Geomorphic, Hydrologic, and Erosion Data for Selected Reclaimed Hillslopes, the Seneca II Mine, Routt County, Colorado, October 1988–July 1990

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Abstract

Geomorphic, hydrologic, and erosion data were collected from five reclaimed hillslopes in two study areas at the Seneca II mine near Hayden, Colorado. Hillslope surveys were used to determine hillslope lengths, which ranged from 670 to 1,280 feet, and hillslope gradients, which ranged from 0.17 to 0.23 foot per foot. Altitudes in the study areas ranged from 6,890 to 7,140 feet, and hillslope aspects generally were west or south. Mean total vegetation cover ranged from 74 to 91 percent. Total monthly precipitation for December 1988 through June 1990 was computed from daily measurements made with weighing-bucket precipitation gages. Several snowpack measurements were made during two winters. Volumetric soil-water content was determined at incremental depths using a neutron probe and in the upper 11.8 inches of soil using a time-domain reflectometer. Active and recent soil erosion was indicated by the presence of rills. Rill density (the sum of rill lengths per unit area) was computed at 50- to 100-foot intervals along survey transects at each hillslope study area. Differences in soil-surface altitudes between September or October 1989 and June 1990 were determined with an erosion frame and replicate soil-surface surveys at 16 erosion-study plots.

INTRODUCTION

Rill and sheet erosion of recently reclaimed hill-slopes in surface-mined areas is a major cause of topsoil loss, poor revegetation success, excessive sediment production, and downstream water-quality degradation. Rill erosion occurs in small channels (generally less than 1 ft wide and 1 ft deep) where runoff is concentrated. Sheet erosion occurs over a broader, unchannelized area where runoff is dispersed. Surface-mining activities have increased the potential for soil erosion in some areas of the Rocky Mountain region. In northwestern Colorado, reclaimed areas have increased credibility because bedrock-controlled dip slopes have been mined and replaced with unconsolidated spoil slopes. Topsoil horizons have been homogenized and compacted by removal prior to mining, transportation to storage areas, and reapplication after mining. Premining native vegetation communities have been replaced by revegetated grasslands. The postmining geomorphology of these areas is partly a result of dragline and spoil-handling activities, and it may be substantially different from the premining geomorphology. Some of these changes also have increased the amount and rate of surface runoff from reclaimed hillslopes (Elliott, 1990).

Conventional soil-loss estimation techniques, such as the Universal Soil Loss Equation (Wischmeier and Smith, 1978) were developed for conditions different from those typical of large surface mines in the western United States. Many conventional soil-loss estimation techniques could be modified for use at reclaimed surface mines using empirical data collected at reclaimed surface mines.

A study was begun in 1988 to identify active hillslope-hydrologic processes on coal-spoil hillslopes and to identify relations between geomorphology, hillslope hydrology, and soil loss in reclaimed surface-mined areas. The study was a cooperative effort by the U.S. Geological Survey and the Colorado Department of Natural Resources, Mined Land Reclamation Division.

Purpose and Scope

This report presents geomorphic and hydrologic data that will be used to analyze hillslope hydrology and soil loss from a representative surface coal mine in northwestern Colorado. Data-collection methods also are presented. Data presented in this report were collected from two reclaimed hillslope areas at Peabody Coal Company's Seneca II mine near Hayden (fig. 1)

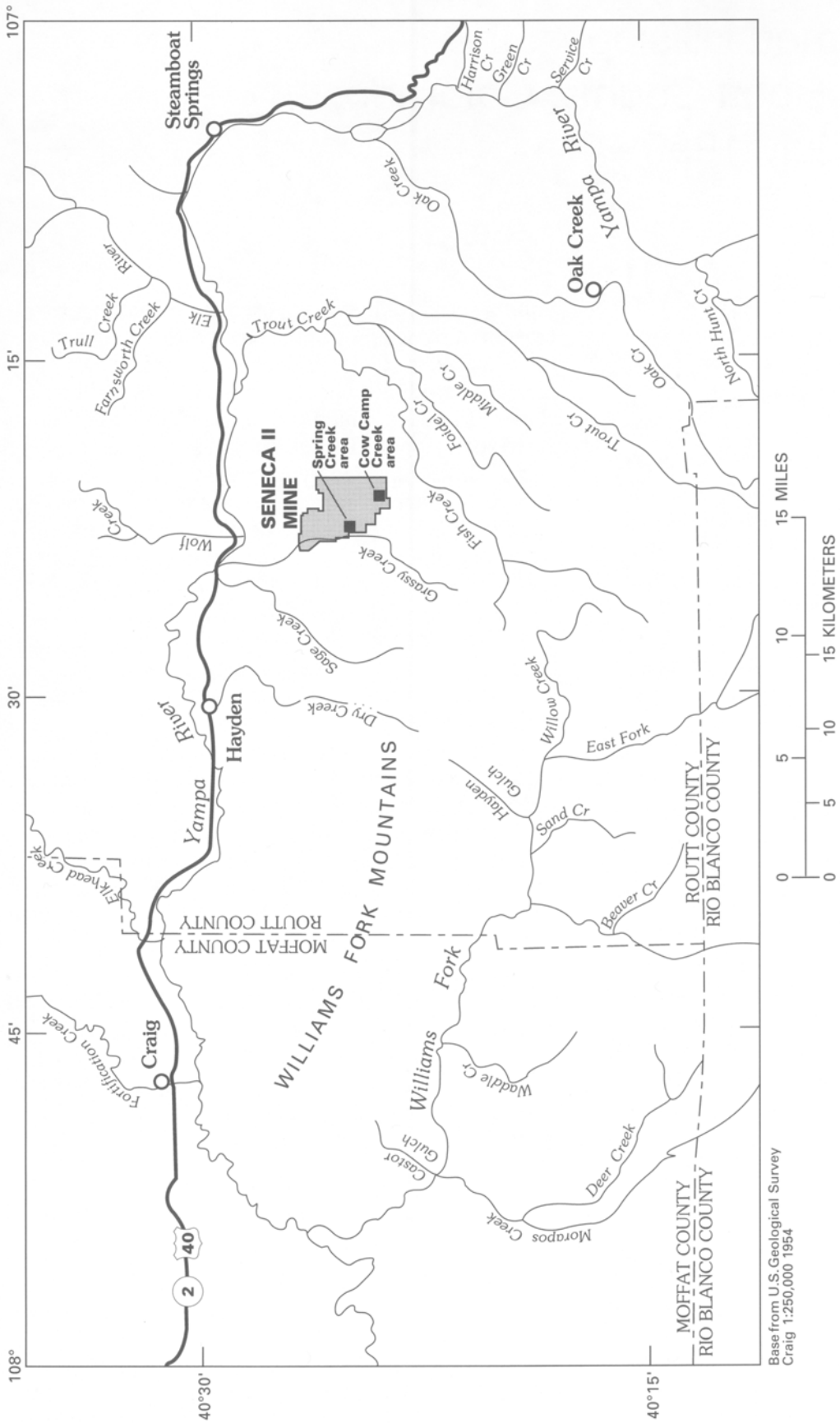

Figure 1. Location of Seneca II mine.

between October 1988 and July 1990. Climatologic and hydrologic data also were collected during a concurrent study at the Seneca II mine (Williams and others, 1993). Additional geomorphic data were collected at the Seneca II mine and at several other surface coal mines in the vicinity in an earlier study (Elliott, 1990).

Geomorphic data were collected from topographic maps and onsite surveys and are presented as hillslope profiles, hillslope lengths, hillslope gradients, rill densities, and soil-surface profiles. Vegetation data were collected with a 10-point vegetation sampling frame and are presented as percent vegetation cover. Precipitation data were collected with weighing-bucket precipitation gages and from snowpack samples. The precipitation data are presented as monthly totals; the snowpack data (depth, water content, and density) are presented as instantaneous values. Hydrologic data (volumetric soil-water content) were collected using neutron-scattering and electromagnetic techniques. Soil-water data are presented as instantaneous values by measurement depth.

Description of Study Area

The Seneca II mine is about 10 mi southeast of Hayden in Routt County. The Seneca II and other surface coal mines in the vicinity are extracting coal from folded and uplifted sedimentary rocks of the Cretaceous Williams Fork Formation. Altitudes at the Seneca II mine range from about 6,600 to 8,100 ft. The climate of the area is semiarid. Mean annual precipitation at Hayden (altitude 6,337 ft) is 16 in. (National Oceanic and Atmospheric Administration, 1982); a large percentage of annual precipitation is snow. Snowmelt is the primary source of streamflow in the area (Williams and Hammond, 1988, p. 7). Native vegetation is a mixture of grassland and mountain shrub, and the undisturbed soils are mostly loams, clay loams, and silt loams (Narten and others, 1983).

The premining topography of the Seneca II mine area was controlled by geologic structure. The mine is at the southern end of the Tow Creek anticline that plunges south-southwest (Tweto, 1976; Williams and Hammond, 1988). The postmining, or reclaimed, topography also reflects the anticlinal structure; reclaimed hillslopes have aspects that range from west, southwest, south, and southeast.

Data presented in this report were collected at two reclaimed areas. The Spring Creek area was reclaimed in 1986-87 and is in the western part of the mine (fig. 2). The Cow Camp Creek area was reclaimed in 1985 and is in the southern part of the mine (fig. 3).

Background

Recently reclaimed, surface-mined hillslopes often are areas of accelerated rill and sheet erosion. Topsoil-loss estimates from reclaimed hillslopes have been made with varying success using conventional soil-loss models developed in areas that have not undergone surface-mine reclamation. More accurate soil-loss estimates for reclaimed areas could be made with models specifically developed for the unique geomorphic, vegetational, hydrologic, and pedologic conditions at reclaimed surface mines. Several previous studies have addressed some of these conditions.

Hillslope rill erosion was studied at six surface coal mines in northwestern Colorado (Elliott, 1990). Data were collected from reclaimed surface-mined hill-slopes and from nearby unmined hillslopes with similar altitude, aspect, average gradient, and length. The reclaimed hillslopes had greater topsoil-bulk densities, lower topsoil-infiltration rates, and less woody vegetation than did the unmined hillslopes. Rill erosion was more common on the reclaimed hillslopes than on the unmined hillslopes. Rill erosion on reclaimed hill-slopes generally occurred on the mid-hillslope to lower hillslope segments and where hillslope segments had steep or convex profiles. Rill density (sum of the rill lengths per unit hillslope area) was positively correlated with the hillslope-length, hillslope-gradient product and was inversely correlated with the time since reclamation (Elliott, 1990, p. 30). However, in the previous study, topsoil loss was not quantified, nor were the hydrologic processes that caused rill and sheet erosion on reclaimed hillslopes investigated.

Surface mining and reclamation can dramatically alter local hydrologic conditions that, in turn, can affect erosion potential. Williams and Hammond (1988) noted differences between reclaimed hillslopes and unmined hillslopes in soil saturation and infiltration rates. In another study at the Seneca II mine, Clark and Williams (1990) used geochemical methods to document the relative contributions of ground water and surface water (precipitation) to a developing coal-spoil aquifer. Additional precipitation and soil-water data are presented in a report by Williams and others (1993).

Acknowledgments

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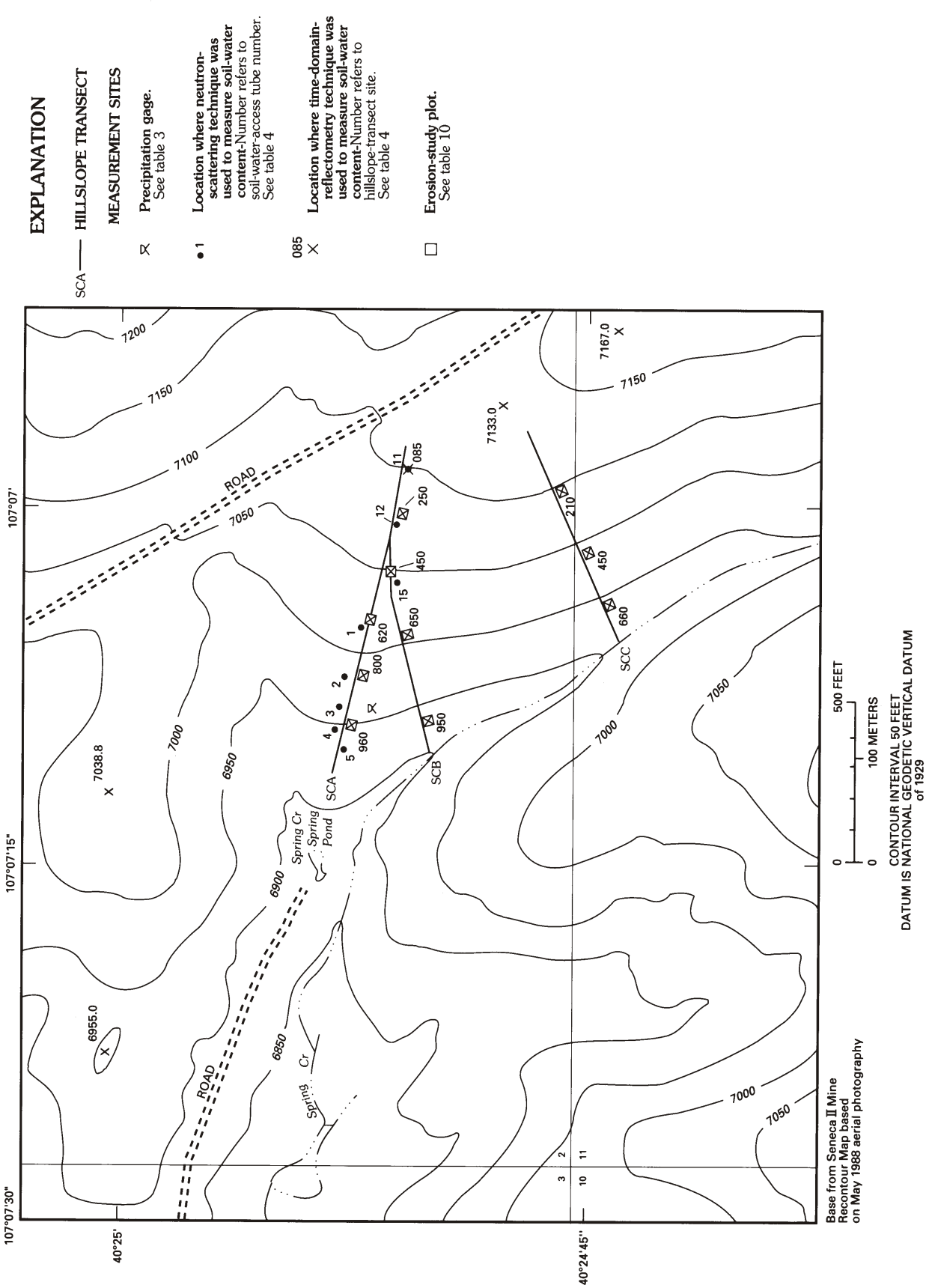

Figure 2. Data-collection sites at the Spring Creek area.

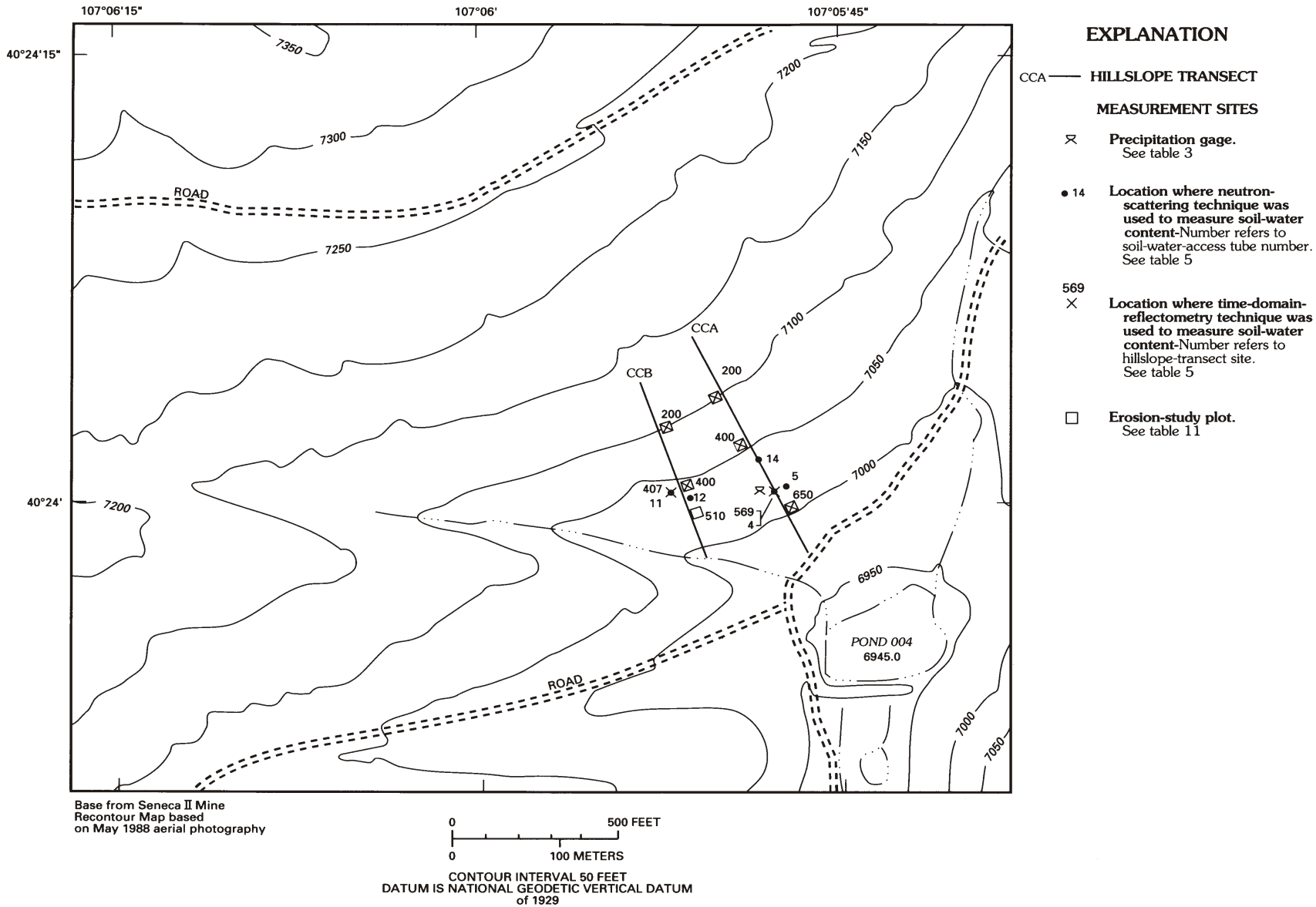

Figure 3. Data-collection sites at the Cow Camp Creek area.

Land Reclamation Division, and Marilyn K. Kastens, U.S. Bureau of Land Management.

DATA COLLECTION AND METHODOLOGY

Geomorphic, hydrologic, and erosion data were collected along three hillslope transects at the Spring Creek area (hillslope transects SCA, SCB, and SCC, fig. 2) and along two hillslope transects at the Cow Camp Creek area (hillslope transects CCA and CCB, fig. 3). Geomorphic data included aspect, hillslope length, altitude, hillslope gradient, and hillslope-profile characteristics. Hydrologic data included precipitation, snowpack depth, snowpack-water content, and soil-water content. Erosion data included rill density and soil-surface altitudes. Some additional data were collected including vegetation cover and onsite observations of soil texture and soil ice layers.

Geomorphology

Each reclaimed hillslope was surveyed from the local surface-runoff hydrologic divide to the hillslope toe with a Zeiss Ni2 self-leveling level. The surveys were made along a linear transect that generally followed the steepest line on the hillslope. Aspects of the hillslope transects were determined using a Brunton compass. Hillslope transects were plotted on Peabody Coal Company 1:4,800 scale maps with 10-ft contour intervals from which altitude ranges were determined. Hillslope length (slope distance) was determined with a tape measure. Hillslope gradient, horizontal distance, and profile characteristics were determined from the survey data. The hillslope transects were monumented with wooden survey stakes and iron rebar, and the transects served as references for additional data collection and other observations.

Hillslopes at the Spring Creek area generally had a westerly aspect and lengths between 750 and 1,280 ft (table 1). Hillslope transects SCB and SCC were on laterally straight hillslopes (straight contour lines) and transect SCA was on a laterally convex hillslope (contour lines convex in the downhill direction) (fig. 2). Because the hillslope morphology changed from laterally straight to laterally convex, transects SCA and SCB shared a common position for the upper 300 ft but were divergent on the mid-hillslope and lower hill-slope segments. Longitudinal hillslope profiles are shown in figures 4-6.

Altitudes ranged from about 6,890 to 7,125 ft along the transects at the Spring Creek area. Mean hill-slope gradients, determined as the ratio of altitude difference to horizontal distance of the hillslope, were between 0.17 and 0.23 ft/ft. Reclamation dates (year of topsoil replacement and seeding) were 1986 for hill-slope transect SCC and 1987 for most of transects SCA and SCB. The upper 300 ft of transects SCA and SCB was reclaimed in 1986.

Hillslopes at the Cow Camp Creek area generally had a southerly aspect and the lengths of transects CCA and CCB were 800 and 670 ft (table 1). Transect CCA was on a laterally straight hillslope. Transect CCB was on a hillslope that was laterally straight throughout the upper segment; but at the middle segment, transect CCB crossed a small, diagonal-trending, hollow-like

Table 1. General characteristics of the hillslope transects

Hillslope transect	Aspect (degrees)	Hillslope length (feet)	Altitude range (feet)	Mean Hillslope Gradient (foot per foot)	Date of reclamation	Mean total-vegetation cover, 1989 (percent)
			SPRING CREEK AREA			
SCA	284	1,280	7,105-6,890	0.17	[1]1987	76
SCB	256	1,020	7,105-6,900	0.20	[1]1987	74
SCC	246	750	7,125-6,955	0.23	1986	80
			COW CAMP CREEK AREA			
CCA	154	800	7,140-6,970	0.22	[2]1985	86
CCB	161	670	7,140-6,995	0.22	1985	91

[1]Upper 300 feet of hillslope was reclaimed in 1986.

[2]Lower 50 feet of hillslope was reseeded in 1988.