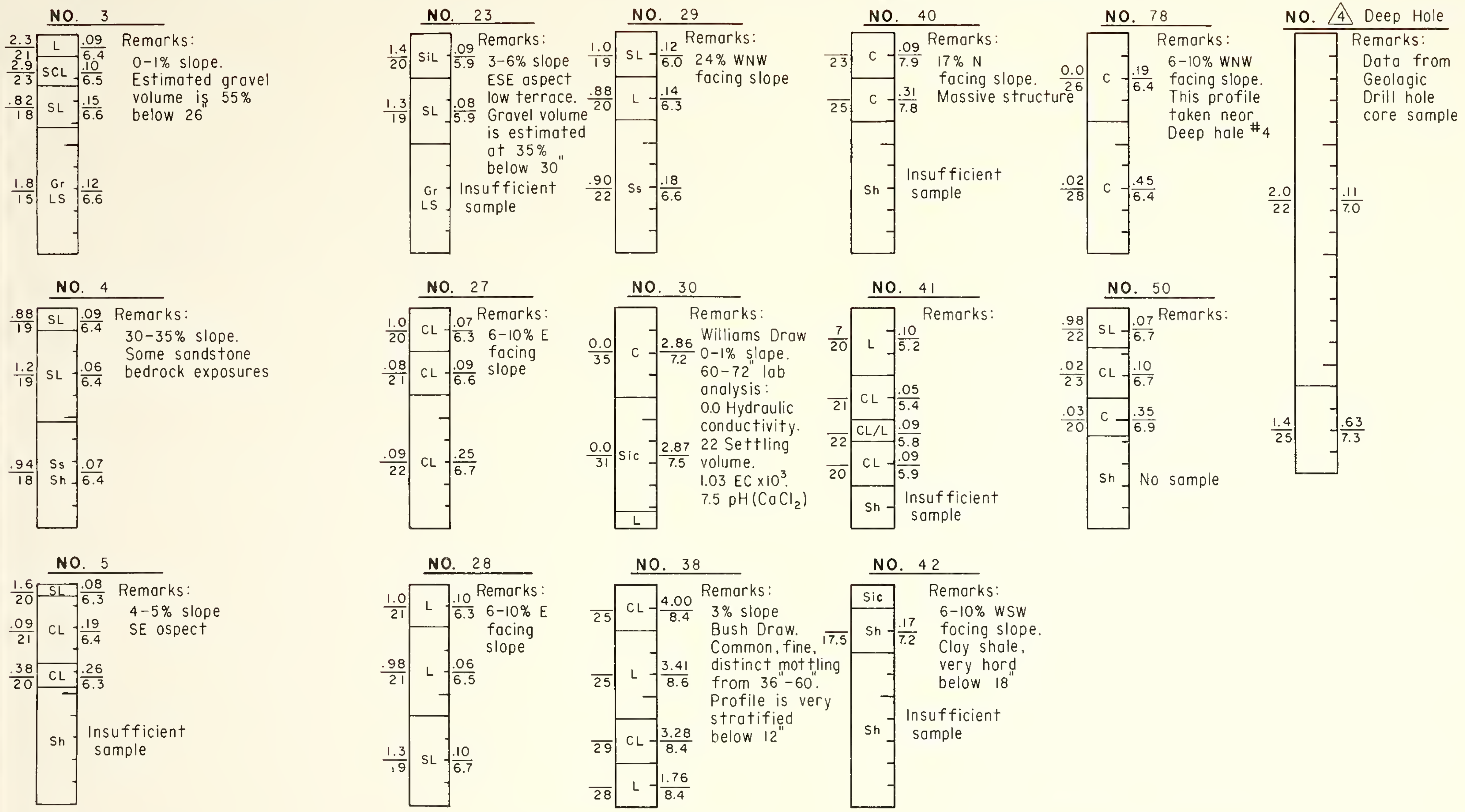
Lab No.	Site Number	Depth Inches	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH CaCl2 .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	of Moisture 1/3 BAR	15 Bars
307	80	0-10	4.8	5.2	8.1	7.4	16			.038				.269	.20	2.6	.18	34.3			.12	.11	7.2	1.5	13.5	6.1
308	"	10-36	.19	.20	9.1	6.8	19			.133											.34		4.6		15.1	7.0
309	"	36-48	.85	.60	9.0	7.0	18			.151											.46		3.5		12.8	6.1
310	"	48-60	.21	.22	8.8	7.2	19			.169											.48		3.6		15.6	5.9
311	81	0-12	.05	.04	8.7	7.2	22			.095				.290	.79	2.2	.75	50.0			.28	.24	20.6	1.2	28.0	13.8
312	"	12-48	—	—	8.8	7.5	30			1.55											7.8		23.0		36.0	18.5
313	"	48-84	—	—	9.6	7.7	23			1.17											8.0		14.6		31.4	10.9
314	"	84-96	—	—	9.5	7.7	19			1.14											6.2		10.6		23.9	9.1
315	82	0-20	.50	.36	7.3	4.3	15			.034				.191	.55	1.2	.71	31.9			.20	.18	28.6	.63	13.4	7.6
316	"	20-30	.64	.44	7.1	4.8	18.5			.091											.80		33.6		19.8	11.7
317	"	30-36	.38	.58	7.2	5.5	17			.169											1.1		21.6		17.6	9.5
318	30	0-24	—	—	8.8	7.2	34.5			2.86				14.2	118.0	62.0	20.9	93.2			18.6	8.8	31.8	27.7	38.8	19.8
319	"	24-56	—	—	8.9	7.5	31			2.87				14.9	134.0	47.4	27.5	77.9			19.4	9.0	28.6	31.5	35.3	17.5
320	"	56-72	—	—	9.6	7.5	22			1.03				5.50	54.5	9.4	25.1	55.1			6.5	2.5	10.6	23.6	24.5	8.3
321	31	0-12	2.7	1.1	5.7	5.1	22			1.76											4.2		29.5		30.5	15.1
322	32	0-12	.98	.78	6.8	5.7	18			.072				.330	.20	3.68	.15	44.2			.12	.11	12.0	.92	12.8	5.0
323	"	12-24	1.1	.72	6.9	6.0	26.5			.068											.26		22.2		20.3	8.8

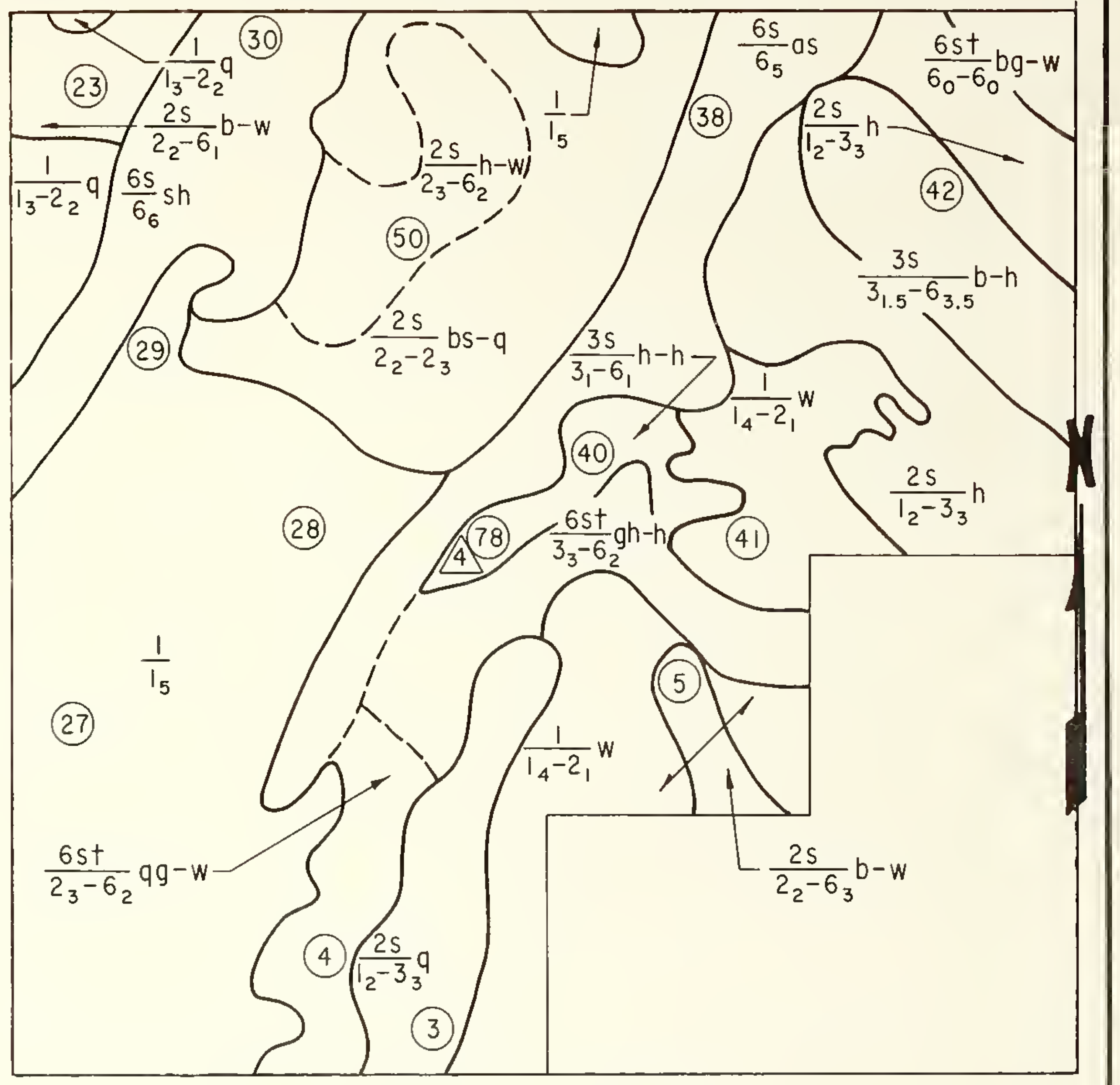
Mc Callan

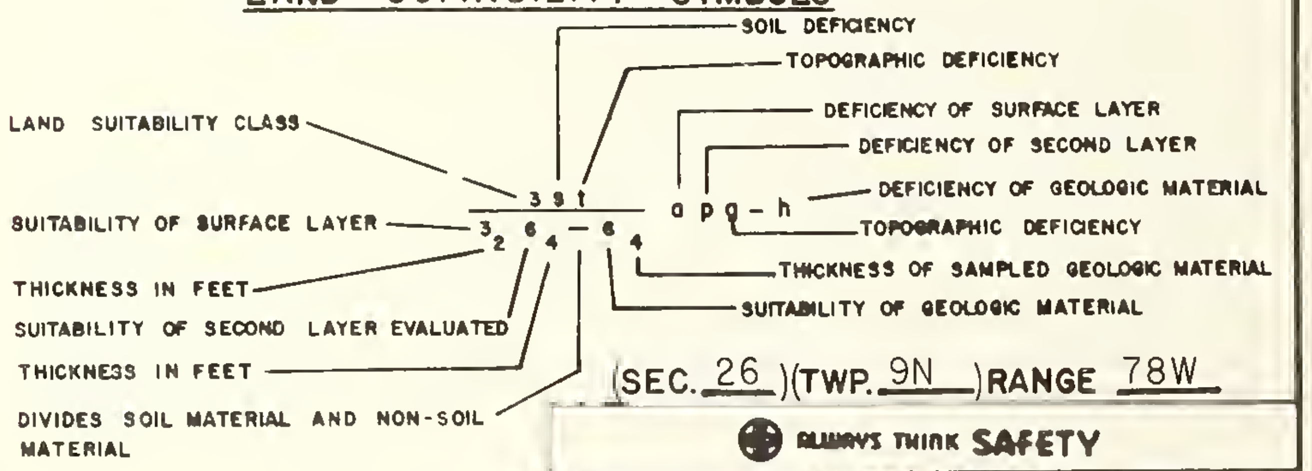
LAB No.	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	Hydraulic Conductivity Inc./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ec x10³ @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ec x10³ @ 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 %	1/3 BAR	15 Bars
324	33	0-12			7.2	5.9	18			.071											.10		13.2		11.9	5.6
325	"	12-30			6.8	5.9	12.5			.064											.12		14.0		12.7	5.5
326	34	0-10			7.0	6.0	18.5			.078											.08		15.3		14.8	6.1
327	"	10-22			7.1	6.0	19.5			.062											.08		20.8		19.0	7.3
328	"	22-26			7.1	6.1	21			.057											.10		21.6		23.5	9.3
329	35	0-12			6.9	5.9	20			.078											.06		13.2		17.0	5.6
330	"	12-30			7.1	6.0	19.5			.052				.155	.15	1.60	.17	53.4			.08	.07	15.6	.45	15.7	6.9
331	36	12-18			8.4	6.8	22			.213				.725	1.65	6.2	.94	52.2			.36	.27	24.2	1.1	27.4	11.1
332	"	28-36			8.5	7.0	21			.223											.44		23.4		29.5	11.6
333	37	0-10			8.1	6.6	19			.053											.22		15.8		12.0	7.1
334	"	10-18			7.6	6.5	19			.044				.128	.73	1.0	1.0	45.3			.26	.23	18.8	1.2	18.1	7.2
335	"	18-26			8.0	6.5	19			.049				.136	1.15	.60	2.1	47.2			.58	.53	19.8	2.7	18.6	7.3
336	38	0-12			9.6	8.4	25			3.99											22.0		12.0		24.9	11.4
337	"	12-36			9.6	8.6	24.5			3.41											17.6		8.8		24.0	8.5
338	"	36-48			9.7	8.4	29			3.28											20.2		16.0		28.9	11.1
339	"	48-60			10.1	8.4	27.5			1.76											13.0		11.2		27.9	7.5
340	40	0-12			8.0	7.9	23			.077											.38		37.6		30.3	14.5

Hydraulic Conductivity	1:2 Extract	Saturation Extract	me/100g

LAB No.	Site Number	Depth INCHES	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ec$\times10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ec$\times10^3$ @ 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 %	[illegible] 1/3 BAR	15 Bars
341	40	12-24			8.3	7.8	25			.307											.28		41.8		36.3	17.3
342	41	0-18			6.5	5.2	20			.098											.18		26.2		29.5	10.4
343	"	18-30			6.6	5.4	21			.054											.20		19.2		25.1	9.9
344	"	30-36			6.7	5.8	21.5			.085											.28		24.4		28.5	10.0
345	"	36-48			6.7	5.9	20			.085											.30		22.2		26.7	10.1
346	42	6-18			8.5	7.2	17.5			.165											.54		11.8		12.4	6.9

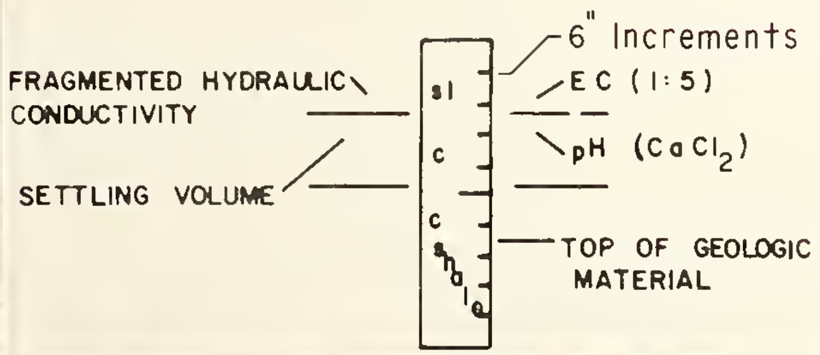






(SEC. 26)(TWP. 9N)RANGE 78W

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
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

○ - Soil Profile Site

△ - Geologic Drill Hole Site

1000 0 1000

SCALE OF FEET

McCALLUM STUDY AREA
COLORADO

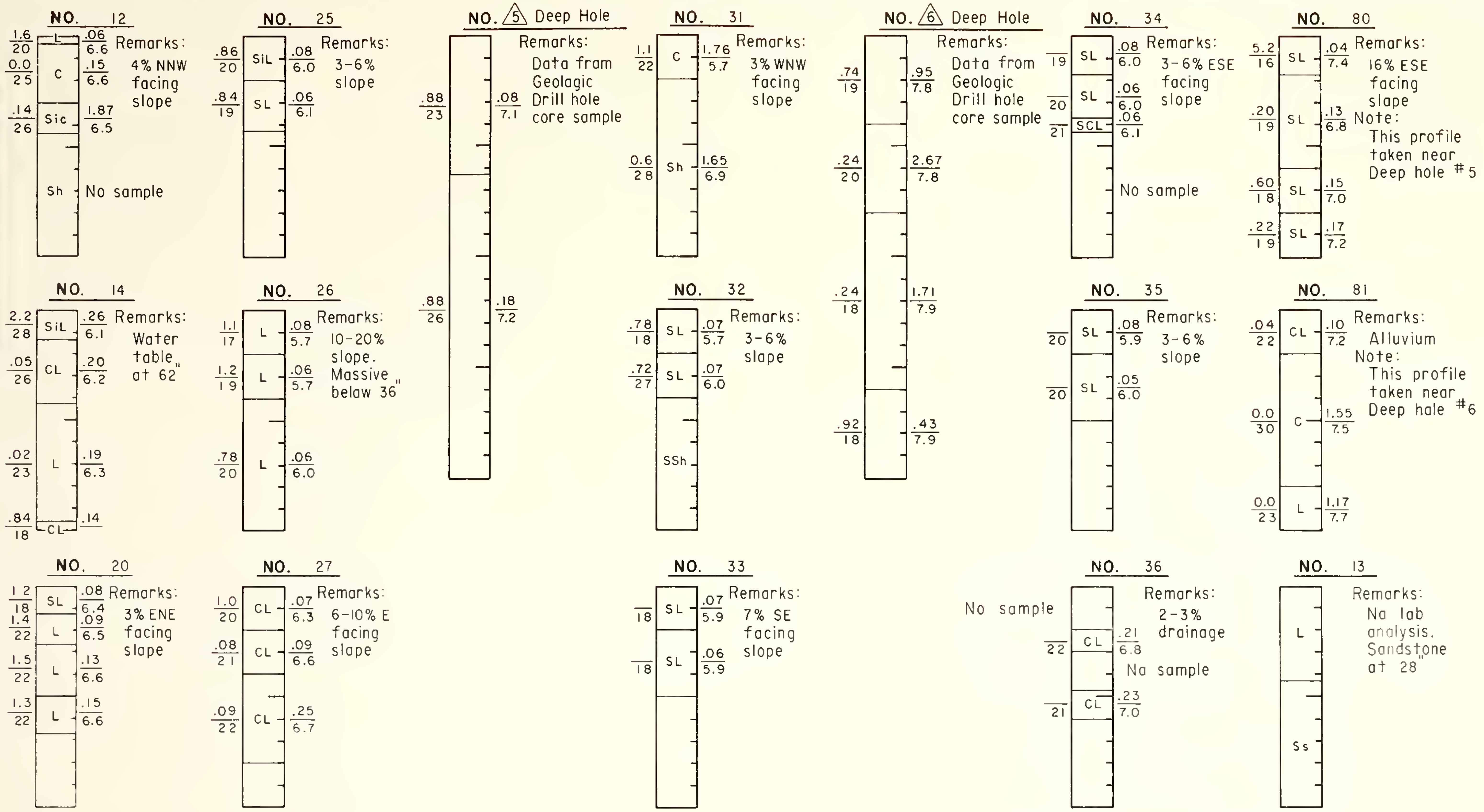
ALWAYS THINK SAFETY

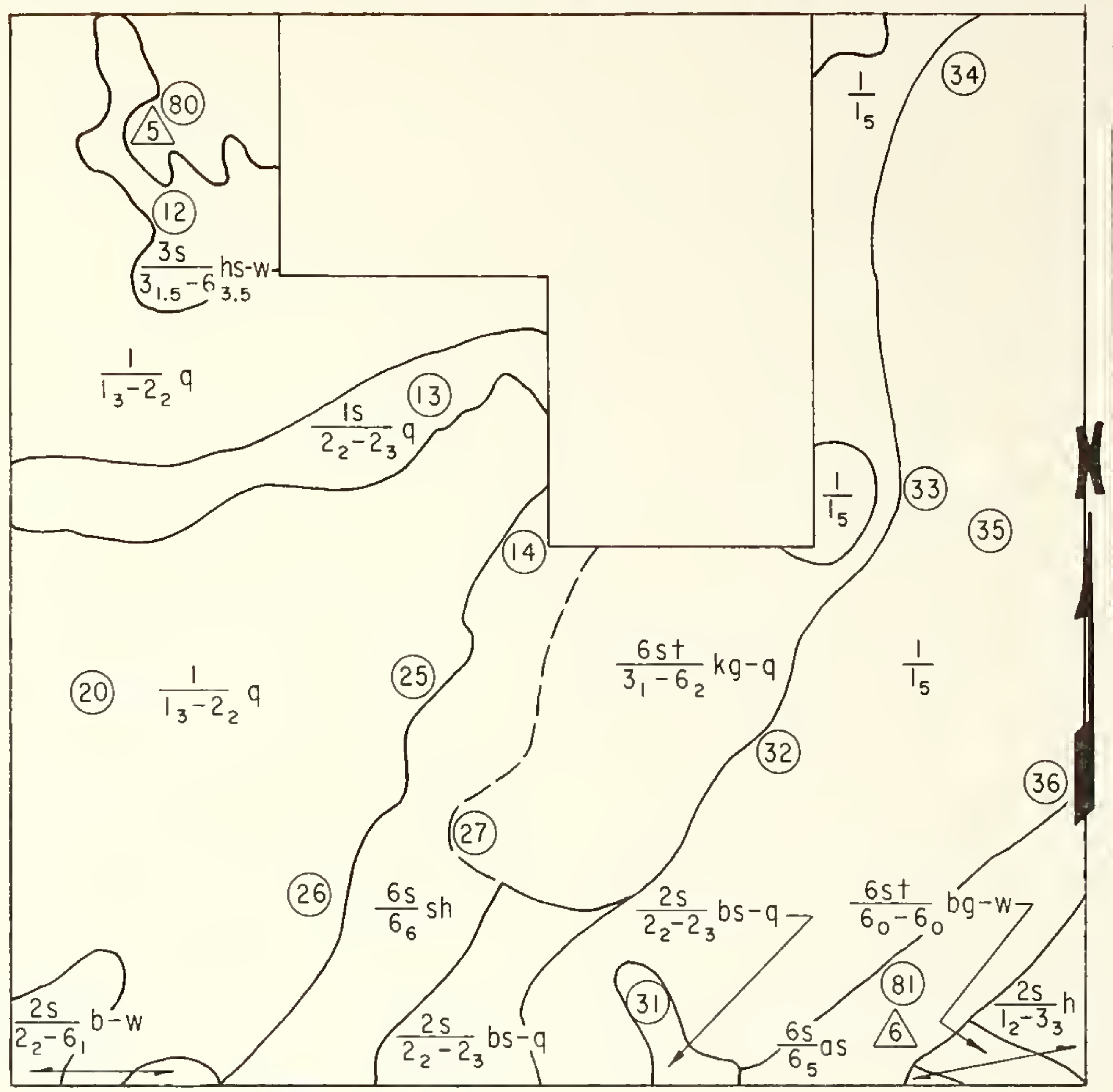
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY
McCALLUM

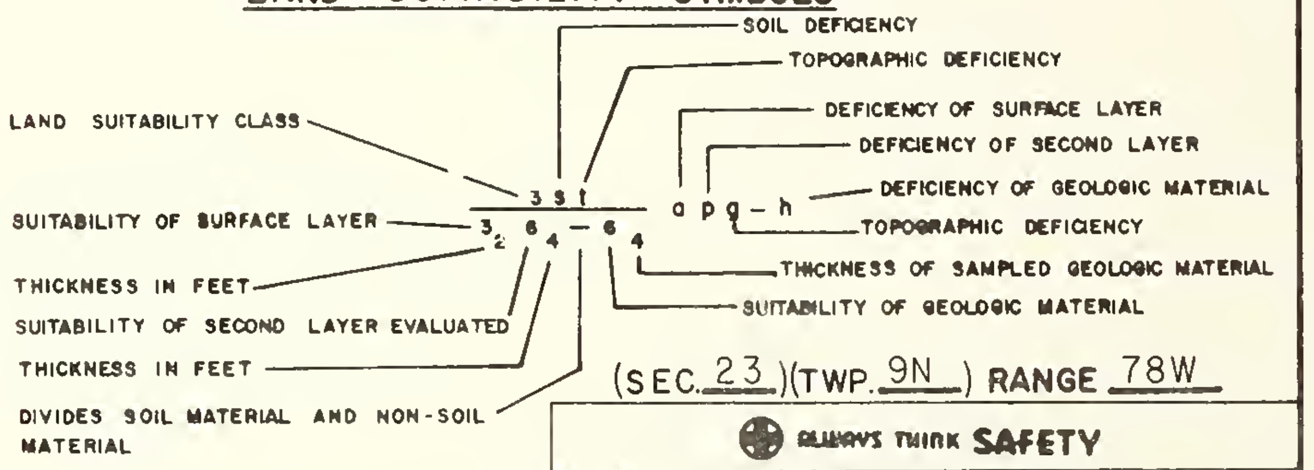
DESIGNED ____	SUBMITTED ____
DRAWN ____	RECOMMENDED ____
CHECKED T. CAPPELLUCCI	APPROVED ____

LM REGION, DEN., COLO.



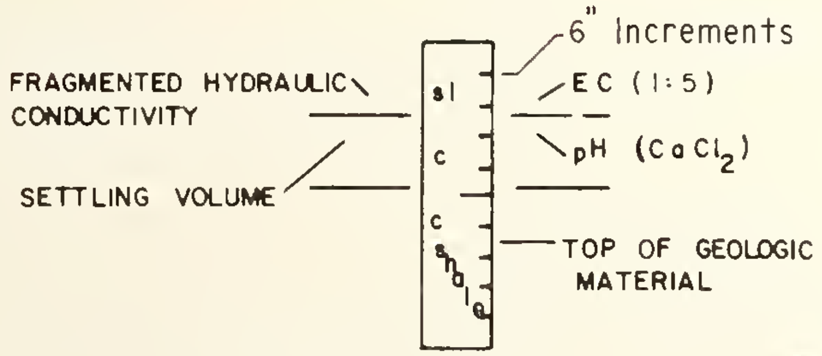


LAND SUITABILITY SYMBOLS



(SEC. 23)(TWP. 9N) RANGE 78W

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
- 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
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

○ - Soil Profile Site

△ - Geologic Drill Hole Site

SCALE OF FEET

McCALLUM STUDY AREA
COLORADO

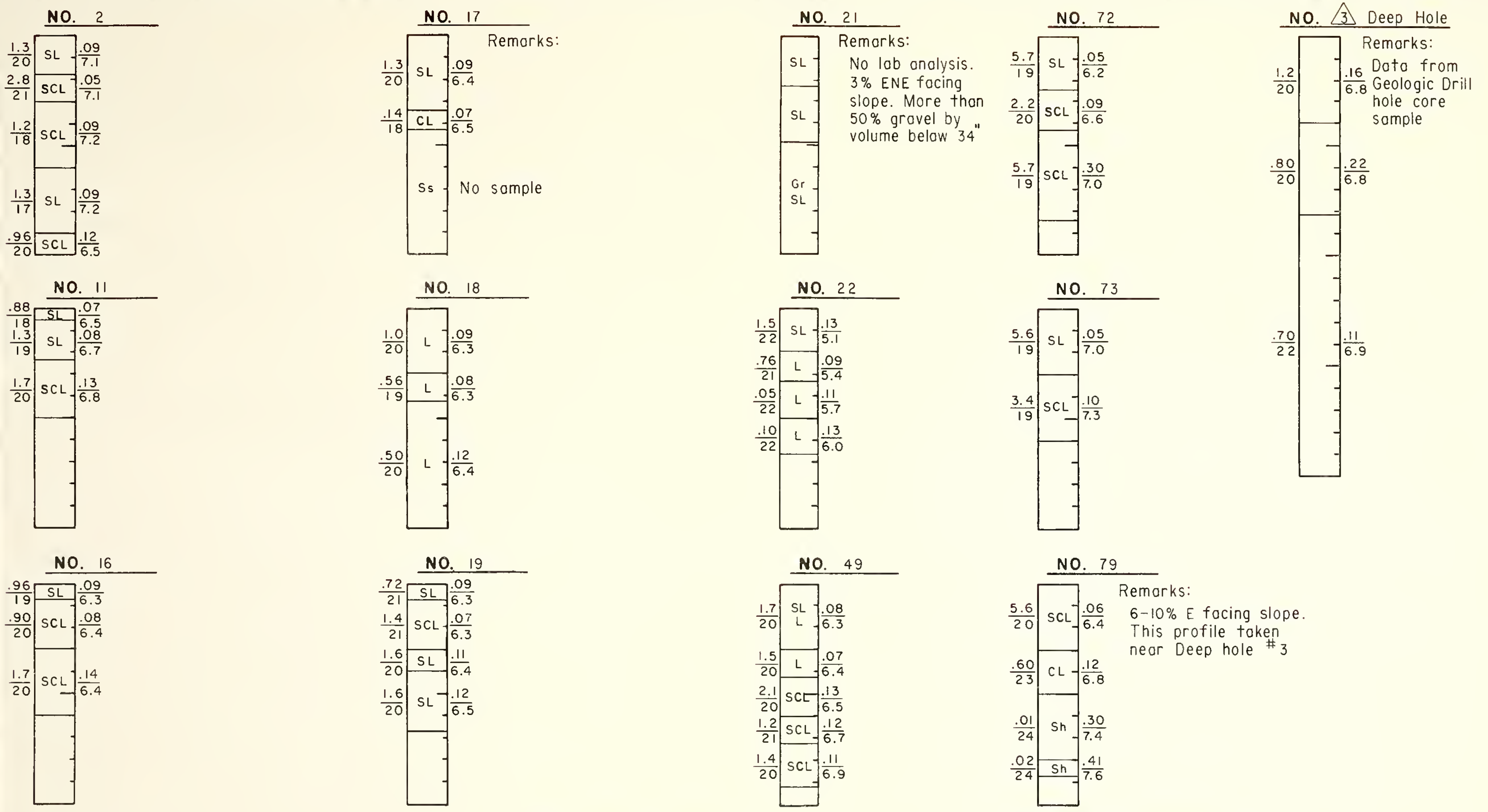
ALWAYS THINK SAFETY

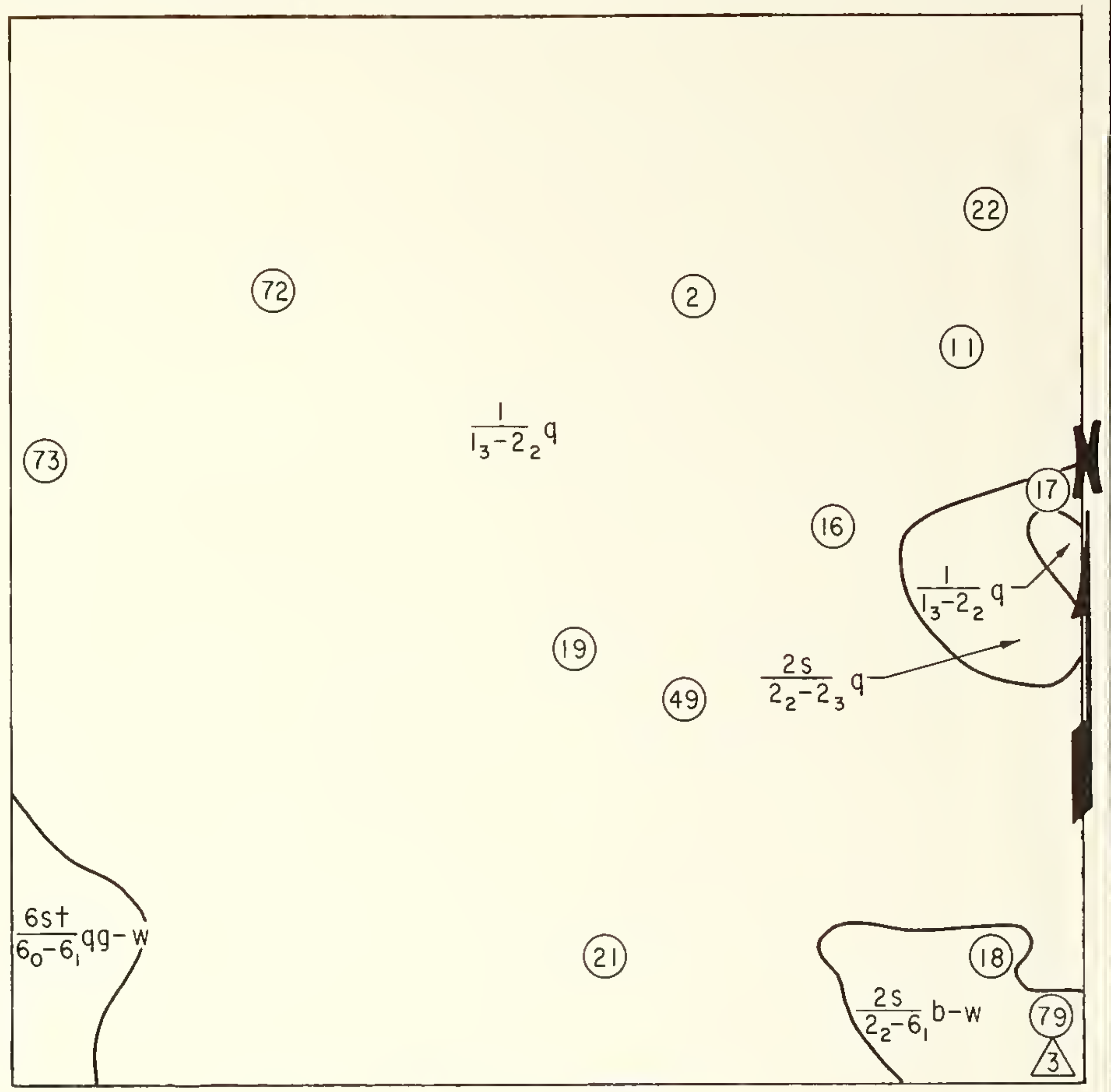
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY
McCALLUM

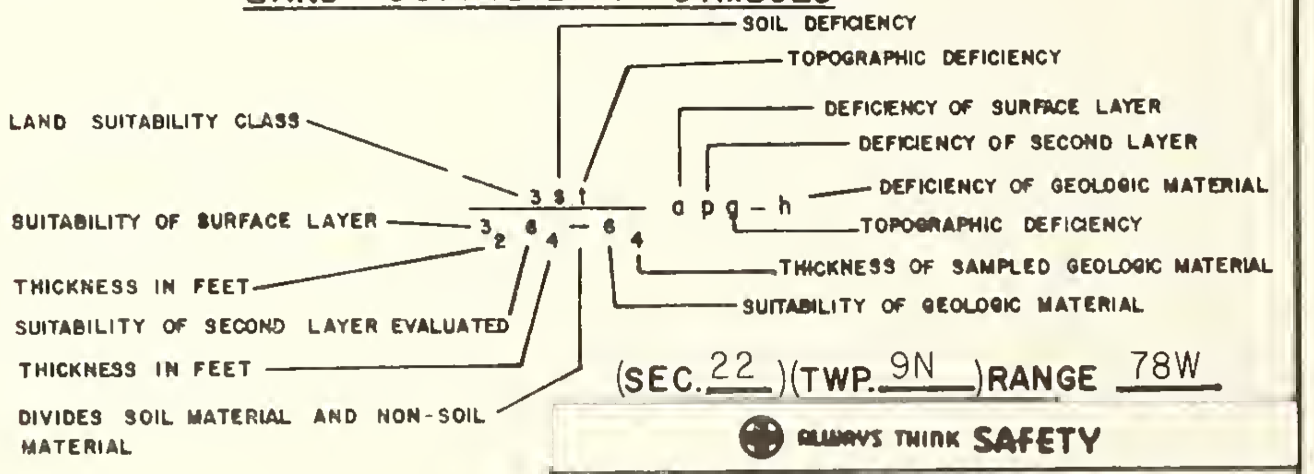
DESIGNED ____ SUBMITTED ____
DRAWN ____ RECOMMENDED ____
CHECKED T. CAPPELLUCCI APPROVED ____

LM REGION, DEN., COLO.



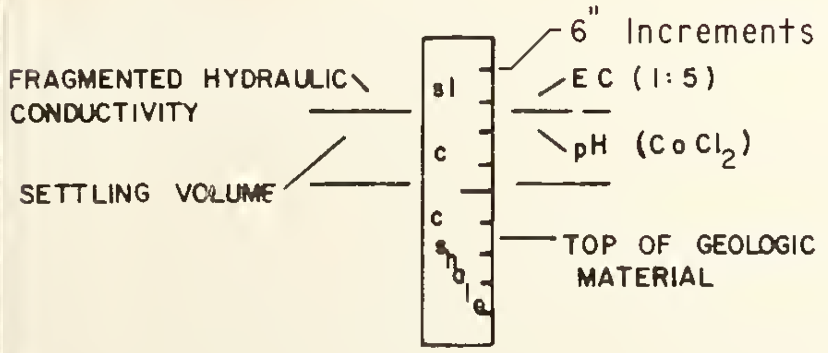


LAND SUITABILITY SYMBOLS



(SEC. 22)(TWP. 9N)RANGE 78W

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
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

○ - Soil Profile Site

△ - Geologic Drill Hole Site

1000 0 1000

SCALE OF FEET

McCALLUM STUDY AREA
COLORADO

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY
McCALLUM

DESIGNED ____ SUBMITTED ____
DRAWN ____ RECOMMENDED ____
CHECKED T. CAPPELLUCCI APPROVED ____

LM REGION, DEN., COLO.

NO. 52

SL	1.4/21	.17/6.9
SCL	1.6/21	.07/6.8
SL	.68/20	.15/7.2
Gr		No sample

Remarks: Mesa, 0-1% slope

NO. 1 Deep Hole

.18/20	.06/4.1
1.7/22	.30/6.4
.01/31	.36/6.4

Remarks: Data from Geologic Drill hole core sample

NO. 56

SL	1.1/19	.19/6.3
SL	.98/20	.19/6.6
SL	.76/19	.18/6.9
SL	.70/19	.23/7.1

Remarks: Ridge

NO. 2 Deep Hole

2.8/22	.21/6.2
.60/21	.94/6.4
.07/30	.76/6.5
.54/25	.25/6.7

Remarks: Data from Geologic Drill hole core sample

NO. 59

L	1.4/20	.14/6.2
CL	.64/20	.10/6.2
C	1.1/25	.11/6.3
SCL	.76/20	.10/6.5
CL	1.2/22	.11/6.7

Remarks: 5% SE facing slope

NO. 61

L	1.0/18	.14/6.4
C	.02/26	.35/6.7
C	1.4/24	2.22/6.8

Remarks: This profile taken near Deep hole # 2

NO. 63

SCL	1.7/24	.07/6.7
SC	.44/23	.05/6.7
SCL	.92/20	.06/6.7
SCL	.98/20	.11/6.8
Gr SL		

Remarks:

NO. 66

C	.58/24	.17/6.0
C	.18/29	1.20/6.1
C	.04/27	1.05/6.1
Sh		No sample

Remarks:

NO. 54

SL	.84/18	.10/6.5
SL	1.7/18	.06/6.5
SCL	3.9/21	.14/6.3
Sic	.02/23	.52/6.7
Sh		

Remarks: 6-10% W facing slope

NO. 57

SL	.94/17	.21/6.9
SL	1.3/19	.12/6.8
LS	1.4/16	.11/6.8

Remarks: 14-36" - gravel content is estimated to exceed 50% by volume

NO. 60

C	1.6/24	.13/6.7
C	.32/25	.23/6.9
C	.04/25	1.89/7.0
Sh		No sample

Remarks: 7% slope

NO. 64

L	1.4/21	.13/6.6
L	1.7/20	.06/6.6
SCL	.86/21	.04/6.6
SL	.56/18	.05/6.6
SL	.74/17	.07/5.2

Remarks: 7% slope. Valley fill soft sandstone at 54"

NO. 67

SCL	5.7/15	.07/4.3
CL	.14/22	.04/6.2
CL	.21/21	.18/6.2

NO. 55

SL	3.9/21	.14/6.3
SL	3.3/16	.10/6.2
SL	1.0/17	.10/6.1
SL	29/16	.09/6.1

Remarks: Valley fill

NO. 58

L	1.5/19	.12/6.3
SCL	1.8/18	.10/6.2
C	0.0/24	.36/6.7
C	.30/19	.57/6.8
CL	.62/23	.93/6.9

Remarks: 4% SSW facing slope, 6-22" depth 5-10% rock

NO. 62

SL	1.5/20	.10/6.8
SL	1.5/20	.04/6.7
CL	.58/22	.08/6.7

Remarks: 19% NNW facing slope. Surface rock is substantial at this profile area. 4" Size rock covers more than 5% of surface. 1-4" Size rock covers 30% of surface

NO. 65

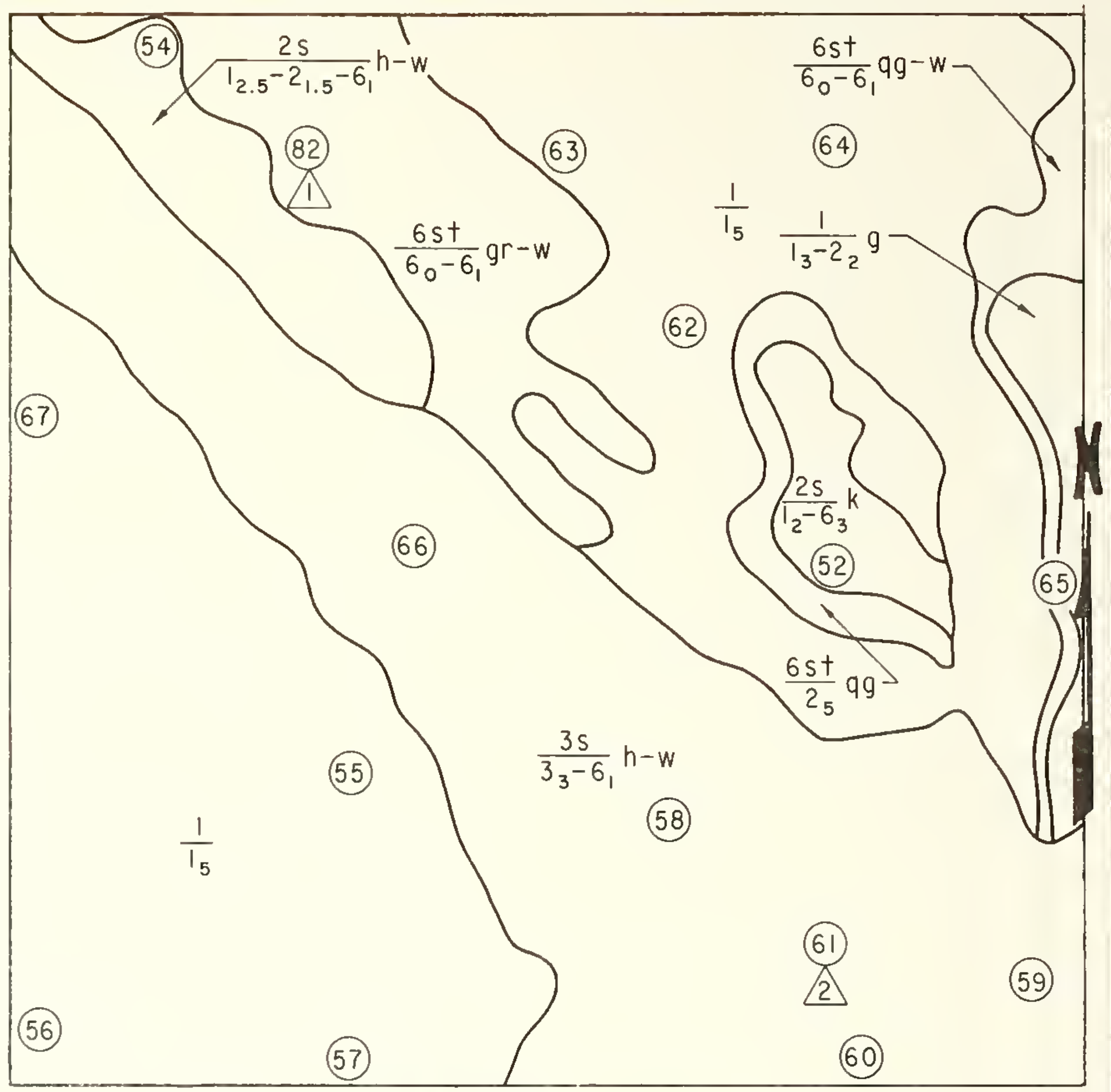
SL	5.7/20	.12/5.1
SCL	3.4/21	.03/5.3
SCL	.80/20	.04/5.3

Remarks: 5-6% NE facing slope, 10-20% by volume rock from 28-44"

NO. 82

SL	.36/15	.03/4.3
SCL	.44/19	.09/4.8
SCL	.58/17	.17/5.5

Remarks: This profile taken near Deep hole #1



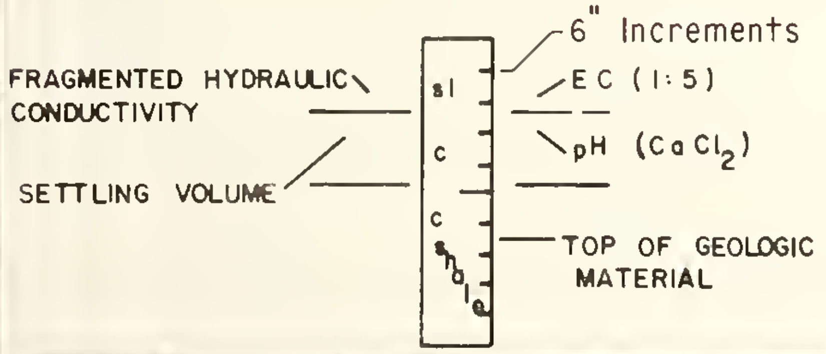
LAND SUITABILITY SYMBOLS

3st / 3₂ 6₄ - 6₄ apg - h

- 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
- Thickness of sampled geologic material
- Suitability of geologic material
- Divides soil material and non-soil material

(SEC. 28) (TWP. 9N) RANGE 78W

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
- 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
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

○ - Soil Profile Site

△ - Geologic Drill Hole Site

1000 0 1000
SCALE OF FEET

McCALLUM STUDY AREA
COLORADO

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY
McCALLUM

DESIGNED ________ SUBMITTED ________
DRAWN ________ RECOMMENDED ________
CHECKED T. CAPPELLUCCI APPROVED ________

LM REGION, DEN., COLO.

NO. 24

1.0/20	SiL	.08/5.8
1.3/19	SL	.07/5.9
1.3/20	SL	.07/6.2
	Gr SL	Insufficient Sample

Remarks: 6-10% ESE facing slope

NO. 69

1.4/20	SCL	.06/6.3
3.8/20	SCL	.04/6.3
2.5/18	SCL	.04/6.3
8.4/19	L	.11/6.4
	Gr SCL	No sample

Remarks: 3-6% East facing slope Lowterrace Gravel content from 36" to 48" is estimated to be 10-20% by volume

NO. 75

1.6/21	L	.11/6.4
.83/22	SCL	.03/6.4
5.7/13	Gr S	.02/6.5

Remarks: 5% East facing slope. Upper end of upland drainage. Soil is much shallower to gravel outwash material than normally found

NO.

NO. 53

1.8/19	L	.50/6.4
3.1/18	SL	.11/6.4
1.4/19	SCL	.07/6.4
1.3/18	SL	.08/6.5
	Soft SS (LS)	

Remarks: Soft sandstone below 27 inches

NO. 70

5.5/22	L	.08/6.3
.80/20	SCL	.11/6.4
1.2/19	Gr SL	.11/6.5
	Gr SL	Insufficient sample

Remarks: 0-3% SE facing slope. Near edge of drainage

NO. 76

1.2/21	L	.12/6.0
1.3/20	L	.04/6.2
1.4/19	L	.03/6.3
	Gr L	No sample

Remarks: 9% East facing slope

NO.

NO. 68

1.7/21	SL	.11/6.3
1.8/22	SCL	.10/6.3
.78/21	SCL	.13/6.3
	Gr SL	No sample

Remarks: 0-3% East facing slope Terrace Gravel content is estimated to be 25% by volume

NO. 74

.40/19	SCL	.03/6.7
3.6/20	SCL	.05/6.9
4.7/21	SCL	.08/7.1
3.3/16	SL	.05/7.2
	Gr SL	No sample

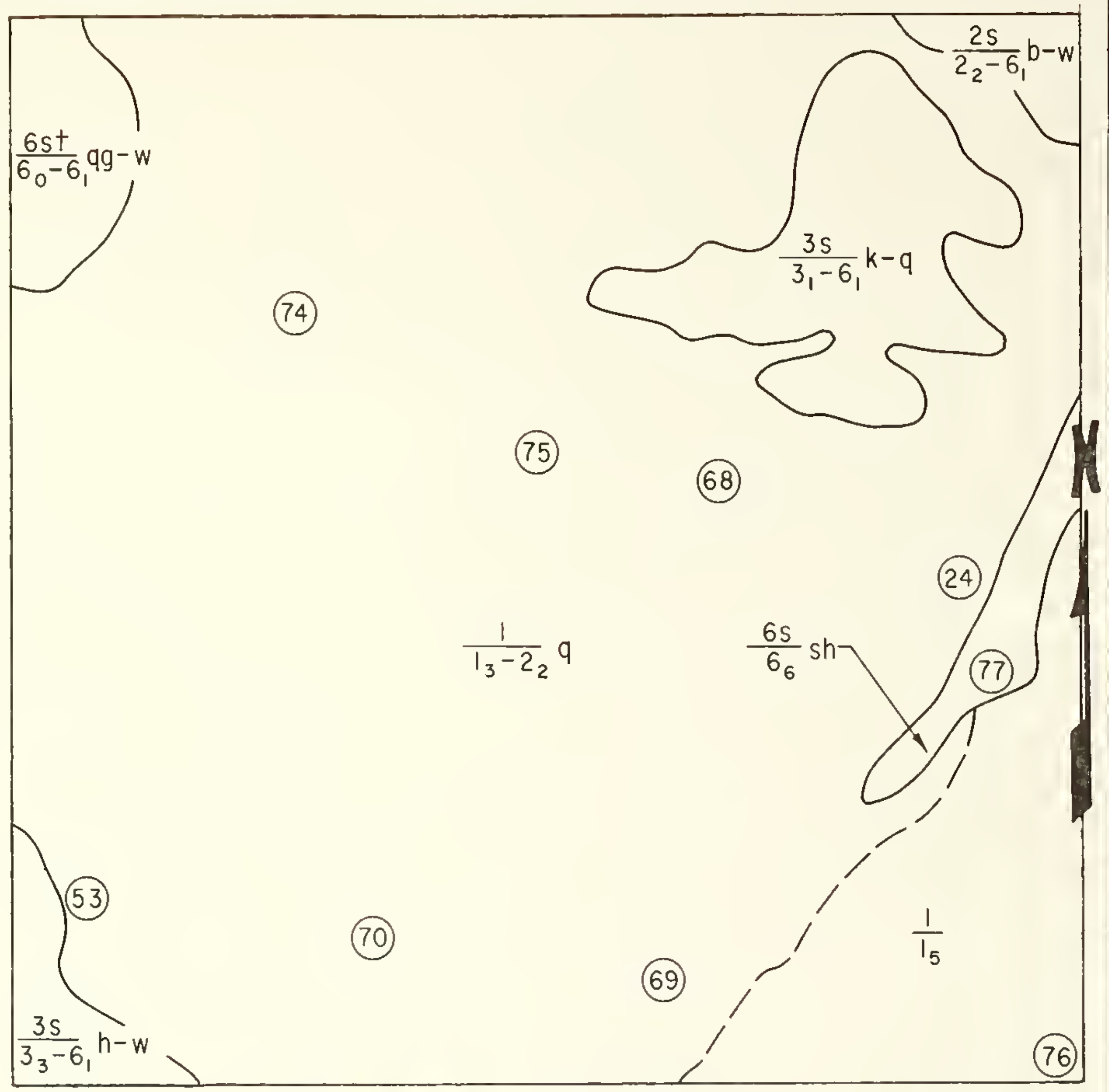
Remarks: 0-1% Outwash fan. Very calcareous below 30"

NO. 77

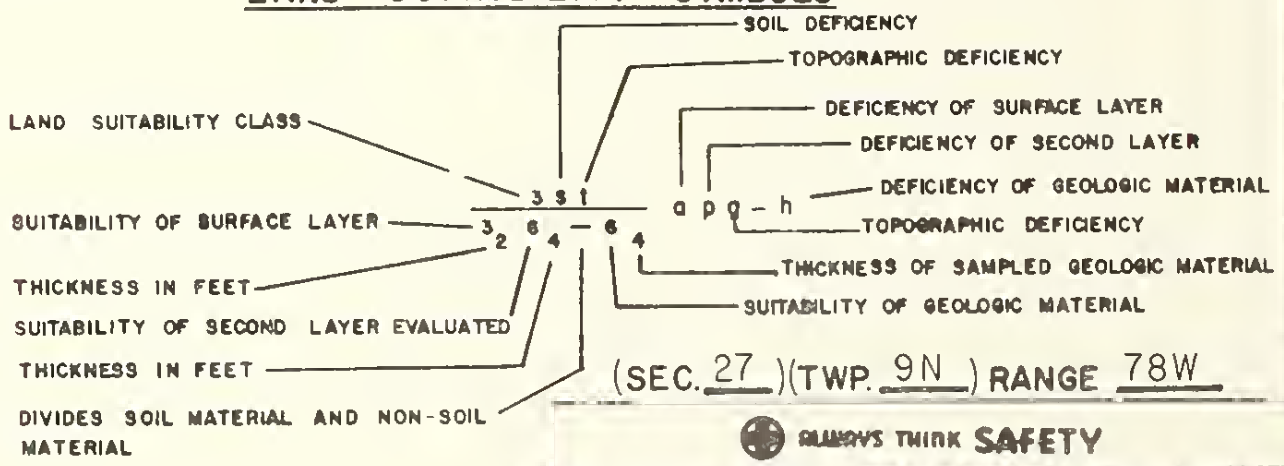
1.3/21	L	.10/6.7
.82/22	CL	.87/7.2
.80/20	SCL	.98/7.3

Remarks: 12% West facing slope Augured to 74". Lab analysis on bottom layer applies to 45-74"

NO.

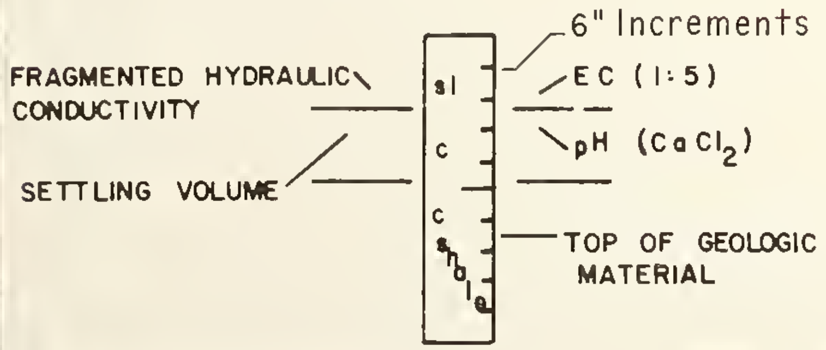


LAND SUITABILITY SYMBOLS



(SEC. 27)(TWP. 9N) RANGE 78W

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
- 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
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

○ - Soil Profile Site

△ - Geologic Drill Hole Site

1000 0 1000
SCALE OF FEET

McCALLUM STUDY AREA
COLORADO

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY
McCALLUM

DESIGNED ________ SUBMITTED ________
DRAWN ________ RECOMMENDED ________
CHECKED T. CAPPELLUCCI APPROVED ________

LM REGION, DEN., COLO.

APPENDIX C
Hydrology

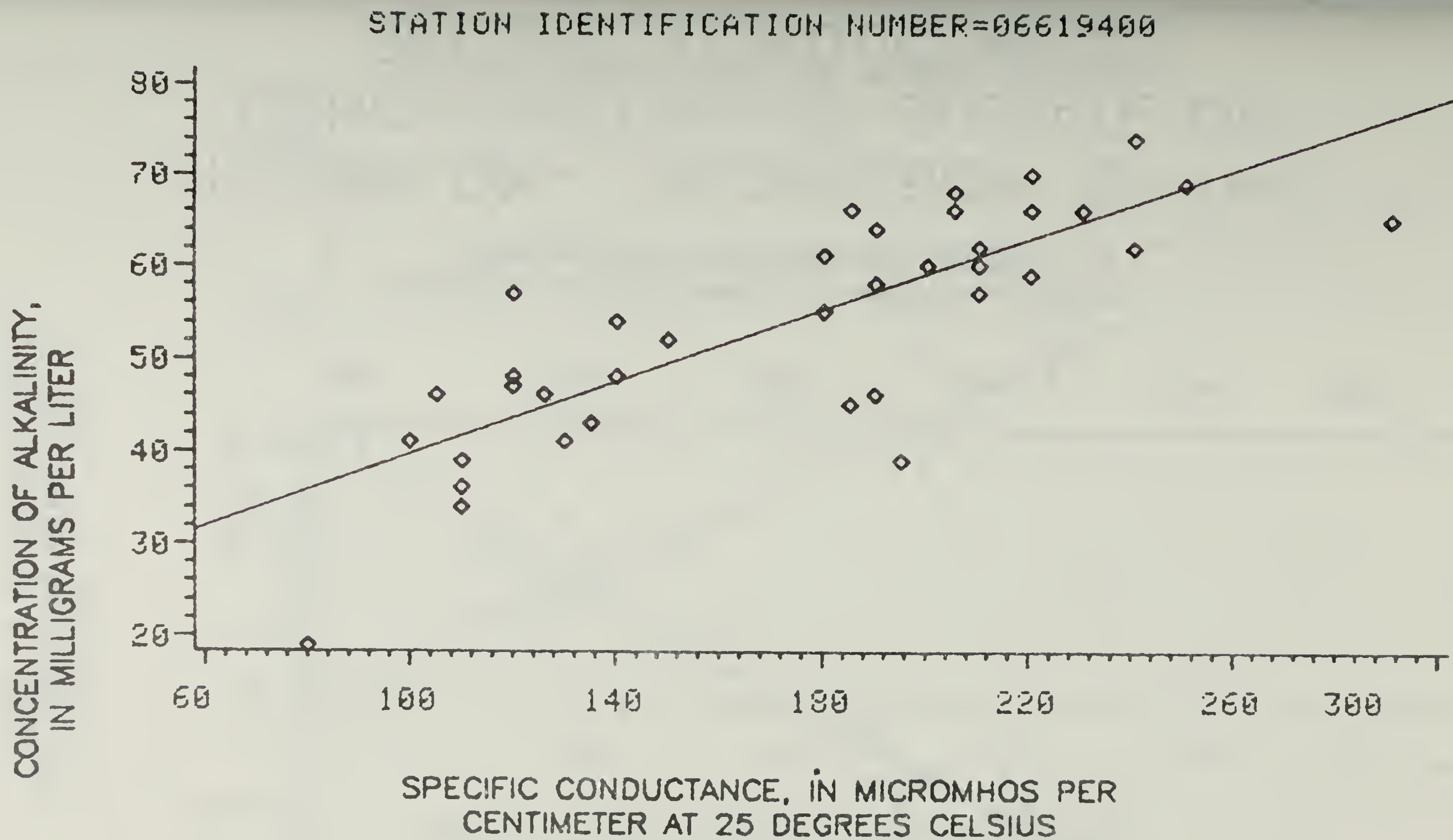


FIGURE C1.--REGRESSION OF THE CONCENTRATION OF ALKALINITY ON SPECIFIC CONDUCTANCE.

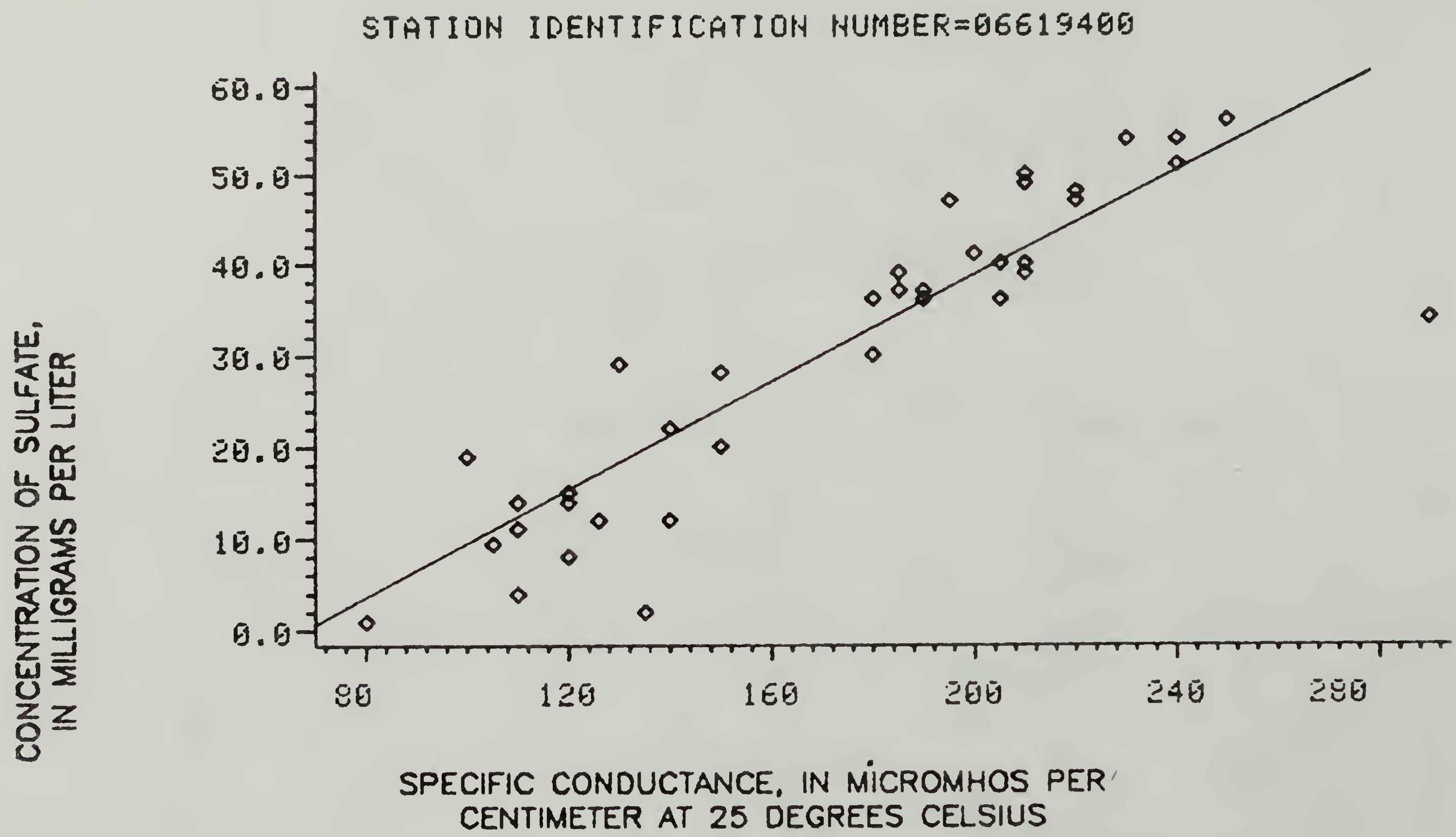


FIGURE **C2**.--REGRESSION OF THE CONCENTRATION OF SULFATE ON SPECIFIC CONDUCTANCE.

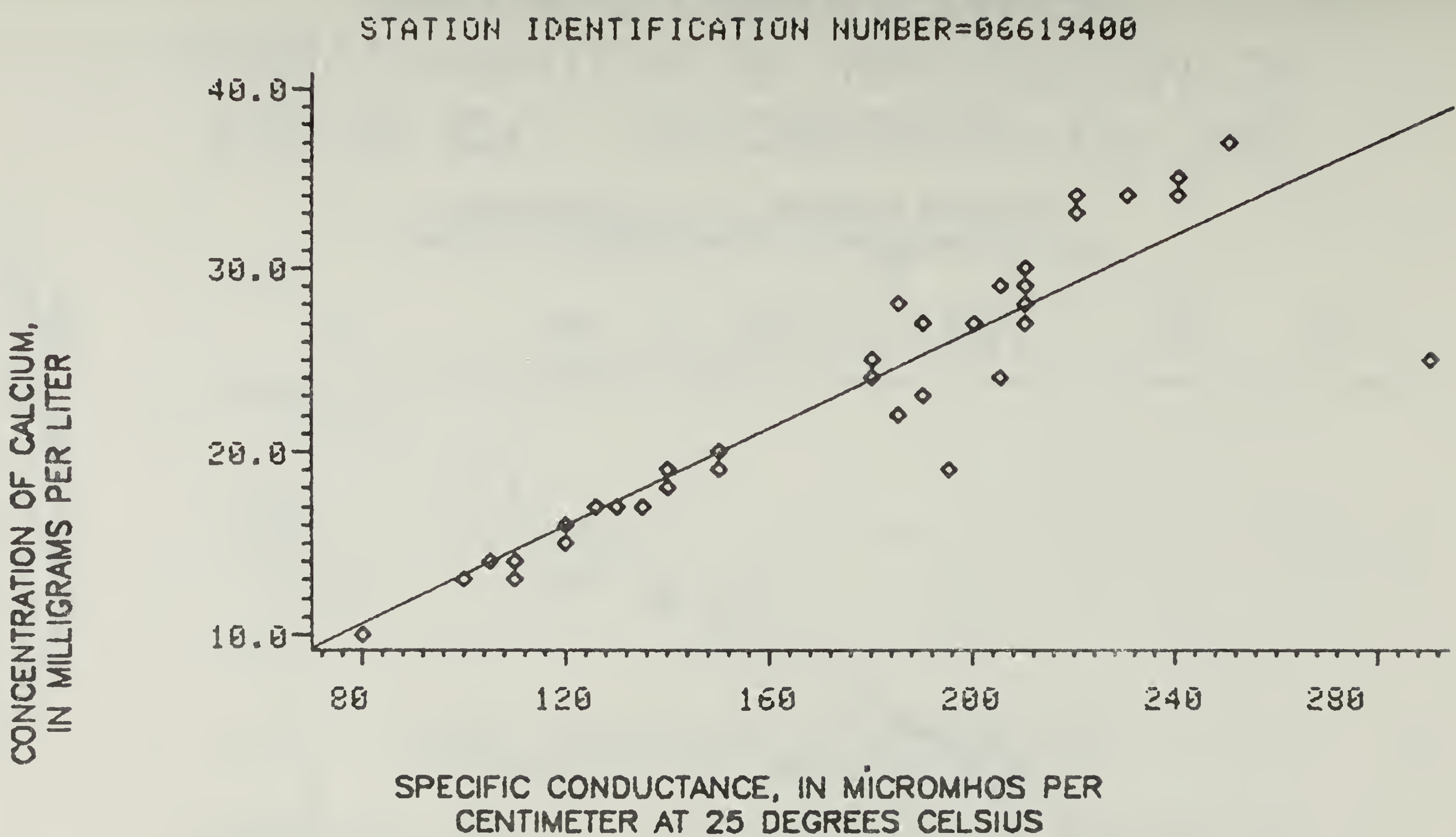


FIGURE C3.—REGRESSION OF THE CONCENTRATION OF CALCIUM ON SPECIFIC CONDUCTANCE.

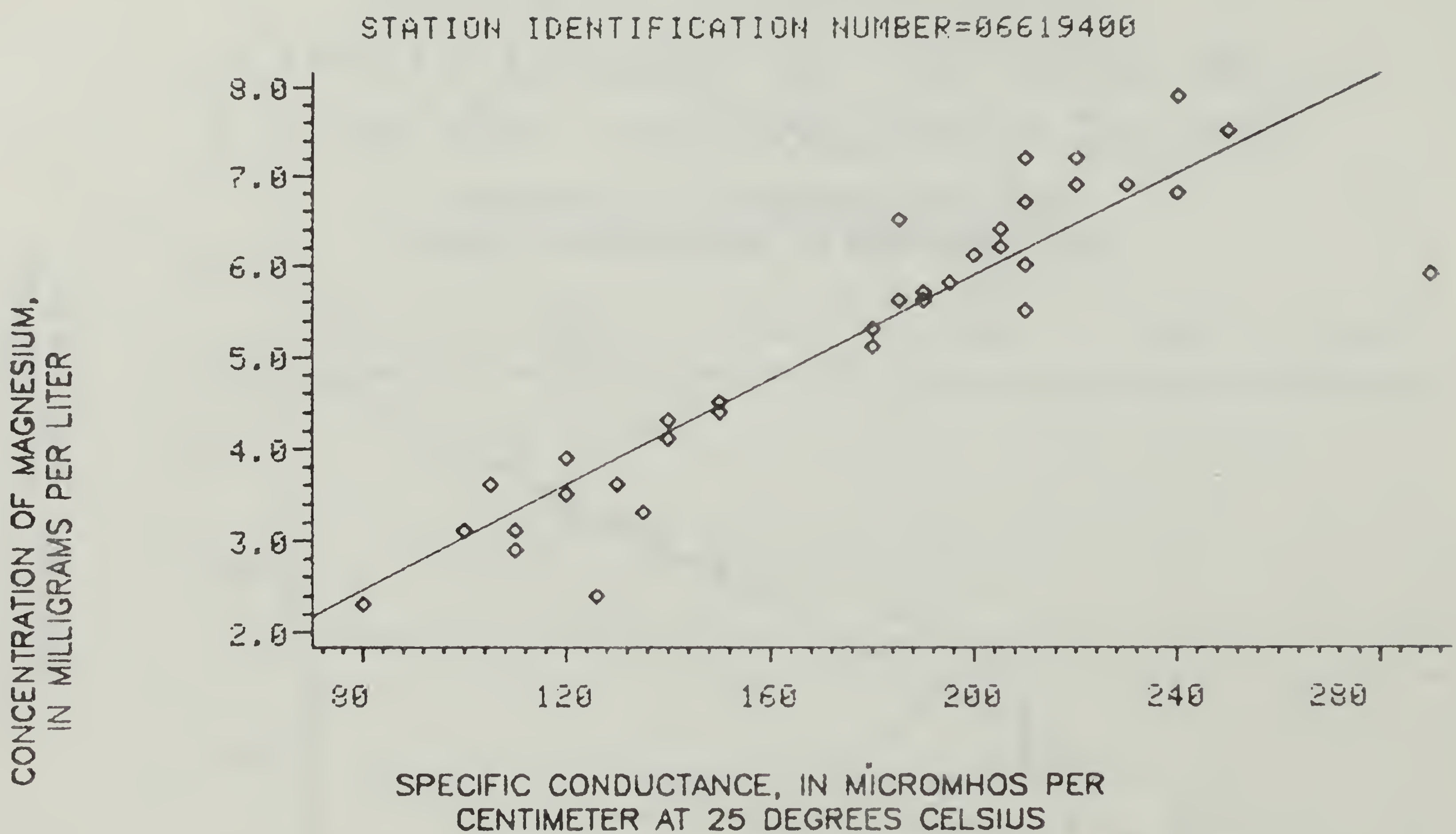


FIGURE **C4**.--REGRESSION OF THE CONCENTRATION OF MAGNESIUM ON SPECIFIC CONDUCTANCE.

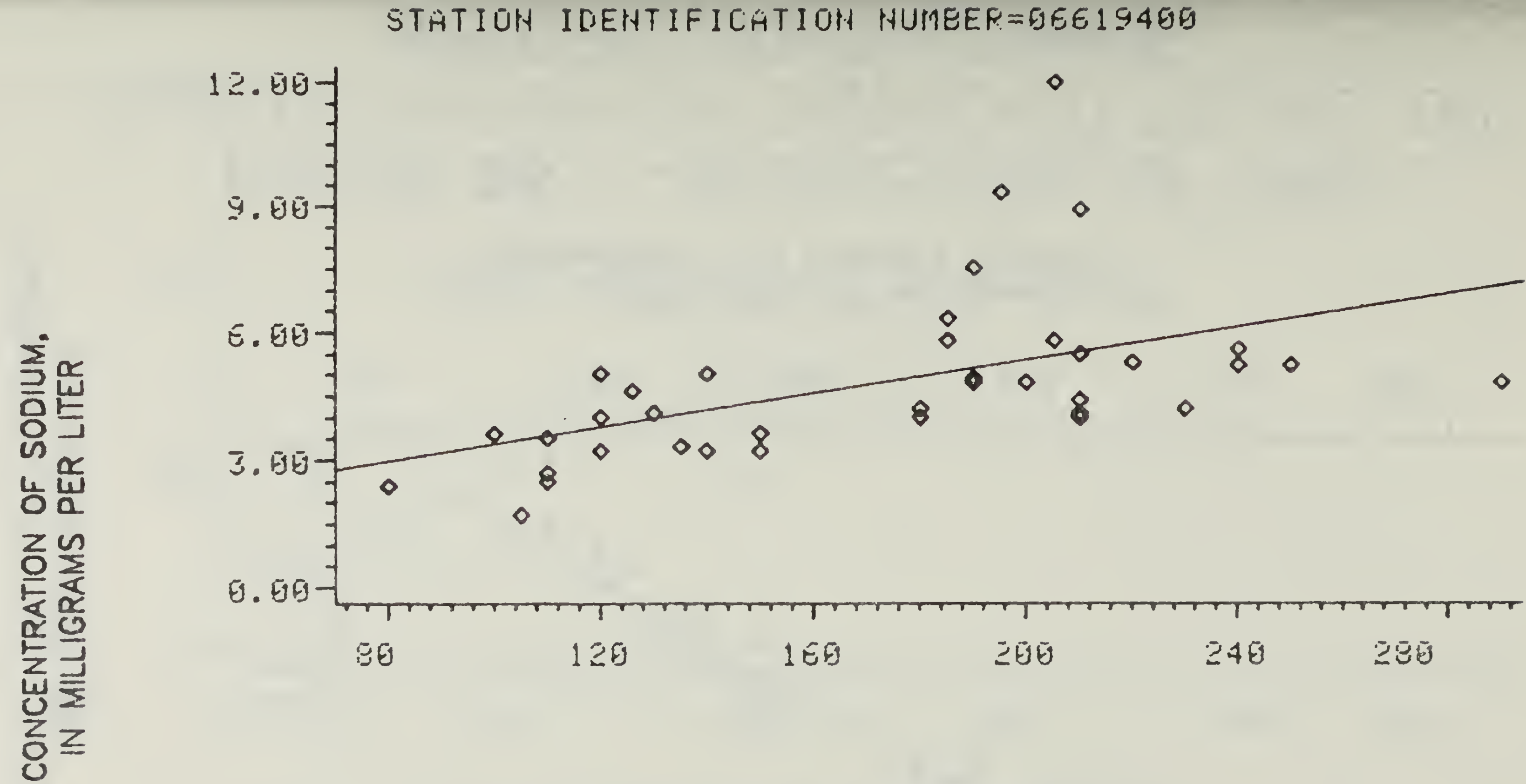


FIGURE **C5**.--REGRESSION OF THE CONCENTRATION OF SODIUM ON SPECIFIC CONDUCTANCE.

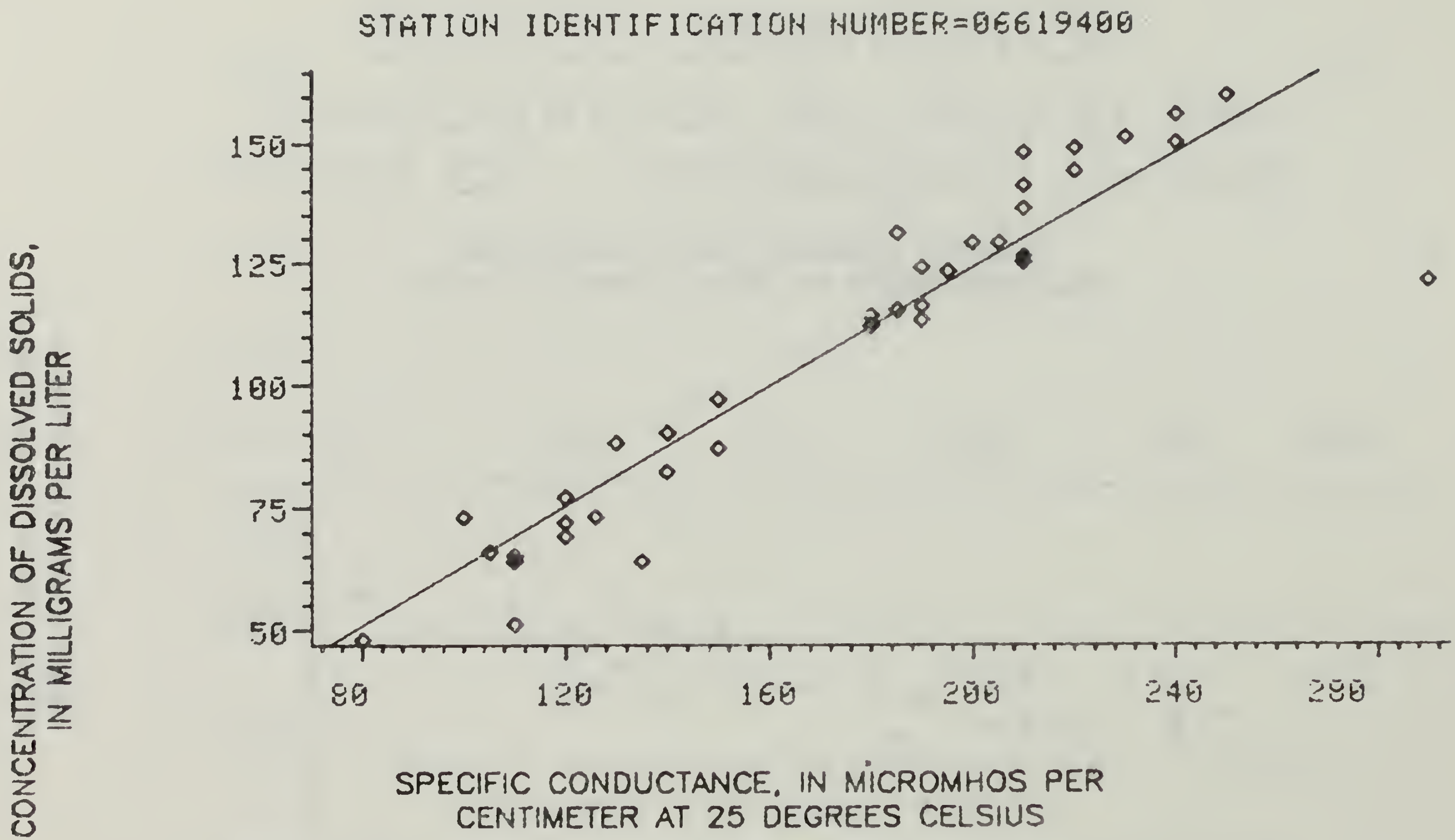


FIGURE C6.--REGRESSION OF THE CONCENTRATION OF DISSOLVED SOLIDS ON SPECIFIC CONDUCTANCE.

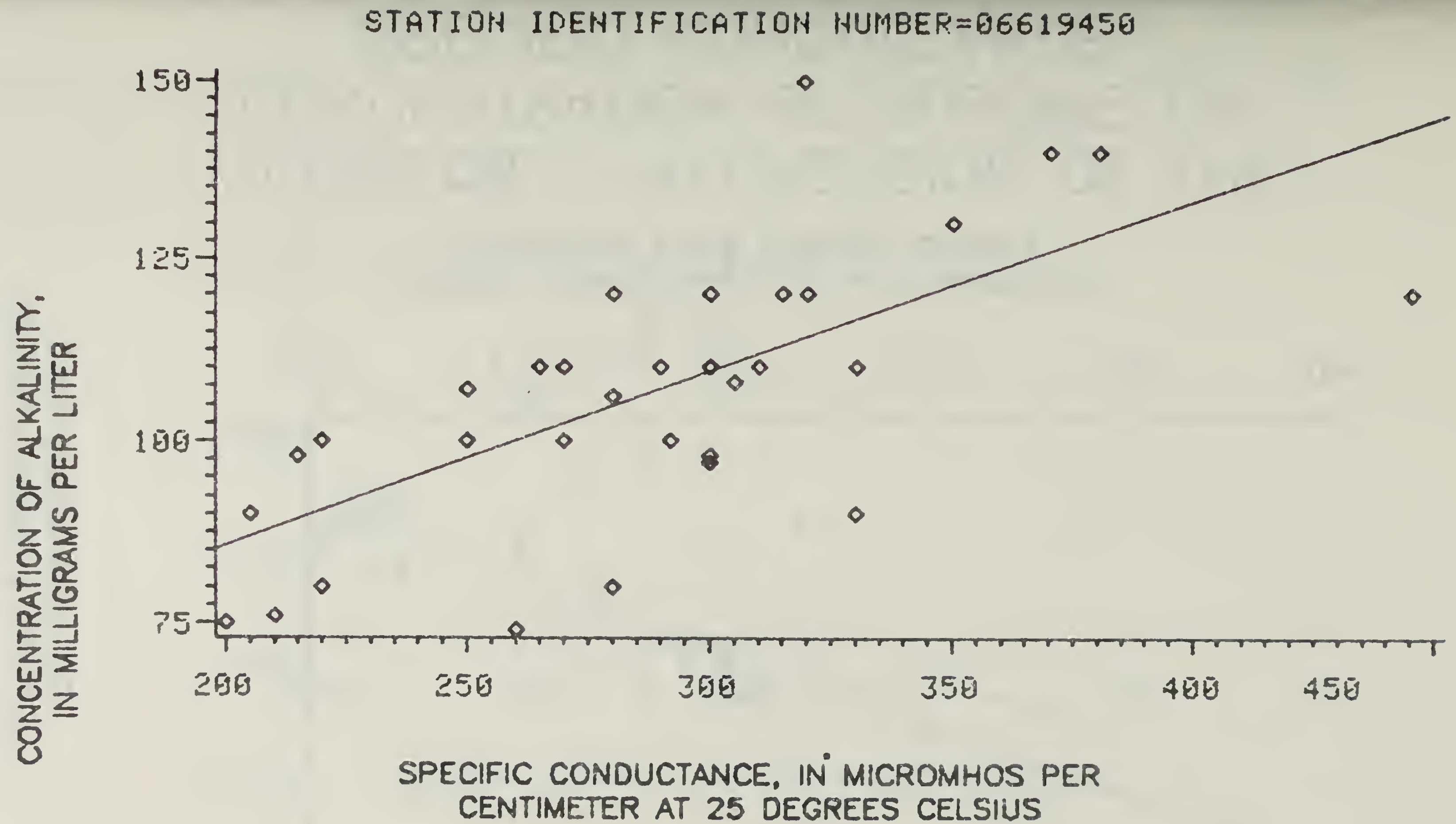


FIGURE **C7**.--REGRESSION OF THE CONCENTRATION OF ALKALINITY ON SPECIFIC CONDUCTANCE.

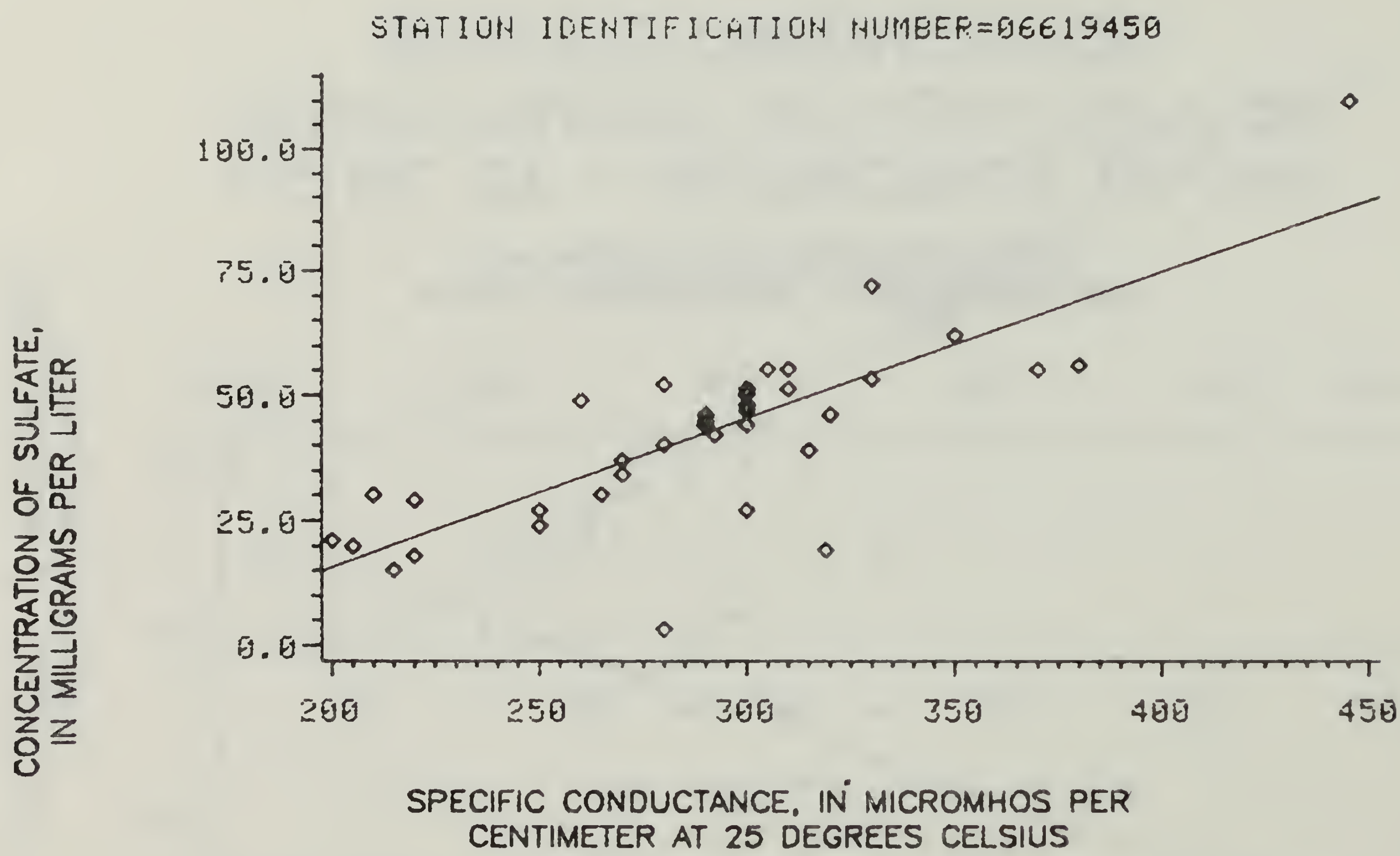


FIGURE **C8**.--REGRESSION OF THE CONCENTRATION OF SULFATE ON SPECIFIC CONDUCTANCE.

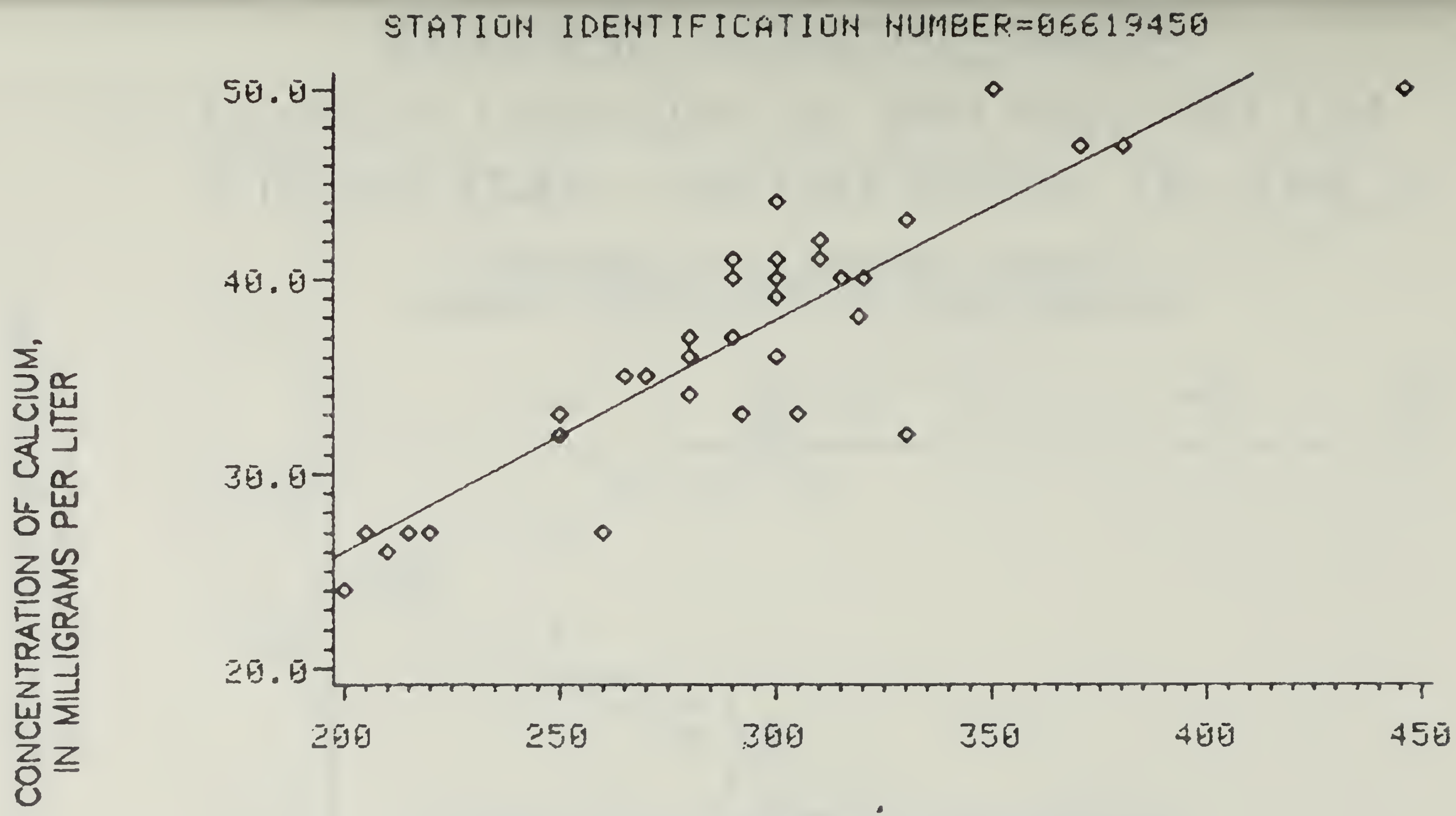


FIGURE **C9**.—–REGRESSION OF THE CONCENTRATION OF CALCIUM ON SPECIFIC CONDUCTANCE.

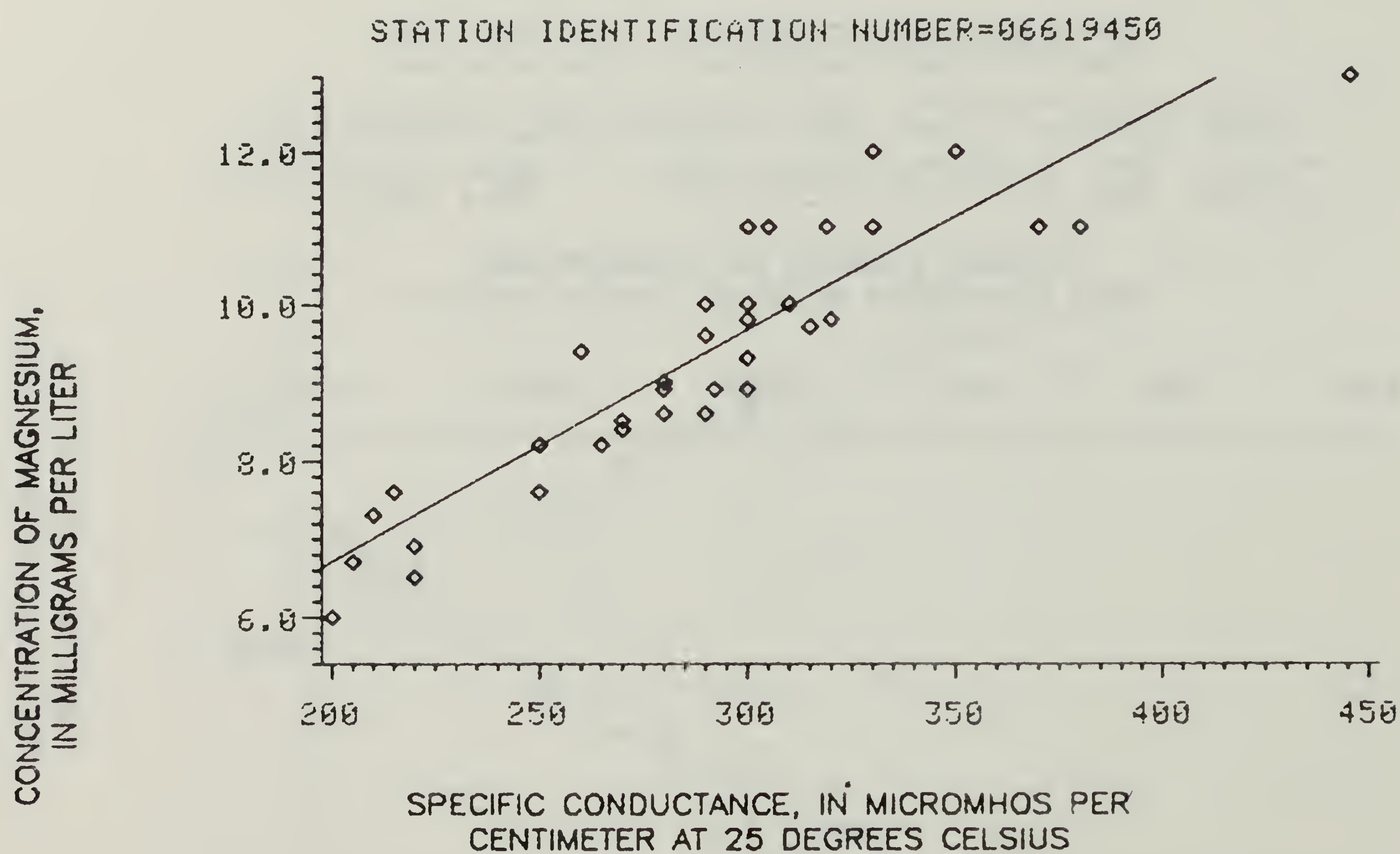


FIGURE **C10**.—REGRESSION OF THE CONCENTRATION OF MAGNESIUM ON SPECIFIC CONDUCTANCE.

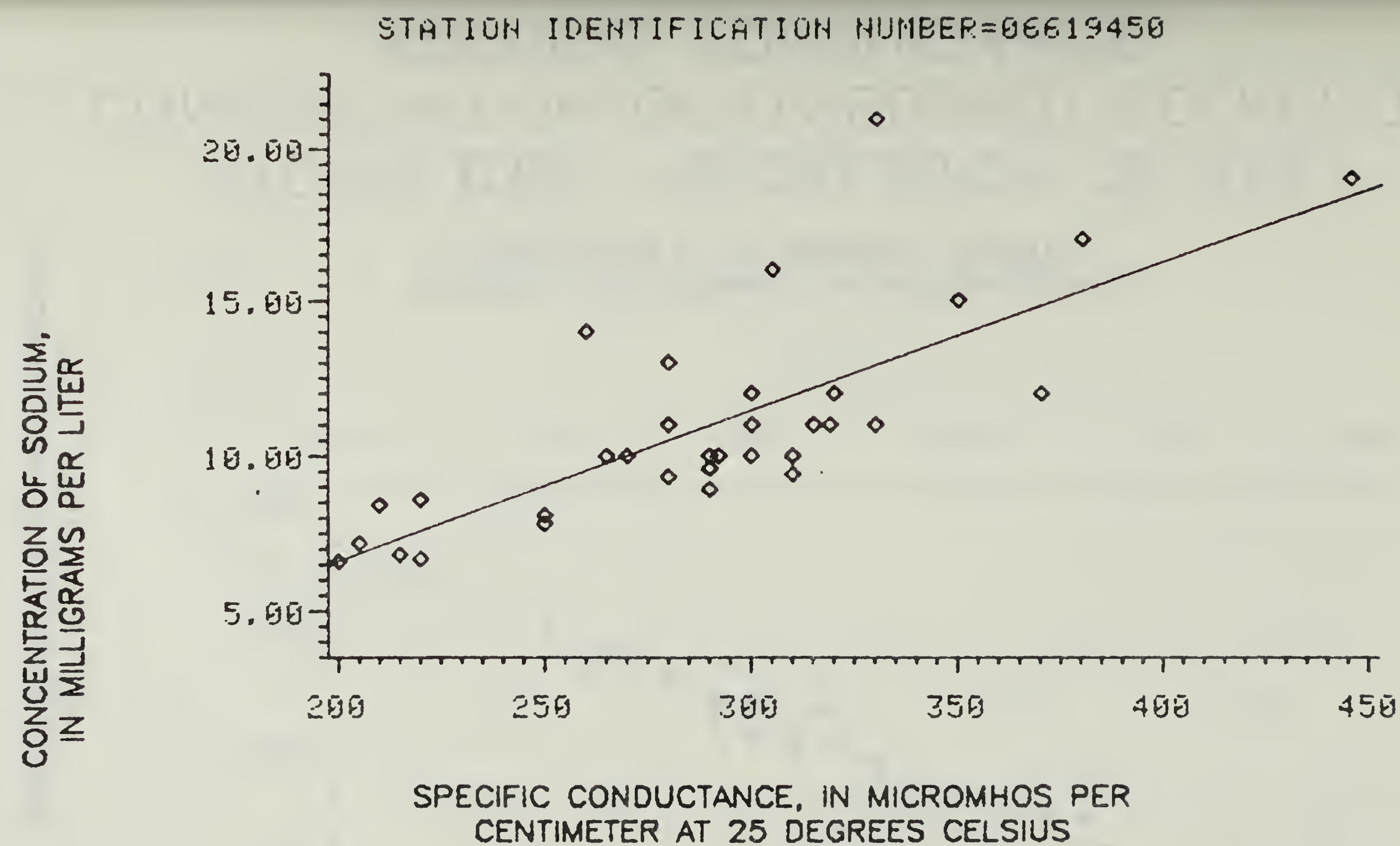


FIGURE **C11**.—REGRESSION OF THE CONCENTRATION OF SODIUM ON SPECIFIC CONDUCTANCE.

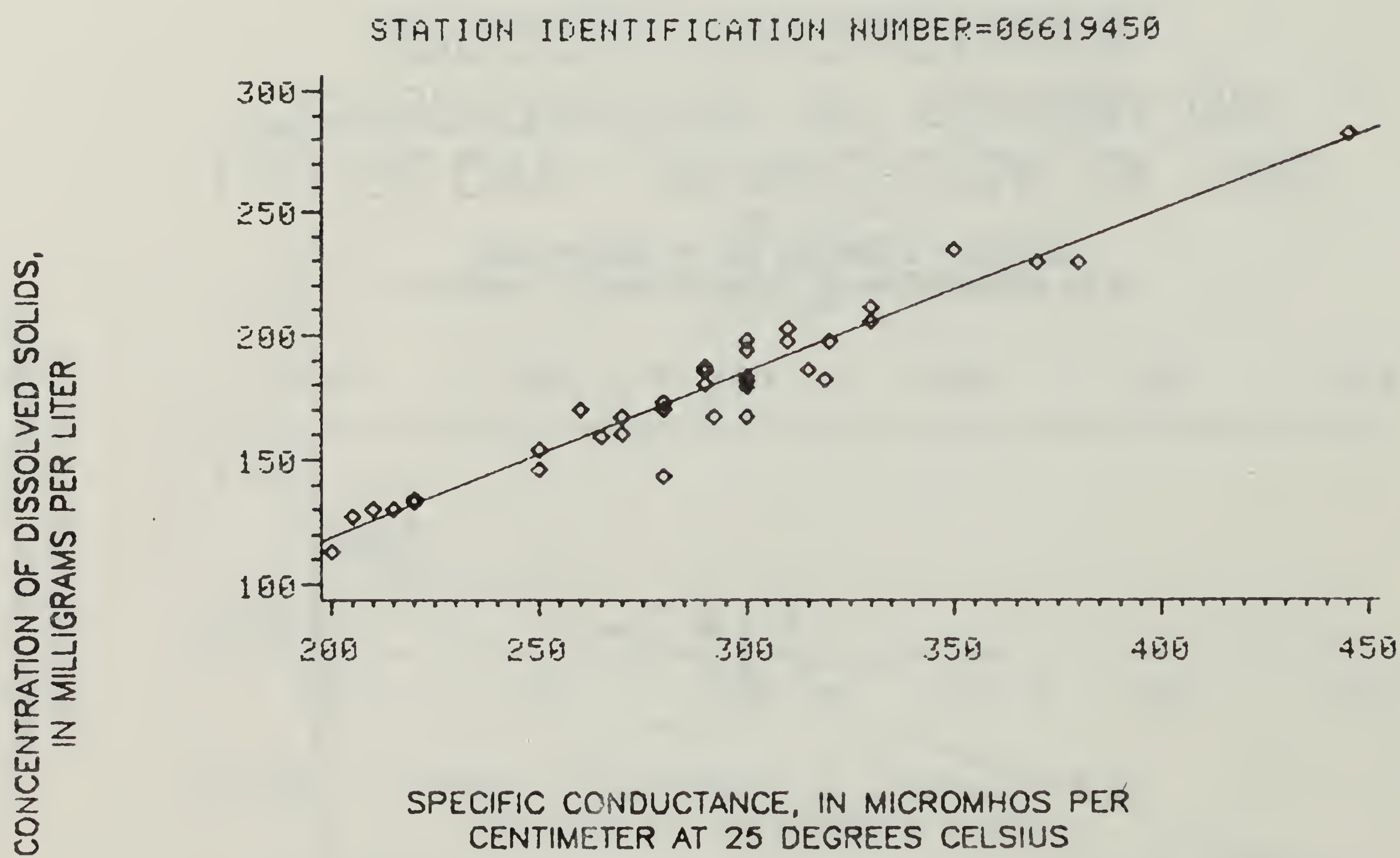


FIGURE **C12**.—REGRESSION OF THE CONCENTRATION OF DISSOLVED SOLIDS ON SPECIFIC CONDUCTANCE.

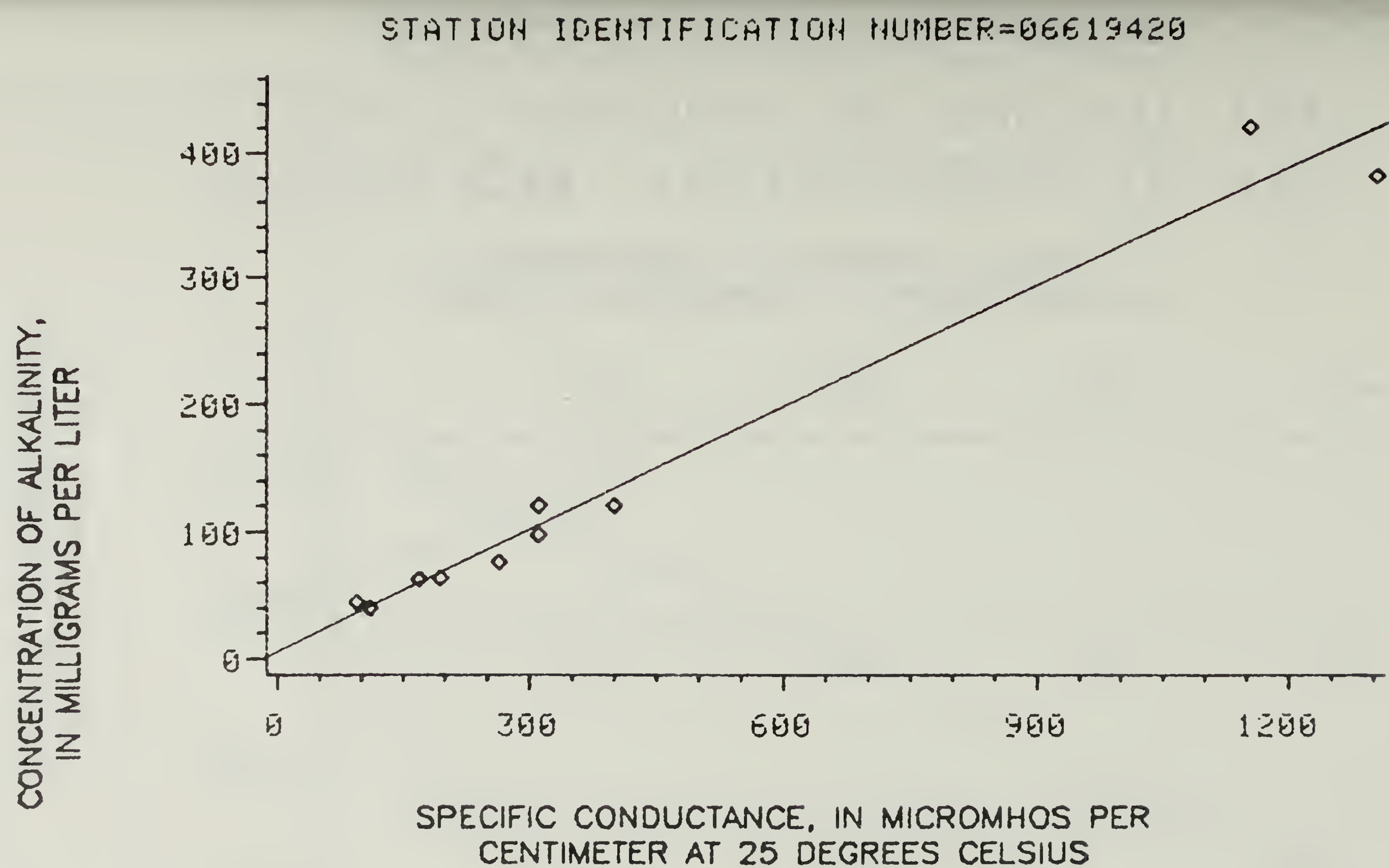


FIGURE **C13**--REGRESSION OF THE CONCENTRATION OF ALKALINITY ON SPECIFIC CONDUCTANCE.

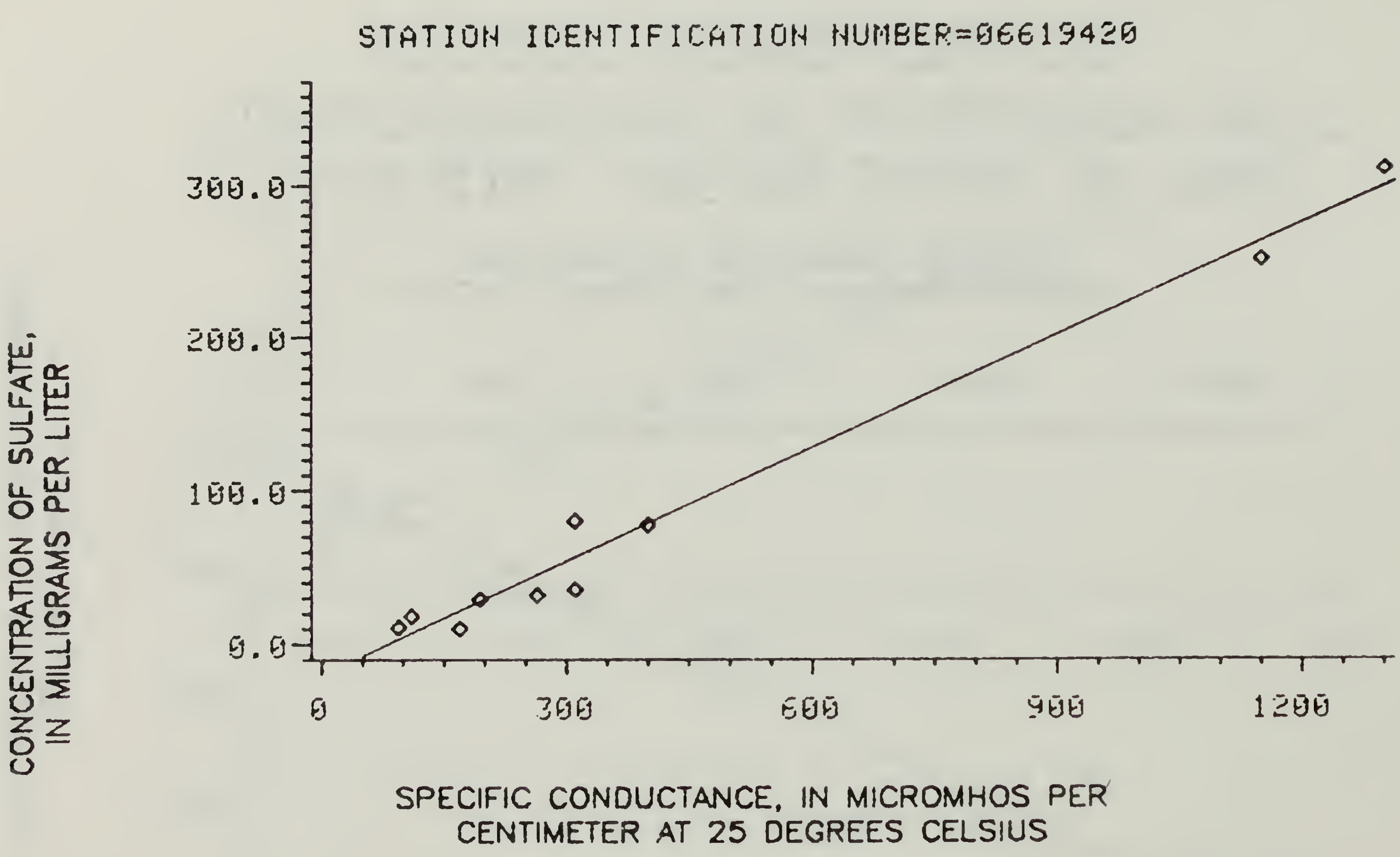


FIGURE **C14**.—REGRESSION OF THE CONCENTRATION OF SULFATE ON SPECIFIC CONDUCTANCE.

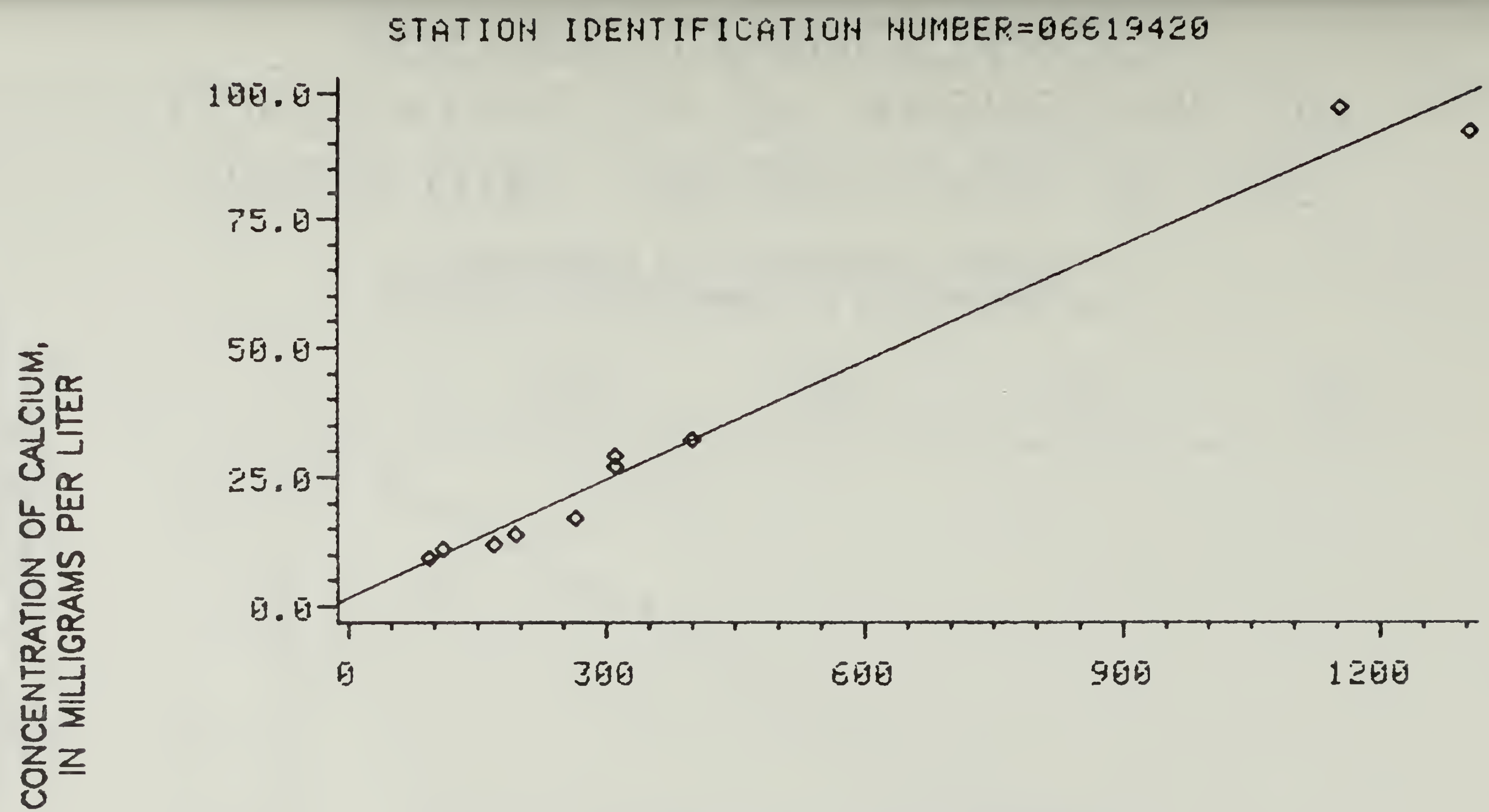


FIGURE **C15**.--REGRESSION OF THE CONCENTRATION OF CALCIUM ON SPECIFIC CONDUCTANCE.

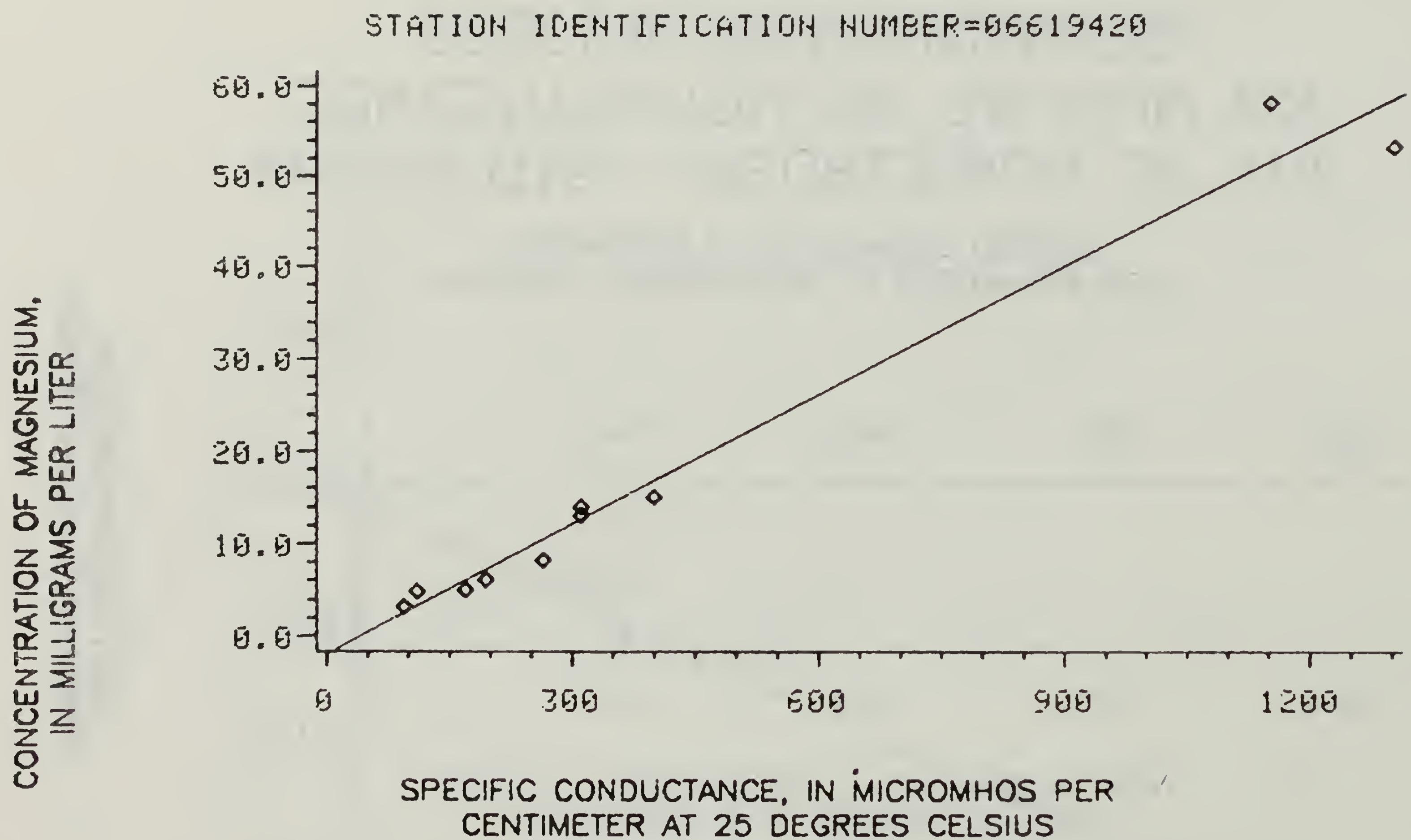


FIGURE **C16**.--REGRESSION OF THE CONCENTRATION OF MAGNESIUM ON SPECIFIC CONDUCTANCE.

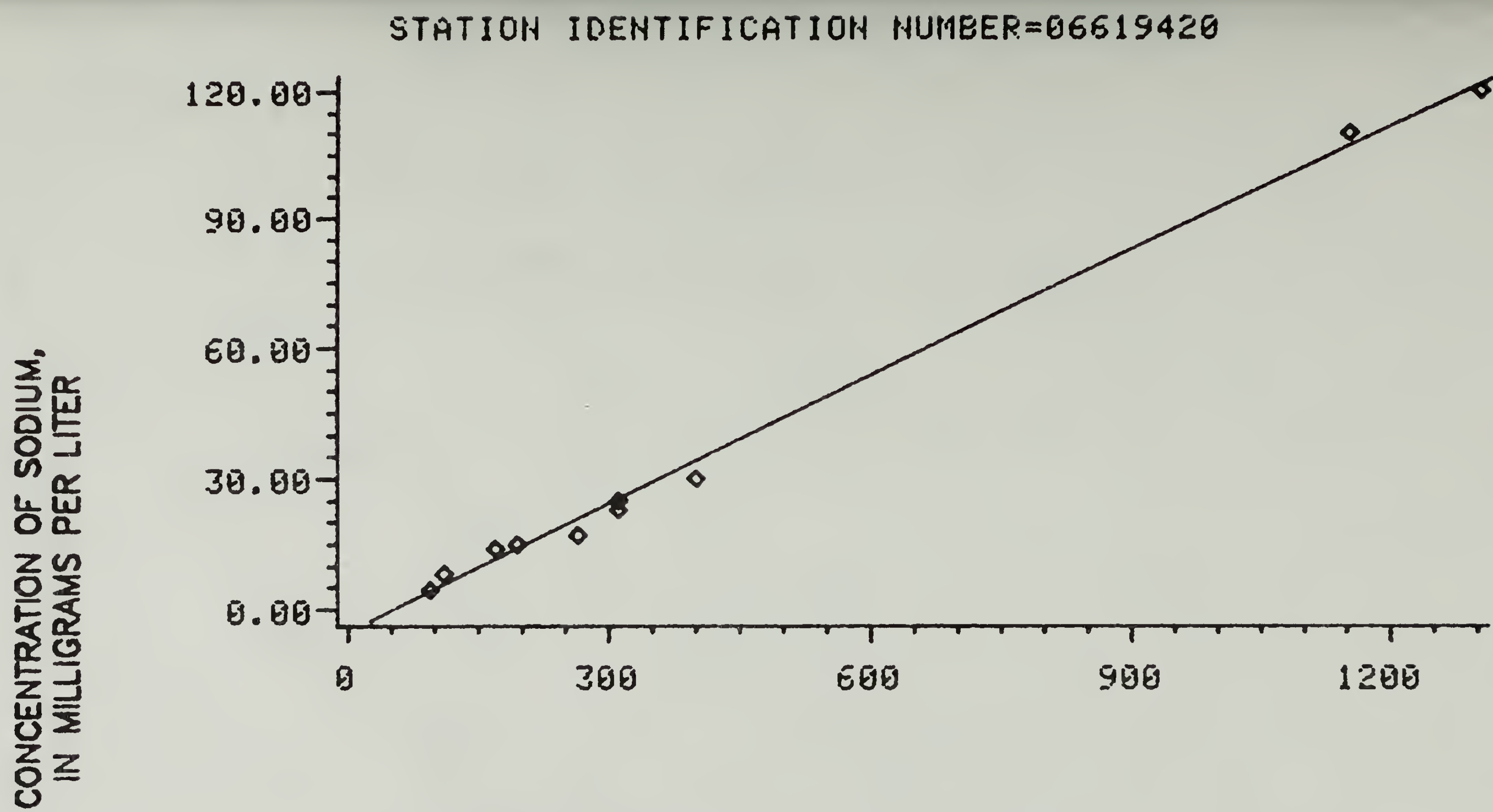


FIGURE **C17**.--REGRESSION OF THE CONCENTRATION OF SODIUM ON SPECIFIC CONDUCTANCE.

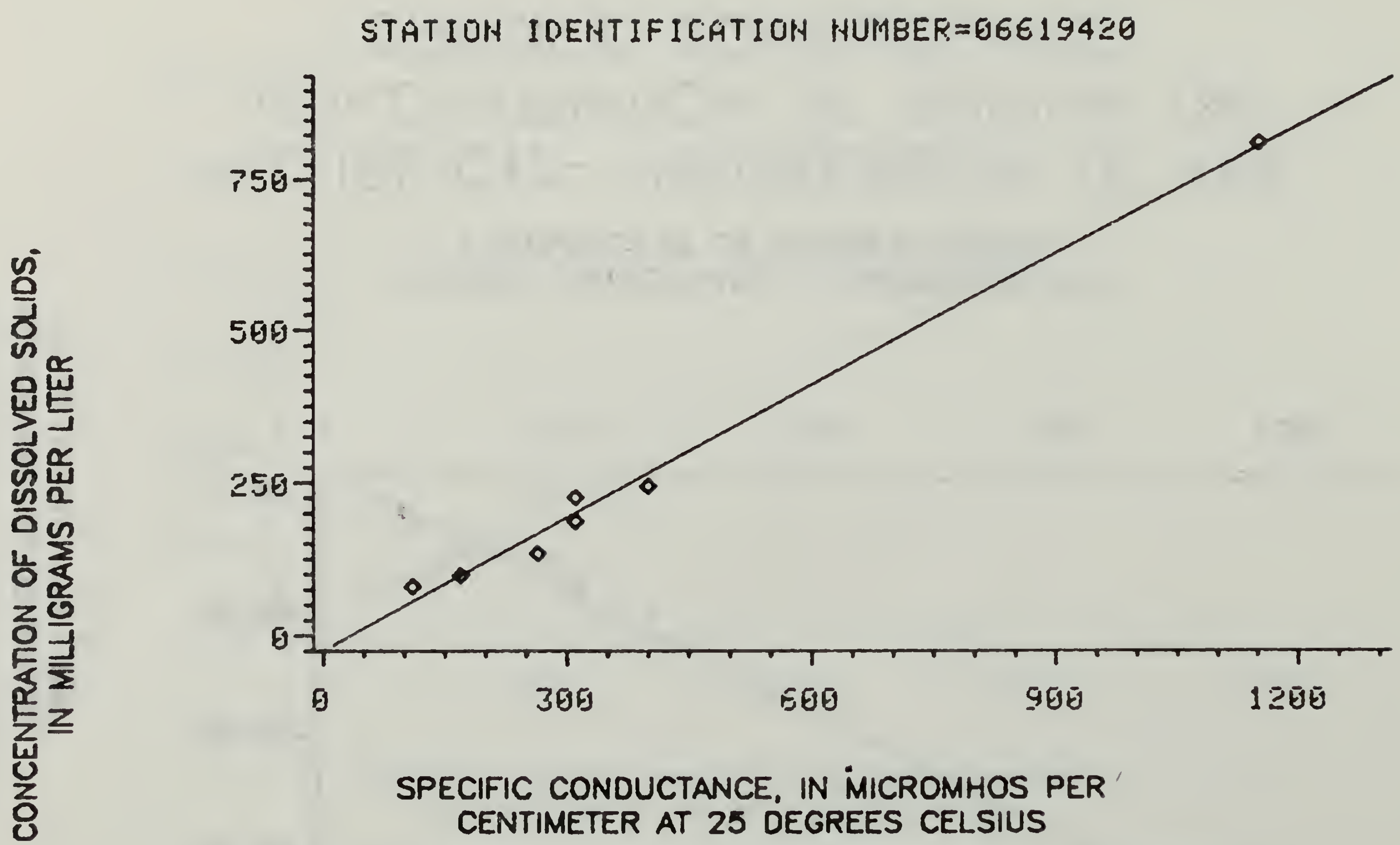


FIGURE C18.—REGRESSION OF THE CONCENTRATION OF DISSOLVED SOLIDS ON SPECIFIC CONDUCTANCE.

APPENDIX D
Greenhouse Study

CHARACTERIZATION OF SOIL AND GEOLOGIC MATERIALS OVERLYING COAL SEAMS AS PLANT GROWTH MEDIA

for

McCALLUM, COLORADO
EMRIA STUDY SITE

INTRODUCTION

This report includes our final evaluation of the greenhouse and laboratory studies of soil and geologic materials submitted from the McCallum, Colorado EMRIA site.

Included in this report are:

1. Yield data and observations from the greenhouse study.

2. Preplant and postharvest laboratory data of geologic materials and preplant data of the soil materials.

3. Evaluation of the suitability of materials as plant growth media.

4. Results of zinc deficiency study.

PART I

PROCEDURES

Laboratory Procedures

Following are the laboratory methods used to analyze the soil and geologic material for those properties selected as a basis for determining plant growth suitability.

Extractable Phosphorus

Determined on a spectrophotometer from a sodium bicarbonate extract. The values are reported in parts per million P and are an index of available P.

Exchangeable Potassium

Determined on the atomic adsorption spectrophotometer from an ammonium acetate extract. The values are reported as parts per million K.

Organic Matter

Determined by wet oxidation with spontaneous heat of reaction. The results are determined colorimetrically and reported as percent organic matter (% O.M.).

Plant Available Zinc, Iron, Manganese and Copper, Cadmium, Nickel and Lead

Determined on the atomic adsorption spectrophotometer from an extracting solution of diethylenetriamine pentaacetic acid (DTPA). The results are reported in parts per million of Zn, Fe, Mn, and Cu.

Salinity (Electrical Conductivity)

Determined by a solu-bridge from a saturation extract. The results are reported as electrical conductivity in millimhos per centimeter (mmhos/cm).

Exchangeable Sodium Percentage (ESP)

Determined by atomic adsorption spectrophotometer and calculated by:

$$ESP = \frac{\text{Exchangeable sodium (meq/100 g)}}{\text{CEC}} \times 100$$

Cation Exchange Capacity (CEC)

Determined by:

$$\text{CEC (meq/100 g)} = \frac{\text{Exchangeable Na (meq/}\ell \text{ x 100)}}{\text{wt. of sample in g}}$$

pH

Determined with a combination electrode pH meter on a saturated soil paste.

Plant Analysis

Plants were digested with perchloric acid and determinations run on the atomic adsorption spectrophotometer.

Greenhouse Procedures

Soil and geologic material received from the Water and Power Resource Service laboratory had been ground to approximately 2 mm size for greenhouse and additional chemical analyses. One kilogram of soil was used per pot and each pot was replicated. Each sample was placed in a plastic bag in a round container and assigned a greenhouse identification number.

Fertilizer Treatment

Before planting, fertilizer was applied at a rate of 150 ppm N as reagent grade NH_4NO_3; 80 ppm of P as a combination of KH_2PO_4 and $CaH_4(PO_4)_2 \cdot 2H_2O$; and 80 ppm K as KH_2PO_4. This was done along with preplant watering.

Before the fertilizer was added, 50 to 100 g of soil was removed from each pot after which the fertilizer and water was added. Additional N was applied at 50 ppm rate 21 days after seed emergence.

Planting

The pots were planted with 75 seeds of western wheatgrass (*Agropyron smithii* var. arriba). The seeds were evenly distributed in the pots and covered with the soil that was removed before fertilization.

The pots were covered with plastic to reduce evaporation and were checked daily to assure that the soil remained moist.

In this experiment, we did not thin the plants hoping to have an average of 60 plants per pot. After consulting other researchers involved in similar work as well as from our own experience, we felt that 60 plants would not put undue stress on the pot and our yields would show more significant differences. This would also give us more plant material for plant analysis.

Daily Management

All pots were weighed every other day and brought to field capacity with distilled water. The greenhouse lights were set to allow 15 to 16 hours of daylight.

Pots were rotated on a regular basis to allow for changes in temperature and lighting within the greenhouse. All pots were randomly arranged on the table.

Harvest

We harvested 48 days after planting. The plants were harvested by cutting at about 2 cm above the soil surface. Plants were then placed in brown paper bags and dried at $60^{o}C$ for 48 to 60 hours in a forced air oven. After drying, the plants were weighed and weights recorded.

Criteria for Evaluation

The properties considered and criteria used for making suitability interpretations follow in Table 1.

Table 1. Suitability Evaluation Criteria

pH

pH	Rating
6.0-8.4	good
5.0-6.0; 8.4-8.9	fair
<5.0; >8.9	poor

Available Zinc[1]

Soil Test - ppm Zn	Availability Status
0-0.5	potentially deficient
>0.5	adequate

Available Iron[1]

Soil Test - ppm Fe	Availability Status
0-2.0	potentially deficient
>2.0	adequate

Available Copper and Manganese[1]

Soil Test - ppm Cu or Mn	Availability Status
0-0.5	potentially deficient
>0.5	adequate

Sodium

Exchangeable Sodium Percent	Rating
0-10	acceptable
10-15	marginal
>15	nonacceptable

Available Phosphorous[1]

Soil Test - ppm P	Soil Phosphorous Fertility Status
0-7	deficient
>7	adequate

Available Potassium[1]

Soil Test - ppm K	Soil Potassium Fertility Status
0-60	deficient
>60	adequate

Salinity[2]

Soil Test - mmhos/cm	Rating
0-4	acceptable
4-8	marginal
8-12	poor
12	unsuitable

[1]Criteria are based on current Colorado State University Soil Testing Laboratory soil interpretation guidelines.

[2]Criteria are based on USDI- Bureau of Reclamation Land Suitability Classification evaluation procedures.

Organic matter (organic carbon data) were not used for evaluating the nitrogen supplying ability of the overburden materials because of lack of data concerning the type of organic materials present. We are quite certain that the nature of organic materials found in the overburden materials is quite different from that found in surface soils, thus any attempt to evaluate the relationship between organic carbon and nitrogen as related to plant growth would be meaningless. As a result, only NO_3-N was used as an indicator of nitrogen status.

PART II

PLANT GROWTH SUITABILITY EVALUATION BASED ON LABORATORY CHARACTERIZATION

This portion of the evaluation and characterization study involved two steps. An initial evaluation was performed to identify the chemical and/or physical problems associated with the materials that influence plant growth. This resulted in the development of "Problem Identification Categories". Secondly, the "Problem Identification Categories" were further grouped into what are described as "Problem Area Groups". The purpose of this latter grouping was to aggregate "Problem Identification Categories" such as fertility, salinity, pH, texture, etc., into more meaningful and manageable groups for evaluating the magnitude of potential long-term management and environmental concerns. Following is described the evaluation process used for interpreting plant growth suitability on the basis of laboratory characterization data.

Geologic Materials

Development of Problem Identification Categories

Basic to determining plant growth suitability is the identification of the specific kinds of problems that affect the use of a material for this purpose. The properties considered and the criteria used for interpretation in this part of the study are shown in Table 1. The chemical and physical data used for this evaluation are shown in Table 2. This step in the process resulted in the identification of 15 "Problem Identification Categories" which are described in Table 3.

A study of these categories indicates that the following specific kinds of limitations exist in terms of the suitability of the materials as plant growth media.

1. Phosphorus deficiencies are common to all the geologic material studied.

2. Potential micronutrient deficiencies occur on a few samples from DH-3 and DH-5 with Zn and Cu being the most common. It is important to point out that the criteria used for evaluating micronutrient deficiencies are based on deficiencies observed on agronomic crops sensitive to these elements.

3. Sodium problems are common to a large percentage (70%) of the geologic materials studied. The Na problem offers reduced plant growth, reduced physical quality of the material, and potential reduced water quality in the study area.

Table 2. Preplant analyses of geological materials from McCallum, Colorado.

Sample No.	Yield gm/pot	Depth ft.	pH	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	P (ppm)	K (ppm)	% O.M.	mmhos/cm E.C.	ESP	CEC
DH-1-3	1.20	4-11.5	7.3	42.0	2.16	2.16	6.08	0	320	1.00	2.740	4.02	42.0
4	1.50	11.5-18.0	6.6	15.6	3.00	3.84	3.68	0	335	1.00	2.200	2.60	55.6
6	1.27	26.0-36.4	7.7	48.0	3.20	3.52	5.12	0	246	1.10	.724	1.60	44.2
8	0.88	41.0-55.0	7.4	35.0	4.16	4.24	.64	0	170	1.20	.806	1.30	30.6
10	2.05	66.2-72.2	7.3	440.0	1.56	1.46	4.64	0	60	.85	1.270	3.70	9.0
11 & 12	1.25	72.2-90.2	7.5	32.0	2.16	2.08	3.52	0	75	.85	.655	1.90	15.1
15	0.64	106.0-122.0	7.4	372.0	2.22	1.34	5.28	0	81	1.20	.942	2.00	11.6
17	0.44	158.5-168.3	8.3	19.4	2.22	.90	.72	0	75	.35	.853	2.40	22.6
19	0.39	173.5-188.7	8.8	70.0	1.00	1.24	1.12	0	39	.45	.532	18.00	8.4
20	0.23	188.7-200.0	8.6	58.0	.44	.62	1.04	0	33	.50	.867	15.10	8.4
22	0.38	205.0-221.0	8.4	20.0	.40	.28	.64	0	27	.35	.668	15.20	8.2
DH-2-3	1.40	4.5-8.0	7.1	12.8	1.24	1.56	8.80	0	285	.30	4.770	8.30	29.0
5	1.68	10.2-23.0	7.7	9.6	1.64	2.08	2.56	0	285	.50	1.180	12.50	61.0
6	1.20	23.0-26.5	7.4	86.0	1.30	1.20	9.92	0	240	.30	.898	11.80	32.0
7	1.46	26.5-33.7	7.6	14.4	1.50	1.70	4.96	0	325	.20	.814	14.10	38.0
8	1.72	33.7-43.9	8.0	24.0	.80	.66	5.12	0	225	.10	.722	12.60	25.8
10	1.12	50.7-60.8	8.0	50.0	2.90	2.16	2.08	0	291	.65	.988	16.10	27.0
11	1.01	60.8-71.7	7.8	58.0	5.40	4.40	1.76	0	370	.75	1.720	14.90	35.6
12	1.47	71.7-87.6	8.1	52.0	7.70	5.76	1.76	0	435	.95	1.520	14.50	31.0
14	1.62	91.2-101.7	8.0	48.0	6.70	4.00	4.00	0	330	1.30	1.280	16.00	25.8
16	1.28	108.2-111.7	7.8	40.0	7.02	2.80	3.04	0	260	1.05	1.730	18.00	24.0
20	0.83	131.7-145.2	7.8	48.0	15.60	4.72	3.52	0	290	1.90	1.260	18.50	22.4
23	0.06	209.0-221.2	7.0	148.0	.80	.88	5.60	0	35	1.75	1.770	34.30	3.5

Table 2. (Continued).

Sample No.	Yield gm/pot	Depth ft.	pH	ppm Fe	Zn	Cu	Mn	P	K	% O.M.	mmhos/cm E.C.	ESP	CEC
DH-3-4	0.62	10.5-18.3	7.3	10.4	.48	.24	10.24	0	33	.05	.413	.84	.26
6	0.66	30.0-36.0	7.3	64.0	.86	2.16	7.36	0	51	.45	.441	.88	.30
8	1.43	41.5-47.0	7.5	180.0	.80	2.80	3.52	0	57	.55	.414	.86	.24
11	0.60	60.0-70.0	7.5	80.0	3.90	2.16	2.72	0	114	.55	.559	1.15	.40
12	0.61	70.0-80.0	7.5	104.0	4.36	1.74	2.56	0	144	1.15	1.470	1.40	.38
16	0.54	106.3-117.7	7.7	64.0	2.50	1.76	1.76	0	190	1.40	1.700	15.30	1.20
17	0.73	117.7-128.5	7.7	68.0	3.10	1.60	2.08	0	230	1.45	1.770	17.80	2.25
18	0.87	128.5-138.1	8.0	102.0	2.50	2.16	1.36	0	231	1.50	--	--	3.00
20	1.55	150.0-160.0	8.5	78.0	2.68	1.86	1.76	0	234	1.35	1.590	22.20	3.50
DH-4-2	1.30	8.0-12.0	7.6	60.0	1.00	1.46	6.40	0	135	.30	4.920	4.40	1.18
3	.64	12.0-20.5	7.7	34.0	.78	2.40	10.56	0	160	1.35	--	--	.56
6	.55	34.9-43.0	7.3	90.0	2.22	1.70	2.40	0	174	1.90	--	--	.56
8	0.36	50.0-64.2	8.0	336.0	2.22	1.70	2.72	0	189	1.65	--	--	2.18
11	1.22	79.8-100.0	8.7	118.0	2.60	3.12	1.92	0	225	1.70	1.140	15.50	5.40
13	1.24	109.3-124.9	8.8	100.0	2.00	2.56	2.24	0	180	1.00	.938	14.30	5.20
15	1.91	133.0-144.0	8.7	88.0	2.16	2.00	1.92	0	216	1.20	1.210	14.20	6.20
18	1.37	153.0-159.0	8.7	106.0	3.10	2.16	3.20	0	195	1.15	1.170	22.50	6.60
20	0.82	163.0-171.9	9.0	28.4	3.00	1.30	3.04	0	180	.50	.809	13.80	6.20
23	0.52	200.0-216.4	9.0	100.0	.80	.72	1.36	0	117	.25	--	--	4.80
25	0.69	231.6-243.0	9.1	26.0	.90	1.00	2.24	0	150	.15	.672	11.8	6.20

Table 2. (Continued).

Sample No.	Yield gm/pot	Depth ft.	pH	Fe	Zn	Cu	Mn	P	K	% O.M.	mmhos/cm E.C.	ESP	CEC
				ppm									
DH-5-2	0.67	3.2-12.4	6.3	108.0	3.90	4.16	14.80	0	60	3.35	--	--	.40
4	0.14	30.5-40.5	6.7	280.0	2.90	.96	6.24	0	--	--	--	--	.26
6	0.26	50.5-59.2	5.7	120.0	1.80	1.22	4.32	0	69	1.10	--	--	.25
8	0.85	70.5-84.0	7.8	70.0	2.50	5.28	1.20	0	135	1.35	2.530	13.0	1.54
9	1.53	84.0-100.0	8.1	74.0	2.30	1.26	1.76	0	162	1.30	1.390	15.8	4.20
11	1.37	110.5-120.5	8.0	56.0	2.50	1.44	2.08	0	160	--	1.820	29.8	6.00
13	1.17	133.7-140.5	8.3	92.0	3.90	2.24	2.24	0	228	1.65	2.340	34.4	7.20
15 & 16	1.23	149.0-169.5	5.9	74.0	2.16	1.36	2.56	0	174	.70	2.300	32.8	6.80
17	1.27	169.5-179.3	8.6	148.0	2.90	.88	1.76	0	165	.85	1.690	33.9	5.60
19	1.09	190.5-200.0	8.8	76.0	1.10	.28	1.04	0	120	.20	.872	16.2	6.40
20	0.70	200.0-220.5	8.4	70.0	.80	.18	1.36	0	141	--	1.040	31.8	6.00
22	0.46	236.5-252.5	8.3	76.0	.80	.38	2.40	0	135	--	1.930	41.4	7.00
DH-6-3	0.10	4.0-8.0	7.6	106.0	.60	.70	52.00	0	123	.35	13.100	26.7	.98
5	0.97	13.0-19.8	7.1	72.0	1.10	1.76	26.20	0	110	--	--	--	2.20
7	1.19	24.3-29.8	8.2	50.0	.90	.26	1.04	0	123	.30	--	--	--
8	0.72	29.8-40.0	8.3	56.0	7.90	6.40	.80	0	355	.65	--	--	4.20
9	0.96	40.0-50.0	8.6	70.0	5.50	4.96	.96	0	380	.90	1.140	22.1	4.20
11	1.91	56.7-65.0	5.9	106.0	4.70	2.64	1.76	0	255	1.00	.710	14.8	5.60
12	2.04	65.0-72.3	5.9	76.0	6.90	3.76	2.56	0	291	1.55	1.420	27.2	5.00
13	1.52	72.3-80.0	8.5	74.0	7.40	3.36	1.36	0	315	--	1.510	24.9	5.20
15	1.33	90.0-100.0	6.2	58.0	7.40	2.16	3.68	0	276	1.70	1.090	20.8	5.40
16	1.88	100.0-110.0	8.4	50.0	10.80	2.72	5.76	0	276	1.35	1.120	14.6	5.40
17	2.13	110.0-120.0	8.4	42.0	14.80	4.16	2.40	0	320	--	1.390	25.4	4.40

Table 3. Geologic Materials Problem Identification Categories, McCallum, Colorado.

Problem Identification Categories	Sample Number	Characteristics
1	DH-1-3	Low P
	DH-1-4	
	DH-1-6	
	DH-1-8	
	DH-1-10	
	DH-1-11 & 12	
	DH-1-15	
	DH-3-11	
	DH-3-12	
	DH-4-3	
	DH-4-6	
	DH-4-8	
	DH-5-2	
	DH-5-4	
2	DH-3-6	Low P and K
	DH-3-8	
3	DH-3-4	Low Zn, Cu, K, and P
4	DH-5-6	Low P, pH fair
5	DH-1-17	Low P, ESP marginal
	DH-2-5	
	DH-2-6	
	DH-2-7	
	DH-1-8	
	DH-2-11	
	DH-2-12	
6	DH-2-3	Low P, EC marginal
	DH-4-2	
7	DH-1-19	Low P, Low K,
	DH-2-23	nonacceptable ESP
8	DH-1-20	Low P, Low Zn, Low K, nonacceptable ESP

Table 3. (continued)

Problem Identification Categories	Sample Number	Characteristics
9	DH-2-10	Low P, ESP nonacceptable
	DH-2-14	
	DH-2-16	
	DH-2-20	
	DH-3-16	
	DH-3-17	
	DH-3-18	
	DH-6-5	
	DH-6-8	
	DH-6-15	
	DH-6-16	
	DH-6-17	
	DH-5-8	
	DH-5-20	
	DH-5-22	
	DH-5-9	
	DH-5-11	
	DH-5-13	
10	DH-3-20	Low P, pH fair,
	DH-4-11	ESP nonacceptable
	DH-4-13	
	DH-4-15	
	DH-4-18	
	DH-6-9	
	DH-6-11	
	DH-6-12	
	DH-6-13	
11	DH-4-20	Low P, pH poor,
	DH-4-23	ESP nonacceptable
	DH-4-25	
12	DH-5-15 & 16	Low P, Low Cu, pH fair,
	DH-5-17	ESP nonacceptable

Table 3. (continued)

Problem Identification Categories	Sample Number	Characteristics
13	DH-6-7	Low P, Low Cu, ESP nonacceptable
14	DH-1-22	Low P, Low Zn, Low Cu, Low K, ESP nonacceptable
15	DH-6-3	Low P, EC unsuitable, ESP nonacceptable

Development and Description of Geologic "Problem Area Groups"

The development of "Problem Area Categories" was the first step in evaluation of materials for plant growth media. Recognizing that some of these categories could be grouped on the basis of problem areas, i.e., fertility, sodium, etc., we further grouped the categories into "Problem Area Groups". This final grouping better identifies the magnitude of the kinds and combinations of problems and are more meaningful from a management decision point of view.

Descriptions of the "Problem Area Groups" and the basis used in determining relative suitability ratings are shown in Table 4.

A summary of the relative suitability ratings of the geologic materials by "Problem Area Groups" are shown in Table 5.

Soil Materials

Preplant laboratory characterization data is lacking on the soil materials from the McCallum site. Table 6 shows the extent of the preplant soil analysis data available on the soils. Soil reaction (pH values) and fertility interpretations can be made based on the interpretative criteria presented in Table 1. A review of the preplant data indicates the following limitations.

1. Phosphorus deficiencies are common.

2. Potential micronutrient deficiencies occur on many of the samples with Zn and Cu being the most common. The criteria used in predicting micronutrient deficiencies are based on deficiencies observed in agronomic crops; however,

Table 4. Description of Geologic "Problem Area Groups"

Problem Area	Description and basis for suitability ratings
1. Fertility	This group includes problem identification categories 1, 2 and 3. Phosphorous deficiencies alone or in combinations with Potassium, Zinc, and Copper affect these materials as plant growth media. These materials are suitable as plant growth media if amended with the proper fertilization program.
2. Fertility, pH fair	This group includes problem identification category 4. Phosphorous deficiencies along with moderately low (5.7) pH values characterize these geologic materials. The materials are classed as suitable.
3. Fertility, marginal sodium	This group includes problem identification category 5. Phosphorous deficiencies together with moderate sodium levels characterize these materials. Plant growth may be reduced due to the sodium concentrations in the materials. This, together with reduced infiltration rates caused by the sodium dispersive effect on clay particles, make these materials questionable as plant growth media.
4. Fertility, moderate salinity	This group includes problem identification category 6. Moderate salinity levels together with potential phosphorous deficiencies characterize these materials. Management by leaching of salts followed by a fertilization program would cause the materials to be classed suitable.
5. Fertility, unacceptable sodium	This group includes problem identification categories 7, 8, 9, 13 and 14. High sodium levels, along with potential deficiencies of phosphorous, potassium and/or zinc and copper, characterize these materials. The potential limitations due to the presence of sodium was the primary reason for rating these materials as unsuitable.
6. Fertility, fair and poor pH, unacceptable sodium	This group includes problem identification categories 10, 11 and 12. High sodium levels, along with potential phosphorous and copper deficiencies, characterize these materials. The materials are classed unsuitable.

Table 4. (continued)

Problem Area	Description and basis for suitability ratings
7. Fertility, unacceptable salinity and sodium	This group includes problem identification category 15. Phosphorous deficiencies along with high salinity and sodium levels would inhibit plant growth except for very salt-tolerant species. These materials would be classed as unsuitable.

Table 5. Summary of Suitability Ratings Developed on the Basis of Laboratory Characterization Data -- Geologic Materials

Problem Area Group	Relative Rating
1	suitable
2	suitable
3	questionable
4	suitable
5	unsuitable
6	unsuitable
7	unsuitable

NOTE: Although pH has been identified as a factor for rating materials, it has little significance in the actual rating.

Table 6. Preplant analysis of soils from McCallum, Colorado

Sample No.	Depth in.	pH	ppm Fe	Zn	Cu	Mn	P	K	% O.M.	Avg. Yield
27-1	0-12	7.1	5.40	.18	.84	10.24	6.25	156	1.40	1.08
2	12-24	7.3	9.00	.20	.58	4.96	0.00	135	1.00	1.27
3	24-48	7.4	64.00	.20	.60	13.60	2.50	135	.85	0.62
30-1	0-24	7.5	8.40	.36	2.00	12.32	35.00	215	.80	0.81
2	24-56	7.1	2.80	.16	.74	1.92	28.75	99	.20	0.16
3	56-72	7.6	6.20	.36	.86	2.08	0.00	66	.40	0.33
32-1	0-14	6.7	26.00	.26	.78	14.08	8.75	183	1.75	0.93
34-1	0-10	6.1	22.00	.50	.80	13.44	18.75	231	2.20	1.04
36-2	12-18	6.7	36.00	1.24	2.40	10.40	48.75	234	2.00	1.05
37-2	10-26	7.3	86.00	.28	.90	30.80	6.88	87	.80	0.75
39-1	0-6	7.2	26.00	.50	1.80	7.04	8.75	180	1.60	0.53
2	6-24	7.7	4.40	.16	1.18	1.60	1.25	108	.70	0.45
3	24-36	7.7	6.80	.24	1.26	3.04	0.00	153	.75	0.31
42-1	0-4	7.6	6.80	.54	2.00	4.80	6.88	261	1.50	1.08
52-1	0-14	6.8	28.00	.50	.86	202.00	5.00	138	1.30	1.09
53-1	0-14	5.9	110.00	2.72	1.26	25.60	50.00	430	3.60	1.63
54-1	0-12	7.0	4.40	.20	.80	7.20	0.00	85	1.65	0.62
58-1	0-12	7.3	280.00	.80	.96	132.80	0.00	100	1.60	0.83
66-1	0-12	7.1	34.00	.90	2.40	32.40	6.29	245	2.05	0.97
70-1	0-16	7.1	8.80	.36	1.02	11.84	7.50	162	1.45	1.21
2	16-36	7.1	96.00	.40	.46	81.60	12.50	78	.95	0.98

Table 6 (continued)

Sample No.	Depth in.	pH	Fe	Zn	Cu	Mn	P	K	% O.M.	Avg. Yield
			ppm							
73-1	0-12	7.2	152.00	.22	.68	70.00	8.75	138	1.45	1.09
78-1	0-14	6.8	80.00	.78	1.76	46.40	16.25	234	2.45	1.26
79-1	0-14	---	4.00	.22	.58	14.88	0.00	120	1.45	1.48
80-1	0-14	6.6	10.40	.26	.46	21.20	2.50	87	1.60	0.83
81-1	0-14	7.4	10.40	.60	3.12	4.64	32.50	231	0.35	1.33
82-1	0-14	6.8	128.00	.28	.48	48.00	1.50	261	1.00	1.20
82-2	20-30	6.5	38.00	.90	1.44	23.20	8.75	261	1.75	.86
83-1	0-12	7.2	4.00	.20	.84	5.28	0.00	123	1.30	0.82
2	12-24	7.3	2.60	.20	.80	2.72	1.50	60	1.05	1.42
3	24-34	7.4	1.40	.28	1.14	1.76	15.00	65	.75	0.85
84-1	0-24	6.9	40.00	.46	1.08	30.00	24.38	162	1.05	0.83
85-1	0-14	6.5	42.00	.44	.70	14.24	38.00	340	1.60	0.66
2	14-40	6.3	7.60	.18	.58	5.28	25.00	198	.75	0.81
87-1	0-12	6.8	84.00	.10	1.70	84.00	31.25	---	1.75	0.77
2	12-24	7.1	7.40	.22	1.20	11.52	5.00	99	1.60	0.97
3	24-30	5.8	118.00	1.00	1.86	115.20	20.50	210	1.20	1.45
88-1	0-12	6.7	312.00	.80	1.10	144.00	13.00	125	1.65	1.03
2	12-28	7.0	7.00	.26	.72	4.96	2.50	171	.60	1.86
3	28-44	6.9	3.40	.40	.74	2.08	21.25	192	.25	1.59

Table 6 (continued)

Sample No.	Depth in.	pH	Fe	Zn	Cu	Mn	P	K	% O.M.	Avg. Yield
			ppm							
89-1	0-20	6.5	280.00	.80	.94	220.00	11.25	180	3.80	1.52
2	20-30	7.3	15.40	.16	.30	9.44	5.00	72	1.30	0.56
3	30-36	7.3	1.60	.10	.26	3.36	2.50	78	.75	1.29
90-1	0-18	7.1	60.00	.24	.54	12.00	3.75	105	1.45	1.03
2	18-42	---	130.00	.22	.50	84.80	25.00	81	.40	0.97
3	42-52	7.9	3.20	.16	.24	7.20	0.00	117	.35	1.83
91-1	0-10	6.8	291.00	2.00	1.54	232.00	15.00	156	1.90	1.21
2	10-18	7.3	5.00	1.10	1.60	5.76	7.50	99	1.45	1.18
3	18-28	7.4	8.00	4.40	1.86	3.52	0.00	50	2.20	1.02
92-1	0-10	7.0	38.00	.52	1.02	24.20	0.00	156	1.45	1.08
2	10-24	7.5	5.00	.20	1.00	6.72	0.00	171	.80	1.17
93-1	0-24	7.0	34.00	.24	.70	11.36	12.50	261	1.40	0.95
2	24-36	6.7	22.00	.18	.44	11.04	6.88	132	---	1.07
94-1	0-24	7.7	48.00	.48	.84	12.48	3.75	192	.70	1.28
2	24-48	6.7	2.60	.20	.46	1.60	10.00	110	.60	1.19
95-1	0-12	7.2	28.40	.48	.86	212.00	13.79	159	2.20	1.09
46-1	0-22	6.6	280.00	.74	1.42	212.00	28.75	243	2.70	1.03
2	22-50	7.0	75.00	.18	.60	48.00	23.75	55	.40	0.96
3	50-60	7.3	12.60	.18	.30	7.20	21.25	60	.40	1.03
Control		7.4	7.00	.70	2.56	13.44	0.00	160	1.20	0.92

Zn deficiencies were observed in wheatgrass plants grown on soil materials that exhibit DTPA-extractable levels of less than 0.24 ppm of plant-available Zn. This suggests that Zn may be a limiting micronutrient in planning the use of soil materials as plant growth media. The results of a Zn deficiency experiment are given in Part V of this report.

3. Two samples (53-1; 87-3) show low (5.9; 5.8) pH values. While not excessively low, these pH ranges may inhibit the germination and emergence of certain grass species.

It follows that all the materials would be classed as suitable as plant growth media. The only observable limitations are fertility related. These limitations can be overcome through a properly managed fertilization program.

PART III

POSTHARVEST EVALUATION

In addition to the chemical data shown in Tables 2 and 6, analyses were carried out on selected geologic samples to identify and evaluate changes in chemical characteristics as a result of the weathering environment created in the greenhouse experiment. Only geologic samples were selected for postharvest analyses due to the lack of preplant data on the soil materials. Postharvest analyses consisted of pH; electrical conductivity; NO_3-N; plant-available P and K; DTPA-extractable Zn, Fe, Mn, and Cu; sodium adsorption ratios; and extractable Ca, Mg, and Na. These post-harvest analyses are shown in Table 7.

A summary of the postharvest data shown in Table 7 indicate the following important relationships when compared to the pre-plant data given in Table 2:

1. Salinity (EC) levels increased in all samples analyzed. We feel this is a result of a combination of two factors. First, salts could be formed through the weathering of the geologic materials and application of fertilizers. Secondly, these salts have the potential to accumulate due to the fact that the pots are a closed system with no leaching possible.

Table 7. Postharvest analysis - Geologic materials, McCallum, Colorado.

	pH	EC	O.M.	NO_3-N	P	K	Zn	Fe	Mn	Cu	Ca	Mg	Na	SAR	ESP
			- % -	ppm							meq/l				
DH-5-4	5.5	8.4	0.4	175	56	111	4.0	94.3	5.9	1.3	-	-	-	-	-
DH-2-12	7.4	4.8	1.2	185	23	475	13.1	47.7	2.1	7.8	12.2	3.2	32.8	11.8	13.0
DH-1-15	6.8	4.7	1.1	200	90	180	6.9	73.7	4.0	3.3	36.3	7.2	1.9	0.4	-
DH-4-6	7.3	6.1	1.6	95	28	235	6.1	27.5	2.6	1.3	31.2	20.8	22.0	4.3	5.0
DH-6-11	7.8	4.1	0.9	110	20	332	8.6	40.6	1.7	3.8	3.3	1.4	37.6	24.6	25.0
DH-5-22	8.0	6.1	0.4	145	33	206	1.8	63.1	1.8	0.6	3.8	0.9	64.8	41.9	37.0
DH-3-20	7.8	7.1	1.5	185	12	306	8.7	44.6	2.1	2.2	12.6	3.2	74.3	26.5	26.0

2. pH values of the selected samples generally showed a tendency to decrease or become more acid as a result or the greenhouse experiment. The salts described in "1" above, contributed to the reduced pH values associated with the samples.

3. In the few samples in which both preplant and postharvest exchangeable sodium percentages (ESP) were calculated, there was very little change throughout the experiment. It appears from preplant vs. postharvest ESP data that materials with an initially high value will remain at a critical level from a plant growth or environmental quality point of view. However, sample number DH-6-11 showed a significant increase (14.8 to 25.0) in ESP. This can be explained by assuming that an increased amount of sodium is weathering from the overburden materials and being held on the exchange sites, thus showing an increase in ESP.

PART IV

GREENHOUSE YIELD DATA AND PLANT TISSUE ANALYSIS

Greenhouse Study

Greenhouse growth studies were carried out to aid in the evaluation of materials as plant growth media and to verify plant growth characteristics predicted from laboratory characterization data relationships. The yield results are given in Tables 2 and 6 for geologic and soil materials, respectively.

A review of the yield results show that a very poor correlation exists between chemical characteristics of both geologic and soil materials to yield. We feel that important interactions existed between the physical condition of the material and growth response, e.g., very coarse materials yielding low. Due to the lack of particle size analysis, we feel the greenhouse data is of limited value in accessing these materials suitability as plant growth media.

Plant Tissue Analysis

Plant tissue analyses data from selected materials are shown in Table 8.

Table 8. Analyses on plants grown on soils and geologic material from McCallum.

	Zn	Fe	Mn	Cu	Al	Ni	Ti	Sr	B	Ba	P	K	Ca	Mg	Na
	ppm										%				
30-2	21	120	58	10	115	<5	10	25	57	8	0.17	2.09	0.08	0.25	0.55
39-2	8	185	64	7	168	3.0	5.3	35	8	26	0.20	2.51	0.34	0.42	0.05
73-1	5	79	64	4	30	2.8	1.4	31	6	39	0.28	2.55	0.78	0.18	0.002
83-3	8	67	87	7	58	1.3	2.4	46	20	10	0.21	2.83	0.33	0.22	0.06
85-2	6	90	53	5	48	2.4	2.0	28	6	35	0.22	2.53	0.65	0.17	0.002
87-1	29	59	106	3	55	1.1	2.3	73	6	34	0.22	2.69	0.56	0.21	0.008
89-2	6	91	79	3	114	2.0	4.4	41	5	59	0.11	1.79	0.62	0.18	0.005
89-3	5	72	128	4	39	2.5	1.9	68	8	63	0.38	1.85	0.56	0.32	0.01
91-1	22	59	73	3	54	1.7	2.3	30	7	31	0.20	2.78	0.49	0.18	0.004
92-1	12	93	67	4	94	1	2.6	44	6	27	0.24	3.24	0.39	0.21	0.009
92-2	5	91	109	7	55	2.2	1.6	56	13	11	0.23	2.83	0.42	0.22	0.03
93-1	10	68	86	3	43	<1	2.2	24	7	44	0.25	3.50	0.54	0.16	0.002
96-1	12	63	87	3	49	<1	2.4	42	4	52	0.23	3.14	0.82	0.17	0.003
DH-1-5	22	60	59	5	46	1.9	2.3	98	10	8	0.13	2.51	0.79	0.14	0.008
DH-2-12	31	73	72	6	56	<1	2.5	109	6	5	0.15	2.90	0.32	0.12	0.09
DH-3-20	28	57	48	4	31	<1	1.4	104	7	3	0.16	2.82	0.24	0.10	0.36
DH-6-11	26	44	44	5	24	1.7	1.4	68	5	7	0.14	2.70	0.18	0.08	0.10
DH5-22	14	124	64	4	117	<1	3.8	93	10	7	0.17	2.67	0.23	0.11	0.38
DH4-6	20	107	54	4	109	1.4	4.6	95	6	20	0.19	2.80	0.28	0.17	0.05

A review of the plant analyses data indicate the following:

1. Total zinc concentrations in the plant materials show levels below what have been reported by Chapman et al. (1966) as causing deficiency symptoms in oats (20 ppm) and corn (9-15 ppm). Samples 30-2, 98-1, 91-1, 1-5, 2-12, 3-20, and 6-11 were the only samples that have total zinc concentrations above 20 ppm. Observed zinc deficiencies were noted in various samples including 89-2, 92-2, and 93-1 which were evaluated for zinc deficiencies in an additional study. The results of this study are given in Part V of this report.

2. Total concentration of other elements studied in plant tissue appear to be well within published tolerance ranges for most agronomic crops (Chapman, 1966; Gough and Shacklette, 1976) and therefore, acceptable from a plant growth point of view.

PART V

ADDITIONAL STUDIES

In the initial greenhouse study, many of the plants grown on the soil materials exhibited characteristics normally associated with Zn or Fe deficiencies exhibited by Zn sensitive agronomic crops, i.e., chlorosis and stunted growth. After reviewing the preplant soil DTPA-extractable levels of micronutrients, we decided the potential for Zn deficiencies existed on some of the materials. Additional greenhouse study on a selected few samples was initiated to determine if the suspected Zn deficiencies were real.

Methods

Four samples (85-2; 89-2; 92-2; 93-11) which exhibited Zn deficiencies in the initial greenhouse experiment were selected for continued analysis. These samples had DTPA-extractable Zn levels of 0.24 ppm which is well below the critical levels shown for Zn in Table 1 of this report. Each sample was divided into two treatments, one with and one without the addition of $ZnSO_4$. Samples were fertilized with N, P, and K as in the initial greenhouse experiment.

Results and Conclusions

Table 9 is a summary of the zinc status and crop yields for initial and secondary greenhouse experiment. Yields with no Zn added are very similar on samples 92-2 and 93-1, while some variation exists on samples 89-2 and 85-2. Second crop yields with added Zn are higher on all samples except 89-2 which showed a reduction in yield. Figures 1, 2, and 3 show the response of the plants to each treatment. From the yield data and the apparent growth responses, it follows that the materials were deficient in Zn and therefore should be managed accordingly.

Table 9. Zinc Uptake Data on Soil and Plant Samples

Sample Number	Preplant first crop available Zn	No Zn post plant available Zn	Zn added post plant available Zn	Zn added plant Zn	No Zn plant Zn	No Zn Yield first crop	No Zn Yield second crop	Zn added Yield second crop
	- - - - - - - -	- - - - - - - -	ppm - - - -	- - - - - - - -	- - - -	- - - -	gm - - - -	- - - -
89-2	.16	.48	5.8	49.18	14.58	.56	1.20	.61
92-2	.20	.20	5.0	21.68	5.91	1.17	1.10	1.96
93-1	.24	.36	2.8	47.47	20.67	.95	.75	1.61
85-2	.18	.28	6.3	25.64	11.92	.81	1.30	2.34

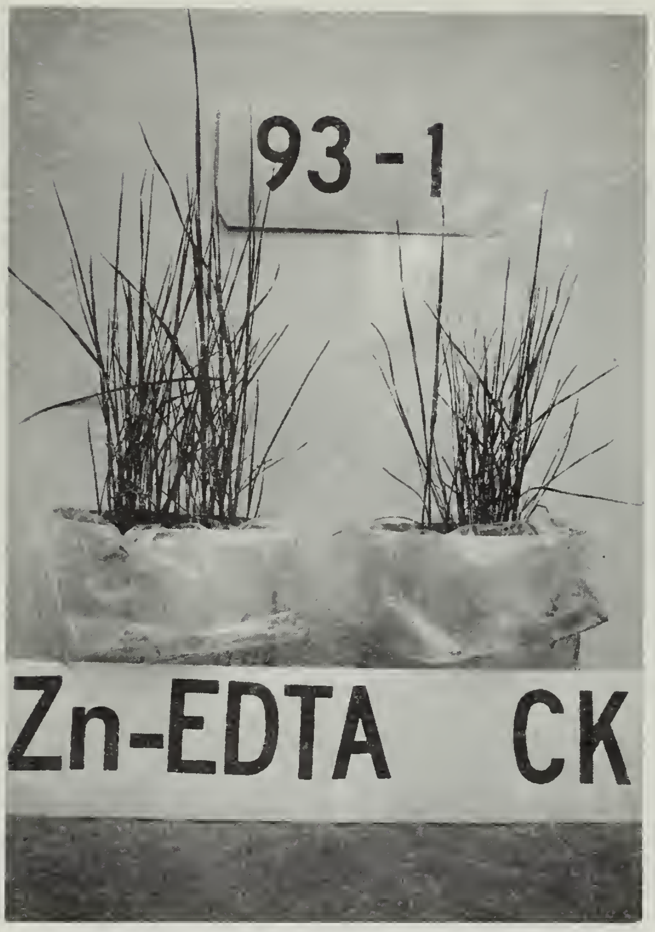


Figure 1.

Figure 2.

Figure 3.