

GROUND-WATER STUDY 10

by

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1.0 ABSTRACT

Geology and the Occurrence of Coal

The Denver Formation, in the Denver basin, contains lignitic coal seams, which are 20 to 60 feet thick. The seams, which are relatively flat, are thickest in the eastern part of the basin.

Hydrology and Hydrologic-Data Collection

The Denver aquifer, part of the Denver Formation, will be affected by the surface mining of the lignite. The transmissivity of the aquifer system ranges from about 50 to 150 ft²/d. Estimates of the storage coefficient range from 0.014 to 0.088, Dissolved-solids concentrations in the ground water increase to the north and east as the potentiometric head decreases.

Probable Hydrologic Impacts

Distance-drawdown curves are used to show the extent of drawdown near the proposed surface mine. After reclamation, the spoils will cause increased concentrations of dissolved solids in the ground water. This increase could affect streams, springs, alluvial aquifers, and ground-water use.

Proposed Monitoring

Additional data on hydraulic characteristics of the aquifer, ground-water levels, streamflow, and chemical quality of ground and stream waters are needed to estimate the impact of mining more accurately. Ideally, the wells will be placed both upgradient and downgradient from the mine site in locations where the maximum hydrologic information can be obtained. The pH, specific conductance and temperature of the mine discharge, and a nearby creek, need to be monitored continuously and samples of water collected periodically for chemical analysis.

2.0 GEOLOGIC SETTING

2.1 DENVER FORMATION AND LIGNITIC COAL RESERVES

THE DENVER FORMATION CONTAINS THE LIGNITIC COAL

The Denver Formation contains lignitic coal seams which are 20 to 60 feet thick and extend from the land surface to a depth of 500 feet in the study area.

The oval-shaped Denver basin is about 120 miles long and 60 miles wide (fig. 2.1-1). The upper formations within the basin are, from shallowest to deepest: Dawson Arkose, Denver Formation, Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone (fig. 2.1-2). The formations on the southern, eastern, and northern margins of the basin dip gently toward the center. However, along the Front Range on the western margin of the basin, the rocks generally dip steeply 40° to 45° to the east (2).

The Denver Formation ranges in age from Late Cretaceous to early Paleocene. This formation consists primarily of 600 to 1,600 feet of medium-yellow, olive to greenish-gray claystone, siltstone, shale, very fine to fine grained sandstone, and andesitic conglomerate. The formation which was deposited in a continental environment, includes all the surface mineable lignite in the basin (fig. 2.1-2). Thick lignite beds, fossilized plant remains, and carbonaceous shales occur in the upper 300 to 500 feet of the formation and are thickest and most prevalent in the eastern part of the basin.

The lignite zone consists of three to eight lignite seams interbedded with carbonaceous shale, claystone, siltstone, and sandstone. The total thickness of the lignite beds in the surface mineable areas ranges from 20 to 60 feet (2). Near the proposed mine site six major seams of lignite are present (fig. 2.1-3). The total thickness of these seams ranges from 20 to 40 feet.

An abandoned kaolinite mine is within 1 mile of the proposed mine site. Kaolin, a kaolinite-rich rock, is the primary parting in the lignite. In some areas kaolinite beds 2 to 5 feet thick overlie individual lignite seams. The kaolinite contains alumina (Al_2O_3), which is a potential source of aluminum (2). If the process for extracting aluminum from kaolinite becomes economically feasible, the Denver Formation may have a dual resource. Therefore, mining of the low-quality lignite may economically benefit from mining of the kaolinite.

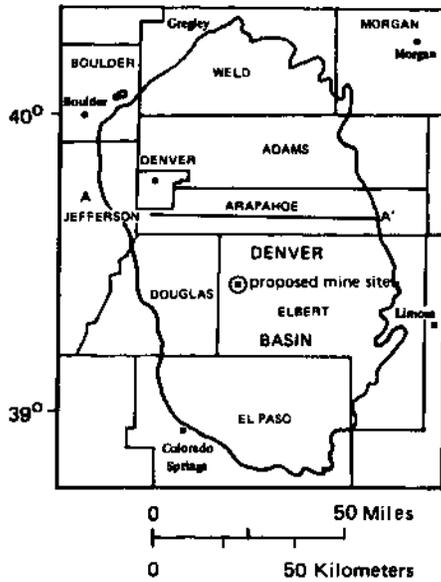


Figure 2.1-1— Location of the Denver basin, proposed mine site

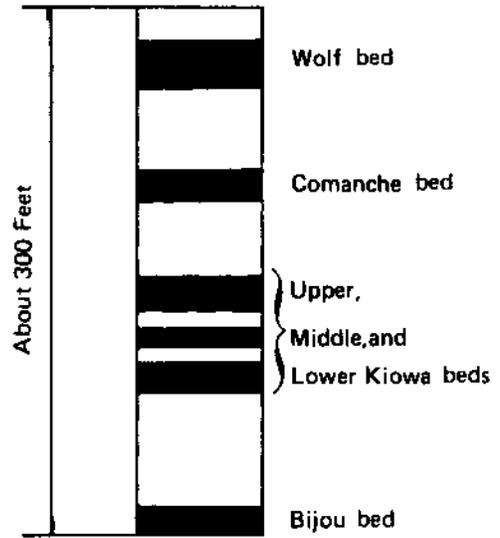


Figure 2.1-2— Generalized geologic section of the Denver basin showing coal

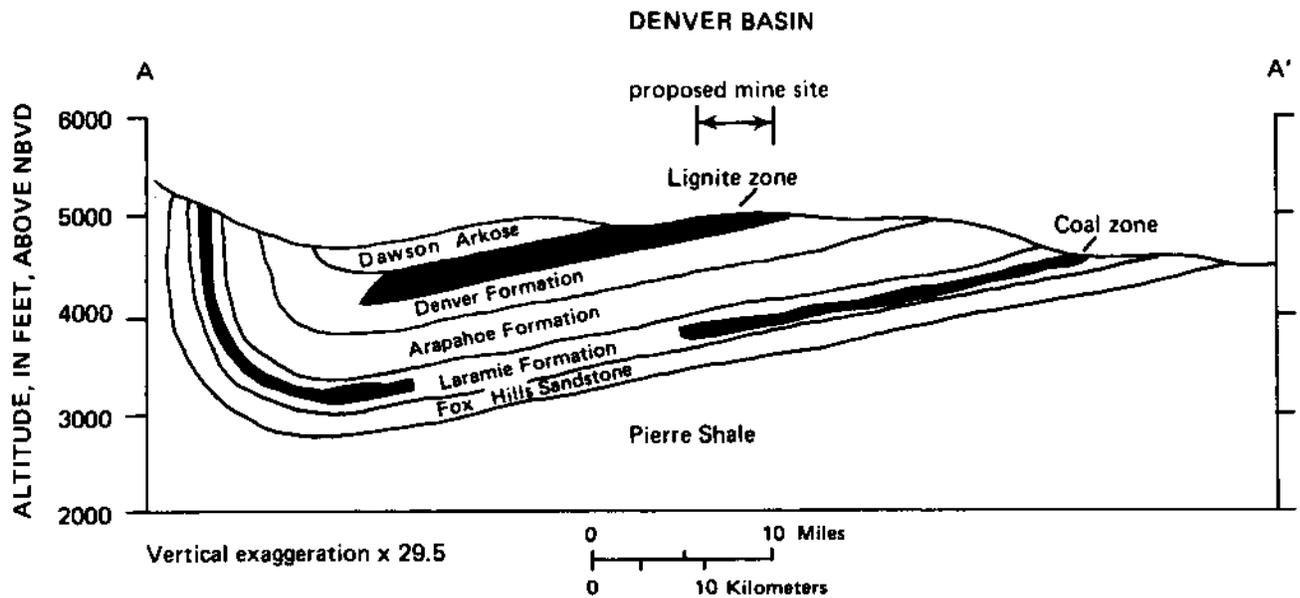


Figure 2.1-3— Generalized section showing location of the lignite beds in the Denver Formation near the proposed mine.

3.0 HYDROLOGIC SETTING

3.1 PHYSIOGRAPHY, VEGETATION, AND CLIMATE OF THE STUDY AREA AREA HAS LOW RELIEF AND SEMIARID CLIMATE

The area is in gently rolling plains, covered by grasses and small cacti, that receive 13 to 17 inches of annual rainfall.

The proposed mine-permit area lies in gently rolling plains with local relief that averages 300 to 500 feet. Altitudes range from 5,500 feet in the north to 6,700 feet in the south. Grasses and small cacti are the primary vegetation. Groves of pine trees grow on some hilltops. Hay and wheat are grown on dryland farms on the plains. The land is used primarily for cattle grazing.

The average annual rainfall in the area ranges from 13 to 17 inches, indicating a semiarid climate. Most of the precipitation falls as rain, primarily in the spring, but 2 to 6 feet of snowfall in the winter is common. Little humidity and strong winds are characteristic of these plains. The mean temperature is 59°F, the normal seasonal temperature fluctuations are from 150 to 75°F, and extremes in temperature range from -38° to about 100°F (1).

3.0 HYDROLOGIC SETTING

3.2 GROUND-WATER SYSTEM

DENVER AQUIFER IS THE ONLY MAJOR AQUIFER AFFECTED BY PROPOSED LIGNITE SURFACE-MINING

The Denver aquifer is the principal source of domestic and stock water near the proposed surface-mine site.

The Denver Formation is a major aquifer in the mine area. Regionally, the Denver aquifer is overlain by the Dawson aquifer and underlain by the Arapahoe aquifer. The Denver aquifer receives recharge from precipitation at the outcrop, from some stream reaches, and from the Dawson aquifer. Water in the Denver aquifer discharges to streams and to the Arapahoe aquifer, as shown in figure 3.2-1. Streamflow in the outcrop area is not significantly increased by the ground-water discharge because most of the gained ground water is lost by evapotranspiration.

The Denver aquifer is the principal source of domestic and stock water in the mine area. Little or no water is withdrawn from this aquifer to irrigate commercial crops (5).

The Denver aquifer consists of a series of lenticular water-bearing sandstone and siltstone units interbedded with lenses of claystone and shale. Because the few drill holes in the area are irregularly spaced, the extent and thickness of the sandstone-siltstone units are difficult to determine. However, the available data indicate that the water-bearing sandstone-siltstone units are lenticular. Intergranular pore space provides the permeability in the aquifer. In the upper 200 feet of the area, the sandstone-siltstone lenses probably range in thickness from several feet to 20 feet; locally, isolated lenses are as much as 40 feet thick.

The lower part of the Denver aquifer is primarily confined, whereas the upper part of the aquifer is generally unconfined (4). Because the lignite beds are in the upper part, the hydrologic setting of the mine area is primarily an unconfined or water-table condition.

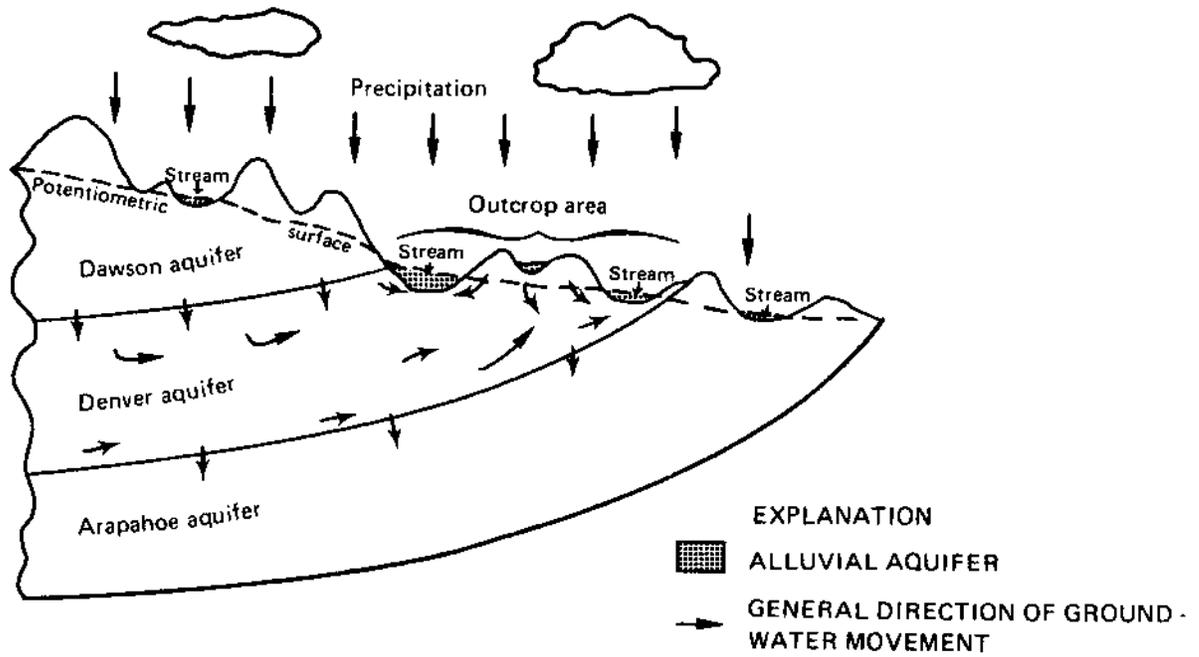


Figure 3.2-1.— Generalized west-to-east cross section showing the hydrologic setting of the Denver aquifer.
 (Modified from Robson and Romero, 1981.)

3.0 HYDROLOGIC SETTING

3.3 HYDRAULIC CHARACTERISTICS

TRANSMISSIVITY AND STORAGE COEFFICIENT DETERMINED FOR AREA

The transmissivity of the Denver aquifer, as determined from specific-capacity tests ranges from about 50 to more than 200 ft²/d. Storage coefficients were determined from specific-yield information.

Transmissivity values for the Denver aquifer were based on specific-capacity tests (6) of wells inventoried near and within the proposed mine permit area. They ranged from about 50 to more than 200 ft²/d. In addition, values for hydraulic conductivity, porosity, specific retention, and specific yield from undisturbed samples of permeable bedrock, which were obtained from the results of laboratory tests (4), are listed in table 3.3-1.

Transmissivity values were also calculated as the product of hydraulic conductivity and saturated thickness. Saturated-thickness values were taken from published maps (5) of the thickness of sandstone and siltstone, which are the water-bearing beds of the Denver aquifer. Figure 3.3-1 illustrates the variation of transmissivity within the proposed mine-permit area.

Storage coefficients of the unconfined systems vary widely. Estimates of the storage coefficient range from 0.014 to 0.088. Therefore, a representative mean value for an unconfined aquifer in the area was used. The storage coefficient of the unconfined aquifer was determined by multiplying the average specific yield of the aquifer by the percent of permeable material in the aquifer—30 percent (4).

Table 3.3-1— Physical properties of sampled water yielding materials in the Denver Formation (4)
[ft/d, feet per day]

Well identifier	Specific yield (percent)	Specific retention (percent)	Porosity (percent)	Hydraulic Conductivity (ft/d)
SC00306328DD	23.9*	20.5	44.4	8.5*
SC00306419DC	18.5*	11.9	30.4	—
SC00406333CC	4.7	10.1	14.8	.006*
SC00506328CC	29.4*	9.2	38.6	.9*
SC00806111AA	24.6	13.8	38.4	4.0*
SC01006214AA	—	—	35.4	—

* Calculated Value

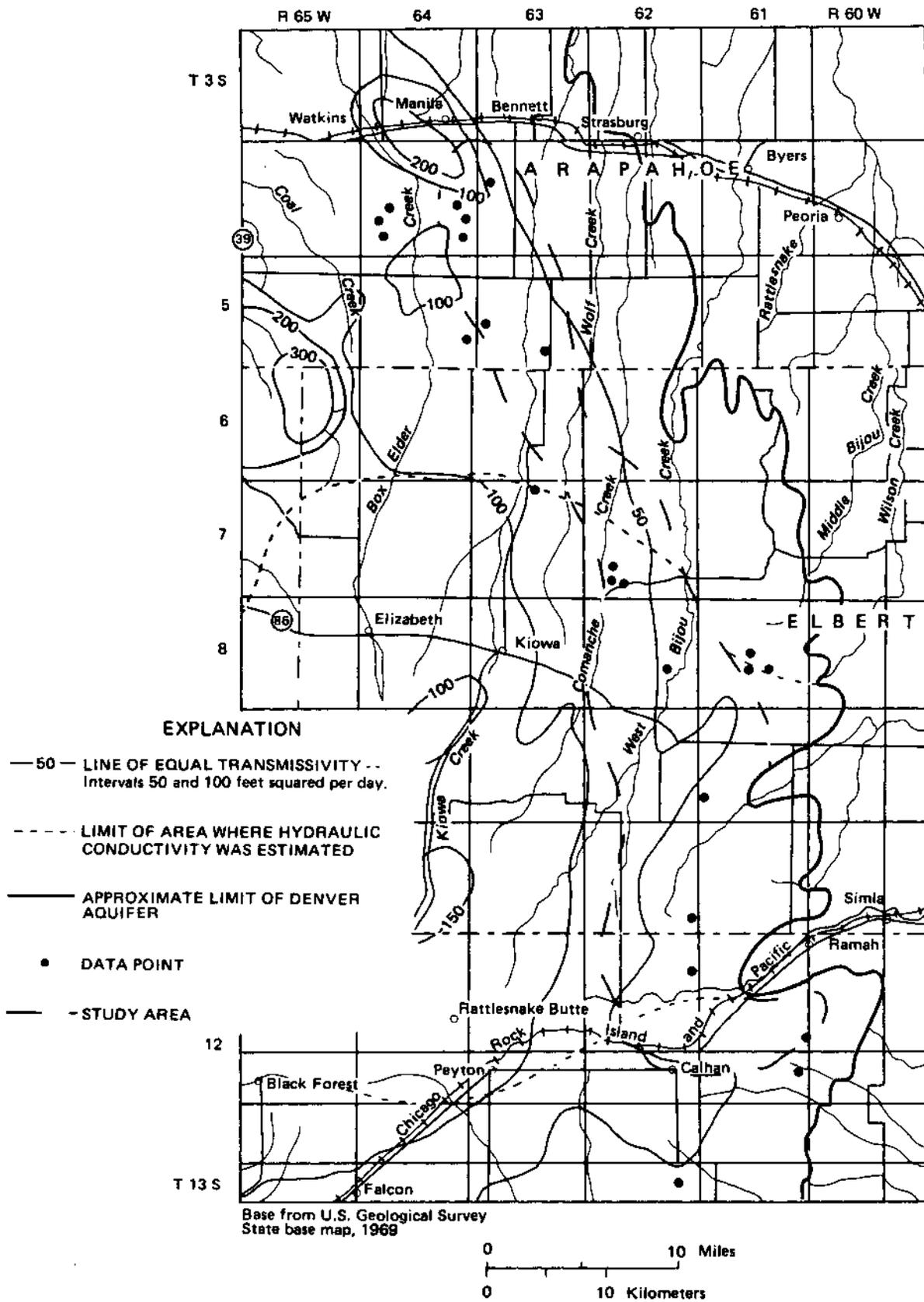


Figure 3.3-1.— Transmissivity of the Denver aquifer.
(Modified from Robson, 1983.)

3.0 HYDROLOGIC SETTING

3.4 POTENTIOMETRIC SURFACE

POTENTIOMETRIC HEAD DECREASES TO THE NORTH AND EAST

Potentiometric-surface map of the Denver aquifer indicates ground water flows toward the north and east.

The potentiometric-surface map (fig. 3.4-1) depicts the altitude of static water levels in part of the Denver aquifer in 1978. The altitude of the potentiometric surface is highest in the south and lowest in the north and east. Water in the aquifer moves from points of high water-level altitude to areas of lower altitude along lines at right angles to the potentiometric contours shown in figure 3.4-1. Therefore, the potentiometric head in the Denver aquifer underlying the study area decreases from the south to the north and east. In the outcrop area of the Denver aquifer, lateral movement of water is determined primarily by the location and altitude of sources of recharge and discharge. At the proposed mine area, water moves through the aquifer from the subsurface-recharge areas in the west and south to the area of discharge into Bijou Creek, which flows to the north.

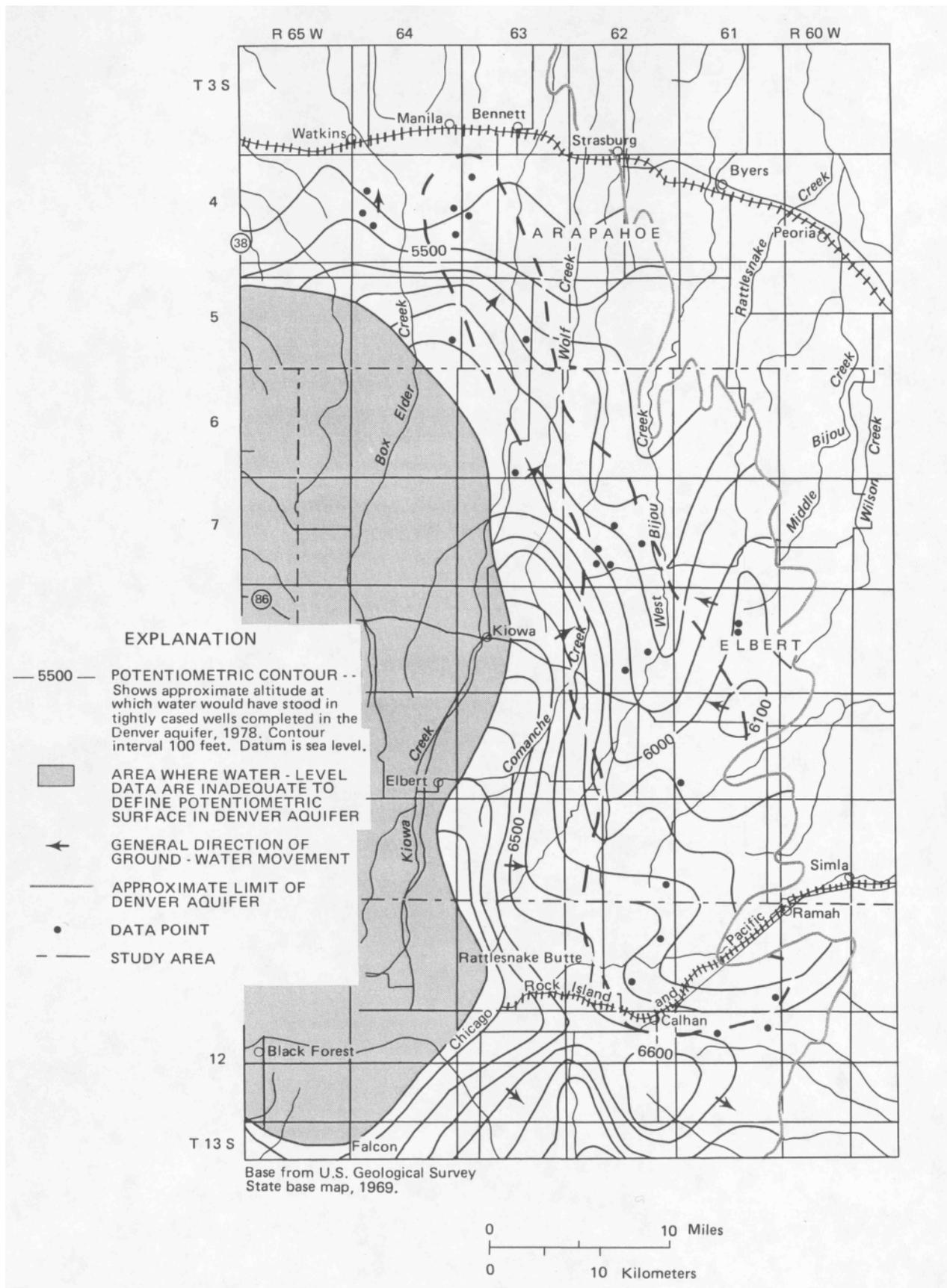


Figure 3.4-1. — Potentiometric surface of the Denver aquifer. (Modified from Robson and Romero, 1981.)

3.0 HYDROLOGIC SETTING

3.5 CHEMICAL QUALITY OF GROUND WATER

PRE-MINING WATER-QUALITY INFORMATION IS NEEDED

Pre-mining water quality can be used to determine the natural flow path, to determine changes in ground-water quality along the flow path, and to predict where water-quality impacts will occur.

The pre-mining flow path and the quality of the ground water are needed to determine the impacts of surface mining on ground-water quality. The flow path shows the direction in which the potential solutes from mining probably would travel. Under normal conditions, these solutes would form certain patterns along the flow path. For example, the dissolved-solids concentrations would be expected to increase downgradient from the mine area.

Twenty domestic and stock wells were sampled near and within the study area (fig. 3.5-1 and table 3.5-1). These wells were selected because they were either in or near the study area, because they were completed solely in the Denver aquifer, or because thorough drilling and completion information was available. Specific conductance, pH, and temperature were measured at the time of sample collection. Samples were analyzed for major and minor dissolved constituents and trace metals. Data on specific conductance, pH, dissolved solids, and major dissolved constituents are given in table 3.5-2, and data on temperature, alkalinity, hardness, and minor dissolved constituents are given in table 3.5-3.

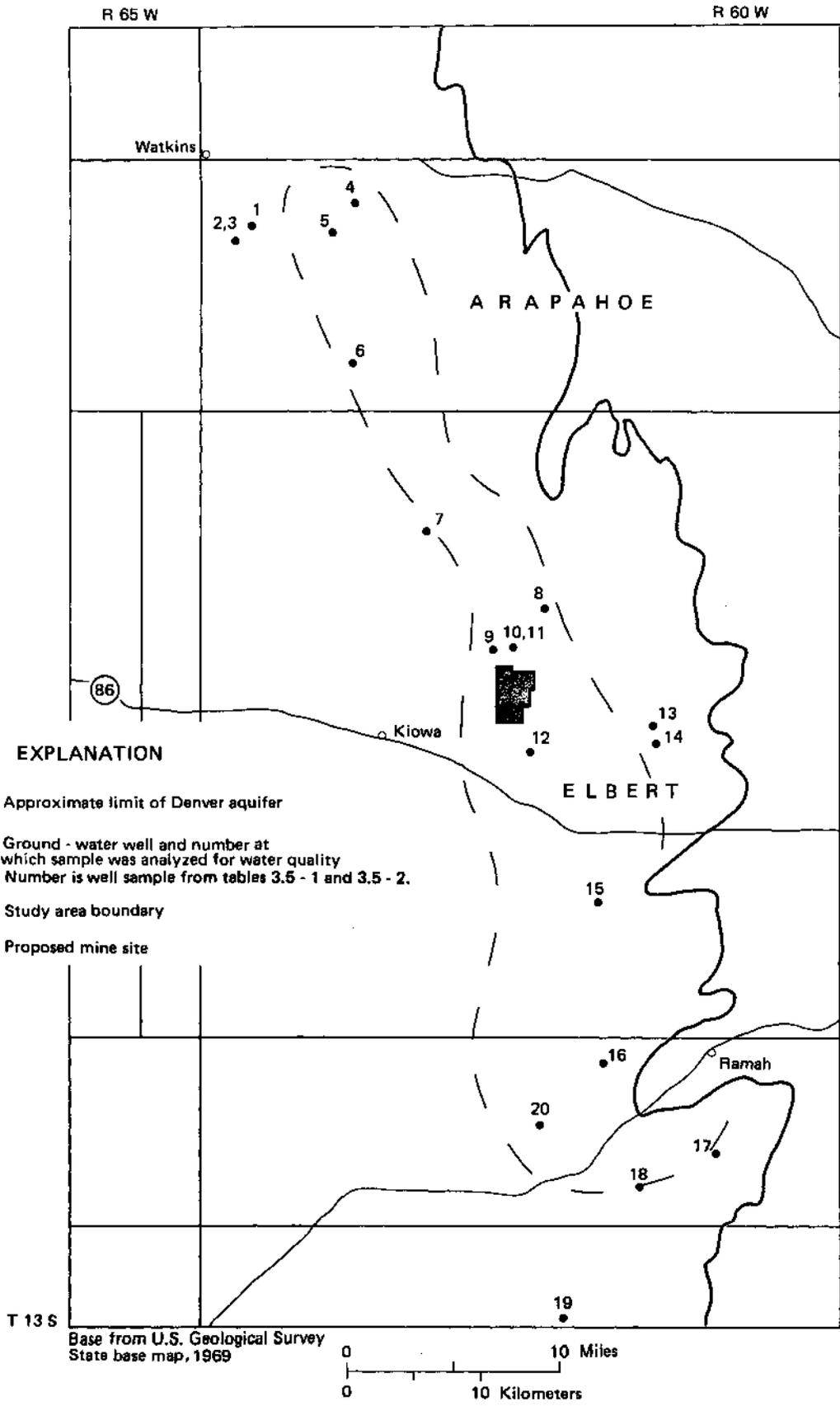


Figure 3.5-1.— Location of wells sampled for water-quality analysis.

Table 3.5-1 – General information on the wells sampled for water-quality analysis.

Map* and sample number	Well identifier	Lithology	Altitude above sea level (feet)	Depth drilled below land surface (feet)	Depth to first opening in well (feet)	Water level below land surface (feet)
1	SC00406416CDD1	Sandy clay	5735	731	468	330
2,3	SC00406420CDB1	Sandstone	5752	575	340	240
4	SC00406307CCB1	Sandstone	5717	515	415	191
5	SC00406413CCA1	Sandstone	5754	755	555	414
6	SC00506424BDA1	Sandy shale	6000	156	114	112
7	SC00606334CAB1	Sandy shale	6067	155	111	120
8	SC00706214BDB1	Sandstone	5770	189	75	64
9	SC00706227BCB1	Sandy shale	5910	307	79	137
10,11	SC00706229ADA1	Sandstone	6150	479	299	399
12	SC00806222AAB1	Sandstone & shale	5960	275	200	156
13	9C00806122ACB1	Sandstone	6110	174	111	125
14	SC00806127BDB1	Sandstone	6224	200	160	178
15	SC01006130ABC1	Sandstone & shale	6325	227	165	12
16	SC01106106DBD1	Sandstone	6360	231	91	145
17	SC01106031AAA1	Sandstone	6535	190	70	178
18	SC01206104CCB1	Sandstone	6660	290	200	144
19	SC01306201CCB1	Sandstone	6673	225	165	171
20	SC01106234DCA1	Sandy clay	6512	195	58	41

* see fig. 3.5-1

Table 3.5-2 – Specific conductance, pH, dissolved solids, and major dissolved constituents in ground-water samples
[mg/L, milligrams per liter]

Map* and sample number	Local identifier	Date of sample	Specific conductance (micro-mhos)	PH lab (units)	Solids sum of constituents, dissolved (mg/L)	Bicarbonate (mg/L as HCO ₃)	Calcium dissolved (mg/L as Ca)	Sodium dissolved (mg/L as Na)	Sulfate dissolved (mg/L as SO ₄)
1	SC00406416CDD1	82-05-12	340	8.6	224	195	11	77	17
2	SC00406420CDB1	78-09-19	450	7.8	309	290	24	98	15
3	SC00406420CDB1	82-05-12	460	8.3	286	293	21	90	<5.0
4	9C00406307CCB1	82-05-12	350	8.6	274	256	22	91	5.0
5	SC00406413CCA1	82-05-12	410	8.5	269	268	15	89	<5.0
6	SC00506424BDA1	82-05-12	1,000	7.6	817	195	130	97	430
7	9C00606334CAB1	78-09-19	845	7.8	600	170	110	70	280
8	9C00706214BDB1	82-05-18	1,400	7.9	964	256	89	200	510
9	SC00706227BCB1	82-05-18	780	7.6	544	317	46	140	170
10	SC00706229ADA1	78-10-09	470	8.1	316	320	12	110	12
11	SC00706229ADA1	82-05-18	500	8.1	369	317	35	140	10
12	SC00806222AAB1	82-05-18	930	8.3	602	293	22	160	250
13	SC00806122ACB1	82-05-18	350	7.0	301	96	63	49	100
14	SC00806127BDB1	82-05-18	890	7.1	659	183	100	100	330
15	SC01006130ABC1	82-05-17	1,100	8.4	676	268	18	210	290
16	SC01106106DBD1	78-09-21	1,480	8.0	972	460	28	320	370
17	9C01106031AAA1	78-10-04	561	8.0	337	210	45	54	59
18	SC01206104CCB1	82-05-17	370	6.7	242	43	68	28	68
19	SC01306201CCB1	78-10-02	232	8.8	145	110	3.3	49	24
20	SC01106234DCA1	82-05-17	600	7.4	446	134	59	70	210

Table 3.5-3 — Temperature, alkalinity, hardness, and minor dissolved constituents in ground-water samples.
[mg/L, milligrams per liter; ug/L, micrograms per liter]

Map* and sample number	Date of sample	Temperature (°C)	Alkalinity field (mg/L as CaCO ₃)	Hardness (mg/L as CaCO ₃)	Magnesium, dissolved (ug/L as Mg)	Nitrogen, NO ₂ +NO ₃ dissolved (mg/L as N)	Phosphorous, dissolved (mg/L as P)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO ₂)	Boron, dissolved (ug/L as B)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Zinc, dissolved (ug/L as Zn)	Selenium, dissolved (ug/L as Se)
1	82-05-12	15.6	160	31	0.9	0.02	0.050	2.5	6.0	2.3	11	60	34	<1	8	13	<1
2	78-09-19	21.0	240	67	1.8	.04	—	3.4	11	1.1	11	—	30	—	20	—	—
3	82-05-12	15.0	240	59	1.5	.03	.060	3.4	9.7	1.3	10	50	39	<1	15	15	<1
4	82-05-12	13.0	210	64	2.3	.03	.070	3.4	8.5	2.6	13	60	95	<1	27	35	<1
5	82-05-12	12.0	220	42	1.2	.18	.060	2.7	9.3	1.7	13	60	73	<1	21	13	<1
6	82-05-12	11.5	160	380	13	.13	.080	10	24	1.1	14	50	440	<1	180	220	1
7	78-09-19	13.0	140	300	6.3	.32	—	9.5	15	.6	23	—	40	—	20	—	—
8	82-05-18	21.0	210	260	8.7	.89	<.010	5.1	9.6	.8	10	60	37	<1	110	120	<1
9	82-05-18	21.5	260	140	7.2	.18	.020	3.2	8.7	1.5	10	60	49	<2	67	110	<1
10	78-10-09	17.0	260	35	1.3	.02	.010	3.1	7.7	1.9	9.9	—	140	—	20	—	—
11	82-05-18	18.5	260	100	3.2	.09	.020	3.8	7.6	1.9	11	60	75	<5	44	25	<1
12	82-05-18	25.0	240	63	2.0	.02	.040	3.2	6.8	.9	13	50	27	<2	57	31	<1
13	82-05-18	25.0	79	100	5.9	.17	<.010	6.0	1.8	1.0	26	40	88	<2	160	280	<1
14	82-05-18	25.0	150	280	8.1	.17	.030	7.4	6.1	.5	15	70	21	<2	110	530	<1
15	82-05-17	18.0	220	53	1.9	.17	.030	2.5	10	1.9	9.4	40	21	5	26	13	1
16	78-09-21	14.0	380	81	2.8	.71	.030	2.8	8.5	1.1	9.1	—	20	—	60	—	—
17	78-10-04	11.5	170	150	10	5.2	.010	4.2	22	.6	15	—	130	—	20	—	—
18	82-05-17	18.0	35	210	10	<50	.030	6.5	17	.1	23	20	100	<5	240	180	10
19	78-10-02	16.0	90	9	.20	.10	.030	.7	2.3	.6	10	—	20	—	<10	—	—
20	82-05-17	19.5	110	170	5.0	.23	<.010	3.1	5.3	.4	26	30	13	<5	5	42	<1

3.0 HYDROLOGIC SETTING

3.6 DISSOLVED SOLIDS

DISSOLVED SOLIDS INCREASE DOWNGRADIENT TO THE NORTH AND EAST

Dissolved-solids concentrations increase naturally to the north and east as the head decreases along the ground-water flow line.

In general, the dissolved-solids concentration in the Denver aquifer increases as the ground water moves downgradient. This increase is due to the solution of minerals by undersaturated water. The dissolved-solids concentration of ground water in the study area ranges from 150 to 1,000 mg/L and increases downgradient perpendicular to the contour lines of the potentiometric surface, as shown in figure 3.6-1. The potentiometric-surface map shows that the flow is generally to the north and east, the directions in which the dissolved-solids concentrations primarily increase.

In the Denver aquifer, the dissolved-solids concentrations in the water gradually increase as the water travels from areas of recharge to areas of discharge. The direction of increase in dissolved-solids concentration helps delineate the flow path of the water. The dissolved-solids concentrations are small where the Dawson aquifer overlies the Denver aquifer (5). The Dawson aquifer, consisting primarily of sandstone, contributes water to the Denver aquifer that is less mineralized than the Denver aquifer generally contains. The large concentrations in the Denver aquifer are due to the fact that the Denver aquifer is part of a formation consisting primarily of shale. As water in the Denver aquifer moves to areas of discharge from its outcrop, the water dissolves additional dissolved minerals carried into the aquifer from near-surface sources, increasing the dissolved-solids concentration.

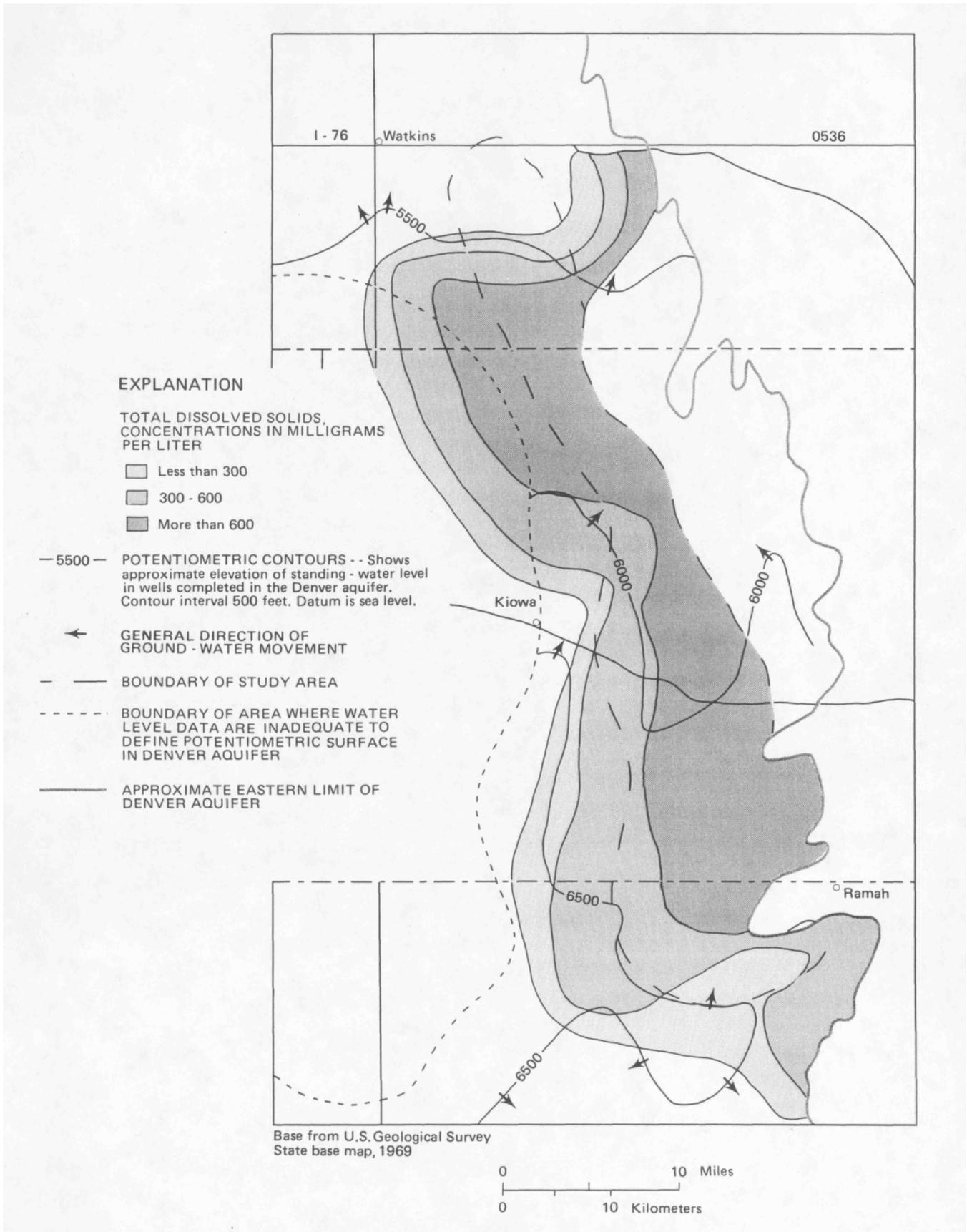


Figure 3.6-1.— Dissolved-solids concentration and flow path in the Denver aquifer.

4.0 PROBABLE HYDROLOGIC IMPACTS

4.1 GEOLOGIC AND HYDROLOGIC CONDITIONS BEFORE AND DURING MINING

DEFINING THE PRE-MINING GEOLOGIC AND HYDROLOGIC CONDITIONS IS NEEDED TO EVALUATE THE CHANGES DURING MINING

Knowledge of the hydrologic conditions before mining can be used to help minimize the impact the active mine will have on the surrounding area.

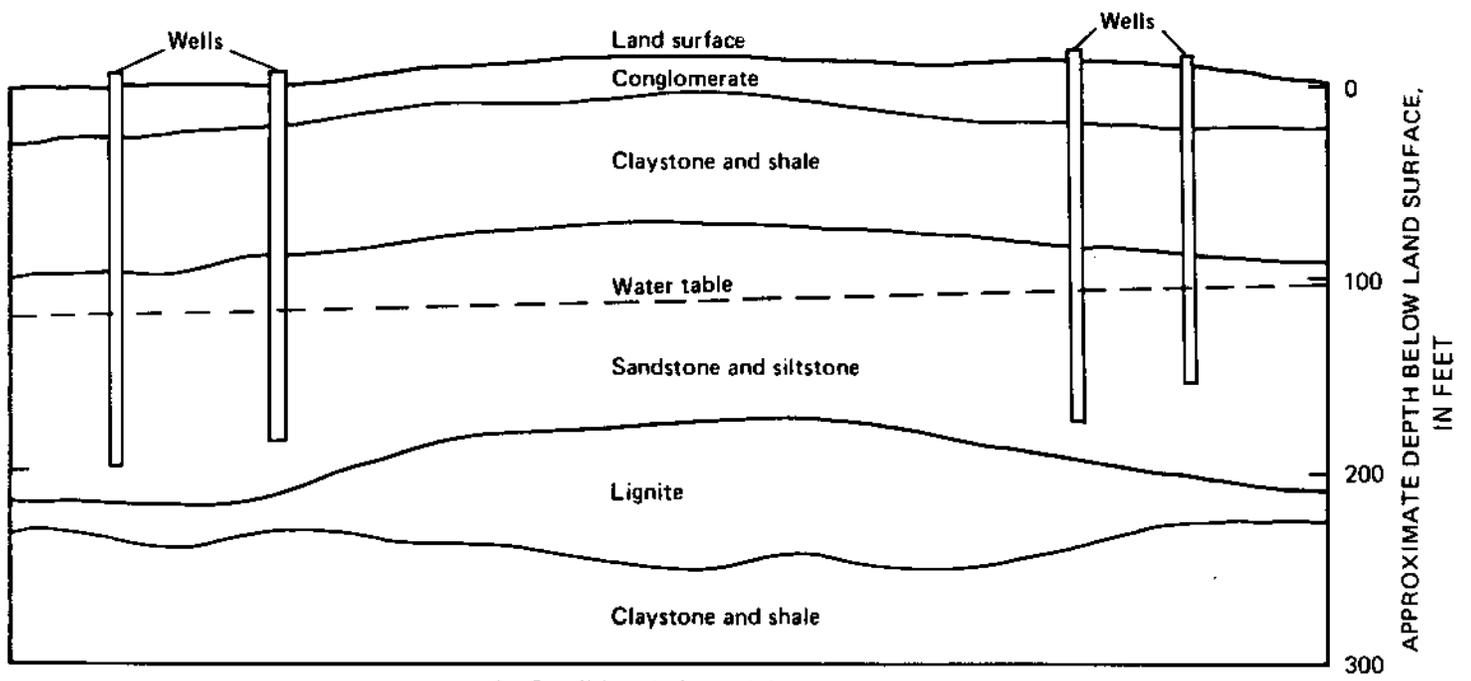
A variety of geologic and hydrologic conditions can exist in an area to be mined. One simple set of pre-mining conditions has been selected to illustrate the impacts of mining on an aquifer system. These conditions are:

1. A sandstone and siltstone unit directly overlies a lignite unit; no intervening confining layers are present.
2. The sandstone-siltstone and lignite units comprise a single, continuous aquifer.
3. The aquifer is unconfined.
4. The aquifer discharges into a stream downgradient from the area to be mined.

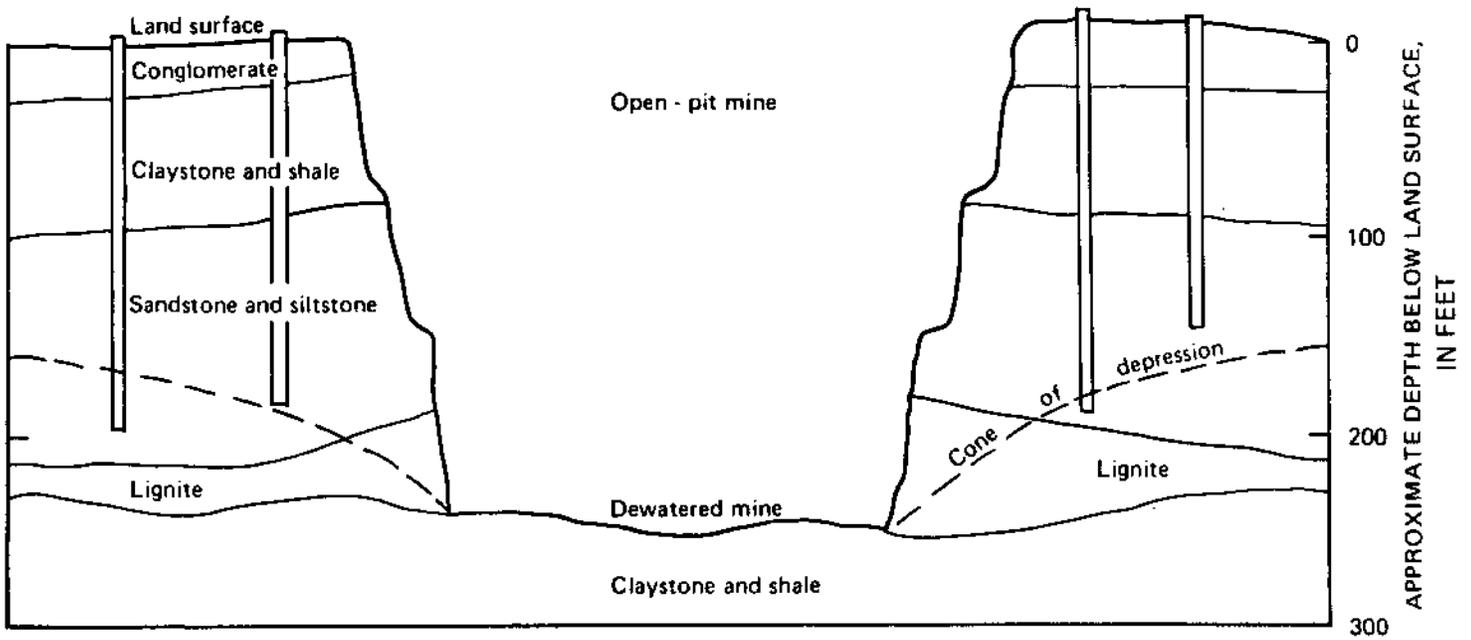
Pre-mining conditions 1, 2, and 3 are depicted in figure 4.1-1A; they can be used to assess the impacts of mining on the hydrologic system in the proposed mine area.

During surface mining, the quantity and flow paths of ground water can be affected significantly, in the vicinity of the mine, by aquifer disruption and disturbance of the recharge areas. Aquifers penetrated by a surface mine will drain into the open pit. Dewatering of the mine further reduces the quantity of water within and surrounding the mine area (fig. 4.1-1B). The conditions before mining are generally: (1) lignite seams are variable in thickness from 20 to 60 feet and are about 500 feet below land surface, (2) the average well depth is about 325 feet (from table 3.4-1), and, (3) the average depth of water level below land surface is 190 feet (from table 3.4-1). The conditions during mining would be an excavation 500 feet deep and a drawdown at the mine floor of about 110 feet for an unconfined aquifer having a transmissivity of 50 ft²/d and a storage coefficient of 0.058 (fig. 4.1-2). The distance-drawdown curves of figure 4.1-2 approximate the long-term and short-term effects of dewatering the excavation in wells near and distant from the mined area. These head-loss curves were calculated using the Theis nonequilibrium formula (3).

The probable outcome of the dewatering would be that domestic and stock wells within the cone of depression either would become completely dry or would contain less water, as shown in figure 4.1-1B. This reduction in water supply would necessitate drilling deeper wells or finding alternative supplies of surface water. A second possible effect from dewatering might be that water levels would decline in streams and alluvial aquifers supplied by the bedrock aquifer within the cone of depression. Although water levels might decline during the mining operation, the water quality of the aquifer would not change significantly until spoils material is replaced in the mine pit.



A. Conditions before mining



B. Conditions during mining

Figure 4.1-1.— Idealized sections showing the effect of mining on the Denver aquifer.

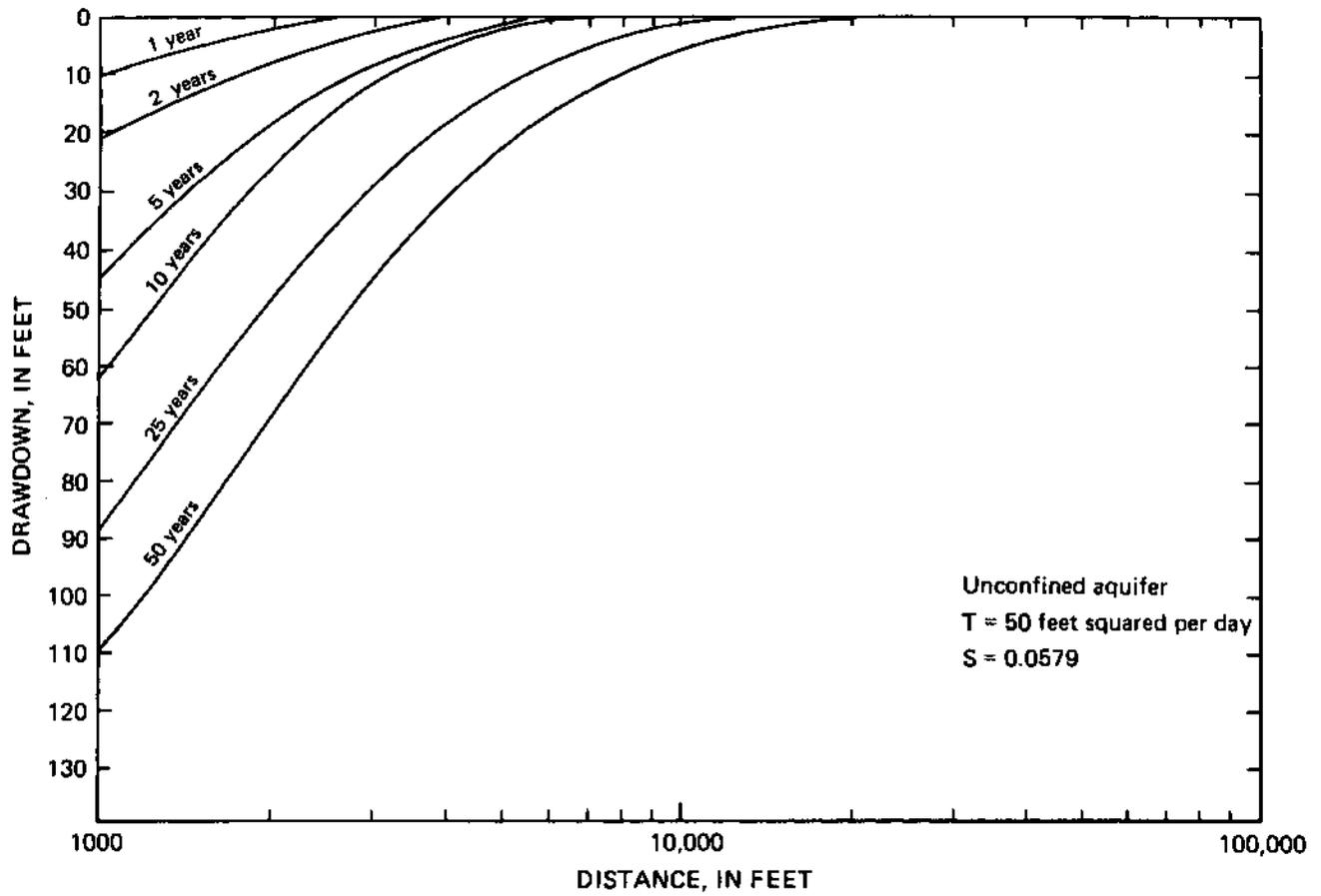


Figure 4.1-2. — Distance-drawdown curves with time for a pumping rate of 100 gallons per minute in unconfined aquifers having a transmissivity of 50 feet squared per day and a storage coefficient of 0.058.

4.0 PROBABLE HYDROLOGIC IMPACTS

4.2 CONDITIONS AFTER MINING

AFTER RECLAMATION THE MINE SPOILS MAY BE A LONG-TERM SOURCE OF INCREASED DISSOLVED SOLIDS

After reclamation the spoils will continue to increase the dissolved-solids concentrations of water in the Denver aquifer. This increase could affect streams, springs, alluvial aquifers, and domestic users.

As mining progresses, the mine spoils are replaced in the mine pit and recontoured to approximate pre-mining conditions. The characteristics of spoils depend upon reclamation techniques and the local spoils. The spoils are assumed to be a heterogeneous mixture of siltstone, sandstone, claystone, and shale, which allows water to percolate easily through the system (fig. 4.2-1). The spoils may locally increase infiltration and deep percolation, thereby altering the hydrostatic conditions. The increased infiltration through the spoils causes recharge and leaching of ions to increase and surface flow to decrease.

During mining, the natural flow path in the aquifer is disrupted. However, when permeable spoils are replaced in the mine, water in the aquifer eventually will return to approximately its pre-mining level.

As the spoils material is replaced, the ground-water quality can be significantly affected by ions leached from replaced overburden. During mining the overburden is scraped, hauled, or dragged outside of the mine pit. The overburden is broken and mixed during this process. While on the surface, some of the overburden is exposed to weathering. When the overburden is replaced in the mine pit during reclamation, further breakage and mixing occur. Therefore, these newly exposed or slightly weathered rock surfaces of the rubble in the pit are readily susceptible to leaching of their ions when in contact with water. As water from rain and overland flow moves over and around these newly exposed surfaces in the permeable spoils, minerals from the overburden are dissolved in the water, which then joins the water from the aquifer. The dissolved-solids concentration of the water in the spoils may be as much as four times the natural concentration.

Because water in the undisturbed aquifer flows from the south to the north, the concentration of dissolved solids from the spoils probably will form a plume that moves northward. The extent of the plume would depend on the boundaries of the aquifer, fractures in the formation, permeability of the bedrock material, kinds of minerals and their solubility equilibrium in the undisturbed aquifer, and area of discharge.

The area of aquifer discharge is within the boundaries of the dissolved-solids plume; therefore, streams and alluvial aquifers in the discharge area might be affected. The dissolved-solids loads would increase in the gaining stream and alluvial aquifer. The concentrations of dissolved solids and the quantity and quality of water in the stream and alluvial aquifer would determine the effects of water from the discharging bedrock aquifer on the alluvial system. Because streams in the area are intermittent, the diluting effect of the stream may be minimal.

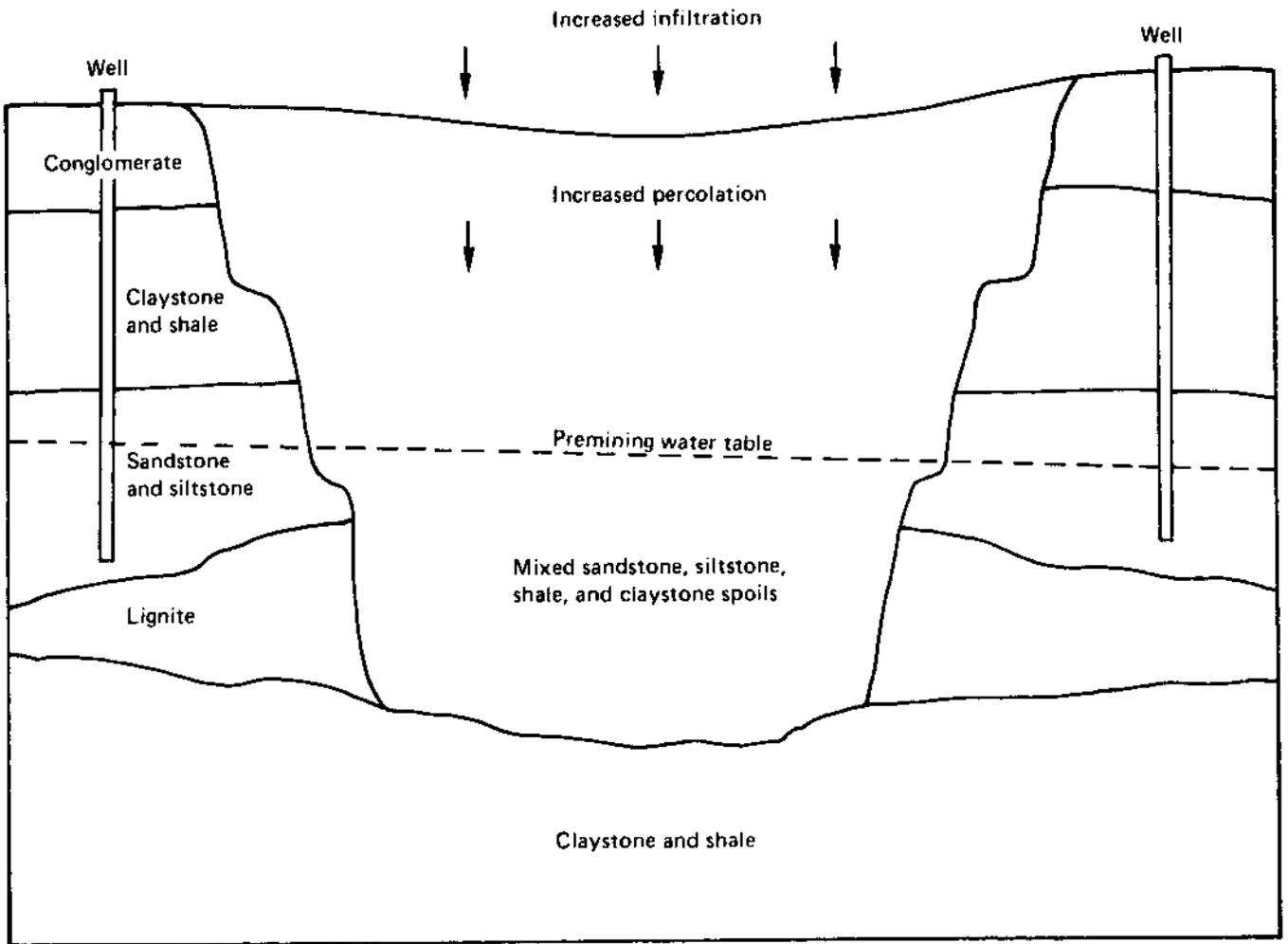


Figure 4.2-1.— Idealized section of a permeable spoils pile showing associated ground-water conditions.

5.0 GROUND-WATER AND SURFACE-WATER MONITORING

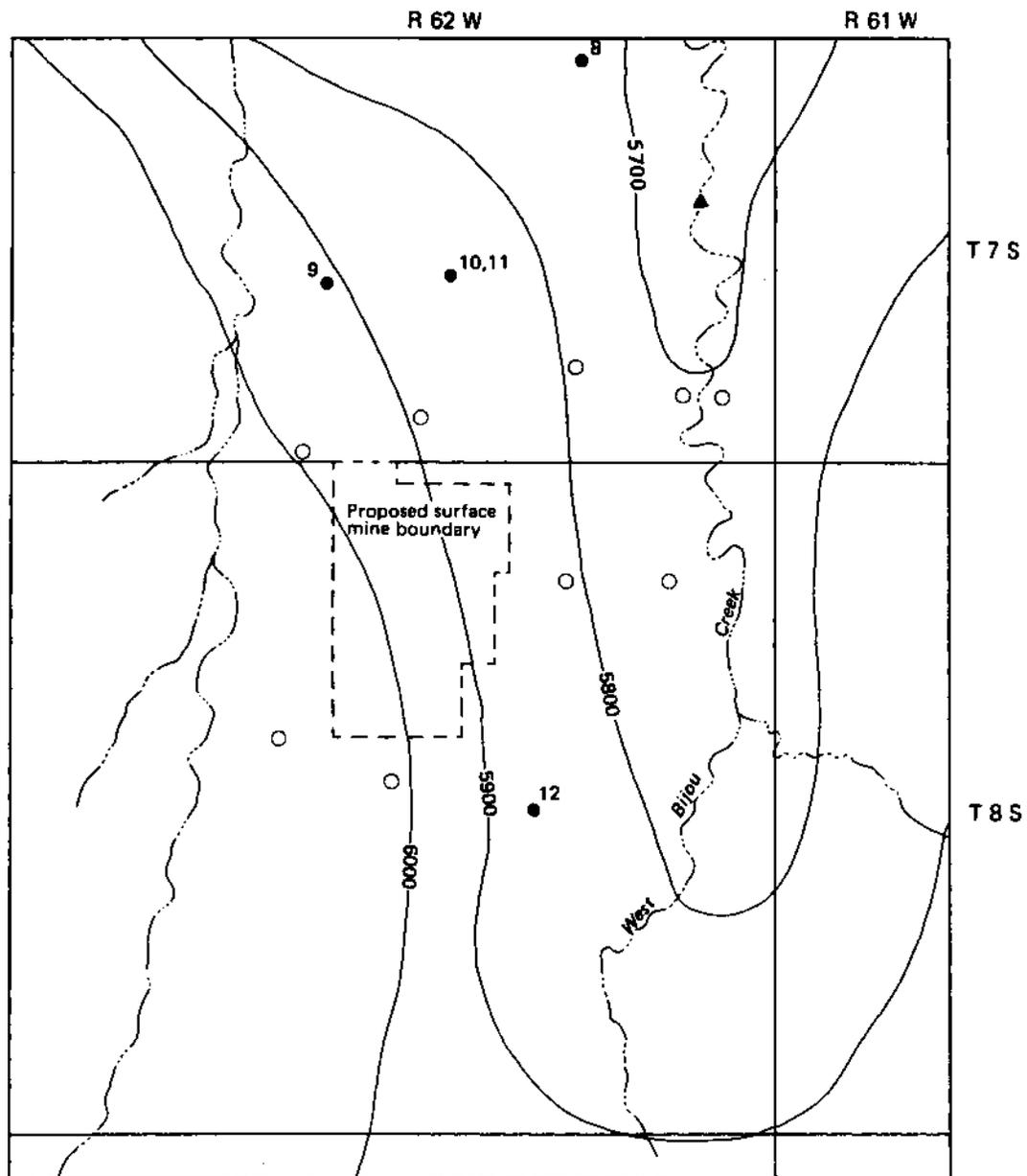
OBSERVATION WELLS AND SURFACE-WATER MONITORING SITES ARE NEEDED

Additional data on hydraulic characteristics of the aquifer, ground-water levels, streamflow, and chemical quality of ground and stream waters are needed to estimate the impact of mining more accurately.

To assess the impacts of the proposed surface mine accurately, additional data on pre-mining conditions are needed. The existing wells in the area are insufficient to provide adequate ground-water information near the mine; therefore, observation wells need to be drilled upgradient and downgradient from the mine. Possible locations for these wells are shown in figure 5.0-1. The location of the wells would be chosen to obtain the maximum hydrologic information. These wells would be test pumped to determine the hydraulic properties of the aquifer near the mine. During and after mining, these wells would be monitored periodically for changes in water level and for changes in water chemistry.

Discharge from the mine needs to be monitored continuously, and water samples for chemical analysis of the discharge taken periodically. The analysis would determine the concentration of major ions, trace metals, and other constituents required by State and Federal regulations. An automatic monitor would provide continuous records of pH, specific conductance, and temperature in relation to mine discharge.

A streamflow-gaging and sampling station installed on West Bijou Creek would monitor the impact, if any, that mining may have on this stream. Because West Bijou Creek is an ephemeral stream, a sampler that is activated once the stream rises to a specific stage seems to be the most feasible.



Base from U.S. Geological Survey, Elbert County, 1980



EXPLANATION

- 5800- POTENTIOMETRIC CONTOURS - - Shows approximate altitude of standing water level in wells. Contour interval 100 feet. Datum is sea level.
- GROUNDWATER WELL AND NUMBER FROM WHICH DATA HAVE BEEN OBTAINED
- PROPOSED OBSERVATION WELL
- ▲ PROPOSED STREAMFLOW GAGING STATION

Figure 5.0-1.— Hypothetical network of observation wells and a streamflow-gaging station used to monitor water levels and water quality near the proposed surface mine.

6.0 REFERENCES

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