RECONNAISSANCE OF THE WATER RESOURCES AND POTENTIAL EFFECTS OF MINING OF THE JOLIET-FROMBERG COAL TRACT, CARBON COUNTY, MONTANA

By M. R. Cannon

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain SI unit
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

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

$$°F = 9/5\ (°C) + 32$$

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ABSTRACT

The Joliet-Fromberg coal tract in Carbon County, Montana, contains subbituminous to bituminous coal suitable for underground mining. A reconnaissance study of the area was conducted to identify the water resources of the coal tract and to determine general effects that underground mining could have on the water resources.

Surface-water resources consist of Elbow Creek, a small perennial stream that drains most of the area, plus irrigation water diverted into the basin from Rock Creek and the Clarks Fork Yellowstone River. Ground-water resources consist of sandstone aquifers in several formations of Late Cretaceous age and alluvial aquifers of Pleistocene and Holocene age.

Chemical analyses were made of the water in Elbow Creek and water from seven wells in the area. Water from Elbow Creek is suitable for use by all livestock, based on the concentration of dissolved solids. Water from most sampled wells had dissolved-solids concentrations larger than the maximum (500 milligrams per liter) recommended by the U.S. Environmental Protection Agency for public water supply.

Effects of underground mining on water resources would be minimal. The Bridger coal bed in the Upper Cretaceous Eagle Sandstone has no significant hydraulic connection with Elbow Creek in most of the area and the coal does not appear to be a significant aquifer. Mining and dewatering of the coal could temporarily lower water levels in aquifers overlying the coal if mining causes subsidence and fracturing of rocks above the mine workings.

INTRODUCTION

The Joliet-Fromberg study area is located in Carbon County, about 32 miles southwest of Billings, Montana, and encompasses about 60 square miles (fig. 1). The study area contains coal deposits within the Eagle Sandstone of Late Cretaceous age. Much of the coal resource is Federally owned and interest exists in leasing a tract of Federal coal for development of an underground coal mine. Prior to leasing of the coal, the U.S. Bureau of Land Management is required to evaluate the environmental effects of coal leasing and development. In 1983, the U.S. Geological Survey in cooperation with the Bureau of Land Management initiated a study to describe the water resources of the area.

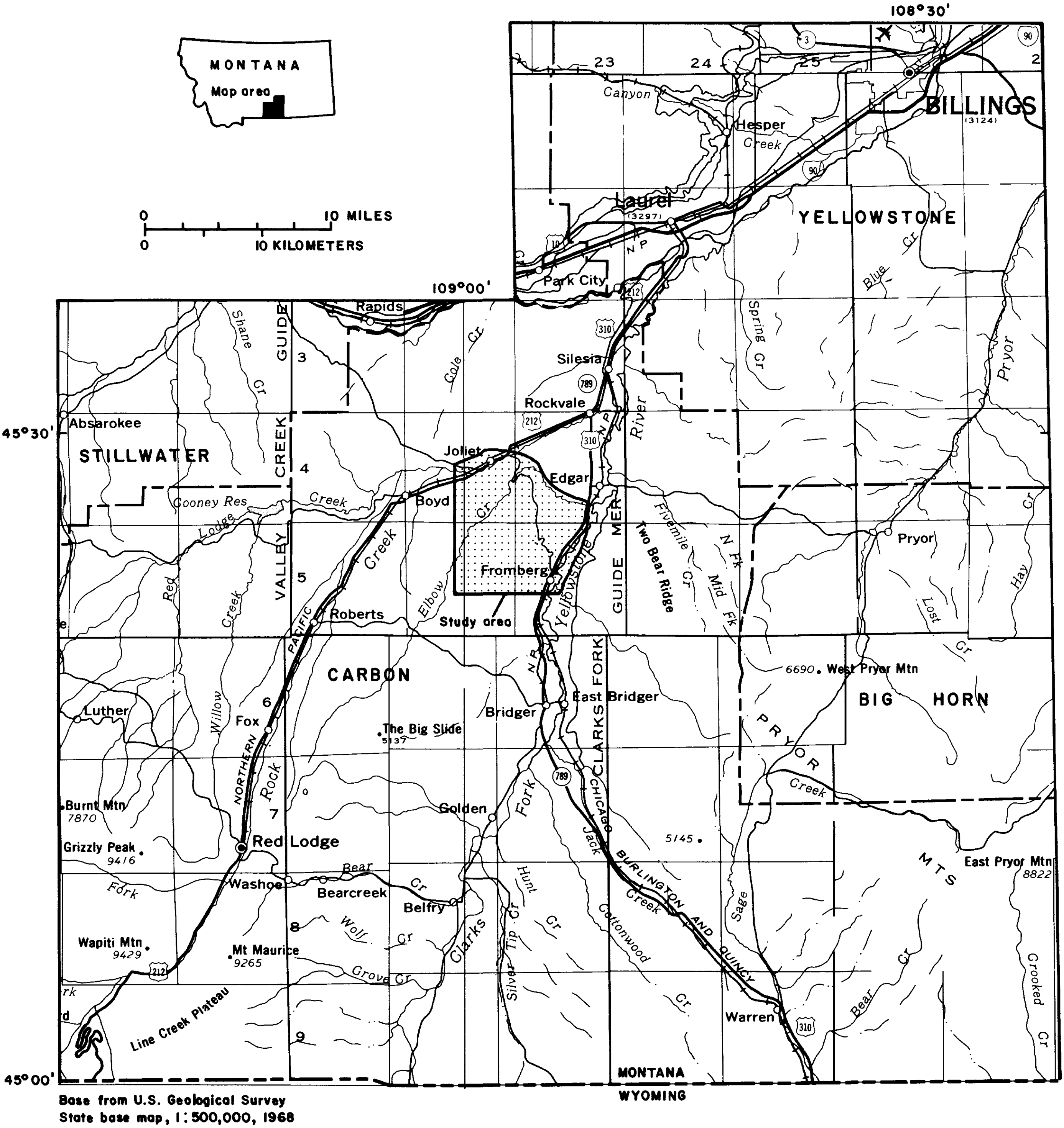


Figure 1.--Location of the Joliet-Fromberg study area.

Purpose and Scope

The purposes of this study were to identify the water resources of the Joliet-Fromberg area and to determine general effects that underground coal mining could have on these water resources. To evaluate surface-water resources, a streamflow-gaging station was established on Elbow Creek. Streamflow measurements and water-quality samples were obtained periodically at this station from October 1983 to August 1984. Selected wells were inventoried to help evaluate ground-water resources, and color-infrared aerial photographs were examined to help delineate ground-water discharge areas. The literature was searched for pertinent water-resources data. Additional onsite work was limited to a brief reconnaissance of the area to examine streamflow and irrigation diversions and to identify ground-water discharge points such as springs or seeps.

Previous Investigations

The geology and mineral resources of the study area and surrounding region were mapped by Knappen and Moulton (1931) as part of an investigation to obtain data for classifying public lands. Their report on the area focuses primarily on geology and coal deposits but includes some generalized information on the availability of ground water. A comprehensive report on a ground-water inventory of Carbon County was prepared by the Montana Water Resources Board (1969a). The inventory report contains data and interpretations of general geology, aquifers, ground-water use, water quality, availability of ground water, and ground-water recharge in Carbon County. Another inventory report produced by the Montana Water Resources Board (1969b) provides generalized data on aquifer characteristics and ground-water storage and recharge. Reports on irrigation diversions, water rights, and irrigated lands in Carbon County were published by the State Engineer and State Water Conservation Board (1946a, 1946b).

GEOLOGY

The study area is situated on the western flank of the Pryor Mountains uplift. Rock strata of the area dip about 3.5 degrees (320 feet per mile) to the west, resulting in successively younger strata exposed in a westward direction. The outcropping bedrock in the middle part of the Elbow Creek drainage basin consists primarily of sandstone and shale of Late Cretaceous age. These rocks, from oldest to youngest, are the Carlile Shale, Niobrara Formation, Telegraph Creek Formation, Eagle Sandstone, Claggett Formation, Judith River Formation, Bearpaw Shale, Lennep Sandstone, and Hell Creek Formation. Outcropping bedrock in the upstream part of the Elbow Creek basin is the Fort Union Formation of Paleocene age. Alluvium of Holocene and Pleistocene age occupies the downstream part of the Elbow Creek basin and the Clarks Fork Valley (fig. 2).

The primary coal bed occurs within the Upper Cretaceous Eagle Sandstone. The coal bed crops out along an approximately north-south line from Joliet to a point about 2 miles southwest of Fromberg, where the coal bed has been displaced by the Fromberg fault (fig. 2). The coal bed is subbituminous to bituminous grade and ranges in thickness from about 12 to 65 inches, with partings of shale or carbonaceous shale (Knappen and Moulton, 1931). The coal bed is locally called the Bridger coal because of past commercial production of the coal from mines at Bridger, Montana, about 5 miles south of the study area.

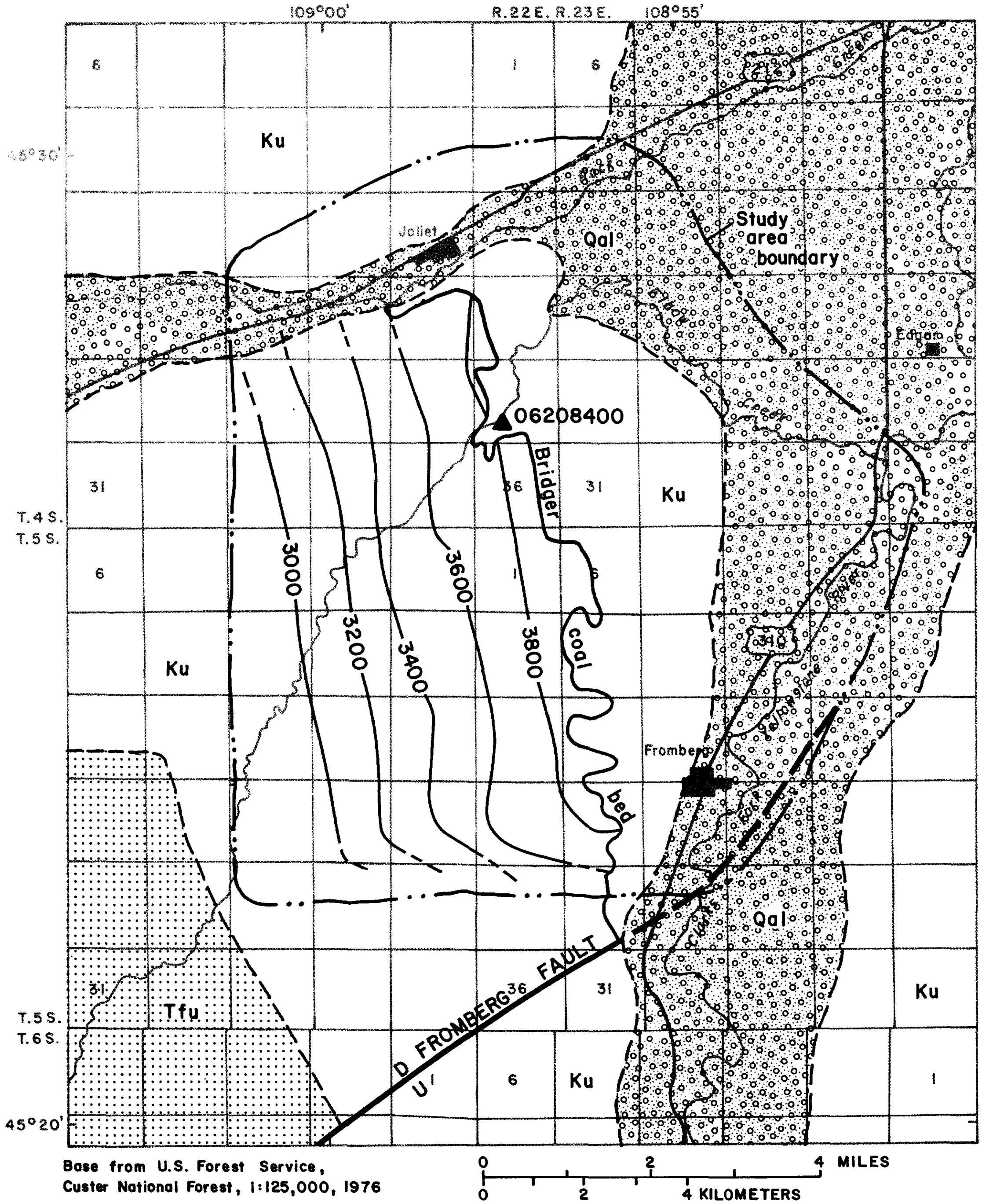


Figure 2.--Surficial geology and structure and altitude of the top of the Bridger coal bed in the Eagle Sandstone in and near the Joliet-Fromberg area. Explanation is at the top of the following page.

EXPLANATION

QaP ALLUVIUM (HOLOCENE AND PLEISTOCENE)

Tfu FORT UNION FORMATION (PALEOCENE)

Ku CRETACEOUS ROCKS, UNDIVIDED--Includes Hell Creek Formation, Lennep Sandstone, Bearpaw Shale, Judith River Formation, Claggett Formation, Eagle Sandstone, Telegraph Creek Formation, Niobrara Formation, and Carlile Shale

CONTACT, APPROXIMATELY LOCATED

3800 STRUCTURE CONTOUR--Shows altitude of top of Bridger coal bed. Dashed where approximately located. Contour interval 200 feet. Datum is sea level

D / U FAULT--Dashed where concealed. U, upthrown side; D, downthrown side

06208400 ▲ STREAMFLOW-GAGING STATION AND NUMBER

WATER RESOURCES

Surface Water

Elbow Creek is a small perennial tributary to the Clarks Fork Yellowstone River that drains most of the Joliet-Fromberg study area. The headwaters of Elbow Creek are in a relatively narrow upland valley at an altitude of about 5,400 feet above sea level. The downstream part of Elbow Creek meanders in the broad valley of the Clarks Fork and has an altitude of 3,470 feet at its mouth.

A streamflow-gaging station (station 06208400) is located on Elbow Creek about 9.4 river miles upstream from the mouth (fig. 2). The drainage area of Elbow Creek at the station is 48.6 square miles. Daily mean discharge at the station (fig. 3) was estimated from once-daily instantaneous stage readings and generally was between 1 and 10 ft^3/s for most days of the 1984 water year (October 1983 through September 1984). Daily mean flows of less than 1 ft^3/s occurred on about 20 days during the winter and on several days in July and August. The minimum daily mean streamflow during the 1984 water year was 0.4 ft^3/s on December 24; the maximum was 85 ft^3/s on May 10 (fig. 3).

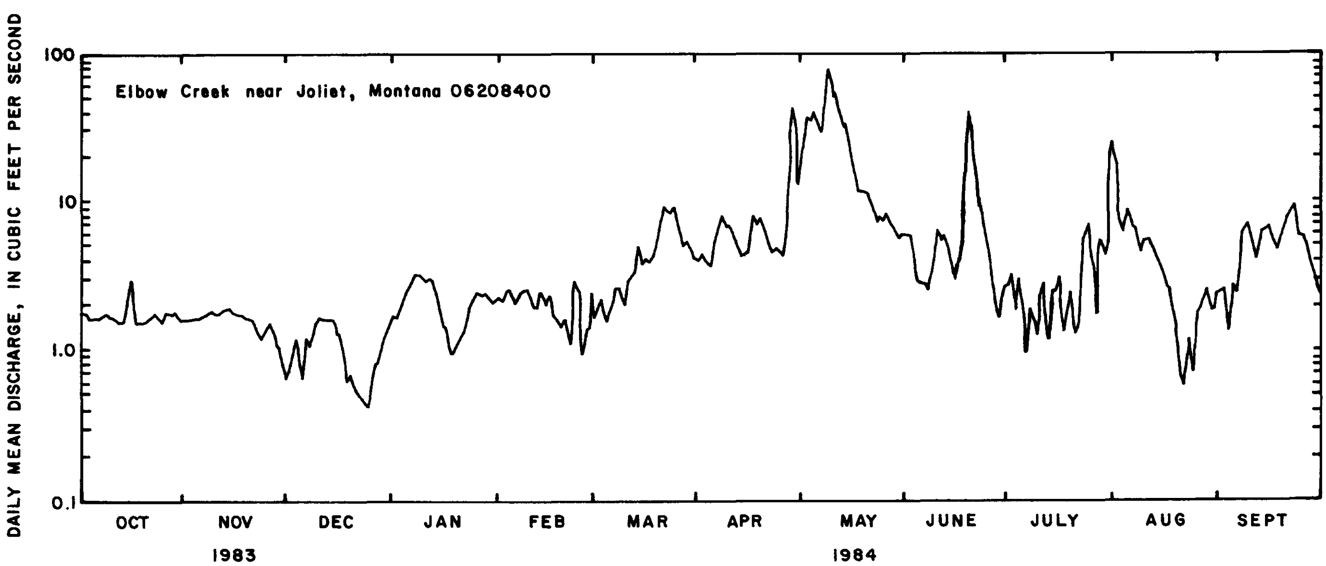


Figure 3.--Hydrograph of Elbow Creek at station 06208400 for the 1984 water year.

Streamflow of Elbow Creek is affected by diversion of irrigation water from Rock Creek near Red Lodge, Montana, into the upstream part of the basin near the headwaters. The diversion of water into the upper Elbow Creek basin helps to maintain summer streamflow throughout the length of Elbow Creek. Without diversion of water into the basin, Elbow Creek likely would be dry for many days during the summer.

Downstream from the gaging station on Elbow Creek, streamflow is largely controlled by irrigation diversions and return flows. Several irrigation ditches transfer water from Rock Creek and the Clarks Fork into the downstream part of the Elbow Creek basin.

Ground Water

Aquifers of the study area include those in alluvium and in sandstones of the Telegraph Creek, Eagle, Claggett, and Judith River Formations. Sandy zones within the combined Niobrara Formation-Carlile Shale also yield some water.

Yields of inventoried wells range from 1.5 gal/min in the combined Niobrara Formation-Carlile Shale to 80 gal/min in alluvium (table 1). Generalized yields of wells completed in various aquifers are reported to be 1 to 18 gal/min for the Telegraph Creek Formation, 12 to 330 gal/min for the Eagle Sandstone, 1 to 40 gal/min for the Judith River Formation, and 10 to 300 gal/min for alluvium (Montana Water Resources Board, 1969a).

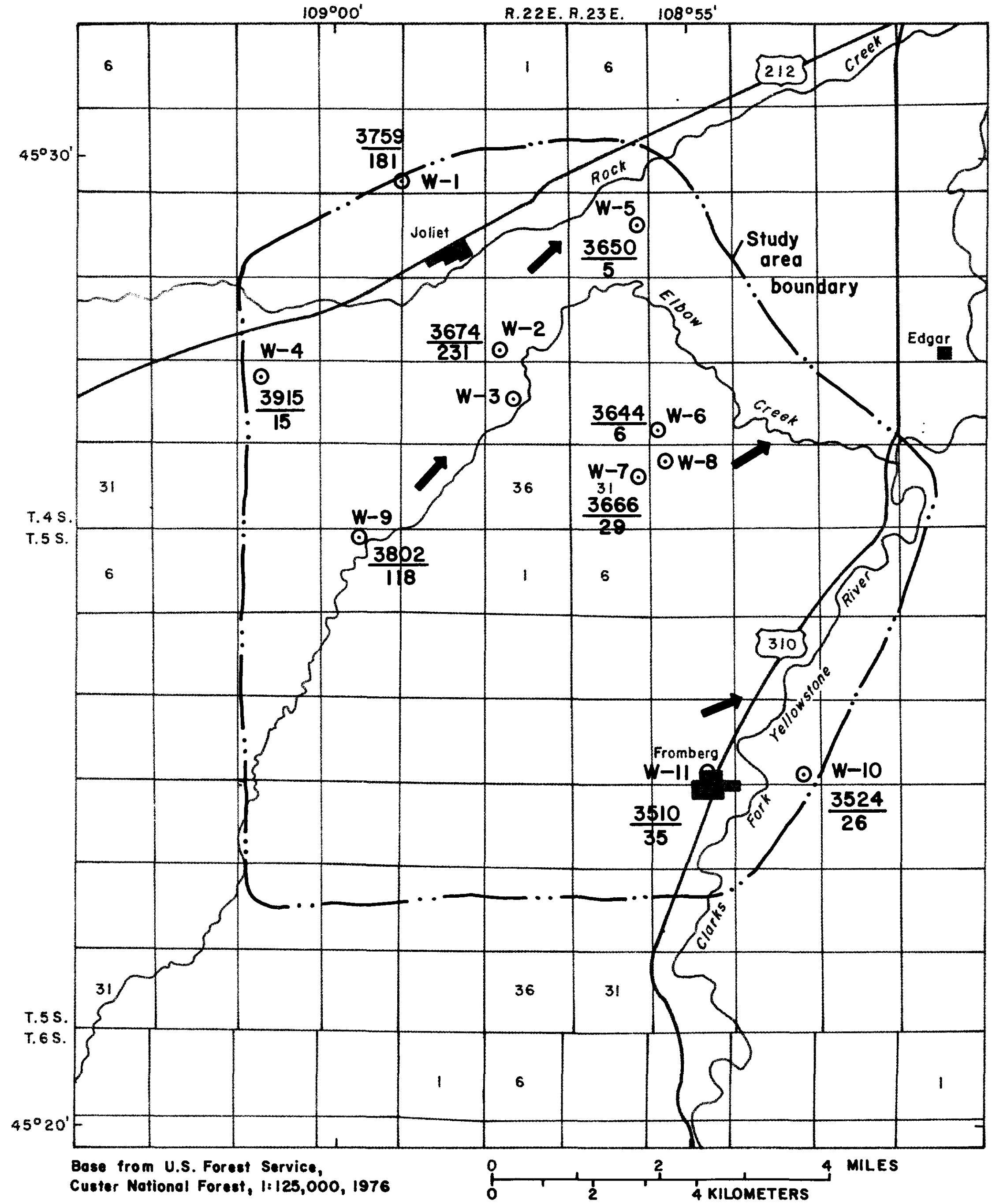
The Bridger coal bed in the Eagle Sandstone probably is water bearing where it is deeply buried or where it lies at an altitude below the level of Elbow Creek. A small coal mine that once operated in sec. 26, T. 4 S., R. 22 E., had water entering the mine when it reached a depth of 75 feet below Elbow Creek (Knappen and Moulton, 1931). In general, however, the Bridger coal bed does not appear to be a significant aquifer in the area. No springs or seeps from the Bridger coal outcrop were observed during a reconnaissance of the study area and none were evident from inspection of color-infrared aerial photographs. None of the inventoried wells are completed in the Bridger coal bed.

Depths to water range from about 5 feet below land surface in wells drilled in alluvium near streams to about 230 feet in some deep wells completed in sandstone aquifers. Depths to water and corresponding altitudes are shown in figure 4 for inventoried wells.

Direction of ground-water flow in the study area cannot be determined accurately because of the paucity of water-level measurements. However, generalized flow directions can be determined based on geology, topography, and available data. Water in the sandstone and alluvial aquifers generally flows north and east as shown in figure 4.

WATER QUALITY

Quality of water in Elbow Creek was determined from six samples collected between October 17, 1983, and August 22, 1984, at gaging station 06208400 and from one sample collected on August 21 at the mouth of Elbow Creek (table 2). At the gaging station, dissolved-solids concentration ranged from 420 mg/L (milligrams per



EXPLANATION

W-2 3674/231 ⊙ WELL SITE AND NUMBER--Number above line is altitude of water level, in feet above sea level; number below line is depth to water, in feet below land surface

➡ GENERALIZED DIRECTION OF WATER MOVEMENT IN AQUIFERS LESS THAN 300 FEET DEEP

Figure 4.--Location of wells, water levels in wells, and generalized direction of ground-water flow in and near the Joliet-Fromberg area.

liter) at the time of largest measured streamflow (123 ft^3/s on May 10, 1984) to 1,600 mg/L on October 17, 1983, when streamflow was 1.6 ft^3/s. The dissolved-solids concentration in Elbow Creek generally was inversely proportional to quantity of streamflow. Water in Elbow Creek at the gaging station generally was a sodium sulfate type; sodium ions in the six samples comprised 40 to 61 percent of the cations, with the smaller percentages occurring at times of larger streamflows.

Elbow Creek is used extensively as a water source for livestock and irrigation. McKee and Wolf (1963) indicate that water in Montana having a maximum dissolved-solids concentration of 2,500 mg/L is suitable for all livestock, and water having a dissolved-solids concentration of 3,500 mg/L is considered fair for livestock. Based on this classification system and the dissolved-solids concentrations measured during the study, water from Elbow Creek is considered to be suitable for all livestock. For irrigation, the water would be classified as having a low to medium sodium hazard and a medium to very high salinity hazard (U.S. Salinity Laboratory Staff, 1954). Considerable improvement in the water for both livestock and irrigation can be expected during times of high flow when snowmelt or rainfall dilutes the baseflow component of streamflow. Evidence of this dilution is shown in the sample collected at the gaging station on May 10, 1984 (table 2).

Water in the downstream part of Elbow Creek, between the gaging station and the confluence with the Clarks Fork, had a different chemical composition than that in the upstream part because of irrigation diversions from Rock Creek and the Clarks Fork. Analysis of a water sample collected at the mouth of Elbow Creek indicated a calcium-magnesium bicarbonate type water (table 2).

Water samples from seven wells in the area were analyzed for chemical composition (table 3). Water samples were obtained from aquifers in the combined Niobrara Formation-Carlile Shale, Telegraph Creek Formation, Claggett Formation, and alluvium. Dissolved-solids concentration of the water ranged from 250 mg/L for well W-5 (completed in alluvium) to 5,100 mg/L for well W-7 (completed in the combined Niobrara Formation-Carlile Shale). Water from six of the seven sampled wells exceeded the maximum concentration of 500 mg/L of dissolved solids recommended by the U.S. Environmental Protection Agency (1979) for secondary standards of public water supply. Most ground water also exceeded the recommended maximum concentration of 250 mg/L for sulfate. The recommended concentrations of sulfate and dissolved solids were established because of possible laxative effects on persons not accustomed to the water and apply if water of a better quality is available.

Water from two wells (W-6 and W-7) completed in the combined Niobrara Formation-Carlile Shale had large concentrations of nitrate nitrogen. Water in well W-6 had 9.7 mg/L of nitrate nitrogen, which is near the maximum limit of 10 mg/L established by the U.S. Environmental Protection Agency (1977) for primary standards of public water supply. Water in well W-7 had 250 mg/L of nitrate nitrogen, or 25 times the maximum for drinking water.

POTENTIAL EFFECTS OF MINING ON WATER RESOURCES

Effects of underground coal mining on water resources would be minimal. In most of the study area, mining would have no direct effect on Elbow Creek, because there is no significant hydraulic connection between Elbow Creek and the Bridger coal bed. Where Elbow Creek crosses the outcrop of the Bridger coal bed, some streamflow could be lost through seepage into the coal or fractured overburden;

however, proper mining techniques would minimize any effect on the quantity or quality of streamflow. Irrigation water diverted into the basin from Rock Creek or the Clarks Fork would be unaffected by underground mining.

Underground mining could locally dewater the Bridger coal bed where it is presently saturated. Decline in water levels of aquifers above the coal bed would likely be minimal owing to the relatively small hydraulic conductivities of the aquifers and the presence of many shale confining beds. However, if underground mine workings cause a significant amount of subsidence, fracturing of overlying rocks in response to subsidence could capture water from aquifers overlying the coal and lead to water-level declines. The water-level declines likely would be temporary, recovering after mining and dewatering operations are completed.

Most inventoried wells in the Joliet-Fromberg study area are completed in alluvium or in bedrock aquifers stratigraphically below the Bridger coal bed and probably would be unaffected by mining. None of the inventoried wells are completed in the Bridger coal bed and only two wells (W-1 and W-9) are completed in bedrock aquifers overlying the Bridger coal. Mining and dewatering of the coal could temporarily lower water levels in these two wells if mining causes subsidence and fracturing of rocks overlying the coal.

SUMMARY

The Joliet-Fromberg study area is located in Carbon County, about 32 miles southwest of Billings, Montana. The study area contains coal deposits (Bridger coal bed) within the Eagle Sandstone of Late Cretaceous age. A reconnaissance study of the area was conducted to identify the water resources of the coal tract and to determine general effects that underground mining would have on the water resources.

Surface-water resources consist of Elbow Creek, a small perennial stream that drains most of the area, plus irrigation water diverted into the basin from Rock Creek and the Clarks Fork Yellowstone River. Daily mean discharge of Elbow Creek, at a gaging station 9.4 miles upstream from the mouth, generally was between 1 and 10 ft^3/s for most days of the 1984 water year. Diversion of water into the upper Elbow Creek basin from Rock Creek helps to maintain summer streamflow throughout the length of Elbow Creek.

Ground-water resources consist of sandstone aquifers in several formations of Late Cretaceous age and alluvial aquifers of Pleistocene and Holocene age. Inventoried wells of the area had depths to water ranging from about 5 to 230 feet below land surface. Yields of inventoried wells range from 1.5 to 80 gal/min.

Water samples from Elbow Creek and seven wells in the area were analyzed for chemical composition. Water in Elbow Creek at the gaging station generally was a sodium sulfate type and is suitable for use by all livestock, based on the concentration of dissolved solids. For irrigation, the water would be classified as having a low to medium sodium hazard and a medium to very high salinity hazard. Water from most sampled wells had dissolved-solids concentrations larger than the maximum (500 milligrams per liter) recommended by the U.S. Environmental Protection Agency for public water supply. Water from two wells (W-6 and W-7) had concentrations near or exceeding the standard for nitrate nitrogen.

Effects of underground coal mining on water resources would be minimal. The Bridger coal bed has no significant hydraulic connection with Elbow Creek in most of the area and the coal does not appear to be a significant aquifer. Irrigation water diverted into the basin from Rock Creek or the Clarks Fork would be unaffected by mining. Mining and dewatering of the coal bed could temporarily lower water levels in overlying aquifers if mining causes subsidence and fracturing of rocks above the mine workings. Most inventoried wells in the study area are completed in alluvium or in bedrock aquifers stratigraphically below the Bridger coal bed and probably would be unaffected by mining.

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Table 1.--*Records of inventoried wells*

Well No.	Location	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (feet below land surface)	Date water level measured	Well discharge (gallons per minute)	Aquifer
W-1	SW¼NE¼SE¼SE¼ sec. 10, T. 4 S., R. 22 E.	3,940	455	181.2	06/21/79	15	Judith River Formation
W-2	SW¼SE¼SW¼SW¼ sec. 24, T. 4 S., R. 22 E.	3,905	255	230.6	08/07/84	--	Telegraph Creek Formation
W-3	NE¼NW¼NE¼SW¼ sec. 25, T. 4 S., R. 22 E.	3,750	255	--	--	--	Telegraph Creek Formation
W-4	SE¼SE¼NW¼NW¼ sec. 28, T. 4 S., R. 22 E.	3,930	33	15.2	07/25/84	20	Probably alluvium
W-5	SE¼SW¼SE¼NE¼ sec. 18, T. 4 S., R. 23 E.	3,655	21	5.0	07/24/77	80	Alluvium
W-6	NW¼SW¼SW¼SW¼ sec. 29, T. 4 S., R. 23 E.	3,650	14	6.0	07/27/84	4.6	Niobrara Formation and Carlile Shale, combined
W-7	SE¼SW¼SE¼NE¼ sec. 31, T. 4 S., R. 23 E.	3,695	200	29.4	05/22/84	1.5	Niobrara Formation and Carlile Shale, combined
W-8	SE¼SW¼NW¼NW¼ sec. 32, T. 4 S., R. 23 E.	3,684	1,200	--	--	--	Niobrara Formation and Carlile Shale, combined
W-9	NW¼SE¼NE¼NW¼ sec. 3, T. 5 S., R. 22 E.	3,920	255	117.5	06/19/81	24	Claggett Formation
W-10	SW¼SW¼SE¼SE¼ sec. 16, T. 5 S., R. 23 E.	3,550	38	26.2	05/23/84	20	Alluvium
W-11	NE¼SW¼SW¼SE¼ sec. 17, T. 5 S., R. 23 E.	3,545	80	35.0	06/24/71	--	Alluvium

Table 2.--*Chemical analyses of water from Elbow Creek*

[Analyses by U.S. Geological Survey, except Aug. 21 sample by Montana Bureau of Mines and Geology. Abbreviations: Ac-ft, acre-feet; ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, no data]

Site of sample collection	Date	Time (24-hour)	Streamflow, instantaneous (ft^3/s)	Cloud cover (percent)	Specific conductance (µS/cm)	pH (standard units)	Temperature, air (°C)	Temperature (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
Gaging station 06208400	OCT 17...1983	1430	1.6	--	2,150	8.6	12.0	8.5	666	8.5	84
Gaging station 06208400	MAR 05...1984	0935	1.5	1	2,290	8.2	-11.0	.0	686	12.6	97
Gaging station 06208400	APR 12...1984	1240	5.3	70	1,380	8.3	9.5	7.5	662	9.8	95
Gaging station 06208400	MAY 03...1984	0845	35	50	990	8.0	7.0	4.5	660	9.3	83
	10...1984	1030	123	70	475	8.7	11.0	7.5	662	7.0	67
At mouth in sec. 34, T. 4 S., R. 23 E.	AUG 21...1984	1530	18	--	745	8.4	--	19.5	--	--	--
Gaging station 06208400	AUG 22...1984	1010	.61	0	1,140	8.2	16.0	15.0	671	9.5	108

Date	Hardness (mg/L as CaCO3)	Hardness, noncarbonate (mg/L CaCO3)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as CaCO3)	Sulfate dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO2)
OCT 17...1983	490	130	88	66	350	7	4.1	357	820	44	0.40	3.9
MAR 05...1984	460	82	85	61	330	7	3.9	382	780	44	.50	5.0
APR 12...1984	330	46	68	40	170	4	3.5	289	410	19	.50	4.6
MAY 03...1984	190	0	38	22	150	5	3.3	196	300	15	.30	4.8
10...1984	200	140	50	18	62	2	4.4	61	120	120	.30	9.4
AUG 21...1984	270	--	58	31	57	2	3.0	204	180	3	.20	8.7
22...1984	310	55	58	39	160	4	3.0	251	370	17	.40	16

Date	Solids, sum of constituents, dissolved (mg/L)	Solids, dissolved (tons per ac-ft)	Solids, dissolved (tons per day)	Nitrogen, NO2+NO3 total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Carbon, organic dissolved (mg/L as C)	Carbon, organic suspended total (mg/L as C)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)
OCT 17...1983	1,600	2.2	6.9	4.5	.040	1.4	1.4	0.040	--	--	400	90
MAR 05...1984	1,500	2.1	6.2	2.2	.430	.97	1.4	.040	--	--	300	50
APR 12...1984	890	1.2	13	.70	.170	.83	1.0	.070	9.4	0.6	140	13
MAY 03...1984	650	.89	62	.80	.460	6.5	7.0	2.30	7.0	12	120	14
10...1984	420	.57	140	.50	.150	1.2	1.3	3.20	7.2	4.4	70	<3
AUG 21...1984	461	.63	22	--	--	--	--	--	--	--	130	10
22...1984	810	1.1	1.3	.30	.050	.35	.40	<.010	4.5	.1	180	86

Table 2.--*Chemical analyses of water from Elbow Creek*--Continued

Date	Arsenic total (µg/L as As)	Arsenic dis- solved (µg/L as As)	Beryl- lium, total recov- erable (µg/L as Be)	Beryl- lium, dis- solved (µg/L as Be)	Cadmium total recov- erable (µg/L as Cd)	Cadmium dis- solved (µg/L as Cd)	Chro- mium, total recov- erable (µg/L as Cr)	Chro- mium, dis- solved (µg/L as Cr)	Copper, total recov- erable (µg/L as Cu)	Copper, dis- solved (µg/L as Cu)	Iron, total recov- erable (µg/L as Fe)	Lead, total recov- erable (µg/L as Pb)
OCT												
17...1983	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
05...1984	--	--	--	--	--	--	--	--	--	--	--	--
APR												
12...1984	<1	<1	10	0.5	<1	<1	10	<10	11	3	2,800	3
MAY												
03...1984	5	1	<10	<.5	<1	<1	60	<10	76	3	5,300	57
10...1984	9	1	<10	<1.0	<1	<1	180	10	200	9	170,000	110
AUG												
21...1984	--	--	--	--	--	<2	--	<2	--	4	--	--
22...1984	--	<1	--	1.0	--	<1	--	<10	--	5	--	--

Date	Lead, dis- solved (µg/L as Pb)	Manga- nese, total recov- erable (µg/L as Mn)	Manga- nese, dis- solved (µg/L as Mn)	Mercury total recov- erable (µg/L as Hg)	Mercury dis- solved (µg/L as Hg)	Nickel, total recov- erable (µg/L as Ni)	Nickel, dis- solved (µg/L as Ni)	Sele- nium, total (µg/L as Se)	Sele- nium, dis- solved (µg/L as Se)	Zinc, total recov- erable (µg/L as Zn)	Zinc, dis- solved (µg/L as Zn)
OCT											
17...1983	--	--	--	--	--	--	--	--	--	--	--
MAR											
05...1984	--	--	--	--	--	--	--	--	--	--	--
APR											
12...1984	<1	140	55	0.2	<0.1	53	<1	4	5	30	31
MAY											
03...1984	<1	1,500	57	--	<.1	45	6	5	4	240	20
10...1984	3	3,900	4	.2	<.1	100	4	<1	<1	650	39
AUG											
21...1984	--	--	--	--	--	--	<10	--	1	--	2
22...1984	9	--	34	--	.2	--	7	--	<1	--	13

Table 3.--*Chemical analyses of water from wells*

[Analyses by Montana Bureau of Mines and Geology. Abbreviations: mg/L, milligrams per liter; µg/L, micrograms per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °Celsius]

Well No.	Location	Aquifer	Date of sample collection	Onsite specific conductance (µS/cm)	Onsite pH (standard units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
W-2	SW¼SE¼SW¼SW¼, sec. 24, T. 4 S., R. 22 E.	Telegraph Creek Formation	08/07/84	6,490	7.7	16.0	100	20	13	1,500
W-3	NE¼NW¼NE¼SW¼, sec. 25, T. 4 S., R. 22 E.	Telegraph Creek Formation	08/02/84	2,740	8.0	12.0	110	23	12	610
W-5	SE¼SW¼SE¼NE¼, sec. 18, T. 4 S., R. 23 E.	Alluvium	07/25/84	482	7.9	9.5	200	55	16	13
W-6	NW¼SW¼SW¼SW¼, sec. 29, T. 4 S., R. 23 E.	Niobrara Formation and Carlile Shale, combined	07/27/84	3,620	7.4	9.0	2,000	530	150	150
W-7	SE¼SW¼SE¼NE¼, sec. 31, T. 4 S., R. 23 E.	Niobrara Formation and Carlile Shale, combined	05/22/84	7,100	7.4	13.5	2,500	520	290	960
W-9	NW¼SE¼NE¼NW¼, sec. 3, T. 5 S., R. 22 E.	Claggett Formaation	08/13/84	1,260	7.4	11.0	300	54	39	190
W-11	NE¼SW¼SW¼SE¼, sec. 17, T. 5 S., R. 23 E.	Alluvium	06/20/84	2,930	7.4	13.5	1,600	390	140	51

Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate, (mg/L as HCO_3)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate dissolved (mg/L as N)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
97	67	2.7	400	490	2,800	15	0.20	7.8	4,600	0.35	--	<2	20
92	26	1.6	550	670	800	44	.70	8.3	1,800	.13	--	13	13
12	.4	1.5	200	240	28	1.4	.10	12	250	.91	--	<2	<1
14	2	7.5	310	380	1,800	20	.10	12	2,900	9.7	--	300	650
45	9	19	350	430	3,000	170	.10	8.7	5,100	250	790	680	97
57	5	1.8	490	600	210	6.4	.30	14	800	.23	--	620	2
7	.6	4.6	300	360	1,300	3.6	.60	16	2,100	.41	200	27	3

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