PREPARED FOR

CONSOLIDATION

COAL COMPANY

2 INVERNESS DRIVE EAST

ENGLEWOOD, COLORADO

HYDROLOGY REPORT
EMERY MINE
EMERY, UTAH

VOLUME 1

watec, inc.

EMERY HYDROGEOLOGICAL REPORT

EMERY MINE

PREPARED FOR: CONSOLIDATION COAL CO.
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EXECUTIVE SUMMARY

This report combines the findings of independent hydrologic research conducted over the past five years in the Emery, Utah vicinity. Data are available from the files of Consolidation Coal Company, United States Geological Survey, Environmental Protection Agency, Soils Conservation Service, the Bureau of Land Management, and State of Utah agencies.

During January and Freruary of 1979, the data available were evaluated and a draft report summary was prepared. From this draft and the pending Permanent Regulatory Program the need for a coordinated, updated network of hydrologic monitoring in the vicinity of the Emery Underground Mine was indicated. During June and July 1979 Consol and WATEC personnel developed a proposed hydrologic monitoring program which Consol presented to the regulatory authorities. In late August WATEC began implementation of the program.

The hydrologic monitoring and testing program now implemented on and near the Emery Underground Mine includes the collection of surface water flow and water quality on Christiansen Wash and Quitchupah Creek, mine water outflow and quality, and ground water levels and water quality. Monitoring of the hydrologic regime is conducted at the frequency and in the manner prescribed by the regulatory authorities.

Sufficient data are available and were collected in the Emery Underground Mine area in order to establish the following:

(1) Mining of the IJ coal seam creates a mineward flow of ground water principally from the upper Ferron Sandstone, and at a much reduced rate from the underlying middle and lower Ferron as evidenced by piezometric levels;

(2) Mine water inflow has resulted in small pressure head declines in the upper Ferron Sandstone over the last three years, and these declines will continue as mining continues;

(3) Quitchupah Creek and Christiansen Wash are in hydraulic communication with the upper Ferron Sandstone in the near vicinity of the mine;

(4) As water levels in the upper Ferron Sandstone decline, so will aquifer outflow to the creeks; however, neither the affected ground nor surface water is relied upon as water supplies in the near vicinity of the mine;

(5) Mine water pumpage discharged after settling, as dictated by EPA NPDES Permit No. UT-0022616, will offset detraction from aquifer outflow thus preserving the hydrologic integrity of the surface water system below the mine;

(6) Irrigated agriculture is and has been practiced historically on the terrace gravels perched high above the mine. These terrace gravels overlay thick Bluegate Shale bluffs which occur between the mine and the town of Emery, Utah. Mining is not projected to extend under the bluffs which practically limits the potential for impact to these gravels and their agricultural base;

(7) Thin, narrow accumulations of alluvial debris occupy the well-defined drainage channels of Quitchupah Creek and Christiansen Wash. However, these alluvial sediments are confined within banks of saline Bluegate Shale and/or resistant Ferron Sandstone in the vicinity of the mine and are not currently in agricultural use; and

(8) In the vicinity of the mine both Quitchupah Creek and Christiansen Wash flow directly over the saline Bluegate Shale and/or receive highly saline irrigation return flows from the terrace gravels which render the quality of water in the streams unfit or marginal for most uses.

1.0 GENERAL BACKGROUND INFORMATION

Site specific studies of the hydrogeologic environment in the area of the existing Emery Underground Mine (hereafter referred to as the Emery Mine) have been few. An initial environmental assessment was conducted in 1974 by VTN. This report (VTN, 1974) gives a very general overview of the surface and ground water characteristics of the Emery area. During the next three years, the area was studied in some detail by Consolidation Coal Company (hereafter referred to as Consol) personnel (Consol, 1976; Kaufman, 1977; Consol, 1978). In these three reports, available data collected by the U.S. Geological Survey (USGS) and Consol yield a better understanding of the hydrologic environment. Specifically, quality and quantity of both surface and ground waters were obtained, thus enabling for the first time estimations of stream and aquifer characteristics. Concurrently, through the auspices of Continental Oil Company's Research and Development Department, Angelus Owili-Eger was studying the hydrology of the area incorporating data which were collected by both himself and Consol personnel (Owili-Eger, 1977, 1979). Recently, the USGS (Salt Lake City, Utah) and the Bureau of Land Management (BLM) have been studying the Emery area in some detail. Through a multidisciplinary integration of field and archival data, the BLM has evaluated coal strip mining reclaimability in the Emery coal field. The initial effort consisted of collecting baseline data for the geology, overburden, hydrology, climate, and vegetation of the area. This data was supplemented with a drilling program which provided additional information on overburden, ground water, and coal characteristics. The results of their study were recently released in EMRIA Report No. 16 (BLM, 1979). In similar fashion, the USGS has been conducting a comprehensive hydrological study of the Emery Mine area. This project began approximately two years ago and will be completed by 1981. The focus of their study is to evaluate both the surface water hydrology of the two main drainages (Quitchupah Creek and Christiansen Wash) which feed through the Emery Mine area and the ground water hydrology of the Ferron Sandstone aquifer including its associated under- and overlying geologic strata. Having generated initial input data, the USGS is presently developing a three-dimensional computer model of the Emery Mine area. Such surface and ground water modelling will aid in the determination of mine water inflow and cumulative impacts of mining.

Including the information obtained from these previous studies, other additional sources of information were found to be extremely valuable. Primarily, these sources were personal contacts made by WATEC, Inc. personnel with individuals working within the following governmental agencies: BLM, Moab, Utah; Soil Conservation Service (SCS), Price, Utah; Utah Division of Oil, Gas, and Mining, Salt Lake City, Utah; Utah Department of Health, Salt Lake City, Utah; and the Environmental Protection Agency (EPA), Salt Lake City, Utah. These agencies have been involved in some manner in an environmental assessment of the Emery area. Other individuals who have worked or are presently working for Consol in the Emery Mine area were also contacted.

The information obtained from the above-mentioned sources has been thoroughly reviewed and evaluated. Most of the available information has been incorporated into this report and where important or appropriate, specific information has been referenced. However, it need be mentioned that the methods and quality control procedures by which much of this information was initially generated were many. As a result, where possible, the accuracy and/or completeness of the data has been noted.

2.0 INTRODUCTION

As a requirement of Consol's permit for the approval of mining and reclamation plan for the Emery Mine, Emery County, Utah, the Office of Surface Mining (OSM) and the Utah State Oil, Gas, and Mining Commission have stipulated that Consol submit to the OSM and the State the results of comprehensive ground and surface water investigations to assess the relationships of the Emery Mine to extant surface and ground water systems. Consol has consulted in some length with the USGS, Water Resources Division, Salt Lake City, with respect to these investigations and the design of the surface and ground water monitoring system.

With approval from the staffs of OSM and the State, the surface and ground water monitoring program (refer to Sections 6.3 and 7.3 for details) was implemented during the fall of this year (1979). The operation of the program is designed to provide data important to a more thorough understanding of the hydrology of the Emery Mine and to provide a base from which to minitor any potential effects mining of the IJ coal seam might have upon the present hydrologic system. The results of the program to date (12/20/79) interfaced with all pertinent existing and previously published data are discussed in detail in the sections following.

3.0 PHYSIOGRAPHY, RELIEF, AND DRAINAGE

The Emery Mine is located at the southern end of Castle Valley, a wide belt of relatively flat land bounded on the west by the Wasatch Plateau and on the east by the San Rafael Swell. Figures 1 and 2 show where the Emery Mine is situated in relationship to these regional physiographic features and drainages. The Wasatch Plateau is comprised of nearly flat-lying resistant sedimentary rocks with maximum elevations exceeding 10,000 feet. Along the eastern flank of the plateau, faulting has created a rugged escarpment known as the Joe's Valley-Paradise fault zone. Within this same area originate the headwaters of snowfed streams such as Muddy Creek, Quitchupah Creek, and Christiansen Wash which drain the Emery area. To the east of Castle Valley lies the San Rafael Swell,

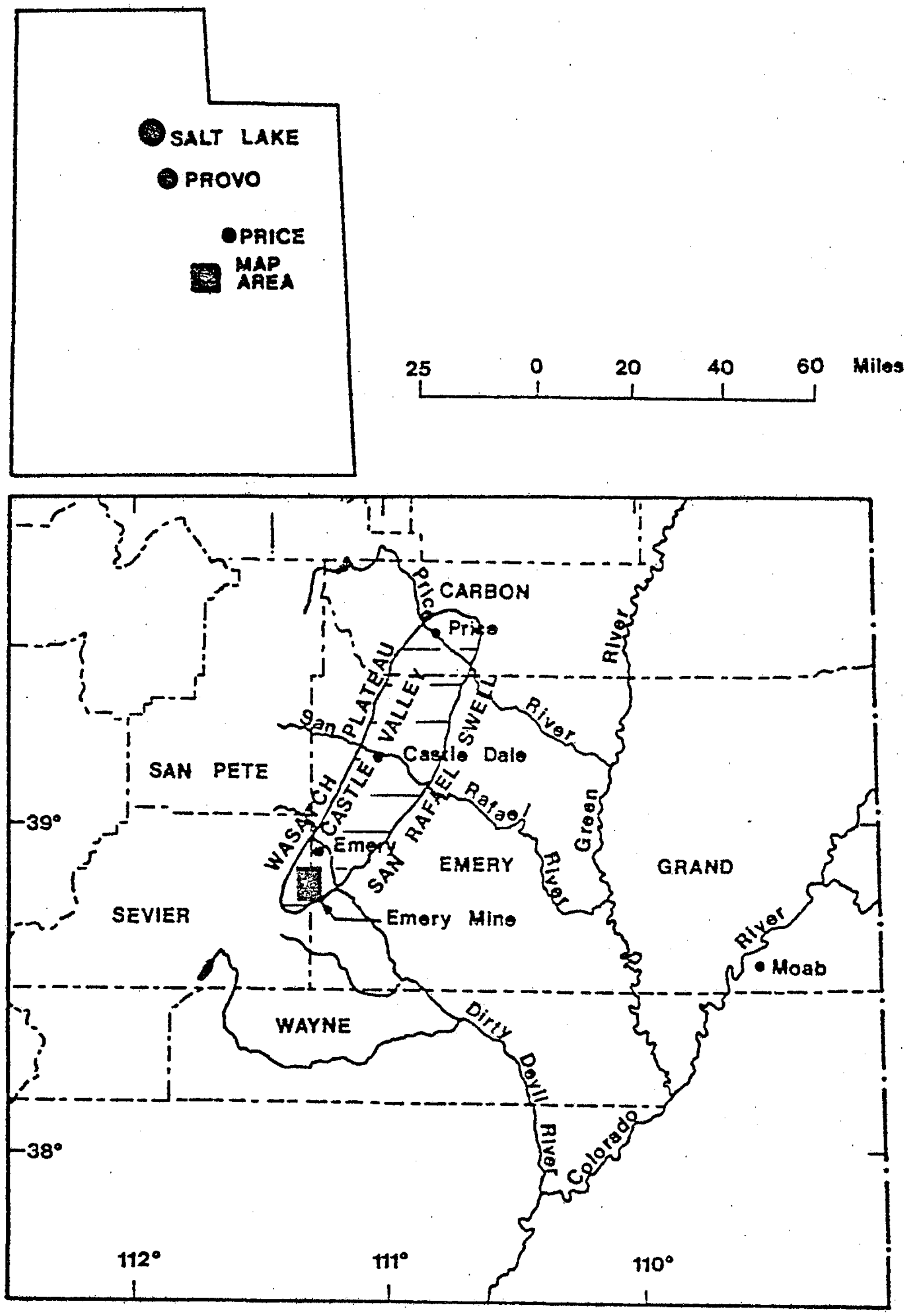
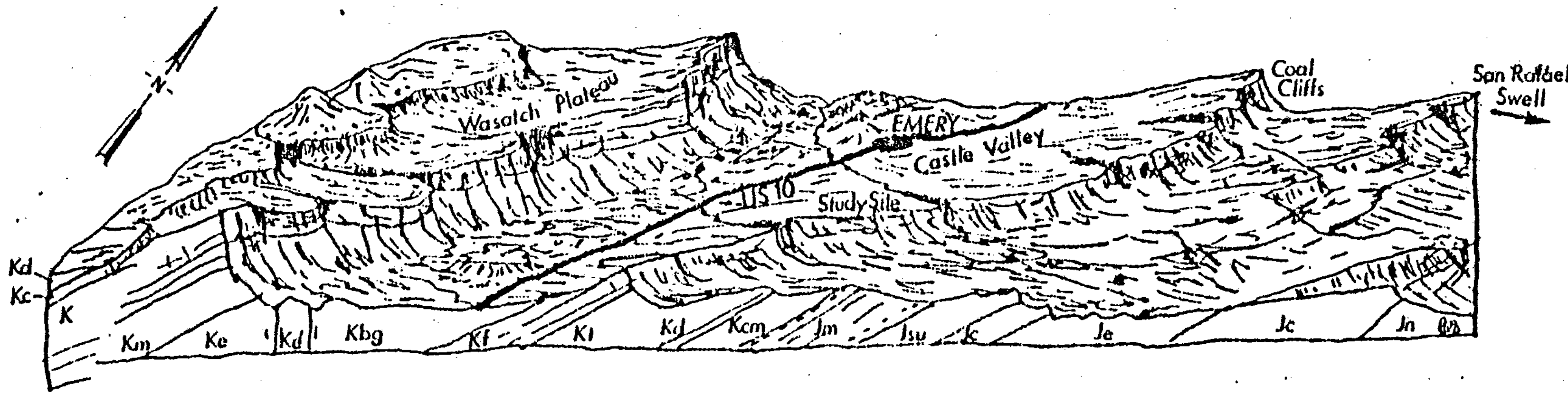


Figure 1. Location map of the Emery Mine area, Emery County, Utah. (Source: Owili-Eger, 1979)



K - Cretaceous (undifferentiated

Kc - Castlegate Sandstone

Km - Masuk Shale (member of Mancos Shale)

Ke - Emery Sandstone (member of Mancos Shale)

Kbg - Blue Gate Shale (member of Mancos Shale)

Kf - Ferron Sandstone (member of Mancos Shale)

Kt - Tununk Shale (member of Mancos Shale)

Kd - Dakota Sandstone

Kcm - Cedar Mountain Formation

Jm - Morrison (?) Formation

Jsu - Summerville Formation

Jc - Curtis Formation

Je - Entrada Formation

Jn - Navajo Sandstone

Figure 2. East-west cross section and physiographic diagram of Emery coal field and surrounding area. (Source: BLM, 1979)

a major anticlinal uplift. Its structural configuration appears as a large kidney-shaped dome marked by concentric rings of cliffs and lowlands.

As shown in Figure 3, the main drainage in the area is the 3rd order Muddy Creek, flowing southeastward along the eastern escarpment of the Wasatch Plateau. Ivie Creek, a 2nd order tributary, flows eastward into Muddy Creek on the south; 2nd order Quitchupah Creek flows southward into Ivie Creek on the west; and 1st order Christiansen Wash flows into Quitchupah Creek at the site of the Emery Mine. All of these streams are perennial being sustained at least in part by irrigation return flows. However, each of these streams has been known to go dry on occasion during the summer. All the 1st order tributaries (except Christiansen Wash) are intermittent, draining the upland west and east into Quitchupah and Muddy Creek drainages. On the upland, the tributaries are incised slightly and drop 200 to 300 feet per mile and range from 800 to 1100 feet per mile across the escarpment. The lowland Quitchupah and Muddy Creeks are deeply incised and grade only 30 feet per mile.

4.0 CLIMATE

At higher elevations (over 11,000 feet) of the Wasatch Plateau, annual precipitation averages more than 30 inches, largely as winter snows which provide most of the streamflow and ground water in the Emery area. This precipitation depletes

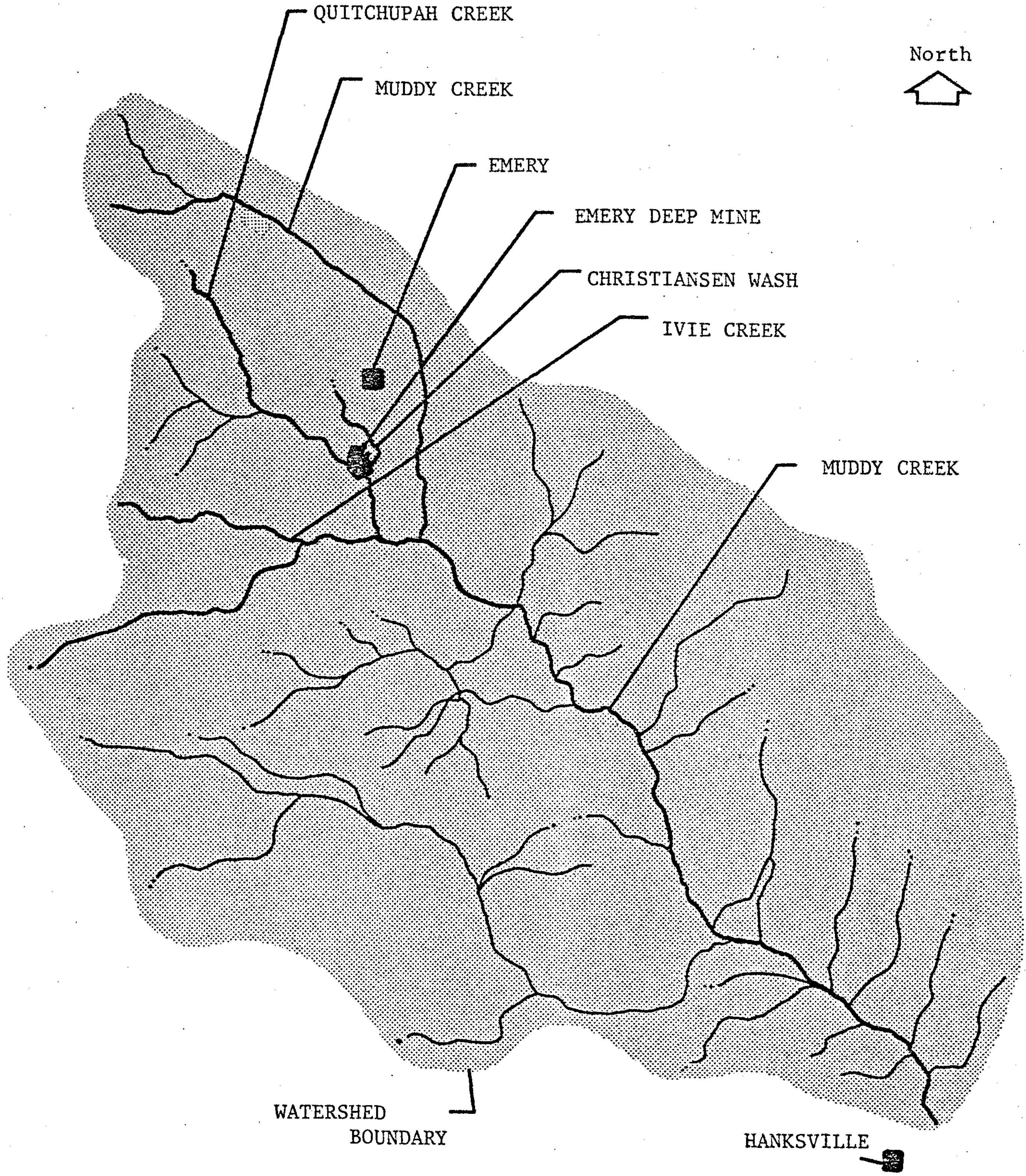


Figure 3. Muddy Creek Watershed (Source: Consol, 1976)

the moisture from the winter-time westerly flow. The general downslope motion of this flow across Castle Valley makes winters rather dry with about 3 inches of winter precipitation.

In contrast, during summer moist air occasionally penetrates northward from the Gulf of Mexico. As this flow rises northwestward from the Colorado River, convective showers and rare thunderstorms are formed, bringing most of the regions precipitation. But the stronger sunshine and warmer temperatures, although only around 70°F, increase evaporation and transpiration so that most of the summer rain evaporates quickly.

Average annual precipitation around Emery is less than 10 inches, with extensive areas receiving less than 8 inches and some less than 6 inches (see Figure 4). The town of Emery at 6,200 feet elevation receives 7.64 inches annually on the average (see Figure 5). Average temperatures experienced at Emery during the 30-year period, 1941-1970, are also shown on Figure 5. The annual maximum, mean, and minimum temperatures for the area are 60.4, 45.8, and 31.3°F, respectively (Richardson, 1975).

5.0 GEOLOGY

5.1 Regional Geologic Setting

The sedimentary strata which underlie the region within which the Emery Mine is located belong to the Mancos Shale of Upper Cretaceous age. These geologic units generally dip to

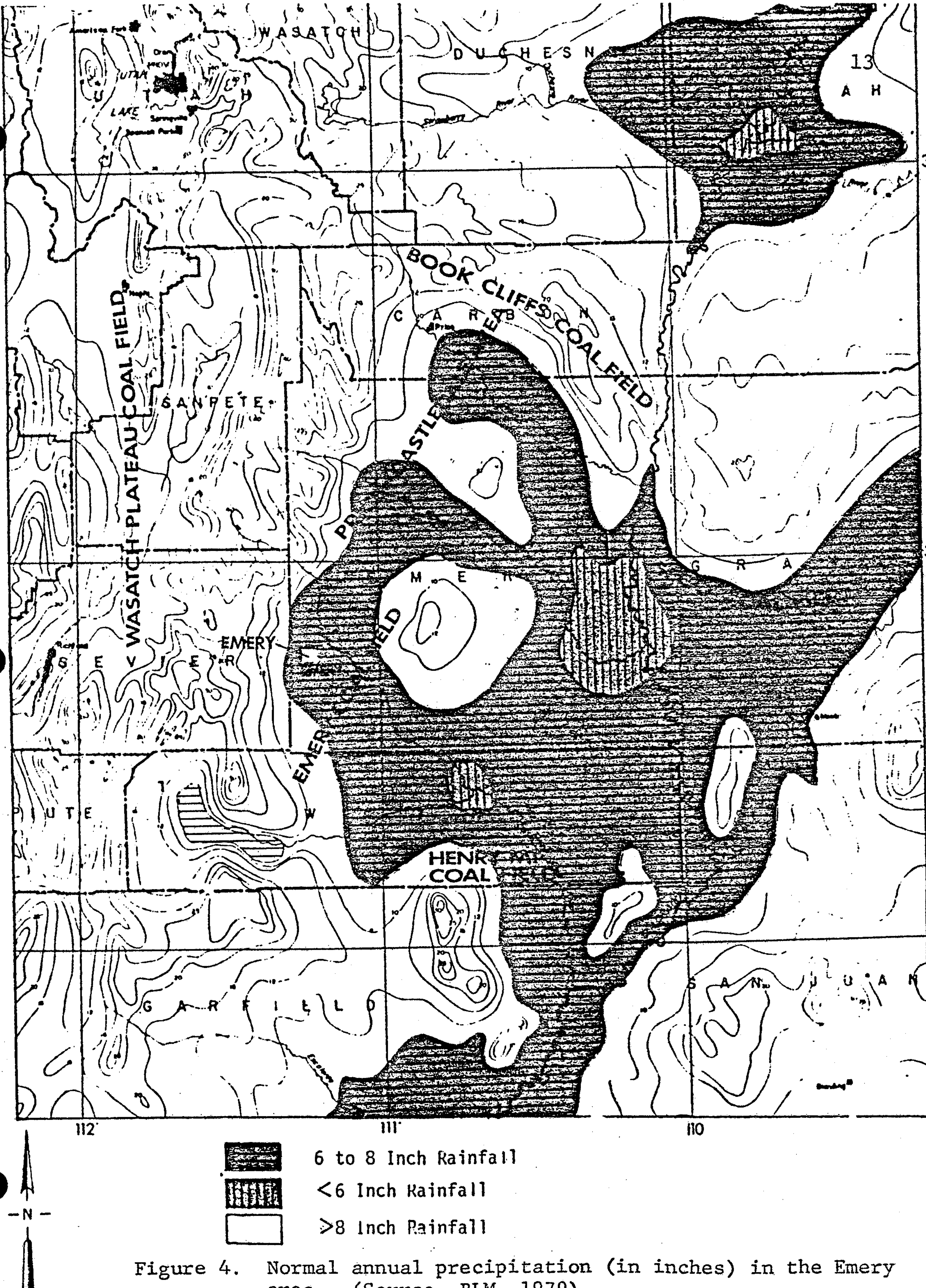


Figure 4. Normal annual precipitation (in inches) in the Emery area. (Source: BLM, 1979)

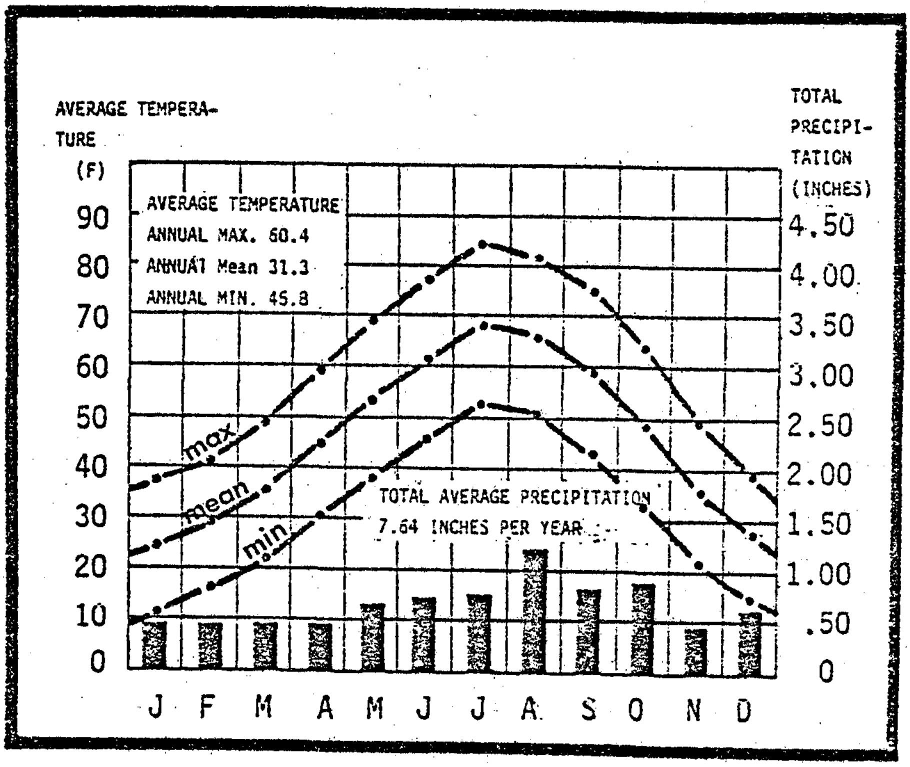


Figure 5. Emery climatological summary (monthly averages 1941-1970). (Source: BLM, 1979)

the northwest and form an extension of the older rocks which make up the plateaus and canyonlands of central Utah. West of Emery, the steep eastward facing cliffs of the overlying westerly dipping Upper Cretaceous and Lower Tertiary Sedimentary rocks mark the eastern edge of the Wasatch Plateau. East of the region, the underlying Cretaceous and Jurassic sediments of the anticlinal San Rafael Swell dip westward beneath the region and form the lowlands and lower benches to the east. The region has been described by Lupton (1916), Spieker (1925), and Doelling (1972).

5.2 Site Geology

Rocks of Quaternary and Cretaceous age are prevalent in the Emery Mine area (see Figure 6). Quaternary deposits include Pleistocene pediments and Holocene alluvial fill and terrace deposits which are generally less than 50 feet thick.

Underlying this thin veneer of Quaternary deposits is a thick sequence of Upper Cretaceous Mancos Shale marine deposits. In order of deposition, the Mancos Shale is comprised of the Tununk Shale, the Ferron Sandstone, the Bluegate Shale and the Emery Sandstone members.

The Tununk Shale, designated by the geologic symbol, Kmt, is a 400- to 600-foot thick, non-resistant, blue-gray to black shale and forms a lower confining layer for the Ferron Sandstone ground water system. The Tununk Shale is not exposed within the area defined by the geologic map, Figure 6.

Explanation

Qal: Alluvium
Qt : Terrace Deposits
Kme : Emery Sandstone
Kmbg : Blue Gate Shale
Kmf : Ferron Sandstone

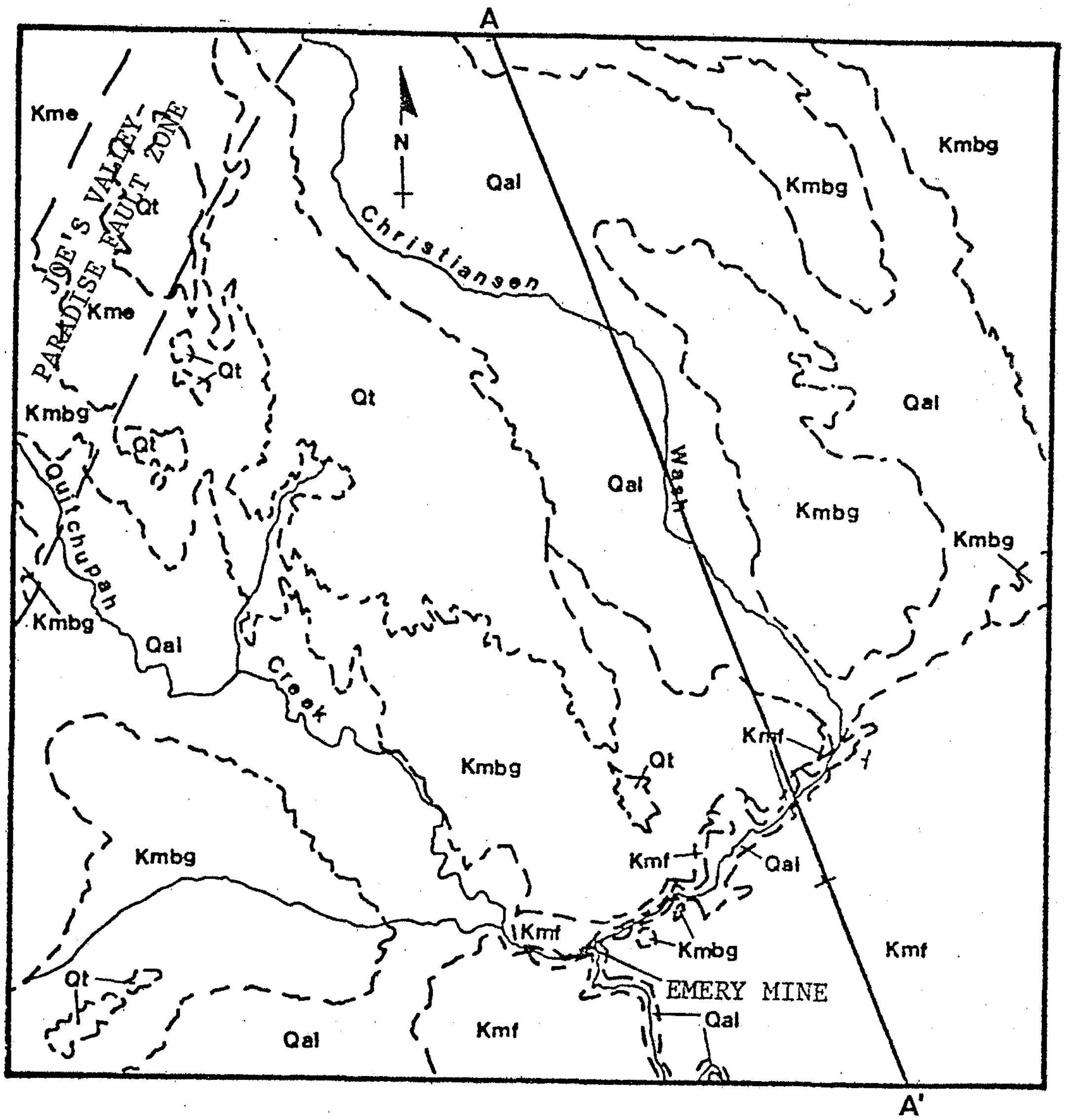


Figure 6. Geologic map of the Emery Mine area, Emery County, Utah. (Source: Owili-Eger, 1979)

The Ferron Sandstone, designated by the geologic symbol, Kmf, is a cliff-forming member of the Mancos Shale and is approximately 400 feet thick in the Emery Mine area. Because of different depositional histories, the Ferron Sandstone is divided into two units. The lower unit, designated by the symbol, Kmf (ℓ), is a light gray, fine-grained calcareous, cross-bedded marine sandstone with siltstone and carbonaceous interbeds. The upper unit is yellow-gray and brown, and locally weathers to a rust color. Unlike the sheet-like lower unit, the upper unit occurs as lenses and pods of medium-grained sandstones and siltstones separated by interbeds of carbonaceous shale, mudstone, and/or coal. These sediments probably originated in floodplain and swamp environments. Within the upper unit of the Feron Sandstone, there are 13 coal beds, the two most important being the A and the IJ coal seams. It is the IJ coal which is presently being mined at the Emery Mine. For the purpose of this report, that portion of the upper unit of the Ferron Sandstone stratigraphically lying between the base of the A coal and the base of the IJ coal is called the middle Ferron Sandstone and is designated by the symbol, Kmf(m). Similarly, the strata lying between the base of the IJ and the top of the Ferron Sandstone is called the upper Ferron Sandstone and is designated by Kmf(u) (see Figure 7).

The Bluegate Shale, designated by the geologic symbol, Kmbg, is a bluish-gray, marine mudstone and siltstone with a

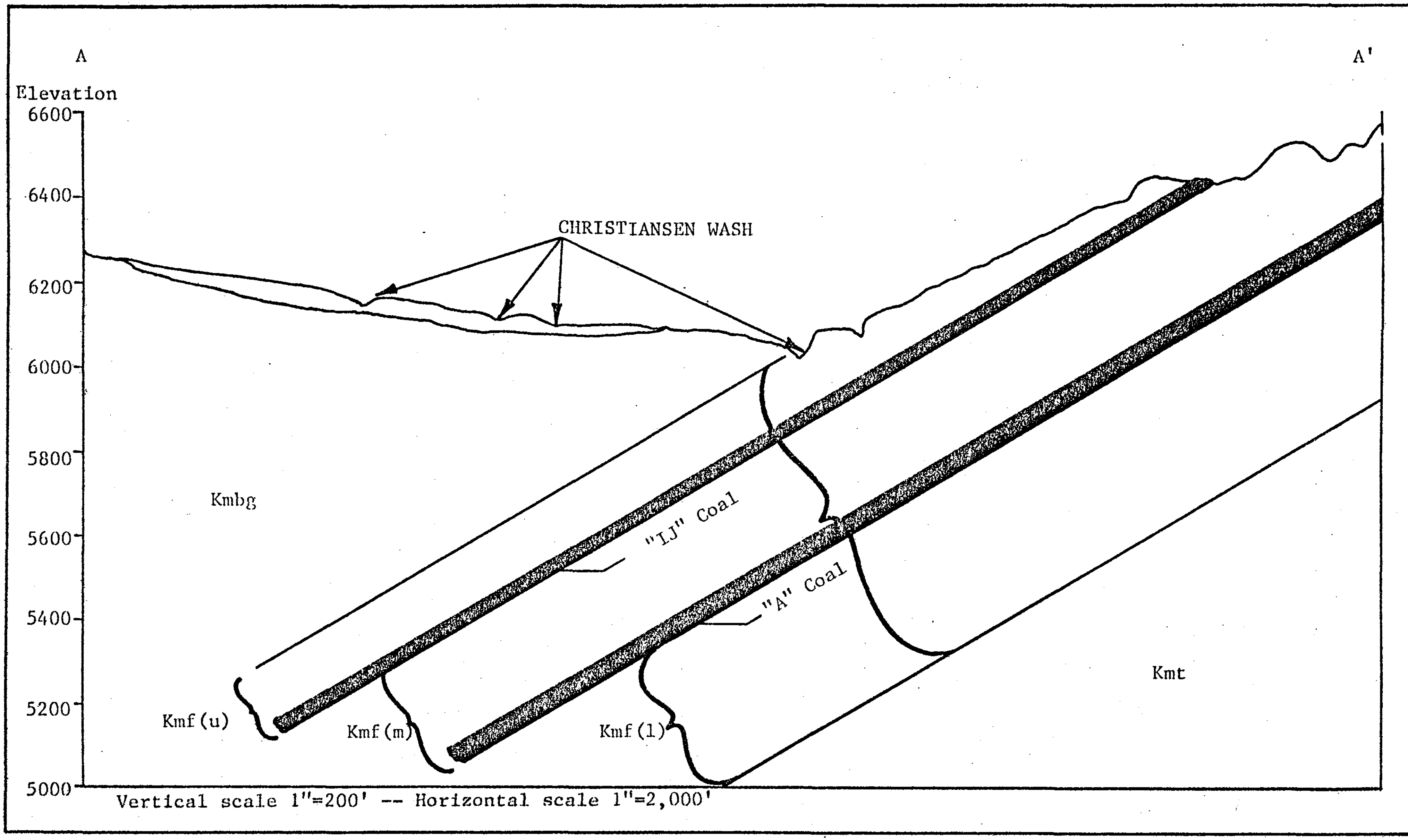


Figure 7. Geologic cross-section (diagrammatic) through A-A'. (Source: After Kaufman, 1976)

few thin sandstone beds. It is generally quite saline with gypsum ($CaSO_4 \cdot 2H_2O$) crystals clearly visible in hand samples. Locally, it has been either stripped completely by erosion exposing the underlying Ferron Sandstone, or it has minimal to moderate thickness. The Bluegate Shale is distinguished in the field by its irregular "badland" topography and general lack of vegetative cover (Stokes and Cohenour, 1956).

The Emery Sandstone, designated by the symbol, Kme, is about 800 feet thick and forms prominent cliffs at the base of the eastern edge of the Wasatch Plateau. This sandstone, yellow-gray in color and friable, appears to be lenticular and contains thin coal beds in some locations (Consol, 1978).

The Mancos Shale is underlain by the Cretaceous Dakota Sandstone and Cedar Mountain Formations. Due to their physical distance from the Emery Mine workings, the hydrogeologic barrier formed by the Tununk Shale and subsequent lack of hydraulic communication with the Ferron Sandstone, these formations are considered too isolated to be affected by the Emery Mine operations and will not be discussed here.

Geologic structure in the vicinity of the Emery Mine is generally typified by the above-described Cretaceous formations which dip approximately 5 degrees to the west and the northwest due to the regional influence of the San Rafael Swell. The major structural feature of the area is the Joe's Valley-Paradise fault zone (see Figure 6) located mostly in Emery County. This fault zone is about two miles wide and extends approximately 75 miles. Vertical displacements along the fault zone are from 1500 to 3000 feet. In the vicinity of the Emery Mine, there is also a prominent vertical and conjugate linear joint system which is easily seen in outcrops of the Ferron Sandstone. East of Quitchupah Creek and near Christiansen Wash occurs a major set of vertical and conjugate joints which are arrayed along ENE-NNW trends. These joints may reflect burn zones, faulting, fracturing, or secondary jointing (Stokes and Cohenour, 1956; Foreman and Raney, 1975). The general trends of Quitchupah Creek and Christiansen Wash seem to indicate that they are following this joint pattern. In any case, because this joint pattern is oriented roughly parallel and perpendicular to the Joe's Valley-Paradise fault zone, it is likely that the joint pattern is part of a regional structural grain.

6.0 SURFACE WATER RESOURCES

6.1 Regional Surface Water Characteristics

The Emery Mine, located approximately 4 miles due south of the town of Emery, is situated at the confluence of Quitchupah Creek and its only major tributary, Christiansen Wash. As indicated on Figure 3, Quitchupah Creek is a tributary to Ivie Creek which in turn is tributary to Muddy Creek. Muddy Creek empties into the Dirty Devil River above Hanksville, Utah; the Dirty Devil River is a major tributary to the Upper Colorado River. The major watershed areas are summarized on the following page in Table 1.

TABLE 1

WATERSHED AREAS AND ELEVATIONS
(Source: VTN, 1974)

Watershed	Area (mi^2)	Elevations (ft)	
		Maximum	Minimum
Dirty Devil River Basin	4400	11,600	4432
Muddy Creek Watershed	1450	11,133	4500
Quitchupah Creek Watershed	430	11,133	5760

Since 1949, the USGS and Consol have gathered a plethora of water quality and streamflow data for the Emery area. During the past 30 years, the USGS has maintained two stream gaging stations on Muddy Creek, one about four miles north of Emery (site S-1 on Plate 1) and the other about 13 miles south-southeast of Emery (site S-41 not shown on Plate 1). The data gathered from these stations including other instantaneous measurements of flow from other streams in the region are summarized on the following page in Table 2.

From the data presented in Table 2 and Figure 8, a few conclusions may be drawn on the regional surface water flow characteristics. First, a rapid rise in the stream hydrograph for Muddy Creek occurs during March, April, and May. Peak flows occur during May while a comparatively slow fall in the hydrograph is evident throughout the summer months. Second, as indicated from a comparison of flow measurements at up- and

TABLE 2

INSTANTANEOUS STREAM DISCHARGE MEASUREMENTS CONDUCTED BY THE USGS IN THE EMERY AREA[1]

Stream	Site No.	Period of Record	No. of Measurements	Mean Discharge (cfs)	Maximum (cfs)	Minimum (cfs)
Muddy Creek	S-1	1949 - 1978	-	38.0[2]	3340[2]	2.7
Muddy Creek	S-2	7/75 - 8/76	6	0.40	1.0	0.0
Muddy Creek	S-4	7/75 - 8/76	5	2.8	6.0	0.0
Muddy Creek	S-6	8/73 - 9/78	87	65.86	4500.0	0.01
Muddy Creek	S-41	1950 - 1961	-	15.4[2]	-	-
Miller Canyon	S-3	7/75 - 8/76	5	0.28	1.0	0.0
Ivie Creek	S-30	7/75 - 8/76	6	0.94	2.5	0.0
Ivie Creek	S-31	7/75 - 9/76	7	4.21	13.0	0.1
Quitchupah Creek	S-18	7/75 - 9/76	7	0.85	2.0	0.01
Quitchupah Creek	S-29	9/75 - 9/76	5	5.02	12.0	0.50
Christiansen Wash	S-8	7/75 - 9/76	7	0.68	3.5	0.01
Christiansen Wash	S-17	7/75 - 8/76	6	2.5	5.0	0.5

[1]Data obtained through EPA STORET Computer System, 1979.

[2]Data from VTN, 1974.

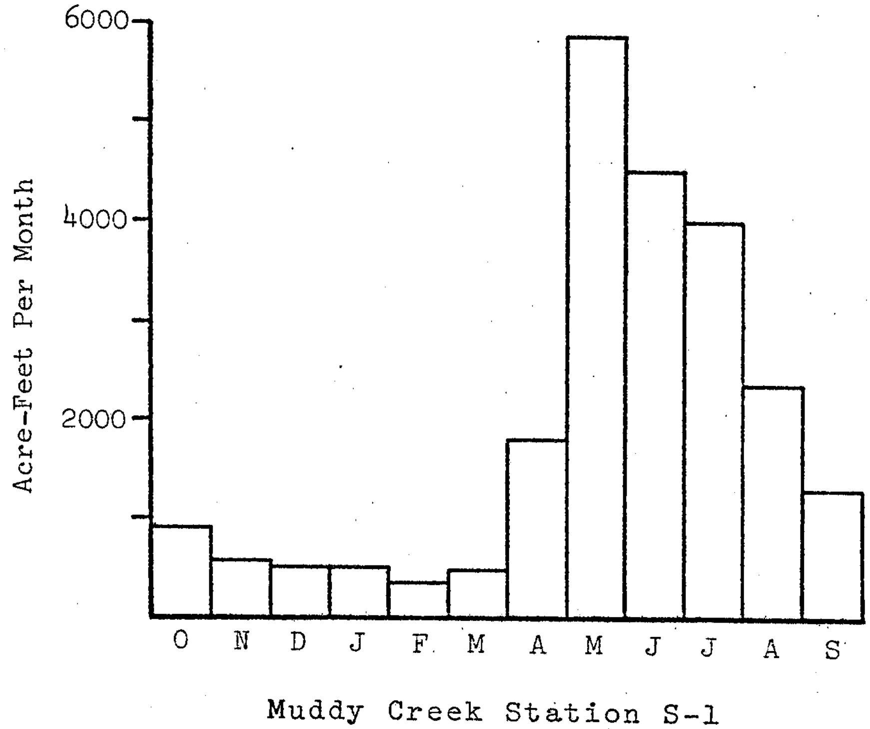


Figure 8. Monthly average flows on Muddy Creek, 1949-1970. (See Plate 1 for site S-1 location.)

downstream gaging stations, Muddy Creek loses approximately 60 percent of its flow between sites S-1 and S-41. This dramatic diminution in flow is primarily due to irrigation diversions and less importantly to surface water inflow to bedrock and evapotranspiration. Third, Muddy Creek can experience sizeable flood flows. As indicated from the flow records for site S-6, a flood flow of 4500 cubic feet per second (cfs) has been recorded. No measured flood flow data exist on the other streams in the area.

A considerable amount of water quality data has been gathered by various governmental agencies in the Emery Mine area. Regionally, over 300 samples have been taken for chemical analysis between 1971 and 1979. Tables 3 through 8 present statistical information on Muddy Creek water quality for sampling locations S-1 through S-6. The samples were analyzed by the USGS and the statistical information was obtained through the STORET data retrieval computer system (EPA, 1979). The arithmetic means of the chemical parameters indicate that Muddy Creek is generally good water excepting a high mean pH of 9.2. At S-1, calcium (Ca) and magnesium (Mg) are the dominant cations, bicarbonate (HCO_3) is the dominant anion and mean total dissolved solids (TDS) is 212.6 milligrams per liter (mg/ℓ). The sodium adsorption ratio (SAR) of 0.23 and a mean lab specific conductivity of 417 μmhos/cm at 25°C classify this water as medium-salinity, low sodium water (see Figure 9) suitable for irrigation of plants with moderate salt

TABLE 3

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-1

Sample Site: S-1
Location: USGS Gaging Station: Muddy Creek No. 1 (D-21-6) 21 ABA
Dates of Collection: 8/4/71 through 9/12/78
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	7	193.3	17.7	221.0	176.0
Hardness (noncarbonate)	7	13.6	5.4	21.0	4.0
Hardness, total	7	208.6	14.6	230.0	200.0
Iron, total (Fe)	18	0.28	0.32	1.0	0.02
Iron, diss. (Fe)	4	0.02	0.06	0.03	0.02
Manganese, total (Mn)	20	0.05	0.08	0.25	0.01
Oil and grease	3	1.6	.66	2.3	1.0
Oxygen, diss. (DO)	34	10.5	2.5	16.0	6.0
pH, lab (units)	33	9.2	.28	9.7	8.8
Sp. conductance, lab (µmhos/cm at 25°C)	87	416.65	53.6	620.0	286.0
Discharge (cfs)	89	33.05	42.9	201.0	2.7
Temperature (°C)	88	7.1	6.5	23.0	0.0
Total dissolved solids (TDS)	7	212.6	25.1	250.0	175.0
Total suspended solids (TSS)	18	13.8	20.9	68.0	.39
CATIONS					
Calcium (Ca)	7	42.6	3.6	48.0	39.0
Magnesium (Mg)	7	24.3	1.3	26.0	23.0
Potassium (K)	7	0.64	.08	0.8	.60
Sodium (Na)	7	6.9	2.1	10.0	5.0
Sodium adsorption ratio (SAR)	7	0.23	.05	0.3	0.2
ANIONS					
Bicarbonate (HCO_3)	7	228.8	12.7	251.0	214.0
Carbonate (CO_3)	7	3.3	5.2	14.0	0.0
Chloride (Cl)	6	2.8	0.7	3.5	1.8
Fluoride (F)	7	0.2	0.1	0.3	0.03
Sulfate (SO_4)	7	15.4	2.9	21.0	12.0
MACRONUTRIENTS					
Ammonia (NH_4)	4	0.03	.03	0.06	0.0
Nitrogen, total KJD as N	4	0.50	0.74	1.6	0.12
Nitrate + Nitrite as N	9	0.45	0.10	0.61	0.27
Phosphorus, total as P	4	0.05	0.10	0.2	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (µg/ℓ, Al)	4	17.5	9.6	30.0	10.0
Arsenic (µg/ℓ,As)	4	1.25	0.5	2.0	1.0
Boron (µg/ℓ,B)	7	16.3	12.0	30.0	0.0
Carbon, diss. organic	2	2.2	0.14	2.3	2.1
Chromium (µg/ℓ,Cr)	2	2.5	3.5	5.0	0.0
Lead (µg/ℓ,Pb)	5	4.4	4.0	11.0	1.0
Lithium (µg/ℓ,Li)	5	20.0	0.01	20.0	20.0
Phenols (µg/ℓ)	3	0.67	1.15	2.0	0.0
Selenium (µg/ℓ,Se)	4	0.25	0.50	1.0	0.0
Silica, diss. (SiO_2)	7	4.9	0.52	5.5	4.2
Strontium (µg/ℓ,Sr)	4	432.5	22.2	460.0	410.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.
2) Total Suspended Solids are given in Jackson Turbidity Units.

TABLE 4

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-2

Sample Site: S-2
Location: Muddy Creek at Highway 10 (D-21-6) 36 BBB
Dates of Collection: 7/23/75 through 5/31/76
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	5	246.0	27.1	287.0	221.0
Hardness (noncarbonate)	5	694.0	196.8	1000.0	500.0
Hardness, total	5	964.0	230.1	1300.0	750.0
Iron, diss. (Fe)	2	0.09	0.02	0.1	0.07
Manganese, total (Mn)	2	0.03	0.03	0.05	0.01
pH, lab (units)	5	7.9	0.2	8.2	7.7
Sp. conductance, lab (μmhos/cm at 25°C)	5	2132.0	465.3	2860.0	1720.0
Discharge (cfs)	6	0.4	0.4	1.0	0.0
Temperature (°C)	5	17.7	10.7	28.0	3.0
Total dissolved solids (TDS)	5	1638.0	380.7	2230.0	1230.0
CATIONS					
Calcium (Ca)	5	204.0	48.3	270.0	160.0
Magnesium (Mg)	5	105.8	21.2	140.0	85.0
Potassium (K)	5	4.5	1.2	6.2	3.5
Sodium (Na)	5	172.0	44.4	240.0	120.0
Sodium adsorption ratio (SAR)	5	2.4	0.4	3.0	1.9
ANIONS					
Bicarbonate (HCO_3)	5	300.0	32.9	350.0	270.0
Carbonate (CO_3)	5	0.0	0.0	0.0	0.0
Chloride (Cl)	5	22.0	4.6	29.0	17.0
Fluoride (F)	5	0.3	0.04	0.4	0.3
Sulfate (SO_4)	5	972.0	266.8	1400.0	690.0
MACRONUTRIENTS					
Nitrate + Nitrite as N	5	0.03	0.03	0.08	0.01
Phosphorus, total as P	5	0.02	0.02	0.03	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (μg/ℓ,Al)	1	20.0			
Arsenic (μg/ℓ,As)	1	0.0			
Boron (μg/ℓ,B)	5	192.0	59.3	290.0	130.0
Lead (μg/ℓ,Pb)	1	10.0			
Lithium (μg/ℓ,Li)	1	110.0			
Selenium (μg/ℓ,Se)	2	0.0	0.0	0.0	0.0
Silica, diss. (SiO_2)	5	8.5	1.2	10.0	6.8
Strontium (μg/ℓ,Sr)	2	2450.0	495.0	2800.0	2100.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 5

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-3

Sample Site: S-3
Location: Miller Canyon at Mouth (D-22-6) 26 DDD
Date of Collection: 7/23/75 through 8/11/75
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	4	171.0	22.1	199.0	147.0
Hardness (noncarbonate)	4	1450.0	591.6	1900.0	600.0
Hardness, total	4	1650.0	591.6	2100.0	800.0
Iron, diss. (Fe)	2	0.03	0.04	0.06	0.0
Manganese, total (Mn)	2	0.45	0.44	0.76	0.14
pH, lab (units)	4	8.02	0.10	8.1	7.9
Sp. conductance, lab (μmhos/cm at 25°C)	4	2795.0	839.6	3470.0	1610.0
Discharge (cfs)	5	0.28	0.42	1.0	0.0
Temperature (°C)	4	15.8	10.3	21.5	0.0
Total dissolved solids (TDS)	4	2407.5	813.4	2990.0	1250.0
CATIONS					
Magnesium (Mg)	4	385.0	142.0	490.0	180.0
Potassium (K)	4	161.0	54.7	200.0	84.0
Sodium (Na)	4	129.7	37.9	170.0	79.0
Sodium adsorption ratio (SAR)	4	1.4	0.22	1.7	1.2
ANIONS					
Bicarbonate (HCO_3)	4	208.8	27.2	243.0	179.0
Carbonate (CO_3)	4	0.0	0.0	0.0	0.0
Chloride (Cl)	4	23.0	5.5	29.0	16.0
Fluoride (F)	4	0.40	0.0	0.40	0.40
Sulfate (SO_4)	4	1590.0	584.6	2000.0	760.0
MACRONUTRIENTS					
Nitrate + Nitrite as N	4	0.5	0.68	1.5	0.03
Phosphorus, total as P	3	0.0	0.0	0.0	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (μg/ℓ,Al)	1	160.0			
Arsenic (μg/ℓ,As)	1	0.0			
Boron (μg/ℓ,B)	4	665.0	217.5	840.0	360.0
Lead (μg/ℓ,Pb)	1	1.0			
Lithium (μg/ℓ,Li)	1	160.0			
Selenium (μg/ℓ,Se)	3	2.0	1.0	3.0	1.0
Silica, diss. (SiO_2)	4	5.9	1.7	6.9	3.3
Strontium (μg/ℓ,Sr)	2	2850.0	212.1	3000.0	2700.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 6

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER SAMPLED IN THE EMERY MINE AREA, SITE S-4

Sample Site:	S-4
Location:	Muddy Creek Below Miller Canyon (D-22-6) 25 CCC
Dates of Collection:	7/23/75 through 8/11/76
Source of Data:	USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	4	298.7	45.9	346.0	239.0
Hardness (noncarbonate)	4	857.5	570.3	1400.0	350.0
Hardness, total	4	1135.0	543.1	1700.0	670.0
Iron, diss. (Fe)	2	0.04	0.06	80.0	0.0
Manganese, total (Mn)	2	0.09	0.08	0.15	0.03
pH, lab (units)	4	8.22	0.22	8.50	8.00
Sp. conductance, lab (µmhos/cm at 25°C)	4	3355.0	1378.4	5190.0	2250.0
Discharge (cfs)	5	2.8	2.6	6.0	0.0
Temperature (°C)	4	16.3	10.9	25.0	1.0
Total dissolved solids (TDS)	4	2685.0	1280.6	4390.0	1670.0
CATIONS					
Calcium (Ca)	4	217.5	118.4	320.0	110.0
Magnesium (Mg)	4	143.5	62.9	220.0	89.0
Potassium (K)	4	8.3	0.5	8.8	7.8
Sodium (Na)	4	427.5	210.0	740.0	300.0
Sodium adsorption ratio (SAR)	4	5.5	1.6	7.8	4.0
ANIONS					
Bicarbonate (HCO_3)	4	360.0	57.6	422.0	291.0
Carbonate (CO_3)	4	1.7	3.5	7.0	0.0
Chloride (Cl)	4	42.7	16.5	67.0	30.0
Fluoride (F)	4	0.4	0.0	0.4	0.4
Sulfate (SO_4)	4	1652.5	885.3	2800.0	940.0
MACRONUTRIENTS					
Nitrate + Nitrite as N	4	0.94	1.65	3.40	0.01
Phosphorus, total as P	4	0.02	0.03	0.06	0.00
TRACE AND OTHER ELEMENTS					
Aluminum (µg/ℓ,Al)	1	170.0			
Arsenic (µg/ℓ,As)	1	1.0			
Boron (µg/ℓ,B)	4	377.5	170.0	570.0	220.0
Lead (µg/ℓ,Pb)	1	2.0			
Lithium (µg/ℓ,Li)	1	350.0			
Selenium (µg/ℓ,Se)	3	5.0	5.2	11.0	2.0
Silica, diss. (SiO_2)	4	7.1	1.9	9.2	4.7
Strontium (µg/ℓ,Sr)	2	3050.0	353.6	3300.0	2800.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 7

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER SAMPLED IN THE EMERY MINE AREA, SITE S-5

Sample Site: S-5
Location: Muddy Creek Above Ivie Creek (D-23-6) 13 (BAC)
Dates of Collection: 7/31/75 through 7/9/76
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	21	272.6	47.5	353.0	164.0
Hardness (noncarbonate)	21	908.1	483.L	1600.0	280.0
Hardness, total	21	1190.0	508.3	2000.0	480.0
Iron, diss. (Fe)	1	0.02			
Manganese, total (Mn)	1	0.06			
Oil and grease	1	34.0			
Oxygen, diss. (DO)	3	8.6	2.1	10.8	6.6
pH, lab (units)	23	8.0	0.2	8.5	7.7
Sp. conductance, lab (μmhos/cm at 25°C)	23	3584.3	1563.4	6190.0	1330.0
Discharge (cfs)	3	7.4	6.8	14.0	0.34
Temperature (°C)	23	8.2	8.6	26.0	0.5
Total dissolved solids (TDS)	20	3065.2	1524.1	5590.0	974.0
CATIONS					
Calcium (Ca)	21	205.1	87.2	350.0	73.0
Magnesium (Mg)	21	164.4	72.0	270.0	59.0
Potassium (K)	21	7.7	3.5	12.0	2.3
Sodium (Na)	21	544.8	288.0	1100.0	140.0
Sodium adsorption ratio (SAR)	21	6.6	2.6	11.0	2.4
ANIONS					
Bicarbonate (HCO_3)	21	330.7	58.3	430.0	200.0
Carbonate (CO_3)	21	0.8	3.7	17.0	0.0
Chloride (Cl)	20	57.8	34.8	140.0	12.0
Fluoride (F)	1	0.6			
Sulfate (SO_4)	21	1975.2	1018.0	3600.0	550.0
MACRONUTRIENTS					
Ammonia (NH_4)	3	0.09	0.01	0.1	0.08
Nitrogen, total KJD as N	3	1.08	0.72	1.8	0.35
Nitrate + Nitrite as N	3	3.3	1.3	4.8	2.3
Phosphorus, total as P	3	0.6	0.88	1.6	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (μg/ℓ,Al)	1	250.0			
Arsenic (μg/ℓ,As)	1	1.0			
Boron (μg/ℓ,B)	1	530.0			
Carbon, diss. organic	2	5.5	2.5	7.3	3.7
Chromium (μg/ℓ,Cr)	1	0.0			
Lead (μg/ℓ,Pb)	1	2.0			
Lithium (μg/ℓ,Li)	1	310.0			
Phenols (μg/ℓ)	3	4.0	2.0	6.0	2.0
Selenium (μg/ℓ,Se)	1	11.0			
Silica, diss. (SiO_2)	1	9.5			
Strontium (μg/ℓ,Sr)	1	3900.0			

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 8

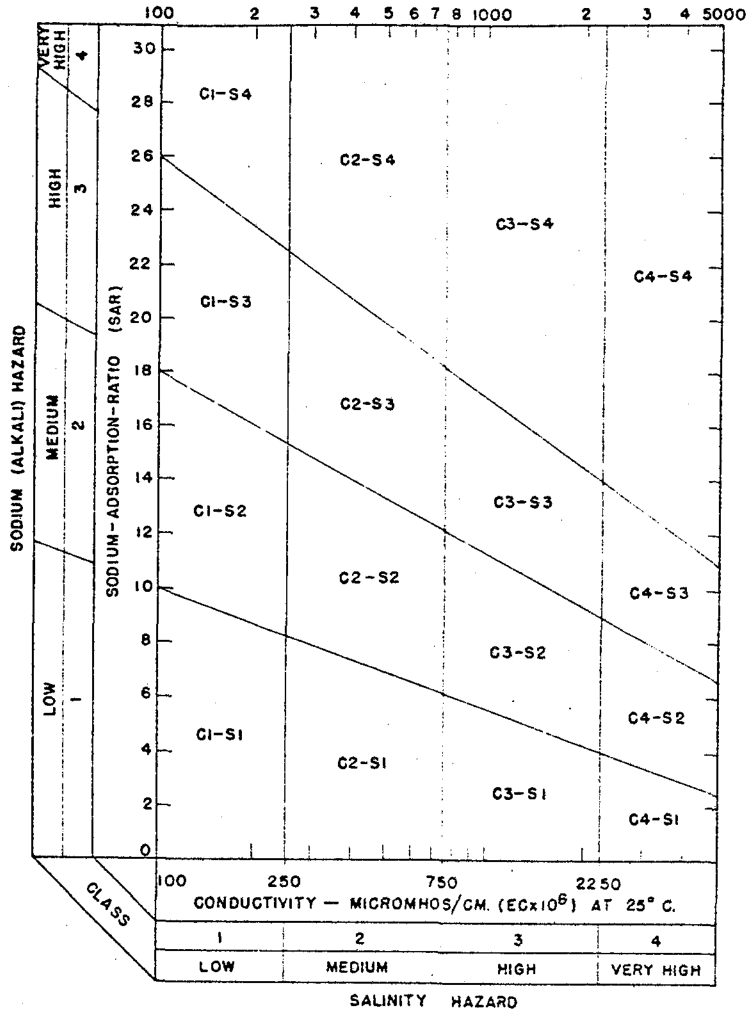
RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER SAMPLED IN THE EMERY MINE AREA, SITE S-6

Sample Site: S-6
Location: Muddy Creek Below I-70 (D-23-6) 13 DCA
Dates of Collection: 8/5/73 through 9/14/78
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	122	252.2	47.4	418.0	139.0
Hardness (noncarbonate)	122	731.0	408.8	3200.0	120.0
Hardness, total	122	987.8	433.0	3700.0	270.0
Iron, diss. (Fe)	8	68.7	49.1	130.0	10.0
Manganese, total (Mn)	7	37.1	23.6	70.0	10.0
Oil and grease	2	1.5	2.1	3.0	0.0
Oxygen, diss. (DO)	4	8.0	2.2	11.2	6.1
pH, lab (units)	123	8.0	0.2	8.5	7.6
Sp. conductance, lab (μmhos/cm at 25°C)	195	2996.5	1124.3	6700.0	691.0
Discharge (cfs)	87	65.9	481.5	4500.0	0.01
Temperature (°C)	190	9.4	8.9	33.0	0.0
Total dissolved solids (TDS)	120	2305.6	926.5	6310.0	431.1
CATIONS					
Calcium (Ca)	122	157.4	53.5	440.0	62.0
Magnesium (Mg)	122	143.0	75.2	620.0	0.0
Potassium (K)	122	7.5	3.0	20.0	2.7
Sodium (Na)	122	385.3	162.2	940.0	41.0
Sodium adsorption ratio (SAR)	122	5.3	1.6	12.0	1.1
ANIONS					
Bicarbonate (HCO_3)	122	306.7	57.9	510.0	170.0
Carbonate (CO_3)	122	0.4	2.8	25.0	0.0
Chloride (Cl)	120	77.9	56.1	350.0	8.5
Fluoride (F)	14	0.5	0.09	0.6	0.3
Sulfate (SO_4)	122	1407.9	634.9	3400.0	200.0
MACRONUTRIENTS					
Ammonia (NH_4)	4	0.02	0.02	0.05	0.0
Nitrogen, total KJD as N	4	0.70	0.14	0.88	0.54
Nitrate + Nitrite as N	16	3.1	1.77	6.5	0.93
Phosphorus, total as P	4	0.52	0.93	1.9	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (μg/ℓ,Al)	6	80.0	86.7	250.0	20.0
Arsenic (μg/ℓ,As)	6	1.2	0.75	2.0	0.0
Boron (μg/ℓ,B)	15	377.0	158.0	620.0	160.0
Carbon, diss. organic	3	9.0	5.5	15.0	4.3
Chromium (μg/ℓ,Cr)	3	23.3	32.1	60.0	0.0
Lead (μg/ℓ,Pb)	7	13.0	20.8	60.0	2.0
Lithium (μg/ℓ,Li)	7	282.8	95.5	440.0	180.0
Phenols (μg/ℓ)	4	1.5	1.7	4.0	0.0
Selenium (μg/ℓ,Se)	8	10.1	3.4	16.0	7.0
Silica, diss. (SiO_2)	14	9.4	1.7	12.0	6.0
Strontium (μg/ℓ,Sr)	8	2862.5	870.0	4100.0	1900.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.



CONDUCTIVITY

C1 Low-salinity water: Can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop.

C2 Medium-salinity water: Can be used if a moderate amount of leaching occurs.

C3 High-salinity water: Cannot be used on soils with restricted drainage. With adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

C4 Very high salinity water: Is not suitable for irrigation under ordinary conditions.

SODIUM

S1 Low-sodium water: Can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

S2 Medium-sodium water: Will present an appreciable sodium hazard in fine-textured soils having a high cation-exchange capacity, especially under low-leaching conditions.

S3 High-sodium water: May produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions.

S4 Very high sodium water: Is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity.

Figure 9. SAR--conductivity classification of irrigation water. (Source: USDA, Diagnosis and Improvement of Saline and Alkali Soils)

tolerance. Downstream of site S-6 before its confluence with Ivie Creek, Muddy Creek's water is noticeably more saline with a mean TDS of 2685. The mean pH has lowered to 8.2 while Na has become the dominant cation and sulfate (SO_4) the dominant anion. The mean lab conductivity of 3355 μmhos/cm at 25°C and a SAR of 5.5 classify the water as very high salinity, medium-sodium water which is not suitable for irrigation under ordinary conditions. At site S-6, Ivie Creek dilutes Muddy Creek's waters slightly such that the mean pH is 8.0 and the TDS is 2306 mg/ℓ; however, the dominant cation and anion, Na and SO_4, remain the same.

Comparing Tables 9 and 3 indicates that the canal water at S-7 is essentially identical to Muddy Creek water at S-1 except for a lower mean pH of 8.2. As is indicated on Plate 1, the canal system servicing the entire Emery area originates at S-1. Thus, the chemical quality of waters sampled at S-1 and S-7 are probably very representative of all irrigation waters in the Emery area.

6.2 Site Specific Surface Water Characteristics

6.2.1 Introduction

As previously mentioned, the Emery Mine site is situated at the confluence of Quitchupah Creek and Christiansen Wash. Quitchupah Creek, its headwaters located on the eastern flank of the Wasatch Plateau, is a perennial stream fed by snowmelt, irrigation runoff and ground water discharge.

TABLE 9

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-7

Sample Site: S-7
Location: Canal Near Emery at U-10 (D-22-6) 9 BCB
Dates of Collection: 8/26/75 through 8/12/76
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	4	192.75	16.6	217.0	180.0
Hardness (noncarbonate)	4	8.2	7.9	15.0	0.0
Hardness, total	4	197.5	12.6	210.0	180.0
Iron, diss. (Fe)	1	0.02			
Manganese, total (Mn)	2	0.05	0.07	0.01	0.0
pH, lab (units)	4	8.2	0.13	8.3	8.0
Sp. conductance, lab (μmhos/cm at 25°C)	5	405.0	44.3	475.0	360.0
Discharge (cfs)	5	14.5	11.0	32.0	2.5
Temperature (°C)	5	13.5	8.1	22.0	1.0
Total dissolved solids (TDS)	4	220.25	29.8	264.0	198.0
CATIONS					
Calcium (Ca)	4	39.5	5.25	44.0	32.0
Magnesium (Mg)	4	19.6	11.6	27.0	2.2
Potassium (K)	4	0.8	0.29	1.2	0.6
Sodium (Na)	4	9.8	6.9	20.0	5.0
Sodium adsorption ratio (SAR)	4	0.3	0.2	0.6	0.2
ANIONS					
Bicarbonate (HCO_3)	4	235.25	20.4	265.0	219.0
Carbonate (CO_3)	4	0.0	0.0	0.0	0.0
Chloride (Cl)	4	3.2	1.8	5.9	2.2
Fluoride (F)	4	0.3	0.0	0.3	0.3
Sulfate (SO_4)	4	19.0	8.8	32.0	13.0
MACRONUTRIENTS					
Nitrate + Nitrite as N	4	0.44	0.08	0.56	0.38
Phosphorus, total as P	4	0.02	0.05	0.09	0.0
TRACE AND OTHER ELEMENTS					
Arsenic (μg/ℓ,As)	1	0.0			
Boron (μg/ℓ,B)	4	25.0	5.8	30.0	20.0
Lead (μg/ℓ,Pb)	1	0.0			
Lithium (μg/ℓ,Li)	1	20.0			
Selenium (μg/ℓ,Se)	1	0.0			
Silica, diss. (SiO_2)	4	5.13	0.88	6.3	4.4
Strontium (μg/ℓ,Sr)	1	420.0			

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

Christiansen Wash, tributary to Quitchupah Creek, is also a perennial stream, receiving its water in part from ground water discharge from terrace gravel aquifers and outcrops of the Ferron Sandstone. Much of the flow in Christiansen Wash, however, is attributable to irrigation return flows south of the town of Emery. As indicated on Plate 1, there is an extensive system of canals in the Emery vicinity which delivers water to local farmlands located on Quaternary alluvium and terrace gravels. Because much of this water goes unused, it returns to the hydrologic system of the area through surface water runoff and ground water seepage.

6.2.2 Streamflow

Systematic stream gaging in the vicinity of the Emery Mine has been conducted by the USGS and Angelus Owili-Eger (1977, 1979). In the spring of 1978, the USGS, Water Resources Division, Salt Lake City, installed bubble gage type continuous water monitoring stations and staff gages on Quitchupah Creek (site S-24, Plate 1), and Christiansen Wash (site S-14). Instantaneous discharges for these two stations are presented in Table 10 and graphically presented in Figure 10. Unfortunately, no discharge data are available for the month of May (1978) which, as indicated in Figure 10, is normally the period of peak streamflow in the region.

The USGS is also conducting seepage studies along Quitchupah Creek and Christiansen Wash. Currently, USGS

TABLE 10

INSTANTANEOUS DISCHARGES MEASURED
AT USGS GAGING STATIONS

Date	Station #09331900 Quitchupah Creek (S-24, Plate 1)	Station #09331950 Christiansen Wash (S-14, Plate 1)
4/14/78	7.96 cfs	0.49 cfs
6/15/78	9.10	3.98
6/29/78	5.94	4.42
7/27/78	2.10	1.43
8/13/78	1.68	1.69
8/24/78	0.59	0.81
9/9/78	2.09	0.34
9/26/78	1.78	-
9/27/78	-	0.66
10/19/78	1.45	0.65
11/8/78	2.88	-
11/15/78	-	0.94
11/19/78	2.39	1.26
12/13/78	5.12	2.14
1/10/79	8.40	0.60
2/8/79	6.55	0.68

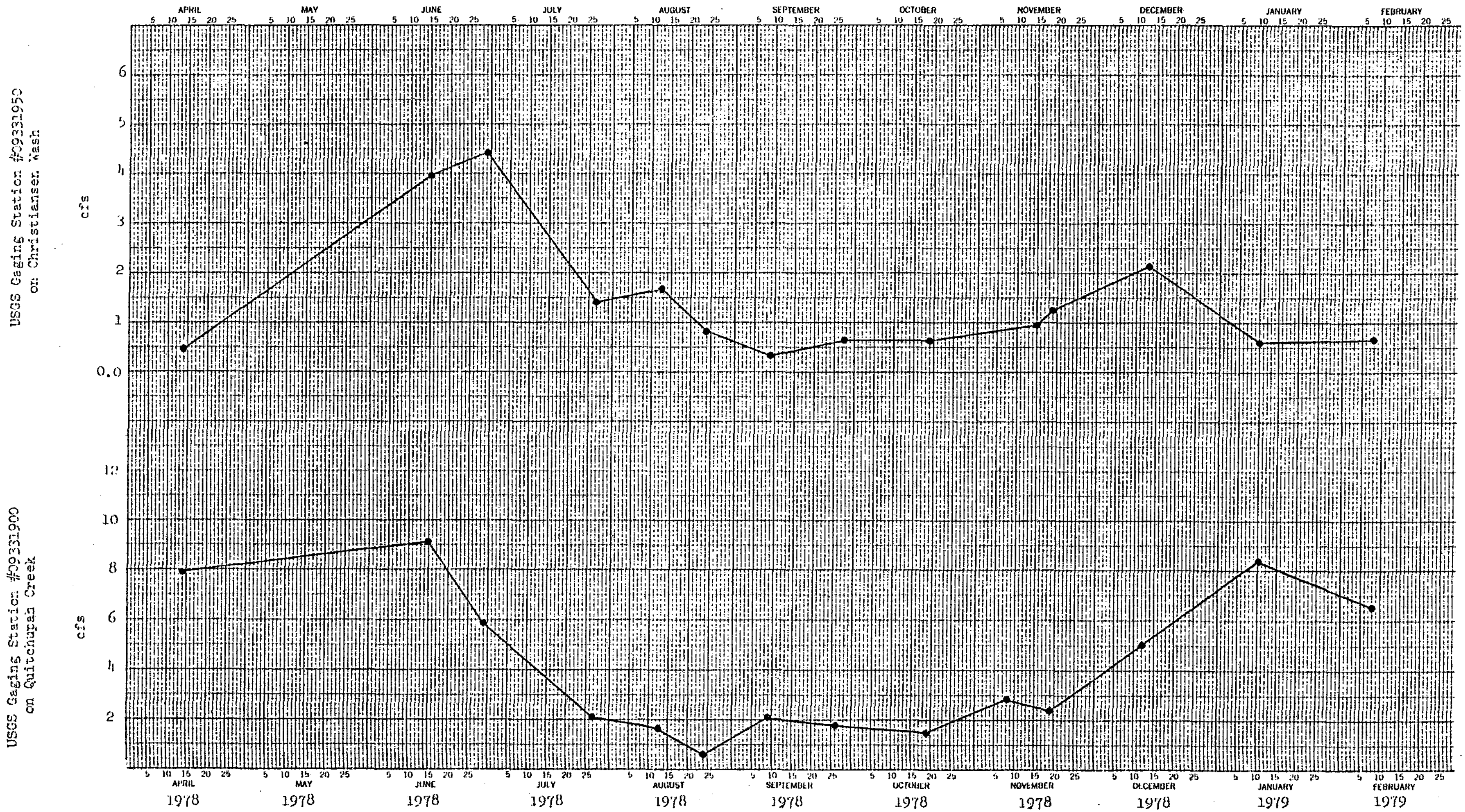


Figure 10. USGS gaging station hydrographs, Christiansen Wash and Quitchupah Creek, 1978-1979. (Source: USGS, 1979)

personnel are measuring discharges and collecting water samples at least twice a year at the sites indicated on Figure 11. The results of the seepage study conducted in 1978 are presented in Table 11.

Although the data are limited, Table 11 indicates that Quitchupah Creek streamflow increases considerably between measuring site 49 and gaging station 09331900. In part, this is due to the average Emery Mine discharge of 0.67 cfs at the time of the study and possibly due to ground water discharge from the Ferron Sandstone which outcrops below site 51S. However, most of the increase in flow is probably due to irrigation caused seepage and runoff. On Christiansen Wash, stream discharge generally increases between measuring site 52 and gaging station 09331950 probably in part due to ground water discharge from the Ferron Sandstone, but more importantly from irrigation caused seepage from terrace gravels.

Between October 1977 and July 1978, Angelus Owili-Eger of CONOCO conducted a seasonal streamflow and water quality study along Christiansen Wash and Quitchupah Creek in order to determine seepage and water quality trends in the vicinity of the Emery Mine. Stream gaging sites used in his study are presented in Figure 12. Stream gaging data are presented in Tables 12 and 13 and graphical representation of seasonal streamflow and water quality trends are illustrated in Figures 13 and 14. On Quitchupah Creek, the following trends may be generalized from the data presented. Gaging station

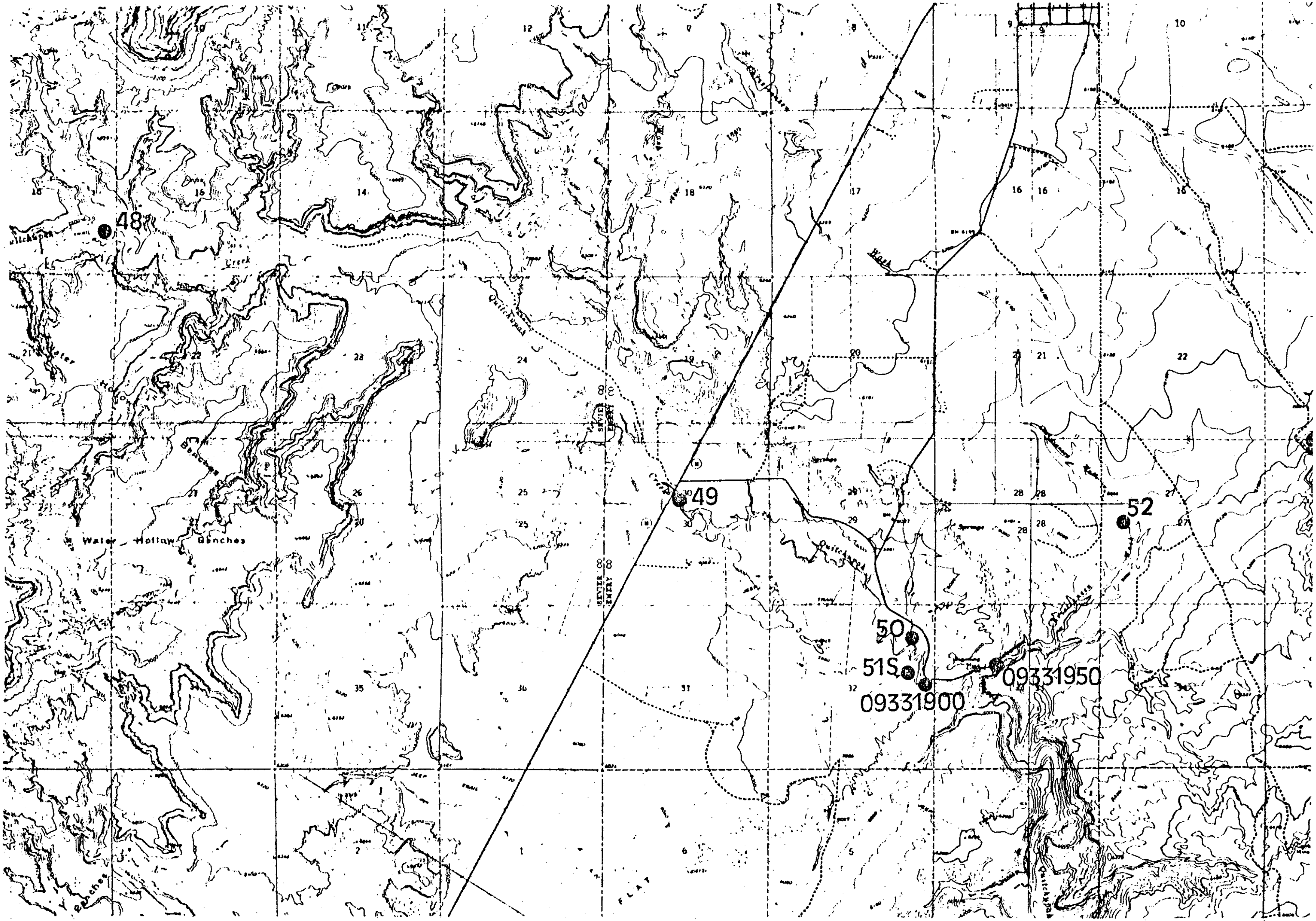


Figure 11. USGS monitoring sites in the Emery area.

TABLE 11

USGS DISCHARGE MEASUREMENTS
ALONG QUITCHUPAH CREEK AND CHRISTIANSEN WASH, 1978

Date	Instantaneous Discharge (cfs) by Station No. (refer to Figure 11)							
	47S	48	49	50	51S	09331900	52	09331950
8/13/78	-	0.91	0.00	0.00	0.26	1.68	1.72	1.69
9/9/78	0.67	0.69	0.02	0.00	1.40	2.09	0.11	0.34
11/18/78	0.34	0.18	1.42					
11/19/78				0.04	0.12	2.39	0.43	1.26

Site Description and Comments

47S and 48 -- Upstream forks of Quitchupah Creek (47S not shown on Figure 11)
49 -- Quitchupah Creek at Route 10 crossing
50 -- Unnamed Quitchupah Creek tributary
51S -- Unnamed Quitchupah Creek tributary into which effluent from the Emery Mine settling pond discharges
09331900 and 09331950 -- USGS gaging stations on Quitchupah Creek and Christiansen Wash, respectively
52 -- Upstream site on Christiansen Wash

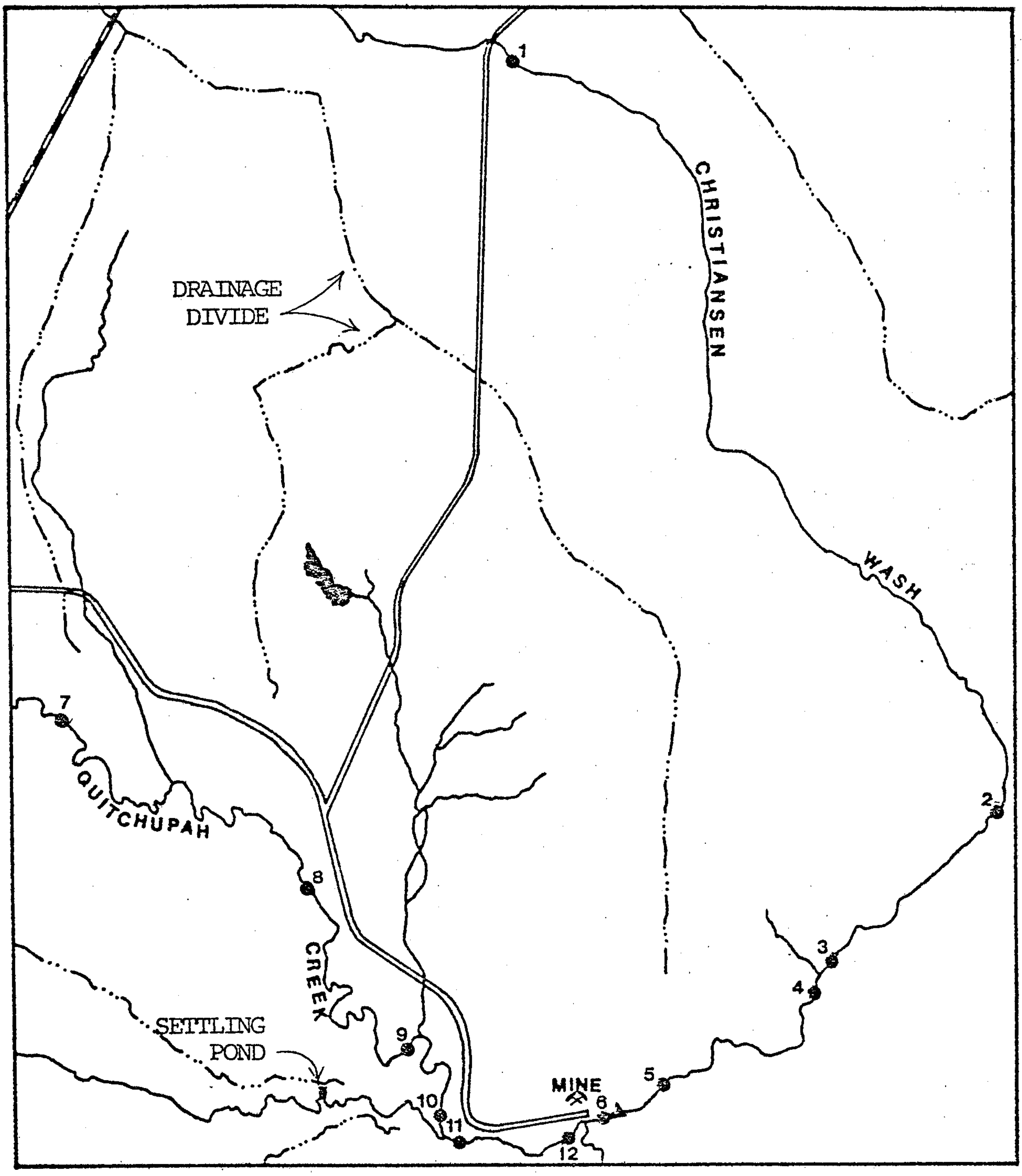


Figure 12. Location map for Owili-Eger's stream gaging sites. (Source: Owili-Eger, 1979)

TABLE 12

QUITCHUPAH CREEK SEASONAL FLOWS, 1977-78
(Source: Owili-Eger, 1979)

Gaging Station No. (Figure 12)	Instantaneous Discharge (cfs) by Dates (mo./day/yr.)			
	10/26/77	2/9/78	4/13/78	7/27/78
7	0	1.071	3.833	0
8	0.501	4.274	17.866	0.800
9	0.898	4.018	21.997	0.650
10	0.690	3.902	13.385	0.699
11	0.951	2.650	15.780	2.140
12	1.123	3.869	14.844	2.450

TABLE 13

CHRISTIANSEN WASH SEASONAL FLOWS, 1977-78
(Source: Owili-Eger, 1979)

Gaging Station No. (Figure 12)	Instantaneous Discharge (cfs) by Dates (mo./day/yr.)			
	10/25/77	2/8/78	4/12/78	7/26/78
1	0.129	0.234	0.523	0.441
2	0.223	0.399	0.559	1.682
3	0.267	0.323	0.597	0.980
4	1.100	0.913	1.267	2.020
5	0.646	1.105	0.891	1.722
6	1.025	0.657	1.365	4.321

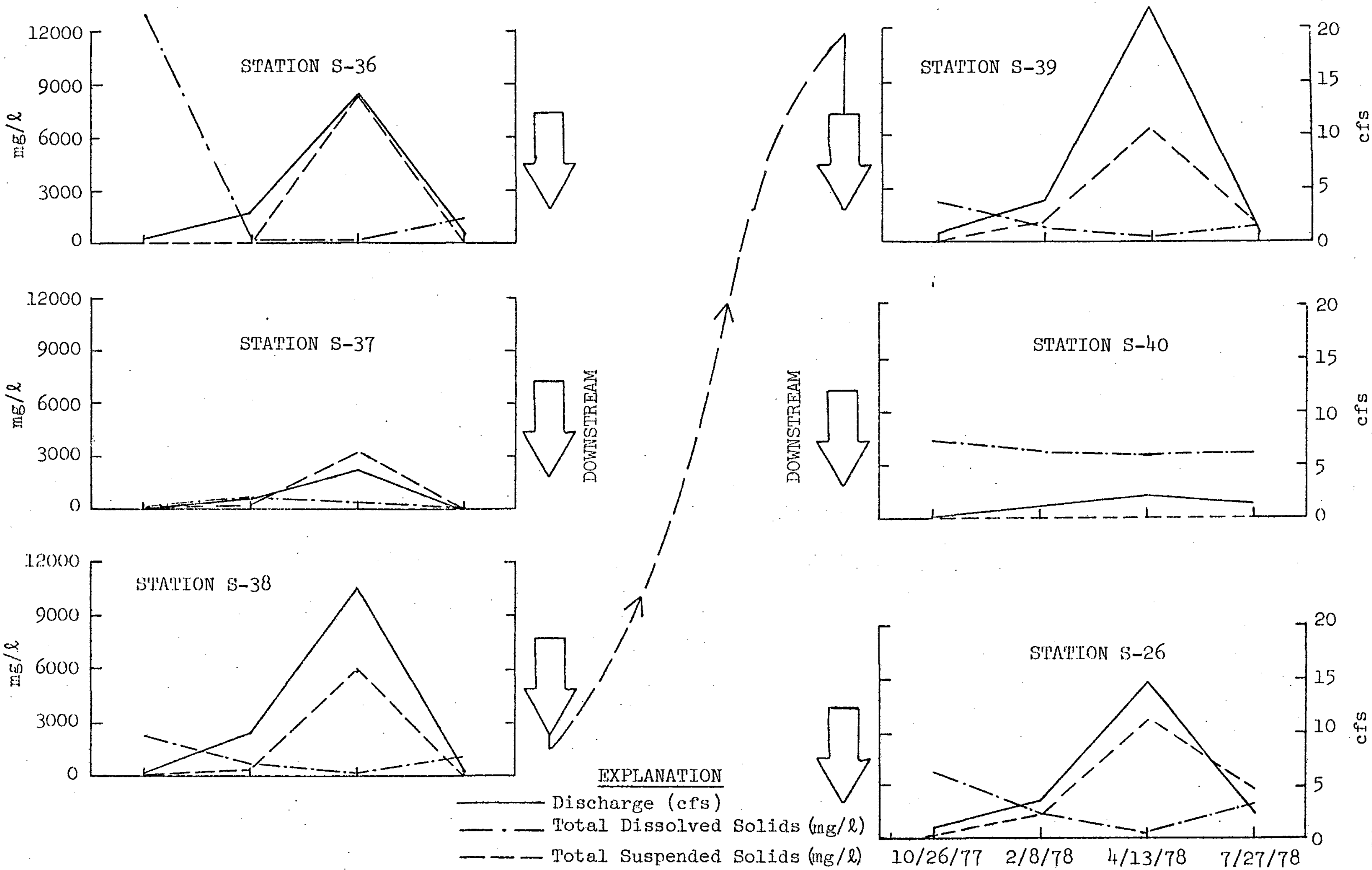


Figure 13. Seasonal discharge and water quality trends on Quitchupah Creek, October 1977 - July 1978. (Source: Owili-Eger, 1979)

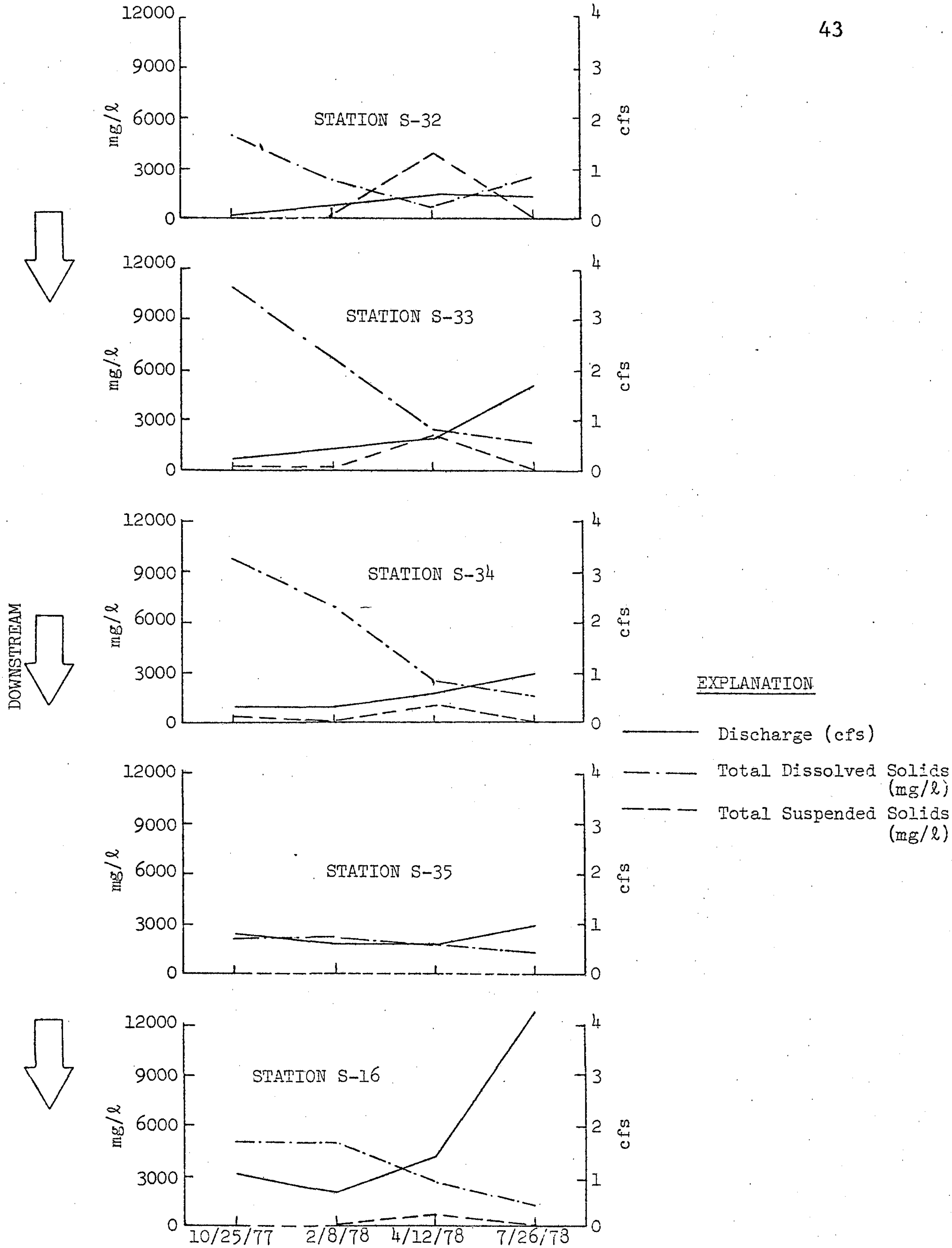


Figure 14. Seasonal discharge and water quality trends on Christiansen Wash, October 1977 - July 1978. (Source: Owili-Eger, 1979)

number 7 was dry during the fall and summer stream gaging runs. Streamflow at station number 8 is probably influenced primarily by irrigation caused runoff and seepage. Owili-Eger ascribes the high flow in spring at this site to a damaged irrigation canal located at the head of the tributary feeding into Quitchupah Creek from the north between stations 7 and 8. Between gaging sites 8 and 9, streamflow increases in the fall and spring and decreases in the winter and summer. Between gaging stations 9 and 10, streamflow decreases in all seasons except summer even though there is an inflowing tributary within this segment. The loss is due to stream infiltration while the summer gain is due to irrigation caused runoff and seepage. The stream segment between gaging stations 10 and 11 includes contributions from the unnamed tributary into which the Emery Mine effluent discharges. Gaging at stations 10 and 11 indicates a fall increase of 0.261 cfs, a winter decrease of 1.252 cfs, a spring increase of 2.395 cfs, and a summer increase of 1.441 cfs. These trends may be due to differences in ground water inflow or due to variances in the Emery Mine discharge since the mine's pumps only operate when necessary. Between gaging stations 11 and 12, streamflow increases in all seasons except spring. Because this segment flows through outcrops of the Ferron Sandstone, the increase is probably due to ground water discharge from the Ferron. For Christiansen Wash, streamflow between gaging stations 1 and 2 increases in all seasons, with the greatest increase in summer due to irrigation runoff. Between gaging stations 2 and 3, there is a small gain in discharge in the fall and spring, a small loss in the winter and a large loss in the summer. The winter loss may be due to snow storage, while the summer loss may be due to evapotranspiration and streambed infiltration. Between gaging stations 3 and 4, there is a large increase in discharge in all seasons due to a tributary fed by irrigation caused seepage and discharge from the Ferron Sandstone. Between gaging stations 4 and 5, there is a decline in streamflow in all seasons except winter. This general loss is probably due to evapotranspiration and ground water inflow into Christiansen Wash's alluvium. Between gaging stations 5 and 6, streamflow increases considerably in all seasons except winter. The increased streamflow is due to ground water discharge while the winter loss may be due to snow and stream bank storage.

In summary, streamflow in the vicinity of the Emery Mine may be characterized as follows: (1) Christiansen Wash is a perennial stream due to irrigation caused runoff and ground water seepage and seepage from a leaking irrigation canal; (2) segments of Christiansen Wash gain and lose flow in response to ground water discharge, irrigation runoff, infiltration, snow storage, and evapotranspiration; (3) average discharge at its mouth is approximately 0.25 cfs with measured maximum and minimum discharges of 5.0 and 0.5 cfs, respectively; (4) segments of Quitchupah Creek likewise gain and lose flow in response to ground water discharge, irrigation runoff and a leaking irrigation canal, infiltration, and Emery Mine discharge; and (5) at its confluence with Christiansen Wash, Quitchupah Creek has a mean discharge of 5.571 cfs with measured maximum and minimum discharges of 14.844 and 1.123 cfs.

Both Quitchupah Creek and Christiansen Wash are subject to flooding due to occasional thunderstorms and rapid snowmelt runoff during the spring. To date, no flood discharge data exist for either Quitchupah Creek or Christiansen Wash. Consequently, flood calculations have been investigated for the following three sites: (1) Quitchupah Creek at USGS gaging station 09331900; (2) Christiansen Wash at USGS gaging station 09331950; and (3) Quitchupah Creek below its confluence with Christiansen Wash at the recently implemented monitoring site (see Section 6.3, Monitoring Program). The peak flows for the three storm events at each of the three monitoring sites are presented in Table 14.

6.2.3 Surface Water Quality

A considerable amount of site specific water quality data has been gathered in the vicinity of the Emery Mine by the USGS, Water Resources Division, Salt Lake City, John Kaufman, formerly of Consol, and Angelus Owili-Eger of CONOCO.

USGS Studies

A year-long water quality study was conducted by the USGS on Quitchupah Creek between July 1975 and September 1976.

TABLE 14

RESULTS OF FLOOD CALCULATIONS FOR QUITCHUPAH CREEK BASIN
(Source: D'Appolonia, 1978)

General Parameters for Calculation of the 10- and 25-Year 24-Hour Storm	
Drainage Area	96.7 $mi.^2$
Length of Longest Water Course	7000 ft.
Elevation Difference	4000 ft.
Curve No.	75
Results for 10-Year 24-Hour Storm	
Cumulative Rainfall	0.67 after 1/2 hour 0.85 after 1 hour 1.50 after 6 hours 1.50 after 24 hours
Time of Concentration	2.11 hours
Peak Discharge	2186.29 cfs
Total Discharge	860.62 ac-ft.
Results for 25-Year 24-Hour Storm	
Cumulative Rainfall	0.75 after 1/2 hour 0.95 after 1 hour 1.50 after 6 hours 1.90 after 24 hours
Time of Concentration	2.11 hours
Peak Discharge	2183.54 cfs
Total Discharge	1675.48 ac-ft.

The USGS collected samples at site S-18 where Utah State Highway 10 crosses Quitchupah Creek and at site S-29 on Quitchupah Creek where it confluences with Ivie Creek. Water quality analyses for sites S-18 and S-29 are summarized in Tables 15 and 16, respectively. Between these two sampling sites, Quitchupah Creek's water increases downstream in concentrations of nearly all constituents: pH increases from 8.1 to 8.3; TDS increases from 939 to 2406 mg/ℓ, and SAR increases from 2.2 to 5.5. At S-18, Ca, Na, and Mg were the dominant cations, while at S-29, Na, Ca, and Mg were the dominant cations. At both stations, SO_4 was the dominant anion, but its relative proportion to HCO_3 and Cl greatly increased downstream at site S-29. At site S-18, the specific conductivity of 1346 μmhos/cm at 25°C and SAR of 2.2 classify the water as high salinity, low-sodium water. This water may be used for irrigation of plants with good salt tolerance produced in well-drained soils (USDA, 1954). At site S-29, the specific conductivity of 3078 μmhos/cm at 25°C and SAR of 5.5 classify the water as very high salinity, medium-sodium water. This water is not suitable for irrigation under ordinary conditions.

In August 1978, the USGS began a systematic water quality study on Quitchupah Creek and Christiansen Wash at USGS gaging stations 09331900 (S-24) and 09331950 (S-14). The USGS sampled for constituents on the schedule presented in Table 17. Analyses at sites S-24 and S-14 are presented in Tables 18 and 19, respectively.

TABLE 15

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-18

Sample Site: S-18
Location: Quitchupah Creek at U-10 Near Emery (D-22-6) 30 BDD
Dates of Collection: 7/23/75 through 9/22/76
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	6	287.2	67.2	371.0	208.0
Hardness (noncarbonate)	6	308.8	172.1	470.0	73.0
Hardness, total	6	595.0	210.0	820.0	280.0
Iron, diss. (Fe)	2	0.01	0.01	0.02	0.0
Manganese, total (Mn)	2	0.05	0.06	0.10	0.01
pH, lab (units)	6	8.1	0.5	8.9	7.6
Sp. conductance, lab (µmhos/cm at 25°C)	7	1345.7	396.6	1740.0	640.0
Discharge (cfs)	7	0.8	0.9	2.0	0.01
Temperature (°C)	7	16.1	7.3	23.0	1.5
Total dissolved solids (TDS)	7	938.8	293.6	1290.0	400.0
CATIONS					
Calcium (Ca)	6	117.5	64.4	200.0	55.0
Magnesium (Mg)	6	59.5	16.5	77.0	35.0
Potassium (K)	6	4.5	1.3	5.7	2.0
Sodium (Na)	6	111.7	39.7	160.0	40.0
Sodium adsorption ratio (SAR)	6	2.2	0.9	3.3	1.0
ANIONS					
Bicarbonate (HCO_3)	6	350.2	81.9	452.0	254.0
Carbonate (CO_3)	6	0.0	0.0	0.0	0.0
Chloride (Cl)	6	37.8	13.7	52.0	14.0
Fluoride (F)	6	0.4	0.05	0.4	0.3
Sulfate (SO_4)	6	405.0	182.0	620.0	120.0
MACRONUTRIENTS					
Nitrate + Nitrite as N	6	0.4	0.4	1.0	0.0
Phosphorus, total as P	6	0.02	0.02	0.06	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (µg/ℓ,Al)	2	30.0	0.03	30.0	30.0
Arsenic (µg/ℓ,As)	2	0.5	0.7	1.0	0.0
Boron (µg/ℓ,B)	6	203.3	65.3	250.0	80.0
Lead (µg/ℓ,Pb)	2	0.5	0.7	1.0	0.0
Lithium (µg/ℓ,Li)	2	80.0	14.1	90.0	70.0
Selenium (µg/ℓ,Se)	2	1.0	0.0	1.0	1.0
Silica, diss. (SiO_2)	6	10.7	2.5	13.0	7.5
Strontium (µg/ℓ,Sr)	2	1450.0	212.1	1600.0	1300.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 16

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-29

Sample Site: S-29
Location: Quitchupah Creek at Mouth Near I-70 (D-23-6) 16 CAA
Dates of Collection: 7/23/75 through 9/21/76
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	5	269.8	26.2	306.0	246.0
Hardness (noncarbonate)	5	708.0	338.6	1100.0	310.0
Hardness, total	5	956.0	312.0	1300.0	570.0
Iron, diss. (Fe)	4	0.04	0.03	0.08	0.02
Manganese, total (Mn)	4	0.09	0.02	0.01	0.0
Oxygen, diss. (DO)	1	8.7			
pH, lab (units)	5	8.3	0.02	8.5	8.0
Sp. conductance, lab (µmhos/cm at 25°C)	5	3078.0	1246.4	4600.0	1500.0
Discharge (cfs)	5	5.0	4.8	12.0	0.5
Temperature (°C)	5	16.2	9.3	22.5	0.0
Total dissolved solids (TDS)	5	2406.0	1122.5	3710.0	1070.0
CATIONS					
Calcium (Ca)	5	150.0	40.6	190.0	100.0
Magnesium (Mg)	5	145.0	55.2	210.0	78.0
Potassium (K)	5	7.5	3.1	11.0	3.7
Sodium (Na)	5	416.0	231.4	700.0	150.0
Sodium adsorption ratio (SAR)	5	5.5	2.4	8.3	2.7
ANIONS					
Bicarbonate (HCO_3)	5	329.0	31.7	373.0	300.0
Carbonate (CO_3)	5	0.0	0.0	0.0	0.0
Chloride (Cl)	5	58.2	29.5	96.0	24.0
Fluoride (F)	5	0.5	0.1	0.6	0.4
Sulfate (SO_4)	5	1428.0	754.3	2300.0	540.0
MACRONUTRIENTS					
Nitrate + Nitrite as N	5	6.4	3.6	10.0	1.6
Phosphorus, total as P	5	0.01	0.01	0.03	0.0
TRACE AND OTHER ELEMENTS					
Aluminum (µg/ℓ,Al)	3	23.3	5.8	30.0	20.0
Arsenic (µg/ℓ,As)	3	0.33	0.58	1.0	0.0
Boron (µg/ℓ,B)	5	340.0	192.0	570.0	150.0
Lead (µg/ℓ,Pb)	3	2.3	2.5	5.0	0.0
Lithium (µg/ℓ,Li)	3	273.3	115.5	340.0	140.0
Selenium (µg/ℓ,Se)	3	19.0	9.2	27.0	9.0
Silica, diss. (SiO_2)	5	8.0	1.8	9.8	5.5
Strontium (µg/ℓ,Sr)	3	2733.3	1266.2	3700.0	1300.0

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 17

USGS WATER ANALYSIS SCHEDULE
ON CHRISTIANSEN WASH AND QUITCHUPAH CREEK

Constituent	Sampling Frequency[1]	Constituent	Sampling Frequency
Air temperature (°C)	M	Nitrite + Nitrate ion	Q
Alkalinity, total	M	Nitrogen, dissolved	Q
Ammonium ion	Q	Nitrogen, total KJD	Q
Arsenic	Q	Oil and grease	Q
Bicarbonate	M	Oxygen, dissolved field	M
Boron	Q	Oxygen, dissolved lab	M
Calcium ion	M	pH, field	M
Carbon, dissolved organic	Q	pH, lab	M
Carbonate	M	Phenols	Q
Chloride ion	M	Phosphate, dissolved	Q
Chromium ion	Q	Phosphorous, total	Q
Conductivity, field	M	Potassium ion	M
Conductivity, lab	M	SAR	M
Fluoride ion	Q	Selenium ion	Q
Hardness, noncarbonate	M	Silica, dissolved	M
Hardness, total	M	Sodium ion	M
Iron ion	Q	Streamflow, instantaneous	M
Lead ion	Q	Strontium ion	Q
Lithium ion	Q	Sulfate ion	M
Magnesium ion	Q	Water temperature (°C)	M
Manganese ion	Q	Zinc ion	Q
Nitrite ion	Q		

[1]M = Monthly; Q = Quarterly.

TABLE 18

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-24

Sample Site: S-24
Location: USGS Gauging Station On Quitchupah Creek (D-22-6) 32 DAA
Dates of Collection: 8/13/78 through 12/13/78
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	5	9.8	1.5	11.8	8.2
Hardness (noncarbonate)	5	518.0	449.9	1300.0	150.0
Hardness, total	5	854.0	493.5	1700.0	470.0
Iron, diss. (Fe)	2	0.01	0.0	0.01	0.01
Manganese, total (Mn)	2	0.02	0.01	0.02	0.01
Oil and grease	2	0.0	0.0	0.0	0.0
Oxygen, diss. (DO)	5	9.8	1.5	11.8	8.2
pH, field (units)	5	8.5	0.18	8.8	8.3
pH, lab (units)	5	8.1	0.25	8.5	7.9
Sp. conductance, field (µmhos/cm at 25°C)	5	2425.2	697.7	3300.0	1500.0
Sp. conductance, lab (µmhos/cm at 25°C)	4	2860.0	1302.9	4623.0	1706.0
Discharge (cfs)	5	2.48	1.5	5.1	1.4
Temperature (°C)	5	7.3	10.1	24.0	0.0
Total dissolved solids (TDS)	5	2297.9	642.1	4188.2	1297.8
CATIONS					
Calcium (Ca)	5	142.8	55.4	230.0	94.0
Magnesium (Mg)	5	121.6	90.6	280.0	56.0
Potassium (K)	5	6.1	1.8	8.2	4.4
Sodium (Na)	5	360.0	152.3	590.0	190.0
Sodium adsorption ratio (SAR)	5	5.36	1.0	6.3	3.8
ANIONS					
Bicarbonate (HCO_3)	5	397.8	95.3	496.0	260.0
Carbonate (CO_3)	5	4.4	3.21	9.0	0.0
Chloride (Cl)	5	67.0	24.9	100.0	40.0
Fluoride (F)	2	0.45	0.07	0.5	0.4
Sulfate (SO_4)	5	1194.0	770.4	2500.0	510.0
MACRONUTRIENTS					
Nitrogen total KJD as N	2	0.7	0.23	0.86	0.53
Nitrate + Nitrite as N	2	1.03	0.09	1.1	0.96
Phosphorus, total as P	2	0.27	0.23	0.43	0.11
TRACE AND OTHER ELEMENTS					
Arsenic (µg/ℓ,As)	2	0.0	0.0	0.0	0.0
Boron (µg/ℓ,B)	2	280.0	110.0	360.0	210.0
Carbon, diss. organic	2	3.35	0.92	4.0	2.7
Chromium (µg/ℓ,Cr)	2	5.0	7.0	1.0	0.0
Lead (µg/ℓ,Pb)	2	29.0	1.0	38.0	2.0
Lithium (µg/ℓ,Li)	2	11.0	4.0	140.0	8.0
Phenols (µg/ℓ)	2	1.5	0.7	2.0	1.0
Selenium (µg/ℓ,Se)	2	4.5	0.04	5.0	4.0
Silica, diss. (SiO_2)	5	9.9	2.53	14.0	7.3
Strontium (µg/ℓ,Sr)	2	1.8	0.42	2.1	1.5

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 19

RESULTS OF CHEMICAL ANALYSES OF SURFACE WATER
SAMPLED IN THE EMERY MINE AREA, SITE S-14

Sample Site: S-14
Location: USGS Gauging Station On Christiansen Wash (D-22-6) 33 BDA
Dates of Collection: 8/13/78 through 11/19/78
Source of Data: USGS

	No. of Samples	Mean	Standard Deviation	Max	Min
GENERAL CHARACTERISTICS					
Alkalinity, total (as $CaCO_3$)	4	340.0	52.3	410.0	300.0
Hardness (noncarbonate)	4	865.0	396.1	1300.0	500.0
Hardness, total	4	1215.0	395.9	1600.0	790.0
Iron, diss. (Fe)	1	0.02			
Manganese, total (Mn)	1	0.01			
Oil and grease	1	0.0			
Oxygen, diss. (DO)	4	9.15	1.2	10.6	7.8
pH, field (units)	4	8.45	0.09	8.5	8.3
pH, lab (units)	4	8.12	0.21	8.3	7.9
Sp. conductance, field (μmhos/cm at 25°C)	3	3716.7	2159.7	4900.0	2250.0
Sp. conductance, lab (μmhos/cm at 25°C)	4	3502.0	1194.5	4702.0	1990.0
Discharge (cfs)	4	1.1	0.51	1.7	0.65
Temperature (°C)	4	12.12	7.2	20.0	3.0
Total dissolved solids (TDS)	4	2902.2	894.9	3642.7	1701.0
CATIONS					
Calcium (Ca)	4	180.0	40.8	210.0	120.0
Magnesium (Mg)	4	182.5	72.3	250.0	120.0
Potassium (K)	4	6.75	1.5	8.0	5.0
Sodium (Na)	4	430.0	157.7	580.0	210.0
Sodium adsorption ratio (SAR)	4	5.33	1.5	6.4	3.2
ANIONS					
Bicarbonate (HCO_3)	4	393.5	75.9	500.0	324.0
Carbonate (CO_3)	4	9.25	10.1	18.0	0.0
Chloride (Cl)	4	76.75	31.7	110.0	34.0
Fluoride (F)	1	0.7			
Sulfate (SO_4)	4	1617.5	597.7	2100.0	870.0
MACRONUTRIENTS					
Nitrogen, total KJD as N	1	3.2			
Nitrate + Nitrite as N	1	23.0			
Phosphorus, total as P	1	0.02			
TRACE AND OTHER ELEMENTS					
Arsenic (μg/ℓ,As)	1	0.0			
Boron (μg/ℓ,B)	1	590.0			
Carbon, diss. organic	1	13.0			
Lead (μg/ℓ,Pb)	1	59.0			
Lithium (μg/ℓ,Li)	1	370.0			
Selenium (μg/ℓ,Se)	1	60.0			
Silica, diss. (SiO_2)	4	11.1	2.0	13.0	8.4
Strontium (μg/ℓ,Sr)	1	2900.0			

REMARKS

1) All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

Kaufman's Studies (Consol)

On three occasions (May 10, 1974; January 7, 1975; and March 22-23, 1977) John Kaufman (formerly with Consol) conducted a water sampling program on Quitchupah Creek and Christiansen Wash to determine water quality trends along these streams. Kaufman collected unrefrigerated grab samples at the sites indicated on Figures 15, 16, and 17. Figure 15, a graphical representation of data presented in Table 20, indicates that on May 10, 1974, Quitchupah Creek's water shows a downstream increase in TDS towards the Emery Mine largely as a result of irrigation caused runoff and seepage from the tributary sampled at S-20. At this time, the Emery Mine discharged its water into this tributary below S-20. Thus the sample taken at S-23 indicates the influence of the Emery Mine discharge. Notably, the streamflow on Quitchupah Creek at site S-28, after the confluence of Christiansen Wash and Quitchupah Creek, contained a considerably smaller ionic concentration than measured upstream at either sites S-25 or S-15. This occurrence is probably due to dilution via ground water inflow from the Ferron Sandstone.

Figure 16 is a graphical presentation of the data presented in Table 21 for water sampling conducted by Kaufman on January 7, 1975. These data are particularly interesting because the samples were collected while the Emery Mine's pumps had been turned off for nine hours. After the streams had been sampled, the pumps were turned on and the sample

TABLE 20

RESULTS OF A SAMPLING PROGRAM CONDUCTED BY CONSOLIDATION COAL CO. ON MAY 10, 1974 TO DETERMINE WATER QUALITY TRENDS ON CHRISTIANSEN WASH AND QUITCHUPAH CREEK

Sample Site:	S-12	S-15	S-18	S-20	S-23	S-25	S-28
Location:	C. Wash Tributary	C. Wash	Q. Creek	Q. Creek Tributary	Q. Creek	Q. Creek	Q. Creek
Date of Collection:	5/10/74	5/10/74	5/10/74	5/10/74	5/10/74	5/10/74	5/10/74
pH, lab (units)	8.4	8.3	7.9	8.2	8.3	8.2	8.2
Sp. conductance, lab (μmhos/cm at 25°C)	10000.0	3460.0	1020.0	5000.0	1350.0	6000.0	1260.0
Total dissolved solids (TDS)	9900.0	2580.0	370.0	4700.0	1000.0	5100.0	910.0
Calcium (Ca)	350.0	180.0	62.0	2400.0	98.0	150.0	110.0
Magnesium (Mg)	830.0	210.0	32.0	270.0	45.0	200.0	62.0
Sodium (Na)	1200.0	440.0	54.0	690.0	110.0	1100.0	140.0
Sodium adsorption ratio (SAR)	8.0	5.3	1.4	3.6	2.3	13.8	2.6
Sulfate (SO_4)	4100.0	1470.0	120.0	2000.0	360.0	3100.0	480.0

Note: All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

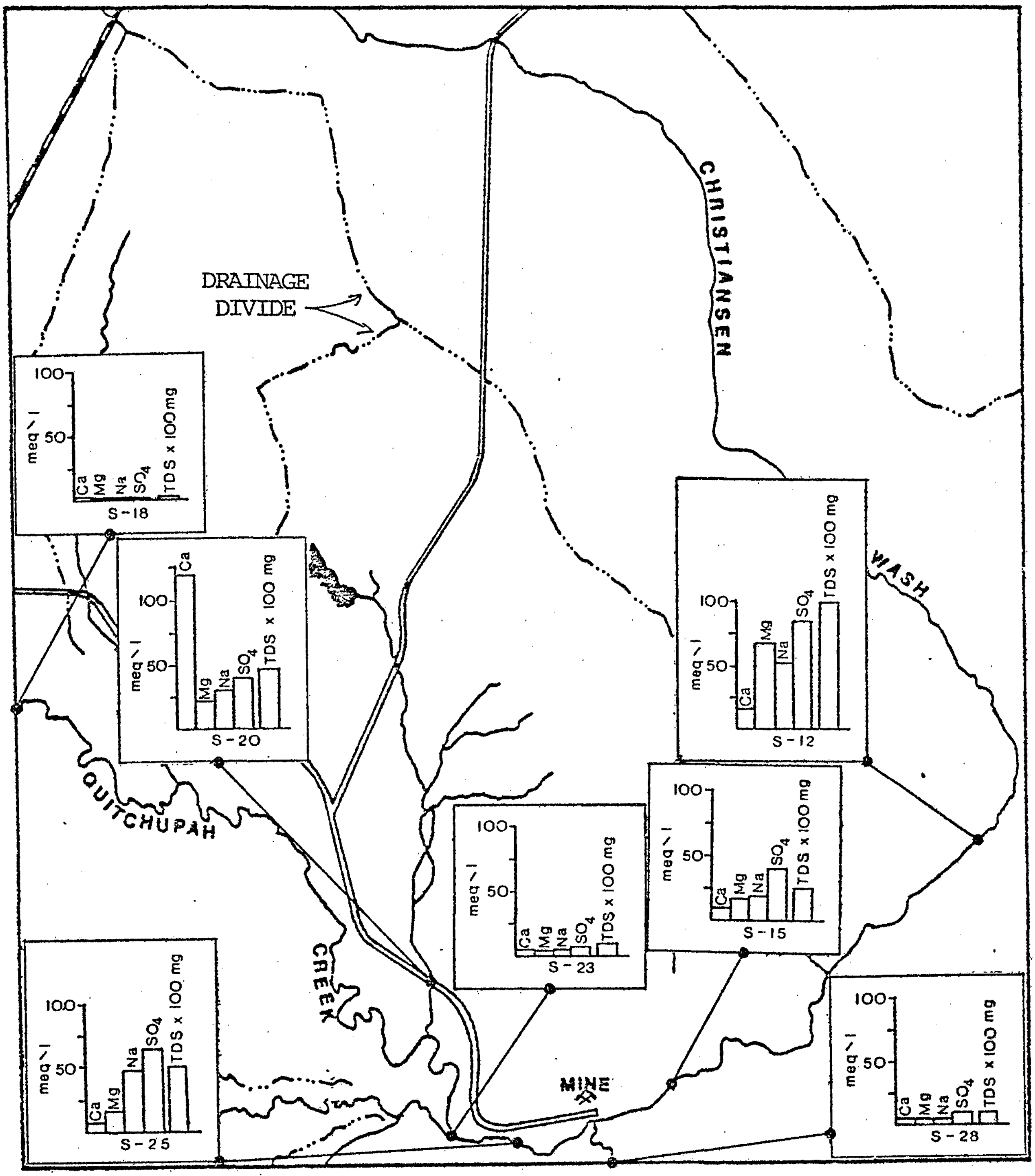


Figure 15. Water quality trends in the Emery Mine area May 10, 1974.

TABLE 21

RESULTS OF A SAMPLING PROGRAM CONDUCTED BY CONSOLIDATION COAL CO. ON JANUARY 7, 1975 TO DETERMINE WATER QUALITY TRENDS ON CHRISTIANSEN WASH AND QUITCHUPAH CREEK

Sample Site: Location: Date of Collection:	S-16 C. Wash 1/7/75	S-19 Q. Creek 1/7/75	S-26 Q. Creek 1/7/75	S-27 Q. Creek 1/7/75	Emery Mine Discharge 1/7/75
Alkalinity, total (as $CaCO_3$)	459.0	397.0	385.0	403.0	432.0
Iron, total (Fe)	0.6	0.5	0.5	0.7	0.5
Iron, diss. (Fe)	0.55	0.13	0.3	0.3	0.5
Manganese, total (Mn)	0.0	0.0	0.0	0.0	
pH, lab (units)	8.0	7.8	7.7	7.9	8.1
Discharge (cfs)			1.6		
Total dissolved solids (TDS)	3120.0	1260.0	1300.0	1680.0	5590.0
Total suspended solids (TSS)	75.0	128.0	81.0	180.0	121.0
Calcium (Ca)	18.9	13.4	13.6	15.4	18.6
Magnesium (Mg)	18.4	6.9	6.6	9.7	21.1
Sodium (Na)	470.0	180.0	182.0	255.0	1250.0
Sodium adsorption ratio (SAR)	18.4	10.0	10.1	12.5	
Chloride (Cl)	64.2	30.5	31.8	39.0	204.4
Sulfate (SO_4)	1083.0	580.0	460.0	740.0	1251.0
Aluminum (Al)		0.0	0.0	0.0	

Note: All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

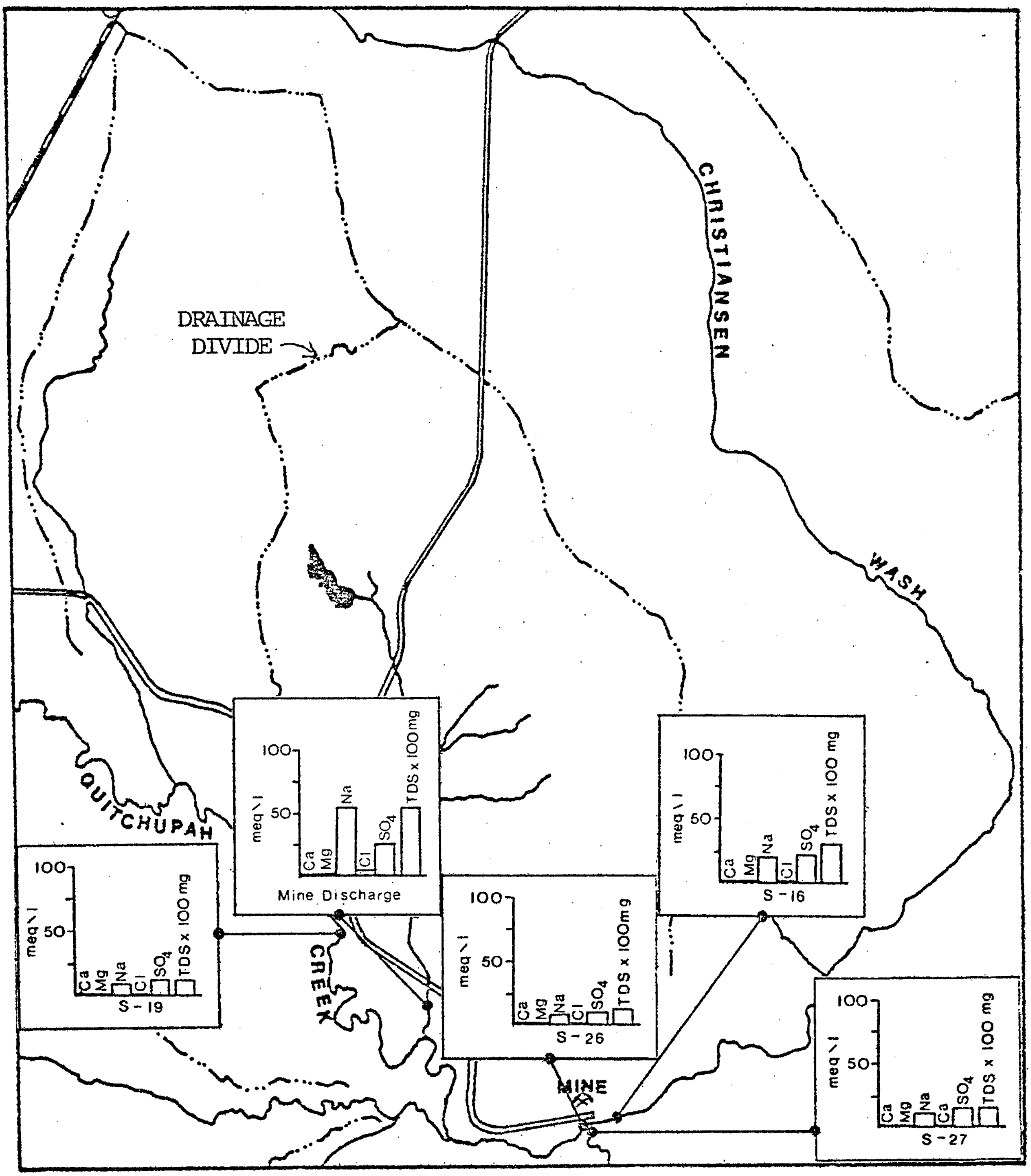


Figure 16. Water quality trends in the Emery Mine area January 7, 1975.

labeled as "Mine Discharge" was collected. Figure 16 indicates that on January 7, 1975, Quitchupah Creek waters above the influence of mine discharge were fairly dilute, and that the mine discharge contained significantly more dissolved Na and SO_4.

Figure 17, a graphical representation of the data presented in Table 22, illustrates water quality trends along Christiansen Wash on March 22 and 23, 1977. Between sites S-9 and S-11, Christiansen Wash's dissolved constituents increase as a result of runoff and ground water inflow caused by irrigation south of Emery. Site S-12 is a tributary fed by seepage from the alluvial and Ferron Sandstone aquifers. Below S-12, water quality in Christiansen Wash improves towards its confluence with Quitchupah Creek due to additional ground water inflow from the Ferron Sandstone aquifer (note that at this time, the Emery Mine settling pond had been constructed and the sample at S-22 was collected).

Owili-Eger's Studies (CONOCO)

Between October 1977 and July 1978, Owili-Eger collected unrefrigerated grab samples in conjunction with his stream gaging program along Christiansen Wash and Quitchupah Creek. Owili-Eger's data are presented in Tables 23 and 24 and are graphically represented in Figures 13 and 14 (see pages 42 and 43 of this report). Figure 14 for Christiansen Wash indicates that between S-32 and S-33, TDS generally increases.

TABLE 22

RESULTS OF A SAMPLING PROGRAM CONDUCTED BY CONSOLIDATION COAL CO. ON MARCH 22 AND 23, 1977
TO DETERMINE WATER QUALITY TRENDS ON CHRISTIANSEN WASH AND QUITCHUPAH CREEK

Sample Site:	S-9	S-10	S-11	S-12	S-13	S-17	S-21	S-22
Location:	C. Wash	C. Wash	C. Wash Tributary	C. Wash Tributary	C. Wash	C. Wash	Q. Creek	Emery Mine Sedimentation Pond Discharge
Date of Collection:	3/23/77	3/22/77	3/22/77	3/22/77	3/22/77	3/22/77	3/23/77	3/23/77
Alkalinity, total (as $CaCO_3$)	345.0	470.0	815.0	439.0	420.0	414.0	452.0	427.0
Iron, total (Fe)	1.0	1.7	1.5	1.2	1.0	1.0	1.2	0.9
Iron, diss. (Fe)	0.9	1.0	0.9	1.0	0.9	0.9	1.0	0.8
Manganese, total (Mn)	0.24	0.03	0.02	0.03	0.08	0.01	0.0	0.0
pH, lab (units)	8.0	8.0	7.6	7.9	8.0	8.0	7.7	8.1
Discharge (cfs)		0.475	0.003	0.51	0.956	1.677		
Total dissolved solids (TDS)	1310.0	5016.0	6584.0	4972.0	3604.0	3304.0	2412.0	4512.0
Total suspended solids (TSS)	70.0	571.0	6962.0	544.0	274.0	529.0	410.0	19.0
Calcium (Ca)	115.0	278.0	335.0	267.0	187.0	169.0	165.0	130.0
Magnesium (Mg)	138.0	681.0	1650.0	365.0	405.0	211.0	131.0	196.0
Potassium (K)	2.67	9.7	11.85	12.6	7.37	8.07	6.09	8.24
Sodium (Na)	120.0	653.0	275.0	598.0	738.0	625.0	480.0	1292.0
Sodium adsorption ratio (SAR)	1.79	3.6	1.3	0.9	6.9	7.6	6.8	16.7
Chloride (Cl)	32.0	113.0	82.0	111.0	82.0	86.0	65.0	183.0
Sulfate (SO_4)	770.0	3750.0	2850.0	3400.0		2060.0	1480.0	2980.0
Aluminum (Al)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0

Note: All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

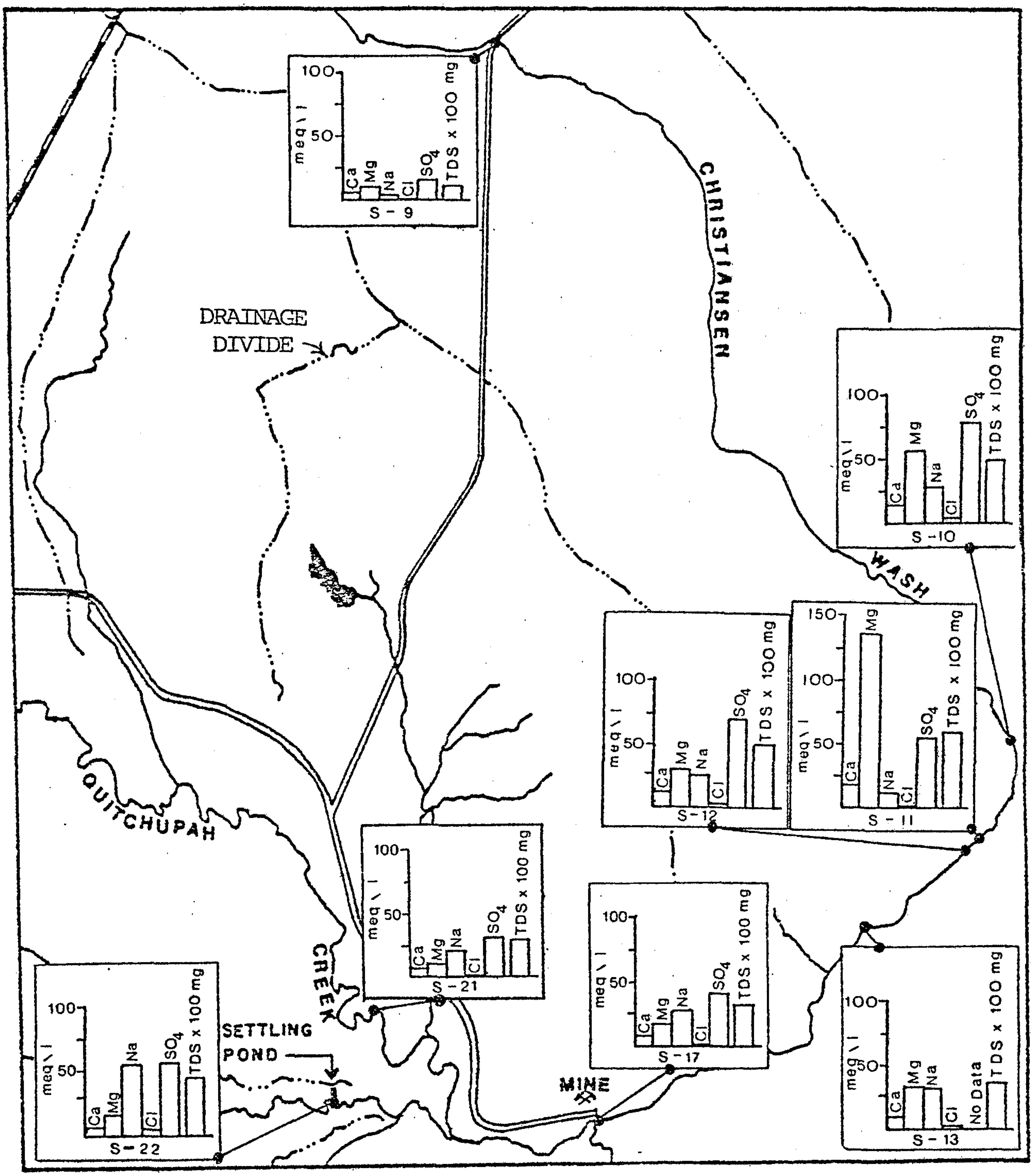


Figure 17. Water quality trends in the Emery Mine area March 22 and 23, 1977.

TABLE 23

RESULTS OF A WATER QUALITY TREND STUDY
ON QUITCHUPAH CREEK, 1977-1978

Sample Site: S-36
Location: Quitchupah Creek Tributary
Dates of Collection: 10/26/77, 2/9/78, 4/13/78, and 7/27/78
Source of Data: Owili-Eger

	10/26/77	2/9/78	4/13/78	7/27/78
GENERAL CHARACTERISTICS				
Hardness, total	3605.0	150.0	955.0	635.0
Iron, total (Fe)	0.4	0.2	1.4	0.1
pH, lab (units)	8.0	8.2	8.1	8.0
Sp. conductance, lab (μmhos/cm at 25°C)	10800.0	290.0	420.0	2025.0
Discharge (cfs)				
Total dissolved solids (TDS)	13175.0	370.0	240.0	1685.0
Total suspended solids (TSS)	135.0	140.0	8450.0	100.0
CATIONS				
Calcium (Ca)	1215.0	80.0	440.0	110.0
Magnesium (Mg)	2390.0	20.0	36.0	85.0
Potassium (K)	17.0	6.0	4.0	5.0
Sodium (Na)	2500.0	37.0	69.0	360.0
Sodium adsorption ratio (SAR)	9.6	1.0	0.9	6.3
ANIONS				
Bicarbonate (HCO_3)	505.0	210.0	170.0	265.0
Chloride (Cl)	250.0	10.0	5.0	25.0
Sulfate (SO_4)	8500.0	95.0	37.0	940.0

TABLE 23 Continued

Sample Site: S-37
Location: Quitchupah Creek
Dates of Collection: 10/26/77, 2/9/78, 4/13/78, and 7/27/78
Source of Data: Owili-Eger

	10/26/77	2/9/78	4/13/78	7/27/78
GENERAL CHARACTERISTICS				
Hardness, total	NO FLOW	680.0	235.0	NO FLOW
Iron, total (Fe)		0.2	1.4	
pH, lab (units)		8.1	8.1	
Sp. conductance, lab (μmhos/cm at 25°C)		516.0	745.0	
Discharge (cfs)	0.0	1.07	3.83	0.0
Total dissolved solids (TDS)		740.0	470.0	
Total suspended solids (TSS)		295.0	3365.0	
CATIONS				
Calcium (Ca)		90.0	230.0	
Magnesium (Mg)		120.0	37.0	
Potassium (K)		9.0	4.0	
Sodium (Na)		140.0	82.0	
Sodium adsorption ratio (SAR)		2.3	1.3	
ANIONS				
Bicarbonate (HCO_3)		255.0	210.0	
Chloride (Cl)		20.0	20.0	
Sulfate (SO_4)		235.0	140.0	

TABLE 23 Continued

Sample Site: S-38
Location: Quitchupah Creek
Dates of Collection: 10/26/77, 2/9/78, 4/13/78, and 7/27/78
Source of Data: Owili-Eger

	10/26/77	2/9/78	4/13/78	7/27/78
GENERAL CHARACTERISTICS				
Hardness, total	1060.0	445.0	210.0	590.0
Iron, total (Fe)	0.4	0.2	1.3	0.1
pH, lab (units)	7.7	8.1	8.0	7.8
Sp. conductance, lab (μmhos/cm at 25°C)	2500.0	545.0	610.0	1440.0
Discharge (cfs)	0.50	4.27	17.87	0.80
Total dissolved solids (TDS)	2295.0	840.0	310.0	1195.0
Total suspended solids (TSS)	15.0	430.0	6130.0	100.0
CATIONS				
Calcium (Ca)	565.0	150.0	370.0	120.0
Magnesium (Mg)	495.0	20.0	37.0	63.0
Potassium (K)	7.0	11.0	3.0	4.0
Sodium (Na)	310.0	130.0	89.0	160.0
Sodium adsorption ratio (SAR)	2.3	2.6	1.2	2.9
ANIONS				
Bicarbonate (HCO_3)	320.0	250.0	185.0	240.0
Chloride (Cl)	70.0	10.0	5.0	25.0
Sulfate (SO_4)	1250.0	365.0	105.0	655.0

TABLE 23 Continued

Sample Site: S-39
Location: Quitchupah Creek
Dates of Collection: 10/26/77, 2/9/78, 4/13/78, and 7/27/78
Source of Data: Owili-Eger

	10/26/77	2/9/78	4/13/78	7/27/78
GENERAL CHARACTERISTICS				
Hardness, total	1035.0	490.0	200.0	350.0
Iron, total (Fe)	0.3	0.2	1.2	0.1
pH, lab (units)	7.2	8.1	8.0	7.9
Sp. conductance, lab (μmhos/cm at 25°C)	2700.0	600.0	620.0	1325.0
Discharge (cfs)	0.90	4.02	22.00	0.65
Total dissolved solids (TDS)	2360.0	880.0	310.0	1075.0
Total suspended solids (TSS)	125.0	1140.0	6460.0	100.0
CATIONS				
Calcium (Ca)	500.0	130.0	320.0	110.0
Magnesium (Mg)	535.0	40.0	34.0	57.0
Potassium (K)	7.0	17.0	3.0	4.0
Sodium (Na)	325.0	130.0	72.0	140.0
Sodium adsorption ratio (SAR)	2.4	2.6	1.0	2.7
ANIONS				
Bicarbonate (HCO_3)	365.0	250.0	190.0	225.0
Chloride (Cl)	70.0	10.0	5.0	20.0
Sulfate (SO_4)	1150.0	370.0	110.0	600.0

TABLE 23 Continued

Sample Site: S-40
Location: Quitchupah Creek Tributary Below Settling Pond
Dates of Collection: 10/26/77, 2/9/78, 4/13/78, and 7/27/78
Source of Data: Owili-Eger

	10/26/77	2/9/78	4/13/78	7/27/78
GENERAL CHARACTERISTICS				
Hardness, total	1085.0	830.0	745.0	760.0
Iron, total (Fe)	0.1	0.2	0.1	0.1
pH, lab (units)	8.2	8.3	8.3	8.6
Sp. conductance, lab (µmhos/cm at 25°C)	5000.0	2340.0	4865.0	4645.0
Discharge (cfs)				
Total dissolved solids (TDS)	4455.0	4060.0	3850.0	3910.0
Total suspended solids (TSS)	60.0	1.0	1.0	100.0
CATIONS				
Calcium (Ca)	425.0	160.0	130.0	82.0
Magnesium (Mg)	660.0	110.0	140.0	120.0
Potassium (K)	10.0	7.0	7.0	8.0
Sodium (Na)	750.0	960.0	990.0	1100.0
Sodium adsorption ratio (SAR)	5.3	14.3	14.4	18.1
ANIONS				
Bicarbonate (HCO_3)	390.0	390.0	405.0	440.0
Chloride (Cl)	160.0	140.0	135.0	130.0
Sulfate (SO_4)	2350.0	2280.0	2270.0	2095.0

TABLE 23 Continued

Sample Site: S-26
Location: Quitchupah Creek
Dates of Collection: 10/26/77, 2/9/78, 4/13/78, and 7/27/78
Source of Data: Owili-Eger

	10/26/77	2/9/78	4/13/78	7/27/78
GENERAL CHARACTERISTICS				
Hardness, total	1230.0	445.0	210.0	1130.0
Iron, total (Fe)	1.8	0.2	0.9	0.6
pH, lab (units)	7.8	8.1	8.0	7.9
Sp. conductance, lab (μmhos/cm at 25°C)	4250.0	545.0	820.0	2255.0
Discharge (cfs)	1.12	3.87	14.84	2.45
Total dissolved solids (TDS)	4040.0	840.0	500.0	2070.0
Total suspended solids (TSS)	60.0	430.0	6810.0	2920.0
CATIONS				
Calcium (Ca)	550.0	150.0	390.0	140.0
Magnesium (Mg)	680.0	20.0	44.0	82.0
Potassium (K)	10.0	11.0	3.0	6.0
Sodium (Na)	730.0	130.0	110.0	480.0
Sodium adsorption ratio (SAR)	4.9	2.6	1.4	8.0
ANIONS				
Bicarbonate (HCO_3)	335.0	250.0	195.0	250.0
Chloride (Cl)	135.0	10.0	10.0	60.0
Sulfate (SO_4)	2100.0	365.0	195.0	1145.0

TABLE 24

RESULTS OF A WATER QUALITY TREND STUDY
ON CHRISTIANSEN WASH, 1977-1978

Sample Site: S-32
Location: Christiansen Wash
Dates of Collection: 10/25/77, 2/8/78, 4/12/78, and 7/26/78
Source of Data: Owili-Eger

	10/25/77	2/8/78	4/12/78	7/26/78
GENERAL CHARACTERISTICS				
Hardness, total	2630.0	1150.0	470.0	1305.0
Iron, total (Fe)	0.8	0.2	1.0	0.1
pH, lab (units)	7.7	8.1	7.8	7.8
Sp. conductance, field (μmhos/cm at 25°C)				
Sp. conductance, lab (μmhos/cm at 25°C)	4250.0	1180.0	1180.0	2280.0
Discharge (cfs)	0.13	0.23	0.52	0.44
Total dissolved solids (TDS)	5020.0	2290.0	915.0	2420.0
Total suspended solids (TSS)	100.0	15.0	4540.0	100.0
CATIONS				
Calcium (Ca)	1125.0	350.0	300.0	300.0
Magnesium (Mg)	1505.0	70.0	65.0	170.0
Potassium (K)	10.0	4.0	5.0	
Sodium (Na)	380.0	200.0	120.0	
Sodium adsorption ratio (SAR)	1.7	2.6	1.6	1.5
ANIONS				
Bicarbonate (HCO_3)	420.0	310.0	210.0	310.0
Chloride (Cl)	50.0	10.0	5.0	25.0
Sulfate (SO_4)	2300.0	1260.0	435.0	1320.0

TABLE 24 Continued

Sample Site: S-33
Location: Christiansen Wash
Dates of Collection: 10/25/77, 2/8/78, 4/12/78, and 7/26/78
Source of Data: Owili-Eger

	10/25/77	2/8/78	4/12/78	7/26/78
GENERAL CHARACTERISTICS				
Hardness, total	3825.0	230.0	990.0	745.0
Iron, total (Fe)	0.6	0.2	2.4	0.1
pH, lab (units)	7.9	8.1	8.0	8.0
Sp. conductance, field (μmhos/cm at 25°C)				
Sp. conductance, lab (μmhos/cm at 25°C)	8400.0	3190.0	2995.0	1960.0
Discharge (cfs)	0.22	0.40	0.56	1.68
Total dissolved solids (TDS)	10950.0	6880.0	2580.0	1710.0
Total suspended solids (TSS)	160.0	100.0	2290.0	100.0
CATIONS				
Calcium (Ca)	1250.0	520.0	320.0	120.0
Magnesium (Mg)	2575.0	240.0	170.0	100.0
Potassium (K)	15.0	14.0	7.0	7.0
Sodium (Na)	1500.0	1100.0	380.0	280.0
Sodium adsorption ratio (SAR)	5.6	10.0	4.3	4.6
ANIONS				
Bicarbonate (HCO_3)	410.0	292.0	275.0	280.0
Chloride (Cl)	90.0	140.0	50.0	35.0
Sulfate (SO_4)	6250.0	3910.0	1605.0	890.0

TABLE 24 Continued

Sample Site: S-34
Location: Christiansen Wash
Dates of Collection: 10/25/77, 2/8/78, 4/12/78, and 7/26/78
Source of Data: Owili-Eger

	10/25/77	2/8/78	4/12/78	7/26/78
GENERAL CHARACTERISTICS				
Hardness, total	3805.0	235.0	1035.0	735.0
Iron, total (Fe)	0.4	0.2	1.8	0.1
pH, lab (units)	8.0	8.1	8.1	8.1
Sp. conductance, field (μmhos/cm at 25°C)				
Sp. conductance, lab (μmhos/cm at 25°C)	8500.0	3180.0	3050.0	2070.0
Discharge (cfs)	0.27	0.32	0.60	0.98
Total dissolved solids (TDS)	9685.0	7030.0	2720.0	1790.0
Total suspended solids (TSS)	225.0	30.0	1080.0	100.0
CATIONS				
Calcium (Ca)	1250.0	550.0	230.0	130.0
Magnesium (Mg)	2555.0	250.0	170.0	110.0
Potassium (K)	15.0	12.0	7.0	7.0
Sodium (Na)	1500.0	1300.0	400.0	350.0
Sodium adsorption ratio (SAR)	5.6	11.5	4.9	5.5
ANIONS				
Bicarbonate (HCO_3)	440.0	420.0	285.0	280.0
Chloride (Cl)	200.0	130.0	40.0	35.0
Sulfate (SO_4)	6000.0	4080.0	1745.0	940.0

TABLE 24 Continued

Sample Site: S-35
Location: Christiansen Wash
Dates of Collection: 10/25/77, 2/8/78, 4/12/78, and 7/26/78
Source of Data: Owili-Eger

	10/25/77	2/8/78	4/12/78	7/26/78
GENERAL CHARACTERISTICS				
Hardness, total	805.0	1040.0	940.0	805.0
Iron, total (Fe)	0.2	0.2	0.1	0.1
pH, lab (units)	8.0	8.1	8.1	7.8
Sp. conductance, field (µmhos/cm at 25°C)		1280.0	2405.0	1735.0
Sp. conductance, lab (µmhos/cm at 25°C)	2000.0			
Discharge (cfs)				
Total dissolved solids (TDS)	1995.0	2370.0	2100.0	1475.0
Total suspended solids (TSS)	25.0	1.0	1.0	100.0
CATIONS				
Calcium (Ca)	290.0	260.0	160.0	130.0
Magnesium (Mg)	515.0	90.0	150.0	110.0
Potassium (K)	5.0	5.0	4.0	3.0
Sodium (Na)	165.0	290.0	250.0	140.0
Sodium adsorption ratio (SAR)	1.4	4.0	3.4	2.2
ANIONS				
Bicarbonate (HCO_3)	268.0	320.0	310.0	330.0
Chloride (Cl)	30.0	40.0	40.0	30.0
Sulfate (SO_4)	500.0	1310.0	1165.0	730.0

TABLE 24 Continued

Sample Site: S-16
Location: Christiansen Wash
Dates of Collection: 10/25/77, 2/8/78, 4/12/78, and 7/26/78
Source of Data: Owili-Eger

	10/25/77	2/8/78	4/12/78	7/26/78
GENERAL CHARACTERISTICS				
Hardness, total	1800.0	1830.0	1070.0	605.0
Iron, total (Fe)	0.4	0.2	2.0	0.1
pH, lab (units)	8.0	8.1	8.2	8.1
Sp. conductance, field (μmhos/cm at 25°C)				
Sp. conductance, lab (μmhos/cm at 25°C)	4500.0	2500.0	3040.0	1495.0
Discharge (cfs)	1.02	0.66	1.37	4.32
Total dissolved solids (TDS)	4936.0	5030.0	2710.0	1235.0
Total suspended solids (TSS)	110.0	50.0	805.0	100.0
CATIONS				
Calcium (Ca)	625.0	430.0	220.0	94.0
Magnesium (Mg)	1255.0	180.0	170.0	90.0
Potassium (K)	11.0	10.0	7.0	5.0
Sodium (Na)	650.0	760.0	390.0	160.0
Sodium adsorption ratio (SAR)	3.5	7.8	4.8	2.8
ANIONS				
Bicarbonate (HCO_3)	315.0	360.0	290.0	210.0
Chloride (Cl)	90.0	100.0	50.0	20.0
Sulfate (SO_4)	2300.0	2700.0	1655.0	680.0

Between S-33 and S-34, TDS remained about the same except for a lower fall value. Site S-35 is a spring fed tributary whose discharge was estimated via the difference in flow between gaging stations 3 and 4 (see Figure 12). Note that the TDS and estimated discharge are nearly constant at site S-35. At site S-16, Christiansen Wash has increased in discharge while TDS decreased in all samples except the April 1978 sample. TSS along Christiansen Wash is generally less than 100 ppm in all seasons except spring when samples containing 4,540 ppm at S-32, 290 ppm at S-33, 1,080 ppm at S-34, and 805 ppm at S-16 were collected.

Figure 13 is a graphical representation of water quality trends along Quitchupah Creek. Site S-36 shows a very high TDS value for fall probably due to runoff and seepage from irrigated farmland and Bluegate Shale; the discharge at this site is a very rough estimate calculated by the difference in discharges at gaging stations 7 and 8. The general trend along Quitchupah Creek indicates that TDS generally increases slightly between S-37 and S-39 in fall and winter and decreases slightly in the spring and summer. Site S-40 is on the unnamed tributary to Quitchupah Creek into which the Emery Mine settling pond discharges. Owili-Eger's data indicate a fairly constant TDS between 3,850 and 4,455 mg/ℓ at site S-40. The discharge at S-40, calculated by the difference between gaging stations 10 and 11, also remains fairly constant in relation to the main stream of Quitchupah Creek. At site S-26, TDS increased in all seasons. TSS trends along Quitchupah Creek reflect streamflow trends; the suspended load is greatest in spring and least in fall and generally increases downstream; at S-26, TSS in April is about 6,810 ppm while in the fall, TSS is 60 ppm.

In summary, there is an abundance of surface water quality data for the Emery Mine area which have been collected over the past five years. The most recent water quality information on Quitchupah Creek and Christiansen Wash was obtained this October, 1979. As part of Consol's surface water monitoring program for the Emery Mine (see Section 6.3 for details), monitoring sites as indicated on Plate 2 have been established for monthly water quality sampling. From the results summarized in Table 25 and graphically presented in Figure 18, it is clear that conclusions drawn from the previously cited studies on water quality types and trends for both Quitchupah Creek and Christiansen Wash are substantiated.

Quitchupah Creek water is generally characterized by the following dominant ions in order of decreasing concentration (me/ℓ): SO_4, Na, Ca, Mg, HCO_3, and Cl. In general, Quitchupah Creek becomes more saline downstream with increasing SO_4 and Na concentrations. As indicated on Figure 18, Quitchupah Creek's water quality noticeably deteriorates between site 1 and 4 where the unnamed tributary into which Emery Mine discharge water confluences with Quitchupah Creek.

TABLE 25

SURFACE WATER MONITORING SITE WATER QUALITY, OCTOBER 1979

Sample Site:	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 8
Location:	See Plate						
Date of Collection:	10/26/79	10/26/79	10/26/79	10/26/79	10/26/79	10/26/79	10/26/79
PARAMETERS[1]							
Acidity, total	0	0	0	0	0		0
Alkalinity, total ($CaCO_3$)	316	389	339	341	351		676
Bicarbonate (HCO_3)	375	453	398	378	410		750
Calcium (Ca)	171	290	164	138	218		512
Carbonate (CO_3)	3.74	8.74	6.24	7.49	7.49		33.7
Chloride (Cl)	37.2	153	77.6	78.8	92		1812
Fluoride (F)	0.52	0.51	0.68	0.70	0.76		0.48
Hardness (noncarbonate)	616	2122	797	561	1194		6924
Hardness, total ($CaCO_3$)	994	2584	1201	946	1611		7708
Iron, dissolved (Fe)	0.03	0.00	0.00	0.00	0.00		0.00
Iron, total (Fe)	0.50	0.745	0.43	0.51	0.29	0.15	0.225
Magnesium (Mg)	128	421	175	126	162		1352
Manganese, total (Mn)	0.016	0.086	0.021	0.014	0.029	0.014	0.133
Nitrate + Nitrite (NO_4 + NO_3)	2.448	26.9	9.487	2.448	17.556		82.86
Oil and grease	1.2	0.4	0.2	0.4	0.4		0.8
pH (units)	7.9	8.1	8.1	8.05	8.25	8.3	8.2
Phosphate, total (PO_4)	0.02	0.015	0.015	0.026	0.036		0.04
Potassium (K)	5.0	15	6.6	5.8	8.0		38.0
Silica (SiO_2)	8.5	8.9	11.75	10.25	15.0		2.6
Sodium (Na)	363	1360	600	580	648		10000
Sodium adsorption ratio (SAR)	5.1	5.1	7.8	8.57	19.98		147
Strontium (Sr)	3.26	5.07	4.94	4.7	4.12		11.5
Sulfate (SO_4)	1275	4530	1320	1675	1740		23000
Total dissolved solids (TDS)	2226	7150	3248	2734	4148	3352	39386
Total suspended solids (TSS)	21.8	27.4	18.0	21.8	15.8	1.0	3.0
FIELD PARAMETERS							
Air temperature (°C)	21	11	22	21	21	16	16
Conductance (μmhos/cm at 25°C)	2856	8443	4070	3721	4939	4768	733000
Oxygen, dissolved (DO)	12.1	10	11.7	11.1	11.7	9.4	12.3
pH (units)	8.4	8.2	8.6	8.5	8.6	8.5	8.5
Stream flow (cfs)	1.05	0.39	3.08	Pending	Pending	0.94	0.001
Water temperature (°C)	4.7	3.2	6.5	6.1	5.7	8.5	5.3

[1] All measurements are in milligrams per liter (mg/ℓ) unless otherwise noted.

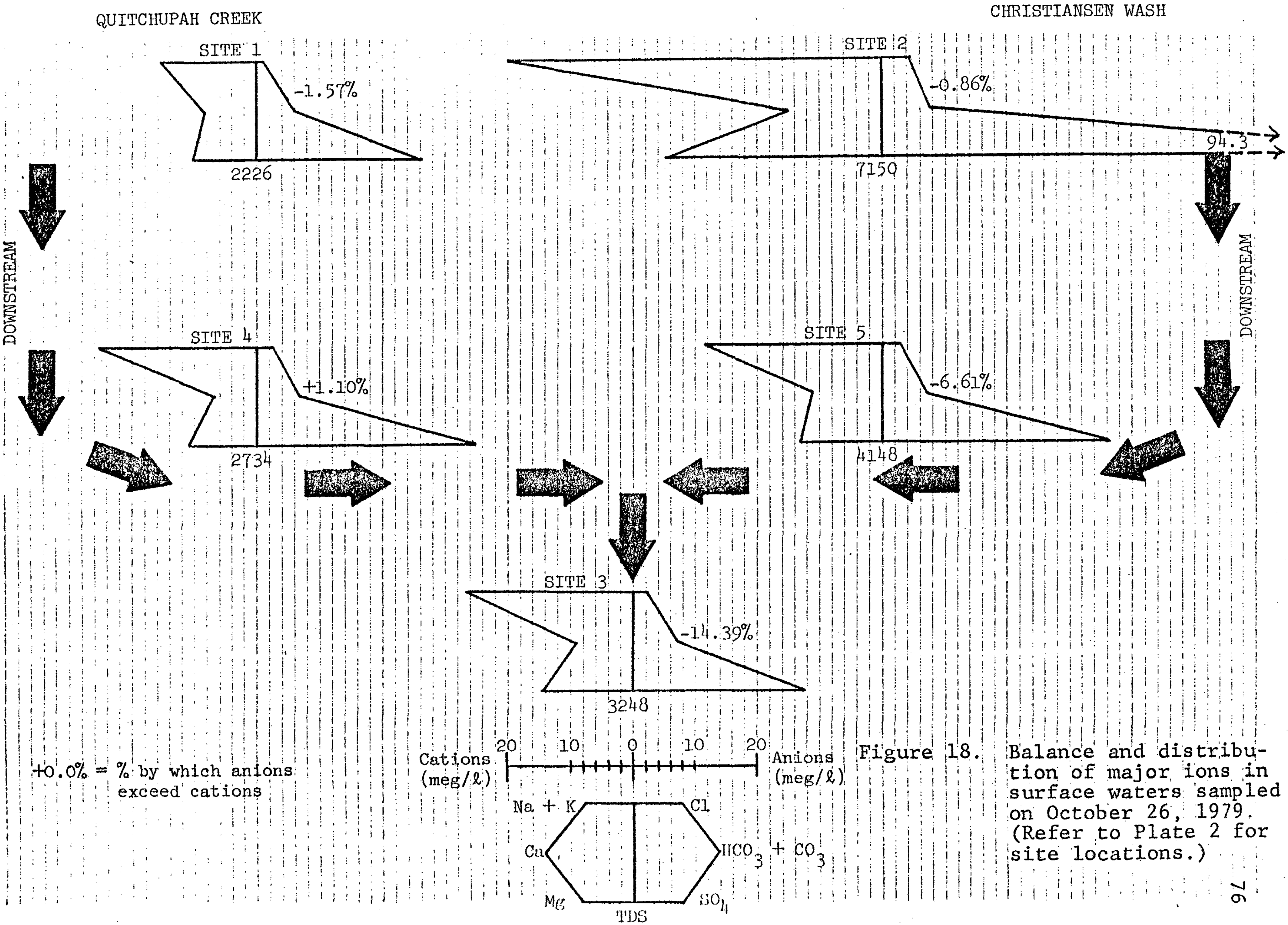


Figure 18. Balance and distribution of major ions in surface waters sampled on October 26, 1979. (Refer to Plate 2 for site locations.)

Other important factors which affect and control water quality type and trends on Quitchupah Creek are runoff and seepage caused by farm irrigation, runoff from the saline Bluegate Shale, and ground water discharge from the Ferron Sandstone.

Christiansen Wash's waters are characterized by the same regime of chemical constituents as Quitchupah Creek, however TDS values are two to three times greater than those of Quitchupah Creek's. Christiansen Wash generally deteriorates in water quality throughout its upper reaches due to runoff from the saline Bluegate Shale. In its lower reaches, Christiansen Wash generally improves in water quality due to ground water inflow from the Ferron Sandstone and pediment gravels.

6.3 Surface Water Monitoring Program

6.3.1 Monitoring Sites

The USGS, Division of Water Resources, has been and is presently conducting a surface and ground water monitoring program in the vicinity of the existing Emery Mine. The purpose of this monitoring program is to generate regional environmental data for the Energy Minerals Resource Inventory Assessment (EMRIA) study.

The USGS initiated the surface water monitoring program in the spring of 1978 by installing a continuous-recorder bubble-type gaging station immediately upstream of the Emery Mine on both Christiansen Wash and Quitchupah Creek. In

August 1978, the USGS began collecting water samples for chemical analyses at both these stations. In addition, the USGS is performing a stream gain-loss (seepage run) study on Quitchupah Creek and Christiansen Wash (fall 1979). Stream discharges at various locations on each creek are monitored at least twice a year. Water samples are collected for chemical analyses in August at two sites, one of which is the unnamed tributary into which the Emery Mine effluent is discharged.

Since the USGS intends to stop collecting surface water data at the end of this year (1979), Consol is presently negotiating with the USGS in Salt Lake City to take over operation of the gaging stations (sites S-4 and S-5) on Christiansen Wash and Quitchupah Creek (see Plate 2). Both of these gaging stations are well situated to measure any potential impacts to streams from discharges produced by the Emery Mine.

Consol will install three Parshall flumes and crest stage gages at sites S-1, S-2, and S-3 as indicated on Plate 2. A Parshall flume with a two-foot throat width and a continuous recorder at site S-1 will be used to measure stream discharge on Quitchupah Creek above the influence of the Emery Mine effluent which is discharged into an unnamed tributary to Quitchupah Creek. A two-foot flume can measure discharges of 0.66 to 16.58 cubic feet per second (cfs); this is a normal range of discharge indicated by available data. A crest stage gage will be used to measure peak discharge from any flood events. In addition, a grab-sample monitoring site (S-8) has been established on the unnamed tributary immediately upstream from where the Emery Mine effluent is being discharged. A crest stage gage will also be installed at this monitoring site.

Consol has installed a nine-inch throat Parshall flume with a continuous recorder on Christiansen Wash (shown as site S-2 on Plate 2). A nine-inch flume can measure discharges of 0.09 to 6.3 cfs; this range of discharge is indicated by available data. The flume will be accompanied by a crest stage gage. This flume location is selected for two reasons. First, it is upstream of the outcrop of the Ferron Sandstone. The Ferron Sandstone is the major aquifer in the vicinity, and it apparently discharges relatively good water into Christiansen Wash. Available data indicate mine pumpage is lowering the potentiometric surface of the Ferron Sandstone aquifer in proximity to the Emery Mine; therefore, the Emery Mine may be influencing stream discharge in Christiansen Wash by reducing ground water inflow. The nine-inch flume at site S-2 will provide data on stream discharge trends prior to any mine influence. The second reason for locating a flume at this site is that it is easily accessible.

Consol has installed a continuously recording two-foot Parshall flume with accompanying crest stage gage at site S-3 on Quitchupah Creek below its confluence with Christiansen

Wash. A two-foot flume will measure normal stream discharge anticipated in this reach of Quitchupah Creek. This flume would measure all stream discharge below the influence of the mining operations.

Two additional sites (S-6 and S-7 on Plate 2) will be monitored under NPDES permit stipulations. Site S-6 is the outfall of the sedimentation pond for the ground water inflow into the underground workings. A continuous flow monitoring recorder will be installed at the outfall of the pond. Site S-7 is the outfall of the sedimentation pond for drainage from the surface facilities area at the mine.

6.3.2 Monitoring Parameters and Schedule

<u>Stream Monitoring Sites (S-1 through S-5)</u>

Each of the five sites will be monitored monthly by a trained Consol technician. During each monthly monitoring period, the continuous recorder and crest stage gage will be inspected, serviced as needed, and the data retrieved; field measurements of water temperature, pH, dissolved oxygen, and specific conductivity will be taken; air temperature and weather conditions will be noted; and grab samples will be collected to determine iron, manganese, pH, sulfate, total dissolved solids and total suspended solids. Each quarter, grab samples will be collected to determine the following additional constituents: total acidity, alkalinity, bicarbonate, calcium, carbonate, chloride, dissolved iron, fluoride, non-bicarbonate hardness, total hardness, magnesium, nitrate and nitrite, oil and grease, phosphate, potassium, silicate, sodium, sodium adsorption ratio, and strontium. Table 26 summarizes the parameters and schedule of monitoring for the stream monitoring sites.

NPDES Discharge Points (Sites S-6 and S-7)

Both sites will be monitored in accordance with NPDES Permit No. UT-0022616. Each month the site will be visited to retrieve flow data from the continuous recorder to inspect the effluent for oil and grease sheen, and to collect grab samples for determination of pH, TDS, TSS, total iron, and total manganese.

Site S-6 is the outfall for the sedimentation pond exclusively receiving mine discharge waters. On a quarterly basis, concurrent with the sampling of the stream sites (S-1 through S-5), samples from site S-6 will be collected to determine the full suite of chemical constituents listed in Table 26.

Grab Sampling Site (S-8)

On a quarterly basis, concurrent with the sampling of the stream sites (S-1 through S-5), samples from site S-8 will be collected to determine the full suite of chemical constituents listed in Table 26.

TABLE 26

SURFACE WATER MONITORING PARAMETERS AND FREQUENCY

MONTHLY PARAMETERS	
Air temperature (°C)	Field
Dissolved oxygen (DO)	Field
*Iron (total Fe)	Lab
*Manganese (total Mn)	Lab
Oil and grease	Lab
*pH	Field and Lab
Specific conductivity (EC)	Field
*Stream flow (cfs)	Field (recorder)
Sulfate (total SO_4)	Lab
*Total dissolved solids (TDS)	Lab
*Total suspended solids (TSS)	Lab
Water temperature (°C)	Field
ADDITIONAL QUARTERLY PARAMETERS	
Acidity, total	Lab
Alkalinity, total	Lab
Bicarbonate (total HCO_3)	Lab
Calcium (total Ca)	Lab
Carbonate (total CO_3)	Lab
Chloride (total Cl)	Lab
Dissolved iron	Lab
Fluoride (total F)	Lab
Hardness (noncarbonate)	Lab
Hardness (total)	Lab
Magnesium (total Mg)	Lab
Nitrate + Nitrite (NO_4 + NO_3)	Lab
Oil and grease	Lab
Phosphate (total PO_4)	Lab
Potassium (total K)	Lab
Silicate (total SiO_4)	Lab
Sodium adsorption ratio (SAR)	Lab
Sodium (total Na)	Lab
Strontium (total Sr)	Lab

*NPDES Permit No. UT-22616 data requirements.

6.3.3 Sampling, Lab Analysis, and Reporting Procedures

At each sample site, a trained Consol technician will take field measurements of water temperature, pH, dissolved oxygen, and specific conductivity with appropriate calibrated portable meters. Air temperature and weather conditions will also be noted. The Consol technician will collect two one-liter samples at each site during monthly sampling periods. One sample will be collected raw and acidified to a pH of less than 2.0. The second sample will be collected raw and untreated. A third sample will be collected during quarterly sampling periods, field filtered, and acidified to a pH of less than 2.0. The sample bottles will be filled completely full to minimize water-air ion exchange. These samples will be properly labeled with the site number, date, whether it is a quarterly, monthly, or NPDES sample, time of collection, and technician's initials. These samples will be refrigerated immediately to 4°C via ice and will remain refrigerated until delivered to a laboratory registered with the Environmental Protection Agency. The samples will be delivered to the laboratory within three days to assure analytical accuracy. The laboratory will analyze for all parameters listed in Table 26 except those indicated as "Field" according to whether it is a monthly, quarterly, or NPDES sample. The methods for collecting water samples and performing analyses are outlined in the Environmental Protection Agency's <u>Manual of Methods for Chemical Analysis of Water and Wastes</u> (1976).

Consol will maintain a surface water monitoring activities log book at the mine office. This log book will contain dates of instrument calibration, discharge records, field data, and results of chemical analysis. Within 30 days after the end of each calendar quarter, Consol will forward to the Utah Division of Oil, Gas, and Mining a copy of all monitoring data, a copy of the NPDES discharge report, and a summary of monitoring data and activities.

6.4 Surface Water Rights

Surface water rights information was requested on December 5, 1979, from the Utah State Engineer's Office, Division of Water Rights, Salt Lake City, Utah. When the information is received, it will be immediately appended to this report.

7.0 GROUND WATER RESOURCES

7.1 Regional Ground Water Characteristics

According to Price (1972), Castle Valley has been classified as an area having well yields of generally less than 10 gpm. Some wells, however, which penetrate more permeable zones may yield as much as a few hundred gallons per minute. Water quality generally ranges from 250 to 1,000 mg/ℓ in TDS. These data obtained from well records collected by the USGS and other cooperating State, local, and Federal agencies are for the Ferron Sandstone member of the Mancos

Shale. The Ferron Sandstone occurs generally less than 1,000 feet below the land surface in the Emery area and contains the IJ coal seam which is presently being mined (see Section 5.0, Geology).

7.2 Site Specific Ground Water Characteristics

7.2.1 Aquifers

7.2.1.1 Quaternary Deposits

A minor, shallow aquifer is contained within the Quaternary alluvium and river terrace deposits scattered throughout the Emery area (see Figure 6). The boundaries of this minor unconfined aquifer are clearly defined by the limits of the Quaternary deposits. Recharge to this aquifer is sustained by the almost constant irrigation activity practices by the local farmers.

Numerous springs can be seen flowing continuously from the contact of the Quaternary deposits and the Bluegate Shale (see Section 7.2.7 and Plate 5). Because of the rolling topography of the Bluegate Shale, water flowing from some of these springs becomes trapped in swales creating "alkali swamps."

The ground water in the unconfined aquifer is not used for consumptive purposes because of its relatively saline quality. Cattle, on the other hand, do drink from the springs. A discussion of water quality is presented in a following section.

7.2.1.2 Ferron Sandstone

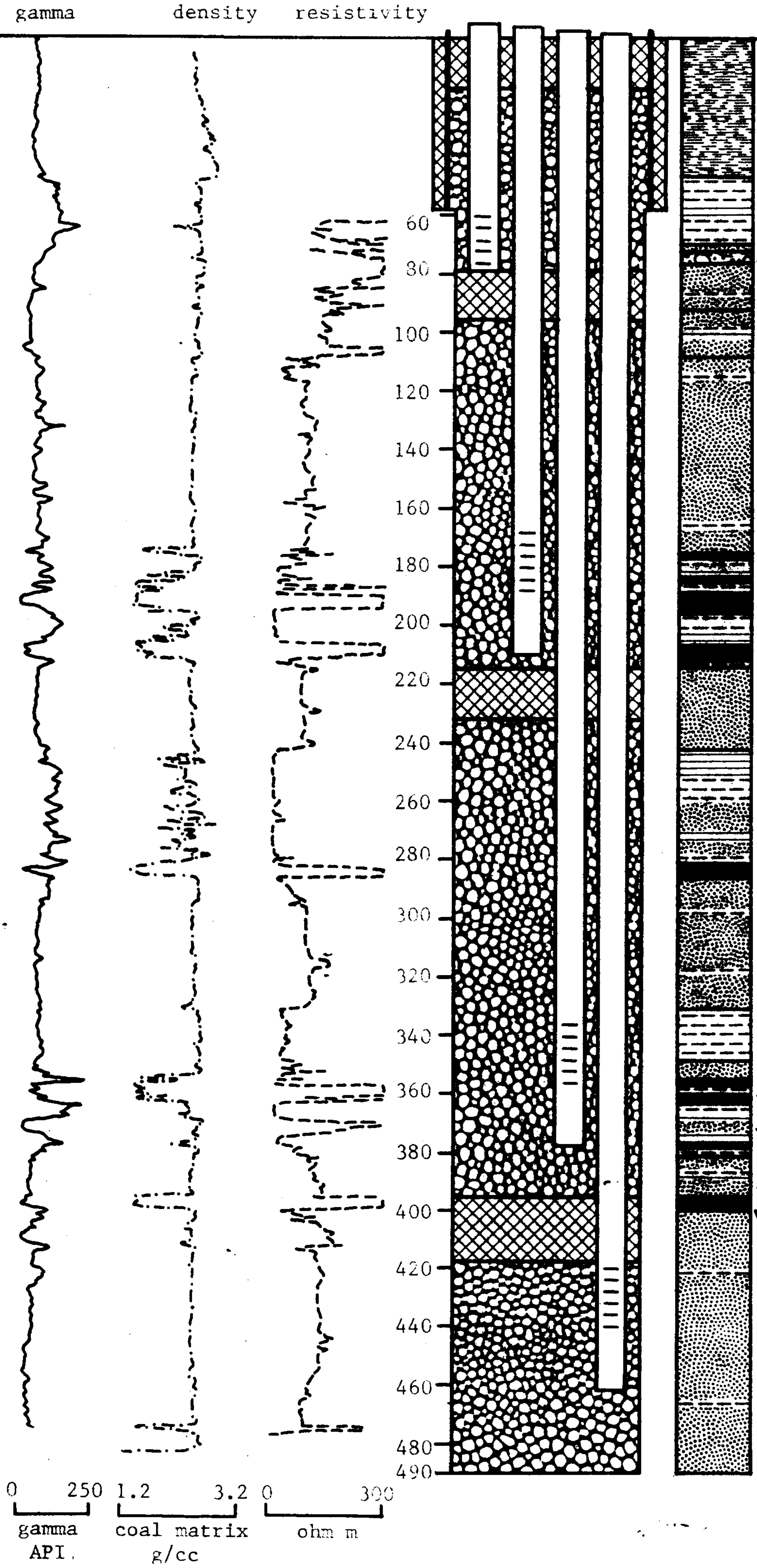
Ground water in the area of the Emery Mine is contained in the permeable Ferron Sandstone member of the Mancos Shale. The Ferron Sandstone is confined above by the Bluegate Shale and is believed to be confined below by the Tununk Shale. Section 5.2 of this report presents data which characterize the Ferron Sandstone deposits. These data are supplemented with lithologic and geophysical data presented in Figures 19 through 23 for the five recently (fall, 1979) drilled hydrological monitoring wells, wells H, I, R, AA, and ZZ (see Plate 2 for locations). Ground water characteristics of the Ferron Sandstone are discussed in detail in the sections that follow.

7.2.2 Aquifer Characteristics

Several aquifer tests were conducted by the USGS, Salt Lake City personnel. These tests were conducted using existing wells, and wells installed by the USGS under their obligations to the EMRIA investigation being conducted by the Bureau of Land Management. The drawdown and recovery data from the several sites tested were provided to WATEC, Inc. on a provisional basis. These test results were analyzed by WATEC, and the coefficients of storage and transmissivity were calculated. These data are tabulated in Table 27. The data plots are included in the Appendix.

For the purpose of this investigation an average transmissivity of 3030 gpd/ft. and a storage coefficient of

Geophysical Logs | Well Completion | Lithologic Description



SOIL, clay.

SHALE, black, sandy, slightly to moderately fissile with minor interbedded CLAYSTONE, black and tan.

SANDSTONE, black, very fine to fine grained.

CONGLOMERATE, quartzose, rounded to subrounded pebbles.

SANDSTONE, light grey to black, very fine to medium grained, mostly well cemented with minor amount of black SHALE and PYRITE.

SANDSTONE, grey brown, very fine to fine grained, very well cemented with minor interbedded black and tan SHALE and CLAYSTONE.

SANDSTONE, salt and pepper, quartzose, fine to medium grained, friable, well rounded with SHALE at 115 and 165-166'.

COAL, vitreous, slightly pyritiferous with interbedded green-brown SHALE and MUDSTONE.

SHALE, brown-green and MUDSTONE, grey-brown with vitreous COAL at 205 and 206-212'.

SANDSTONE, grey, quartzose, very fine to fine grained, well cemented at top, decreasing downward.

MUDSTONE, grey, SHALE, grey-green and SANDSTONE, grey to white, very fine to fine grained.

COAL, vitreous.

SANDSTONE, grey, quartzose, fine to medium grained, friable and minor amount of green-brown SHALE.

SHALE, dark green-brown

SANDSTONE, dark green-brown to brown, very fine to fine grained, silty/shaley, well cemented.

COAL, vitreous, with SHALE partings at 356-357 and 361'.

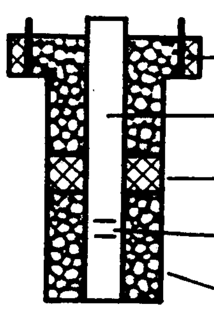
SHALE, grey-green, MUDSTONE, grey, SANDSTONE, light grey, quartzose, very fine to fine grained, well cemented and COAL, vitreous, at 377-378'.

SANDSTONE, green-brown to grey, very fine to fine grained with minor amounts of SHALE and MUDSTONE.

COAL, vitreous.

SANDSTONE, grey to white, quartzose, very fine to fine grained with very minor amount of green-brown SHALE and possible vitreous COAL at 474-475'.

LEGEND



vertical scale: 1" = 50'

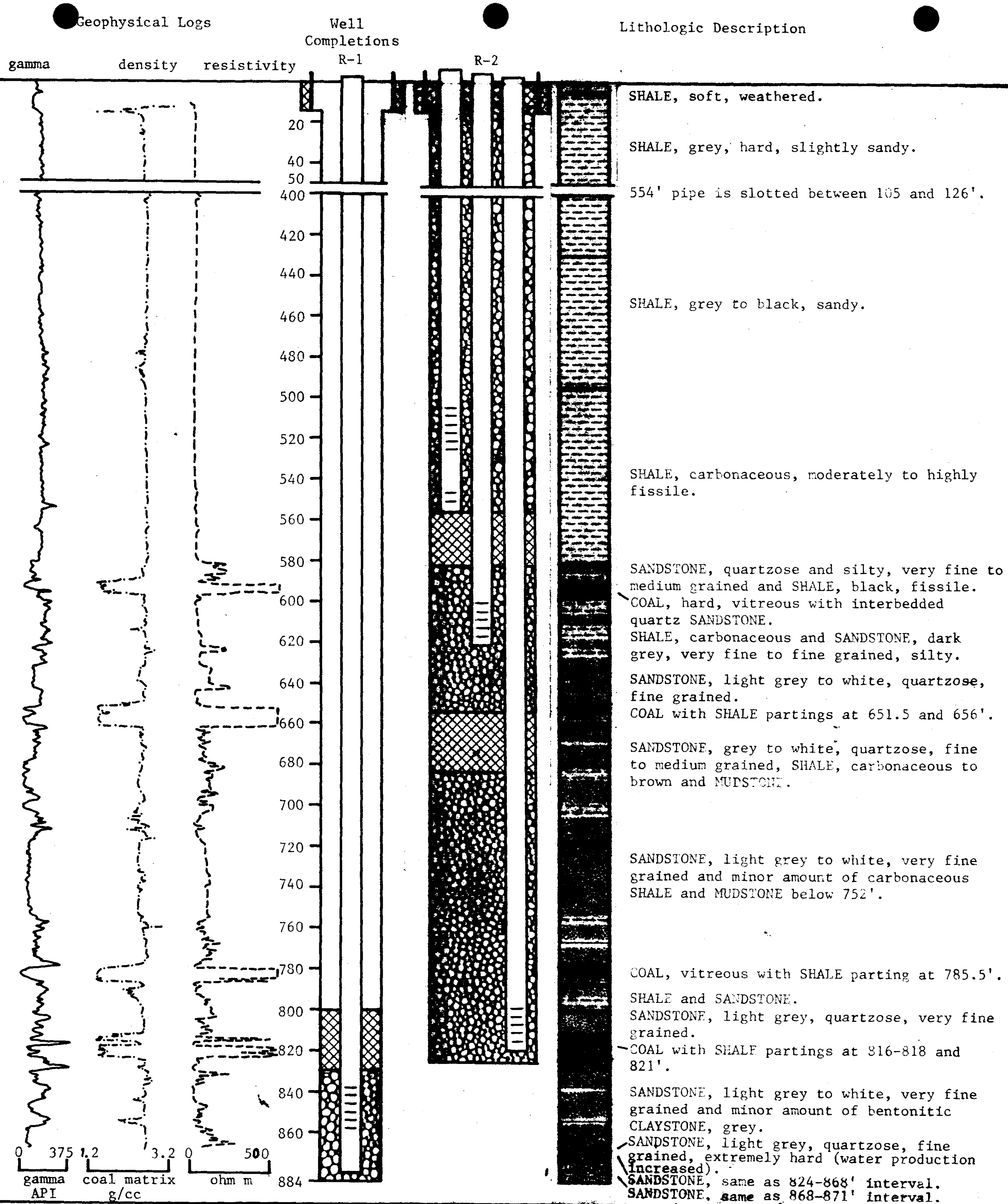
FIGURE 23
CONSOLIDATION COAL CO.

Emery Mine, Emery, Utah

Hydrogeologic Log

Well #AA

Prepared by Watec, Inc., December 1979.



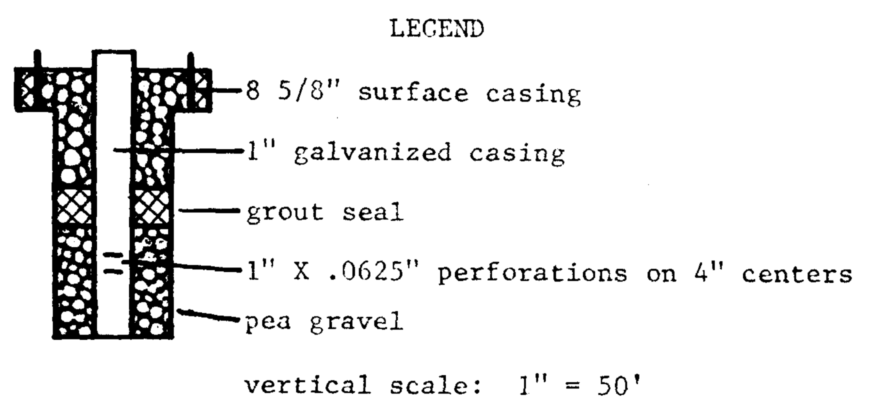


FIGURE 22

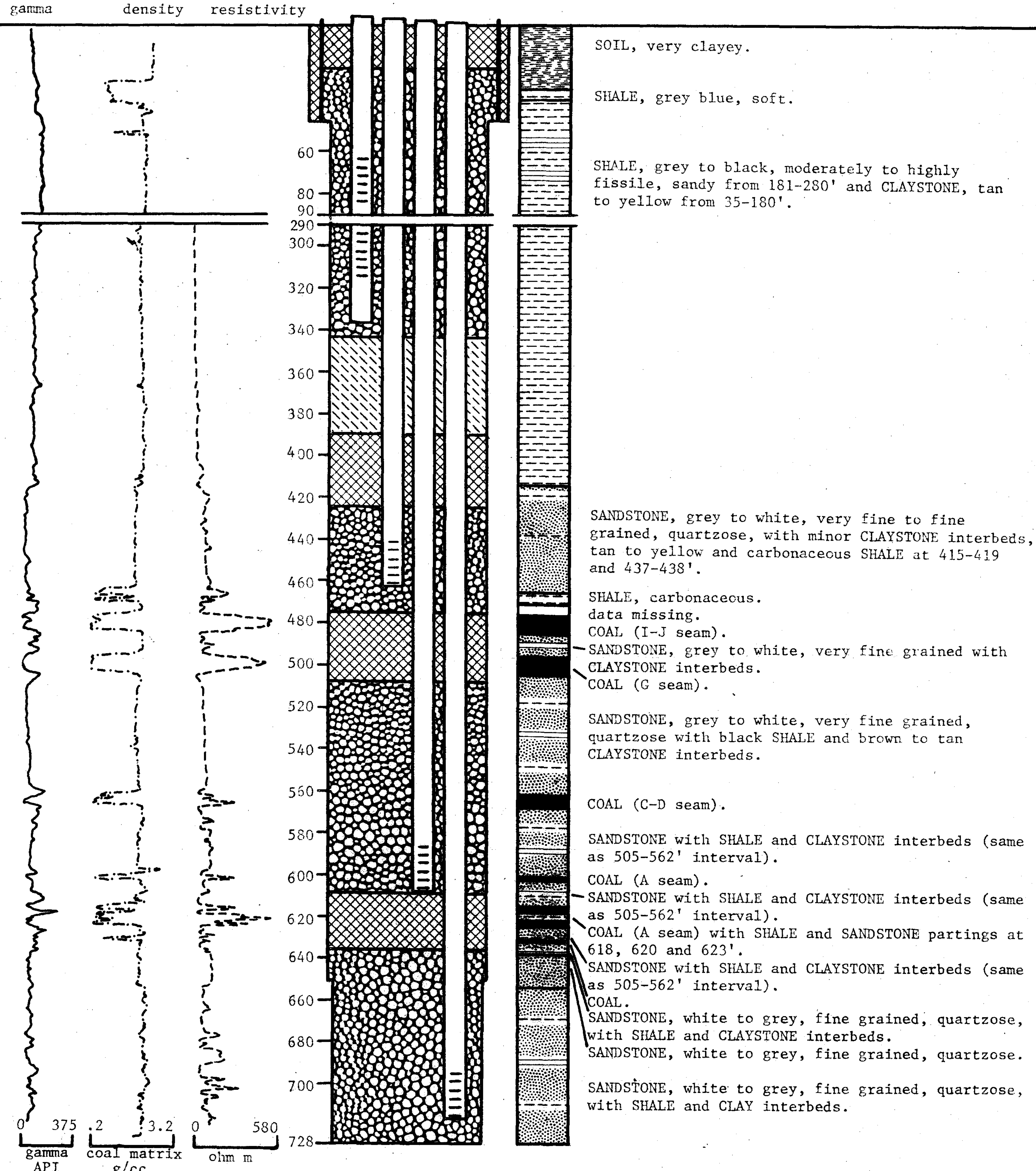
CONSOLIDATION COAL CO.

Emery Mine, Emery, Utah

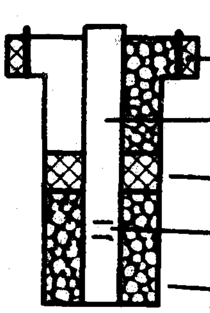
Hydrogeologic Log

Well #R-1 &
Well #R-2

Prepared by Watec, Inc., November 1979.



LEGEND



vertical scale: 1" = 50'

FIGURE 20

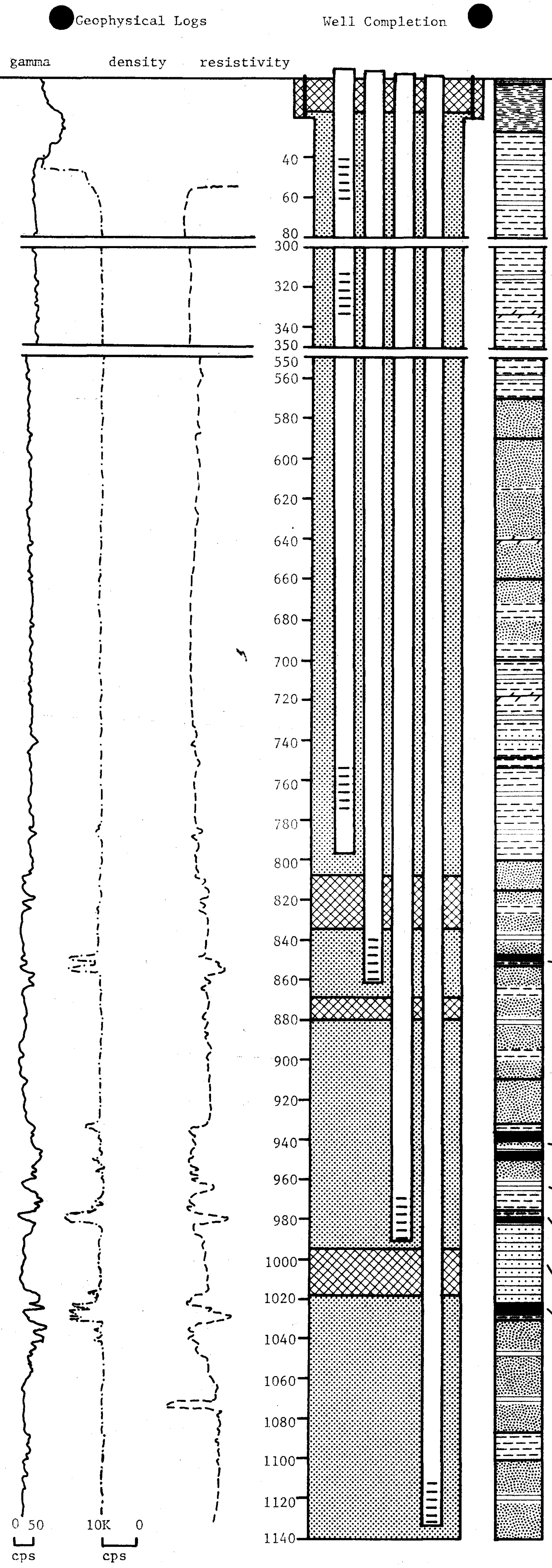
CONSOLIDATION COAL CO.

Emery Mine, Emery, Utah

Hydrogeologic Log

Well #I

Prepared by Watec, Inc., November 1979.



Lithologic Description

SOIL.

MUDSTONE, yellow.

SHALE, carbonaceous, silty below 190' with interbedded grey CLAY, brown CLAYSTONE and occassional banded, fibrous GYPSUM stringers.

SANDSTONE, black, silty, very fine grained.

SANDSTONE, dark grey to black, silty to clayey, very fine grained with occasional interbedded carbonaceous SHALE and GYPSUM/CALCITE stringers around 640'.

SILTSTONE, dark grey to black and SHALE, carbonaceous.

SHALE, dark grey to black, carbonaceous, CLAY, grey and CLAYSTONE, green with interbedded sandy SILTSTONE, black, fine grained and GYPSUM/CALCITE.

SHALE, black, silty.

SHALE, dark grey to black, carbonaceous, silty with interbedded brown CLAYSTONE and dark green SHALE.

SANDSTONE, grey to dark grey, silty, fine grained.

SANDSTONE, white, quartzose, fine to medium grained with interbedded green SHALE, brown CLAYSTONE and minor amount of PYRITE.

COAL (I-J seam), vitreous with black SHALE and SILTSTONE parting at 852'.

SANDSTONE, light grey to white, quartzose, with interbedded carbonaceous SHALE, green to tan CLAYSTONE and minor amount of GYPSUM.

SANDSTONE, light grey to white, quartzose, very fine to fine grained.

SHALE, carbonaceous.

COAL, (G seam), vitreous, SANDSTONE, light grey, very fine to fine grained, CLAYSTONE, tan to brown and carbonaceous SHALE.

SANDSTONE, grey, quartzose, micaceous, very fine to fine grained, CLAYSTONE, brown, platy and SHALE, blue grey.

SHALE, brown to black, carbonaceous, COAL (C-D seam) and minor amount of very fine to fine grained SANDSTONE.

SILTSTONE, grey green to green, sandy, well indurated.

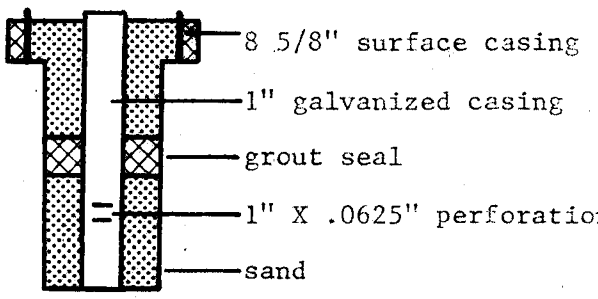
COAL (A seam), vitreous, with partings at 1024-1025, 1027 and 1029'.

SANDSTONE, light grey, quartzose, micaceous, with interbedded tan to brown CLAYSTONE and minor amounts of carbonaceous SHALE and COAL.

SHALE

SANDSTONE with interbedded CLAYSTONE, same as 1031-1087' interval.

LEGEND



vertical scale: 1" = 50'

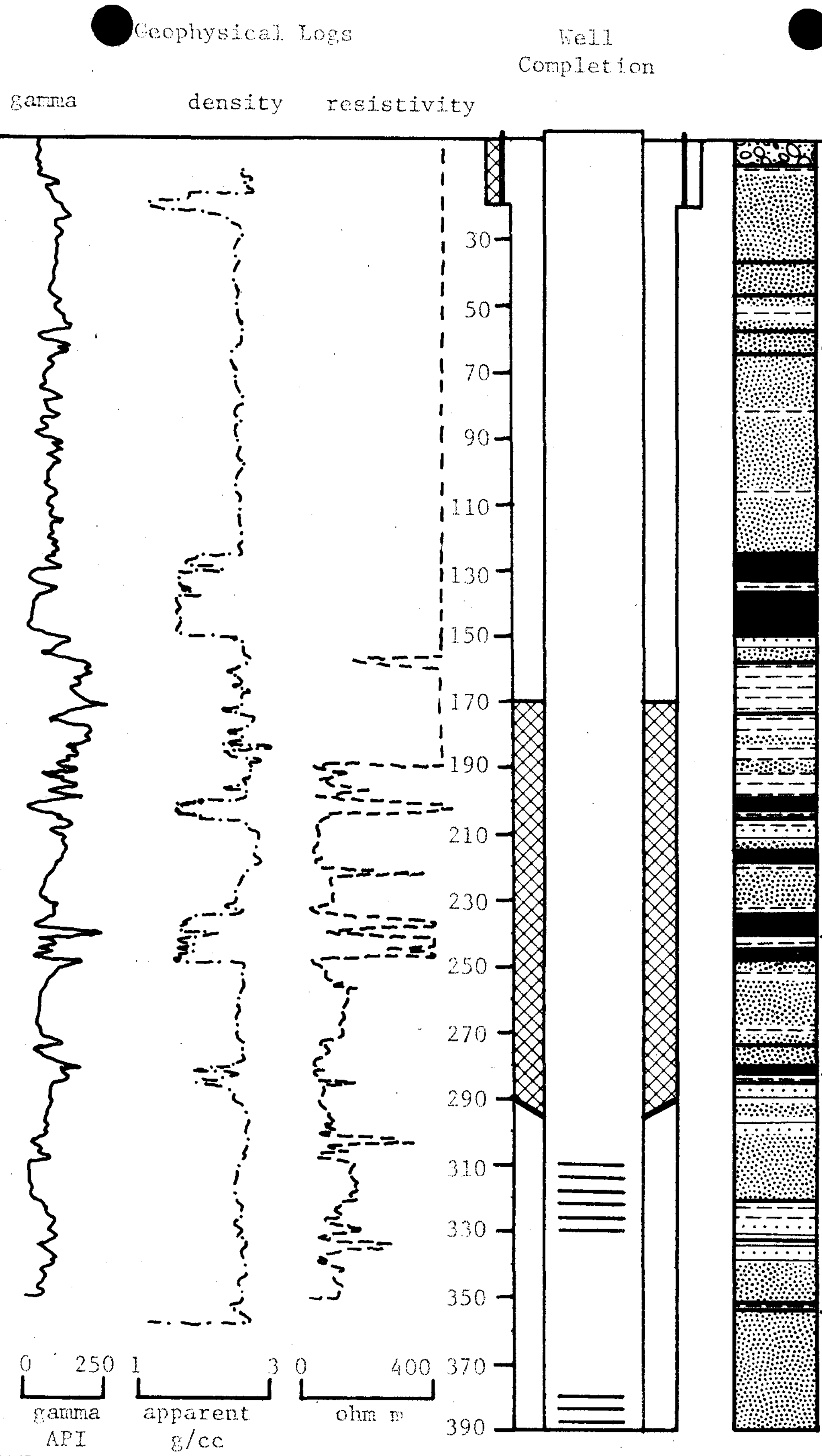
FIGURE 20
CONSOLIDATION COAL CO.

Emery Mine, Emery, Utah

Hydrogeologic Log

Well #H

Prepared by Watec, Inc., November 1979.



Lithologic Description

SAND and GRAVEL.

SANDSTONE, light to dark brown and rust, medium to fine grained with SHALE at the top.

SANDSTONE, yellow to medium grey, well sorted, friable.

SANDSTONE, grey, fine grained and SHALE, dark grey and black, carbonaceous.

SANDSTONE, brown, well indurated and grey, quartzose.

SANDSTONE, grey, medium grained, dirty below 91' and dark SHALE streaks.

COAL (I-J seam), partings at 129-130, 135-136, 137-138'.

SILTSTONE, grey and SANDSTONE, very fine grained.

SHALE, light to dark grey, carbonaceous.

SHALE, grey, slightly carbonaceous with interbedded SANDSTONE, grey, fine grained, indurated.

COAL (G seam), parting at 203.5-204.5'.

SHALE, SILTSTONE and SANDSTONE.

COAL, vitreous.

SANDSTONE, dark grey, fine grained with carbonaceous SHALE at top and bottom.

COAL (C-D seam), platy to massive, vitreous, partings at 239-240.5 and 244.5-245.5'.

SANDSTONE, light grey, very fine to medium grained, micaceous with SHALE at top and bottom.

SANDSTONE, grey, fine-medium grained.

COAL (A seam), partings at 281.5-283 and 284-284.5'.

SANDSTONE, grey, very fine to medium grained and SILTSTONE, grey, shaley.

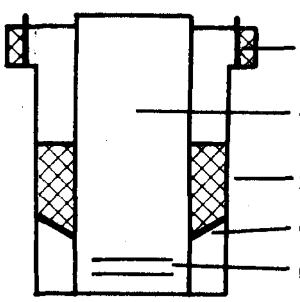
SHALE, black and SILTSTONE.

SANDSTONE, grey, fine-medium grained and SILTSTONE, dark grey, very fine grained, shaley.

SHALE, carbonaceous.

SANDSTONE, grey, fine-medium grained, shaley.

LEGEND



vertical scale: 1" = 50'

FIGURE 19

CONSOLIDATION COAL CO.

Emery Mine, Emery, Utah

Hydrogeologic Log

Well #ZZ

Prepared by Watec, Inc., November 1979.

TABLE 27

AQUIFER CHARACTERISTICS OF THE FERRON SANDSTONE
(Source: USGS, 1979)

Aquifer Test Site[1]	Geologic Unit Tested	Transmissivity (gpd/ft)	Storage Coefficient
EMRIA #3 (pumped well)	Kmf(u) and Kmbg	120	
WELL 3A (observation)	Kmf(u) and Kmbg	2610	1.3×10^{-3}
WELL 3A (recovery)	Kmf(u) and Kmbg	3880	
EMRIA #2 (pumped well)	Kmf		
WELL #1 (observation)	Kmf	1170	5.9×10^{-4}
MUDDY #3 (pumped well)	Kmf(u) and Kmbg		
USGS 1-2 (observation)	Kmf(u)	3485	1.13×10^{-2}
BRYANT WELL (pumped well)	Kmf(u) and Kmbg	1584	
EMERY TOWN WELL (pumped well)	Kmf(ℓ)	3812	
DOG VALLEY MINE (pumped well)	Kmf	980	3.1×10^{-4}
WELL WW#3 (observation)	Kmf	5632	3.7×10^{-4}
WELL WW#5 (observation)	Kmf	5632	6.03×10^{-4}
WELL WW#6 (observation)	Kmf	3730	1.4×10^{-4}
WELL WW#6 (observation)	Kmf	2283	0.98×10^{-4}
WELL WW#9 (observation)	Kmf	3840	
WELL WW#9 (observation)	Kmf	770	1.6×10^{-4}

[1] See appendix for aquifer test data.

5×10^{-4} were used to describe the upper Ferron Sandstone (Kmf(u)) aquifer properties. The transmissivity of the EMRIA #3 pumped well was judged atypical and was not used in the average. The storage coefficient of 1.13×10^{-2} was not considered.

By inspection of the data given in Table 27, the upper Ferron Sandstone was not tested individually except at the Muddy #3 test. Each test included some Bluegate Shale or the wells tested undifferentiated Ferron Sandstone. Despite this shortfall, the range of values for wells known to include the upper Ferron Sandstone suggests that a transmissivity of about 3000 gpd/ft. is representative.

7.2.3 Aquifer Interrelationships

An important consideration in evaluating potential hydrologic disturbances is the degree to which aquifers are interconnected with the mine zone. The greater degree to which the aquifers are interconnected, the greater becomes the potential for the development of hydrologic disturbances related to mine water inflow, and the related aspects of water level decline and mine water discharge.

From the static water level data obtained from the 41 hydrology wells in the area (see Table 28), it is apparent from head differences that ground water has the generally widespread potential to move upward from the lower Ferron into the coal bearing section of the Ferron (see Plates 3

TABLE 28

STATIC WATER LEVEL DATA FOR WELL MONITORING SITES
IN THE EMERY MINE AREA

Explanation for Table Headings: Well Monitoring Sites (Source of Data)
Location/Geologic Unit Monitored
Land Surface Elevation (ft.-amsl)

FC6WW (Kemmerer/USGS)[1] (D-22-6)17ABC/Kmf(ℓ) 6285		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
9-10-75	-48.00[2]	6333
12-30-75	-48.00	6333
3-18-76	-49.00	6334
9-2-76	-46.00	6331
11-15-76	-47.00	6332
2-15-77	-45.50	6330.5
3-30-77	-45.50	6330.5
5-6-77	-46.50	6331.5
6-2-77	-47.00	6332
7-7-77	-47.00	6332
7-22-77	-46.00	6331
9-3-77	-45.50	6330.5
9-21-77	-46.00	6331
10-21-77	-45.00	6330.5
11-8-78	-46.00	6331
5-3-78	-46.00	6331
7-5-78	-45.00	6330
8-2-78	-45.00	6330
8-31-78	-45.00	6330
9-29-78	-44.20	6329.2
10-26-78	-44.50	6329.5
12-9-78	-44.90	6329.9
2-5-79	-44.50	6329.5
3-5-79	-44.00	6329
4-3-79	-43.75	6328.75
5-9-79	-43.00	6328
6-4-79	-43.00	6328
7-9-79	-43.00	6328
8-1-79	-43.00	6328
9-6-79	-43.00	6328
10-30-79	-42.00	6327

FC346WW (CONSOL/USGS)[1] (D-22-6)23BBC/Kmf(u) and Kmbg 6121.7		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
8-5-75	21.67	6100.03
1-29-76	23.25	6098.45
9-16-76	23.95	6097.75
9-28-76	24.23	6097.47
10-7-76	24.49	6097.21
10-20-76	24.68	6097.02
11-10-76	24.89	6096.81
2-15-77	25.92	6095.78
3-30-77	26.74	6094.96
5-6-77	27.06	6094.64
6-2-77	27.23	6094.47
6-23-77	27.42	6094.28
7-8-77	27.44	6094.26
7-22-77	27.54	6094.16
9-8-77	27.74	6093.96
9-21-77	27.83	6093.87
10-21-77	27.99	6093.71
11-8-77	28.19	6093.51
3-15-78	34.13	6087.57
5-3-78	33.87	6087.83
5-31-78	34.78	6080.92
7-5-78	35.05	6086.65
8-2-78	33.88	6087.82
8-31-78	33.01	6088.69
9-30-78	32.63	6089.07
10-27-78	33.00	6088.70
12-5-78	32.52	6089.18
1-3-79	33.2	6088.50
2-5-79	33.39	6088.31
3-5-79	34.07	6087.63
3-30-79	36.28	6085.42
5-9-79	37.13	6084.57
6-4-79	37.63	6084.07
7-2-79	36.57	6085.13
8-1-79	35.14	6086.56
9-6-79	34.99	6086.71
9-28-79	35.41	6086.29
10-30-79	35.85	6085.85

[1] Water surface elevations for these wells are presently being periodically monitored by the USGS.

[2] Minus sign (-) denotes above land surface.

TABLE 28 Continued

FC343WW (CONSOL/USGS)[1] (D-22-6)28DAB/Kmf(u) and Kmbg 6095		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
8-5-75	23.42	6071.58
1-29-76	23.17	6071.83
9-16-76	23.29	6071.71
9-28-76	23.45	6071-55
10-7-76	23.53	6071.47
10-20-76	23.64	6071.36
11-10-76	23.68	6071.22
2-15-77	24.36	6070.64
3-30-77	24.65	6070.35
5-6-77	24.84	6070.16
6-2-77	25.01	6069.99
6-23-77	25.14	6069.86
7-8-77	25.21	6069.79
7-22-77	25.28	6069.72
9-8-77	25.56	6069.44
9-21-77	25.59	6069.41
10-21-77	25.65	6069.35
11-8-77	25.93	6069.07
3-15-78	28.59	6066.41
5-3-78	26.90	6068.10
5-31-78	27.00	6068.00
7-5-78	26.94	6068.06
8-2-78	26.40	6068.60
8-31-78	25.73	6069.27
9-29-78	25.38	6069.62
10-27-78	25.31	6069.69
12-10-78	25.25	6069.75
1-3-79	25.18	6069.82
2-5-79	25.15	6069.88
3-5-79	25.23	6069.77
3-30-79	25.25	6069.75
5-9-79	25.20	6069.80
5-31-79	25.17	6069.83
7-2-79	24.98	6070.02
8-1-79	24.47	6070.53
9-6-79	24.10	6070.90
9-28-79	23.98	6071.02
10-30-79	24.14	6070.86

FC363WW (CONSOL/USGS)[1] (D-22-6)27CBB/Kmf(u) and Kmbg 6043.99		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
1-29-76	8.50	6035.49
9-16-76	7.57	6036.42
9-28-76	7.54	6036.45
10-7-76	7.69	6036.30
10-20-76	7.54	6036.45
11-10-76	7.34	6036.65
2-15-77	7.48	6036.51
3-30-77	7.67	6036.32
5-6-77	7.46	6036.53
6-2-77	7.83	6036.16
6-23-77	8.20	6035.79
7-8-77	8.38	6035.61
7-27-77	8.69	6035.30
9-8-77	8.73	6035.26
9-21-77	8.98	6035.01
10-21-77	8.84	6035.15
11-8-77	9.25	6034.74
3-14-78	11.59	6032.40
5-3-78	12.20	6031.79
5-31-78	12.65	6031.34
7-5-78	12.97	6031.02
8-2-78	13.07	6030.92
8-31-78	13.02	6030.97
9-29-78	13.08	6030.91
10-27-78	13.09	6030.90
12-10-78	13.06	6030.93
1-3-79	12.64	6031.35
2-5-79	12.95	6031.04
3-3-79	13.12	6030.27
3-30-79	12.83	6031.16
5-9-79	12.93	6031.06
5-31-79	13.30	6030.69
7-2-79	13.06	6030.93
8-1-79	13.04	6030.95
9-6-79	12.92	6031.07
9-28-79	13.39	6030.60
10-30-79	13.82	6030.07

TABLE 28 Continued

FCJKWW (CONSOL/USGS)
(D-22-6)28DAB/Kmf(u) and Kmbg
6085

Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
9-16-76	22.43	6062.57
9-28-76	22.11	6062.89
10-7-76	22.42	6062.58
10-20-76	22.34	6062.66
11-12-76	22.41	6062.59
2-15-77	23.22	6061.78
3-29-77	24.18	6060.82
5-6-77	24.36	6060.64
6-2-77	23.90	6061.10
6-28-77	26.75	6058.25
7-8-77	26.54	6058.46
7-22-77	27.11	6057.89
9-8-77	29.29	6055.71
9-21-77	30.51	6054.49
10-21-77	33.29	6051.71
11-8-77	34.38	6050.62
3-14-78	34.62	6050.38

BRYANT (BRYANT/USGS)[1]
(D-22-6)31DBA/Kmf(u) and Kmbg
6030

10-7-76	-3.53[2]	6033.53
5-6-77	-3.80	6033.80
6-2-77	-3.50	6033.50
6-23-77	-3.50	6033.50
9-21-77	-3.80	6033.80
10-21-77	-3.70	6033.70
11-8-77	-3.80	6033.80

USGS 1-1 (USGS)[1]
(D-22-6)27CBB/Kmf(ℓ)
6060

Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
12-6-78	71.50	5988.50
12-10-78	103.88	5956.12
1-3-79	104.26	5955.74
2-5-79	104.50	5955.50
3-5-79	104.64	5955.36
3-30-79	104.86	5955.14
5-9-79	105.14	5954.86
5-31-79	105.28	5954.72
7-2-79	105.28	5954.72
8-1-79	105.45	5954.55
9-28-79	101.64	5958.36
10-30-79	101.54	5958.46

USGS 1-2 (USGS)[1]
(D-22-6)27CBB/Kmf(u)
6060

12-6-78	36.81	6023.19
12-10-78	37.68	6022.32
1-3-79	36.73	6023.27
2-5-79	36.77	6023.23
3-5-79	40.45	6019.55
5-9-79	42.49	6017.51
5-31-79	43.78	6016.22
7-2-79	43.79	6016.21
8-1-79	43.59	6016.41
9-6-79	45.34	6014.66
9-28-79	50.29	6009.71
10-30-79	54.11	6005.89

USGS 3-1/USGS
(D-22-6)27CBB/Kmbg
6060

6-13-79	17.23	6042.77
7-2-79	17.24	6042.76
8-1-79	17.33	6042.67
9-6-79	17.43	6042.57
9-28-79	17.54	6042.46
10-30-79	17.65	6042.35

TABLE 28 Continued

USGS 4-1/USGS (D-22-6)27CBB/Kmbg 6060		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
6-13-79	18.77	6041.23
7-2-79	17.75	6042.25
8-1-79	17.84	6042.16
9-6-79	17.93	6042.07
9-28-79	18.01	6041.99
10-30-79	18.14	6041.86

EMRIA #1 (BLM/USGS) (D-22-6)23AAC/Kmf 6180		
10-27-78	138.17	6041.83

EMRIA #1 OBS (BLM/USGS) (D-22-6)23AAC/Kmf 6180		
10-27-78	149.14	6030.86

EMRIA #2 (BLM/USGS)[1] (D-22-6)26BBB/Kmf 6090		
9-29-78	26.62	6063.38
10-27-78	28.50	6061.50
12-5-78	26.42	6063.58
1-3-79	26.16	6063.84
8-2-79	28.73	6061.27
9-6-79	27.24	6062.76

EMRIA #2 OBS (BLM/USGS)[1] (D-22-6)26BBB/Kmf 6090		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
10-27-78	33.50	6056.50
12-5-78	32.89	6057.11
1-3-79	33.18	6056.82
7-2-79	33.34	6056.66
9-28-79	32.60	6057.40

EMRIA #3 (BLM/USGS)[1] (D-22-6)22CDD/Kmf(u) and Kmbg 6090		
9-22-78	53.36	6036.34
10-27-78	53.39	6036.41
12-11-78	54.13	6035.87
1-4-79	54.01	6035.99
2-5-79	55.38	6034.38
3-5-79	55.99	6034.01
5-9-79	57.11	6032.89
6-4-79	57.55	6032.45
7-2-79	56.05	6033.95
8-1-79	55.25	6034.75
9-2-79	55.95	6034.05
9-28-79	57.29	6032.71
10-30-79	58.37	6031.63

TABLE 28 Continued

EMRIA #3A (BLM/USGS)[1]
(D-22-6)22CDD/Kmf(u) and Kmbg
6090

Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
9-22-78	44.05	6045.95
10-27-78	43.72	6042.28
12-11-78	43.81	6046.19
1-4-79	43.71	6046.29
2-5-79	44.93	6045.07
3-5-79	45.62	6044.38
6-4-79	48.12	6041.88
7-2-79	46.64	6043.36
8-1-79	45.59	6044.41
9-6-76	45.93	6044.07
9-28-79	47.23	6042.77
10-31-79	48.34	6041.66

EMRIA #3B (BLM/USGS)[1]
(D-22-6)22CDD/Kmbg
6090

9-22-78	16.55	6073.45
10-27-78	16.44	6073.56
12-11-78	16.28	6073.72
1-4-79	15.49	6074.51
2-5-79	15.95	6074.05
3-5-79	16.06	6073.94
6-4-79	15.31	6074.69
7-2-79	14.44	6075.56
8-1-79	13.54	6076.46
9-2-79	13.04	6076.96
9-28-79	12.67	6077.33
10-30-79	12.63	6077.37

EMRIA #4 (BLM/USGS)
(D-22-6)34CAC/Kmf
6200

12-5-78	82.85	6117.15

BLUEGATE #3 (USGS)
(D-21-6)35AAC/Kmbg
6280

Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
11-7-78	8.37	6271.73
1-3-79	8.31	6271.69

MUDDY #1/USGS[1]
(D-22-6)33ABA/Kmf(u) and Kmbg
6050

7-2-79	141.08	5908.92
8-1-79	141.25	5908.75
9-6-79	141.88	5908.12
9-28-79	138.43	5911.57
10-30-79	134.64	5915.36

MUDDY #2/USGS
(D-22-6)28DDB/Kmf(u) and Kmbg
6045

6-13-79	44.18	6000.82
7-2-79	43.54	6001.46
8-1-79	41.74	6003.26
9-6-79	43.20	6001.80
9-28-79	46.21	5998.79
10-30-79	48.80	5996.20

MUDDY #3/USGS
(D-22-6)27CBB/Kmf(u) and Kmbg
6060

6-13-79	25.45	6034.55
7-2-79	21.14	6038.86
9-6-79	20.61	6039.84
9-28-79	20.69	6039.31
10-30-79	20.79	6039.21

TABLE 28 Continued

MUDDY #4/USGS (D-22-6)27BDA/Kmf(u) and Kmbg 6060		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
6-13-79	8.19	6061.81
7-2-79	7.26	6052.74
8-1-79	8.12	6051.88
9-6-79	8.65	6051.35
9-28-79	9.28	6050.72
10-30-79	9.63	6050.37

WELL ZZ (CONSOL/USGS) (D-22-6)33ABA/Kmf(ℓ) 6045		
9-12-79	150.40	5894.6
9-28-79	145.16	5899.84
10-30-79	142.79	5902.21

WELL H (CONSOL/USGS) (D-22-6)20BAA/Multi-Completions 6260		
Monitored Unit: Kmbg		
10/24/79	32.14	6227.86
11/15/79	35.64	6224.36
	Kmf(u)	
11/15/79	64.18	6195.82
	Kmf(m)	
10/24/79	-60	6320
11/15/79	-25	6285
	Kmf(ℓ)	
10/24/79	-13.5	6273.5
11/15/79	-13	6273

WELL I (CONSOL/USGS) (D-22-6)21CAA/Multi-Completions 6110		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
Monitored Unit: Kmbg		
10/25/79	9.56	6100.44
11/15/79	11.69	6098.31
	Kmf(u)	
10/25/79	>300	<5810
11/15/79	335.7	5774.3
	Kmf(m)	
10/25/79	62.25	6172.25
11/15/79	51.14	6058.86
	Kmf(ℓ)	
10/25/79	11.33	6098.67
11/15/79	-1.33	6111

WELL R-1 (CONSOL/USGS) (D-22-6)30ADA/Kmf(ℓ) 6020		
10/30/79	-85.47	6105
11/16/79	-87.78	6108

WELL R-2 (CONSOL/USGS) (D-22-6)30ADA/Multi-Completions		
Monitored Unit: Kmbg		
12/7/79	53.3	5966.7
	Kmf(u)	
12/7/79	-175.33	6195.7

TABLE 28 Continued

WELL AA (CONSOL/USGS) (D-22-6)32DBC/Multi-Completions 5955		
Date	Depth to Water from Land Surface (ft.)	Water Surface Elevation (ft.-amsl)
Monitored Unit: Kmbg		
11/16/79	24.84	5930.16
	Kmf(u)	
11/16/79	No static water level due to gas issuing from monitored zone.	
	Kmf(m)	
11/16/79	-2.23	5957.23
	Kmf(ℓ)	
11/16/79	73.0	5882

and 4). Based upon the quality of water (see Section 7.2.9) there does not appear to be a clear separation of water quality between the upper and lower Ferron Sandstone. While water quality does not indicate a positive separation of the upper and lower Ferron Sandstone, the head differences do. Plates 3 and 4 indicate that while the upper Ferron Sandstone water levels appear to be stressed as a result of mine water inflow, those in the lower Ferron Sandstone do not. Seven monitor locations were set into the lower Ferron Sandstone during the summer and fall of 1979; five by Consol and two by the USGS. These locations will be monitored monthly for water level to determine any lower Ferron Sandstone water level fluctuations. Supplementally, there have been only a few noted occurrences of water entering the floor of the mine. While this does not preclude upward leakance, it may suggest minimal hydraulic connection.

7.2.4 Ground Water Recharge

Recharge to the ground water body in the area of the mine is believed to take place on the Wasatch Plateau and along the Joe's Valley-Paradise fault zone (Kaufman, 1976; Owili-Eger, 1979). Relatively higher amounts of precipitation in the recharge zone (>30 inches/year on the Wasatch Plateau) and the shape and southeastward slope of the potentiometric surface suggest this to be the case.

Although the amount of ground water recharge to the Ferron Sandstone is not well understood, both the upper and lower sandstone units within the Ferron Sandstone are known to contribute subsurface outflow to Muddy and Quitchupah Creeks, Christiansen Wash, and Miller Canyon. Subsurface flow contributions to Miller Canyon and Muddy Creek are generally believed to be beyond the radius of influence of mining, and therefore, are not critical to the area of the mine.

Based upon data provided by Owili-Eger (1979), subsurface flow contributions from the upper Ferron Sandstone to Quitchupah Creek and to Christiansen Wash are in the range of 3.241 cfs. In the vicinity of the mine, this value must be nearly equivalent to recharge. Because water levels in the near vicinity of the mine have been stressed due to mine water discharge, the rate of assumed recharge may be somewhat low.

Bluegate Shale overlies the Ferron Sandstone throughout much of the region. The Bluegate by virtue of its fine-grained lithology is believed to have notoriously poor permeability. Consequently, vertical percolation of precipitation and applied water in the mine vicinity are not believed to be major sources of recharge to the Ferron Sandstone.

7.2.5 Ground Water Movement and Fluctuation

Plates 3 and 4 indicate that throughout the Ferron Sandstone, ground water moves generally updip, and in a southeast direction toward the areas of the mine and toward areas of outcrop. Throughout most of the region the ground water in the Ferron Sandstone west of the mine is under sufficient artesian pressure to flow at ground surface. In very near proximity to the mine the potentiometric surface map of the upper Ferron Sandstone reflects the effects of mine water inflow and discharge to the streams at the outcrop.

Figures 24 through 28 show ground water surface trends throughout the period of record. With some exception, water levels in the vicinity of the mine have tended to decline in the upper Ferron Sandstone throughout recent years. The period of record available is not sufficient to establish what part of the measured declines may be in response to long-term differences in recharge, and what part may be in direct response to mining. Because a large number of wells are included in the program of monthly water level monitoring (see Section 7.3), a seasonal pattern of fluctuation will be established.

It is reasonable to expect that water levels in the upper Ferron Sandstone in the near vicinity of the mine will continue to decline in response to mine water inflow (see Section 9.0, Hydrologic Consequences of Mining). However, water pumped from the mine is settled and discharged back into Quitchupah Creek not far from the mine. This water would have entered the stream system through bedrock aquifer discharge in the near vicinity of the mine.

7.2.6 Ground Water Discharge

After migrating southeastward toward the mine site, ground water in the Ferron Sandstone daylights in the channels

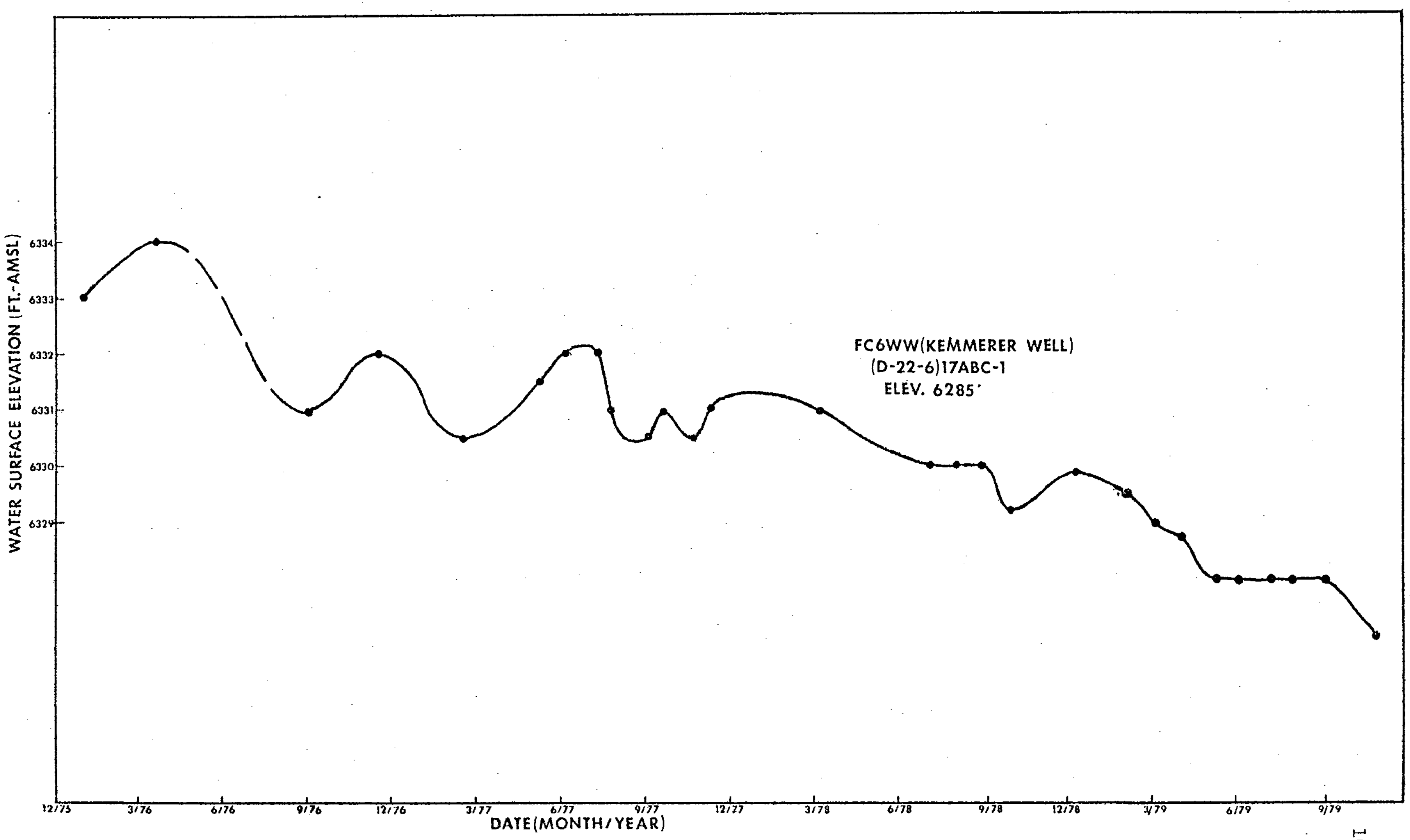


Figure 24. Hydrograph of monitoring well FC6WW.

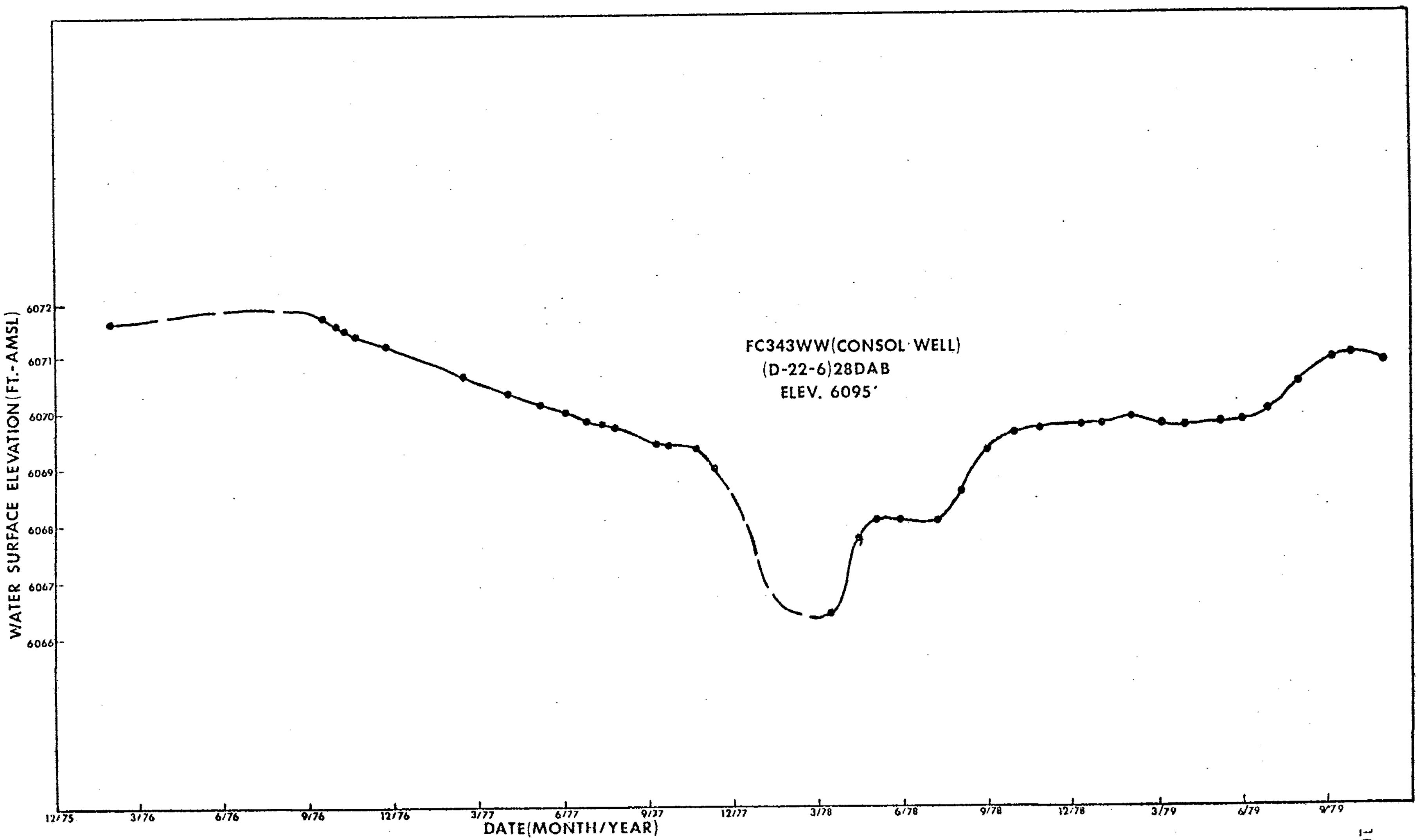


Figure 25. Hydrograph of monitoring well FC343WW.

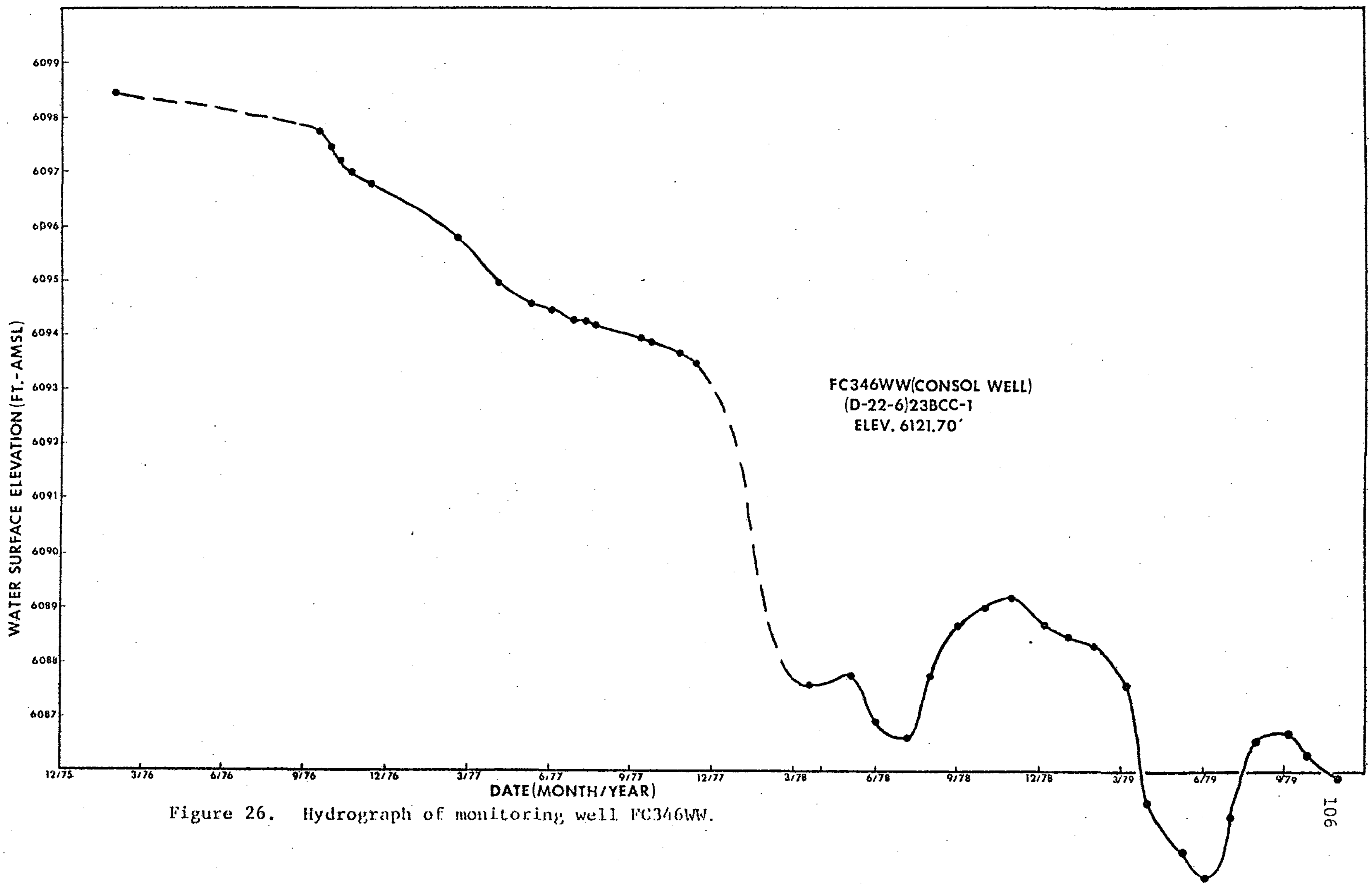


Figure 26. Hydrograph of monitoring well FC346WW.

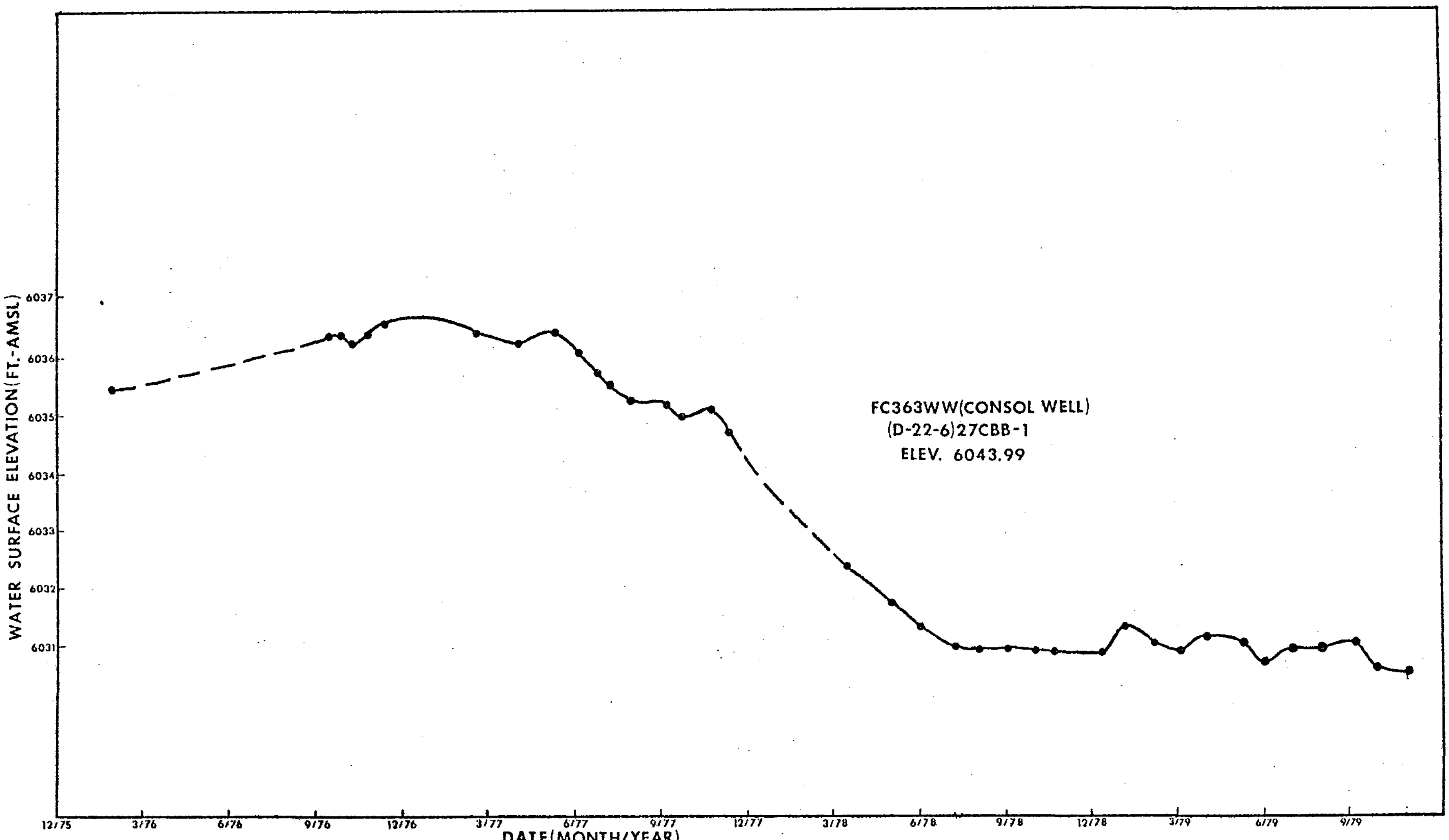


Figure 27. Hydrograph of monitoring well FC363WW.

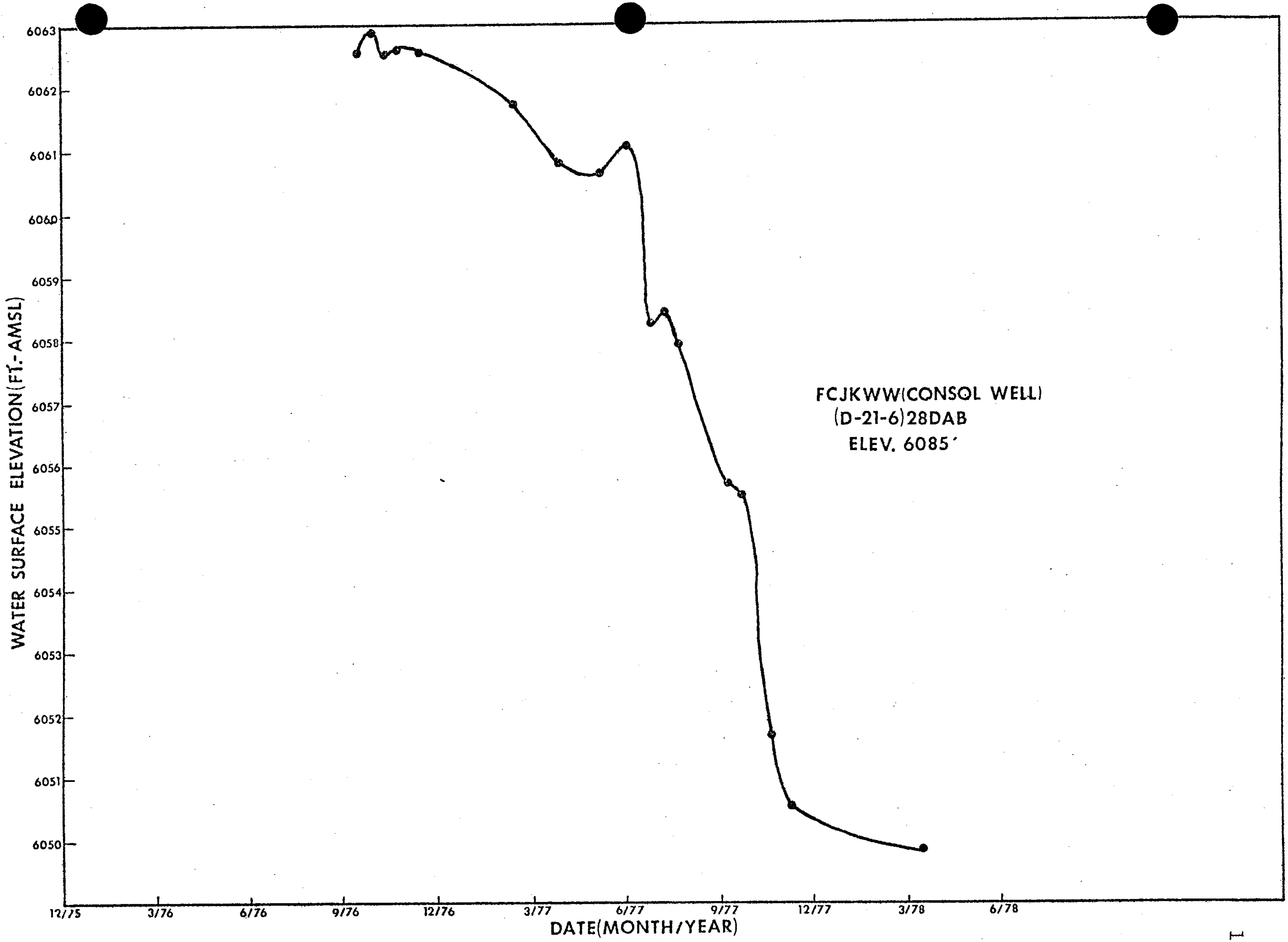


Figure 28. Hydrograph of monitoring well FCJKWW.

of Quitchupah Creek and Christiansen Wash along sandstone outcrops just east of the mine boundary. These natural points of effluence are shown on Figure 6. Based upon data provided by Owili-Eger (1979), sandstone bedrock discharge principally from the upper Ferron Sandstone is in the range of 3.241 cfs.

While declining water levels may be expected to result in decreased amounts of bedrock effluent to Christiansen Wash and Quitchupah Creek, pumped mine water is returned to Quitchupah Creek above its confluence with Christiansen Wash. Surface flows in Quitchupah Creek, as a consequence, are expected to remain relatively stable throughout the period of mining.

7.2.7 Springs and Seeps

A spring and seep inventory for the Emery Mine was conducted on October 24, 1979, to establish the current hydrology of springs and to establish a base from which to evaluate potential mining-related effects on springs. With the aid of results from a previous study conducted by Consol personnel in 1977, discussion with the USGS, Salt Lake City, color air photos, and on-site field observations, springs and seeps within and one mile outside of the permit boundary were located and evaluated. Locations were plotted as accurately as possible on 7.5' USGS topographic maps. Each of the springs was evaluated for the field parameters of temperature, pH, conductivity, dissolved oxygen, and discharge where possible.

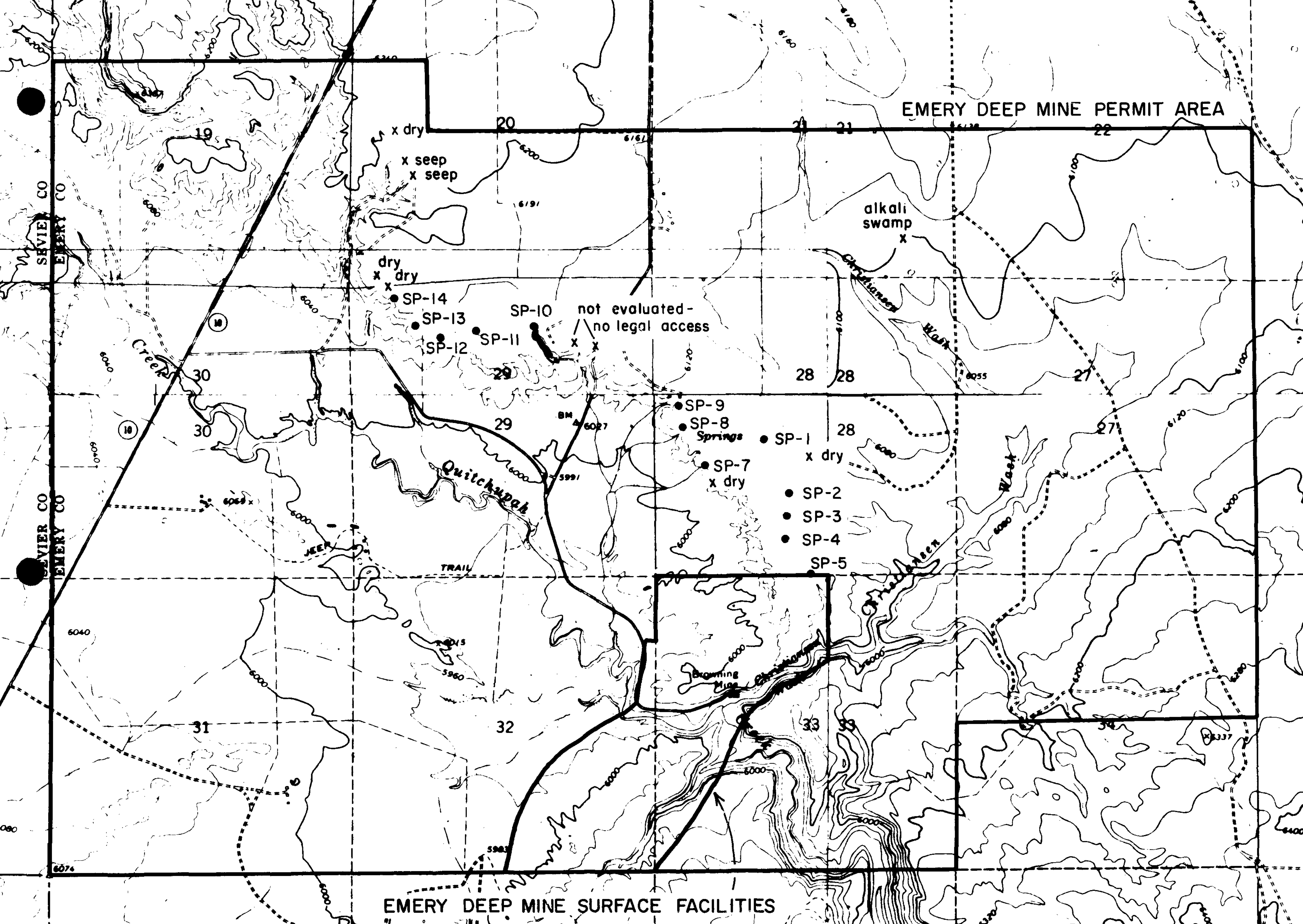
Each of the springs was also evaluated for its particular geologic setting.

Within the study area, fourteen springs were identified. Locations and field measurements for each of the sites are exhibited on Plate 5 and Table 29, respectively. All of the springs were observed to be issuing from terrace gravels overlying the Bluegate Shale. No springs were found to be issuing from either the Bluegate Shale or the Ferron Sandstone. As previously mentioned, the springs are probably recharged by infiltrating irrigation waters used for farming south of Emery on the weathered terrace gravels.

Conductivity of the spring waters ranged from 658 to 2015 with an average of 1155 μmhos/cm at 25°C. pH ranged from 7.1 to 8.3 with an average of 7.7. Although discharge at most of the spring sites was not able to be measured because of the unlocalized nature of the spring and/or vegetative overgrowth, most springs had flows which were less than 10 gpm. It is not expected that mining will have any degrading or diminutive effect on these springs because of their general lack of hydrologic interconnection with the upper Ferron Sandstone by virtue of the presence of essentially impermeable Bluegate Shale interburden.

7.2.8 Ground Water Storage

The regional ground water body contained within the Ferron Sandstone is quite large, and extends many miles to



LEGEND

- ● Spring
- x Site previously (1977) mapped as a spring

PLATE 5: SPRING AND SEEP LOCATION MAP (Spring and seep inventory was conducted during October, 1979)

WATEC, INC.

11/79

TABLE 29

RESULTS OF SPRING AND SEEP INVENTORY, OCTOBER 1979, EMERY MINE; EMERY, UTAH

Spring Site:	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6	SP-7
Location:							
Sample Date:	10/24/79	10/24/79	10/24/79	10/24/79	10/24/79	10/24/79	10/24/79
Developed:	No	No	No	No	No	No	No
FIELD DATA							
pH (units)	7.1	7.3	7.3	7.3	8.1	7.8	8.2
Temperature (°C)	13.5	13.9	12.9	14.5	9.2	15.9	17.1
Oxygen, dissolved (mg/ℓ)	3.0	5.0	7.6	8.1	10.9	9.2	11.1
Conductivity (μmhos/cm at 25°C)	1196	1613	1307	1295	2015	1086	1023
Color	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Discharge (gpm)	NM[1]	NM	NM	NM	≃1.0	NM	NM
Water-bearing material	Qt[2]	Qt	Qt	Qt	Qt	Qt	Qt
						Salt precipitates abundant	

Spring Site:	SP-8	SP-9	SP-10	SP-11	SP-12	SP-13	SP-14
Location:							
Sample Date:	10/24/79	10/24/79	10/24/79	10/24/79	10/24/79	10/24/79	10/24/79
Developed:	No	No	Yes	No	No	No	No
FIELD DATA							
pH (units)	8.3	7.9	7.2	7.5	7.9	7.5	7.8
Temperature (°C)	16.1	13.7	12.9	13.8	15.1	14.3	13.3
Oxygen, dissolved (mg/ℓ)	9.3	9.3	9.0	9.2	8.5	8.0	8.3
Conductivity (μmhos/cm at 25°C)	732	658	1043	800	1338	1046	1022
Color	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Discharge (gpm)	NM	NM	NM	NM	NM	NM	7
Water-bearing material	Qt	Qt	Qt	Qt	Qt	Qt	Qt

[1] NM = Not able to be measured because of ubiquitous nature of spring and/or vegetative overgrowth.

[2] Qt = Quaternary terrace gravels.

the north and south of the mine area (see Section 5.0). Although data are not available to establish the amount of ground water in storage in the large system, it must be considerable. Within the comparatively small portion of the aquifer inside the radius of influence of the mine, data are available to estimate ground water storage.

As a rule, the amount of ground water in storage attributable to artesian pressures is small. For example, based upon aquifer test data, the upper Ferron Sandstone has an artesian storage coefficient of about 5×10^{-4} (see Section 7.2.2) as computed by the equation

$$S = A \times Sc \times h$$

where:

S = ground water in storage, ac-ft.

Sc = artesian storage coefficient, 5×10^{-4}

h = height of water surface over top of aquifer, ft.

A = area, acres

It is not uncommon to encounter 400 feet or more of artesian head over the top of the aquifer in down dip locations west of the mine. Under these stated conditions about 0.25 ac-ft. of drainable ground water in storage are attributable to artesian storage per acre of land area. Conversely, the amount of ground water attributable to storage within the pore spaces of the aquifer is much greater. The upper Ferron

Sandstone averages about 80 feet thick. Its assumed specific yield is 0.10. Under these stated conditions about 8 ac-ft/ac of ground water are attributable to water table storage.

At the present (October 1979, Consol Mine Records) rate of mine water discharge (520 gpm), about 840 ac-ft/yr of ground water is removed from ground water storage within the upper Ferron Sandstone. This volume is available from about one land section comprising 640 acres during the next six years of mining. About 6 $mi.^2$ of land are believed to lay within the radius of influence of the mine. In the absence of recharge this volume of water removed from storage could lower water levels over a 6-$mi.^2$ area on the average of about 0.2 feet, a rather minimal decline. Naturally, water level declines will be greatest near the mine, and less with distance away from the mine.

The only production wells of record within the radius of influence of the mine are the Emery town and Bryant wells (see Plate 2). The Emery well is sufficiently removed from the area of mining that minimal declines in water level will be incurred during the next six years of mining. The Bryant well levels will decline to a greater extent. The Bryant well is included in the water level and water quality monitoring programs.

7.2.9 Ground Water Quality

Chemical quality data for waters contained in the Ferron Sandstone are available for at least 21 ground water wells located in the vicinity of the Emery Mine (see Table 30 and Plate 2). In order to better understand the general chemical quality of the water, measurements of specific conductivity and total dissolved solids (TDS) were plotted at each well location where data were available. Specific conductivities range from as low as 990 (well FC6WW) to as high as 5800 (well SRU8-1068). For waters of the Ferron Sandstone aquifer (undifferentiated), it can be assumed from Figure 29 that TDS is essentially 0.88 times specific conductivity. Thus, the average TDS concentration is approximately 2300 ppm. This value is much higher than the 250-1000 ppm range that is given by Price (1972) for Ferron Sandstone aquifer waters in the Castle Valley area. However, because some of the wells sampled were not completed solely in the Ferron Sandstone and/or were not pumped prior to sampling (John Kaufman, personal communication, February 1979), contamination of the well water from drilling fluids and the overlying saline Bluegate Shale and terrace gravels was undoubtedly inevitable. As a result, a lower average value of TDS for upper Ferron Sandstone aquifer waters would seem more reasonable. Support for this reasoning is given by the fact that the average TDS concentration in ground waters sampled from five different roof locations within the Emery Mine (see Table 31 and Figure 30) is approximately 1100 ppm, considerably less than the figure cited above for waters sampled from the ground water wells.

TABLE 30

RESULTS OF CHEMICAL ANALYSES OF GROUND WATER SAMPLED FROM WELLS IN THE EMERY MINE AREA

Ground Water Well:	FC47WW	FC47WW-1	FC6WW
Location:	(D-22-6)4CAB	(D-22-6)4CAB	(D-22-6)17ABC
Date of Collection:	9/10/75	2/5/79	9/10/75
Static Water Level:	-48		-52
Geologic Unit[1]:	Kmf(ℓ)	?	Kmf(ℓ)
Source of Data:	USGS	USGS	Layne Western
Completion Data[2]:	Yes	No	Yes
Present Use of Well:	Domestic	Domestic	Monitoring
GENERAL CHARACTERISTICS[3]			
Alkalinity, total (as $CaCO_3$)		230	
Hardness (noncarbonate)		0	
Hardness, total		160	
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field	7.6	7.9	8.7
pH, lab		7.7	
Sp. conductance, field (µmhos/cm at 25°C)	1080	1100	990
Sp. conductance, lab (µmhos/cm at 25°C)		1200	
Temperature (°C)		26	
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)		31	
Magnesium (Mg)		19	
Potassium (K)		4.1	
Sodium (Na)		180	
Sodium adsorption ratio (SAR)		6.3	
ANIONS			
Bicarbonate (HCO_3)		280	
Bromide (Br)		0.1	
Chloride (Cl)		20	
Sulfate (SO_4)		350	
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)		0.22	
Silica, diss. (SiO_2)		15	
REMARKS	Emery town well	New Emery town well	Kemmerer well

[1]Geologic unit refers to those strata or formations from which the ground waters have been sampled.

[2]See appendix.

[3]All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 30 Continued

Ground Water Well:	FC6WW	FC343WW	FC343WW
Location:	(D-22-6)17ABC	(D-22-6)28DAB	(D-22-6)28DAB
Date of Collection:	7/10/79	4/22/75	8/5/75
Static Water Level:		23.4	23.5
Geologic Unit:	Kmf(ℓ)	Kmf(u)/Kmbg	Kmf(u)/Kmbg
Source of Data:	USGS	CONSOL	CONSOL
Completion Data:	Yes	Yes	Yes
Present Use of Well:	Monitoring	Monitoring	Monitoring
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	250		323
Hardness (noncarbonate)	0		
Hardness, total	150		
Iron, total (Fe)		0.4	0.5
Iron, diss. (Fe)			
Manganese, total (Mn)		0.29	0.1
pH, field			
pH, lab	7.6	7.4	7.5
Sp. conductance, field (μmhos/cm at 25°C)	900		
Sp. conductance, lab (μmhos/cm at 25°C)	1153	14000	2100
Temperature (°C)	25		
Total dissolved solids (TDS)		15336	1604
Total suspended solids (TSS)			60
CATIONS			
Calcium (Ca)	29	410	100
Magnesium (Mg)	19	445	102
Potassium (K)	4.4	8.9	16
Sodium (Na)	200	3380	150
Sodium adsorption ratio (SAR)	7.1	27.5	2.5
ANIONS			
Bicarbonate (HCO_3)	300		
Bromide (Br)	0.2		
Chloride (Cl)	32		15
Sulfate (SO_4)	300	7400	
TRACE AND OTHER ELEMENTS			
Aluminum (Al)		0	0.25
Boron (B)	0.23		
Silica, diss. (SiO_2)	16		
REMARKS		Probable contamination of sample	

TABLE 30 Continued

Ground Water Well:	FC343WW	FC346WW	FC346WW
Location:	(D-22-6)28DAB	(D-22-6)23BCC	(D-22-6)23BCC
Date of Collection:	1/29/76	4/22/75	8/5/75
Static Water Level:	23.2	25.4	21.7
Geologic Unit:	Kmf(u)/Kmbg	Kmf(u)/Kmbg	Kmf(u)/Kmbg
Source of Data:	CONSOL	CONSOL	CONSOL
Completion Data:	Yes	Yes	Yes
Present Use of Well:	Monitoring	Monitoring	Monitoring
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	338		223
Hardness (noncarbonate)			
Hardness, total			
Iron, total (Fe)	0.5	0.5	0.3
Iron, diss. (Fe)	0.3		
Manganese, total (Mn)	0	0.15	0.01
pH, field			
pH, lab	7.2	7.4	7.6
Sp. conductance, field (µmhos/cm at 25°C)			
Sp. conductance, lab (µmhos/cm at 25°C)	2150	4750	488
Temperature (°C)			
Total dissolved solids (TDS)	1638	4656	232
Total suspended solids (TSS)	58		48
CATIONS			
Calcium (Ca)	176	395	15
Magnesium (Mg)	112	235	25
Potassium (K)	14.7	7.0	4.8
Sodium (Na)	220	775	23
Sodium adsorption ratio (SAR)	3.2	7.6	0.8
ANIONS			
Bicarbonate (HCO_3)			
Bromide (Br)			
Chloride (Cl)	36		15
Sulfate (SO_4)	969	2300	85
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0.55	0	0.4
Boron (B)			
Silica, diss. (SiO_2)			

REMARKS

TABLE 30 Continued

Ground Water Well:	FC346WW	FC363WW	USGS1-1
Location:	(D-22-6)23BCC	(D-22-6)27CBB	(D-22-6)27CBB
Date of Collection:	1/29/76	1/29/76	11/30/78
Static Water Level:	23.3	7.5	
Geologic Unit:	Kmf(u)/Kmbg	Kmf(u)/Kmbg	Kmf(ℓ)
Source of Data:	CONSOL	CONSOL	USGS
Completion Data:	Yes	Yes	Yes
Present Use of Well:	Monitoring	Monitoring	Monitoring
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	193	435	510
Hardness (noncarbonate)			0
Hardness, total			20
Iron, total (Fe)	0.3	0.3	
Iron, diss. (Fe)	0.2	0.1	
Manganese, total (Mn)	0	0	
pH, field			
pH, lab	7.3	8.3	8.8
Sp. conductance, field (μmhos/cm at 25°C)			1250
Sp. conductance, lab (μmhos/cm at 25°C)	600	1100	1249
Temperature (°C)			10.0
Total dissolved solids (TDS)	324	688	
Total suspended solids (TSS)	52	50	
CATIONS			
Calcium (Ca)	76	26	4.5
Magnesium (Mg)	32	7.5	2.2
Potassium (K)	4.95	7.12	5.0
Sodium (Na)	50	290	310
Sodium adsorption ratio (SAR)	1.2	12.9	30
ANIONS			
Bicarbonate (HCO_3)			620
Bromide (Br)			4.6
Chloride (Cl)	12	14	19
Sulfate (SO_4)	90	127	170
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0.55		
Boron (B)			0.60
Silica, diss. (SiO_2)			8.9

REMARKS

TABLE 30 Continued

Ground Water Well:	USGS1-2	USGS1-3	USGS2-3
Location:	(D-22-6)27CBB	(D-22-6)21CCB	(D-23-6)4BCB
Date of Collection:	11/17/78	11/30/78	11/30/78
Static Water Level:			
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf
Source of Data:	USGS	USGS	USGS
Completion Data:	Yes	Yes	Yes
Present Use of Well:	Monitoring	None	None
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	270	480	260
Hardness (noncarbonate)	980	0	200
Hardness, total	1300	110	460
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field		9.0	8.4
pH, lab	7.4	8.3	8.1
Sp. conductance, field (μmhos/cm at 25°C)	5000	2100	3400
Sp. conductance, lab (μmhos/cm at 25°C)	4884	2304	3502
Temperature (°C)	8.5	10.5	14.0
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	140	19	110
Magnesium (Mg)		16	45
Potassium (K)	48	4.4	8.4
Sodium (Na)	760	460	600
Sodium adsorption ratio (SAR)	9.3	19	12
ANIONS			
Bicarbonate (HCO_3)	330	570	320
Bromide (Br)	0.5	0.2	0.5
Chloride (Cl)	20	31	83
Sulfate (SO_4)	2500	590	1400
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	0.43	0.61	0.67
Silica, diss. (SiO_2)	21	12	8.3

REMARKS

TABLE 30 Continued

Ground Water Well:	USGS3-1	EMRIA #1	EMRIA #3
Location:	(D-22-6)27CBB	(D-22-6)23AD	(D-22-6)22CDD
Date of Collection:	5/31/79	10/25/78	4/19/79
Static Water Level:			
Geologic Unit:	Kmbg	Kmf	Kmf(u)
Source of Data:	USGS	USGS	USGS
Completion Data:	No	Yes	Yes
Present Use of Well:	Monitoring	Monitoring	Monitoring
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	250	480	530
Hardness (noncarbonate)	4700	0	1400
Hardness, total	5000	420	1900
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field			7.1
pH, lab	7.9	7.4	7.2
Sp. conductance, field (µmhos/cm at 25°C)	20000	2400	6100
Sp. conductance, lab (µmhos/cm at 25°C)	18950	3404	6262
Temperature (°C)		13	
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	170	130	300
Magnesium (Mg)	1100	23	290
Potassium (K)	46	6.1	12
Sodium (Na)	4000	640	880
Sodium adsorption ratio (SAR)	25	14	8.7
ANIONS			
Bicarbonate (HCO_3)	300	580	640
Bromide (Br)	0.8	0.4	0.5
Chloride (Cl)	230	35	120
Sulfate (SO_4)	12000	1300	3200
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	1.1	0.89	0.62
Silica, diss. (SiO_2)	6.9	16	19

REMARKS

TABLE 30 Continued

Ground Water Well:	DVM-WW #2	DVM-WW #4	Bluegate #3
Location:	(D-23-6)32BDA	(D-23-6)32BBC	(D-21-6)35AAC
Date of Collection:	6/21/78	9/22/78	8/10/78
Static Water Level:			
Geologic Unit:	Kmf	Kmf	Kmbg
Source of Data:	USGS	USGS	BLM/USGS
Completion Data:	Yes	Yes	Yes
Present Use of Well:	None?	None?	Monitoring
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	340	340	620
Hardness (noncarbonate)	0	0	390
Hardness, total	160	24	1000
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field			7.1
pH, lab	8.0	8.7	7.2
Sp. conductance, field (µhos/cm at 25°C)	1600	1650	31000
Sp. conductance, lab (µmhos/cm at 25°C)	1577	1666	30100
Temperature (°C)	18.5	13.5	13.5
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	30	6.0	90
Magnesium (Mg)	20	2.1	190
Potassium (K)	2.7	1.8	29
Sodium (Na)	330	370	7600
Sodium adsorption ratio (SAR)	11	33	104
ANIONS			
Bicarbonate (HCO_3)	410	420	750
Bromide (Br)	0.2	0.4	17
Chloride (Cl)	13	16.0	4100
Sulfate (SO_4)	440	450	7000
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	0.25	0.33	1.5
Silica, diss. (SiO_2)	11	8.1	12
REMARKS	Dog Valley mine well	Dog Valley mine well	

TABLE 30 Continued

Ground Water Well:	QUITCH #1	SRU8-1046	SRU8-1061
Location:	(D-22-6)19CDB	(D-22-6)26BDB	(D-22-6)26BBA
Date of Collection:	5/16/79	5/31/78	5/31/78
Static Water Level:		7.89	28.95
Geologic Unit:	Kmbg	Kmf	Kmf
Source of Data:	USGS	USGS	USGS
Completion Data	No	No	No
Present Use of Well:		None	None
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	250	460	5
Hardness (noncarbonate)	0	0	2800
Hardness, total	170	430	2800
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field			
pH, lab	8.4	7.5	4.9
Sp. conductance, field (µmhos/cm at 25°C)	1250	2200	4500
Sp. conductance, lab (µmhos/cm at 25°C)	1241	2119	4408
Temperature (°C)	20.5	11.0	12.5
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	36	75	510
Magnesium (Mg)	19	58	370
Potassium (K)	4.4	7.2	8.3
Sodium (Na)	220	370	240
Sodium adsorption ratio (SAR)	7.4	7.8	2
ANIONS			
Bicarbonate (HCO_3)	300	560	6
Bromide (Br)	0.3	0.1	0.3
Chloride (Cl)	28	28	45
Sulfate (SO_4)	340	700	3000
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	0.25	0.51	2.6
Silica, diss. (SiO_2)	12	13	18
REMARKS		Seismic test hole	Seismic test hole

TABLE 30 Continued

Ground Water Well:	SRU8-1037	SRU8-1068	SRU8-1049
Location:	(D-22-6)26BDC	(D-22-6)23CCB	(D-22-6)26BAC
Date of Collection:	5/31/78	5/31/78	5/31/78
Static Water Level:	11.98	32.23	7.71
Geologic Unit:	Kmf	Kmf	Kmf
Source of Data:	USGS	USGS	USGS
Completion Data:	No	No	No
Present Use of Well:	None	None	None
GENERAL CHARACTERISTICS			
Alkalinity, total (as $CaCO_3$)	400	420	410
Hardness (noncarbonate)	1600	2400	0
Hardness, total	2000	2800	260
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field			
pH, lab	7.1	7.2	7.5
Sp. conductance, field (μmhos/cm at 25°C)	4100	5800	1700
Sp. conductance, lab (μmhos/cm at 25°C)	4300	4777	1720
Temperature (°C)	13.0	12.0	12.0
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	380	470	44
Magnesium (Mg)	260	400	37
Potassium (K)	9.3	16	6.3
Sodium (Na)	480	320	300
Sodium adsorption ratio (SAR)	4.6	2.6	8.1
ANIONS			
Bicarbonate (HCO_3)	490	510	500
Bromide (Br)	0.5	0.4	0.1
Chloride (Cl)	100	96	28
Sulfate (SO_4)	2400	2900	470
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	1.1	0.59	0.48
Silica, diss. (SiO_2)	11	13	12
REMARKS	Seismic test hole	Seismic test hole	Seismic test hole

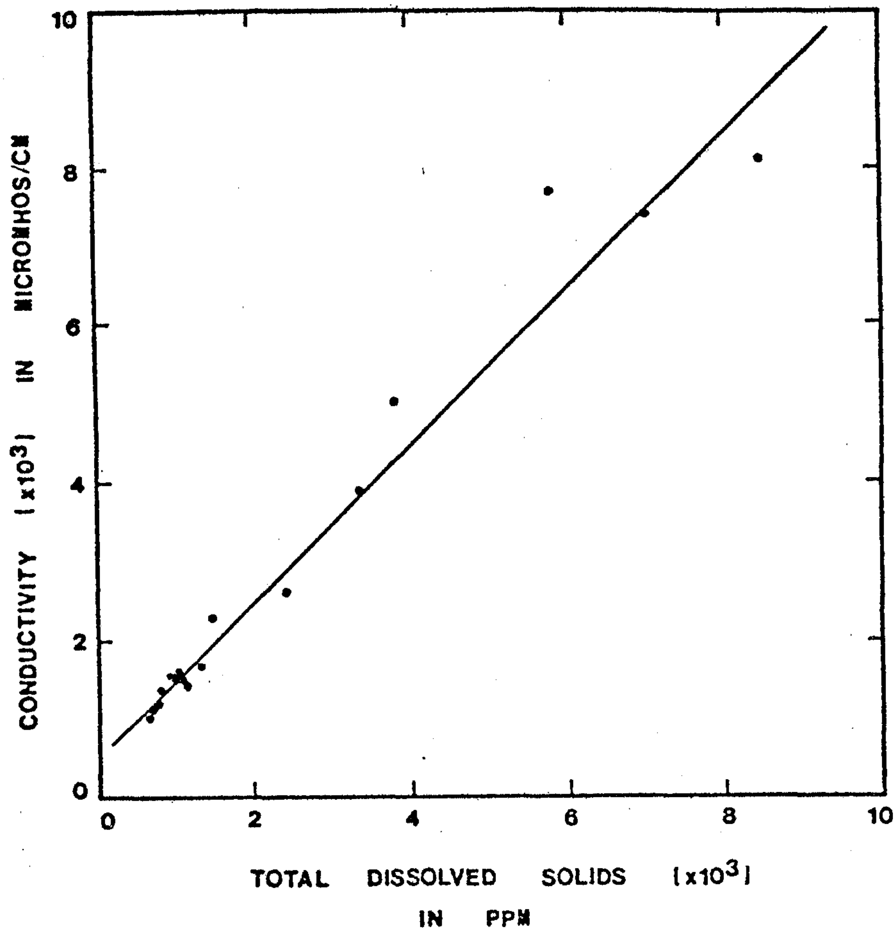


Figure 29. Plot of total dissolved solids (ppm) and specific conductivity (μmhos/cm at 25°C) for the Ferron Sandstone aquifer, undifferentiated. (Source: Owili-Eger, 1979)

TABLE 31

RESULTS OF CHEMICAL ANALYSES OF GROUND WATERS SAMPLED FROM VARIOUS LOCATIONS WITHIN THE EMERY MINE

Sampling Site:	U-1	U-2	U-3
Location:	U-grd Mine	U-grd Mine	U-grd Mine
Date of Collection:	3/22/77	3/22/77	6/9/76
Geologic Unit[1]:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	Consol	Consol	Consol
GENERAL CHARACTERISTICS[2]			
Alkalinity, total ($CaCO_3$)	508	446	463
Hardness (noncarbonate)[3]			
Hardness, total			
Iron, total (Fe)	0.9	1.0	0.2
Iron, diss. (Fe)	0.8	0.8	0.2
Manganese, total (Mn)	0	0	0
pH, field			
pH, lab	7.4	7.4	6.8
Sp. conductance, field (µmhos/cm at 25°C)			
Sp. conductance, lab (µmhos/cm at 25°C)			
Temperature (°C)			
Total dissolved solids (TDS)	4858	5000	5907
Total suspended solids (TSS)	15	43	9
CATIONS			
Calcium (Ca)	279	219	
Magnesium (Mg)	230	233	
Potassium (K)	13.8	24.0	
Sodium (Na)	1040	1055	
Sodium adsorption ratio (SAR)	11.2	11.8	
ANIONS			
Bicarbonate (HCO_3)			
Bromide (Br)			
Carbonate (CO_3)			
Chloride (Cl)[3]	143	139	
Fluoride (F)			
Iodide (I)			
Sulfate (SO_4)	2850	3000	
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0	0	0.25
Boron (B)			
Silica, diss. (SiO_2)			
REMARKS	Seepage from #2 & #3 seals at 1st south	Flow on coal floor below #5 seal at 1st south	Discharge from mine

[1]Geologic unit refers to those strata or formations from which the ground waters have been sampled.

[2]All results are in milligrams per liter (mg/ℓ) unless otherwise noted.

TABLE 31 Continued

Sampling Site:	U-3	U-4	U-4
Location:	U-grd Mine	U-grd Mine	U-grd Mine
Date of Collection:	3/22/77	6/9/76	3/22/77
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	Consol	Consol	Consol
GENERAL CHARACTERISTICS			
Alkalinity, total ($CaCO_3$)	464	621	571
Hardness (noncarbonate)			
Hardness, total			
Iron, total (Fe)	0.8	0.2	0.8
Iron, diss. (Fe)	0.7	0.2	0.7
Manganese, total (Mn)	0.03	0	0.01
pH, field			
pH, lab	7.4	7.0	7.5
Sp. conductance, field (μmhos/cm at 25°C)			
Sp. conductance, lab (μmhos/cm at 25°C)			
Temperature (°C)			
Total dissolved solids (TDS)	5840	2415	2512
Total suspended solids (TSS)	16	7	13
CATIONS			
Calcium (Ca)	230		40
Magnesium (Mg)	263		60
Potassium (K)	15.9		6.57
Sodium (Na)	1315		668
Sodium adsorption ratio (SAR)	14.1		16.2
ANIONS			
Bicarbonate (HCO_3)			
Bromide (Br)			
Carbonate (CO_3)	216		94
Chloride (Cl)			1050
Fluoride (F)			
Iodide (I)			
Sulfate (SO_4)	3800		
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0	0.25	
Boron (B)			
Silica, diss. (SiO_2)			
REMARKS	Discharge from mine	Seepage from #6 seal at #5 south	Seepage from #6 seal at 5th south

TABLE 31 Continued

Sampling Site:	U-5	U-5	U-6
Location:	U-grd Mine	U-grd Mine	U-grd Mine
Date of Collection:	6/9/76	3/22/77	3/22/77
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	Consol	Consol	Consol
GENERAL CHARACTERISTICS			
Alkalinity, total ($CaCO_3$)	571	558	602
Hardness (noncarbonate)			
Hardness, total			
Iron, total (Fe)	0.9	0.9	0.9
Iron, diss. (Fe)	0.1	0.7	0.8
Manganese, total (Mn)	0	0.01	0
pH, field			
pH, lab	7.1	8.3	8.7
Sp. conductance, field (µmhos/cm at 25°C)			
Sp. conductance, lab (µmhos/cm at 25°C)			
Temperature (°C)			
Total dissolved solids (TDS)	3541	2142	774
Total suspended solids (TSS)	147	39	6
CATIONS			
Calcium (Ca)		22	1.85
Magnesium (Mg)		104	59
Potassium (K)		6.3	1.7
Sodium (Na)		403	170
Sodium adsorption ratio (SAR)		8.0	4.7
ANIONS			
Bicarbonate (HCO_3)			
Bromide (Br)			
Carbonate (CO_3)			
Chloride (Cl)		72	33
Fluoride (F)			
Iodide (I)			
Sulfate (SO_4)		1100	69
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0.85	0.10	0.1
Boron (B)			
Silica, diss. (SiO_2)			
REMARKS	Discharge to ground surface	Discharge to ground surface	Seepage from roof at 38+20 entry #3 main west

TABLE 31 Continued

Sampling Site:	U-7	U-7	U-8
Location:	U-grd Mine		
Date of Collection:	6/9/76	3/22/77	3/22/77
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	Consol	Consol	Consol
GENERAL CHARACTERISTICS			
Alkalinity, total ($CaCO_3$)	602	520	627
Hardness (noncarbonate)			
Hardness, total			
Iron, total (Fe)	0.1	0.8	0.9
Iron, diss. (Fe)	0.05	0.7	0.9
Manganese, total (Mn)	0	0	0.01
pH, field			
pH, lab	7.2	7.8	9.8
Sp. conductance, field (μmhos/cm at 25°C)			
Sp. conductance, lab (μmhos/cm at 25°C)			
Temperature (°C)			
Total dissolved solids (TDS)	850	798	836
Total suspended solids (TSS)	14	10	15
CATIONS			
Calcium (Ca)		2.55	3.5
Magnesium (Mg)		26	20
Potassium (K)		8.0	4.3
Sodium (Na)		153	403
Sodium adsorption ratio (SAR)		6.25	18.4
ANIONS			
Bicarbonate (HCO_3)			
Bromide (Br)			
Carbonate (CO_3)			
Chloride (Cl)		40	30
Fluoride (F)			
Iodide (I)			
Sulfate (SO_4)		200	235
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0.25	0	0
Boron (B)			
Silica, diss. (SiO_2)			
REMARKS	Seepage from roof fall at #2 entry 6th north	Seepage from roof fall at #2 entry 6th north	Seepage from roof fall at #2 entry 6th north

TABLE 31 Continued

Sampling Site:	U-9	U-10	U-11
Location:			
Date of Collection:	3/22/77	3/22/77	1/7/75
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	Consol	Consol	Consol
GENERAL CHARACTERISTICS			
Alkalinity, total ($CaCO_3$)	477	533	432
Hardness (noncarbonate)			
Hardness, total			
Iron, total (Fe)	0.9	0.9	0.55
Iron, diss. (Fe)	0.8	0.8	0.48
Manganese, total (Mn)	0.07	0.01	0
pH, field			
pH, lab	8.1	7.6	8.1
Sp. conductance, field (μmhos/cm at 25°C)			
Sp. conductance, lab (μmhos/cm at 25°C)			
Temperature (°C)			
Total dissolved solids (TDS)	5826	3034	5590
Total suspended solids (TSS)	46	14	121
CATIONS			
Calcium (Ca)	221	169	18.6
Magnesium (Mg)	298	183	21.1
Potassium (K)	8.3	9.54	
Sodium (Na)	1363	485	1250
Sodium adsorption ratio (SAR)	14.1	6.2	47.12
ANIONS			
Bicarbonate (HCO_3)			
Bromide (Br)			
Carbonate (CO_3)			
Chloride (Cl)	194	52	204.4
Fluoride (F)			
Iodide (I)			
Sulfate (SO_4)	3900	1650	1251
TRACE AND OTHER ELEMENTS			
Aluminum (Al)	0	0	
Boron (B)			
Silica, diss. (SiO_2)			
REMARKS	Discharge from sprayer of continuous miner	Seepage from drill hole into flooded old works--3rd north	Discharge to Quitchupah Creek--prior to sedimentation pond construction

TABLE 31 Continued

Sampling Site:	U-12	U-13	U-14
Location:	U-grd Mine	U-grd Mine	(D-22-6)28BCA
Date of Collection:	9/1/78	9/1/78	3/29/79
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	USGS	USGS	USGS
GENERAL CHARACTERISTICS			
Alkalinity, total ($CaCO_3$)	520	560	480
Hardness (noncarbonate)	0	0	0
Hardness, total	180	5	61
Iron, total (Fe)			
Iron, diss. (Fe)	0.02	0.03	
Manganese, total (Mn)	0.01	0.02	
pH, field	8.4	9.5	8.7
pH, lab	8.2	8.9	8.6
Sp. conductance, field (μmhos/cm at 25°C)	2180	1300	1620
Sp. conductance, lab (μmhos/cm at 25°C)	2041	1283	1633
Temperature (°C)	13.5	13.0	13.0
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	24	0.9	9.3
Magnesium (Mg)	29	0.6	9.2
Potassium (K)	2.6	1.4	2.6
Sodium (Na)	420	320	380
Sodium adsorption ratio (SAR)	14	64	21
ANIONS			
Bicarbonate (HCO_3)			590
Bromide (Br)	0.3	0.3	0.2
Carbonate (CO_3)			
Chloride (Cl)	32	27	28
Fluoride (F)	0.7	2.3	
Iodide (I)	0.02		
Sulfate (SO_4)	520	74	390
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	0.58	0.85	0.59
Silica, diss. (SiO_2)	13	9.5	12
REMARKS	Seepage from ceiling	Seepage from ceiling	Seepage from ceiling

TABLE 31 Continued

Sampling Site:	U-15	U-16	U-17
Location:	(D-22-6)28CBA	(D-22-6)29DAC	(D-22-6)32ABA
Date of Collection:	3/29/79	3/29/79	3/29/79
Geologic Unit:	Kmf(u)	Kmf(u)	Kmf(u)
Source of Data:	USGS	USGS	USGS
GENERAL CHARACTERISTICS			
Alkalinity, total ($CaCO_3$)	530	500	540
Hardness (noncarbonate)	0	0	0
Hardness, total	200	5	63
Iron, total (Fe)			
Iron, diss. (Fe)			
Manganese, total (Mn)			
pH, field	8.4	9.3	8.9
pH, lab	7.7	9.1	8.4
Sp. conductance, field (μmhos/cm at 25°C)	2000	1120	3080
Sp. conductance, lab (μmhos/cm at 25°C)	2068	1293	2798
Temperature (°C)	12	12.5	10
Total dissolved solids (TDS)			
Total suspended solids (TSS)			
CATIONS			
Calcium (Ca)	30	1.2	8.6
Magnesium (Mg)	30	0.6	10
Potassium (K)	4.2	1.1	4.6
Sodium (Na)	440	290	640
Sodium adsorption ratio (SAR)	14	54	35
ANIONS			
Bicarbonate (HCO_3)	640	580	660
Bromide (Br)	0.2	0.2	0.3
Carbonate (CO_3)			
Chloride (Cl)	31	29	71
Fluoride (F)			
Iodide (I)			
Sulfate (SO_4)	530	92	830
TRACE AND OTHER ELEMENTS			
Aluminum (Al)			
Boron (B)	0.57	0.77	0.88
Silica, diss. (SiO_2)	11	9.3	8.2
REMARKS	Seepage from ceiling	Seepage from ceiling	Mine water

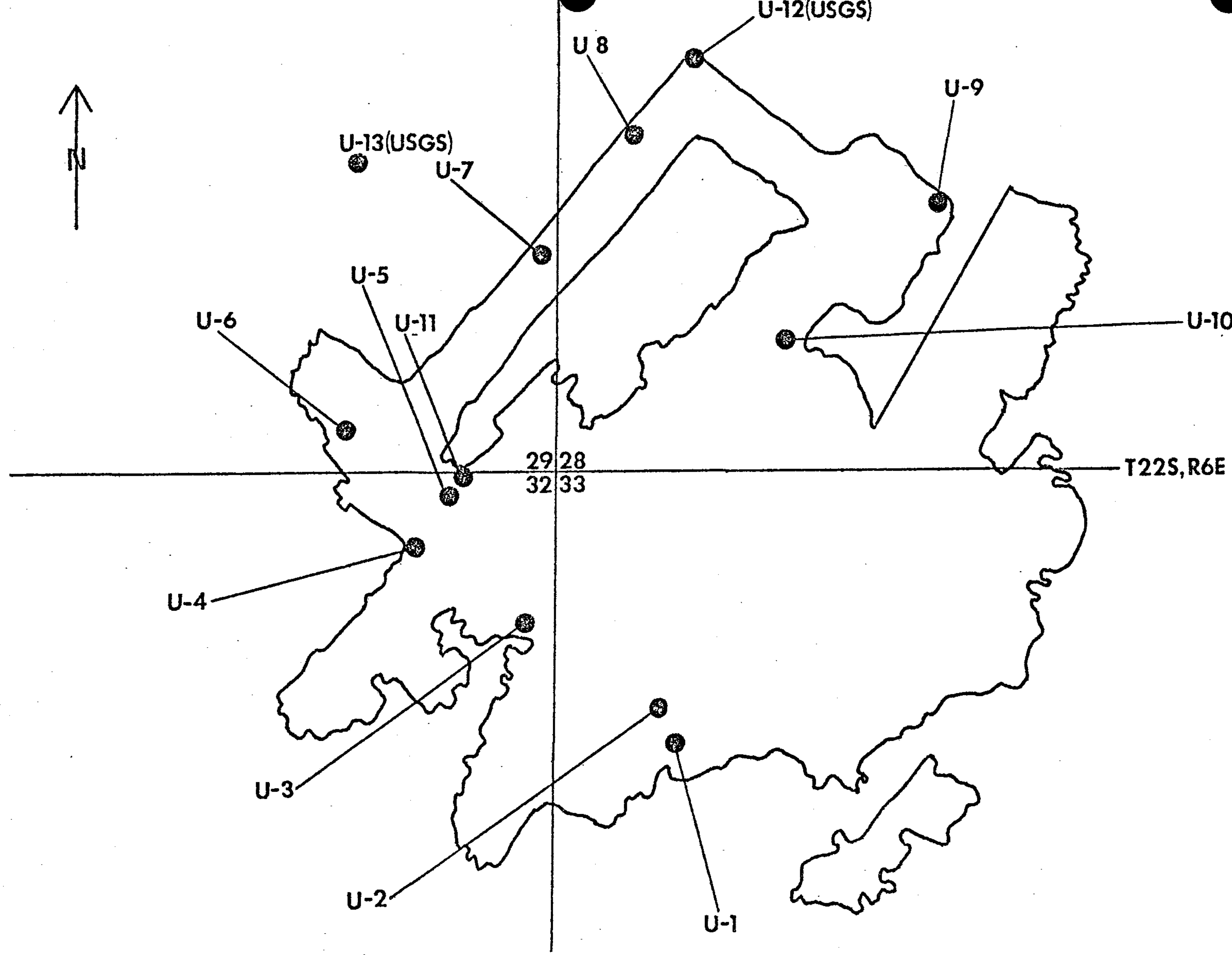


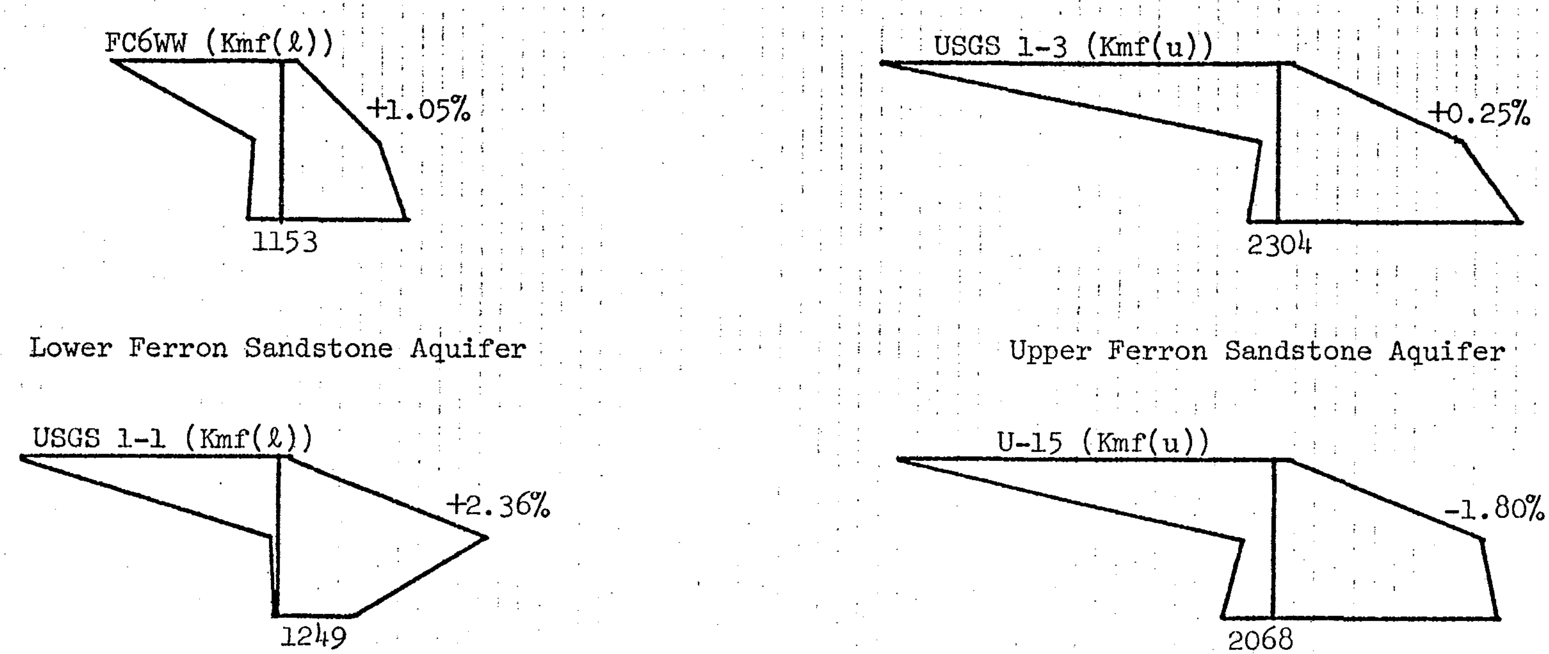
Figure 30. Location map for ground water samples taken from inside the Emery Mine. Sample U-12 and U-13 locations are only approximate; samples U-14 through U-17 are not shown. (Source: Consol, 1978)

The main chemical constituents which characterize the quality of the upper Ferron Sandstone aquifer waters are primarily sulfate (SO_4) and sodium (Na) (see Figure 31). As a result, SAR values tend to be high, averaging about 9. Other important chemical constituents which qualify the chemical type of the upper Ferron Sandstone aquifer waters are calcium (Ca), magnesium (Mg), chloride (Cl), and bicarbonate (HCO_3). Values of pH generally range between 7.0 and 8.5.

Water quality samples have also been collected from the lower Ferron Sandstone aquifer; a medium-grained sandstone, shale sequence extending below the coal-bearing section of the Ferron Sandstone. Data are contained in Table 31 and on Figure 31. Like the upper Ferron Sandstone, the lower tends to be a sodium-bicarbonate-sulfate type water, but water from the lower Ferron Sandstone tends to average about one-half the TDS. The principal user of water derived from the lower Ferron Sandstone is the town of Emery.

Upward leakage from the lower Ferron Sandstone through the middle Ferron Sandstone and into the mine floor does not appear to be occurring with importance, as was discussed in Section 7.2.3, Aquifer Interrelationships. The lack of floor leakage in the mine and the uninterrupted flow pattern of the lower Ferron Sandstone suggest that this is true (see Plate 3).

Trace element analyses were also performed on two ground waters sampled by the USGS from two different roof



+0.0% = % by which anions exceed cations

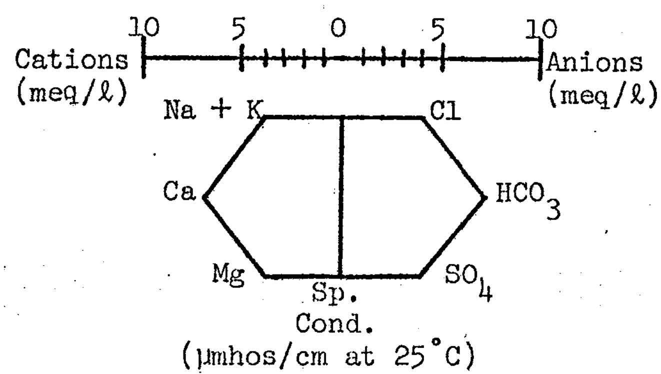


Figure 31. Balance and distribution of major ions in ground waters sampled in the Emery Mine area

locations in the mine. The results of these analyses are reported in Table 32. Note that there are only a few trace elements which were found in concentrations above the analytical detection limit (i.e., Sr, B, Ba, Cd, Li); their concentrations pose no water quality hazard.

Aside from the waters sampled from the rooffall locations within the mine, ground water in the mine is of poorer quality than the aquifer waters. From the results of chemical analyses of ground waters sampled from various locations within the mine (see Table 31 and Figure 30), TDS concentrations tend to average around 4000 ppm. These results indicate that the ground water after entering the mine picks up an additional load of dissolved solids, i.e., mostly magnesium (Mg), sodium (Na), sulfate (SO_4), and chloride (Cl). Apparently, the source of these additional dissolved solids is from soluble minerals which are directly associated with coal and rock dust in the mine. These findings are confirmed by the results of leach tests performed on the coal and rock dust (see Table 33). The results show that these materials contribute an additional load of sulfate (SO_4), magnesium (Mg), sodium (Na), and chloride (Cl) to the mine effluent.

Independent of the results of chemical analyses reported for waters in the mine are the results of chemical analyses of waters being discharged from the Emery Mine into the unnamed tributary to Quitchupah Creek (see Table 34 and Figure 32). These waters were sampled monthly (in compliance

TABLE 32

RESULTS OF TRACE ELEMENT ANALYSES OF GROUND WATERS SAMPLED FROM THE CEILING OF THE EMERY MINE

Sampling Site:	U-12	U-13
Location:	U-grd Mine	U-grd Mine
Date of Collection:	9/1/78	9/1/78
Geologic Unit:	Kmf(u)	Kmf(u)
Source of Data:	USGS	USGS
TRACE ELEMENTS[1]		
Aluminum (Al)	0.100	-0.050[2]
Antimony (Sb)	-0.030	-0.030
Barium (Ba)	0.030	0.050
Beryllium (Be)	-0.001	-0.001
Bismuth (Bi)	-1.000	-1.000
Boron (B)	0.500	0.700
Cadmium (Cd)	0.003	-0.001
Chromium (Cr)	-0.050	-0.050
Cobalt (Co)	-0.005	-0.005
Copper (Cu)	-0.010	-0.010
Gallium (Ga)	-0.030	-0.030
Germanium (Ge)	0.100	-0.030
Lead (Pb)	-0.030	-0.030
Lithium (Li)	0.070	0.030
Molybdenum (Mo)	-0.010	-0.010
Nickel (Ni)	-0.050	-0.050
Silver (Ag)	-0.010	-0.010
Strontium (Sr)	5.000	0.100
Tin (Sn)	0.100	-0.050
Titanium (Ti)	-0.005	-0.005
Vanadium (V)	-0.010	-0.010
Zinc (Zn)	-0.005	-0.005
Zirconium (Zr)	-0.005	-0.005

[1] All results are in milligrams per liter (mg/ℓ).

[2] Minus (-) indicates concentrations below the analytical detection limit.

TABLE 33

RESULTS OF LEACH TEST PERFORMED ON THE UPPER FERRON SANDSTONE AND IJ COAL (Source: Consol, 1978)

Sample	Sulfate mg/ℓ	Calcium mg/ℓ	Magnesium mg/ℓ	Potassium mg/ℓ	Sodium mg/ℓ	Chloride mg/ℓ
Coal dust	57	13	38	0.7	46	22
Rock dust	36	15	11	5.6	8.2	34

Note: 100 grams of each dust sample was leached with 100 milliliters of distilled water.

TABLE 34

RESULTS OF CHEMICAL ANALYSES OF WATERS BEING DISCHARGED FROM THE EMERY MINE INTO QUITCHUPAH CREEK

Parameters[1,2]	3rd Quarter, 1976			4th Quarter, 1976		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Flow (discharge-mgd)		.03			0.1	
Dissolved solids, total (mg/ℓ)	4923	5298	5537	4928	5031	5133
Suspended solids, total (mg/ℓ)	7	11	17	6	21	35
Iron, total (mg/ℓ)	0.2	0.3	0.3	0.25	0.28	0.3
Oil and grease (visual)		No visual sheen			No visual sheen	
pH, field (units)	7.6	7.7	7.8	7.1		7.9

Parameters	1st Quarter, 1977			2nd Quarter, 1977		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Flow (discharge-mgd)		0.43			0.66	
Dissolved solids, total (mg/ℓ)	4979	5103	5187	4502	4656	4896
Suspended solids, total (mg/ℓ)	5	12	21	9	14	20
Iron, total (mg/ℓ)	0.2	0.54	0.71	.60	.93	1.20
Oil and grease (visual)		No visual sheen			No visual sheen	
pH, field (units)	7.9		8.1	7.8		8.0

Parameters	3rd Quarter, 1977			4th Quarter, 1977		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Flow (discharge-mgd)		0.26			0.40	
Dissolved solids, total (mg/ℓ)	610	2639	4668	4018	4363	4794
Suspended solids, total (mg/ℓ)	8	14	20	6	12.5	23
Iron, total (mg/ℓ)	0.7	0.7	0.7	0.5	1.5	4.5
Oil and grease (visual)		No visual sheen			No visual sheen	
pH, field (units)	8.1		8.1	8.0		8.3

[1] Grab samples were taken once a month from the weir at the effluent end of the sedimentation pond.

[2] The parameters measured are those which are cited in the Discharge Monitoring Report forms provided by the EPA as part of the National Pollutant Discharge Elimination System (NPDES).

TABLE 34 Continued

Parameters	1st Quarter, 1978			2nd Quarter, 1978		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Flow (discharge-mgd)		0.42			0.46	
Dissolved solids, total (mg/ℓ)	3558	3763	3870	3348	3553	3796
Suspended solids, total (mg/ℓ)	12	22.7	32	3	17.7	38
Iron, total (mg/ℓ)	0.5	0.57	0.6	0.3	0.33	0.4
Oil and grease (visual)		No visual sheen			No visual sheen	
pH, field (units)	8.0	8.13	8.3	8.2		8.4

Parameters	3rd Quarter, 1978			4th Quarter, 1978		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Flow (discharge-mgd)		0.447			0.40	
Dissolved solids, total (mg/ℓ)	3570	3653	3728	62	1803	3544
Suspended solids, total (mg/ℓ)	2	4	6	2	6.5	11
Iron, total (mg/ℓ)	0.01	0.01	0.01	0.01	0.03	0.04
Oil and grease (visual)		No visual sheen			No visual sheen	
pH, field (units)	8.7		8.8	8.3		8.5

Parameters	1st Quarter, 1979			2nd Quarter, 1979		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Flow (discharge-mgd)		0.456			0.460	
Dissolved solids, total (mg/ℓ)	3662	4233	4682	4026	4233	4340
Suspended solids, total (mg/ℓ)	4	18.3	37	2	4	6
Iron, total (mg/ℓ)	0.03	0.16	0.3	0	0.01	0.02
Oil and grease (visual)		No visual sheen			No visual sheen	
pH, field (units)	8.0		8.2	8.2		8.5

Parameters	3rd Quarter, 1979		
	Min.	Ave.	Max.
Flow (discharge-mgd)		0.566	
Dissolved solids, total (mg/ℓ)	3640	3821	3956
Suspended solids, total (mg/ℓ)	3	3	4
Iron, total (mg/ℓ)	0	0	0
Oil and grease (visual)		No visual sheen	
pH, field (units)	8.2		8.7

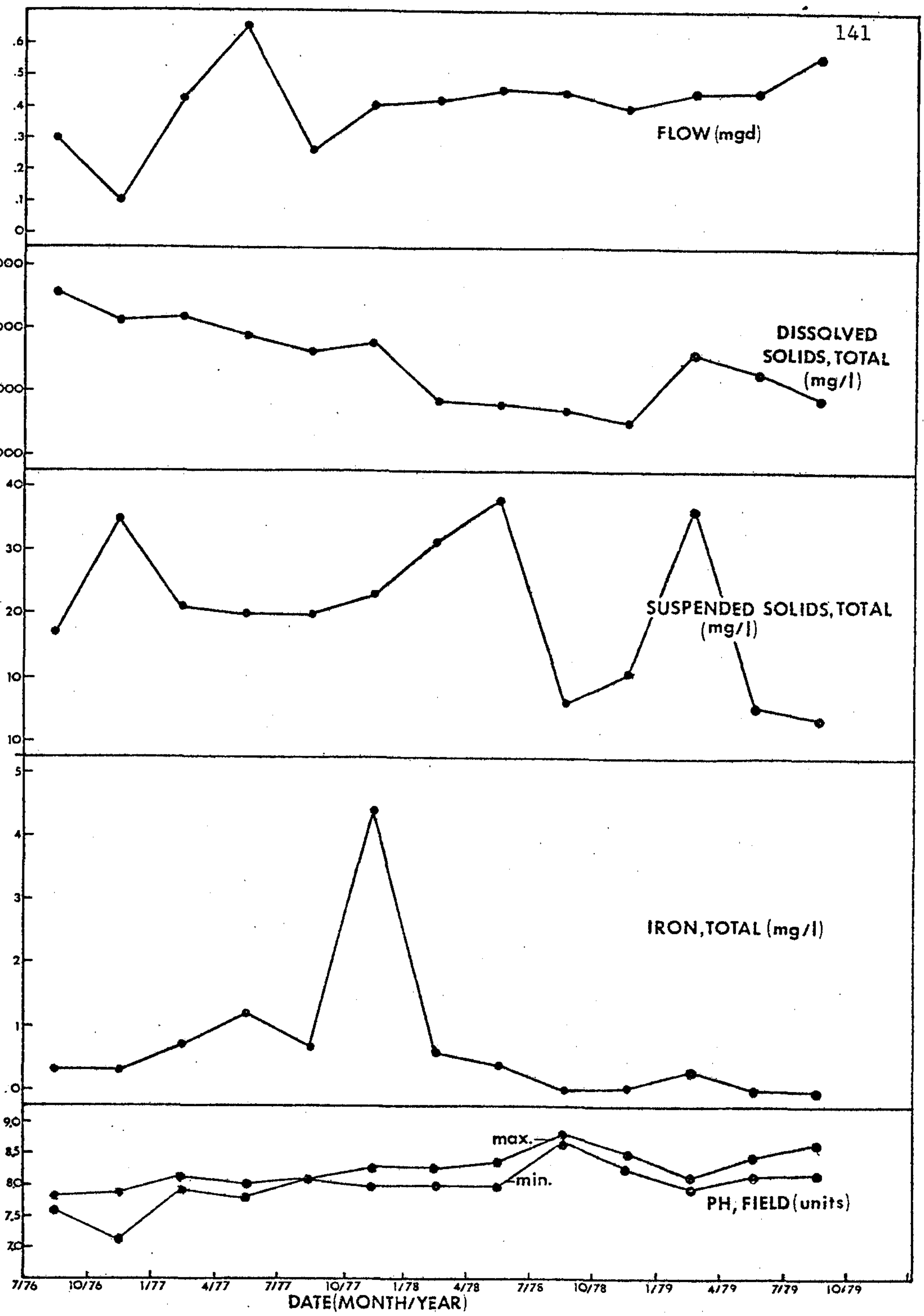


Figure 32. Graphic presentation of chemical analyses of waters being discharged from the Emery Mine (results plotted are maximum values for each quarter year except for flow and pH which show average and minimum/maximum values, respectively).

with the National Pollutant Discharge Elimination System (NPDES) monitoring program) from the weir at the end of the sedimentation pond and analyzed for TDS, total suspended solids (TSS), total iron (Fe), and pH (field). Two general trends are apparent. First, pH appears to have been rising at a rather constant rate from as low as 7.1 in the fourth quarter of 1976 to as high as 8.8 in the third quarter of 1978. Second, TDS has generally been steadily decreasing from an initial high of 5500 mg/ℓ in the fall of 1976 to about 4000 mg/ℓ in the fall of 1979.

7.3 Ground Water Monitoring Program

7.3.1 Monitoring Sites

As part of the hydrologic study of the Emery area, the USGS is presently monitoring static water levels in eighteen ground water wells on a monthly basis (see Plate 2). Consol is presently negotiating with the USGS to take over monitoring of all the wells which the USGS is presently monitoring. From the distribution of these monitoring wells and the particular geologic unit being monitored in each well, a more than adequate number are located to the east and northeast of the Emery Mine; however, because additional monitoring wells were necessary to the west and south of the Emery Mine in order to better determine the hydraulic gradient and ground water flow directions in the Ferron Sandstone aquifer, an additional five monitoring sites were established by Consol during 1979 (wells H, I, R, AA, and ZZ on Plate 2). From each of these wells, monthly static water levels will be measured. At each of these monitoring sites (except site ZZ), a hole has been drilled at least 100 feet into the lower Ferron Sandstone and four 1-inch I.D. piezometer pipes were installed. Each of the pipes isolates a portion of the Ferron Sandstone such that the lower Ferron Sandstone (Kmf(ℓ)) composed of marine sediments, the upper coal-bearing portion of the Ferron Sandstone between the A and IJ coal seams (Kmf(m)), the upper coal-bearing portion of the Ferron Sandstone above and including the IJ coal seam (Kmf(u)), and the Bluegate Shale (Kmbg), will each be monitored separately for static water levels. Well ZZ will monitor the lower Ferron Sandstone (see Figures 19 through 23 for well completion details). From this additional data, the ground water hydrologic regime will be better monitored and, consequently, better understood.

Ground water discharge from the Emery Mine is presently being monitored by calculating the amount of mine water periodically being discharged by both a centrifugal and turbine pump inside the mine. Because of the potential inaccuracy and unreliability of this approach, a continuously recording 9-inch Parshall flume has been installed at the effluent end (site S-6) of the sedimentation pond into which this mine water is pumped. In this manner, continuously recorded mine discharge data can be interfaced with static water level measurements and flow data obtained from the permanent surface water monitoring sites on Quitchupah Creek. The result of this approach will provide a better understanding of the ground and surface water hydrologic balance.

7.3.2 Water Levels

Static water levels will be measured monthly at each of the twenty-three monitoring wells shown on Plate 2. Depending upon the data recovered, the number of wells in the program may be reduced.

7.3.3 Sampling Parameters and Schedule

The general chemical quality of ground water in the Ferron Sandstone has been fairly well determined by previous work of Consol and the USGS. Thus, ground water from wells FC6WW, EMRIA #2, USGS 1-1, USGS 1-2, Well ZZ and the Bryant well will be sampled on a semi-annual basis for the chemical constituents listed in Table 35.

7.3.4 Sampling, Lab Analysis, and Reporting Procedures

At each sample well, a trained Consol technician will take field measurements of the static water level, water temperature, pH, and specific conductivity. Air temperature and weather conditions will also be noted. The Consol technician will collect three 1-liter samples at each well. One sample will be field filtered through a 0.45 micron filter and acidified to a pH of less than 2.0 with redistilled nitric acid (HNO_3). A second sample will be collected raw and

TABLE 35

GROUND WATER MONITORING PARAMETERS

Acidity, total	Lab
Air temperature (°C)	Field
Alkalinity, total	Lab
Bicarbonate (total HCO_3)	Lab
Calcium (total Ca)	Lab
Carbonate (total CO_3)	Lab
Chloride (total Cl)	Lab
Fluoride (total F)	Lab
Hardness (noncarbonate)	Lab
Hardness (total)	Lab
Iron (total Fe)	Lab
Dissolved iron	Lab
Magnesium (total Mg)	Lab
Manganese (total Mn)	Lab
Nitrate + Nitrite (NO_4 + NO_3)	Lab
pH	Field and Lab
Phosphate (total PO_4)	Lab
Potassium (total K)	Lab
Silicate (total SiO_4)	Lab
Sodium adsorption ratio (SAR)	Lab
Sodium (total Na)	Lab
Specific conductivity (EC)	Field
Static water level (ft. amsl)	Field
Strontium (total Sr)	Lab
Sulfate (total SO_4)	Lab
Total dissolved solids (TDS)	Lab
Total suspended solids (TSS)	Lab
Water temperature (°C)	Field

acidified to a pH of less than 2.0. The third sample will be collected raw and untreated. All three sample bottles will be filled completely full to minimize water-air ion exchange. These samples will be properly labeled with the site number, date, time of collection, and technician's initials. These samples will be refrigerated immediately to 4°C via ice and will remain refrigerated until delivered to a laboratory registered with the Environmental Protection Agency. The samples will be delivered to the laboratory within three days to assure analytical accuracy. The laboratory will analyze for all parameters listed in Table 35 except those indicated as "Field." The methods for collecting water samples and performing analyses are outlined in the Environmental Protection Agency's Manual of Methods for Chemical Analysis of Water and Wastes (1976).

Consol will maintain a ground water monitoring activities log book at the mine office. This log book will contain dates of instrument calibration, static water level records, aquifer pump test data, field data, and results of chemical analysis. Within thirty days of the end of each calendar quarter, Consol will forward a copy of all monitoring data and a summary of well and spring information to the Utah Division of Oil, Gas, and Mining.

7.4 Ground Water Rights

Ground water rights information was requested on December 5, 1979, from the Utah State Engineer's Office, Division of Water Rights, Salt Lake City, Utah. When the information is received, it will be immediately appended to this report.

8.0 POTENTIAL MINE WATER INFLOW

8.1 Introduction

Ground water has the potential to enter the Emery Mine from sandstone units within the Ferron Sandstone. Because the IJ coal has permeable, saturated sandstones above and below, water has the potential to enter through both the floor and roof of the mine workings.

Based upon drilling and geophysical logs, and upon discussions with Consol mine engineering personnel, underclays which constitute the floor of the mine effectively preclude serious upward leakage. As reported by Owili-Eger (1979), upward leakage in the form of a spring has occurred at only one location within the existing mine.

The principal source of inflow to the mine is and will presumably continue to be the roof of the workings. Mining is conducted in such a way as to leave some roof coal. In the absence of rooffalls or fracture connection to overlying sandstones, the presumed reduced permeability of the coal controls the amount of seepage to the mine. By and large this is the case within the mine today. However, sporadic rooffalls and fracturing introduce water into the mine from overlying sandstones. Table 36 summarizes the estimated mine water pumpage at various times during the past three years.

TABLE 36

ESTIMATED MINE WATER PUMPAGE

Date	Estimated Daily Volume[1] (gpd)	gpm
Jan. 1977	-	360
Oct./Nov. 1978	425,000	295
Oct./Nov. 1979	750,000	521

[1]Estimated from pump efficiency and power consumption records.

The number and location of connecting fractures and the incidence and location of rooffalls cannot be predicted with certainty. As a routine practice, those old workings which could contribute significant quantities of water to the mine are sealed off. With the mine continually advancing on several fronts and with abandoned water-yielding sections being continually sealed, an extremely dynamic ground water regime has been and will continue to be created in the near vicinity of the mine. The mathematics available with which to simulate these conditions are not well suited to the problem. Rather than attempting to predict micro-regimes near advancing fronts in the mine or over sealed abandoned sections of previous mining, the worst-case condition of mine water inflow and resulting effects upon the hydrologic system will be evaluated.

8.2 Mine Water Inflow Model

Computer programming techniques were employed to simulate the hydrologic system around the mine site. This included the array of real and image wells shown on Plate 7. This configuration was used to simulate the effects of the enlarging mine as if it were a pumping well. The upper Ferron Sandstone (immediately above and including the IJ coal seam) crops along Quitchupah Creek and Christiansen Wash. An image mine inflow well was set equidistant from the mine across the crop to simulate an impermeable boundary condition.

Both Quitchupah Creek and Christiansen Wash receive outflow from the upper Ferron Sandstone. These points of outcrop discharge were treated as discharging wells until water levels had declined to the point that bedrock outflow would no longer be possible. A system of image recharge wells was then begun to simulate a zero potential line.

The ground water system receives recharge as is evidenced by outflow from the upper Ferron Sandstone to the creeks. Within the area encompassed by this investigation the amount of recharge was assumed equal to the amount of discharge to the creeks. Other investigators (Kaufman, 1977; Owili-Eger, 1979) suggest that the Joe's Valley-Paradise fault zone is the principal area of recharge to the Ferron Sandstone.

Contours on the potentiometric surface maps of the upper and lower Ferron Sandstone (Plates 3 and 4) suggest this to be the case. A recharging image well was placed west of the fault zone to simulate recharge. The amount of recharge was set equal to discharge from the upper Ferron Sandstone to Quitchupah Creek and Christiansen Wash (3.241 cfs; Section 7.2.4).

The model is sensitive to the transformation from artesian to water table conditions by recognizing the change in an initial storage coefficient to a specific yield at the instant of transformation. Under water table conditions, the model is sensitive to changing transmissivity with changing water levels.

The model was set with October/November 1979 as being the base year, and was run for the following six years. Input data are as follows:

Oct./Nov. 1979 size of mine ≈ 4800 $ft.^2$; r ≈ 2710 ft.

Monthly advance rate ≈ 278,850 $ft.^2$; Δr ≈ 298 ft./mo.

Subsurface outflow ≈ 3.241 cfs (Owili-Eger, 1979)

T = 3030 gpd/ft. (average from USGS aquifer tests)

m = 80 ft.

Sc = 5×10^{-4} (average from USGS aquifer tests)

Sy = 0.10 (assumed)

Annual recharge rate = 3.241 cfs

Average roof permeability = 0.0325 gpd/ft. (based upon average mine pumpage rate Oct./Nov. 1979 and 1979 roof area of mine)

Observation wells were set about the area of investigation to record calculated drawdown over the six-year mining period Oct./Nov. 1979 to Oct./Nov. 1985.

8.2.1 Calculated Mine Water Inflow

Because the mine for this analysis is being treated as a large diameter well, it is reasonable to assume that as the well diameter increases so does the yield. It has been demonstrated that inflow through the roof of the 1979 mine averaged 0.0325 gpd/ft.^{2} of roof area. Based upon the projected rate of mining, about 278,850 ft.^{2} of roof area will be exposed each month. Without water level decline in the upper Ferron Sandstone and without sealing off older workings, about 6.3 gallons per minute of inflow will result each month of mining advance over the next six years. This equates to about 75 gpm of increased inflow per year of mining. Table 37 provides the average weighted annual mine water inflow rates over the projected six-year mining period. These inflow rates are constantly increasing based upon an average roof leakance rate of 0.0325 gpm/ft.^{2} of roof area.

Plate 7 shows the calculated pattern of water level decline after six years of mine operation.

8.2.2 Factors Affecting Calculations of Mine Water Inflow

Throughout this section of the report, worst-case conditions of mine water inflow have been examined. In so doing, it was assumed that inflow would increase on a 1:1

TABLE 37

PROJECTED MINE WATER INFLOW, 1979-1985

Year	Projected Inflow (gpm)	Weighted Average Inflow (gpm)
1979	520	520
1980	596	560
1981	672	580
1982	748	610
1983	786	630
1984	862	660
1985	938	680

ratio with the expanding roof area of the mine. When these projected inflows are used in the model, observation points near the mine perimeter indicate loss of all artesian pressure within a year or two of model operation. Based upon present water levels in wells adjacent to the mine, as much as 90 feet of artesian pressure remains in the upper Ferron Sandstone over the mine's center. This suggests that the hydraulic gradient predicted by the model is unrealistically more steep than the observed existing hydraulic gradient; a lower gradient suggests less inflow. Additionally, if the mine is analogous to a large diameter well, the lessons of well hydraulics demonstrate that increasing a well's diameter does not result in

1:1 increased inflow. As an example, if the Darcy equation is applied to inflow to the size of the six-year mine,

$$Q = kiA_6 = 0.0325 \times 1^{*} \times 24{,}713{,}067/1440 = 558 \text{ gpm.}$$

If it is assumed that previously worked areas will continue to be sealed, this would further set to reduce inflow.

9.0 POTENTIAL HYDROLOGIC CONSEQUENCES OF MINING

There are several possibilities by which mining could influence the hydrologic balance in the vicinity of the Emery Mine. These are as follows:

(1) Depletions of flow in both Quitchupah Creek and Christiansen Wash resulting from ground water level declines;

(2) Temporary creation of mineward gradients induced by mine water inflow affecting ground water level declines; and

(3) Redistribution of ground water quality within water-bearing units of the Ferron Sandstone.

9.1 Stream Depletion

As has been noted throughout the report, the hydraulic gradient within the upper and lower Ferron Sandstone slopes southeast toward Quitchupah Creek and Christiansen Wash. The upper Ferron is known to discharge directly into both stream systems in the near vicinity of the mine. The lower Ferron

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*Hydraulic gradient of unity assumed. Actual gradient would be some potential drop over 20 feet of roof coal.

Sandstone discharges into Quitchupah Creek below its confluence with Christiansen Wash and south of the mine.

It has been discussed (Sections 7.2.3 and 7.2.9) that the lower Ferron Sandstone is well isolated from the mine and does not appear to have been affected to the small extent that the upper Ferron Sandstone has. Continued mining is not expected to impart serious residual effects upon the lower Ferron Sandstone; it follows that outflow to Quitchupah Creek south of the mine will not be diminished. Several lower Ferron Sandstone monitoring points around the mine will be monitored monthly for water level to verify this condition.

It has been shown that the upper Ferron Sandstone does contribute to the flow of Christiansen Wash and Quitchupah Creek. It is also true that the upper Ferron Sandstone presently contributes most of the water flowing into the mine. The effect of the declining upper Ferron Sandstone water levels will be, in part, a reduction of outflow from the aquifer to the streams. At the projected rate of mining, the mathematical model employed to simulate the physical system predicted that the hydraulic gradients would be sufficiently lowered toward the creeks to reduce aquifer outflow to zero in 1980. It may be seen, however, that an average of about 90 feet of artesian pressure continues to overlie the mine as of the fall of 1979. The mine has been active for many years now and artesian pressure still exists; artesian pressure will presumably continue into the future. The array of monitor wells selected by Consol for monthly monitoring of well levels will help define this relationship.

There are no registered surface water rights between the area of potential decreased upper Ferron Sandstone aquifer outflow and the point where the unnamed tributary (into which Emery Mine discharges) discharge confluences with Quitchupah Creek. Potential diminution of stream flow within this reach will be offset by discharge from the settling pond. The quantity of water available to any existing rights is, therefore, not expected to be diminished.

9.2 Water Level Declines

Hydrographs of water levels in wells were presented in Section 7.2.5. The hydrographs indicate water level declines in the upper Ferron Sandstone of about four feet or more within about two miles of the mine over the last three years. The mathematical model predicts additional water level declines in proximity to the mine as it becomes larger. The calculated drawdown data from the model after the next six years of mining are included in Plate 7. The calculated worst-case cone of depression around the mine varies from about 160 feet near the mine to about 10 feet at the outer limits of the cone, which is projected to be at a distance of about 13,000 feet from the mine. The only production well within this radius of influence is the Bryant Well in (D-22-6)24ACD. The model predicts as much as 70 feet of drawdown at this location in six years. Since the fall of 1976, water levels in this well have declined from about four feet to less than one foot of head.

Water levels in the mine area are to be monitored monthly from a large number of points which include points in the Bluegate Shale, upper, middle, and lower Ferron Sandstone. These data will be extremely useful in monitoring the effects of mining and in projecting future water level declines.

9.3 Water Quality Changes

Mining within the IJ coal seam is not expected to produce any widespread changes in the existing water quality within the water-bearing materials. In Section 7.2.9, data are presented which indicate a wide variation in upper Ferron Sandstone water quality. This variation is believed to result from the degree to which the Bluegate Shale, a notorious producer of limited amounts of poor quality water, is included within the well construction. Hydraulic communication between the Bluegate Shale and upper Ferron Sandstone is imperfectly understood; the degree to which water from the Bluegate Shale may be induced to flow into the upper Ferron Sandstone with declining water levels is, therefore, also not known. However, the four piezometer nests installed by Consol during the fall of 1979 are designed to monitor water levels in four separate zones: Bluegate Shale, upper, middle, and lower Ferron Sandstone.

The quality of water being discharged from the mine is currently monitored under the limitations of an NPDES permit, and will continue to be as mining progresses.

9.4 Alluvial Valley Floors

With respect to the presence of alluvial valley floors in the Emery area, the BLM has recently completed a report on the Land Use Plans of the San Rafael Resource Area as part of their Management Framework Plan (BLM, 1979). This resource area includes known and probable coal resource lands in the Emery area. In their report, the BLM concludes that according to the opinion of the SCS (Price, Utah) and the unsuitability criteria used for qualifying known and probable coal areas, there are no designated alluvial valley floors within the Wasatch Plateau Known Recoverable Coal Resource Area (KRCRA) and the Emery Probable Coal Area (PCA). According to John Coleman (District Manager, BLM, Moab, Utah, personal communication, November 14, 1979), the Emery Coal Field has recently been designated as a KRCRA by the USGS.

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