POTENTIAL EFFECTS OF SURFACE COAL MINING ON THE HYDROLOGY OF THE SNIDER CREEK AREA, ROSEBUD AND ASHLAND COAL FIELDS, SOUTHEASTERN MONTANA

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METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System (SI) of units.

Multiply inch-pound unit	By	To obtain SI unit
acre	4047	square meter
acre-foot	1233	cubic meter
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.0929	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
inch	25.40	millimeter
mile	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) by the equations:

$$°F = 1.8°C + 32$$

$$°C = 0.556\ (°F-32)$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The Snider Creek area of the Rosebud and Ashland coal fields contains strippable reserves of Federal coal that have been identified for potential lease sale. A hydrologic study has been conducted in the potential lease area to describe the existing hydrologic systems and to assess potential impacts of surface coal mining on local water resources.

Hydrogeologic data collected from stock wells, observation wells, and drill holes show that shallow aquifers exist within the Tullock, Lebo Shale, and Tongue River Members of the Fort Union Formation (Paleocene age) and within valley alluvium (Pleistocene and Holocene age). Most of the wells in the area are completed in the basal part of the Tongue River Member or in the upper part of the Lebo Shale Member and are used for watering of livestock. Small stock reservoirs are the primary source of surface water; Snider Creek and all other streams that originate in the area are ephemeral.

The Terrett coal bed of the Tongue River Member is the primary coal bed of the area and is located above the water table. Mining of the Terrett coal bed would destroy one stock well and several small reservoirs. Four other wells near the coal outcrop might be destroyed by mining. Alternative ground-water supplies are available to replace those lost by mining. Degradation of the quality of ground water, caused by the leaching of soluble salts from mine spoils, is not anticipated.

INTRODUCTION

Southeastern Montana contains vast deposits of low sulfur coal that are under both Federal and private ownership. Considerable interest exists in developing these and other western reserves of low sulfur coal to meet the increased demand for clean, domestically produced energy. To meet the demand for Federal coal and to ensure orderly leasing and development of Federal coal lands, a Federal Coal Management Program has been developed. Under this program, the U.S. Bureau of Land Management is required to identify tracts of coal for potential lease, analyze the tracts for potential environmental impacts, and schedule selected tracts of coal for lease sale.

One of the primary considerations in the selection of tracts for lease is potential adverse impacts to the water resources of the area during mining and reclamation operations and after abandonment. To determine potential impacts and reclamation potential of coal tracts, the U.S. Geological Survey is cooperating with the U.S. Bureau of Land Management under the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program. As part of this program, the U.S. Geological Survey is conducting hydrologic studies on several potential coal-lease tracts in the Powder River structural basin of southeastern Montana. The Snider Creek area of the Rosebud and Ashland coal fields is in one of these tracts.

Purpose and scope

A hydrologic study of the Snider Creek area was conducted by the U.S. Geological Survey to identify water resources of the area and to assess potential impacts of surface coal mining on the water resources. Specific objectives of the study were to:

1. Identify ground-water resources of the area;
2. identify surface-water resources and runoff characteristics;
3. determine quality of the water resources;
4. determine probable impacts to existing water resources from mining operations, including changes in the quantity and quality of water; and
5. evaluate the potential for reclamation of local water resources.

To meet the objectives of this study, all pertinent data on local geology and hydrology were compiled. Hydrogeologic data were collected from existing wells and test holes. During the summer of 1979, seven additional wells and test holes were completed where data were lacking. A network of observation wells was established and monitored to determine seasonal fluctuations in ground-water levels and direction of ground-water flow. Aquifer tests were performed to determine local aquifer characteristics, and water samples were collected from wells and surface-water sources for chemical analysis. Channel-geometry measurements were made on Snider Creek to estimate runoff characteristics.

Location and description of area

The Snider Creek study area occupies about 35 mi^2 in the southern part of the Sweeney Creek-Snider Creek potential coal-lease tract in the Rosebud and Ashland coal fields of southeastern Montana (fig. 1). The town of Colstrip is located about 13 miles west of the area and the town of Forsyth is located near the Yellowstone River, about 29 miles northwest of the Snider Creek area.

The study area is situated along the drainage divide between the northward-flowing Tongue River and Rosebud Creek. Maximum topographic relief between the divide and the Tongue River is about 550 feet; maximum relief between the divide and Rosebud Creek is about 450 feet. Altitudes range from about 2,700 feet above sea level along the Tongue River and 2,800 feet along Rosebud Creek to about 3,250 feet at points along the drainage divide.

Upland areas along the interstream divide are characterized by irregular, tree- and grass-covered hills formed by the erosion of flat-lying strata of varying degrees of resistance. The lowland areas between the divide and the major stream valleys are characterized by irregular, dissected slopes and areas of badlands

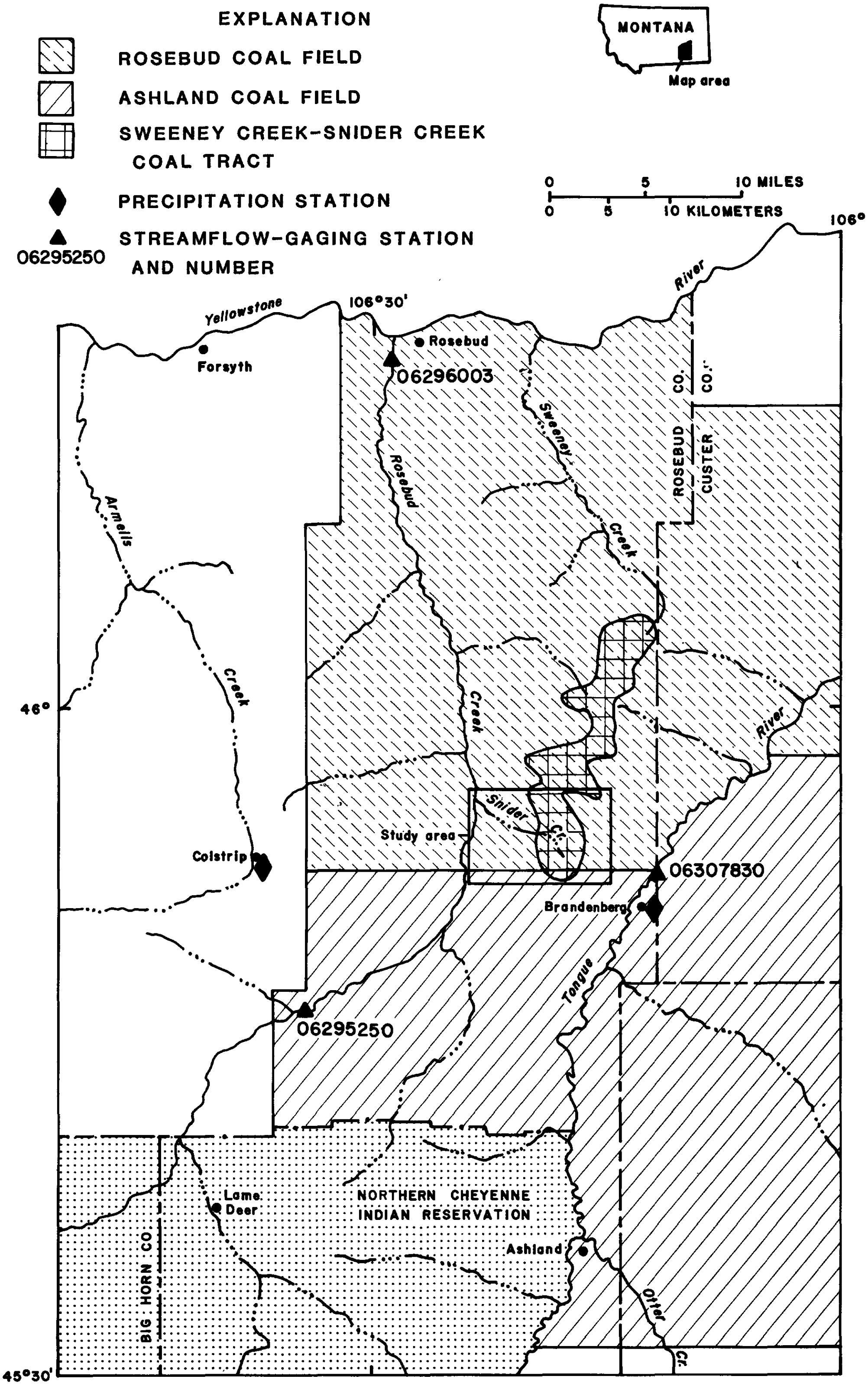


Figure 1.--Location of study area, Rosebud and Ashland coal fields, and Sweeney Creek-Snider Creek coal tract.

that merge with the relatively flat valley bottoms. The lowlands are sparsely vegetated with grasses and sagebrush and contain few trees.

Average annual precipitation in the study area is about 15 inches, based on precipitation stations at Colstrip and Brandenberg (fig. 1). Greatest precipitation generally occurs during April, May, and June. Annual potential evaporation is greater than precipitation and is estimated to be 36 inches. Temperatures in the study area typically have an annual range from about -35° to 100°F.

Previous investigations

The geology, coal deposits, and water resources of the Snider Creek and surrounding areas have been the subjects of several investigations. Renick (1929) described the geology and ground-water resources of central and southern Rosebud County. Coal deposits of the Ashland (Bass, 1932) and Rosebud (Pierce, 1936) coal fields were mapped and described in detail by the U.S. Geological Survey as part of a systematic study and classification of western coal lands. Kepferle (1954) mapped the Snider Creek coal deposit during a study of strippable coal deposits in central Rosebud County. Matson and Blumer (1973) described the quality and quantity of strippable coal within the Sweeney Creek-Snider Creek area in a comprehensive report on strippable coal deposits of southeastern Montana.

Hydrogeologic characteristics of rock units of the area have been studied by Perry (1935), Lewis and Roberts (1978) and Stoner and Lewis (1980). Hydrogeologic data from many wells in the area have been reported by Slagle and Stimson (1979).

Chemical quality of ground water and geochemical processes that control the quality of water in the Fort Union Formation have been investigated by Lee (1979, 1981) and Dockins and others (1980). Studies have been made on the quality of surface water of the region (Knapton and McKinley, 1977; Knapton and Ferreira, 1980) and the quality of base flow of Otter Creek, the Tongue River, and Rosebud Creek (Lee and others, 1981).

WATER USE AND SUPPLY

The primary use of both ground water and surface water is for watering of livestock. Domestic water use is limited to a few residences in the Rosebud Creek valley near the western boundary of the study area. No crops are irrigated in the Snider Creek study area.

Wells are the most reliable source of water for livestock and they are used extensively during the summer when many of the stock reservoirs are dry. An inventory was made of all local stock wells to determine water levels and aquifer type. Hydrogeologic data from these stock wells and from test holes and observation wells are listed in table 1. Location of the wells is shown in figure 2. Most of the stock wells in the area are completed in the basal part of the Tongue River Member of the Fort Union Formation, near the contact with the Lebo Shale Member of the Fort Union Formation, or in the upper part of the Lebo Shale Member. In addition, one stock well (W-13) obtains water from the Tullock Member of the Fort Union Formation and one stock well (W-1) is completed in alluvium near the channel of Snider Creek. All wells obtain water from strata at altitudes lower than the Terrett and Burley coal beds of the Tongue River Member.

Surface water is an important source of water for livestock during years of adequate precipitation. Small reservoirs scattered throughout the area (fig. 2) retain surface-water runoff and supply water for stock during the spring and early summer. The reservoir located in the NW1/4 sec. 22, T. 2 N., R. 43 E., is probably the most reliable source of surface water in the Snider Creek drainage basin; the reservoir is recharged by surface runoff and ground-water seepage.

A water sample was collected from the stock reservoir located in the SE 1/4 sec. 30, T. 2 N., R. 44 E. Chemical analysis of the sample (site S-1, table 2) indicates that concentrations of all constituents tested are much less than the recommended maximum limits for use by livestock (McKee and Wolf, 1963).

Use of ground water in the area presently (1982) is less than the potential supply. Alluvial deposits along the channel of Snider Creek, from its mouth to about 3 miles upstream, appear to be favorable for the development of stock wells. Water in the alluvium can be obtained at a relatively shallow depth and properly developed wells could be expected to yield 5 to 10 gal/min. In the eastern part of the Snider Creek basin, near the drainage divide, water may be available to wells that penetrate to the base of the Tongue River Member or into the uppermost part of the Lebo Shale Member. Yields of wells completed in the Tongue River Member may be about 1 to 5 gal/min. The Tullock Member generally will yield an adequate supply of water for stock use and is a favorable source of water if an adequate supply cannot be obtained from shallower sources.

POTENTIAL EFFECTS OF MINING ON AREA HYDROLOGY

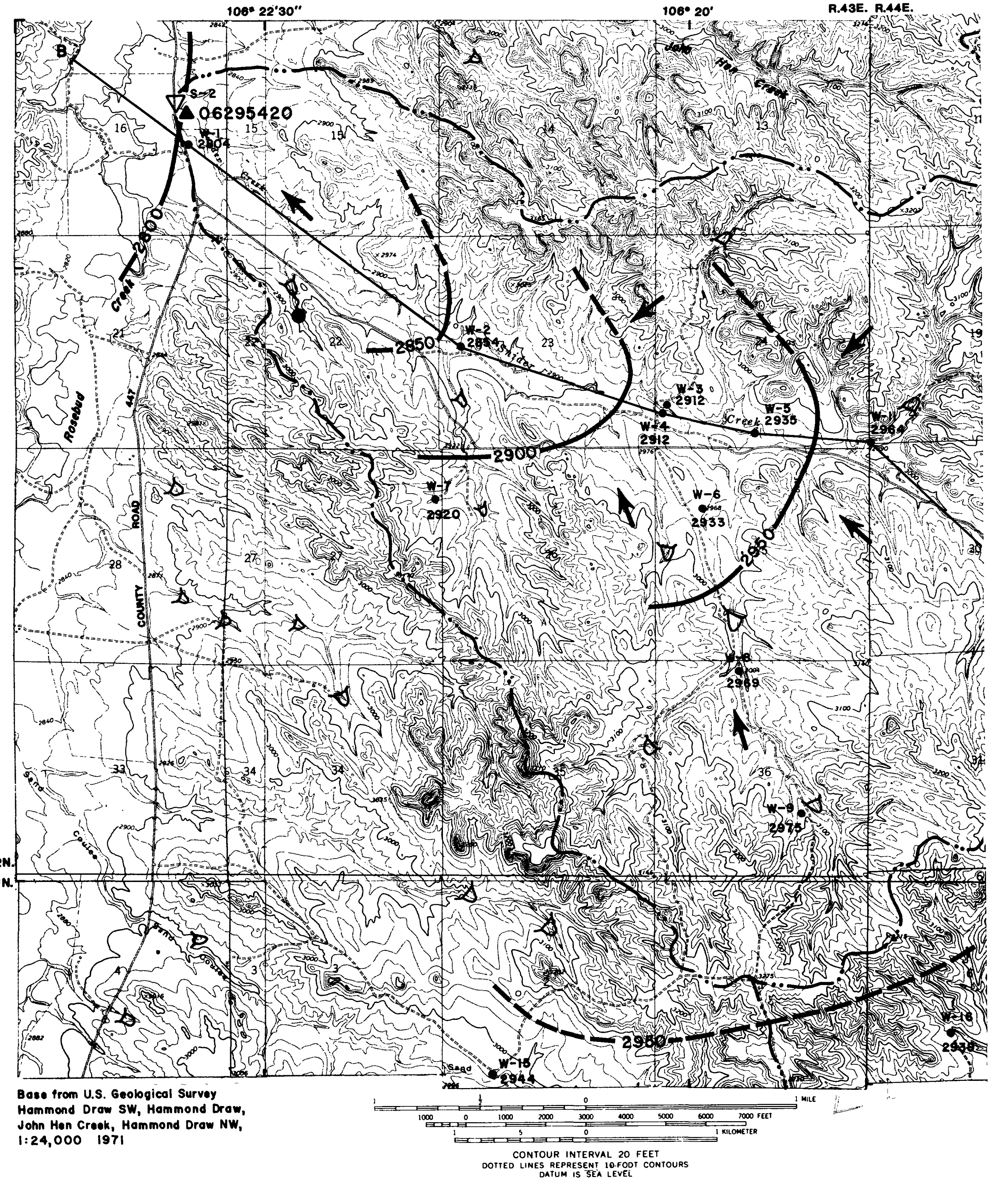
Assumptions

For the purpose of determining the effects of mining on local hydrologic systems, the following conditions were assumed: (1) Mining would remove the entire Terrett coal bed in the area along the Rosebud Creek-Tongue River drainage divide (fig. 3); (2) the mine boundary would be the outcrop of the Terrett coal, or the edge of unburned coal in areas of clinker; and (3) mining regulations established by the U.S. Office of Surface Mining and the Montana Department of State Lands that pertain to the protection of the hydrologic regime would be adhered to during mining and reclamation.

Effects during mining

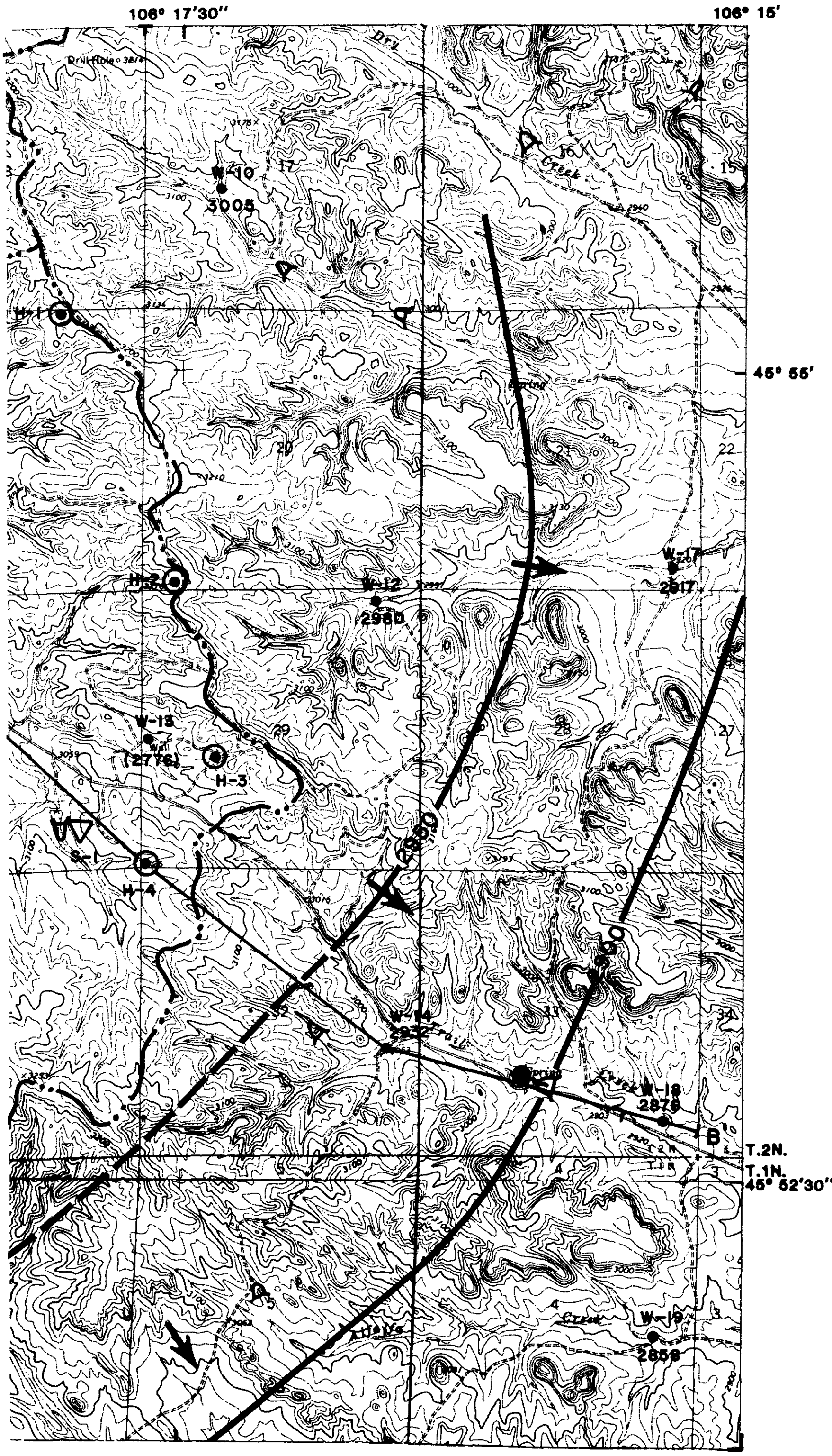
Mining of the Terrett coal bed would involve the removal of the ridgetop along the Rosebud Creek-Tongue River divide. Width of the area to be mined ranges from about 1 to 2 miles, which is the distance between the east and west outcrops of the Terrett coal. The Terrett coal and the overlying strata of shale and sandstone contain no aquifers capable of sustaining yields for livestock use. No dewatering efforts would be necessary at the mine site and the mine pit would not withdraw water from the alluvial or the basal Tongue River Member aquifers.

One potential impact to the local hydrology would be a change in the rate of aquifer recharge. The mine area is in the recharge area for both the basal aquifer in the Tongue River Member and the alluvial aquifer in Snider Creek valley. The effect of mining on recharge rates is largely dependent upon procedures used at



Base from U.S. Geological Survey
Hammond Draw SW, Hammond Draw,
John Hen Creek, Hammond Draw NW,
1:24,000 1971

Figure 2.--Altitude of potentiometric surface and location of wells, test



EXPLANATION

2950 — POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells completed in the first aquifer below land surface, 1972-79. Dashed where approximately located. Contour interval 50 feet. Datum is sea level

DIRECTION OF GROUND-WATER FLOW IN SHALLOW AQUIFERS

B — B' TRACE OF HYDROGEOLOGIC SECTION (fig. 5)

DRAINAGE-BASIN BOUNDARY

DATA SITE AND NUMBER

W-1 2804 Well--Lower number is hydraulic head, in feet above sea level; number in parentheses indicates hydraulic head from aquifer deeper than first aquifer below land surface

H-2 Test hole

S-1 Surface-water sampling site

06295420 U.S. Geological Survey streamflow-gaging station and number

STOCK RESERVOIR

SEEP OR SPRING

holes, stock reservoirs, and streamflow-gaging stations.

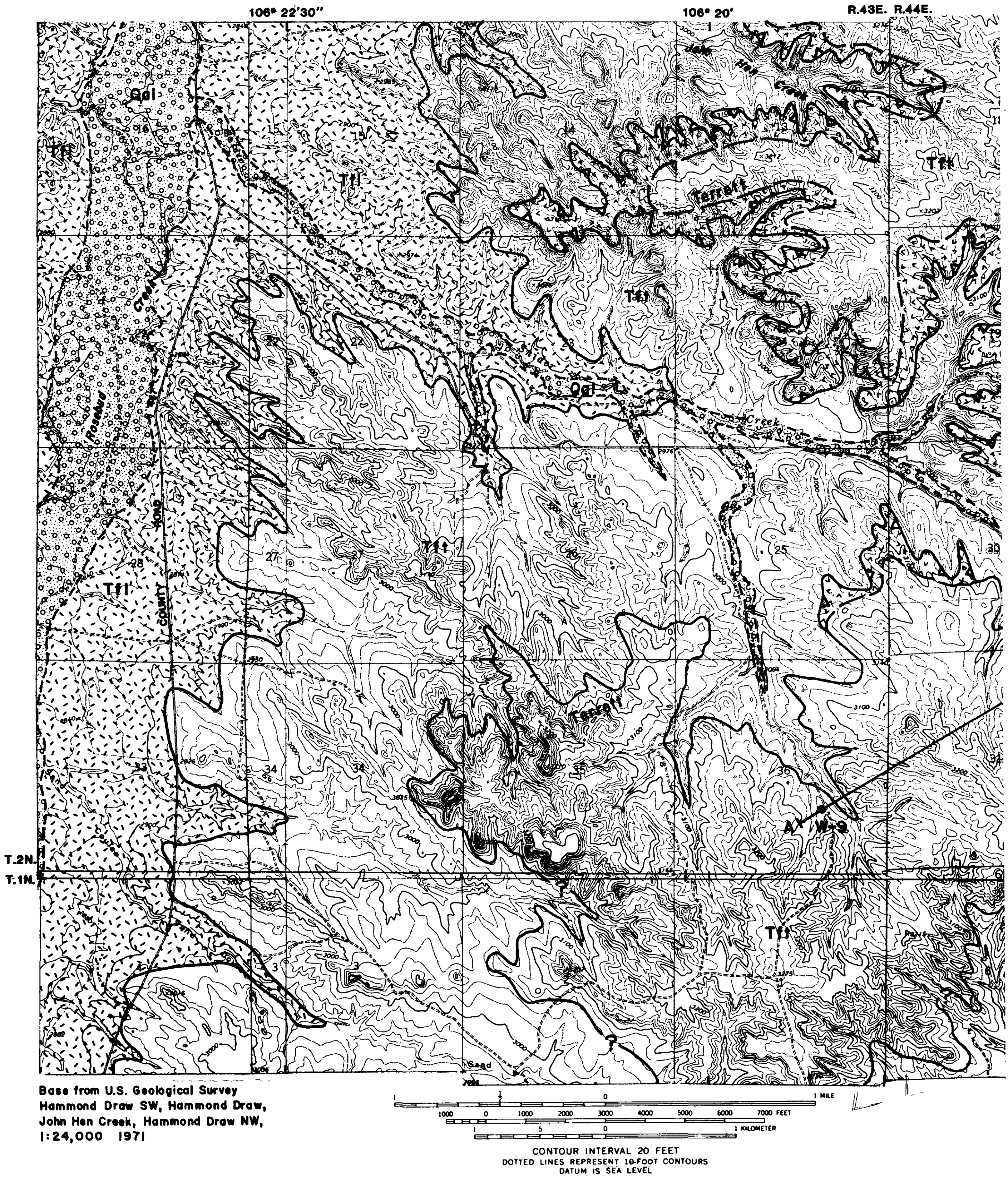
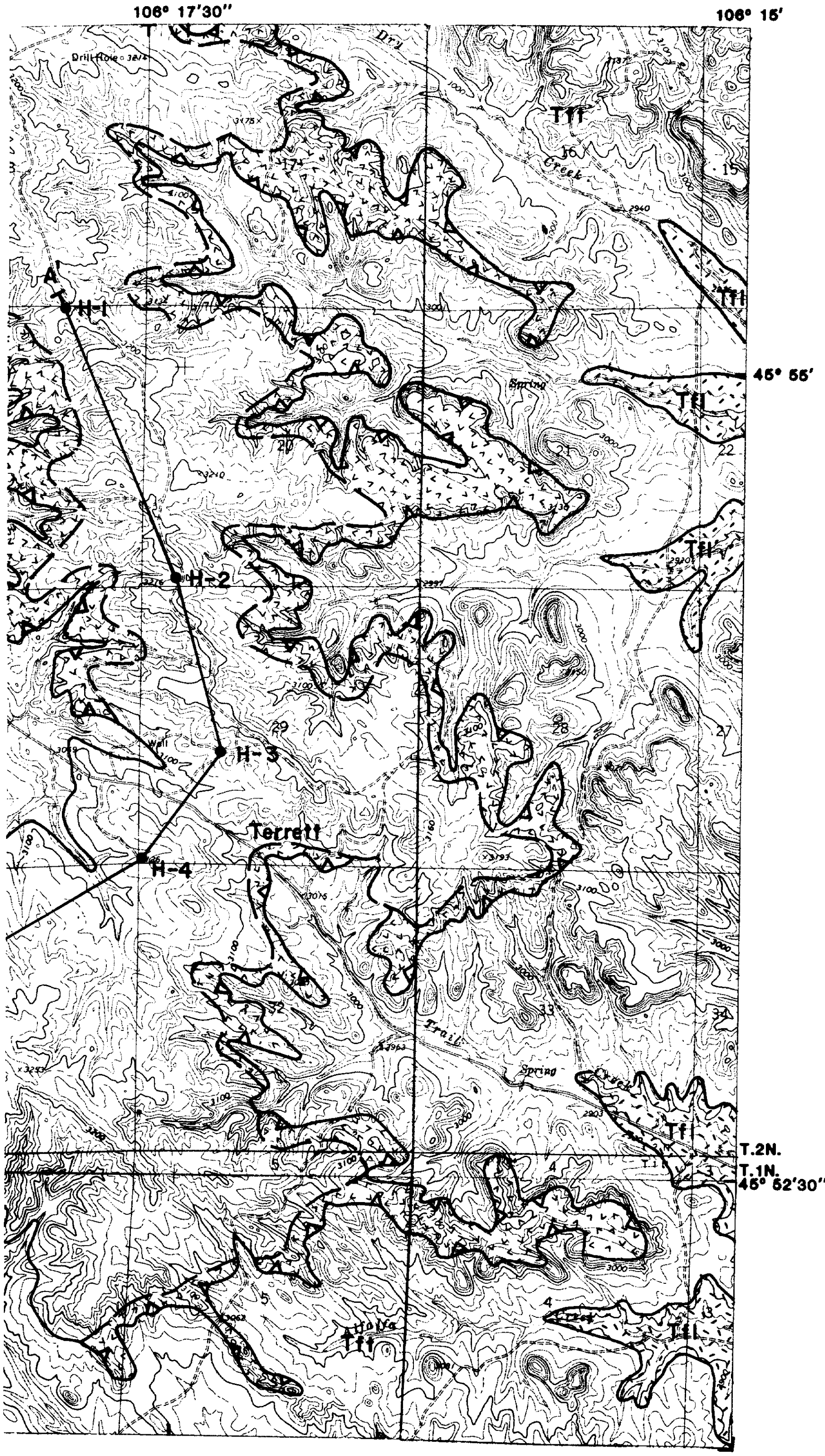


Figure 3.--Geologic map showing outcrop of the Terrett coal bed of Tongue



EXPLANATION

Qal — ALLUVIUM (HOLOCENE AND PLEISTOCENE)--Occurs principally in the valleys of Rosebud and Snider Creeks

Tft — TONGUE RIVER MEMBER OF FORT UNION FORMATION (PALEOCENE)

Tfl — LEBO SHALE MEMBER OF FORT UNION FORMATION (PALEOCENE)

CONTACT--Dashed where approximately located

CLINKER FORMED BY BURNING OF TERRETT COAL BED--Dashed line is approximate limit of burning. Sawteeth show base of clinker bed

Terrett ?— OUTCROP OF TERRETT COAL BED OR APPROXIMATE LIMIT OF UNBURNED COAL--Queried where location uncertain

A A' TRACE OF CORRELATION SECTION (fig. 4)

Geology modified from Bass (1932), Pierce (1936), and Matson and Blumer (1973)

River Member of Fort Union Formation.

the mine to store water from surface-water runoff and to store water used for dust control. If surface water is stored in ponds, the recharge rate to the basal aquifer in the Tongue River Member might be increased through seepage from the ponds. An increase in recharge to the alluvial aquifer also might occur. A potential detrimental effect from an increase in recharge is the possible development of saline seeps downgradient from the water-storage ponds.

Mining of the Terrett coal bed probably would not decrease the quantity of water available to stock wells located outside of the mine boundary, provided that no wells would have to be installed in aquifers of the Fort Union Formation for a water supply for the mining operation. Withdrawal of water from the deeper Fox Hills-lower Hell Creek aquifer for use at the mine site would have no effect on area wells.

Mining in the headwaters of the small tributaries of Rosebud Creek and the Tongue River would alter the timing and magnitude of runoff in these tributaries. Peak-flow volumes probably would be decreased because of runoff-control practices mandated in surface-mining regulations; sediment discharge probably would be decreased for the same reason. Mining probably would have no measureable effect on the flow rates or sediment loads in Rosebud Creek or the Tongue River.

Long-term impacts

Long-term impacts to local water resources are those that are permanent or exist for many years after mining is completed, such as the loss of springs and wells or the degradation of water quality. Long-term effects of mining on local water resources in the Snider Creek area are expected to be minimal. Few impacts are expected because the area to be mined is situated above the saturated zone and no significant saturation of mine spoils is anticipated after completion of mining.

One stock well (W-13) and several small stock reservoirs located in the mine area would be destroyed by mining. Four other stock wells (W-8, W-10, W-12, and W-16) located near the outcrop of the Terrett coal might be destroyed or have lowered water levels during mining.

Degradation of the quality of ground water, caused by the leaching of soluble salts from mine spoils, is not anticipated. A method of predicting the changes in chemical quality of ground water in coal strip mines in the western United States (Hounslow and Fitzpatrick, 1978) indicates that where the coal seam is above the water table, mining operations are unlikely to cause changes in ground-water chemistry. Data used to develop the predictive method were collected from eight western coal mines, including the mine at Colstrip, Mont., located about 14 miles west of the Snider Creek area.

POTENTIAL FOR RECLAMATION OF WATER RESOURCES

Stock wells destroyed or adversely affected by mining could be replaced with new wells completed in the Tullock Member of the Fort Union Formation. In the area along the Rosebud Creek-Tongue River drainage divide, the Tullock Member is likely to be a more reliable source of water than either the lower part of the Tongue River Member or the Lebo Shale Member, although wells completed in the Tullock would have lower static water levels and require greater pumping lift.

Stock reservoirs removed by mining could be reconstructed during mine reclamation. Lining of all stock reservoirs, which are constructed over mine spoils, with clay or bentonite would prevent any significant loss of water to seepage and would decrease the potential for leaching of soluble salts from mine spoils under the stock reservoirs.

SUPPORTING TECHNICAL DISCUSSION

Geology

Stratigraphy

All rocks that crop out in the Snider Creek area are part of the Fort Union Formation of Paleocene age, with the exception of alluvial deposits of Pleistocene and Holocene age in some stream valleys. The Fort Union Formation is divided into three members which are, in ascending order, the Tullock, Lebo Shale, and Tongue River Members. Only the Lebo Shale and Tongue River Members crop out in the study area (fig. 3). Older formations of Late Cretaceous age, which do not crop out in the area but form important regional aquifers, are the Fox Hills Sandstone and the Hell Creek Formation.

The Lebo Shale Member of the Fort Union Formation is exposed at the surface in the western part of the Snider Creek basin, in the valley of Rosebud Creek, and in the valleys of several small streams on the east boundary of the study area (fig. 3). The Lebo Shale Member is composed of soft, dark-colored shale with lenses of gray and yellow sandstone. Thickness of the Lebo is about 170 feet (Pierce, 1936).

The lower part of the Tongue River Member of the Fort Union Formation crops out within most of the study area. Along the perimeter of the Snider Creek basin, the Tongue River Member has a thickness of about 380 feet. Minimum thickness of the Tongue River Member occurs where the member has been eroded down to the Lebo Shale Member. The contact between the Tongue River Member and the Lebo Shale Member is not distinct, but is gradational for 25 to 30 feet (Pierce, 1936). In the Snider Creek area, the altitude of the Tongue River Member-Lebo Shale Member contact is about 2,920 feet.

The lower part of the Tongue River Member is composed of interbedded shale and fine-grained sandstone with several thin coal beds and a few massive beds of fine-grained sandstone. Coal beds within the lower part of the Tongue River Member from top downward are local coal beds, the Terrett coal, the Burley coal, and the Trail Creek coal (fig. 4). The Terrett and Burley coals are the thickest and most extensive of the coal beds; the Terrett coal ranges in thickness from about 9 to 17 feet and the Burley from about 2 to 5 feet. The Terrett coal bed has burned along most of its outcrop, forming a porous and permeable layer of red clinker. The local coal bed and Trail Creek coal bed generally are less than 2 feet thick.

Alluvial deposits are present along the main channel of Snider Creek, along the downstream parts of some tributaries to Snider Creek, and in the valley of Rosebud Creek (fig. 3). Alluvium along the channel of Snider Creek is composed of interbedded layers of sand, gravel, silt, and clay. The gravel and larger sand grains are derived primarily from fragments of clinker. Thickness of the alluvium

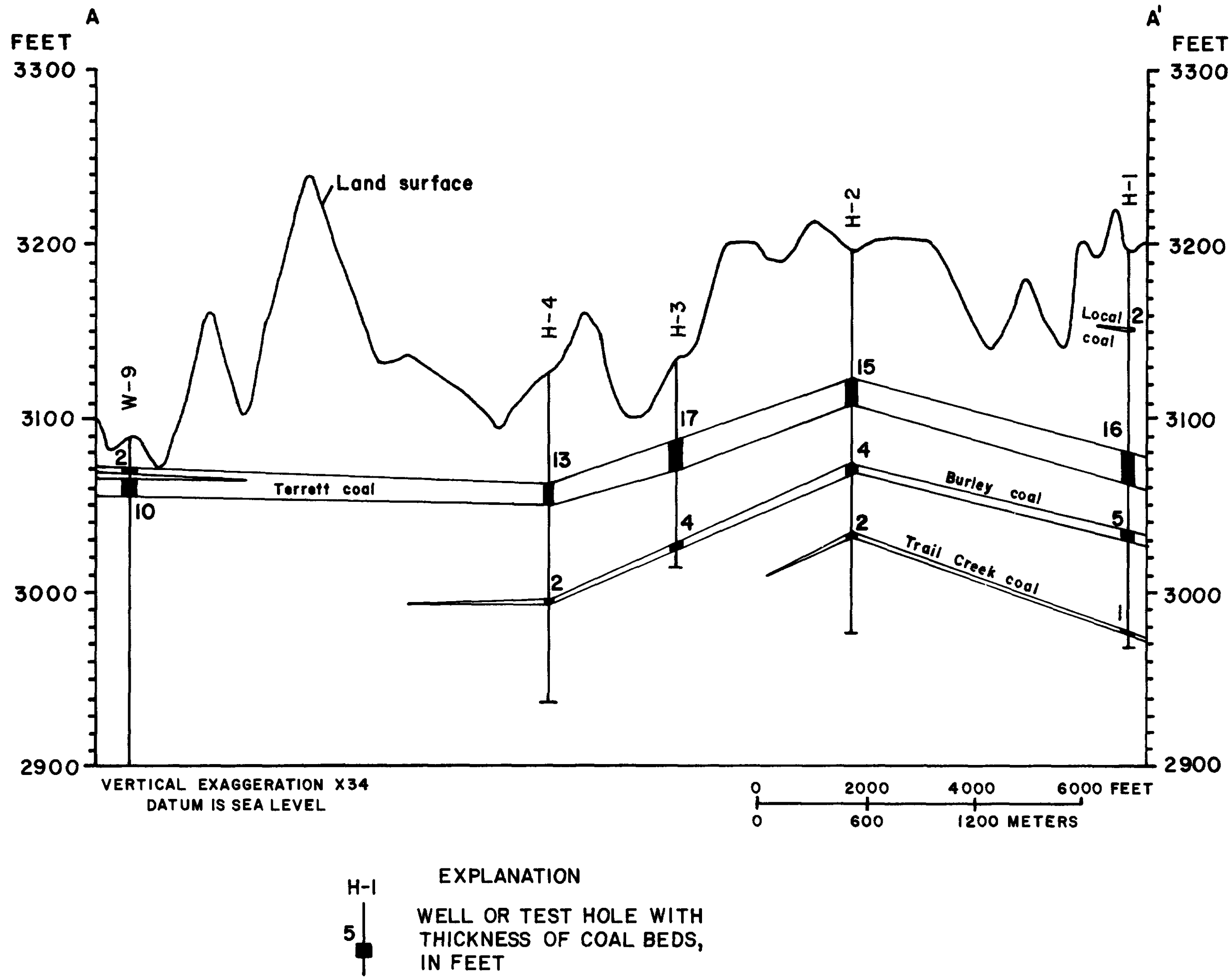


Figure 4.--Correlation section A-A' showing thickness and location of coal beds in Tongue River Member of Fort Union Formation. Altitude of the land surface was estimated from a topographic map having a contour interval of 20 feet. Trace of section is shown in figure 3.

along Snider Creek is 65 feet at well W-3, 60 feet at well W-4, and 20 feet at well W-5 (locations shown in fig. 2).

Structure

Strata of the Tongue River and Lebo Members are nearly horizontal throughout the study area. The strata dip about 1° to the south-southeast, which is toward the Tongue River valley. Major structural features that affect the attitude of these beds are the Tongue River syncline and the Powder River structural basin. The Snider Creek area is situated on the northwest limb of the northeast-trending Tongue River syncline and near the northern boundary of the Powder River structural basin. The axis of the Tongue River syncline closely parallels the Tongue River.

Ground-water resources

Shallow aquifers are the most utilized aquifers in the Snider Creek area. Shallow aquifers occur within sandy lenses in the Lebo Shale Member of the Fort Union Formation, within sandstone lenses near the base of the Tongue River Member of the Fort Union Formation, and within alluvial deposits along the channel of Snider Creek and the valley of Rosebud Creek. Deeper aquifers exist within the Tullock Member of the Fort Union Formation, the lower part of the Hell Creek Formation, and the upper part of the Fox Hills Sandstone. Hydrogeologic data collected from local wells and drill holes (table 1) help in the delineation of the shallow aquifers and the local ground-water flow systems.

Lebo Shale Member of Fort Union Formation

The Lebo Shale Member does not yield much water to wells or springs and the member, as a whole, generally is not considered to be an aquifer. Water for use by livestock can sometimes be obtained from the Lebo where sandstone lenses occur within the member.

Recharge to the Lebo is limited by its relatively small hydraulic conductivity. Recharge water that percolates downward from the overlying Tongue River Member is restricted from further downward movement when it reaches the thick shale beds of the Lebo. Most recharge to the Lebo Shale Member probably occurs where sandy lenses in the Lebo are overlain by saturated alluvium or sandstone of the Tongue River Member.

Discharge from the Lebo Shale Member to seeps was observed only from the upper part of the member, near the contact with the Tongue River Member. At least three stock wells in the area discharge water from the Lebo (see table 1 and fig. 2).

Tongue River Member of Fort Union Formation

Hydrogeologic properties

Hydrogeologic properties of the Tongue River Member were investigated by drilling several test holes, installing one observation well, conducting aquifer tests, and measuring water levels in existing stock wells. Three test holes (H-1, H-2, and H-4) were drilled through the Terrett and Burley coal beds. These holes were located near the basin divide in the eastern part of Snider Creek (see fig. 2). All coal and sandstone beds penetrated in these holes were unsaturated, although the bottom several feet of rock penetrated in holes H-1 and H-2 were moist. These three test holes penetrated all but the lower 20 to 60 feet of the Tongue River Member.

One observation well (W-9) was installed in the southern part of the Snider Creek basin near the basin divide. This observation well bottoms near, or slightly below, the Tongue River Member-Lebo Shale Member contact and is perforated in shale, carbonaceous shale, and a thin coal stringer in the lower part of the Tongue River Member. A slug-injection test conducted at well W-9 indicates the hydraulic conductivity of the shale is about 0.01 ft/d. Well yield is less than 1 gal/min.

Several stock wells in the area are completed in sandstone aquifers in the lower part of the Tongue River Member. Hydraulic conductivity of the sandstone aquifers was not measured because the stock wells were not suitable for conducting aquifer tests.

Shallow flow systems

A relatively continuous saturated zone occurs at the base of the Tongue River Member, near the contact with the Lebo Shale Member, based on water levels measured in observation well W-9 and in stock wells W-6, W-7, W-8, W-10, W-12, W-14, and W-15. This saturated zone is composed primarily of fine-grained sandstone and shale, and it serves as a satisfactory source of water for stock wells. Test holes H-1, H-2, and H-4 were drilled between existing stock wells and penetrated most of the Tongue River Member, but were reported as dry holes. These test holes likely would have penetrated the same aquifer near the base of the Tongue River Member if they had been drilled an additional 20 to 60 feet to the the top of the Lebo Shale Member. Because the bottom several feet of rock penetrated in test holes H-1 and H-2 were moist, the drill bit may have just entered the saturated zone.

Altitudes of water levels were measured in stock and observation wells, and the measured water levels were used to construct a map of the potentiometric surface (fig. 2). The configuration of the potentiometric surface indicates that water in the basal aquifer in the Tongue River Member flows from near the topographic divide in the eastern part of the Snider Creek basin towards the channel of Snider Creek. Ground water also flows from near the Rosebud Creek-Tongue River drainage divide eastward toward the Tongue River. The direction of shallow ground-water flow in this area appears to be controlled largely by the configuration of the local topography.

Recharge to the basal aquifer in the Tongue River Member occurs solely from infiltration and percolation of precipitation. Water that infiltrates below the root zone moves downward under unsaturated-flow conditions until it reaches either a small perched aquifer or the basal aquifer of the Tongue River Member. Farther downward movement is restricted by the Lebo Shale Member. Recharge probably occurs only during the late winter and spring months when the rate of snowmelt or precipitation exceeds the rate of evapotranspiration. The average rate of recharge is unknown, but is probably less than 0.1 inch per year. This value is based on recharge rates to coal, sandstone, and shale of the Tongue River Member, which were calculated by Woessner, Andrews, and Osborne (1979) during a study on the Northern Cheyenne Indian Reservation, about 15 miles south of the study area. Clinker is especially favorable for recharge because of its large porosity and permeability. During years of less-than-normal precipitation, the basal aquifer in the Tongue River Member may receive no recharge.

Discharge from the basal aquifer in the Tongue River Member is to alluvium along the channel of Snider Creek, to small seeps located near the contact with the Lebo Shale Member, and possibly to deeper aquifers in the Lebo and Tullock Members. Based on the configuration of both the local topography and the potentiometric surface, a major part of the discharge from this aquifer appears to be to the alluvium. Seeps that discharge near the contact between the Tongue River Member and the Lebo Shale Member are located in the SE1/4 NW1/4 sec. 22, T. 2 N., R. 43 E., and the SE1/4 NE1/4 SW1/4 sec. 33, T. 2 N., R. 44 E. Both of these seeps flow into small stock reservoirs. The seep in sec. 22 flows during most years and maintains water in the stock reservoir downstream. However, during the summer of 1980 the seep was dry as a result of less-than-normal precipitation. The seep in sec. 33 had no visible flow during the summer of 1980, although the stock reservoir downstream was not dry.

Coal beds within the Tongue River Member appear to be relatively permeable; however, they support limited ground-water flow because of their topographic position and small rates of ground-water recharge. The Terrett and Burley coal beds crop out along both sides of the Rosebud Creek-Tongue River drainage divide (fig. 5). The distance across the divide between one outcrop of a coal bed and its other outcrop, is about 1 to 2 miles. The relatively small area of potential recharge combined with relatively steep slopes along the divide preclude the development of a significant saturated zone in the Terrett and Burley coal beds. Only one area was observed that may contain a limited quantity of water in the Terrett coal bed. This area is in the SE1/4 sec. 30, T. 2 N., R. 44 E., where the Terrett crops out along the bottom of a small draw. The draw contains a stock reservoir, which is recharged by surface runoff and limited ground-water seepage. Water in this area appears to be perched on relatively impermeable shale. The extent of this saturated zone appears to be limited, because no water was observed in test hole H-4, which is located in sec. 29, adjacent to the southeast corner of sec. 30.

Alluvium

Determinations of aquifer properties of the alluvium underlying the channel of Snider Creek were attempted at wells W-3, W-4, and W-5. Hydraulic conductivity of the gravel and sand aquifer determined at wells W-3 and W-4 is about 30 ft/d; transmissivity of the aquifer ranges from about 700 to 800 ft^2/d. Storage coefficient for the alluvial aquifer at wells W-3 and W-4 was calculated to be 0.001, indicating semiconfined conditions. Aquifer properties at well W-5 could not be reliably determined. Both pumping and slug-injection tests were attempted at well W-5 with limited success. Test data indicate a partly plugged well or very small hydraulic conductivity of the aquifer.

Recharge to the alluvium underlying the channel of Snider Creek occurs as lateral flow from the adjacent basal aquifer in the Tongue River Member, from infiltration of surface runoff, and from direct precipitation on the alluvium. Recharge to the alluvial aquifer underlying the Snider Creek channel was less than ground-water discharge during the entire period of study, as shown by the hydrograph in figure 6. The hydrograph was constructed from data collected from a water-level recorder installed on well W-4. Water-level data were collected at this well for 21 months from August 16, 1979, to May 8, 1981. Precipitation during this time was less than average, with little or no recharge to shallow aquifers.

Discharge from the alluvial aquifer underlying the Snider Creek channel is through transpiration by plants and subsurface flow to the Rosebud Creek valley. Color-infrared photographs taken July 5, 1979, indicate vigorous growths of vegeta-

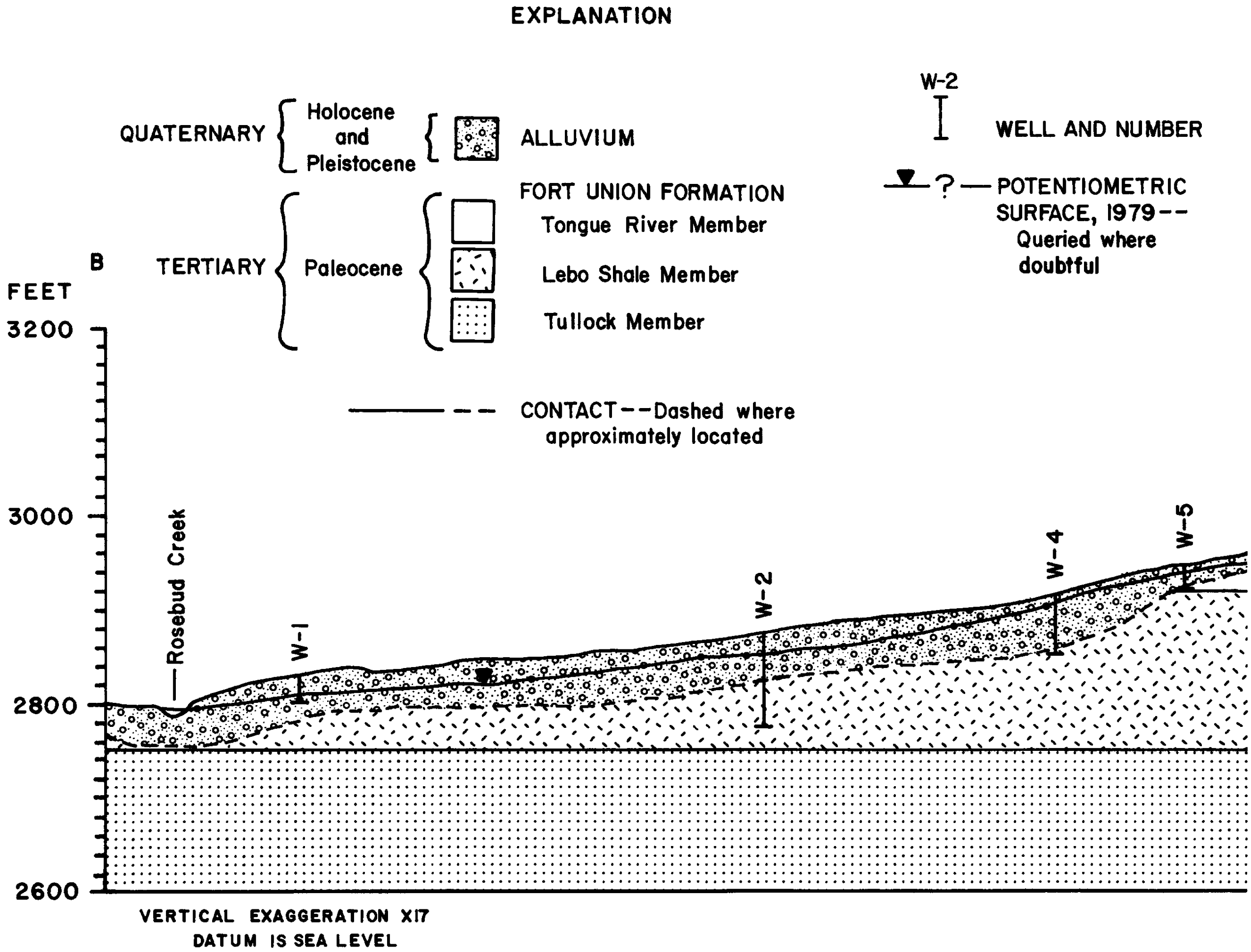
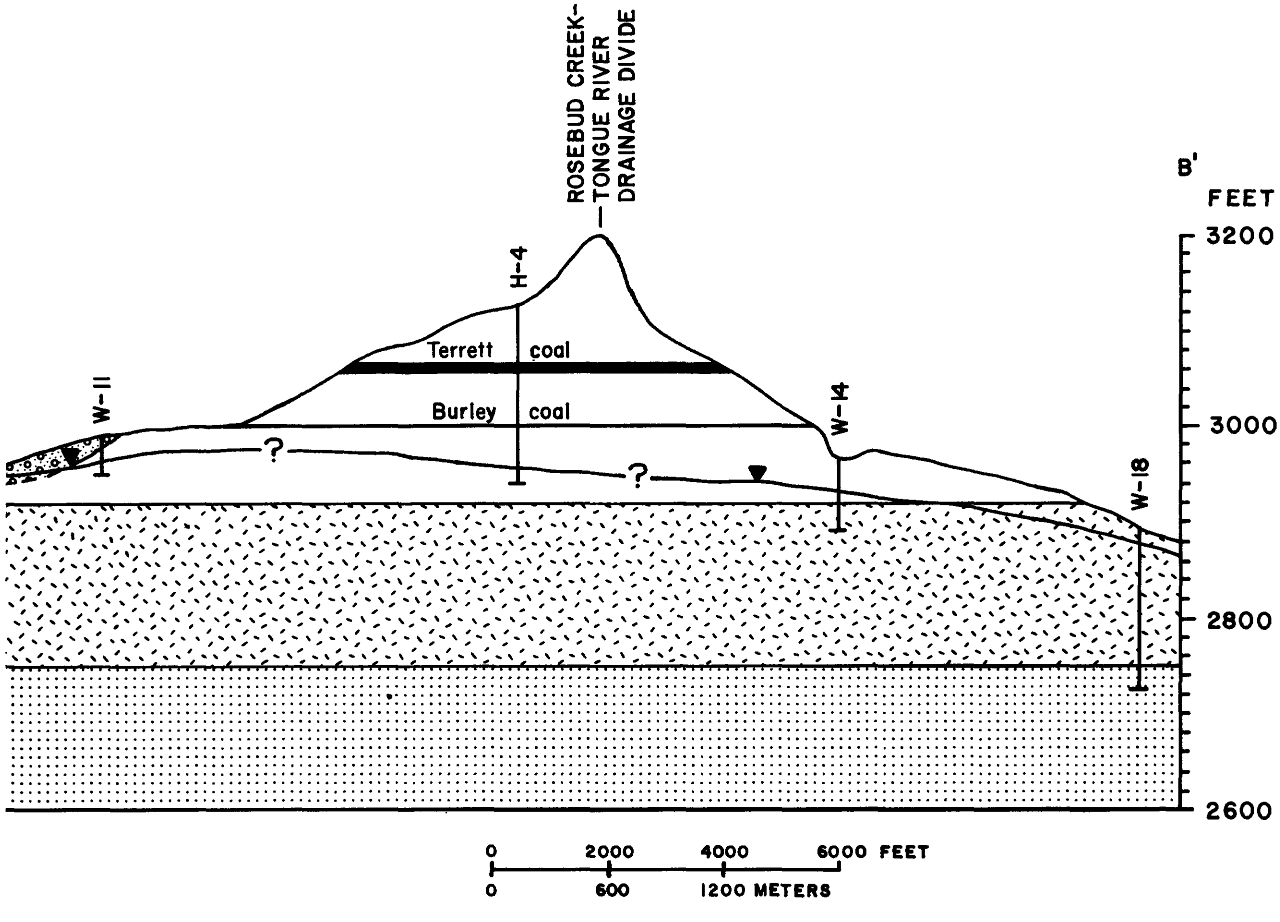


Figure 5.--Hydrogeologic section B-B' showing the potentiometric



surface. Trace of section is shown in figure 2.

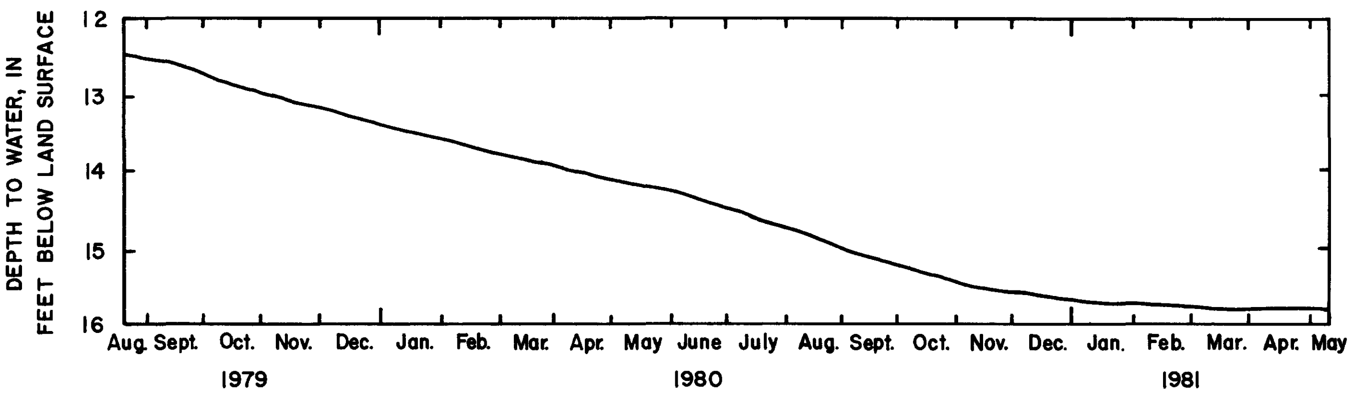


Figure 6.--Water-level hydrograph for well W-4 completed in alluvium.

tion distributed throughout the main channel of Snider Creek, with the downstream reach of the channel containing more lush vegetation than other reaches of the channel. The quantity of water removed from the alluvial aquifer through plant transpiration is unknown. Subsurface discharge from the alluvium was determined by using the aquifer properties measured at wells W-3 and W-4, and by the Darcy equation, to estimate the quantity of water moving through the aquifer. Estimated flow through the alluvium at wells W-3 and W-4 is about 1,000 to 2,000 ft^3/d. This estimated flow, minus downstream losses to transpiration, is the approximate rate that subsurface water discharges from the alluvial aquifer of Snider Creek to the alluvial aquifer of the Rosebud Creek valley.

Deep aquifers

Several geologic units that underlie the Lebo Shale Member contain aquifers that supply water to many stock and domestic wells in Rosebud County. These aquifers are sandstone in the upper part of the Fox Hills Sandstone, sandstone in the lower part of the Hell Creek Formation, and sandstone and coal beds within the Tullock Member of the Fort Union Formation.

The sandstones of the Fox Hills Sandstone and the lower part of the Hell Creek Formation generally form a single aquifer known as the Fox Hills-lower Hell Creek aquifer. Thickness of the Fox Hills-lower Hell Creek aquifer is about 400 to 500 feet and its base is at an altitude of about 1,600 feet (Lewis and Hotchkiss, 1981). At present (1982), no wells in the Snider Creek area are completed in this aquifer. However, in other areas of the Powder River Basin, the Fox Hills-lower Hell Creek aquifer yields as much as 70 gal/min to stock and domestic wells (Lewis and Roberts, 1978).

The Tullock Member of the Fort Union Formation is composed of sandstone and shale with a few thin coal beds. Thickness of the Tullock in the Snider Creek area is about 250 to 300 feet, based on a section measured by Pierce (1936) in sec. 15, T. 5 N., R. 42 E., about 16 miles north of the study area. Hydrogeologic properties of the Tullock were not measured during this study; however, sandstones and coal beds within the Tullock Member generally supply small quantities of water for stock and domestic use. Well yields may be as much as 40 gal/min, but generally average about 15 gal/min (Lewis and Roberts, 1978). One well (W-13) in the upstream part of the Snider Creek basin is completed in the Tullock Member. The water level in this well is 316 feet below land surface or about 200 feet lower than in a nearby well (W-12), which is completed in the basal aquifer in the Tongue River Member.

Surface-water resources

The study area is located along the drainage divide between the northward-flowing Tongue River and Rosebud Creek. Many small tributaries to the Tongue River and Rosebud Creek drain to the east and west from the area along the divide. Snider Creek, a tributary of Rosebud Creek, has a drainage area of 11.9 mi^2 and drains most of the study area. Other small tributaries that drain part of the study area include Dry Creek, Trail Creek, Alfalfa Creek, John Hen Creek, and Sand Coulee (fig. 2).

Snider Creek and other small drainages in the area are ephemeral and flow only in response to surface runoff from rainfall or snowmelt. The creek channels are above the water table at all times of the year. From June 1979 to November 1980 there were no known intervals of runoff in the Snider Creek basin. The only streamflow data available for Snider Creek are two flow measurements made in March 1978. At this time, Snider Creek was flowing in response to runoff from snowmelt. Flow was measured as 10 ft^3/s on March 19, 1978, and 52 ft^3/s on March 20, 1978.

The mean annual discharge and the magnitude and frequency of floods of Snider Creek were estimated by indirect methods. The method used to estimate mean annual flow requires measurements of the channel geometry. The method was developed through regression analysis based on the correlation of streamflow with the dimensions of the channel (Hedman and Kastner, 1977). Estimates of flood peaks were made from an empirical equation, which uses the basin characteristics of drainage area and percentage of forest cover within the basin, combined with a geographical factor that is dependent on the location of the basin within the State (Parrett and Omang, 1981). Based on indirect methods, mean annual flow of Snider Creek is about 170 acre-feet per year; magnitudes of flood peaks are 790 ft^3/s for the 25-year flood, and 170 ft^3/s for the 5-year flood.

Runoff from the Snider Creek basin is attenuated by the presence of 10 small stock reservoirs on tributaries of the main stem of Snider Creek (fig. 2). Most of these reservoirs have areas of less than 1 acre, although a few have areas of 2 to 3 acres when full. These reservoirs may become dry during years of less-than-average precipitation. The stock reservoir in the NW1/4 sec. 22, T. 2 N., R. 43 E. is perennial most years, but was dry during the summer of 1980.

The U.S. Geological Survey maintains several streamflow-gaging stations near the study area. Continuous water-stage recorders are maintained on Rosebud Creek near Colstrip (station 06295250), Rosebud Creek at mouth, near Rosebud (station 06296003), and Tongue River below Brandenberg Bridge, near Ashland (station 06307830) (see fig. 1). Miscellaneous-flow measurements are made on Snider Creek near Brandenberg (station 06295420) during infrequent intervals of runoff. Hydrologic data collected from the stations on Rosebud Creek and the Tongue River are published annually by the U.S. Geological Survey (1981).

Water quality

Quality of water was determined by the analysis of water samples from local stock and observation wells and surface-water sources. Results of the water analyses are listed in tables 2 and 3. Analyses of additional water samples from wells and springs in the general area are available in a report by Lee (1979).

Ground-water samples from the Snider Creek area had pH values ranging from 7.1 to 8.7 and dissolved-solids concentrations ranging from 600 to 3,460 mg/L (milligrams per liter). In the Snider Creek area, water in the Fort Union Formation can be classified into four distinct types, based on concentrations of dominant ions expressed in milliequivalents per liter. These water types are: (1) Magnesium calcium bicarbonate type water with moderate concentrations of sodium and sulfate and very small concentrations of chloride, (2) calcium magnesium sulfate type water with moderate concentrations of sodium and bicarbonate and very small concentrations of chloride, (3) sodium sulfate type water with moderate concentrations of calcium, magnesium, and bicarbonate and very little chloride, and (4) sodium bicarbonate type water with a large chloride concentration, a relatively large fluoride concentration, and almost no calcium, magnesium, or sulfate. The cation(s) and anion(s) named in each of these water types constitute 50 percent or more of the total cations and anions.

The four water-quality types in the Snider Creek area can be attributed to aquifer mineralogy, the length of the ground-water flow path, travel time along the flow path, and solution chemistry. Geochemistry of water in the Fort Union Formation and possible chemical reactions to explain the evolution of the various types of water found in the area have been discussed by Lee (1981).

Based on a conceptual model developed by Lee (1981), the evolution of the major chemical types of ground water found in the Snider Creek area can be summarized as follows. Recharge water that has entered a ground-water flow system and has traveled only a short distance has small concentrations of dissolved solids that are dominated by calcium, magnesium, and bicarbonate, with smaller concentrations of sodium and sulfate. These ions are derived through the dissolution of calcite, gypsum, and other minerals combined with the exchange of calcium ions for sodium ions by clay minerals. Water of the magnesium calcium bicarbonate type is found in well W-15. This well appears to be completed in a sandstone lens that is recharged locally by precipitation and snowmelt. As ground water moves farther along a flow path, concentrations of sodium, calcium, magnesium, and sulfate increase, resulting in a calcium magnesium sulfate water type and an overall increase in dissolved solids. Water of this type is locally predominant in the shallow aquifers. A calcium magnesium sulfate water is found in wells W-8, W-11, and W-12.

Additional travel time within a ground-water flow system produces an increased dissolved-solids concentration, primarily in sodium and sulfate ions, which results in a sodium sulfate type water. Water of this type occurs in alluvial wells W-3 and W-4 and in well W-14, which penetrates the Tongue River Member and Lebo Shale Member of the Fort Union Formation. Water from well W-14 had the largest measured concentration of dissolved solids (3,460 mg/L), and water from wells W-3 and W-4 had the next largest concentrations. The alluvium penetrated by wells W-3 and W-4 overlies the Lebo Shale Member, which may account, in part, for the similar water type in both aquifers.

As water travels into deeper aquifers, a sodium bicarbonate water may develop. In water of this chemical type, most calcium and magnesium ions have been exchanged for sodium ions and sulfate ions likely have been reduced by sulfate-reducing bacteria (Lee, 1981; Dockins and others, 1980). Only one well in the Snider Creek area (W-13) has a sodium bicarbonate water type. Well W-13 is a deep well completed in the Tullock Member of the Fort Union Formation. In water from this well, sodium plus potassium ions compose about 99 percent of the cations, and bicarbonate ions compose more than 70 percent of the anions, when expressed in milliequivalents per liter. Concentrations of chloride and fluoride are also large in this water. The fluoride concentration in this water exceeds the maximum limit established by the U.S. Environmental Protection Agency (1976) for a public water supply. Concentrations of calcium, magnesium, and sulfate are each less than 1 percent of the total ion concentration.

Analyses of water samples from surface-water sources (fig. 2) in the Snider Creek basin are limited because of the ephemeral nature of most streams and livestock reservoirs. One water sample from a reservoir in the upstream part of the Snider Creek basin (site S-1) and two samples from Snider Creek (site S-2) were analyzed. The water samples from Snider Creek were collected during runoff in March 1978. The dissolved-solids concentration was 1,000 mg/L for the reservoir and 38 mg/L and 49 mg/L for Snider Creek. Water quality of Rosebud Creek is well documented and water-quality data are available in other publications (Knapton and McKinley, 1977; Knapton and Ferreira, 1980).

CONCLUSIONS

Ground-water and surface-water resources of the area are used primarily for livestock watering. Shallow wells, most of which are completed in the basal part of the Tongue River Member or in the upper part of the Lebo Shale Member, provide a reliable source of stock water. Alluvial deposits along the channel of Snider Creek, from its mouth to about 3 miles upstream, and the Tullock Member of the Fort Union Formation appear to be favorable aquifers for the development of additional stock wells. Many small reservoirs supply stock water during years of adequate precipitation. Snider Creek and its tributaries are ephemeral and flow only in response to surface runoff from rainfall or snowmelt.

Chemical analysis of a water sample from one livestock reservoir (site S-1) indicated that the concentrations of all constituents tested were much less than maximum limits established for use by livestock. Ground-water samples from stock and observation wells had pH values ranging from 7.1 to 8.7 and dissolved-solids concentrations ranging from 600 to 3,460 mg/L. The fluoride concentration in water from stock well W-13 exceeds the maximum limit established by the U.S. Environmental Protection Agency for a public water supply.

Mining of the Terrett coal bed of the Tongue River Member would remove the ridgetop along the Rosebud Creek-Tongue River divide. The Terrett coal and overlying strata contain no significant aquifers. No dewatering efforts would be necessary at the mine site and the mine would not decrease the quantity of water available to stock wells located outside of the mine boundary. Within the mine boundary, one stock well (W-13) and several small stock reservoirs would be destroyed. Four other stock wells (W-8, W-10, W-12, and W-16) located near the outcrop of the Terrett coal might be destroyed or adversely affected during mining.

After mining, destroyed wells could be replaced by wells completed in the Tullock Member. Wells completed in the Tullock Member would have lower water levels than those in the Tongue River or Lebo Members and would require a greater pumping lift. Degradation of the quality of ground water, caused by the leaching of soluble salts from mine spoils, is not anticipated.

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Table 1.--*Hydrogeologic data from wells and test holes*

[<, less than; >, greater than]

Site designation[1]	Location	Altitude of land surface (feet above sea level)	Depth of well or test hole (feet below land surface)	Principal aquifer[2]	Interval of aquifer (feet below land surface)	Hydraulic conductivity of aquifer (feet per day)
W-1	NW1/4 NW1/4 NE1/4 SE1/4 sec. 16, T. 2 N., R. 43 E.	2,830	29	Alluvium	--	--
W-2	NW1/4 NE1/4 NW1/4 SW1/4 sec. 23, T. 2 N., R. 43 E.	2,875	>100	Lebo Shale Member or Tullock Member	--	--
W-3	NE1/4 NW1/4 SW1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	2,935	69	Alluvium (gravel)	44-65	30
W-4	SW1/4 NW1/4 SW1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	2,925	61	Alluvium (gravel and sand)	30-60	30
W-5	NE1/4 SE1/4 SE1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	2,945	21	Alluvium (gravel)	10-16	--
W-6	NE1/4 NE1/4 SW1/4 NW1/4 sec. 25, T. 2 N., R. 43 E.	2,968	74	Tongue River Member	--	--
W-7	SE1/4 SE1/4 NE1/4 NE1/4 sec. 27, T. 2 N., R. 43 E.	2,938	--	Tongue River Member or Lebo Shale Member	--	--
W-8	NW1/4 NE1/4 NE1/4 NW1/4 sec. 36, T. 2 N., R. 43 E.	3,004	84	Tongue River Member	--	--
W-9	SE1/4 SE1/4 NW1/4 SE1/4 sec. 36, T. 2 N., R. 43 E.	3,090	185	Tongue River Member (shale and coal)	--	.01
W-10	SW1/4 NW1/4 NE1/4 SW1/4 sec. 17, T. 2 N., R. 44 E.	3,070	228	Tongue River Member (sandstone)	--	--
W-11	SW1/4 SW1/4 SW1/4 SW1/4 sec. 19, T. 2 N., R. 44 E.	2,990	41	Alluvium or Tongue River Member	--	--
W-12	NE1/4 NW1/4 NE1/4 NE1/4 sec. 29, T. 2 N., R. 44 E.	3,010	46	Tongue River Member (sandstone)	--	--
W-13	NW1/4 NW1/4 NW1/4 SW1/4 sec. 29, T. 2 N., R. 44 E.	3,092	800	Tullock Member	--	--
W-14	SW1/4 NE1/4 NE1/4 SE1/4 sec. 32, T. 2 N., R. 44 E.	2,963	75	Tongue River Member and Lebo Shale Member	--	--
W-15	SE1/4 SE1/4 SW1/4 SW1/4 sec. 2, T. 1 N., R. 43 E.	2,985	50	Tongue River Member (sandstone)	--	--
W-16	NW1/4 NE1/4 SE1/4 SW1/4 sec. 6, T. 1 N., R. 44 E.	3,020	85	Tongue River Member	--	--
W-17	NW1/4 SE1/4 SE1/4 SE 1/4 sec. 21, T. 2 N., R. 44 E.	2,920	150	Lebo Shale Member	--	--
W-18	SW1/4 NE1/4 SE1/4 SE1/4 sec. 33, T. 2 N., R. 44 E.	2,890	168	Lebo Shale Member	--	--
W-19	SE1/4 NW1/4 NE1/4 SE1/4 sec. 4, T. 1 N., R. 44 E.	2,880	45	Lebo Shale Member	--	--
H-1	NE1/4 NE1/4 NW1/4 NE1/4 sec. 19, T. 2 N., R. 44 E.	3,195	230	--	--	--
H-2	SW1/4 SE1/4 SW1/4 SW1/4 sec. 20, T. 2 N., R. 44 E.	3,195	221	--	--	--
H-3	SW1/4 NW1/4 NE1/4 SW1/4 sec. 29, T. 2 N., R. 44 E.	3,136	120	--	--	--
H-4	SW1/4 SW1/4 SW1/4 SW1/4 sec. 29, T. 2 N., R. 44 E.	3,126	189	--	--	--

[1] W, well; H, test hole

[2] Tongue River, Lebo Shale, and Tullock are members of the Fort Union Formation

Water level (feet below land surface)	Date of water level measurement	Well discharge (gallons per minute)	Date of discharge measurement	Remarks
25.6	10-02-73	3	10-02-73	Stock well
21.4	8-29-79	--	--	Stock well. Hydrograph available
23.9	8-29-79	10	9-21-79	Observation well. Hydrograph and aquifer-test data available
12.5	8-29-79	31	9-20-79	Observation well. Hydrograph and aquifer-test data available
10.1	8-29-79	<1	9-20-79	Observation well. Hydrograph available
34.8	8-29-79	--	--	Stock well with windmill
18.0	9-27-73	--	--	Stock well with windmill
35.3	8-29-79	--	--	Stock well with windmill
114.6	8-29-79	<1	9-21-79	Observation well. Hydrograph available
64.9	9-03-75	20	4-05-62	Stock well. Well discharge is reported
25.7	8-29-79	--	--	Stock well with windmill
30.2	8-29-79	--	--	Stock well with windmill
316	9- -73	--	--	Stock well with engine and pump jack
30.8	8-29-79	--	--	Stock well with windmill. Hydrograph available
41.1	9-28-73	--	--	Stock well with windmill
81.0	9-28-73	--	--	Stock well with windmill
3.1	10-26-72	--	--	Stock well
13.8	9-13-73	--	--	Stock well with windmill
21.8	9- -73	--	--	Stock well with windmill
--	--	--	--	Dry hole
--	--	--	--	Dry hole
--	--	--	--	State drill hole SS-1c
--	--	--	--	Dry hole

Table 2.--*Analyses of major chemical constituents and physical properties of ground water and surface water*

[Unless indicated otherwise, constituents are dissolved and constituent values are reported in milligrams per liter. Abbreviations: micromhos, micromhos per centimeter at 25° Celsius; °C, degrees Celsius; ft^3/s, cubic feet per second. Analysis by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey]

Site designation[1]	Location	Date of collection	Geologic source[2]	Onsite specific conductance (micromhos)	Onsite pH (standard units)	Onsite water temperature (°C)	Hardness (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)
W-1	NW1/4 NW1/4 NE1/4 SE1/4 sec. 16, T. 2 N., R. 43 E.	6-27-79	Alluvium	2,850	7.5	9.1	1,080	150	170
W-3	NE1/4 NW1/4 SW1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	6-17-80	Alluvium (gravel)	4,250	7.5	10.5	1,100	160	170
W-3	----do----	9-21-79	Alluvium (gravel)	4,070	7.5	10.0	1,100	150	180
W-4	SW1/4 NW1/4 SW1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	9-20-79	Alluvium (gravel and sand)	3,810	7.4	9.5	980	130	160
W-6	NE1/4 NE1/4 SW1/4 NW1/4 sec. 25, T. 2 N., R. 43 E.	9-28-73	Tongue River Member	[3]2,060	[3]7.7	11.0	860	98	150
W-8	NW1/4 NE1/4 NE1/4 NW1/4 sec. 36, T. 2 N., R. 43 E.	6-18-80	Tongue River Member	2,700	7.1	11.5	1,350	240	180
W-11	SW1/4 SW1/4 SW1/4 SW1/4 sec. 19, T. 2 N., R. 44 E.	6-18-80	Alluvium or Tongue River Member	3,050	7.3	10.0	1,340	200	210
W-12	NE1/4 NW1/4 NE1/4 NE1/4 sec. 29, T. 2 N., R. 44 E.	6-17-80	Tongue River Member (sandstone)	1,530	7.2	12.5	680	140	84
W-13	NW1/4 NW1/4 NW1/4 SW1/4 sec. 29, T. 2 N., R. 44 E.	6-17-80	Tullock Member	2,120	8.7	12.5	13	3.3	1.1
W-14	SW1/4 NE1/4 NE1/4 SE1/4 sec. 32, T. 2 N., R. 44 E.	6-18-80	Tongue River Member and Lebo Shale Member	4,850	7.5	11.0	480	86	64
W-15	SE1/4 SE1/4 SW1/4 SW1/4 sec. 2, T. 1 N., R. 43 E.	6-18-80	Tongue River Member (sandstone)	1,010	7.4	11.0	450	89	54
S-1	SE1/4 NE1/4 SW1/4 SE1/4 sec. 30, T. 2 N., R. 44 E.	6-18-80	--	1,320	7.9	20.5	650	120	85
S-2	NW1/4 SW1/4 SE1/4 NE1/4 sec. 16, T. 2 N., R. 43 E.	3-19-78	--	65	7.7	1.0	25	6.7	1.9
S-2	----do----	3-20-78	--	75	7.4	3.0	28	7.7	2.1

[1]W, well; S, surface-water site

[2]Tongue River, Lebo Shale, and Tullock are members of the Fort Union Formation

[3]Laboratory determination

Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Bicarbonate (HCO_3)	Alkalinity (total as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (sum of constituents)	Nitrate, as N	Analysis by	Remarks
290	4	11	670	550	1,120	10	0.6	28	2,110	0.22	BM	Stock well
670	9	10	480	390	2,090	20	1.5	16	3,370	.05	BM	Observation well
610	8	10	370	300	2,100	19	.5	16	3,270	--	GS	Observation well
550	8	9	490	400	1,700	18	1.0	13	2,820	--	GS	Observation well
190	3	5	290	230	970	11	.0	11	1,720	.0	BM	Stock well with windmill
140	2	6	520	420	1,200	10	.2	9.4	2,040	3.7	BM	Stock well with windmill
190	2	10	390	320	1,370	10	.7	12	2,190	.25	BM	Stock well with windmill
80	1	9	440	360	470	10	.3	16	1,020	.54	BM	Stock well with windmill
520	63	2	1,010	840	1.6	200	6.3	7.9	1,250	.20	BM	Stock well
980	20	7	670	550	1,970	19	.5	7.7	3,460	.05	BM	Stock well with windmill
37	.8	3	360	290	230	5	.2	9.4	600	.39	BM	Stock well with windmill
46	.8	20	83	68	670	17	.2	5.4	1,000	.01	BM	Stock reservoir
3.2	.3	4	28	23	3.3	.9	.0	4.6	38	--	GS	Snowmelt runoff; flow of 10 ft^3/s
3.0	.2	4	42	34	5.1	.9	.0	4.7	49	--	GS	Snowmelt runoff; flow of 52 ft^3/s

Table 3.--*Analyses of trace elements in ground water and surface water*

[Constituents are dissolved and concentrations are reported in micrograms per liter. Symbol: <, less than. Analysis by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey]

Site designation[1]	Location number	Sample date	Aluminum (Al)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)
W-3	NE1/4 NW1/4 SW1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	6-17-80	60	780	<2	3	18
W-4	SW1/4 NW1/4 SW1/4 SW1/4 sec. 24, T. 2 N., R. 43 E.	9-20-79	--	--	0	10	1
W-8	NW1/4 NE1/4 NE1/4 NW1/4 sec. 36, T. 2 N., R. 43 E.	6-18-80	119	371	<2	14	30
W-11	SW1/4 SW1/4 SW1/4 SW1/4 sec. 19, T. 2 N., R. 44 E.	6-18-80	76	1,180	<2	7	22
W-12	NE1/4 NW1/4 NE1/4 NE1/4 sec. 29, T. 2 N., R. 44 E.	6-17-80	40	410	<2	6	20
W-13	NW1/4 NW1/4 NW1/4 SW1/4 sec. 29, T. 2 N., R. 44 E.	6-17-80	<20	490	<2	<2	<2
W-14	SW1/4 NE1/4 NE1/4 SE1/4 sec. 32, T. 2 N., R. 44 E.	6-18-80	<30	840	<2	<2	<2
W-15	SE1/4 SE1/4 SW1/4 SW1/4 sec. 2, T. 1 N., R. 43 E.	6-18-80	76	<18	3	<2	13
S-1	SE1/4 NE1/4 SW1/4 SE1/4 sec. 30, T. 2 N., R. 44 E.	6-18-80	<24	780	<2	6	16
S-2	NW1/4 SW1/4 SE1/4 NE1/4 sec. 16, T. 2 N., R. 43 E.	3-19-78	130	--	3	20	9

Site designation[1]	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (N)	Selenium (Se)	Vanadium (V)	Zinc (Zn)	Analysis by
W-3	87	<40	4	--	<10	11	3	9	7	BM
W-4	870	0	40	0.1	--	0	0	--	20	GS
W-8	1,680	<40	44	--	<10	9	5	14	40	BM
W-11	140	<40	5	--	<10	<6	11	18	12	BM
W-12	530	<40	10	--	27	20	5	5	38	BM
W-13	43	<40	21	--	<10	<6	.1	<1	<3	BM
W-14	2,290	<40	60	--	65	10	.2	<1	<4	BM
W-15	56	<40	4	--	<10	7	3	7	10	BM
S-1	36	<40	73	--	<10	18	.3	9	<3	BM
S-2	--	10	10	.0	1	4	0	2	20	GS

[1] W, well; S, surface-water site