State of Utah
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING

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April 5, 1995

Thomas E. Ehmett, Acting Director
Office of Surface Mining
Reclamation and Enforcement
505 Marquette N.W., Ste. 1200
Albuquerque, NM 87102

Re: Updated Appendix 7-J and Appendix 7-N (PHC), Bear Canyon Mine, Co-Op Mining Company, ACT/015/025-95C, Folder #2, Carbon County, Utah

Dear Mr. Ehmett:

Enclosed please find updated Appendix 7-J and Appendix 7-N, approved and effective March 9, 1995.

Sincerely,

Pamela Grubaugh-Littig
Permit Coordinator

Enclosure
cc: Price Field Office

CO-OP MINING COMPANY

P.O. Box 1245
Huntington, Utah 84528

(801) 381-5238
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March 27, 1995

Pamela Grubaugh-Littig
Permit Coordinator
Utah Division of Oil, Gas & Mining
3 Triad Center, Suite 350
Salt Lake City, Utah 84180-1203

Ms. Grubaugh-Littig,

#2

Re: **Update to Appendix 7-J and Appendix 7-N (PHC), Bear Canyon Mine, ACT/015/025-95C, Emery County, Utah**

Enclosed are Three finalized copies of the above referenced proposal, which were approved per Division letter dated March 9, 1995.

If you have any questions, please call Charles Reynolds at (801) 687-2450.

Thank You,

Wendell Owen
Wendell Owen,
Resident Agent

Enclosure(s)
cr

APPENDIX 7-J

PROBABLE HYDROLOGIC CONSEQUENCES OF MINING
AT BEAR CANYON MINE,
EMERY COUNTY, UTAH

CO-OP MINING COMPANY
Bear Canyon Mine
Emery County, Utah

Prepared by

EARTHFAX ENGINEERING, INC.
Salt Lake City, Utah

April 30, 1993

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PROBABLE HYDROLOGIC CONSEQUENCES OF MINING AT BEAR CANYON MINE EMERY COUNTY, UTAH

1.0 INTRODUCTION

The purpose of this document is to present an assessment of the probable hydrologic consequences of operating and reclaiming Bear Canyon Mine. Where possible, the impacts from potential future expansions will be addressed. Although data collected from the expansion areas are included in this document, it is recognized that baseline water monitoring requirements for proposed Federal Lease expansion areas have not been satisfied as of the date this document was submitted. When baseline monitoring in the proposed expansion areas is complete, this document will be revised and re-submitted.

This document is divided into five sections, including this introduction. Section 2.0 presents probable groundwater impacts and groundwater monitoring plans. A similar discussion of surface water impacts and monitoring is provided in Section 3.0. Conclusions and references are listed in Sections 4.0 and 5.0, respectively.

2.0 GROUNDWATER

2.1 BACKGROUND INFORMATION

Detailed information on groundwater and the physical resources that effect groundwater in the permit and adjacent areas is found in Chapters 6 and 7 of the M&RP and the Revised Hydrogeologic Evaluation of the Bear Canyon Mine Permit and Proposed Expansion Areas, (EarthFax Engineering, 1992). This information is summarized herein for convenience.

2.1.1 Climatology

The Bear Canyon Mine is located in an area of semiarid to subhumid climate (Danielson, 1981). According to the monthly climatological data collected by the Utah Climate Center (Table 2-1), temperatures at the Hiawatha Station have an average range during the period of record (1989 through 1991) from 7.5° to 70° F.

A new rain gauge was installed at the Bear Canyon Mine in August 1991 by Co-Op Mining Company (Table 2-2). Average precipitation measured at the Bear Canyon Mine station is 0.89 inches per month for the period from August 1991 to May 1992. Monthly average precipitation has ranged from 0.04 to 2.65 inches per month.

Wind velocities recorded at the nearby Huntington Research Farm are typically less than 15 mph, for years 1990 and 1991 (Table 2-3). Average wind velocities are estimated at 10 mph near the Bear Canyon portal area (Chapter 11, M&RP). Wind directions are generally controlled by the orientation of the canyons. The prevailing wind direction in the area of the Bear Canyon portal is west-southwest (Chapter 11, M&RP).

TABLE 2-1

Monthly Temperatures
Measured at the Hiawatha Station [a]

	January	February	March	April	May	June	July	August	September	October	November	December
1989	19.5	23.4	38.5	47.9	51.9	58.8	70.0	62.8	(M)	45.8	36.9	28.8
1990	23.2	26.7	37.5	46.1	50.5	63.3 [f]	67.3	65.40	60.5	45.5	7.5	16.9
1991	20.0	32.6	29.6	39.0	49.2	59.7	67.5	64.5	57.2	48.3	30.9	23.6
Avg	20.9	27.6	35.2	44.3	50.5	60.6	68.3	64.2	58.9	46.5	25.1	23.1

[a] Utah Climate Center (1992).
[f] Indicates 1 to 9 days of data are missing; a monthly value was calculated from available data.
(M) Indicates 10 or more days of data are missing; no monthly value was calculated.

TABLE 2-2

Bear Canyon Mine Precipitation Data

MONTH/YEAR	MONTHLY TOTAL (inches)	DAILY MAXIMUM (inches)	DAILY MINIMUM (inches)
Aug. 1991*	0.82	0.18	0.00
Sept. 1991	2.65	0.98	0.00
Oct. 1991	0.74	0.46	0.00
Nov. 1991	0.85	0.24	0.00
Dec. 1991	0.14	0.04	0.00
Jan. 1992	0.28	0.06	0.00
Feb. 1992	0.07	0.04	0.00
Mar. 1992	0.71	0.27	0.00
Apr. 1992	0.34	0.33	0.00
May 1992	2.25	0.67	0.00

* The installation date of reading gauge was in the month of August. The initial gauge reading was taken on Aug. 14, 1991.

TABLE 2-3

Huntington Research Farm Wind Data[a]

Date	Average mph	Maximum mph	Minimum mph	V-Direction[b] degree
March 1990	6.9 (m)	10.0 (m)	3.6 (m)	228 (m)
April	9.4	14.3	6.1	230
May	8.7	12.5	6.0	237
June	10.1	12.3	7.4	219
July	9.8 (m)	11.9 (m)	8.4 (m)	232 (m)
August	9.8	12.7	4.9	236
September	10.5 (m)	13.0 (m)	6.4 (m)	218 (m)
October	8.5	12.8	5.7	242
November	8.6 (m)	13.9 (m)	4.3 (m)	233 (m)
December	-	-	-	-
January 1991	5.7 (m)	11.6 (m)	1.9 (m)	237 (m)
February	8.3 (m)	9.1 (m)	7.6 (m)	311 (m)
March	7.7	11.7	3.0	299
April	10.2	14.2	6.5	316
May	9.5	15.7	5.9	309
June	9.4	12.0	5.2	301 (m)
July	9.6	12.9	6.5	301 (m)
August	9.9	13.0	6.9	308
September	9.5	12.7	3.0	307
October	9.5	14.7	4.0	307

(a) Utah Climate Center (1992).
(b) Azimuthal direction of wind .
(m) Indicates ten or more days of data are missing for the month.

TABLE 2-3 (Continued)

Huntington Research Farm Wind Data[a]

Date	Average mph	Maximum mph	Minimum mph	V-Direction[b] degree
November	6.8	14.4	3.0	285
December	5.8	12.3	2.3	247
January 1992	6.9	17.6	2.4	261
February	7.2	14.0	1.6	300
March	8.8	16.2	4.3	332

(a) Utah Climate Center (1992).
(b) Azimuthal direction of wind.

2.1.2 Hydrogeology

The North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, and Mancos Shale outcrop in the permit area. The stratigraphic sequence reflects an oscillating, yet overall regressive depositional environment. This changing environment resulted in great thicknesses of discontinuous sandstone, coal, and mud/siltstone units. Table 2-4 presents the stratigraphic relationships and surface water yield of these geologic units.

The main coal-bearing strata in the Wasatch Plateau is the Blackhawk Formation. The Trail Canyon and the Bear Canyon mines produce coal from the upper Blind Canyon Seam and the lower Hiawatha Seam (EarthFax Engineering, 1992, p. 2-4). Co-Op Mining Company proposes to begin mining the Tank Seam (approximately 220 to 250 feet above the Blind Canyon Seam) in 1994. Regionally, the strata in the study area dip to the south and southeast at an angle of two to three degrees (Brown, et al., 1987); this dip direction was confirmed by the stratigraphy observed during in-mine drilling conducted in 1992, although dip angles determined from in-mine drilling ranged from 0.44 to 1.47 degrees. The Bear Canyon and Trail Canyon mines are located in a complex graben bounded by the Pleasant Valley Fault (on the west) and the Bear Canyon Fault (on the east), (Plate 1, EarthFax Engineering, 1992). Vertical displacements on both faults are approximately 100-150 feet. Brown, et al. (1987) describe a shattered zone within the graben, approximately two miles north of the current northernmost extent of the Bear Canyon Mine. In the portion of the graben within the permit area, only minor faults (vertical displacements of 20 feet or less) have been identified, with the exception of the Blind Canyon fault (Plate 1, EarthFax Engineering, 1992), which is estimated to have approximately 220 feet of vertical displacement (down to the west) in the vicinity of the Bear Canyon Mine (M&RP).

The Castlegate and the Star Point Sandstones are regionally continuous. Although the Castlegate Sandstone contains some water (Danielson, 1981), it is not considered to be a regional aquifer. The Star Point Sandstone together with the lower Blackhawk Formation

TABLE 2-4

Stratigraphic relationships, thicknesses, lithologies, and water-bearing characteristics of geologic units in the upper drainages of Huntington and Cottonwood Creeks (adapted from Stokes, 1964)

System	Series	Formations and members	Thickness (feet)	Lithology and water-bearing characteristics
Quaternary	Holocene and Pleistocene		0-100	Alluvium and colluvium; clay, silt, sand, gravel, and boulders; yields water to springs that may cease to flow in late summer.
Tertiary	Eocene and Paleocene	Flagstaff Limestone	10-300	Light-gray, dense, cherty, lacustrine limestone with some interbedded thin gray and green-gray shale; light-red or pink calcareous siltstone at base in some places; yields water to springs in upland areas. (See table 9.)
	Paleocene	North Horn Formation.	800±	Variegated shale and mudstone with interbeds of tan-to-gray sandstone; all of fluvial and lacustrine origin; yields water to springs. (See table 9.)
Cretaceous	Upper Cretaceous	Price River Formation	600-700	Gray-to-brown, fine-to-coarse, and conglomeratic fluvial sandstone with thin beds of gray shale; yields water to springs locally.
		Castlegate Sandstone	150-250	Tan-to-brown fluvial sandstone and conglomerate; forms cliffs in most exposures; yields water to springs locally.
		Blackhawk Formation	600-700	Tan-to-gray discontinuous sandstone and gray carbonaceous shales with coal beds; all of marginal marine and paludal origin; locally scour-and-fill deposits of fluvial sandstone within less permeable sediments; yields water to springs and coal mines, mainly where fractured or jointed.
		Star Point Sandstone	350-450	Light-gray, white, massive, and thin-bedded sandstone, grading downward from a massive cliff-forming unit at the top to thin interbedded sandstone and shale at the base; all of marginal marine and marine origin; yields water to springs and mines where fractured and jointed.
		Mancos Shale	600-800	Dark-gray marine shale with thin, discontinuous layers of gray limestone and sandstone; yields water to springs locally.

(Blackhawk-Star Point aquifer) are considered by Lines (1981) to be a regional aquifer. However, evidence from recent drilling and testing of the Star Point Sandstone indicates that the regional aquifer lies below the Star Point/Mancos Shale contact (EarthFax Engineering, 1992, p. 2-13). Additionally, separate and distinct aquifers were defined in the Spring Canyon, Storrs, and Panther tongues of the Star Point Sandstone (EarthFax Engineering, 1992, pp. 2-21 and 2-22). Other groundwater occurring above the Star Point aquifers is contained in perched, discontinuous aquifers in the upper Blackhawk Formation, the Castlegate Sandstone, the Price River Formation, and the North Horn Formation (EarthFax Engineering, 1992, p. 2-11).

Data collected from pumping tests and core analyses from the Trail Mountain area (approximately 10 miles south-southwest of the Bear Canyon Mine) indicate that the transmissivity of the full thickness of the Blackhawk-Star Point aquifer probably ranges from about 20 to 200 ft^2/day (Lines, 1985). Slug tests performed on the three tongues of the Star Point Sandstone (Spring Canyon, Storrs, and Panther) within the permit area yielded transmissivities ranging from 1 to over 50 ft^2/day (EarthFax Engineering, 1992, Table 4-2, p. 4-8).

Average linear velocities of groundwater in the three Star Point Sandstone aquifers were calculated using slug test data (EarthFax Engineering, 1992, Table 4-2, p. 4-8) and ranged from 0.0036 to 0.191 feet per day. These velocities indicate that groundwater beneath the Bear Canyon Mine moves to the south and southeast at between 1.31 and 69.72 feet per year.

Outcrops within the permit area include the Price River Formation, Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, and the Mancos Shale. Danielson, et al. (1981) indicate that recharge to the Star Point-Blackhawk aquifer from direct infiltration of snowmelt to formations which outcrop below the North Horn Formation is small in comparison to recharge through low relief surfaces on the North Horn Formation. In the study area, exposures of formations below the North Horn Formation and above the coal outcrops are limited to steep canyons. Therefore, the potential for recharge through these formations to the regional groundwater system within the permit area is limited. Within the proposed expansion area, there are three springs associated with the perched aquifers above the coals mined by Co-Op Mining Company. No springs were found within the present permit area. A number of low volume springs (2 gpm or less) occur north of the permit area and issue from the perched aquifers lying above the coals (Appendix 7-M, M&RP). All other springs in the permit and adjacent areas discharge from the Star Point Sandstone or from colluvial slopes which cover the Star Point Sandstone. The two largest springs in the area (Big Bear Springs and Birch Springs) are associated with fault and joint zones and issue from the Panther Tongue of the Star Point Sandstone (Chapter 7, M&RP and EarthFax Engineering, 1992, pp. 2-14 and 2-17). These two springs have been developed and are used by the Huntington-Cleveland Irrigation Company and the North Emery Water Users Association for culinary purposes.

Table 2-5 presents flow rates measured during the initial sampling of each spring and mine water monitoring point. Locations of these monitoring points are presented on Plate 7-4 of this M&RP. Average flow rates measured at Co-Op Mining monitoring points in 1991 are presented in Table 2-6. Average 1991 annual flow rates at BP-1, SBC-9, and TS-1 are higher than initial flow rates, while the average annual flow rate at SBC-6 is lower. The increase in flow at SBC-9 is due to the progression of mining into a wetter area of the mine (Co-Op Mining Company, 1992a). The decrease in flow rate at SBC-6 is likely due to the drought conditions of the last several years (Section 2.1.1). The cause of the higher flow rates measured at BP-1 and TS-1 is unknown.

Springs FBC-2 through FBC-6A are located in proposed Federal Lease U-024316 and adjacent areas (Plate 7-4 of this M&RP). These springs issue from the North Horn Formation (Co-Op Mining Company, 1992a) and flow intermittently (Table 2-7). FBC-6A is the largest of seven small springs monitored at FBC-6 (Table 2-7). Water flowing from these springs is absorbed by colluvium within 10 to 70 feet of each spring. These springs are not known to contribute to stream flow in the area (Co-Op Mining Company, 1992a).

TABLE 2-5

Initial Spring and Mine Water Flow Rates

Source	Date	Flow (gpm)
BP-1 (Ballpark Spring)	5/90	0.15
CS-1 (Trail Co-Op Spring)	5/90	NM
NPDES (Mine Discharge)	4/91	60
PS-1 (Portal Spring)	5/90	Dry
Roof Drips above Su-1	2/85	3 - 5
Roof Drips above Su-3	10/84	3 - 5
SBC-1 (Mine Water Sump)	2/86	Dry
SBC-4 (Big Bear Spring)	10/84	NM
SBC-5 (Birch Spring)	10/84	NM
SBC-6 (CoOp Dev. Spr)	9/86	12
SBC-7 (#33 West Spring)	2/90	1
SBC-8 (#30 East Spring)	2/90	<1
SBC-9 (Sump Su-3)	10/84	NM
Su-1	10/84	NM
TS-1 (Trail Canyon Spring)	5/90	0.5

NM = Not Measured

TABLE 2-6

1991 Average Spring and Mine Water Flow Rates

Source	Flow (gpm)	Number of Samples
BP-1 (Field)	0.38	2
CS-1 (Trail Co-Op Spring)	16	2
NPDES (Mine Discharge)	78	9
PS-1 (Portal Spring)	Dry	2
SBC-4 (Big Bear Spring)	119	8
SBC-5 (Birch Spring)	31	8
SBC-6 (CO-OP Develop. Spring)	Dry	4
SBC-9 (Mine Sump Su-3)	114	5
TS-1 (Trail Canyon Spring)	12.6	2

TABLE 2-7

Initial Spring Water Flow Rates (proposed Federal Lease U-024316)

Spring	June 1990	August 1991	October 1992
FBC-2	0.25 gpm	12 gpm	Dry
FBC-3	Dry	1.5 gpm	Dry
FBC-4	0.25 gpm	8.7 gpm	0.5 gpm
FBC-5	Dry	8.5 gpm	0.6 gpm
FBC-6	Dry	9.8 gpm	1.5 gpm
FBC-6A	NM	NM	1.1 gpm

NM = Not measured.

Three monitoring wells (SBC-2, SBC-3, and WM-C) were initially included in the groundwater monitoring program. SBC-2 is located immediately outside the mine portal (Co-Op Mining Company, 1992a) and the location of SBC-3 is presented on Plate 7-4 of this M&RP. There is no location information for WM-C and only one sample has been collected from this well (February 1985). Therefore, data from WM-C are not presented and are excluded from this discussion. Monitoring of SBC-2 was discontinued in 1991 because the well caved and was lost (1991 Annual Report). SBC-3 was damaged in 1990 and surface water began leaking into the well. In March 1992, SBC-3 was repaired and sealed (Co-Op Mining Company, 1992a). Static water levels and analytical data collected from 1990 through March 1992, are not representative of SBC-3 and have been excluded from the data set. This well has been dry throughout the balance of the period of record (Co-Op Mining Company, 1992a).

Groundwater enters the Blind Canyon Seam of the Bear Canyon Mine through fractures and roof bolt holes. Typically, water encountered by roof bolt holes flows moderately at first. Over a period of one or two months, flow decreases and eventually stops. Sources of these short-lived flows are inferred to be localized perched aquifers which store a limited amount of water (EarthFax Engineering, 1992, p. 2-19). This flow pattern is typical of the mines (Deer Creek, Plateau, and others) in the area (Danielson, et al., 1981).

Inflows through seven of eight exploratory borings into the Tank Seam (drilled up from the mine workings in the Blind Canyon Seam) are less than 0.1 gpm. The remaining boring (near the intersection of 3rd West and the 3rd West Bleeders) flows at 0.5 gpm. Thus, inflows to the proposed Tank Seam workings are expected to be less than those encountered in the Blind Canyon Seam.

Prior to 1991, mine water inflow was small and often insufficient to meet the operational needs of the mine (Chapter 7, M&RP). During 1991, mining proceeded into the northern portion of the permit area and groundwater inflow to the mine increased. During 1991, Co-Op Coal Company began discharging between 30 and 60 gpm from the mine. By January, 1992, mine discharge increased to 300 gpm and continued at this rate through

March, 1992 (Co-Op Mining Company, 1992a). Present total mine inflow is approximately 210 gpm. Of this total, 30 gpm is used in the mining operations, and 180 gpm is discharged to Bear Canyon Creek.

This increase in mine inflow is attributed to interception of perched aquifers by mining. Tritium analyses were performed on samples from four groundwater monitoring points (Birch Springs, Big Bear Springs, a North Mains roof dripper, and floor water) in order to define the relative ages of the groundwater in the permit and adjacent areas. Tritium values for Birch Springs (1.12 TU), North Mains (1.0 TU) and the Second East Bleeders floor sump (1.73 TU) (Plate 2, EarthFax Engineering, 1992) are within the same order of magnitude, whereas the value for Big Bear Springs (17.4 TU) is an order of magnitude greater, suggesting that the source of Big Bear Springs is different from that of the mine inflow and Birch Springs.

According to Thiros and Cordy (1991), prior to above-ground nuclear weapons tests conducted from 1953 to 1969, the natural tritium concentration in precipitation was 8.7 TU. Assuming a half-life of 12.26 years, tritium levels in groundwater stored since 1952 would now be 0.95 TU, thus, water collected from SBC-9 (North Mains) sample is likely 100% pre-bomb groundwater (water stored since before 1953). Waters from SBC-5 (Birch Spring) and SBC-10 (floor water) are probably mixtures rich in stored pre-bomb groundwater, with a slight amount of post-bomb water.

There are three possible explanations for the relatively high concentration of tritium in the SBC-4 (Big Bear Springs) water: 1) The groundwater could be freshly recharged; current tritium concentrations in freshly fallen rain water in Utah range between 10 and 20 TU (Thiros, 1992); 2) it could be stored post-bomb water which originally had a very high concentration of tritium which has since decayed; or 3) water from Big Bear Springs could be a mixture of pre-bomb and post-bomb waters.

Because tritium concentrations in rainwater were greater than 1000 TU during periods of active above-ground testing (Fritz and Fontes, 1980), the age of water from Big Bear Spring

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cannot be determined. Regardless of the source(s) of recharge to Big Bear Spring, the concentrations of tritium in the remaining groundwater samples (SBC-5, SBC-9, and SBC-10) suggest that Birch Spring water and the mine inflow are of similar age (pre-1953), and are not significantly recharged by modern precipitation.

Data presented in the Revised Hydrogeologic Evaluation of the Bear Canyon Mine Permit and Proposed Expansion Areas (EarthFax Engineering 1992, pp. 2-21 and 2-22) indicate there are three separate piezometric surfaces associated with the Panther, Storrs, and Spring Canyon tongues of the Star Point Sandstone. These aquifers are separated by mudstones, which serve as aquitards. Groundwater flow within these aquifers generally follows the regional dip of the Star Point Sandstone(0.5 to 1.5 degrees to the south and southeast). Hydraulic gradients in the Spring Canyon, Storrs, and Panther aquifers are 0.046, 0.050, and 0.053 feet per foot, respectively.

2.1.3 Groundwater Quality

Spring- and mine-water monitoring stations are sampled at various intervals throughout the year as a part of the Co-Op Coal Company hydrologic monitoring program (Plate 7-4 of this M&RP). A summary of water-quality analyses for groundwater samples collected is presented in Chapter 7 of the M&RP and in the Annual Hydrologic Monitoring Report (Co-Op Mining Company, 1990 and 1991). Groundwater-quality samples are routinely collected in the permit and adjacent areas from the underground bleeders, monitoring wells, and springs associated with faults and joints in the Panther Tongue of the Star Point Sandstone.

Table 2-8 presents analytical data from the first sampling event for each spring and mine water monitoring point. Locations of these monitoring points are presented on Plate 7-4 of this M&RP. The general character of the groundwater in the permit and adjacent areas is that of a calcium-bicarbonate water that is slightly alkaline and contains low concentrations of total dissolved solids (TDS), nutrients, and metals. Table 2-9 presents the average

TABLE 2-8

Initial Spring and Mine Water Analytical Results
(all values except pH expressed as mg/l)

Source	Date	TDS	TSS	Acid.[a]	Hard.[b]	Alk.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH
BP-1 (Ballpark Spring)	5/90	402	11	0	382	302	68	51.4	0.07	13	3.3	368	82	13	NA	8.1
CS-1 (Trail Co-Op S)	5/90	402	4	0	392	336	76	48.1	0.09	5	3.0	410	61	11	NA	8
NPDES (Mine Disch.)	4/91	464	46	NA	NA	NA	NA	NA	0.19	NA	NA	NA	NA	NA	NA	7.8
PS-1 (Portal Spring)	5/90	Dry														
Roof Drips above Su-1	2/85	235	1	0	NA	216	46	35.0	0.03	3	1.4	NA	66	4	0.06	8.1
Roof Drips above Su-3	10/84	380	17	0	NA	314	60	38.4	0.12	19	3.7	383	40	2	0.03	7.3
SBC-1 (Mine Water)	2/86	280	2	NA	292	232	51	40	0.04	4	3.0	232	49	3	0.09	8

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.

TABLE 2-8 (Continued)

Initial Spring and Mine Water Analytical Results
(all values except pH expressed as mg/l)

Source	Date	TDS	TSS	Acid.[a]	Hard.[b]	Alk.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH
SBC-4 (Big Bear Spring)	10/84	362	11	0	NA	254	80	22	0.33	26	0.97	310	27	50	0.24	7.4
SBC-5 (Birch Spring)	10/84	440	6	0	NA	310	64	59	0.12	12	2.0	378	80	30	0.04	7.9
SBC-6 (CO-OP Dev. Spr.)	9/86	458	NA	NA	331	291	83	30	0.5	5	1.0	355	1	6	0.05	8
SBC-7 (#33 West Spring)	2/90	Dry														
SBC-8 (#30 East Spring)	2/90	Dry														
SBC-9 (Sump Su-3)	10/84	300	5	0	NA	234	36	36	0.19	29	4.4	285	55	8	0.06	7.3
Su-1	10/84	362	11	0	NA	254	80	22	0.33	26	0.97	309	27	50	0.24	7.4
TS-1 (Trail Cyn. Spring)	5/90	410	1	0	382	287	72.3	49	0.13	12	3.2	349	84	16	NA	8.1

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.

TABLE 2-9

1991 Average Groundwater Analytical Results
(all values except pH expressed as mg/l)

Source	TDS	TSS	Acid.[a]	Hard.[b]	Alka.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH	Number of Samples
BP-1 (Field)	451	NA	NA	399	NA	82	47	0.56	11	3.8	437	62	11.0	NA	8.0	2
CS-1 (Trail Co-Op S)	380	NA	NA	309	NA	79	27	0.36	4.9	2.5	320	63	4.6	NA	7.9	2
NPDES (Mine Disch.)	371	13	NA	NA	NA	NA	NA	0.11	NA	NA	NA	NA	NA	NA	7.9	9
PS-1 (Portal Sp)	Dry															
SBC-4 (Big Bear Spring)	381	5	NA	347	291	84	34	0.15	4.9	2.0	352	65	7.8	ND	7.7	8
SBC-5 (Birch Spring)	485	0.9	0	440	276	102	45	0.06	6.5	2.4	382	126	12.0	0	7.5	8
SBC-6 (CO-OP Dev. Spr)	Dry															
SBC-9 (Mine Sump Su-3)	360	0.5	NA	325	275	77	35	0.17	4.2	1.7	355	57	4.4	ND	7.9	5
TS-1 (Trail Cyn Spring)	452	NA	NA	389	NA	83	44	0.17	13	3.0	399	84	11.6	NA	8.0	2

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.
ND = Not detected.

analytical results from 1991 groundwater sampling documented in the 1991 Annual Report. The general character of the groundwater in 1991 is also that of a slightly alkaline calcium-bicarbonate water that contains low concentrations of TDS, nutrients, and metals. Average iron concentrations increased significantly in BP-1 water. This is due to a single high value of 0.97 mg/l detected in October 1991 (1991 Annual Report).

Analytical results for groundwater sampled in 1991 and 1992 at proposed Federal Lease U-024316 monitoring points FBC-2 through FBC-6A are presented in Tables 2-10 and 2-11, respectively. The character of the groundwater defined in these initial surveys is similar to and within the range of chemical concentrations found in the present permit initially (Table 2-8) and in 1991 (Table 2-9). Sulfate and chloride concentrations increase from 1991 to 1992 in FBC-4, FBC-5, and FBC-6 waters. All other chemical concentrations did not change significantly from 1991 to 1992 in waters sampled at FBC-2 through FBC-6.

Figure 2-1 presents a Piper diagram of average analytical results of the sampling events in 1991 for 6 groundwater monitoring points: Birch Spring (SBC-5, eight samples), North Mains (SBC-9, five samples), Ball Park Spring (BP-1, two samples), Big Bear Spring (SBC-4, eight samples), Co-Op Spring (CS-1, 2 samples), and Trail Canyon Spring (TS-1, 2 samples). The Piper diagram is divided into three fields: cations, anions, and the combined field. Values are in percent milliequivalents, and are plotted in the anion and cation fields and projected into a combined field. Spatial relationships of samples that are similar among the three fields are indicative of hydraulic connection between waters. Spatial relationships among the six waters are not the same in all three fields; thus, it is inferred that the waters are not hydraulically connected. Birch Spring has the least similarity to the other waters. For example, Birch Spring water plots very close to mine water in the cation field, but it plots as an outlier in the anion field and in the combined field. This is due to a higher percentage of sulfate in Birch Spring water than in the mine water or the other spring water in the area. In fact, the mine water and BP-1 water have the lowest percentages of sulfate of the groundwater represented in the Piper diagram. Thus, the spatial relationships exhibited in the Piper diagram suggest that the mine water is of a higher quality than Birch Spring water. Furthermore, the difference

TABLE 2-10

1991 Spring and Mine Water Analytical Results (proposed Federal Lease U-024316)
(all values except pH expressed as mg/l)

Source	Date	TDS	TSS	Acid.[a]	Hard.[b]	Alka.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH
FBC-2	8/91	352	NA	NA	305	NA	77.8	26.9	7.60	4.90	0.89	379	5.76	2.33	0.00	8.05
FBC-3	8/91	274	NA	NA	258	NA	72.4	18.8	0.22	3.50	0.84	307	12.3	2.43	0.38	8.00
FBC-4	8/91	396	NA	NA	326	NA	86.3	27.0	9.51	4.60	3.40	391	8.64	5.27	0.00	7.50
FBC-5	8/91	328	NA	NA	302	NA	81.7	23.9	1.24	5.80	2.91	367	13.0	7.20	0.00	8.00
FBC-6	8/91	272	NA	NA	261	NA	69.2	21.5	0.10	5.10	0.61	303	15.0	5.27	0.29	8.40

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.

TABLE 2-11

1992 Spring and Mine Water Analytical Results (proposed Federal Lease U-024316)
(all values except pH expressed as mg/l)

Source	Date	TDS	TSS	Acid.[a]	Hard.[b]	Alka.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH
FBC-2	10/92	Dry														
FBC-3	10/92	Dry														
FBC-4	10/92	318	NA	NA	342	NA	66.1	42.9	0.00	6.83	0.27	314	90.0	10.0	0.43	7.26
FBC-5	10/92	149	NA	NA	319	NA	103.8	14.6	0.10	1.81	0.00	328	9.00	25.0	0.10	7.68
FBC-6	10/92	277	NA	NA	280	NA	60.4	31.3	0.67	3.83	2.64	368	28.0	15.0	0.04	7.80
FBC-6A	10/92	814	NA	NA	359	NA	94.1	30.0	0.60	3.91	89.7	410	35.0	25.0	0.09	7.82

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.

2-22

1-BIRCH SPRINGS SBC-5

2-SBC-9

3-BP-1

4-BEAR SPRING SBC-4

5-CS-1

6-TS-1

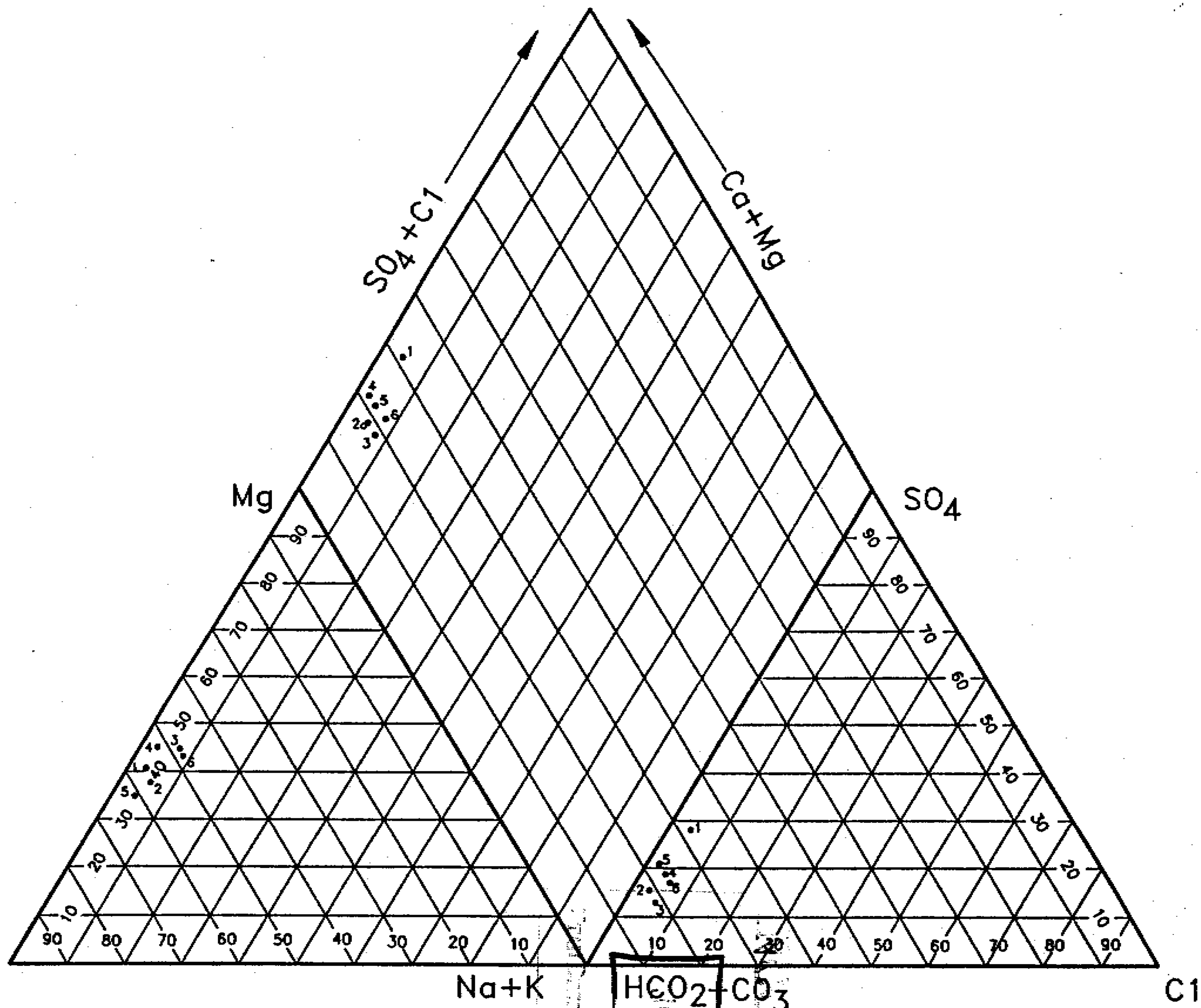

FIGURE 2-1. PIPER DIAGRAM OF AVERAGE GROUNDWATER ANALYTICAL RESULTS

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in spatial relationships in the different fields suggests the waters are not hydraulically connected.

Figure 2-2 presents a series of Stiff diagrams which characterize waters from the same six groundwater monitoring points used in Figure 2-1. The six waters display a similar Stiff pattern, that of a calcium-bicarbonate water. Additionally, the Stiff patterns indicate that SBC-9 (North Mains) water has the lowest sulfate concentration (1.18 meq) and SBC-5 (Birch Spring) has the highest sulfate concentration (2.62 meq) of the groundwater sampled. SBC-4 (Big Bear Spring) water has a sulfate concentration of 1.36 meq. SBC-9 also has the lowest chloride value of the groundwaters sampled. This relationship between the sulfate and chloride concentrations does not suggest that the mine water could diminish the quality of the spring water in the area.

The major portion of water inflow to the mine is used within the mine or for culinary purposes by Co-Op Mining Company. According to the Co-Op Bear Canyon Mining and Reclamation Plan, the water which flows from Big Bear Spring (also called Huntington Spring) and Birch Spring is used by the Huntington community for culinary purposes (Co-Op Mining Company, 1990). Water collected in Trail Canyon from TS-1 (Trail Canyon Spring) is also used by Trail Canyon residents for culinary purposes.

Wells in the permit and adjacent areas are either observation wells owned by Co-Op Mining, or exploration wells owned by Northwest Energy. Three new monitoring wells (DH-1A, DH-2, and DH-3, Plate 1, EarthFax Engineering, 1992) were drilled within the permit area for this study. DH-1A and DH-2 were drilled in late 1991 and DH-3 was drilled in early 1992. The three wells were completed in the Spring Canyon Tongue of the Star Point Sandstone, and were developed, tested, and sampled in May, 1992. The results of laboratory analyses of the monitoring well samples are summarized on Table 2-12 from the complete analytical reports (Appendix 7N-H, EarthFax Engineering, 1992).

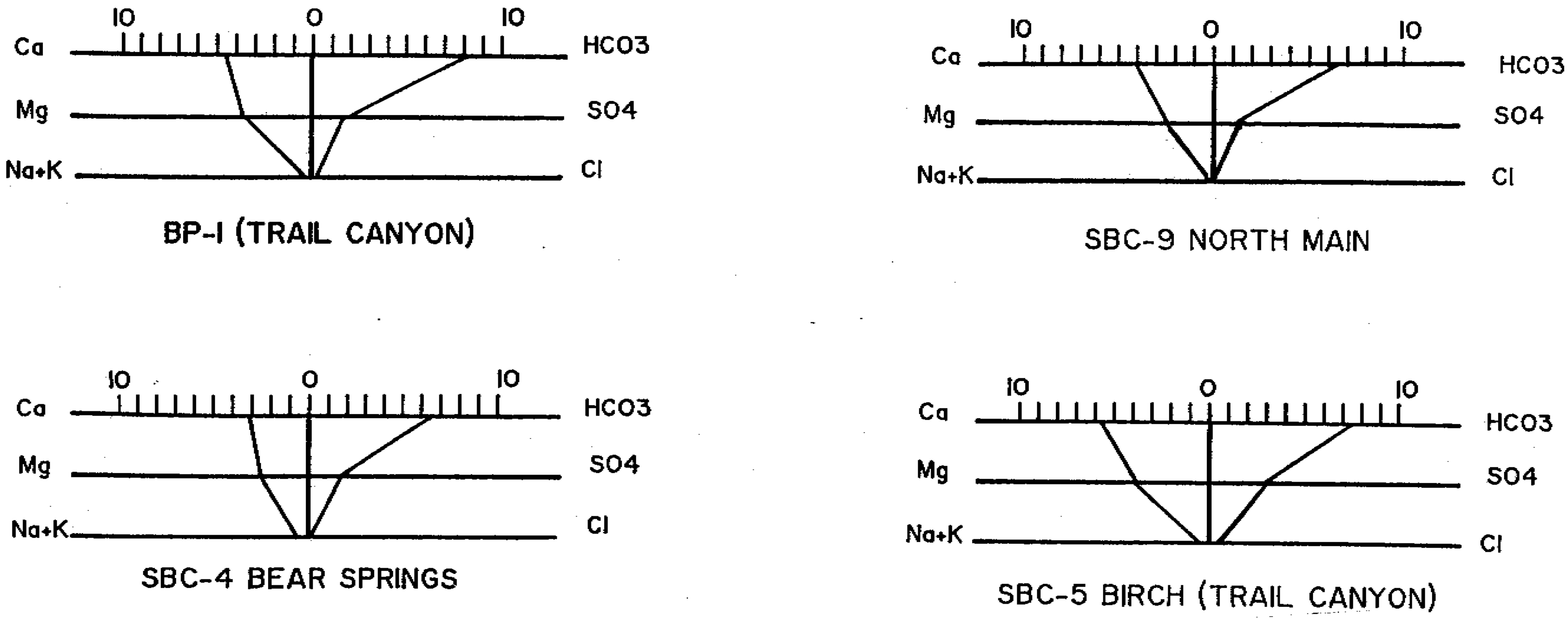

FIGURE 2-2. Stiff Diagrams of Spring Water Analytical Results

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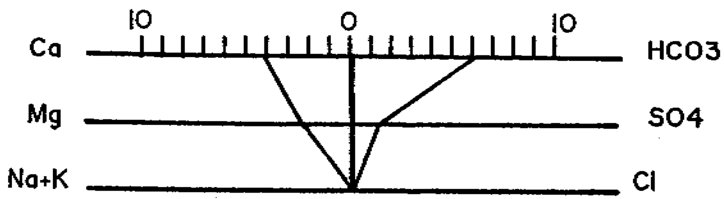
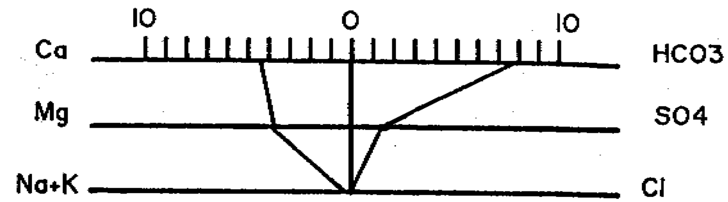


CS-1 CO-OP SPRING (TRAIL CANYON)



TS-1 TRAIL CANYON SPRING

FIGURE 2-2 (continued). Stiff Diagrams of Spring Water Analytical Results

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TABLE 2-12

Summary of Laboratory Analytical Results
for Groundwater From In-Mine Monitoring Wells

ANALYTE (mg/l)	DH-1A	DH-2	DH-3
Aluminum	0.2	<0.1	<0.1
Arsenic	<0.05	<0.05	<0.05
Barium	0.071	0.127	0.129
Cadmium	<0.01	<0.01	<0.01
Calcium	38.9	51.9	50.9
Chromium	0.025	<0.01	<0.01
Copper	<0.01	<0.01	<0.01
Iron	0.505	0.280	0.220
Lead	<0.01	0.030	<0.01
Magnesium	20.1	29.5	28.9
Manganese	0.062	0.101	0.232
Mercury	<0.0005	<0.0005	<0.0005
Molybdenum	0.058	0.010	<0.01
Nickel	<0.01	<0.01	<0.01
Potassium	31.2	1.5	2.6
Selenium	<0.0005	<0.0005	<0.0005
Sodium	14.1	8.8	15.2
Zinc	<0.01	<0.01	<0.01
Oil & Grease	2.0[a]	<0.5	<0.5

[a] Oil and Grease expected (hydraulic fluid leak on rig).

TABLE 2-12 (Continued)

Summary of Laboratory Analytical Results
for Groundwater From In-Mine Monitoring Wells

ANALYTE (mg/l)	DH-1A	DH-2	DH-3
TDS	285	330	339
Hardness as CaCO3	162	321	307
Boron	<0.05	0.064	0.061
Alkalinity as CaCO3	94	285	294
Bicarbonate	110	340	336
Carbonate	2.3	3.5	11.5
Hydroxide	0	0	0
Chloride	4.9	4.2	4.2
Fluoride	0.28	0.18	0.16
Ammonia	<0.2	0.64	0.22
Nitrate	0.42	0.74	<0.5
Phosphate	0.129	0.25	0.027
Sulfate	128	33	38
Sulfide	<0.1	<0.1	<0.1

Figure 2-3 presents Stiff diagrams of ions in groundwater from the in-mine wells. Waters from DH-1A and DH-3 have Stiff patterns similar to those of the calcium-bicarbonate spring water depicted on Figure 2-2. Water from DH-2 has a calcium, magnesium, sodium, potassium-sulfate pattern. This pattern is distinctly different from other groundwater that has been sampled in the permit and adjacent areas, and is presumed to be due to the dissolution of locally-occurring sulfate salts.

Groundwaters sampled from the in-mine wells have a TDS range of 285 to 339 mg/l. Dissolved iron and manganese concentrations range from 0.220 to 0.505 mg/l and from 0.062 to 0.232 mg/l, respectively.

Groundwater quality analyses (1991 Annual Report) were compared to the primary drinking water standards (40 Code of Federal Regulations (CFR) 141) and the secondary drinking water standards (40 CFR 143). In September 1991, a chromium concentration of 0.06 mg/l was detected in water sampled from SBC-5 (Birch Spring), exceeding the chromium standard of 0.05 mg/l. There were no analyses for silver.

One exceedance of the secondary drinking water standards was detected for the mine water samples; in August 1991, an iron concentration of 0.55 mg/l was detected in water from SBC-9 (Mine Sump #3), exceeding the iron standard of 0.3 mg/l. Additionally, exceedances of iron, manganese, and TDS standards were found in groundwater sampled in 1991. These exceedances constituted fifteen percent of iron, five percent of manganese, and ten percent of TDS analyses performed on these respective constituents. It should be noted that the secondary drinking water standards "represent reasonable goals for drinking water quality," (40 CFR 143) and are not mandatory standards.

2.2 POTENTIAL GROUNDWATER IMPACTS

Potential groundwater impacts that could result from mining and reclamation operations at the Bear Canyon Mine include:

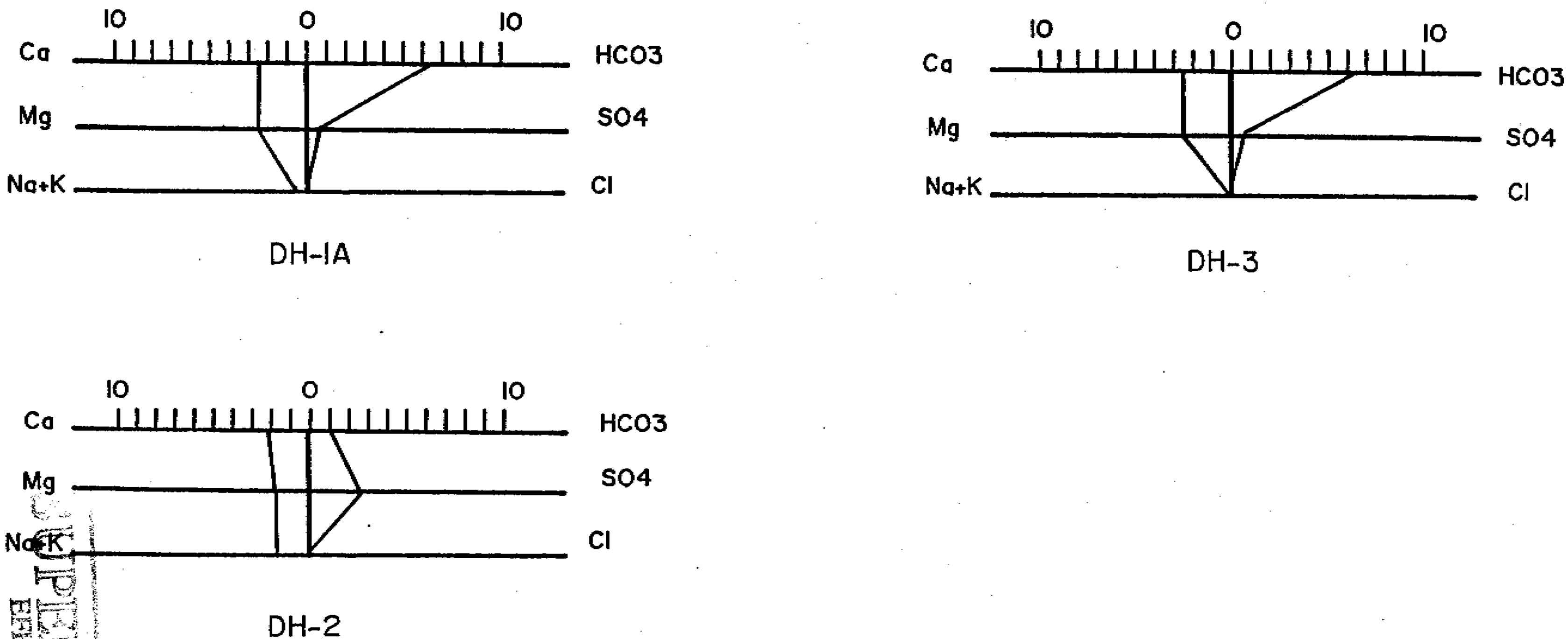

FIGURE 2-3. Stiff Diagrams of In-Mine Monitoring Well Analytical Results

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- o Contamination from acid- or toxic- forming materials;
- o Impacts to groundwater quantity; and
- o Impacts to groundwater quality:
  - * Contamination due to rock dust usage,
  - * Contamination due to the use of hydrocarbons, and
  - * Contamination from road salting.

2.2.1 Potential Contamination from Acid- and Toxic-Forming Materials

Information on acid- or toxic-forming materials monitoring is presented in Appendix 6-C of the M&RP. Evaluation of these data using Table 2 in the Guidelines for Management of Topsoil and Overburden (Leatherwood and Duce, 1988) revealed that there have been no poor or unacceptable (acid- or toxic-forming) materials encountered in the permit area. Co-Op Mining Company mined through a small, highly localized sulfur-bearing mineral zone in January and March, 1992, but no waste rock was produced as the sulfur-bearing minerals were sold with the coal (Co-Op Mining Company, 1992a). In addition, as noted in Section 2.1.3 of this PHC, the alkalinity of the groundwater in the area is approximately 300 times the acidity. No waste rock is expected to be produced in the future (Co-Op Mining Company, 1992a).

Given past experience at the mine and the generally alkaline nature of the groundwater, the probability of acid- and/or toxic-forming materials being found or produced from the mine in the future is low. However, if any of these materials are discovered in waste rock in the future through the on-going monitoring plan, these materials will be disposed of in accordance with the requirements of Utah Mining Regulations R645-301-731.300 and as outlined in Chapter 3 of the M&RP.

2.2.2 Groundwater Quantity Impact

Mining will remove groundwater both from formations adjacent to the coal seams and from mine-water contained in the coal itself. The removal of water from the surrounding formations occurs when groundwater flows into the underground mine workings as the coal is removed. Drainage of water from faults and fractures produces the largest volume of water flowing into the mine (EarthFax Engineering, 1992, pp. 2-17 and 2-19). As noted in Section 2.1.2, the volume of groundwater flow into the mine has only recently increased sufficiently to produce water in excess of that needed for mine operations.

Groundwater flows into the Bear Canyon Mine at a rate of 500 gpm. 200 gpm are used in the mine operations and 300 gpm are discharged into Bear Creek. A minimum of one third of the water used in the mine operations is returned to the groundwater regime because the majority of this water is used for dust suppression within the mine. The balance of the mine water is utilized at the surface facilities for culinary water and dust suppression on surface roads (Co-Op Mining Company, 1992a).

The approximate *in situ* moisture content of coal mined in the Bear Canyon Mine is 5.3 percent water by weight (this does not include moisture added from dust suppression, Appendix 6-B, M&RP). This water leaves the mine in the coal as part of the mining process. Using an extraction rate of 432,140 tons of coal for 1991, approximately 18 acre-feet of water will be diverted annually in the coal from the groundwater system. Based on a long-term coal production rate of 500,000 tons per year, approximately 22 acre-feet of water per year will be diverted from the groundwater system. However, because most of this water is perched (not connected to surface springs), its removal will have little or no effect on spring flow in the area.

Springs presently monitored in proposed Federal Lease U-024316 issue from the North Horn Formation and are perched (EarthFax Engineering, 1992, p. 2-11) at least 1000 feet above the top of the Blind Canyon coal seam (Plate 7-4 in this M&RP). Thus, mine dewatering is not expected to impact these springs.

Figure 2-4 depicts drawdown expected at distances measured along the long (D_y) axis and the short (D_x) axis of the mine. Based on a mine life of 20 years (Co-Op Mining

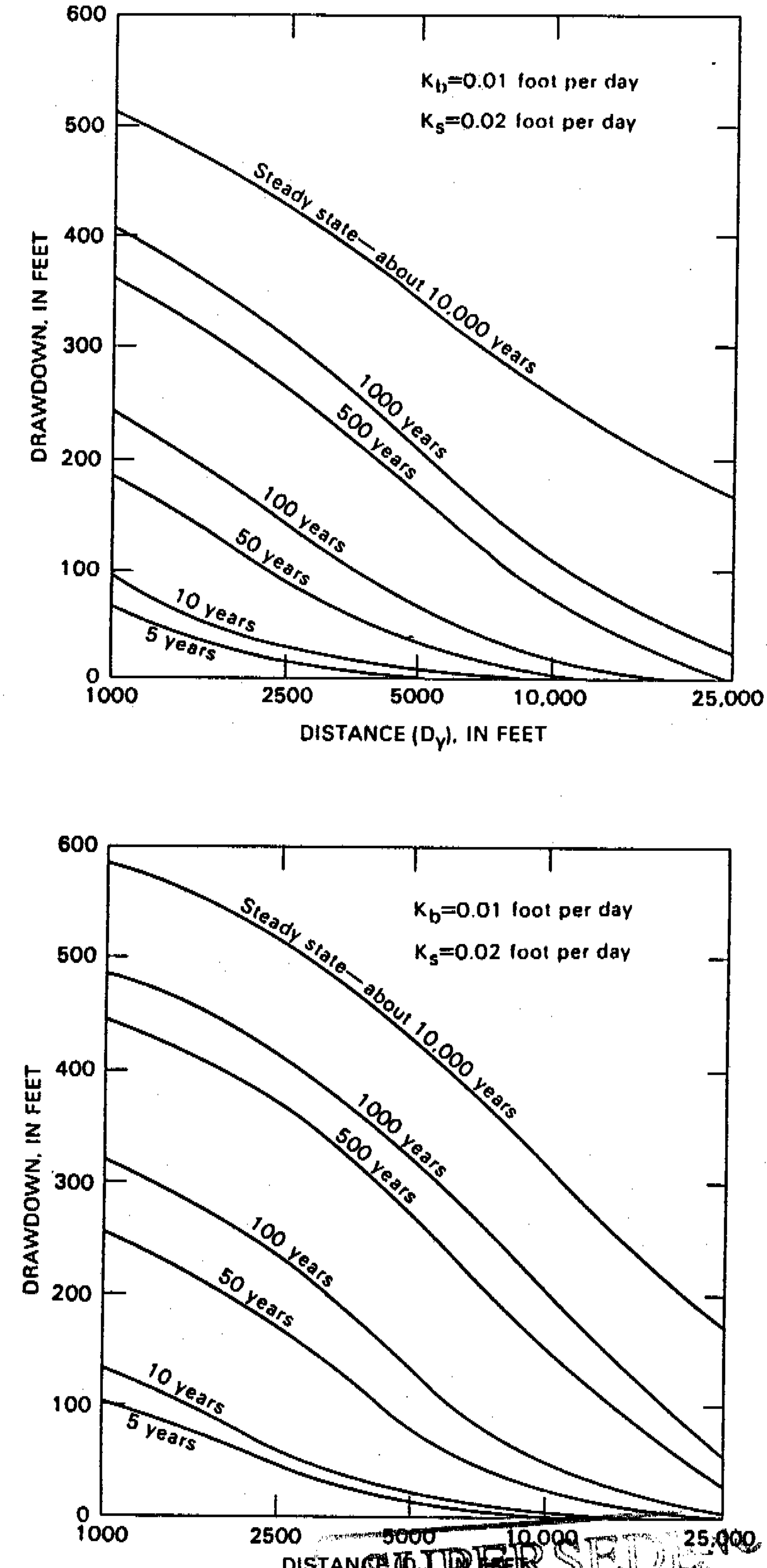

FIGURE 2-4. PREDICTED DRAWDOWN AS A FUNCTION OF DISTANCE (LINES, 1985)

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Company, 1992a), the maximum expected lateral limits of the cone of depression caused by dewatering of the Bear Canyon Mine would be approximately 9,000 feet (1.7 miles) from the mine boundary in the north and south directions and 15,000 feet (2.8 miles) from the mine boundary in the east-west directions. This drawdown terminates wherever the strata immediately above the coal seams being mined are truncated by canyons as in Bear, Blind, and Trail Canyons.

There are no water supply wells located in the permit and adjacent areas. As indicated in the baseline data discussed in Section 2.1.2 of this PHC, there are three springs located above the coal seam in the northern proposed expansion area. There are no water rights associated with these springs (EarthFax Engineering, 1992, p. 2-38).

Because the aquifers that supply springs above the Blind Canyon coal seam are perched, mining operations will have no effect on spring flow or spring water quality (EarthFax Engineering, 1992, pp. 2-23 thru 2-30). It is unlikely that Bear Canyon Mine will impact Birch and Big Bear Springs for six reasons:

1. Tritium data indicate that the source of groundwater inflow to the mine is not the same as the source of Big Bear Springs (the Panther Tongue of the Star Point Sandstone), but perched aquifers containing relict stored water (Section 2.1.2).

2. Stiff and Piper diagrams indicate that the mine water is of a higher quality than that of the other waters in the area and that Birch Spring and the mine water are not hydraulically connected (Section 2.1.3).

3. Information collected during the drilling of the three in-mine monitoring wells suggests that the mine workings may intercept groundwater from the Spring Canyon Tongue of the Star Point Sandstone. However, both Birch and Big Bear Springs issue from the Panther Tongue, which is the lowest tongue of the Star Point Sandstone and 400 feet below the Blind Canyon seam (EarthFax Engineering, 1992, p. 2-17 and Appendix 7N-G).

4. The mine and Birch Spring are separated by a complex zone of fractures and faults. The Blind Canyon Fault is a normal fault with 220 feet of vertical displacement and is located near the western limit of mining in the Bear Canyon Mine. This fault could act either as a conduit (if it has open voids) or as a

barrier (if it is filled with gouge) to groundwater flow. In either case, the fault would probably prevent groundwater from moving from the mine to Birch Spring. If the fault did not act as a barrier, it would convey the water moving within it to the surface as a spring. No such spring is present where the Blind Canyon fault intersects the surface, approximately 800 feet east of Birch Spring.

5. Birch Spring is approximately 8,500 feet from the North Mains section of the mine. The linear velocities calculated for the aquifers of the Star Point Sandstone range from 1.31 to 69.75 feet per year (Section 2.1.2). At the fastest calculated velocity, impact to water quality and quantity at Birch Spring from water in the mine would not occur for at least 122 years.

   Lines (1985) presented laboratory determinations of porosity (ranging from 2 to 17 percent) and horizontal hydraulic conductivities (ranging from 1.1×10^{-8} to 3.1×10^{-2} feet per day). Using these data and the maximum hydraulic gradient measured in the in mine drill holes of 0.053 feet per foot (Section 2.1.2), the fastest calculated velocity is 29.98 feet per year. At this velocity, the mine water would not impact Birch Spring for 283 years.

6. Three piezometric surfaces in the Spring Canyon, Storrs, and Panther Tongues of the Star Point Sandstone have been defined by EarthFax Engineering (1992, pp. 2-21 and 2-22) through drilling and testing (Plates 3, 4, and 5, EarthFax Engineering, 1992). The hydraulic gradients are to the south (parallel to the Blind Canyon Fault) and to the southeast (away from the Blind Canyon Fault) (Plate 1, EarthFax Engineering, 1992).

Discharge of groundwater from the underground workings and removal of groundwater in the coal is expected to continue through the life of the mining operation. To date, no negative impact to seeps or springs has been demonstrated. The springs which issue from the perched aquifers will probably remain unaffected by the dewatering. In addition, as noted above, impacts to groundwater availability from the Panther Tongue of the Star Point Sandstone (Birch and Big Bear Springs) in the permit and adjacent areas is unlikely.

2.2.3 Potential Groundwater Quality Impacts

Potential groundwater quality impacts include:

- o Contamination due to rock dust usage;

- o Contamination due to usage of hydrocarbons; and
- o Contamination from road salting.

Rock Dust Usage Impact. The practice of using rock dust for the suppression of coal dust in the mine may potentially impact the groundwater flowing through the mine by dissolution of the rock dust constituents into the water. The use of gypsum rock dust can raise the TDS and sulfate concentrations in the groundwater. Until recently, Co-Op Mining Company used a non-gypsum rock dust. In 1990, use of gypsum rock dust began (Co-Op Mining Company, 1992a).

During January and March, 1992, TDS concentrations were detected that exceed the NPDES Permit guidelines for discharge from the Bear Canyon Mine. Gypsum used in rock dusting is considered to have contributed to the high TDS concentrations. Co-Op Mining Company now uses only lime dust in the Bear Canyon Mine (Co-Op Mining Company, 1992b). Due to the relative dryness of the mine, no future increase in TDS or sulfate concentrations in the groundwater is expected.

Impact of Hydrocarbons. Hydrocarbons (in the form of fuels, greases, and oils) are stored and used in the permit area. Groundwater contamination could result from spillage of hydrocarbon products during maintenance of equipment during operations, filling of storage tanks and vehicle tanks, or from tank leakage due to the rupture of tanks.

The probable future extent of the contamination caused by diesel and oil spillage is expected to be small for six reasons.

1. All above-ground storage tanks are bermed and inner and/or outer catchments are utilized in accordance with the 1992 Spill Prevention Control and Countermeasure Plan (SPCC).
2. No underground storage tanks exist at the site.
3. Because the tanks are located above ground, leakage from the tanks can be readily detected and repaired.

4. Spillage during filling of the storage or vehicle tanks is minimized to avoid loss of an economically valuable product.

5. The surface operations area is drained by a series of ditches, which feed into a sedimentation pond at the lower end of the disturbed area.

6. The 1992 SPCC Plan provides (and Co-Op Mining Company has implemented) inspection and operation measures to minimize the extent of contamination resulting from the use of hydrocarbons at the site.

There are no transformers in the mine permit area which contain polychlorinated biphenyls (PCBs).

Road Salting Impact. Co-Op Mining Company utilizes salt to maintain the roads within the permit area in the winter. Road salt could contaminate the groundwater if sufficient amounts of salt were stored on, or washed into recharge areas.

Co-Op Mining Company salts 2,100 feet of road in the winter (this will be increased to 4,200 feet with the addition of the proposed Tank Seam access road). The potential for impact to the groundwater is low and not likely to occur; however, because the steepness of the canyon allows very little recharge within the permit area. Salt is stored by Emery County outside the permit area (Co-Op Mining Company, 1992a).

3.0 SURFACE WATER

3.1 BACKGROUND INFORMATION

Detailed information on surface water and the physical resources that effect surface water is found in Chapter 7 of the M&RP and in the Revised Hydrogeologic Evaluation of the Bear Canyon Mine Permit and Proposed Expansion Areas (EarthFax Engineering, 1992). This information is summarized herein for convenience. These documents should be consulted for more detail.

3.1.1 Hydrology

The Bear Canyon Mine is located in the San Rafael River Basin. Within the permit area, Bear Creek is a perennial stream and Trail Creek is an intermittent stream. On the southern end of the permit area, ephemeral streams discharge into Huntington Creek, a perennial stream (Chapter 7, M&RP).

All streams in the permit and adjacent areas are classified by the Utah Department of Health as follows:

- 1C Protected for domestic use with prior treatment processes,
- 3A Protected for cold water aquatic life, and
- 4 Protected for agricultural uses including stock watering.

The primary source of water for the streams in the area is snowmelt (Danielson, 1981). Hence, peak flows generally occur in the late spring and early summer. The 1989 annual watershed yield of the Huntington Creek drainage measured upstream from the bridge to Deer Creek Mine is 21,449 ft^3 (Water Resources Division, USGS, 1992).

Seasonal variations in perennial stream flow monitored in Huntington Creek during 1989 range from 4,100 to 66,000 gpm, averaging 22,000 gpm. These extremes in flow rates are typical of high elevation locations in the western United States and are graphically displayed in the Revised Hydrogeologic Evaluation of the Bear Canyon Mine Permit and Proposed Expansion Areas (1992, Appendix 7N-B).

Flow rates for Bear Creek are monitored at BC-1, BC-2, and BC-3, while flow rates for Trail Canyon are monitored at UT-1 and LT-1. The sediment pond inlet is monitored at SP-1. Locations of these monitoring points are presented on Plate 7-4 of this M&RP. Flow rates measured during the initial monitoring of flow rates for each of these monitoring points are presented in Table 3-1. Monitoring points BC-3, SP-1, and UT-1 were dry. Table 3-2 presents the average annual flow rates for surface water in 1991. Average flow rates recorded at BC-2 during 1991 are higher than the initial flow (due to mine water discharge from the NPDES discharge point). Average flow rates at LT-1 are also higher than initial flows (due to one high flow rate recorded in October 1991). There is no corresponding increase at BC-1, and no cause for this increase is known.

Annual monitoring of proposed Federal Lease U-024316 surface water monitoring point FBC-1 began in 1990. In August 1991, the intermittent stream monitored at FBC-1 flowed through McCadden Hollow at the rate of 1.5 gpm. It was dry in June 1990 and October 1992 (Appendix 7-M of this M&RP).

3.1.2 Water Quality

Sediment Yield. Danielson (1981) collected water samples from Bear Creek during 1978 and 1979 in order to determine total suspended solids (TSS) concentrations and loads of the stream. Analyses of these samples yielded TSS concentrations of 8,860 and 2,140 mg/l and loads of 1.9 and 4.0 tons/day. Danielson attributes TSS concentrations in Bear Creek to erosion of shales and mudstones in the North Horn Formation by the springs that feed Bear Creek.

TABLE 3-1

Initial Surface Water Flow Rates

Source	Date	Flow (gpm)
BC-1 (Upper Bear)	11/84	26.0
BC-2 (Lower Bear)	12/84	26.8
BC-3 (Right Fork Bear)	1/86	Dry
LT-1 (Lower Trail)	5/90	29
SP-1 (S. Pond Inlet)	5/90	Dry
UT-1 (Upper Trail Creek)	5/90	Dry

TABLE 3-2

1991 Average Surface Water Flow Rates

Source	Flow (gpm)	Number of Measurements
BC-1 (Upper Bear)	27	7
BC-2 (Lower Bear)	100	7
BC-3 (Right Fork Bear)	Dry	7
LT-1 (Lower Trail Creek)	47	2
SP-1 (Sed Pond Inlet)	Dry	2
UT-1 (Upper Trail Creek)	Dry	2

Chemical Quality. Surface water quality samples are routinely collected in the permit and adjacent areas from stations located on Bear Creek and Trail Creek. Analytical data from these sources are summarized in Chapter 7 of the M&RP and the Annual Reports. Locations of these monitoring points are presented on Plate 7-4 of the M&RP.

Table 3-3 presents analytical results from the initial sampling of each surface water monitoring point. The general character of the surface water is that of a slightly alkaline calcium-bicarbonate water containing low concentrations of TDS, nutrients and metals. Three (BC-3, SP-1, and UT-1) out of the six surface water monitoring points have been dry, historically. The source of the high TSS concentration detected at BC-1, is unknown, but occurs upstream of the mine, and is not considered to be mine-related.

Chemical analyses presented in the 1991 Annual Report were averaged for each monitoring point and are presented in Table 3-4. These data indicate that the general character of the surface water is also that of a slightly alkaline calcium-bicarbonate water, low in concentrations of nutrients. However, average TDS, TSS, calcium, magnesium, iron, and sulfate concentrations in BC-1 and BC-2 are significantly higher than the corresponding initial concentrations. Comparison of initial and average 1991 analytical results for LT-1 water indicate that chemical concentrations at this station are relatively unchanged.

Table 3-5 presents 1991 and 1992 initial data for proposed Federal Lease U-024316 surface water monitoring point FBC-1. These chemical concentrations correlate closely to the chemical concentrations of LT-1 water (Tables 3-3 and 3-4).

Total dissolved solids content in BC-1, BC-2, and LT-1 waters measured in 1991 range from 404 to 1810 mg/l (1991 Annual Report). Anomalously elevated TDS concentrations (accompanied by high TSS, calcium, magnesium, iron, and sulfate concentrations) were detected in BC-1 and BC-2 water collected during February 1991. These elevated concentrations occur both upstream and downstream of the mine,

TABLE 3-3

Initial Surface Water Analytical Results
(all values except pH expressed as mg/l)

Source	Date	TDS	TSS	Acid.[a]	Hard.[b]	Alka.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH
BC-1 (Upper Bear)	11/84	415	1620	0	NA	200	43	57.0	4.8	8.0	3.5	NA	161	4.0	0.47	8.1
BC-2 (Lower Bear)	10/84	375	13.5	0	NA	200	50	50.4	19.8	7.1	5.77	244.0	116	20.0	0.14	8.1
BC-3 (Rt Fk Bear)	1/86	Dry														
LT-1 (Lower Trail)	5/90	472	6	0	412	355	72.3	56.2	0.32	17.6	3.9	433.4	88.5	14.7	NA	8.1
SP-1 (S. Pond Inlet)	5/90	Dry														
UT-1 (Upper Trail Creek)	5/90	Dry														

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.

TABLE 3-4

1991 Average Surface Water Analytical Results
(all values except pH expressed as mg/l)

Source	TDS	TSS	Acid.[a]	Hard.[b]	Alka.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH	Number of Samples
BC-1 (Upper Bear)	783	623	0	656	262	113	95	26.3	13	6.4	313	430	9.5	NA	8.0	4
BC-2 (Lower Bear)	793	342	0	613	308	51	113	4.0	11	5.2	370	323	9.3	NA	8.0	4
BC-3 (Rt. Fk. Bear)	Dry															
LT-1 (Lower Trail Cr.)	476	1	NA	398	NA	70	54	0.13	18.5	4.7	401	85	20.0	NA	8.0	2
SP-1 (S Pond Inlet)	Dry															
UT-1 (Upper Trail Cr)	Dry															

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.
NS = Not sampled.

TABLE 3-5

Surface Water Analytical Results (proposed Federal Lease U-024316)
(all values except pH expressed as mg/l)

Source	Date	TDS	TSS	Acid.[a]	Hard.[b]	Alka.[c]	Ca	Mg	Fe	Na	K	HCO_3	SO_4	Cl	NO_3	pH
FBC-1	7/91	468	NA	NA	445	NA	85.9	56.1	0.44	13.8	1.53	464	72.8	15.3	0.0	0.0
FBC-1	10/92	Dry														

(a) Acidity as $CaCO_3$.
(b) Hardness as $CaCO_3$.
(c) Alkalinity as $CaCO_3$.
NA = Not analyzed.

indicating that they are unrelated to mining activities. Additionally, these anomalies do not correlate with fluctuations in flow rate and may be related to "sloughing events" mentioned by Danielson (1981). These "sloughing events" are the result of the continuous erosion of shale and mudstone by the springs which flow from the North Horn Formation at the head waters of Bear Creek (Danielson, 1981).

Iron concentrations in the streams vary widely through time at the three stream locations (LT-1, BC-1 and BC-2), possibly due to dissolution of iron-bearing cement in the Blackhawk Formation. Iron concentrations have ranged from 0.03 to 98.9 mg/l during the period of record (1990 and 1991 Annual Reports) and proportionally correlate with TSS concentration.

Manganese concentrations in the permit area are low, ranging from below detection to 1.13 mg/l. High concentrations correlate with higher TSS concentrations (1990 and 1991 Annual Reports).

Changes in surface water quality from upstream (BC-1) to downstream (BC-2) of the Bear Canyon Mine during 1990 and 1991 were analyzed with a Student's t-test and the difference in the means of chemical concentrations were statistically insignificant (EarthFax Engineering, 1992, p. 2-6). This suggests that surface water quality does not change significantly as it flows past the mine. No comparison can be made for Trail Creek as the upstream monitoring point is consistently dry (1990 and 1991 Annual Report).

A comparison of surface water quality data (1991 Annual Report) with the national secondary drinking water standards indicates that the chemical quality of local surface water is typically within drinking water standards. No primary drinking water analytes were included in the surface water analysis suite.

Exceedances of secondary drinking water standards were found (iron, 4 out of 19 samples; manganese, 1 out of 19 samples; sulfate 1 out of 10 samples; and TDS, 3 out of

19 samples), however, these exceedances are typical of Bear Creek and other steams in the area prior to mining (Danielson, 1981). The sulfate exceedance (BC-1, February 28, 1991) is questionable in that BC-1 and BC-2 analyses are very similar in all other parameters. Yet, the sulfate analytical results differ for these two samples by two orders of magnitude. There were no exceedances of the secondary drinking water standards found in the analytical results for water collected at the NPDES mine water discharge point.

3.2 POTENTIAL SURFACE WATER IMPACTS

The potential surface water impacts that could result from mining and reclamation operations at the Bear Canyon Mine include:

- o Contamination from acid- or toxic-forming materials;
- o Increased sediment yield from disturbed areas;
- o Flooding or stream flow alteration;
- o Impacts to the chemical quality of surface water; and
- o Impact to surface water quantity.

3.2.1 Potential Contamination from Acid- or Toxic-Forming Materials

As noted in Section 2.2.1 of this PHC, no poor or unacceptable (acid- or toxic-forming) materials have been found in the permit area. The small, highly localized sulfur-bearing mineral zone discussed in Section 2.2.1 produced no acid- or toxic-forming waste rock. Historically,alkalinity of the mine water ranges from 141 to 314 mg/l and acidity ranges from 0 to 7 mg/l (Chapter 7 of this M&RP, 1990 Annual Report, and 1991 Annual Report). Due to the naturally alkaline character of the ground and surface waters in the area and the lack of acid- or toxic- forming materials, the probability of an impact from acid-and toxic-forming materials is minimal. However, if any of these materials are discovered in the future through the on-going mine plan, these materials will be disposed of within the guidelines set down in R645-301-731.300 and in Chapter 3 of the M&RP.

3.2.2 Potential Increase in Sediment Yield

Mining activities may result in an increase in sediment yield downstream of the disturbed areas. Sedimentation control measures (such as sedimentation ponds, diversions, etc.) have been installed to minimize this impact. These facilities are regularly inspected (see Chapter 7 of this M&RP) and maintained.

Current monitoring (10/17/91) indicates that no significant increase of TSS concentrations occurs from BC-1 (9 mg/l), upstream of the mine discharge, to BC-2 (5 mg/l), downstream of the mine discharge. Although TSS concentrations vary greatly at these two sample points, the relationship is typically that of higher TSS concentration upstream of the mine discharge and lower TSS concentrations below the mine discharge (1990 and 1991 Annual Report). Thus, control measures at the mine are effective at controlling sediment yields before discharging to the surface water. As a result of ongoing inspection and maintenance of the sediment-control facilities, there is a very low probability that sediment yield will increase due to mining activities.

3.2.3 Potential for Flooding or Stream Flow Alteration

Runoff from all disturbed areas flows through sedimentation ponds or other sediment-control facilities prior to discharge to adjacent undisturbed drainages. Three factors indicate that these sediment-control facilities minimize or preclude flooding impacts to downstream areas as a result of mining operations:

1. The sediment-control facilities have been designed and constructed to be geotechnically stable. Thus, the potential is minimized for breaches of the sediment-control devices to occur that could cause downstream flooding.

2. The flow routing that occurs through these sediment-control devices reduces peak flows from the disturbed areas. This precludes flooding impacts to downstream areas.

3. By retaining sediment on site in the sediment-control devices, elevations of stream channels downstream from the disturbed areas are not artificially raised. Thus, the hydraulic capacity of the stream channels is not altered.

Following reclamation, stream channels will be returned to as close to their original configuration as possible (see Chapter 7 of this M&RP). The reclamation channels have been designed to safely pass the peak flow resulting from the 100-year, 6-hour storm in Bear Canyon and the 10-year, 6-hour storm in the ephemeral side drainages. Thus, potential for flooding of the reclaimed areas will be minimized. Interim sediment-control measures and maintenance of reclaimed areas during the post-mining period will prevent deposition of significant amounts of sediment in downstream channels following reclamation, thus maintaining the hydraulic capacity of the channels and preventing adverse flooding impacts.

The mine has been designed to prevent subsidence beneath perennial streams identified in Chapter 3 of this M&RP. Thus, no alteration of perennial stream flow patterns is anticipated.

Subsidence will occur in areas occupied by ephemeral stream channels. Although surface cracks that result from subsidence in the permit area tend to heal with time (DeGraff, 1978), ephemeral stream flows may be partially intercepted prior to completion of the healing process. In addition, the broad depressions created by subsidence may locally retain runoff that would normally discharge from an area. However, the following factors indicate that the impact of subsidence on ephemeral stream flow will be minimal:

1. Ephemeral stream flow in the area is sporadic, allowing significant periods of time for surface cracks to heal between flow events. As the cracks heal, the potential for interception of stream flow is minimized.

2. Ephemeral stream flow typically carries a high sediment load. This sediment will fill remaining cracks, ~~thus accelerating~~ the healing process and minimizing stream flow interception. Additionally, alluvial and colluvial deposits in the stream channels are unconsolidated and will assist in filling subsidence cracks that may occur.

3. The depressions created by subsidence are generally broad and changes in slope are not of sufficient magnitude to cause ponding. This is especially true in the steep terrain typical of the permit and adjacent areas.

The overburden thickness within the present permit area is 0 to 1500 feet. (Plate 7-4 of this M&RP). Maximum recorded cumulative subsidence within the permit area is 0.31 feet. Subsidence features in the area are associated with the coal outcrop (1991 Annual Report and Plate 3-3 of this M&RP). Within proposed Federal Lease U-024316 the thickness of overburden is 1000 to 1800 feet and no coal outcrops occur (Plate 7-4 of this M&RP). The effects of subsidence diminish with increased overburden thickness (Hustrulid, 1980). Thus, subsidence is not expected to impact stream flow patterns within proposed Federal Lease U-024316. Additionally, there will not be any surface facilities or portals in the proposed federal lease (Co-Op Mining Company, 1992a); thus, no disturbed areas will be created.

3.2.4 Potential Chemical Quality Impacts

Potential impacts to the chemical quality of surface water in the permit and adjacent areas include:

- Increased acidity, total suspended solids, and total dissolved solids;
- Contamination from hydrocarbon usage;
- Contamination from rock dust usage;
- Contamination from road salt; and
- Contamination from coal haulage.

Acidity, Total Suspended Solids, and Total Dissolved Solids Impact. As indicated in Sections 3.2.1 and 2.2.1 of this PHC, no significant impacts are expected to occur to the acidity of surface water in the permit and adjacent areas as a result of Co-Op mining and reclamation operations. Likewise, no significant impacts are expected to occur to TSS concentrations in the permit and adjacent areas (see Sections 3.2.2 and 3.2.3 of this PHC).

Historic TDS concentrations downstream of the mine water discharge point are generally lower than those found upstream. Average quarterly TDS concentrations for BC-1 and BC-2 measured during 1991 were 783 and 793 mg/l, respectively. The 10 mg/l difference in means was determined statistically insignificant through application of a Student's t-test (EarthFax Engineering, 1992 p. 2-6). The average TDS concentration measured during 1991 at the NPDES discharge point is 371 mg/l, which is significantly less than either Bear Creek average TDS concentration (1991 Annual Report). These data indicate that mine water does not decrease the quality of the surface water in the area.

Subsidence due to mining within proposed Federal Lease U-024316 is not expected to impact stream flow and no disturbed areas will be created within the lease due to mining activities (Section 3.2.3). Thus, impact to TDS concentrations is not expected to occur due to mining in this lease area.

Hydrocarbon Usage Impact. The potential impacts of hydrocarbon usage are contamination of soils and surface water resulting from spillage of hydrocarbon based products during maintenance of equipment or from tank leakage due to rupture of the tank. These potential impacts are presently being prevented and mitigated through the Co-Op Mining Company SPCC Plan (1992). These mitigations have been discussed in greater detail in Section 2.2.3 of this PHC. As a result of the implementation of this SPCC plan, the probability of spills and leaks of hydrocarbons contaminating the soil or surface water is low.

Rock Dust Usage Impact. The use of gypsum rock dust for the suppression of coal dust in the mine may potentially increase the sulfate and TDS concentrations of the water flowing into the mine. Mine water which has become enriched in the rock dust constituents will increase the concentrations of those constituents in surface water when discharged. Until recently, Co-Op Mining Company used a non-gypsum rock dust. In 1990, use of gypsum rock dust began.

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During January and March, 1992, TDS concentrations of discharged mine water exceeded the NPDES Permit guidelines. Gypsum used in rock dusting is considered to have contributed to the high TDS concentrations. Co-Op Mining Company no longer uses gypsum dust in the Bear Canyon Mine (Co-Op Mining Company, 1992c). Due to the relative dryness of the mine, no future increase in TDS or sulfate concentrations in the mine discharge water is expected.

Road Salting Impact. Co-Op Mining Company utilizes salt to maintain the roads within the permit area in the winter. Road salt could contaminate the surface water if sufficient amounts of salt were washed into the creeks.

Co-Op Mining Company salts 2,100 feet of road (4,200 feet including the proposed Tank Seam access road) in the winter. The potential for impact to the surface water is low and not likely to occur for the following reasons:

1. 7,255 feet of road (including the Tank Seam access road) lie with the sediment control area.
2. Salt is stored by Emery County outside the permit area.
3. Mild winters have minimized the need for road salt.

Coal Haulage Impact. Coal is presently hauled from the loadout facility by independent trucking firms. Surface water could be impacted by coal spills that would either fall directly into Bear Creek or be washed down into the creek during a storm event. These spills could occur due to a vehicle accident involving a coal truck, or through failure to close the coal hoppers on the truck.

No vehicle accidents have occurred in which coal has been spilled and no coal spills have occurred outside of the sediment control area. All coal spills that have occurred have been due to failure to close the hoppers on the trucks. These spills were quickly and

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thoroughly cleaned (Co-Op Mining Company, 1992a). Thus, the impact of spills related to coal haulage is low, and the likelihood of occurrence is low also.

In addition to spills, wind may carry coal dust or small pieces of coal from the open top of the coal truck into creeks near the road. The potential impact from fugitive coal dust is presumed to be insignificant due to the small amounts lost during haulage in the permit and adjacent areas.

3.2.5 Potential Surface Water Quantity Impacts

Surface water availability may possibly be diminished through subsidence due to the pulling of pillars. Surface water availability is increased in Bear Creek due to mine-water discharges.

There is no evidence of surface water loss or diminishment related to subsidence at the Bear Canyon Mine (Chapter 3 of the M&RP). When subsidence occurs in the Wasatch Plateau area, the cracks seal rapidly (DeGraff, 1978), preventing the deep percolation and subsequent loss of water previously destined for springs and other water sources. Therefore, the probability of surface water availability being affected by the subsidence is low (see also Section 3.2.3 of this PHC). Subsidence is adequately monitored under the subsidence monitoring plan (Chapter 7 of this M&RP).

The effects of subsidence within the proposed Federal Lease U-024316 are expected to be less than those experienced within the present permit area due to the greater thickness of overburden and lack of coal outcrops (Section 3.2.3). Thus, impact to surface water availability is expected to be less than that experienced in the present permit area.

4.0 CONCLUSIONS

The potential impacts of these mining operations upon the hydrologic balance are summarized in Table 4-1. All of the potential impacts of mining on the hydrologic balance are being properly monitored and mitigation plans have been implemented.

TABLE 4-1

Summary of Potential Impacts and Mitigations

Potential Impact	Potential Effect	Potential Magnitude of Impact	Probability of Occurrence	Mitigation Measures
Leaching of acid- or toxic-forming materials	Degradation of surface and groundwater quality.	Low	Low	Monitoring, materials handled in approved manner.
Groundwater availability	Decrease in spring flow due to subsidence	Low	Low (no history of impact)	Monitoring
Groundwater availability	Interception of perched groundwater by mine workings	Low	High (ongoing)	Monitoring
Groundwater availability	Removal of water with coal	Low	High (ongoing)	Monitoring
Groundwater quality	Decrease in quality due to leaching of rock dust	Low	Low (Dryness of mine)	Monitoring, discontinued use of gypsum rock dust
Groundwater quality	Decrease in quality due to hydrocarbon usage	Low	Low	Monitoring, SPCC plan, inspections and maintenance
Sediment yield	Increase in TSS	Moderate	Low	Sedimentation ponds, diversions, interior sediments, control, monitoring
Flooding	Damage to downstream areas	Moderate	Low	Sedimentation ponds, diversion, monitoring
Stream flow alteration	Damage to streams due to subsidence	Low	Low	Protection of perennial streams, monitoring

TABLE 4-1 (Continued)

Summary of Potential Impacts and Mitigations

Potential Impact	Potential Effect	Potential Magnitude of Impact	Probability of Occurrence	Mitigation Measures
Groundwater quality	Decrease in quality due to road salting	Low	Low	Sedimentation ponds, monitoring, storing of salt off site by County
Surface water quality	Decrease in quality due to leaching of rock dust	Low	Low	Monitoring, discontinued use of gypsum rock dust
Surface water quality	Decrease in quality due to hydrocarbon usage	Low	Low	Monitoring, SPCC plan, inspections, maintenance
Surface water quality	Increase in TSS due to coal spills and wind blown coal dust	Low	Low	monitoring, sedimentation ponds
Surface water quality	Decrease in water quality due to road salting	Low	Moderate	Sedimentation ponds, monitoring
Surface water quality	Increase in flow of Bear Creek due to mine discharge	Low	High (ongoing)	Monitoring, underground. i.e., use of water

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APPENDIX 7-N

REVISED HYDROGEOLOGIC EVALUATION OF THE BEAR CANYON MINE PERMIT AND PROPOSED EXPANSION AREAS

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April 26, 1993

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REVISED HYDROGEOLOGIC EVALUATION OF THE BEAR CANYON MINE PERMIT AND PROPOSED EXPANSION AREAS

1.0 INTRODUCTION

1.1 Scope

This report is an evaluation of the potential for operations at the Co-Op Mining Company Bear Canyon Mine to affect water quality and quantity at Birch and Big Bear Springs. The report also addresses revisions to the Bear Canyon permit area to allow incorporation of new Federal Coal leases U-024316 and U-024318, and the potential impacts that the lease expansions may have on the springs. This document is intended to supersede a previously-issued hydrogeologic evaluation report (EarthFax Engineering, 1991), which is herein updated and supplemented with additional hydrogeologic and water-quality data.

The work performed for this evaluation included:

1) A review of technical literature from the United States Geological Survey and the Utah Division of Water Resources, and permits on file with the Utah Division of Oil, Gas, and Mining.

2) Visits to the mine site to evaluate springs, collect historical spring flow data, tour accessible underground workings to evaluate groundwater inflow, and conduct preliminary water quality assessments (pH, temperature, and conductivity) of all accessible water sources.

3) A search of surface water and groundwater rights recorded with the Utah Division of Water Rights for the mine permit area and adjacent sections.

4) Discussions with Co-Op Mining representatives concerning historic groundwater inflows to the mine and the general operational history of the Bear Canyon mine.

5) Analysis of monthly precipitation, stream flow, spring flow, and geochemical data derived from monitoring stations in the vicinity of the Bear Canyon Mine.

6) Incremental drilling and aquifer testing of three borings from the mine floor to the Mancos Shale, and completion of the borings as monitoring wells.

7) Installation of dedicated purging and sampling systems in the monitoring wells, and collection of groundwater quality samples.

This report is divided into six sections, including this introduction. Section 2.0 is a description of area hydrogeology, Section 3.0 is a description of monitoring well installation and groundwater sampling, and aquifer testing is summarized in Section 4.0. Conclusions and recommendations are presented in Section 5.0, and references are contained in Section 6.0.

1.2 Background Information

The Bear Canyon Mine is located near the eastern margin of the Wasatch Plateau Coal Field in Bear Creek Canyon, a tributary to Huntington Creek Canyon (Figure 1-1). The mine is located approximately 9.5 miles west of Huntington, Utah.

Coal mining in the region of the study area began in the early 1900's. Mining operations have been or are presently being conducted by U.S. Fuel at Hiawatha, by Plateau Resources at Wattis, and by Co-Op Mining Company in the Trail Canyon and the Bear Creek Canyon. All of these operations have intersected the faults with which Big Bear and Birch Springs are associated, although the Co-Op Mining Company Trail Canyon and Bear Canyon operations are closest to the springs. The Trail Canyon Mine discontinued operations in late 1982 and has since been sealed; operations have been continuous at the Bear Canyon Mine since 1982.

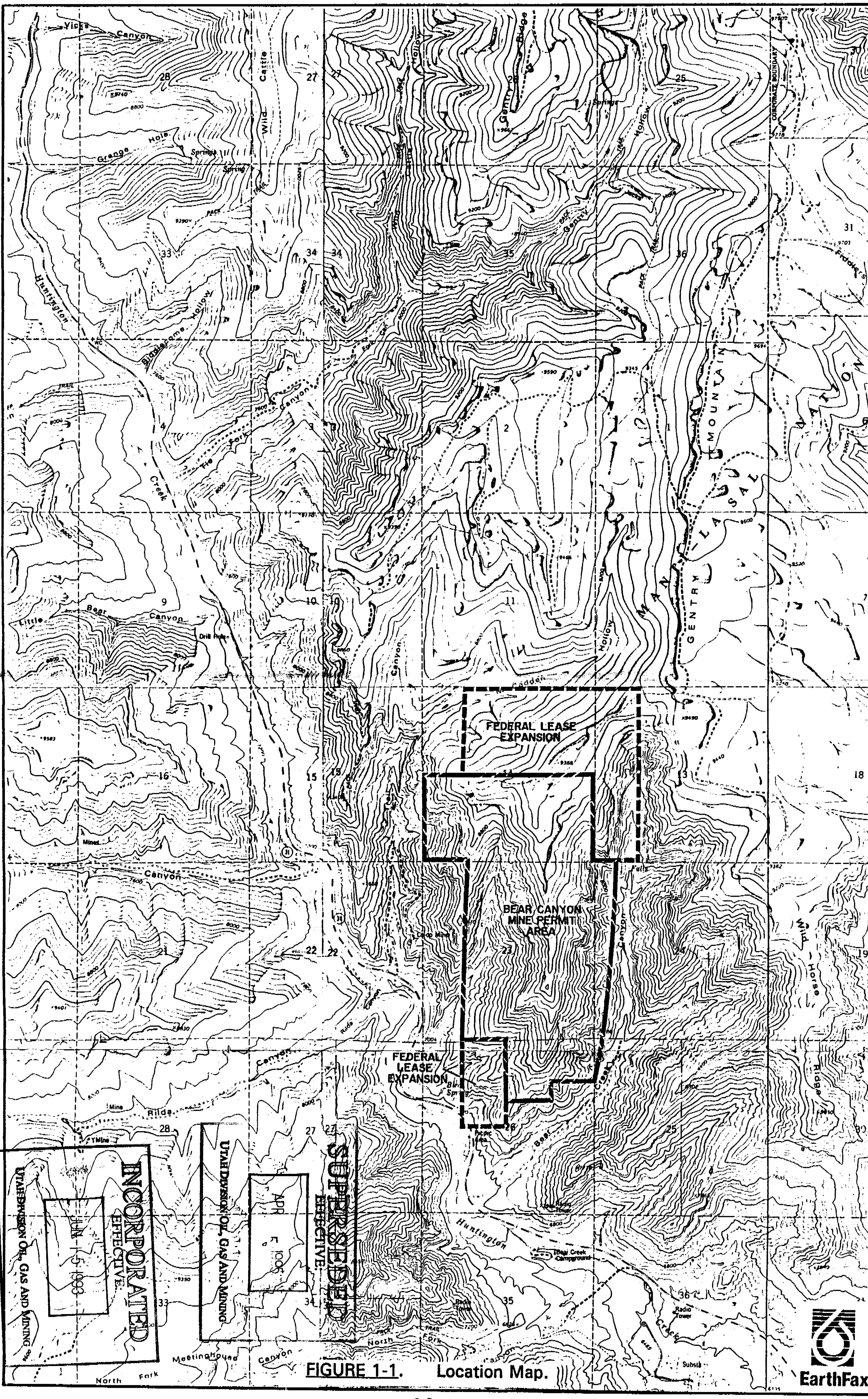

FIGURE 1-1. Location Map.

2.0 HYDROGEOLOGY

2.1 Climate

The Bear Canyon Mine permit and adjacent area (referenced herein as the study area) are located near the eastern margin of the Wasatch Plateau. Elevations within the study area range from approximately 6,500 to over 9,000 feet above sea level. This elevation range results in a significant variation in average annual precipitation amounts. At the higher elevations of the Wasatch Plateau, the average annual precipitation exceeds 40 inches.

Precipitation data has been collected at the Bear Canyon Mine since August 14, 1991. Because the period of Bear Canyon Mine precipitation records is short and because the data is collected at only one location, data from five surrounding precipitation recording stations were averaged to provide a more representative estimate of precipitation across the study area. The stations used in the averages are the NOAA weather stations at Hiawatha and Electric Lake and the SCS SNOWTEL stations at Stuart Ranger Station, Red Pine Ridge, and Cottonwood-Mammoth (Figure 2-1). The Bear Canyon Mine data, monthly precipitation data from each of the five stations and monthly five-station precipitation averages are presented in Appendix A.

2.2 Geology

2.2.1 General. Table 2-1 is a summary of stratigraphic relationships of the geologic units in the study area. The stratigraphic sequence of the lower Cretaceous-to-lower Tertiary section in the area suggests a regressive trend, from marine (Mancos Shale), through littoral and lagoonal (Blackhawk and Star Point Formations interbedded silt/mudstone and sandstone), to fluvial (Castlegate Sandstone, Price River Formation, and North Horn Formation sandstones and conglomerates), and lacustrine (Flagstaff Limestone) deposition.

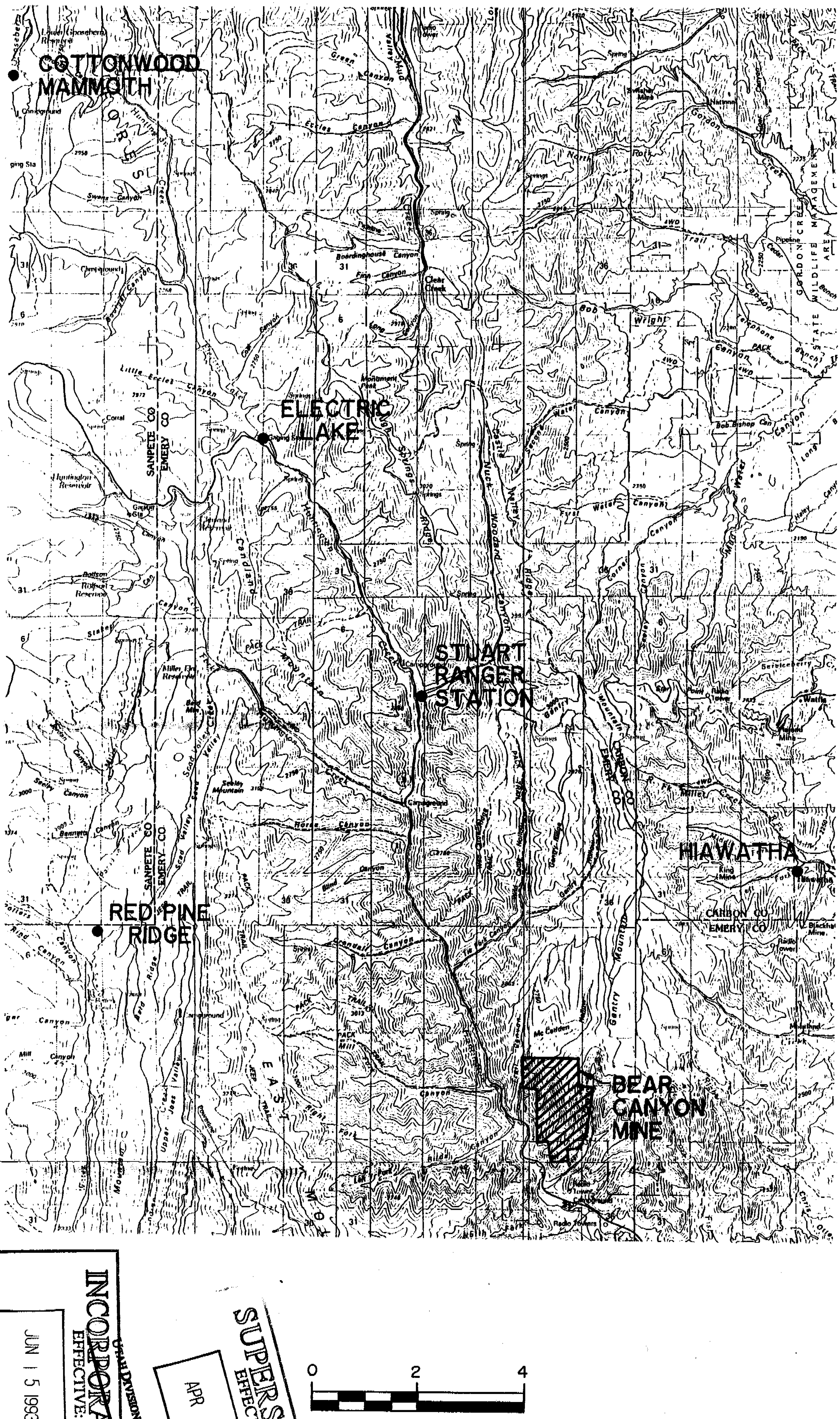

FIGURE 2-1. Location of Precipitation Monitoring Stations.

EarthFax

Table 2-1

Stratigraphic relationships, thicknesses, lithologies, and water-bearing characteristics of geologic units in the upper drainages of Huntington and Cottonwood Creeks (adapted from Stokes, 1964)

System	Series	Formations and members	Thickness (feet)	Lithology and water-bearing characteristics
Quaternary	Holocene and Pleistocene		0-100	Alluvium and colluvium; clay, silt, sand, gravel, and boulders; yields water to springs that may cease to flow in late summer.
Tertiary	Eocene and Paleocene	Flagstaff Limestone	10-300	Light-gray, dense, cherty, lacustrine limestone with some interbedded thin gray and green-gray shale; light-red or pink calcareous siltstone at base in some places; yields water to springs in upland areas. (See table 9.)
	Paleocene	North Horn Formation	800±	Variegated shale and mudstone with interbeds of tan-to-gray sandstone; all of fluvial and lacustrine origin; yields water to springs. (See table 9.)
Cretaceous	Upper Cretaceous	Price River Formation	600-700	Gray-to-brown, fine-to-coarse, and conglomeratic fluvial sandstone with thin beds of gray shale; yields water to springs locally.
		Castlegate Sandstone	150-250	Tan-to-brown fluvial sandstone and conglomerate; forms cliffs in most exposures; yields water to springs locally.
		Blackhawk Formation	600-700	Tan-to-gray, discontinuous sandstone and gray carbonaceous shale with coal beds; all of marginal marine and deltaic origin; locally scour-and-fill deposits of fluvial sandstone within less permeable sediments; yields water to springs and coal mines, mainly where fractured or jointed.
		Star Point Sandstone	350-450	Light-gray, white, massive, and thin-bedded sandstone, grading downward from a massive cliff-forming unit at the top to thin interbedded sandstone and shale at the base; all of marginal marine and marine origin; yields water to springs and mines where fractured and jointed.
		Masuk Member Mancos Shale	600-800	Dark-gray marine shale with thin, discontinuous layers of gray limestone and sandstone; yields water to springs locally.

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Plate 1 depicts surface outcrops and geologic structures within the study area. Regionally, the strata in the study area dip to the south and southeast at an angle of two to three degrees (Brown, et al., 1987); this dip direction was confirmed by the stratigraphy observed during in-mine drilling conducted for this study, although dip angles determined from in-mine drilling ranged from 0.44 to 1.47 degrees. As shown on Plate 1, the Bear Canyon and Trail Canyon Mines are located in a complex graben bounded by the Pleasant Valley Fault (on the west) and the Bear Canyon Fault (on the east). Vertical displacements on both faults are approximately 100-150 feet. Brown, et al. (1987) describe a shattered zone within the graben, approximately two miles north of the current northernmost extent of the Bear Canyon Mine. In the portion of the graben within the permit area, only minor faulting (vertical displacements of 20 feet or less) has been identified, with the exception of the Blind Canyon fault (Plate 1), which is estimated to have approximately 220 feet of vertical displacement (down to the west) in the vicinity of the Bear Canyon Mine (Co-Op Mining Company, 1990a).

The major coal-bearing unit of the Wasatch Plateau Coal Field is the Blackhawk Formation. In the Bear Canyon mine, coal is removed from two seams within the Blackhawk Formation: the Blind Canyon seam is approximately 100 feet above the Blackhawk/Star Point contact and is continuous throughout the permit area; the Hiawatha seam thins and (in places) pinches out, and lies in direct contact with the Star Point Sandstone (Co-Op Mining Company, 1990a).

<u>2.2.2 Stratigraphy of In-Mine Drill Holes</u>. Descriptive logging and aquifer testing was conducted in three in-mine drill holes installed as part of this study. During the investigation, it was revealed that the Star Point Sandstone beneath the permit area is comprised of three separate sandstone units (in descending order: the Spring Canyon, Storrs, and Panther Tongues) interbedded with two mudstone units (inferred to be tongues of the Blue Gate member of the Mancos Shale). In this report, the mudstone tongue between the Spring Canyon and Storrs is termed the Mancos No. 1 mudstone, and that between the Storrs and the Panther is termed the Mancos No. 2 mudstone. A similar intertonguing of Blue Gate shale with the three Star Point sandstone units has been documented in the area of the Scofield

S.W. and Scofield S.E. quadrangles, immediately north of the study area (Doelling, 1972). Characteristics of the three Star Point Sandstone aquifers are summarized in Section 2.5, and stratigraphic logs are contained in Appendix G.

2.3 Surface Water

2.3.1 Hydrology. Most of the study area is drained by two canyons, Trail Canyon (on the west) and Bear Canyon (on the east). Several smaller canyons drain the remaining southeast portion of Bear Canyon permit area. The Trail Canyon and Bear Canyon drainages contain intermittent streams, while the small drainages in the southeast portion of the permit area contain ephemeral streams. These streams discharge to Huntington Creek, the major drainage in the area.

The tributary streams primarily flow during the snowmelt period. From 65 to 80 percent of the annual discharge at the Huntington Creek gauging station (located near the Utah Power and Light diversion for the Deer Creek Power Plant) occurs during the snowmelt period from April through July (Danielson, et al., 1981). Flow records for the period from 1981 through 1983 and 1985 were obtained from Utah Power & Light. Data for the 1984 - 1985 water year are not available. Flow records for 1986 through September, 1991 were obtained from the U.S.G.S. Water Resources Division. Stream flow data are summarized in Appendix B.

2.3.2 Surface Water Quality. Danielson, et al. (1981) conducted surface water sampling of flows from selected streams in the study area. The waters sampled at the Huntington Creek gauging station were predominantly a calcium-bicarbonate water type. Waters sampled from the tributaries of Huntington Creek were predominantly a calcium-magnesium-bicarbonate water type. During periods of low flow, the concentrations of sulfate in the tributaries were up to ten times greater than in Huntington Creek itself (Danielson, et al., 1981).

Stream water monitoring points BC-1 (Upper Bear Creek) and BC-2 (Lower Bear Creek) were monitored for stream flow six and seven times, respectively, during the period from February through November, 1990 and average flow rates are presented in Table 2-2. During 1990 average flow rates increased by 12 gpm from BC-1 to BC-2. Water samples were collected from both BC-1 and BC-2 three and four times, respectively, during 1990 (Co-Op Mining Company, 1990b) and averages of these data are presented in Table 2-2. These averages were examined using a Student's t-test to test the hypothesis that the differences between the mean values for BC-1 and the mean values for BC-2 are insignificant. The t-test for difference in means is defined by the following formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

where

$$\sigma = \sqrt{\frac{N_1 s_1^2 + N_2 s_2^2}{N_1 + N_2 - 2}}$$

with: N_1 and N_2 = number of samples from the two populations,
X_1 and X_2 = the means of the two populations,
s_1 and s_2 = the standard deviations of the two populations.

If the absolute calculated t value is less than the table t value, the difference in the means of the two data sets is considered insignificant (Spiegel, 1961). Table 2-3 presents the results of the statistical analysis. According to the Student's t-test, the means of the 1990 parameters for BC-1 and BC-2 displayed in Table 2-2 are not significantly different. Thus, the data suggest that there is no significant difference between the surface water collected upstream from the mine at BC-1 and the surface water collected downstream from the mine at BC-2.

Prior to 1991, all water inflows to the mine were used in mining operations, and no discharge was made to the surface. Increased mine water inflow as development continued to the north made it necessary to begin discharging to Bear Creek in 1991. During 1991, discharge rates increased from 60 gpm to 194 gpm (Co-Op Mining Company, 1991). Mine water discharge in 1992 has typically been 300 gpm (Co-Op Mining Company, 1992a).

TABLE 2-2

Comparison of 1990 and 1991 Surface Water Monitoring Results for BC-1 and BC-2

	BC-1		BC-2	
	1990	1991	1990	1991
Average Flow Rate (gpm)	32	27	44	100
Average pH	8.1	8.0	8.2	8.0
Average Specific Conductance (mmhos)	1392	971	1170	837
Average TSS (mg/l)	1770	623	1712	342
Average TDS (mg/l)	1361	783	1066	793
Average Fe (mg/l)	4.1	26.3	3.8	4.0
Average Oil & Grease (mg/l)	<5	<5	60	<5

TABLE 2-3

Results of t-Test for BC-1 and BC-2, 1990

	BC-1		BC-2		Combined Statistics		
Parameter	Mean	Standard Deviation	Mean	Standard Deviation	σ	t (calc.)	Significant ?
Flow Rate (gpm)	32	17	44	22	21.59	0.99[a]	No
pH	8.1	0.08	8.2	0.16	0.14	1.25[a]	No
Specific Conductance (mmhos)	1392	1114	1170	772	934	0.42[a]	No
TSS (mg/l)	1770	2781	1712	2493	3100	0.02[b]	No
TDS (mg/l)	1361	1592	1066	1373	1740	0.22[b]	No
Fe (mg/l)	4.1	5.8	3.8	3.5	5.49	0.07[b]	No
Oil & Grease (mg/l)	<5	0.00	60	120	120	0.58[c]	No

[a] t (table) = 1.78 (Spiegel, 1961)
[b] t (table) = 1.94 (Spiegel, 1961)
[c] t (table) = 2.02 (Spiegel, 1961)

During the period from May through October 1991, Bear Creek stream flow was measured seven times. Average stream flow increased from Upper Bear Creek (BC-1) to Lower Bear Creek (BC-2) by 73 gpm (Table 2-4), due to discharge from the Bear Canyon Mine. Surface water samples were collected quarterly from both BC-1 and BC-2. Utilizing the Student's t-test defined above, the 1991 data suggest that the one significant difference between the surface water collected at BC-1 and at BC-2 is the increase in flow rate due to mine water discharge from the NPDES discharge point (Table 2-4).

Flow rates above the mine water discharge, specific conductance, TSS, and TDS concentrations generally decreased from 1990 to 1991. Total precipitation measured at Red Pine Ridge and Mammoth-Cottonwood also decreased from 26.20 and 22.30 inches, respectively in 1990, to 13.20 and 6.00 inches respectively, in 1991 (Appendix A). The decrease in precipitation caused a decrease in both runoff and recharge to springs. In turn, the erosion of sediments due to runoff decreased and likely caused the decrease in chemical and sediment concentrations. During November 1990 and February 1991, chemical concentrations in both BC-1 and BC-2 increased to several times the concentrations detected throughout the balance of each respective year. The fact that this increase occurs both upstream and downstream of the mine suggests that it is not related to mining activities.

The mine water discharge typically has a pH of 7.9 and a specific conductance of 546 mmhos. The TDS and TSS concentrations average 371 and 13 mg/l, respectively. Iron concentrations are typically 0.11 mg/l and oil and grease are usually less than detection. These concentrations are generally less than the corresponding concentrations at both the upper and lower Bear Creek monitoring stations (Co-Op Mining Company, 1991). Thus, it is unlikely that the mine water discharge decreases the quality of water in Bear Creek.

Mine water collected in sumps in the mine is discharged to Bear Creek, and is monitored according to guidelines in NPDES Permit number UT[illegible]. During the months

TABLE 2-4

Results of t-Test for BC-1 and BC-2, 1991

	BC-1		BC-2		Combined Statistics		
Parameter	Mean	Standard Deviation	Mean	Standard Deviation	σ	t (calc.)	Significant ?
Flow Rate (gpm)	27	9	100	78	60	2.30[a]	Yes
pH	8.0	0.10	8.0	0.10	0.01	0.00[a]	No
Specific Conductance (mmhos)	971	747	837	511	979	0.26[a]	No
TSS (mg/l)	623	913	342	299	784	0.50[b]	No
TDS (mg/l)	783	633	793	679	758	0.02[b]	No
Fe (mg/l)	26.3	49	4.1	4.7	40	0.79[b]	No
Oil & Grease (mg/l)	<5	0.00	<5	0.00	0.00	0.00[b]	No

[a] t (table) = 1.77 (Spiegel, 1961)
[b] t (table) = 1.90 (Spiegel, 1961)

of January and March, 1992, TDS concentrations measured at the NPDES discharge point exceeded the maximum allowable concentration of 2,000 lbs./day. This increase was attributed to localized sulfur-bearing minerals in the mine's 3rd West section and the use of gypsum rock dust in the mine (Co-Op Mining Company, 1992a), which began in 1991 (Co-Op Mining Company, 1992b). This problem was corrected by using lime dust in the active sections of the mine. The 3rd West section is not presently active. Should mining resume in 3rd West, discharge from that part of the mine will be restricted (Co-Op Mining Company, 1992a).

2.4 Groundwater

The groundwater system in the study area has been investigated by Danielson, et al. (1981), Co-Op Mining Company (1986), and Montgomery (1991). The recharge, movement, and discharge of water within the groundwater system is dependent on climatic and geologic conditions in the study area. Although groundwater occurs in all of the geologic units listed in Table 2-1, none of the units are saturated everywhere (Danielson, et al., 1981).

<u>2.4.1 Occurrence of Groundwater</u>. The formations in the study area have been identified as having a combination of perched and regional water tables. In most of the study area, perched zones exist in the North Horn, Price River, Castlegate Sandstone and upper Blackhawk Formations.

Although a regional aquifer (termed the Star Point-Blackhawk Aquifer by Danielson, et al., 1981) has been proposed for the area, in-mine drilling and aquifer testing conducted for this study indicate that the three aquifers within the Star Point Sandstone have individual static water levels. Further, in the southernmost hole (DH-3) none of the three aquifers are fully saturated (Figure 2-2). The fact that the Star Point aquifers are separate and hydraulically distinct (a single water table does not transect the stratigraphic units as proposed

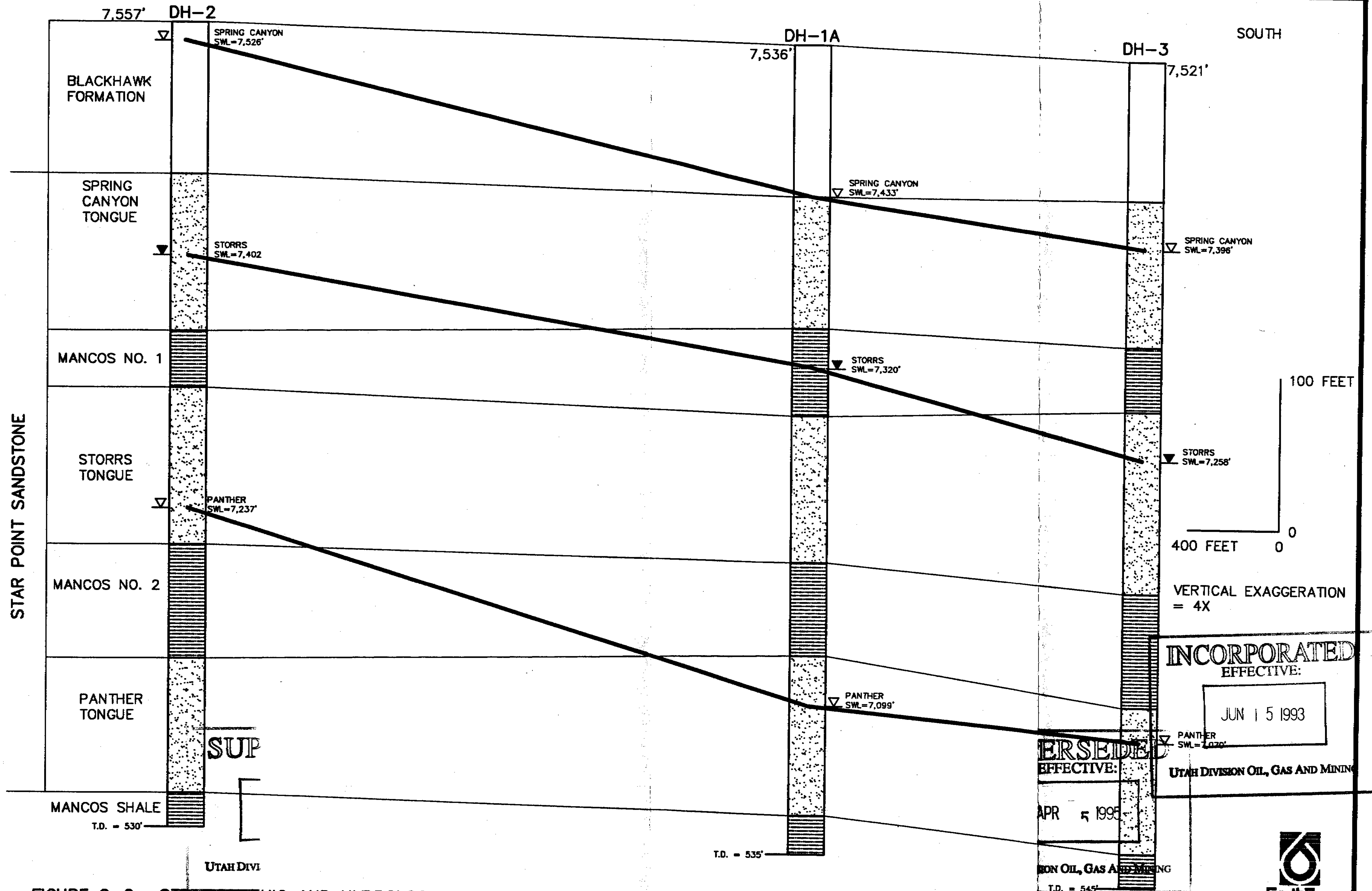

FIGURE 2-2. STRATIGRAPHIC AND HYDROLOGIC CROSS-SECTION THROUGH IN-MINE DRILLHOLES DH-1A, DH-2, AND DH-3

2-12

by Danielson, et al. 1981) suggests that the "regional" aquifer in the study area is actually located below the Star Point/Mancos Shale contact.

2.4.2 Recharge. Snow at the higher elevations provides the greatest source of groundwater recharge. Deuterium analyses of groundwater in the region indicate that most, if not all, groundwater is derived from snowmelt (Danielson et al., 1981). The percentage of water derived from snowmelt which recharges the groundwater system versus that which runs off to stream flow is controlled by the surface relief, the permeability of exposed strata, the depth of snowpack, and the rate of snowmelt. The highest recharge occurs in areas of low surface relief and on formations which have high permeability from fractures and/or solution openings.

In the study area, the criteria which encourage recharge from snowmelt are typical of the areas of exposed North Horn and upper Price River Formations. The main recharge area to the groundwater system in the area of the Bear Canyon Mine is expected to be the shattered zone identified by Brown, et al. (1987) in Section 1, 2, and the north half of Section 11, in Township 16 South, Range 7 East (Plate 1). An additional area of recharge could also be expected in the southern half of Section 11 and the northern half of Section 14, due to the surface exposure of North Horn Formation (Plate 1), however, this area is not as highly fractured as the area to the north.

Outcrops within the permit area include the Price River Formation, Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, and the Mancos Shale. Danielson, et al. (1981) indicate that recharge to the Blackhawk-Star Point aquifer from direct infiltration of snowmelt to formations which outcrop below the North Horn Formation is small in comparison to recharge through low relief surfaces on the North Horn Formation. In the study area, low-relief exposures of formations below the North Horn Formation and above the coal outcrops is limited due to the steepness of the canyons. Therefore, the potential for recharge through these formations to the regional groundwater system within the permit area is limited.

Co-Op Mining Company has conducted spring and seep surveys of the permit and adjacent area and has identified three springs and two seeps which occur above the coal seam. These water sources are located in the northern part of the permit and adjacent area. As shown on the water rights map (Figure 2-3), no groundwater rights are found on the ridge overlying the Bear Canyon Mine. The only groundwater sources identified in the southern portion of the permit and adjacent area are Big Bear Spring and Birch Spring. These springs are located approximately 500 feet below the Blind Canyon seam mine floor, and issue from the contact between the Panther Tongue of the Star Point Sandstone and the Mancos Shale. The limited number of springs which occur in areas which overlie the mine is further indication that only limited recharge occurs in the Bear Canyon permit area.

<u>2.4.3 Movement</u>. The movement of groundwater in the study area is strongly controlled by faults and the dip of strata. Most of the water movement in the study area is through fractures, faults, and partings between the beds (Danielson, et al., 1981). According to Danielson, et al. (1981), a portion of the snowmelt recharge water is discharged close to the original recharge source, where the downward movement of water is impeded by impermeable beds of shale or mudstone. If lateral movement occurs close to the canyon edge, this movement continues until the land surface is encountered and discharge occurs as a perched spring. If the movement occurs on the interior of the mountain, the lateral movement continues until other vertically permeable lithologies or zones of fracturing are encountered.

Fracture-enhanced permeability allows water to pass vertically through strata which would normally impede flow. Depending on the extent to which the fractures are interconnected, vertical groundwater flow can be limited to a short distance, or it can extend to the regional water table (see Figure 2-4). Lines (1985) indicated that for the hydrogeologically similar area of Trail Mountain (south of the study area), despite a thick section of very low-permeability rock, some hydraulic connection exists between the perched aquifers and the proposed regional aquifer; such transfer occurs as downward unsaturated flow from perched aquifers to the regional aquifer along the fractures and faults.

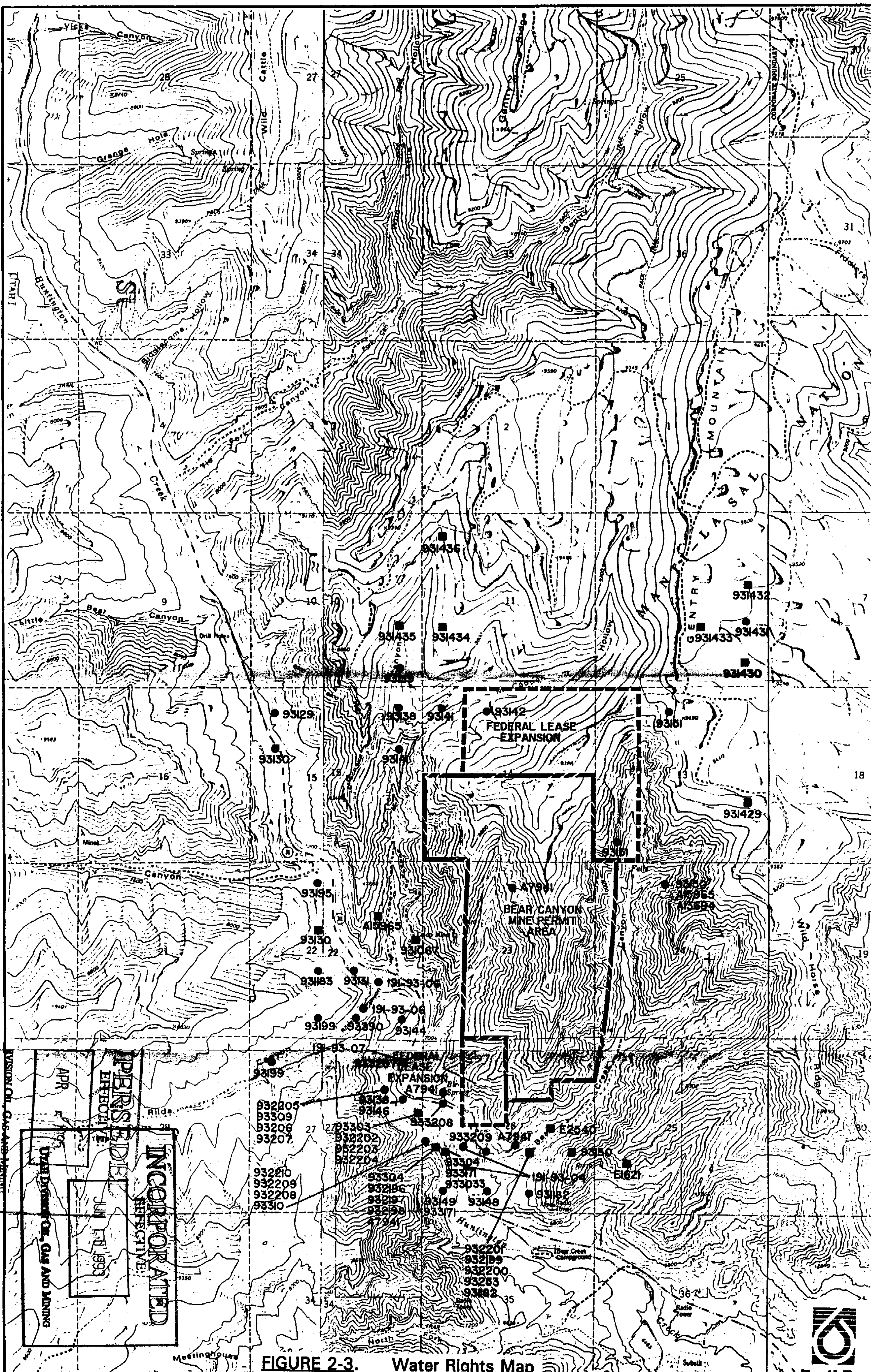

FIGURE 2-3. Water Rights Map

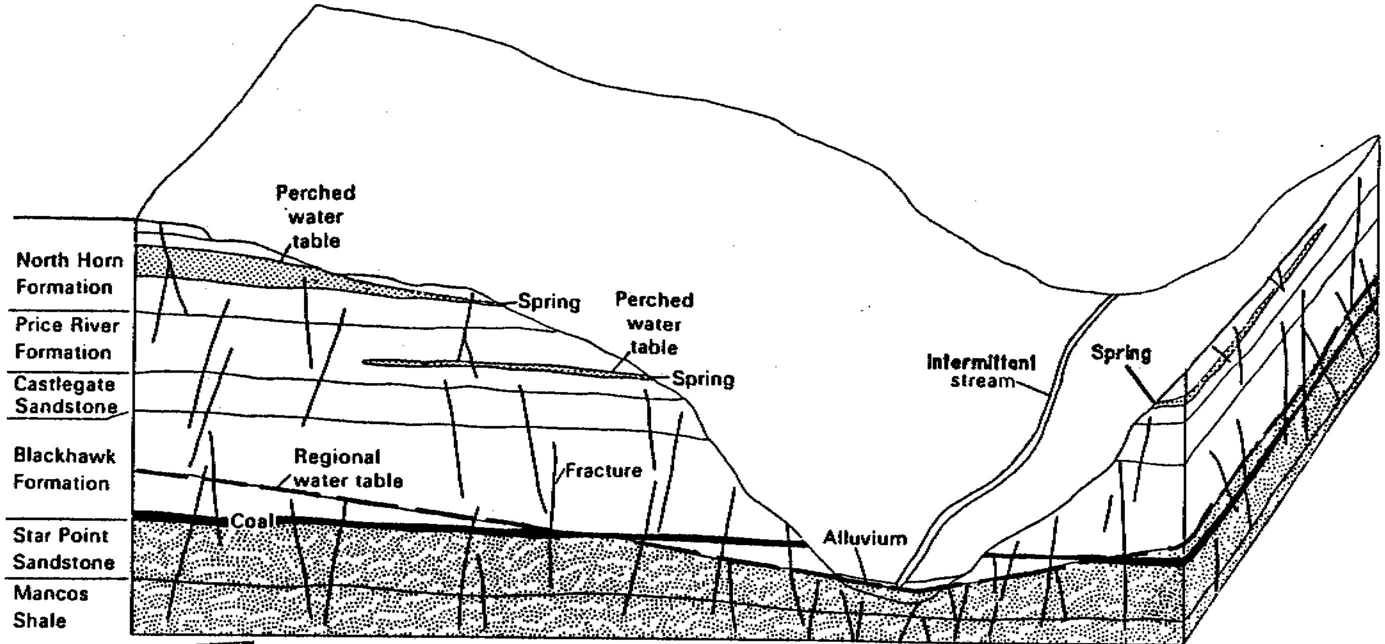

FIGURE 2-4. Generalized Block Diagram Showing Occurrence of Groundwater

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<u>2.4.4 Discharge</u>. Groundwater naturally discharges through springs, seeps, and by evapotranspiration. Some discharge from the groundwater system in the mine area may occur either by flow in the faults and fractures out of the Huntington Creek drainage or as subsurface flow to alluvial fill in the canyons, although such flow cannot be quantified. The major source of quantifiable discharge is springs. Within the area of the mine, two major springs have been identified: Big Bear Spring and Birch Spring. Two additional nearby springs (Tie Fork and Little Bear) have been identified outside the Bear Canyon Mine permit area. The locations of the springs are shown on Figure 2-5.

Big Bear Spring (maintained by the Castle Valley Special Services District) discharges from three prominent joints. Birch Spring (maintained by the North Emery Water Users Association) discharges from a normal fault which has approximately 20 feet of vertical displacement. Both springs issue from the lowest sandstone unit of the Star Point Sandstone (the Panther Tongue), where the Mancos Shale serves as a barrier to downward movement of groundwater (Montgomery, 1991). Tie Fork is not a true spring, but two flowing geophysical boreholes which have been developed by the Castle Valley Special Services District. Little Bear Spring issues from faults, and also is maintained by the Castle Valley Special Services District. Flow records for these springs have been obtained from the water companies and are presented in Appendix D. Big Bear Spring has an 12-year period of record (1981 to present), Birch Spring has a 4-year period of record (1989 to present), Tie Fork has an 9-year period of record (1984 to the present), and Little Bear Spring has an 11-year period of record (1982 to the present).

<u>2.4.5 Inflow to Mine</u>. According to Wendell Owen, the Bear Canyon Mine had water inflow to the old abandoned workings prior to the start of operations by Co-Op Mining Company in 1982. During the development of the East Bleeder entries (Plate 7-10A), water was encountered in two small faults subsidiary to the Bear Canyon Fault. Within a short time of this interception, the inflow to the abandoned workings ceased. The rate of inflow to the East Bleeders during development was approximately that which previously had flowed to the abandoned workings.

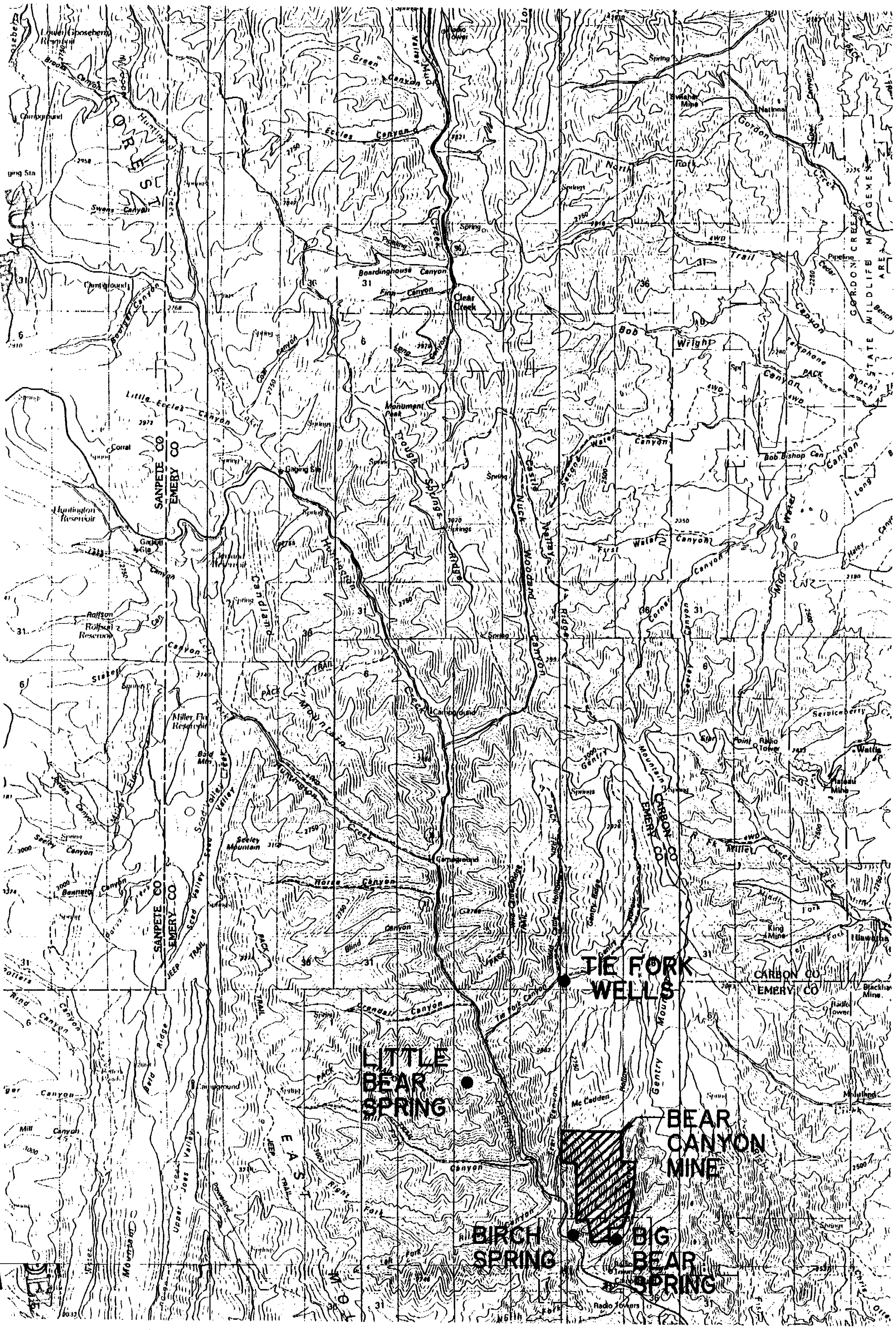

FIGURE 2-5. Locations of Springs in the Vicinity of the Mine Permit Area

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Inflow to the East Bleeders continued until the summer of 1989, when water was encountered as the North Main entries were advanced northward. According to Wendell Owen, inflow to the East Bleeders gradually diminished and flow into the North Mains was approximately 110 gpm. As the North Main entries were advanced, former zones of inflow several crosscuts back from the working face would drain, and the inflow rate would diminish and eventually cease. This observed coordination between upgradient inflow interception and downgradient inflow cessation as mine development advanced northward indicates a high degree of hydraulic interconnection through fractures in the portion of the Blackhawk Formation which overlies the mine, and that this fracture system directs flows to the southeast, along the dip of the beds.

The current major area of water inflow to the mine is located at the north end of the Second East entries (Plate 7-10A). Sumps located in the Second East and North Main entries in the area of the inflow are used to collect and store this water. Water from these sumps is pumped to the East Bleeder sumps, where a portion is diverted for in-mine use. The remainder of the water is pumped to the surface and discharged into Bear Creek (such discharges are recorded in the annual reports). A portion of the inflow to the area of the North Mains is used for culinary purposes at the mine.

Additional minor inflows to the mine consist of small quantities from diffuse sources throughout the mine. During the February 1991 underground tour, only one small roof dripper was found with sufficient flow (0.1 gallon per minute) to be sampled. Values of pH, temperature, and conductivity measured at the time of sampling are presented in Table 2-5. At the time of the underground tour, Wendell Owen indicated that several of the areas surveyed had previously been much wetter; however, only limited water inflows were found during the survey. This pattern is similar to that observed in other mines (e.g., Deer Creek, Plateau, and others) in the Wasatch Plateau (Danielson et al., 1981). In areas which do not intersect faults upon initial mining, moderate water inflows occur from diffuse sources (primarily from roof bolts). Flows from such sources are generally less than one gallon per

TABLE 2-5

Field Parameter Results

Sample I.D.	pH (Units)	Temperature (°C)	Conductivity (μmhos/cm)
Big Bear Overflow	6.9	10.9	460
Seepage Above Big Bear Spring	8.1	12.4	2000
Roof dripper in 3rd West Entries	7.7	14.2	510

minute. Typically, the roof bolt intersects and provides a drain for a localized perched aquifer,often a sandstone lens, which has a limited extent and limited quantity of water in storage. Once the stored water is drained (typically in one or two months), recharge to the perched zone is not sufficient to maintain the previous flow, and the inflow is reduced or ceases entirely.

Inflows in the north ends of the North Main and Second East entries are through roof bolt holes and hairline fractures which are presumed to drain overlying perched aquifers in the Blackhawk Formation. An indeterminate amount of water flows upward through the floor in the area of the Second East entries, and probably originates from the Spring Canyon Tongue aquifer (extrapolation of the Spring Canyon piezometric surface determined during testing of three in-mine monitoring wells indicates it would be approximately 15 feet above the mine floor in the north end of Second East).

Because mine inflow is from numerous and diverse sources, and because measurements prior to 1992 were not metered, the precision and accuracy of the flow rate measurements is considered by Co-Op to be insufficient to demonstrate that flow rates decrease over time when mine advancement is halted. Flow meters were installed in 1992 to allow more accurate and precise measurement of inflows, and continued periodic monitoring of inflow rates will provide more reliable data from which more definitive conclusions regarding the nature of the inflows may be drawn. Based on observations by Co-Op personnel, however, consistency of inflows in the north ends of the North Main and Second East entries is related to the rate at which the entries are advanced northward. When advancement is relatively constant and new fractures are encountered and drained, inflows are relatively constant. When the entries are not advanced, as the fractures are drained of their storage the inflow rate decreases (as was evident in 1992).

__2.4.6 Long-Term Impacts__. Springs in the vicinity of the Bear Canyon Mine issue from joints at the contact between the Panther Tongue and the Mancos Shale. Water inflows to the mine through bolt holes and fractures are from perched zones of limited storage.

Most of the inflow observed to migrate with northward mine advancement in the North Mains and northern Second East areas is presumed to be due to the interception of stored water in fractures which drain a more laterally continuous perched aquifer. This concept is further supported by the observation that inflows to the Third West Bleeders diminished and eventually ceased as the North Mains and Second East entries were advanced northward in 1989.

The absence of springs and the presence of efflorescence on sandstone outcrops in areas of seepage in the downgradient (southern) portions of the permit area suggests that groundwater movement potential in aquifers perched above the Bear Canyon seam is limited. Additionally, the absence of spring flows from the strata above the Panther Tongue/Mancos Shale contact and the presence of efflorescence on sandstone outcrops indicates a slow rate of groundwater movement and that most of the groundwater that reaches the outcrop evaporates on contact with the atmosphere. Further, no drainage through the mine floor in areas of known faults, or other evidence of hydraulic connection between such perched zones and the springs which issue from the Panther Tongue/Mancos Shale contact has been found. Thus, dewatering and diversion of inflows such as those discussed in Section 2.4.5 are not expected to affect nearby spring water quality or quantity in either the long- or short-term.

Potential negative impacts to spring water quality due to water leaking from the old workings and flowing over mudstones and into the spring collection system will not occur, because pumping into the old workings will not occur. To prevent inadvertent accidental discharge into the old workings, a locked valve has been installed in front of the pressure relief valve shown on Plate 7-10a.

After mining and associated dewatering/diversion operations cease, the local piezometric surface will recover toward pre-mining conditions. Although inflows are expected to diminish and cease once the perched zones are drained, if inflows continue after mining is completed, the abandoned mine will not flood because the strata dip to the south-southeast; natural flow through the subsided entries and drainage to the surface will prevent accumulation (flooding) in the mine. As shown on maps of Bear (Blind) Canyon Seam structure and the 1990 water survey (Plates 6-4 and 7-10A, respectively, of the M&RP) mine inflows originating in the northern portions of the current mine and proposed expansion areas will be conveyed to the surface through the subsided entries and will ultimately discharge along the eastern limits of the mine, probably from the area of the present fan portal, which is the lowest-elevation coal outcrop in the lease area (7,440 feet).

Flooding of the old (pre-Co-Op) abandoned workings in the south end of the lease area and potential consequent impacts to water quality or quantity due to surface-flow contamination of springs 500 feet downslope from the coal outcrop will not occur; the lowest floor elevation of the sealed entries which lead into the old workings is 7,494 feet, or 54 feet above the elevation at the fan portal. Any post-abandonment inflow originating in the northern portions of the mine will be conveyed to the east, over the mine floor surface, well north of the old workings. Discharge from the fan portal will be conducted via culvert to channel RC-3 (Plate 7-7), which is designed to accommodate a 10-year, 6-hour flow of 3.77 cfs (1,700 gpm). The addition of a hypothetical 1.11 cfs (500 gpm) discharge from the mine would not require a change in channel design. Further, a hypothetical 2.22 cfs (1,000 gpm) discharge would require only that the channel riprap D_{50} be increased from 9 inches to 10 inches. Culvert sizing and other design details will be revised prior to mine reclamation, if required, when quantities and conditions are known. However, for current mine conditions, the reclamation plan is adequate to accommodate discharges in excess of those currently intercepted by the mine.

2.5 Summaries of Star Point Sandstone Aquifers

2.5.1 Spring Canyon Tongue. The Spring Canyon Tongue of the Star Point Sandstone is 88 feet thick at DH-1A, 103 feet thick at DH-2, and 98 feet thick at DH-3. It is generally light gray with minor dark minerals, but varies from dark gray to white. The grains range in size from fine to medium, and are moderately well sorted, subangular to subround, and cemented with calcium carbonate. The unit is generally moderately- to well-indurated.

Bedding is variable through the unit, from massive to laminated, with muddy zones and partings and locally dense bioturbation. The contact with the overlying Hiawatha coal seam of the Blackhawk Formation is abrupt; the lower contact with the Mancos No. 1 mudstone tongue is gradational.

The static water level measured in the Spring Canyon aquifer during drilling and testing was 3 feet below the top of the unit in DH-1A, 71 feet above the top of the unit in DH-2, and 25 feet below the top of the unit in DH-3. Thus, the Spring Canyon aquifer is confined by the Hiawatha coal seam in the northernmost drill hole (DH-2), and unconfined in the remaining two (DH-1A and DH-3).

__2.5.2 Storrs Tongue__. The Storrs Tongue is 96 feet thick at DH-1A, 105 feet thick at DH-2, and 120 feet thick at DH-3. It is generally light gray to dark gray, with minor dark minerals. The grains range in size from very fine to fine, and are moderately well sorted, subangular to subround, and well cemented with calcium carbonate. The unit is generally well-indurated. Bedding is variable through the unit, from massive to laminated, with muddy zones and partings and locally dense bioturbation, particularly in the lower portion of the unit. The contacts with the overlying Mancos No. 1 and underlying Mancos No. 2 mudstones are gradational. The Storrs Tongue sandstone is generally finer-grained, more dense, more highly indurated, and less permeable (as demonstrated by aquifer tests, Section 4.0) than the other two Star Point Sandstone aquifers.

The static water level measured in the Storrs aquifer during drilling and testing was 30 feet above the bottom contact of the confining Mancos No. 1 mudstone in DH-1A, 89 feet above the bottom of the Mancos No. 1 in DH-2, and 23 feet below the top of the unit in DH-3. The Storrs is unconfined by the Mancos No. 1 mudstone in only the most southern drill hole (DH-3).

__2.5.3 Panther Tongue__. The Panther Tongue is 105 feet thick at DH-1A, 88 feet thick at DH-2, and 97 feet thick at DH-3. It is generally light gray with minor dark minerals, but, like the Spring Canyon and Storrs tongues, varies from dark gray to white. The grains range in size from fine to coarse, and are poorly to moderately well sorted, round to subround, and poorly cemented with calcium carbonate. The unit is generally poorly to moderately-well indurated, and locally friable. Bedding is variable through the unit, from massive to laminated, with muddy partings and local bioturbation. The contact with the overlying Mancos No. 2 mudstone is gradational; the lower contact with the Mancos Shale is abrupt. The Panther Tongue sandstone is less dense, coarser-grained, less well cemented less indurated, and more permeable than the Spring Canyon and Storrs tongues.

The static water level measured in the Panther aquifer during drilling and testing was 33 feet below the top of the unit in DH-1A, 103 feet above the top of the unit in DH-2, and 27 feet below the top of the unit in DH-3. The Panther aquifer is confined by the Mancos No. 2 mudstone only in DH-2; unsaturated conditions exist in southern drill holes DH-1A and DH-3.

2.6 Groundwater Quality

Monitoring stations are sampled four times per year as a part of the Co-Op Coal Company hydrologic monitoring program (Plate 2). A summary of water-quality analyses for groundwater samples collected is presented in the Annual Hydrologic Monitoring Report (Co-Op Mining Company, 1991). Groundwater-quality samples are routinely collected in the permit and adjacent areas from the underground bleeders, monitoring wells, and springs associated with faults and joints in the Panther Tongue of the Star Point Sandstone.

The general character of the groundwater in the permit and adjacent areas is that of slightly alkaline calcium-bicarbonate water that contains low concentrations of total dissolved solids (TDS), nutrients, and metals. Field conductivity ~~and pH range from 300 to 842 mg/l~~ and from 6.1 to 8.1, respectively. ~~TDS is typically~~ 400 mg/l. Historically, acidity is zero and average alkalinity is 290 mg/l. Sulfate and magnesium concentrations are typically 70 and

40 mg/l, respectively. Iron and manganese concentrations are typically 0.3 and 0.1 mg/l, respectively.

Figure 2-6 presents a Piper diagram of average analytical results of the sampling events in 1991 for six groundwater monitoring points: Birch Spring (SBC-5, eight samples), North Mains (SBC-9, five samples), Ball Park Spring (BP-1, two samples), Big Bear Spring (SBC-4, eight samples), Co-Op Spring (CS-1, two samples), and Trail Canyon Spring (TS-1, two samples). The Piper diagram is divided into three fields: cations, anions, and the combined field. Values are in percent milliequivalents, and are plotted in the anion and cation fields and projected into a combined field. Spatial relationships that are repeated in all three fields are indicative of relationships between waters. The spatial relationships among the six waters differ from field to field. Birch Spring has the least similarity to the other waters. For example, Birch Spring water plots very close to mine water in the cation field, but it plots as an outlier in the anion field and in the combined field. This is due to a higher percentage of sulfate in Birch Spring water than in the mine water or the other spring water in the area. In fact, the mine water and BP-1 water have the lowest percentages of sulfate of the groundwater represented in the Piper diagram. Thus, the spatial relationships exhibited in the Piper diagram suggest that the mine water is of a higher quality than Birch Spring water. Furthermore, the difference in spatial relationships in the different fields suggests the waters are not hydraulically or chemically connected.

Figure 2-7 presents a series of Stiff diagrams which characterize waters from the same six groundwater monitoring points used in Figure 2-6. The six waters display a similar Stiff pattern, that of a calcium-bicarbonate water. Additionally, the Stiff patterns indicate that SBC-9 (North Mains) water has the lowest sulfate concentration (1.18 meq) and SBC-5 (Birch Spring) has the highest sulfate concentration (2.62 meq) of the groundwater sampled. SBC-4 (Big Bear Spring) water has a sulfate concentration of 1.36 meq. SBC-9 also has the lowest chloride value of the groundwaters sampled. This relationship between the sulfate and chloride concentrations does not suggest that the mine water would diminish the quality of the spring water in the area.

1–BIRCH SPRINGS
SBC-5

2–SBC-9

3–BP-1

4–BEAR SPRING
SBC-4

5–CS-1

6–TS-1

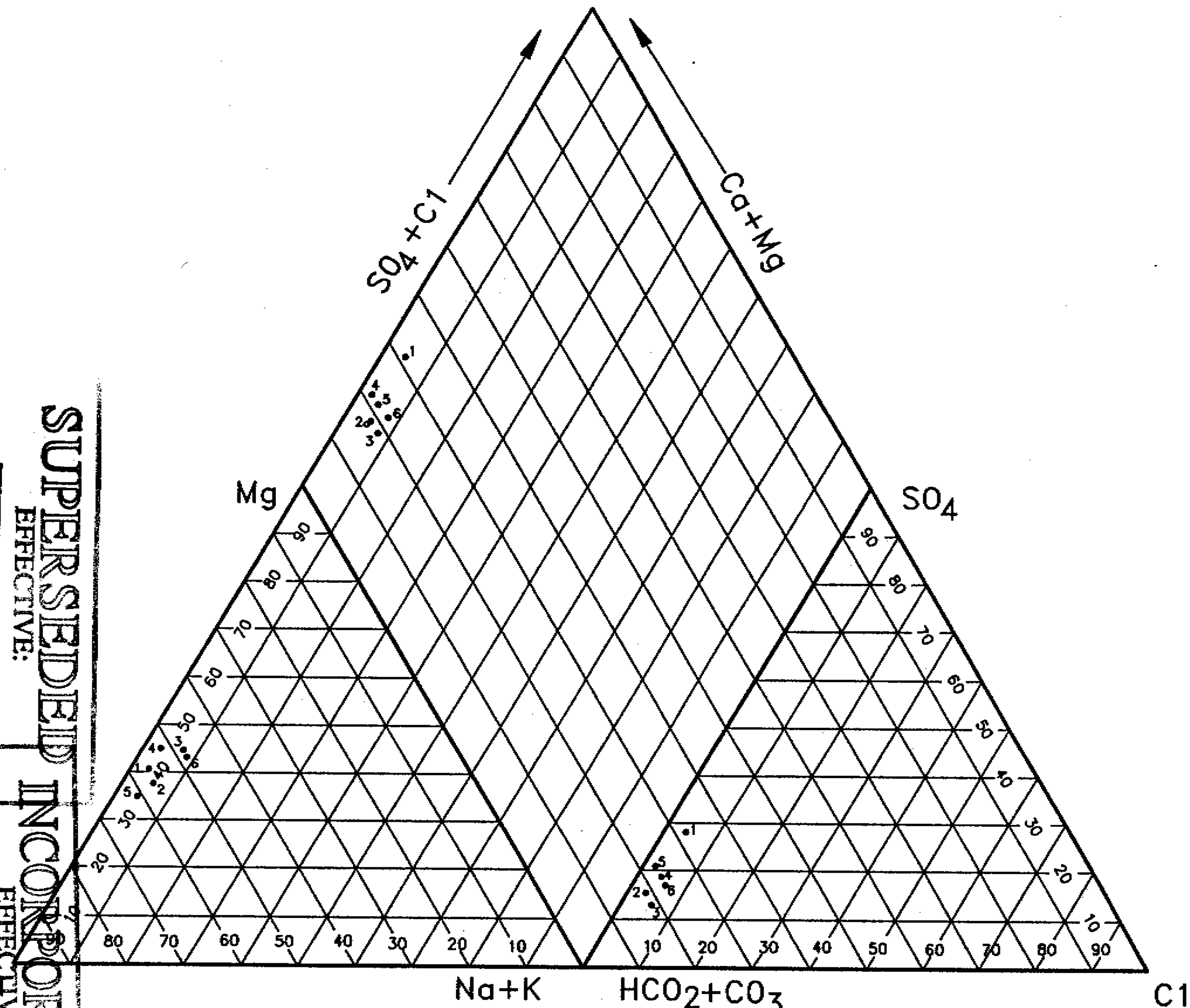

FIGURE 2–6. PIPER DIAGRAM OF AVERAGE GROUNDWATER ANALYTICAL RESULTS

EarthFax

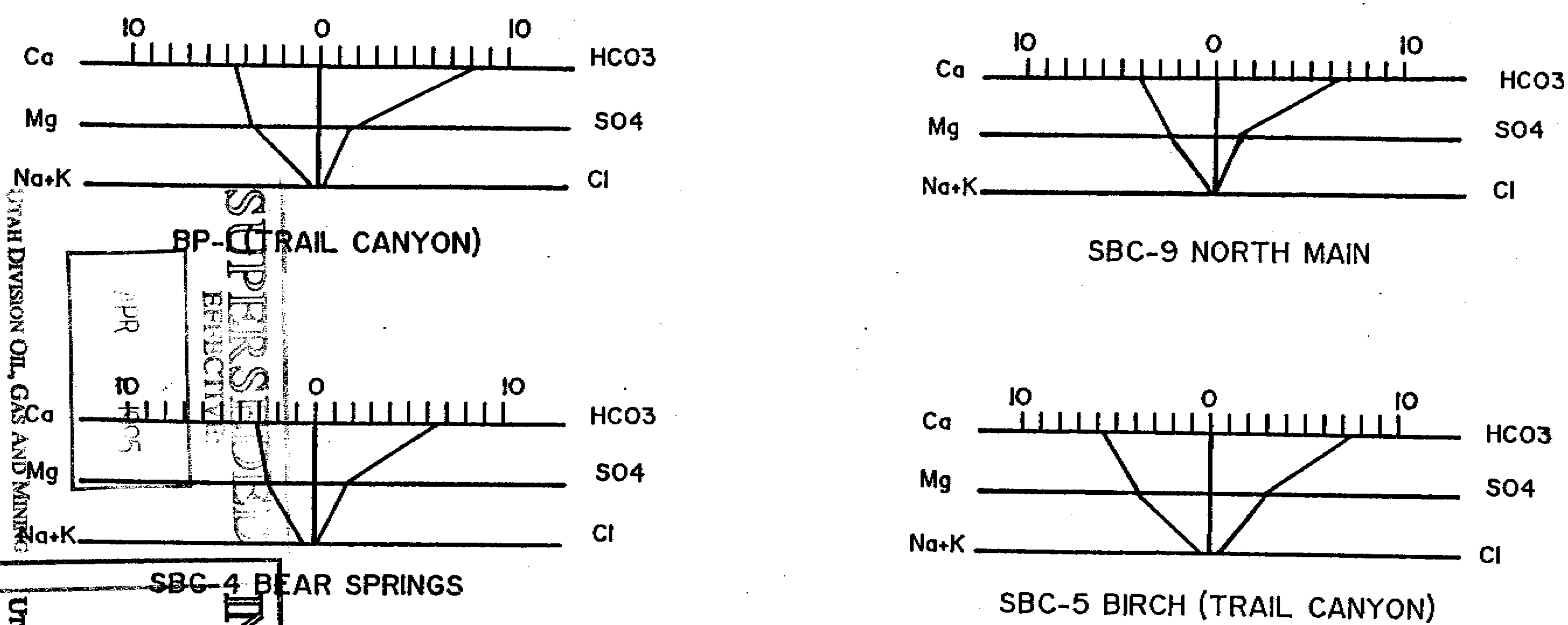

FIGURE 2-7. Stiff Diagrams of Spring Water Analytical Results

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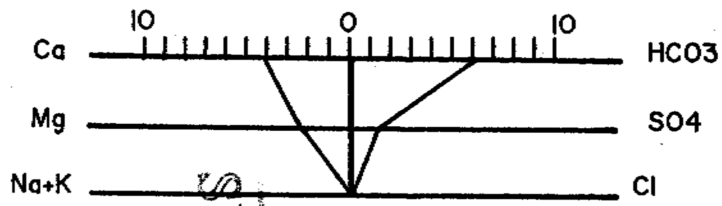
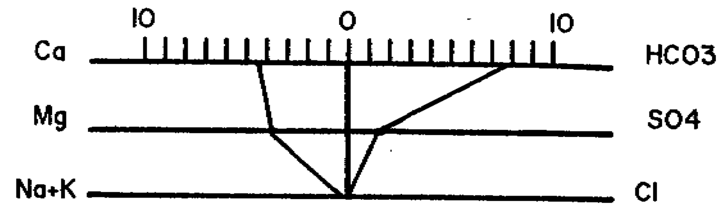


CS-1 CO-OP SPRING (TRAIL CANYON)



TS-1 TRAIL CANYON SPRING

FIGURE 2-7 (continued). Stiff Diagrams of Spring Water Analytical Results

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The major portion of water inflow to the mine is used within the mine or for culinary purposes by Co-Op Mining Company. According to the Co-Op Bear Canyon Mining and Reclamation Plan, the water which flows from Big Bear Spring (also called Huntington Spring)and Birch Spring is used by the Huntington community for culinary purposes (Co-Op Mining Company, 1985). Water collected in Trail Canyon from TS-1 (Trail Canyon Spring) is also used locally for culinary purposes. CS-1 (Co-Op Spring) was used in the past, but is no longer used for culinary purposes (Co-Op Mining Company, 1992a).

Wells in the permit and adjacent areas are either observation wells owned by Co-Op Mining, or exploration wells owned by Northwest Energy. Three new monitoring wells (DH-1A, DH-2, and DH-3, Plate 1) were drilled within the permit area for this study. DH-1A and DH-2 were drilled in late 1991 and DH-3 was drilled in early 1992. The three wells were completed in the Spring Canyon Tongue of the Star Point Sandstone, and were developed, tested, and sampled in May, 1992. The results of laboratory analyses of the monitoring well samples are summarized on Table 2-6, and complete analytical reports are presented in Appendix H.

Figure 2-8 presents Stiff diagrams of ions in groundwater from the in-mine wells. Waters from DH-1A and DH-3 have Stiff patterns similar to those of the calcium-bicarbonate spring water depicted on Figure 2-7. Water from DH-2 has a calcium, magnesium, sodium, potassium-sulfate pattern. This pattern is distinctly different from other groundwater that has been sampled in the permit and adjacent areas, and is presumed to be due to the dissolution of locally-occurring sulfate salts.

TABLE 2-6

Summary of Laboratory Analytical Results for Groundwater From In-Mine Monitoring Wells

ANALYTE (mg/l)	DH-1A	DH-2	DH-3
Aluminum	0.2	<0.1	<0.1
Arsenic	<0.05	<0.05	<0.05
Barium	0.071	0.127	0.129
Cadmium	<0.01	<0.01	<0.01
Calcium	38.9	51.9	50.9
Chromium	0.025	<0.01	<0.01
Copper	<0.01	<0.01	<0.01
Iron	0.505	0.280	0.220
Lead	<0.01	0.030	<0.01
Magnesium	20.1	29.5	28.9
Manganese	0.062	0.101	0.232
Mercury	<0.0005	<0.0005	<0.0005
Molybdenum	0.058	0.010	<0.01
Nickel	<0.01	<0.01	<0.01
Potassium	31.2	1.5	2.6
Selenium	<0.0005	<0.0005	<0.0005
Sodium	14.1	8.8	15.2
Zinc	<0.01	<0.01	<0.01
Oil & Grease	2.0[a]	<0.5	<0.5

[a] Oil and Grease expected (hydraulic fluid leak on rig).

SUPERSEDED
EFFECTIVE:
APR 5 1995
UTAH DIVISION OIL, GAS AND MINING

INCORPORATED
EFFECTIVE:
JUN 15 1993
UTAH DIVISION OIL, GAS AND MINING

TABLE 2-6 (Continued)

Summary of Laboratory Analytical Results for Groundwater From In-Mine Monitoring Wells

ANALYTE (mg/l)	DH-1A	DH-2	DH-3
TDS	285	330	339
Hardness as CaCO3	162	321	307
Boron	<0.05	0.064	0.061
Alkalinity as CaCO3	94	285	294
Bicarbonate	110	340	336
Carbonate	2.3	3.5	11.5
Hydroxide	0	0	0
Chloride	4.9	4.2	4.2
Fluoride	0.28	0.18	0.16
Ammonia	<0.2	0.64	0.22
Nitrate	0.42	0.74	<0.5
Phosphate	0.129	0.25	0.027
Sulfate	128	33	38
Sulfide	<0.1	<0.1	<0.1

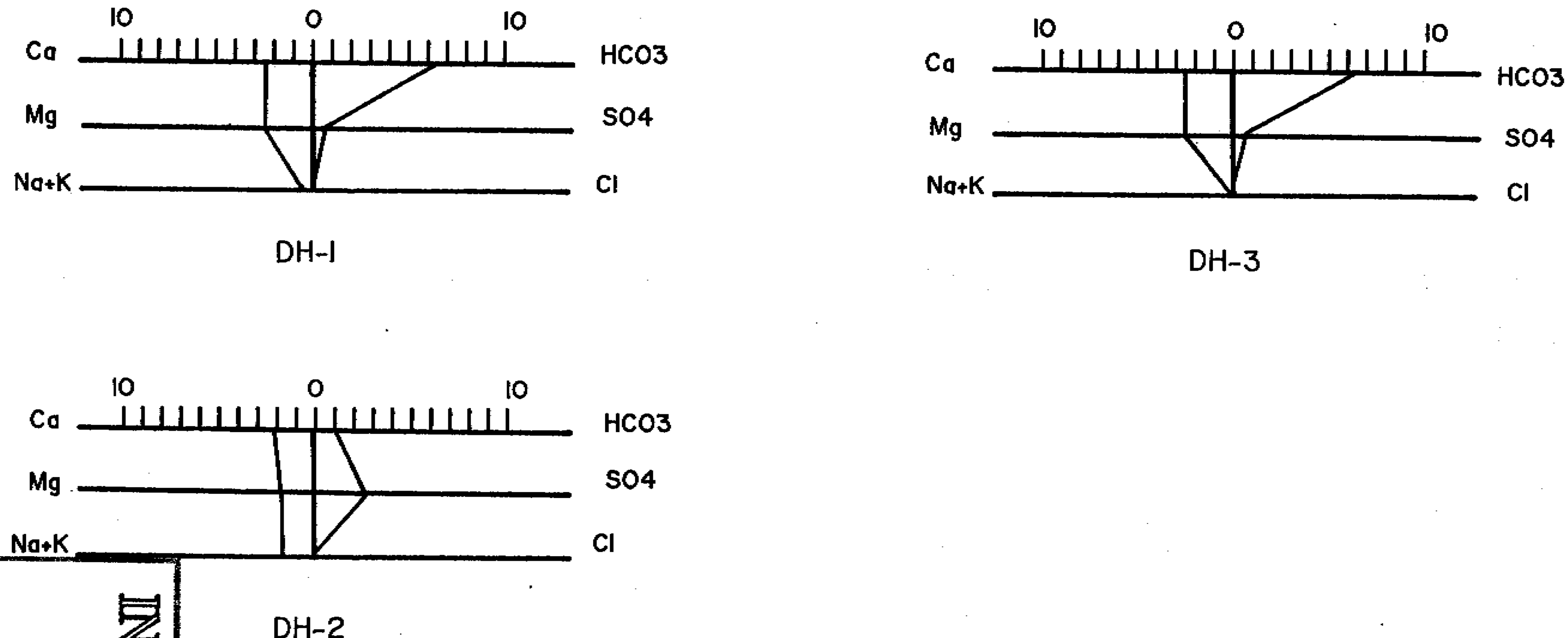

FIGURE 2-8. Stiff Diagrams of In-Mine Monitoring Well Analytical Results

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Groundwaters sampled from the in-mine wells have a TDS range of 285 to 339 mg/l. Dissolved iron and manganese concentrations range from 0.220 to 0.505 mg/l and from 0.062 to 0.232 mg/l, respectively.

2.7 Spring Flow

Big Bear and Birch Springs were visited on February 18 and 19, 1991, during a site survey to evaluate the geology of the spring locations and to collect samples of discharge water, if available. No surface flow occurred at the Birch Spring and the collection system was locked. At Big Bear Spring, a sample was taken from the spring overflow from the northernmost joint.

A second sample was taken from seepage flow which occurs on the slope above the Big Bear Spring. The seepage originates from the cliffs at the contact between the Star Point Sandstone and Blackhawk Formation, and occurs in two areas approximately 100 yards apart. Seepage in each area appears to occur directly from the formation contact, along approximately 100 to 150 feet of the outcrop. The flow is difficult to quantify, but it is concentrated at several bedrock ledges, and was estimated at the time of the site visit to be approximately 10 gallons per minute. The easternmost seep occurs at a location that is in shade most of the day, and considerable accumulations of ice where found at this seep, due to continual freezing of the discharge. The pH, temperature, and conductivity values for these samples are presented in Table 2-5.

As indicated on Table 2-5, the electrical conductivity of water within the mine is similar to that of water from Big Bear Spring. Water from seeps above the spring is considerably different, with a conductivity approximately four times that of the spring samples, presumably due to the dissolution of gypsum from mudstone in the area from which the seeps issue.

Monthly flows from the Big Bear, Birch, and Little Bear springs and the Tie Fork wells were analyzed. Little Bear Spring and the Tie Fork wells were included in the analysis because of their long periods of record and their proximity to the mine permit area. The spring flows were compared to five-station average monthly precipitation (see Appendix A) and stream flow for Huntington Creek gauging station above the Deer Creek Diversion (see Appendix B) plotted against time. These three plots were combined in a single graph to allow a direct comparison. For readability, the graph durations were limited to one year per sheet for each spring analyzed (an example is presented in Figure 2-9). All graphs are presented in Appendix E.

__2.7.1 Little Bear Spring__. Plots of flow from Little Bear Spring for the period of 1982 through 1985 show that the peak spring flows occur one month behind the peak stream flow in Huntington Creek. In 1986, the peaks occur in the same month, possibly indicating an early snowmelt. In 1987, the peak from Little Bear Spring was delayed by two months.

In the period from 1988 through 1990, no significant spring peak flow is evident. There was a gradual rise in the flow in the fall of 1988 and a gradual decline in early 1989. During 1991, peak spring flow occurred one month behind peak stream flow.

__2.7.2 Tie Fork Wells__. Flows from the Tie Fork wells show no seasonal variation, except for a period from July through November, 1988. By December, 1988 flows had returned to approximately the previous level and flows through 1991 have been essentially constant. This flow fluctuation corresponds to the flow increase in the Little Bear Spring, though the fluctuation of Little Bear was over a longer period.

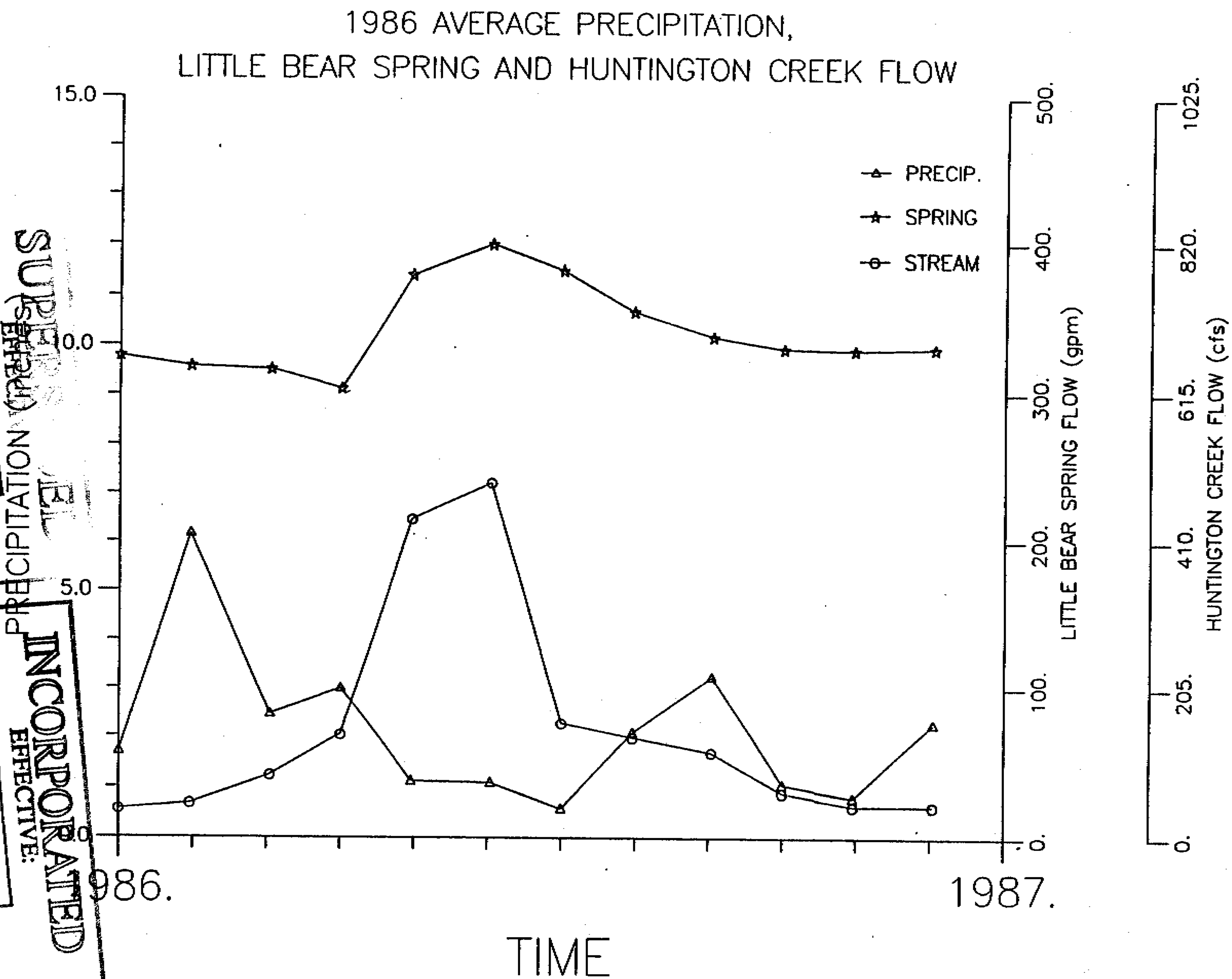

FIGURE 2-9. Example of Spring Flow Graph

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2.7.3 Big Bear Spring. Plots of flow from Big Bear Spring show that peak flows during the period of 1980 through 1986 occurred about one month later than peak flows at the Huntington gauging station (above the Deer Creek Mine access road). In the 1987-1988 water year, the lag period between peaks in the stream and spring discharge is approximately two months. This increase in lag time is due to a combination of lower precipitation accumulations (28.4 inches average annual precipitation 1980-1986 versus 19.75 inches 1987-1990, see Appendix A) and shorter snowmelt period.

Year-by-year comparisons of the flow recessions at Big Bear Spring for the years 1980 through 1986 show very similar patterns; the slope line of the spring flow decline and the base flow level for the spring are generally the same from year to year. This indicates that the snowmelt recharge is greater than the volume required to recharge the groundwater system storage, and that excess water is being discharged from the system as peak flows through the spring. It also suggests that no outside influence (i.e., mining) affected the groundwater system.

For the period from 1988 to 1991, no snowmelt peak can be identified on the flow spring flow graphs. Also, a comparison of spring flow from years 1987 through 1991 indicates a general decline in flow. This is inferred to be due to the small amount of precipitation during this period. The quantity of snowmelt recharge during these years was not sufficient to create either of the following conditions: 1) completely fill the depleted storage in the system, (resulting in a base flow lower than that of the previous year), or 2) provide a spring flush (although recharge may be sufficient to restore deleted storage).

Under the first condition, the groundwater system is being drained and a new base flow condition will eventually be established, provided precipitation inputs are stabilized. Once the groundwater system was stabilized, the second condition would prevail until the precipitation (and recharge) increased sufficiently to fill the excess storage capacity in the groundwater system. It appears that the first condition occurred at the Big Bear Spring during the period of 1987 through 1991.

2.7.4 Birch Spring. The Birch Spring flow increased by almost 300 percent for a three month period and a reduction in water quality in the fall of 1989 (North Emery Water Users Association, 1991). Table 2-7 is a summary of water quality data before, during, and after the anomalously high flow event, and shows that water quality returned to normal once flow rates normalized. The reason for this fluctuation is unknown. The event occurred shortly after the Bear Canyon mine intercepted an inflow of about 110 gpm in the North Mains, though the response of the spring if this were a mine related impact would be a reduction in flow rather than an increase. Montgomery (1991) attributed this flow rise to a release of collected water in the abandoned Trail Canyon Mine. This is highly unlikely as both the Trail Canyon and Bear Canyon Mines are above the regional water table, as discussed in Section 2.4.1. Additionally, a sustained discharge of 230 gallons per minute for 90 days would result in a cumulative flow volume of approximately 30 million gallons (92 ac-ft) of water. This would require a significant storage volume; assuming that four entries each 12 feet wide and 8 feet high were filled with water, they would need to be 2 miles long to be able to store the required volume of water to sustain this flow during a low flow period of the year. Prior to the increased flow at Birch Spring, the pillars were pulled in the Trail Canyon Mine. The subsidence of the mine significantly reduced the open area within the mine where water could collect. Portals on the down-dip side of the mine have been visually monitored on a regular basis since reclamation. No seepage has been observed at these portals, suggesting that the mine was dry before, during, and after the increased flow at Birch Springs (Co-Op Mining Company, 1992a). Given the contention that the area is extensively faulted and the faults and fractures are interconnected, the possibility of storing this volume of water as a perched water table above a large extent of the mine, without discharge occurring in other locations, is very unlikely.

TABLE 2-7

Summary of Birch Spring Analytical Results

Parameters	April 1987	October 1989	March 1991
pH	8.0	8.33	8.05
Conductivity (umhos/cm)	748	1090	812
TDS (mg/l)	412	810	484
TSS (mg/l)	2	56	1
Bicarbonate (mg/l)	392	367.17	376
Chloride (mg/l)	7	12.65	8.17
Sulfate (mg/l)	102	298.34	129
Calcium (mg/l)	87	128.01	101
Magnesium (mg/l)	48	71.82	42.5
Potassium (mg/l)	2	5.56	2.09
Sodium (mg/l)	7	10.80	6.1
Iron (mg/l)	<0.05	0.21	0.10
Manganese (mg/l)	<0.02	0.02	<0.02

An alternative source of the surge in flow could be the opening or connection of saturated fractures which previously did not convey water to Birch Spring. These fractures could have contained a significant volume of water which had built up over a long period of time. As these fractures drained, the flow contributed to the Birch Spring was sufficient to raise the water level in the fractures to a level which previously had not conveyed water. This would result in a flush of sediment and dissolved constituents, as reported by North Emery Water User Association, which had accumulated over time. Once the excess water in the fractures had drained the flow in the spring and the water quality returned to normal levels.

Because the period of record for Birch Spring is limited, and the published stream flow data for Huntington Creek do not include the period of record for Birch Spring, a comparison to stream flow prior to 1990 cannot be made.

The flows from Birch Spring show some seasonal fluctuation; however, three years of data do not provide sufficient information to identify the general flow characteristics. The available data (Appendix E) indicate that flow from the spring gradually diminished in 1990, an occurrence that was noted by the North Emery Water Users Association (verbal communication, 1991). Flow during 1991 was stable, with only slight fluctuations.

The declining flow at Birch Spring is considered a result of below-normal precipitation in the region over the past four to six years. Big Bear and Little Bear Springs also exhibited similar flow reductions. Here again, as proposed for Big Bear Spring, when recharge to the groundwater system is reduced below the amount required to replace the storage volume depleted by base flow discharge over the previous year, the discharge from the system at the various discharge locations is adjusted to balance the change in storage of the system.

2.8 Water Rights Search

To assist in understanding the potential impacts of the mining operations on the surrounding water resources, a search of the Utah State Water Rights records was conducted.

The computer records were scanned for all water rights, surface and groundwater, which exist in the area of Sections 10 through 15 and 22 through 27 of Township 16 South, Range 7 East. The search included an area between one half and one mile beyond the permit boundary. The water rights which were identified are located on Figure 2-3 and presented in Appendix C.

There are three surface water rights within the permit and proposed expansion areas (Figure 2-3). No springs with water rights were identified above the coal seams within the permit or proposed expansion areas. In the adjacent area, 30 surface water rights and 29 groundwater rights were identified. Fifteen of the groundwater rights were associated with flows from Big Bear and Birch Springs. The remaining rights were associated with the mines or with small stockwatering springs north of the permit area.

3.0 MONITORING WELL INSTALLATION AND GROUNDWATER SAMPLING

3.1 Well Drilling

For the purpose of collecting stratigraphic and hydrologic data for this study, three holes were drilled from the mine floor (the base of the Blind Canyon coal seam) to the Mancos Shale (Figure 3-1). A Diamec model 251 hydraulic drilling rig was used by Co-Op personnel to drill the holes, and EarthFax Engineering geologists performed lithologic logging and aquifer testing within the Star Point Sandstone. The holes were later completed as monitoring wells, to allow groundwater quality in the uppermost aquifer below the mine to be characterized. Stratigraphic logs and completion diagrams are contained in Appendix G.

The original drilling program specified the use of AW-size drilling rod and core barrels to produce a 1.89-inch diameter pilot hole, which would be enlarged by reaming to a diameter of 3 inches prior to aquifer testing. Difficulties in reaming the pilot hole required that larger BW-size equipment be used to produce a 2.36-inch diameter hole. No fluid additives or lost circulation material was used during drilling; only clear water was used as drilling fluid.

The holes were drilled and the aquifers were tested incrementally; i.e., as each aquifer was penetrated, drilling would cease, the aquifer would be isolated, and aquifer testing would be conducted. Because underlying impermeable shale was used as a seal at the bottom of the aquifer to be tested, a single packer was placed at the top of the subject aquifer. Aquifer testing procedures are discussed in Section 4.0.

<u>3.1.1 Drill Hole DH-1A</u>. To obtain detailed stratigraphic information, drill hole DH-1 was continuously cored with AW rod from the mine floor to a depth of 195 feet. Due to drill-stem instability during attempted reaming of the AW hole to a diameter of 3 inches, DH-1 was abandoned and a second hole (DH-1A) was offset approximately 20 feet to the east. DH-1A was drilled with BW rod to 195 feet (through the interval for which core had already been obtained from DH-1), and then cored continuously from 195 to 535 feet (total depth).

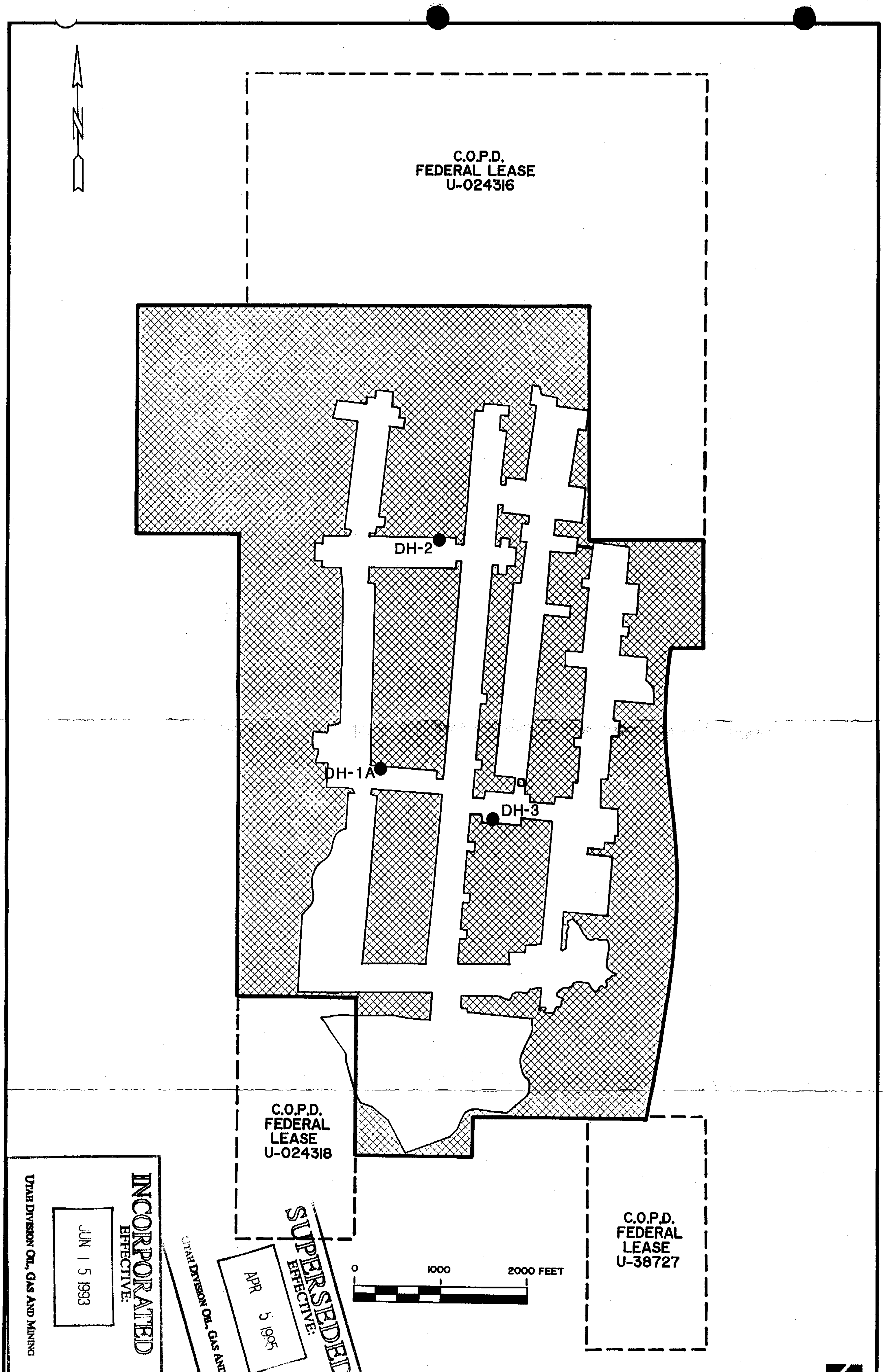

FIGURE 3-1. In-Mine Monitoring Well Locations

As core was retrieved from the borehole, it was cleaned, described, allowed to dry, and boxed. The core boxes were permanently labeled as to the hole and depth interval from which the samples were obtained. All core samples are in the possession of Co-Op Mining Company.

<u>3.1.2 Drill Holes DH-2 and DH-3</u>. Drill holes DH-2 and DH-3 (Figure 3-1) were cored selectively, across intervals within which stratigraphic contacts were expected (based on the stratigraphy observed in the continuous core from DH-1 and DH-1A). Table 3-1 is a summary of intervals cored in each of the drill holes. Lithologies of drilled intervals between core runs in DH-2 and DH-3 (Appendix G) were inferred from the color of drill cuttings. Because the bit used in drilling these intervals produces a fine rock powder, no grains or lithic fragments are contained in the drilling fluid returns. DH-2 was drilled to 530 feet, and DH-3 was drilled to 545 feet below the mine floor.

3.2 Well Completion and Development

To plug the lower portion of the drill hole and isolate the Spring Canyon aquifer for well completion, DH-1A was filled with cement from a total depth of 535 feet to 171 feet below the mine floor. Due to binding of the tremie line during cement emplacement in DH-1A, gravity-emplaced granular bentonite was used to plug the lower portions of DH-2 (from 530 to 190 feet) and DH-3 (from 545 to 189 feet).

Each well was completed with 20 feet of 1.5-inch diameter, flush-threaded Schedule 40 PVC 10-slot screen set near the base of the Spring Canyon Tongue. Blank casing of the same specification was used to complete the wells to the mine floor. A 20-40 mesh silica sand filter pack was emplaced in the annular space from the bottom of the screen to the top of the Spring Canyon Tongue, and granular bentonite was placed on top of the filter-pack to prevent infiltration of cement. The upper 50 feet of annular space was filled with neat cement. A 10-inch diameter cast-iron watertight manhole was cemented flush with the mine floor at each well. To further protect the monitoring wells, wooden boxes were installed

TABLE 3-1

Summary of Cored Intervals

Drill hole I.D.	Cored Interval (depth in feet below mine floor)	Stratigraphic Targets
DH-1	0 - 195'	Continuous core.
DH-1A	195 - 535'	Continuous core.
DH-2	95 - 106'	Blackhawk/Spring Canyon contact.
	190 - 245'	Spring Canyon/Mancos No. 1/Storrs contacts.
	335 - 430'	Storrs/Mancos No. 2/Panther contacts.
	500 - 530'	Panther/Mancos Shale contact.
DH-3	82 - 98'	Blackhawk/Spring Canyon contact.
	175 - 440'	Spring Canyon/Mancos No. 1/Storrs/ Mancos No. 2 /Panther contacts.
	500 - 545'	Panther/Mancos Shale contact.

across the mine openings on either side of each well. Well completion diagrams are contained in Appendix G.

The completed wells were developed with a 1-inch diameter stainless steel bailer attached to stainless steel cable. The bailer was used to surge and bail the well until the water was visibly clean.

3.3 Groundwater Sampling

<u>3.3.1 Monitoring Wells</u>. One-inch diameter bladder pumps were installed in each of the three monitoring wells. The pumps can be driven with nitrogen or other non-flammable compressed gas, and are intrinsically safe for mine use. The sample lines, drive lines and the bladder are constructed of Teflon, and the pump body is stainless steel. The dedicated pumps are designed to be left in-place throughout the life of the wells, thus, the need for decontamination and storage of purging and sampling equipment between sampling rounds is eliminated.

To ensure the collection of samples representative of formation water, each well was purged of three casing volumes prior to sampling. Samples were collected in laboratory-supplied containers, and were stored in insulated ice chests at 4° C until delivery to the analytical laboratory. Laboratory analytical results for samples collected during the May 1992 sampling round are presented in Appendix H.

<u>3.3.2 Additional Sampling Points</u>. Groundwater-quality samples are routinely collected by Co-Op mining personnel from the North Mains section of the mine (SBC-9 and SBC-10), Bear Creek (BC-1 and BC-2), and springs associated with faults and joints in the Panther Tongue of the Star Point Sandstone (SBC-4, SBC-5, BP-1, TS-1, and CS-1). Sampling locations are depicted on Plate 2.

3.4 Radioisotope Dating

Groundwater samples were collected from SBC-4 (Big Bear Spring), SBC-5 (Birch Spring), SBC-9 (North Mains), and SBC-10 (Mine Floor water) in April, 1992, and submitted for tritium analyses to the Rosenstiel School of Marine and Atmospheric Science Tritium Laboratory in Miami, Florida.

The results of the tritium analyses are presented in Table 3-2. Tritium concentrations (expressed as tritium units, TU) for Birch Spring (1.12 TU), North Mains (0.90 TU), and the floor water (1.73 TU) are within the same order of magnitude, whereas the concentration for Big Bear Spring (17.4 TU) is an order of magnitude greater.

According to Thiros and Cordy (1991), prior to above-ground nuclear weapons tests conducted from 1953 to 1969, the natural tritium concentration in precipitation was 8.7 TU. Assuming a half-life of 12.26 years, tritium levels in groundwater stored since 1952 would now be 0.95 TU, thus, water collected from SBC-9 (North Mains) sample is likely 100% pre-bomb groundwater (water stored since before 1953). Waters from SBC-5 (Birch Spring) and SBC-10 (floor water) are probably mixtures rich in stored pre-bomb groundwater, with a slight amount of post-bomb water.

There are three possible explanations for the relatively high concentration of tritium in the SBC-4 (Big Bear Springs) water: 1) The groundwater could be freshly recharged; current tritium concentrations in freshly fallen rain water in Utah range between 10 and 20 TU (Thiros, verbal communication, 1992); 2) it could be stored post-bomb water which originally had a very high concentration of tritium which has since decayed; or 3) water from Big Bear Springs could be a mixture of pre-bomb and post-bomb waters.

Because tritium concentrations in rainwater were greater than 1000 TU during periods of active above-ground weapons testing (Fritz and Fontes, 1980), the age of water from Big

TABLE 3-2

Tritium Analytical Results

Sampling Point I.D.	Location	Tritium Concentration
SBC-4	Big Bear Spring	17.2 TU
SBC-5	Birch Spring	1.12 TU
SBC-9	North Mains	0.90 TU
SBC-10	Floor Water	1.46 TU

Bear Spring cannot be determined. Regardless of the source(s) of recharge to Big Bear Spring, the concentrations of tritium in the remaining groundwater samples (SBC-5, SBC-9, and SBC-10) suggest that Birch Spring water and the mine inflow are of similar age (pre-1953), and are not significantly recharged by modern precipitation.

4.0 AQUIFER TESTING

4.1 General

To estimate the hydraulic conductivities of the aquifers within the Star Point Sandstone, slug injection and withdrawal tests were conducted in each of the three borings. To ensure that test results were representative of the individual aquifers, testing was done incrementally; as each aquifer was penetrated, an inflatable packer was used to isolate the subject aquifer from over- and underlying formations.

A slug test consists of rapidly changing the water level in a well or borehole by means of the injection or withdrawal of a body of known volume (a "slug") into or from the water column. When the slug is rapidly lowered into the water column, the water level rises abruptly. Rapid withdrawal of the slug after the water level has fully recovered causes the water level to drop abruptly. The rate of water level recovery to static conditions is monitored through time.

The slug used in this investigation consisted of a five-foot length of 0.5-inch diameter 316-stainless steel rod attached to 0.05-inch diameter stainless steel cable. The five-foot long slug has a displacement of 11.78 cubic inches, which is equivalent to a displacement of 3.20 feet in the 0.625-inch inside diameter of the drill rod.

Although it is recognized that the radius of influence for slug tests is smaller than for the more conventional long-term pumping tests, slug tests are considered to provide adequate information about hydraulic conditions in areas where studies are not aimed at designing an exploitation program of the aquifer (Freeze and Cherry, 1979). Both the slug injection and slug withdrawal tests produce similar results if performed under similar field conditions, and if a sufficient length of time is allowed to achieve maximum recovery of the water level.

4.2 Field Procedures

<u>4.2.1 Water-Level and Total Depth Measurements</u>. The static water level was measured with a pressure transducer in each subject aquifer prior to slug testing. The packer and transducer were placed at a known depth in the drill hole, and the water column height measured by the transducer was added to this known depth to approximate the water level. Total depth was determined by tallying the five-foot lengths of drill pipe as they were removed from the hole after a completed drilling or coring run.

Static water level and total depth measurements in the completed monitoring wells were made with an electric water-level indicator. Each of the measurements were made relative to the top of the protective surface casing. These values were used to determine the saturated thickness of the zone to be tested.

<u>4.2.2 Open-Hole Slug Tests</u>. During open-hole testing, an Instrumentation Northwest pressure transducer with an operating range of 0 to 50 pounds per square inch (up to 115.5 feet of water) was attached to the packer. Data derived from the transducer were recorded by a model 21X Micrologger manufactured by Campbell Scientific. The micrologger was programmed to record water-level changes to within 0.001 foot at either one-half second or one second intervals, depending on the response of the aquifer.

During the drilling program the bore hole was advanced through an aquifer into a confining unit. The top of the aquifer was then sealed off and isolated from overlying aquifers with a 2-inch diameter pneumatic packer (Aardvark model 12). The transducer was connected to the packer, and measured the height of the water column inside the drill stem. After pre-test measurements the slug was introduced through the drill stem and the test was recorded by the micrologger.

As data were collected, water-levels displayed by the micrologger were examined to monitor trends and the progress of the test. The accuracy and completeness of data were thereby reviewed before each test was terminated. Each test was allowed to proceed until the water-level recovered at least 95% of the height displaced by slug injection. All data were stored in the final memory of the micrologger and transferred to a data-storage module in the field. Data from the storage module were transferred to diskette storage in the office.

Following completion of the slug injection test and stabilization of the water-level, a slug withdrawal test was performed. Hence, a minimum of two tests were conducted in each well. When recovery was rapid, additional slug tests were performed. All data thus collected are on file with EarthFax Engineering.

__4.2.3 Slug Tests in Completed Wells__. Because the larger diameter of the well casing (1.5-inch) would permit a less restricted and more representative test (e.g., more smooth introduction and withdrawal of the slug, less turbulence within the water column) than that possible through the drill stem (0.625-inch) and packer, slug tests of the Spring Canyon Tongue aquifer were repeated after completion and development of DH-1A, DH-2, and DH-3 as monitoring wells. The hydraulic characteristics of the Spring Canyon Tongue aquifer listed on Table 4-1 and contained in Appendix F are those obtained from tests conducted in the completed wells.

A pressure transducer with a maximum operating pressure of 10 pounds per square inch (23.1 feet of water) was used to measure water levels during the slug tests in the completed and developed wells. After pre-test measurements and programming of the micrologger, the pressure transducer was lowered into the water to a depth that was below the lowest point to which the slug would be lowered, but within the depth range of the transducer. The slug was then rapidly lowered into the water column in the monitoring well, and data were recorded as in the open-hole tests.

TABLE 4-1

Hydraulic Conductivity and Transmissivity Values

Well Identification and Test Number	Aquifer Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)	Average Linear Velocity (ft/day)
DH-1A SPRING	88.0	0.146	12.848	0.0443
DH-1A STORRS	97.0	0.031	3.007	0.0155
DH-1A PANTHER	70.0	0.732	51.24	0.1911
DH-2 SPRING	103.0	0.012	1.236	0.0036
DH-2 STORRS	106.0	78.422[a]	8,313[a]	39.21[a]
DH-2 PANTHER	88.0	0.025	2.200	0.0065
DH-3 SPRING	65.0	0.058	3.770	0.0176
DH-3 STORRS	87.0	0.008	0.070	0.0040
DH-3 PANTHER	72.0	0.096	6.912	0.0251

[a] Anomalous value (see Section 4.4)

4.3 Interpretation Procedures

Data recorded on the data-storage module in the field were transferred to diskette by means of either a model PC201 tape and serial I/O card and associated software or a PC208 software package and serial cable with adapter, both developed by Campbell Scientific. These data sets are stored as comma-delineated ASCII data files. The contents of each data file were subsequently transferred to an analytical program (AQTESOLV™), which allows rapid, graphical representation and log-linear regression analysis of test data.

Recently published microcomputer software AQTESOLV™ (Duffield and Rumbaugh, 1989) was used to evaluate the slug test data. The method of Bouwer and Rice (1976), which determines hydraulic conductivity for wells penetrating unconfined aquifers, is available in the AQTESOLV™ software for the evaluation of slug test data, and was used to estimate the hydraulic conductivities of aquifers tested for this study.

Values of time and actual water-level displacement due to injection or withdrawal of the slug are displayed on a semi-logarithmic plot (i.e., water-level displacement is represented on a logarithmic y-axis and time is represented on a normal arithmetic x-axis). The hydraulic conductivity is estimated from the equation:

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} \frac{1}{t} \ln \frac{y_o}{y_t} \qquad (4\text{-}1)$$

where:

- y_o = initial drawdown or residual drawdown in well due to instantaneous removal or injection of the slug from the well (ft)
- y_t = drawdown in well at time t (ft)
- L = length of well screen (ft)
- r_c = radius of well casing (ft)
- R_e = equivalent radius over which head loss occurs (ft)
- r_w = radius of well, including gravel pack (ft)
- H = static height of water in well (ft)

t = time (min)

and

$$\ln (R_e/r_w) = \left(\frac{1.1}{\ln (H/r_w)} + \frac{C}{L/r_w}\right)^{-1} \qquad (4\text{-}2)$$

where:

C = dimensionless parameter which is a function of L/r_w (see Equation 4-1);

and other parameters are previously defined.

According to Bouwer and Rice (1976), Equation (4-1) allows the hydraulic conductivity to be calculated from the water-level change in the well. Because the hydraulic conductivity, casing radius, well radius, the radius over which head loss occurs, and the screen length are constants, (1/t) ln y_o/y_t must also be a constant. Thus, the time-drawdown data should approximate a straight line if plotted in terms of ln y_o versus t. The quantity (1/t) ln y_o/y_t in Equation (4-1) is obtained from the first straight-line segment drawn through the field data.

The AQTESOLV™ software program prompts the user to supply values of well casing radius, drill hole radius, aquifer saturated thickness, well screen length, and static height of water in the well. Time and water-level data are read into the software program in the form of ASCII data files, which are down-loaded from the field data-logger.

Once the field data and constants are entered, the AQTESOLV™ software generates semi-log plots of the data and automatically fits a straight line to the data according to user-defined weighting. If the entire range of field data do not approximate a straight line, only those early data which form a valid straight-line segment are weighted by the user such that the software package produces the desired straight line approximation through the valid part of the data set.

The straight-line fit produced by AQTESOLV™ automatically determines the value of y_0 (y-intercept) and an arbitrary value of y_t at time t to solve Equation (4-1). Based on user-defined values of screen length and drill hole radius, the software determines the value of C to evaluate R_e in Equation (4-2).

The software generates the straight line approximation by means of a nonlinear weighted least-squares parameter estimation technique, i.e., the Gauss-Newton linearization method (Duffield and Rumbaugh, 1989). The estimation technique minimizes the difference between observed and estimated values through iterative solution of the system of linearized equations until convergence is achieved. To ensure the fit of the straight line, the software prints out the values of actual water levels, calculated water levels, and residual values (the difference between the actual and calculated water levels) derived by the parameter estimation technique. Additionally, the statistical values of mean, standard deviation, and variance also are provided for the weighted residuals. These statistics indicate the goodness-of-fit of the straight line generated through the weighted slug test data by the estimation technique. Table 4-2 is a summary of the information collected in the field and subsequently used in the slug test analyses.

4.4 Aquifer Test Data and Results

Slug test plots for the wells tested are presented in Appendix F. Included with the time-drawdown plots are printouts of well constants and field data used to estimate values of hydraulic conductivity. Also listed in Appendix F are values of actual water levels, calculated water levels, and residual values (the difference between the actual and calculated water levels) derived by the parameter estimation technique. Statistical values of mean, standard deviation, and variance also are provided for the weighted residuals. Table 4-1 is a summary of aquifer saturated thickness, hydraulic conductivity, transmissivity, and average linear velocity values calculated for each well.

TABLE 4-2

Slug Test Input Data

Well Identification And Test Number	Static Water Level (ft btc*)	Diameter Of Casing (in)	Radius Of Borehole (in)	Screen Length (ft)	Total Depth (ft)	Aquifer Saturated Thickness (ft)
DH-1A SPRING	70.0	2.5	2.9	20.0	171.0	70.0
DH-1A STORRS	97.0	2.9	2.9	95.0	NA	97.0
DH-1A PANTHER	70.0	2.9	2.9	60.0	NA	70.0
DH-2 SPRING	160.0	2.5	2.9	20.0	190.0	160.0
DH-2 STORRS	106.0	2.9	2.9	104.0	NA	106.0
DH-2 PANTHER	190.0	2.9	2.9	86.0	NA	88.0
DH-3 SPRING	50.0	2.5	2.9	20.0	190.0	50.0
DH-3 STORRS	127.0	2.9	2.9	70.0	NA	72.0
DH-3 PANTHER	72.0	2.9	2.9	70.0	NA	72.0

* Below Top of Casing.

The hydraulic conductivity values used are taken directly from AQTESOLV™ plots, and a plot from each slug test is analyzed. Plots with convoluted or broken data lines are rejected. Plots from tests that were aborted prematurely or had other technical difficulties are also rejected. One plot was selected per formation, per hole from the remaining plots, based on goodness of fit.

According to Driscoll (1986), hydraulic conductivity indicates the quantity of water that will flow through a unit cross-sectional area of a porous media per unit time. Transmissivity is the transmission capability of an aquifer, and can be calculated by multiplying the saturated thickness of an aquifer by its hydraulic conductivity.

The horizontal rate of groundwater flow (or average linear velocity) of groundwater in each tested aquifer was calculated using a modified form of the Darcy equation (Freeze and Cherry 1979):

$$\bar{v} = (K/n)(dh/dl) \qquad (4\text{-}3)$$

where:

v	=	average linear groundwater velocity (ft/day).
K	=	hydraulic conductivity (ft/day).
n	=	porosity (fraction).
dh/dl	=	hydraulic gradient (ft/ft).

Calculation results are shown in Table 4-1. The results from all of the tests are deemed satisfactory, with the exception of tests run on the Storrs Tongue aquifer in DH-2. During analysis of test data for this aquifer and later field checks, it was discovered that the packer bladder had not seated properly during slug testing of this interval, and had allowed water to communicate around the packer. This fact explains the large discrepancy between the values from this unit, as compared to values derived from Storrs tests in DH-1A and DH-3.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on this study the following conclusions are made:

- The groundwater system in the area of the Trail Canyon and Bear Canyon mines in mainly controlled by geologic structures (faults and fractures) and lithology.

- In the area of present development, the regional water table is located below both the Blind Canyon and Hiawatha seams in the Bear Canyon mine, as indicated by in-mine drilling and aquifer testing. The three aquifers within the Star Point Sandstone have separate, distinct static water levels, and are not fully saturated in the southern portion of the permit area.

- At the present time, there is no evidence to suggest that interception of water within the workings of the Bear Canyon mine has had an impact on water quantity or quality at Big Bear Spring or Birch Spring.

  -- Tritium analyses suggest that Bear Canyon Mine water is primarily relict "pre-bomb" water, and does not recharge Big Bear Spring which is "post-bomb" (more recently recharged) water.

  -- Analysis of Piper diagrams does not suggest a hydraulic relationship between Bear Canyon Mine water and the water from Birch Springs.

-- Analytical results of groundwater samples collected in 1991 indicate that water intercepted by and stored in sumps within the Bear Canyon Mine is of higher quality than that discharged at Big Bear and Birch Springs.

- Mine water discharge may increase the quantity and improve the quality of water in Bear Creek.

- Subsidence over the southwest portion of the Bear Canyon Mine cannot impact Birch Springs; Blind Canyon truncates the coal seam before it reaches Blind Canyon Fault or the fault and fracture zone associated with Birch Springs.

- The recent reductions in spring flows appear to be the result of significant reductions in precipitation amounts over the last five to six years.

5.2 Recommendations

The following recommendations are presented to assist in addressing some of the concerns of the water companies and the Utah Division of Oil, Gas, and Mining:

- Co-Op Mining Company should continue to periodically monitor flows and water quality at Big Bear and Birch Springs. Regular monitoring will ensure the collection of adequate data for the evaluation of potential mining-related impacts to the springs. Each round of flow monitoring and sample collection should be performed by the same individual, to reduce the possibility of error due to technique.

  Special attention should be paid to sampling and preservation techniques. Recently obtained comparative laboratory results should be reviewed and consideration should be given to the selection of a new laboratory. Quality assurance/quality control samples should be submitted with each round of samples, to allow sampling techniques and laboratory performance to be evaluated.

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Appendix 7N-A
Precipitation Data

TABLE A-1

1980 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1980	March	3.34	1.88	2.31	5.42	3.20	3.23
1980	April	1.27	0.76	3.15	3.26	2.10	2.11
1980	May	3.09	2.78	2.72	3.15	4.00	3.15
1980	June	0.12	0.00	0.52	0.00	0.10	0.15
1980	July	0.37	0.30	0.00	0.00	0.30	0.19
1980	August	0.38	0.82	0.00	0.00	0.70	0.38
1980	September	1.80	2.53	3.35	3.40	2.30	2.68
1980	October	1.45	2.07	0.00	0.00	2.10	1.12
1980	November	0.98	0.36	0.00	0.00	1.70	0.61
1980	December	0.32	0.00	2.35	4.45	0.30	1.48
	TOTAL	NC	NC	NC	NC	NC	NC

* No Data Reported
NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1981 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1981	January	1.30	0.29	0.25	0.72	1.00	0.71
1981	February	1.04	0.30	1.45	3.54	2.10	1.67
1981	March	3.20	2.82	3.15	4.90	3.50	3.51
1981	April	1.45	0.84	1.84	3.45	1.20	1.76
1981	May	3.06	2.40	3.04	3.80	3.70	3.20
1981	June	0.39	0.20	0.00	1.27	1.00	0.57
1981	July	1.61	1.49	0.00	0.00	0.00	0.62
1981	August	2.73	2.64	0.00	0.00	1.90	1.45
1981	September	1.44	2.29	6.81	5.65	2.80	3.80
1981	October	4.18	3.71	0.00	0.00	0.00	1.58
1981	November	1.44	0.43	0.00	0.00	0.00	0.37
1981	December	4.79	1.21	0.00	17.10	9.40	6.50
	TOTAL	26.63	18.62	16.54	40.43	26.60	25.74

* No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1982 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1982	January	5.26	3.08	11.82	4.32	4.80	5.86
1982	February	1.66	0.36	1.36	3.34	2.30	1.80
1982	March	5.06	1.56	3.48	4.91	4.20	3.84
1982	April	1.11	1.11	0.45	1.52	2.50	1.34
1982	May	1.40	1.40	1.07	1.63	1.80	1.46
1982	June	0.59	0.59	0.26	0.81	1.00	0.65
1982	July	1.26	1.26	0.00	0.00	0.00	0.50
1982	August	2.29	2.29	0.00	0.00	0.00	0.92
1982	September	4.49	4.49	8.40	9.80	9.40	7.32
1982	October	1.88	1.88	0.00	0.00	0.00	0.75
1982	November	3.68	3.68	0.00	0.00	0.00	1.47
1982	December	2.76	2.76	5.58	12.10	10.50	6.74
	TOTAL	31.44	24.46	32.42	38.43	36.50	32.65

* No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1983 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1983	January	2.41	0.96	1.12	2.30	1.80	1.72
1983	February	4.00	1.23	2.29	3.60	4.60	3.14
1983	March	4.30	2.04	4.94	6.18	4.30	4.35
1983	April	2.35	1.66	1.59	2.58	2.80	2.20
1983	May	2.81	1.04	2.50	2.70	3.60	2.53
1983	June	1.35	1.25	0.00	0.18	1.80	0.92
1983	July	1.34	2.74	0.00	0.00	0.00	0.82
1983	August	1.5	1.67	0.00	0.00	0.00	0.63
1983	September	2.88	2.15	7.26	7.02	8.10	5.48
1983	October	2.15	1.57	0.00	0.00	0.00	0.74
1983	November	4.81	2.98	0.00	0.00	5.00	2.56
1983	December	7.43	2.55	14.23	21.00	7.10	10.46
	TOTAL	37.33	21.84	33.93	45.56	39.10	35.55

* No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1984 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1984	January	1.27	0.22	0.40	0.80	0.90	0.72
1984	February	1.56	0.50	2.60	0.93	1.80	1.48
1984	March	2.77	0.69	1.06	2.73	2.70	1.99
1984	April	3.23	1.37	2.81	5.00	3.50	3.18
1984	May	1.73	0.66	2.37	3.38	1.30	1.89
1984	June	3.41	1.50	4.53	4.50	4.50	3.69
1984	July	2.55	2.56	0.00	0.00	2.40	1.50
1984	August	2.26	3.27	0.00	0.00	1.50	1.41
1984	September	1.47	0.76	6.00	5.90	2.70	3.37
1984	October	2.92	3.80	0.00	5.51	0.00	2.45
1984	November	2.63	0.79	0.00	0.00	5.40	1.76
1984	December	3.24	1.70	9.12	9.45	2.60	5.22
	TOTAL	29.04	17.82	28.89	38.20	29.30	28.66

* No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1985 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1985	January	1.54	0.41	0.63	1.15	2.10	1.17
1985	February	1.09	0.55	1.54	2.67	1.90	1.55
1985	March	3.54	1.13	2.60	4.16	2.40	2.77
1985	April	1.95	1.59	2.56	3.40	2.70	2.44
1985	May	1.19	2.18	1.51	3.16	1.90	2.00
1985	June	0.89	0.68	1.04	1.59	1.60	1.16
1985	July	3.04	4.02	0.00	4.11	3.00	2.83
1985	August	0.03	0.00	0.00	0.00	0.50	0.11
1985	September	2.24	2.79	5.70	2.74	2.40	3.17
1985	October	0.00	1.28	0.00	5.51	2.70	1.90
1985	November	6.62	2.05	0.00	0.00	6.30	2.99
1985	December	1.99	0.30	7.64	11.74	2.30	4.79
	TOTAL	24.12	16.98	23.22	40.23	29.80	26.88

No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1986 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1986	January	1.81	0.13	2.02	3.10	1.40	1.69
1986	February	8.54	2.39	7.43	5.86	6.60	6.16
1986	March	2.48	1.36	1.88	3.41	3.10	2.45
1986	April	3.79	1.27	2.11	3.89	3.90	2.99
1986	May	1.62	0.38	0.00	1.90	1.70	1.12
1986	June	0.26	0.33	2.47	2.37	0.00	1.09
1986	July	1.01	1.28	0.00	0.00	0.60	0.58
1986	August	1.68	1.66	4.15	0.00	2.90	2.08
1986	September	2.73	2.22	1.75	6.10	3.40	3.24
1986	October	1.86	1.64	0.00	0.00	1.80	1.06
1986	November	1.98	0.22	0.00	0.00	1.80	0.80
1986	December	0.55	0.07	4.19	5.68	0.80	2.26
	TOTAL	28.31	12.95	26.00	32.31	28.00	25.52

No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1987 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1987	January	2.14	1.10	0.00	0.00	1.70	0.99
1987	February	2.07	0.97	3.97	6.80	2.50	3.26
1987	March	2.47	1.57	2.03	3.01	2.20	2.26
1987	April	1.03	1.31	1.40	2.41	1.60	1.55
1987	May	2.93	2.59	0.00	2.90	3.40	2.36
1987	June	0.79	0.52	4.73	4.37	1.90	2.46
1987	July	2.12	2.90	0.00	0.00	1.90	1.38
1987	August	1.22	1.54	0.00	0.00	1.40	0.83
1987	September	0.49	0.09	5.80	6.10	1.30	2.76
1987	October	1.39	2.34	2.00	3.02	0.90	1.93
1987	November	1.68	1.59	1.66	2.52	2.80	2.05
1987	December	3.50	0.92	1.99	3.03	2.50	2.39
	TOTAL	21.83	17.44	23.58	34.16	24.10	24.22

No Data Reported
Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1988 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1988	January	3.06	2.60	2.21	2.92	3.10	2.78
1988	February	0.72	0.06	2.08	3.40	0.60	1.37
1988	March	3.32	0.99	3.29	4.45	3.70	3.15
1988	April	2.14	1.73	2.79	4.15	2.00	2.56
1988	May	1.60	0.68	1.24	1.28	2.30	1.42
1988	June	0.86	1.38	0.77	1.33	0.60	0.99
1988	July	1.04	0.65	1.15	0.94	0.70	0.90
1988	August	2.23	1.08	1.50	2.08	1.50	1.68
1988	September	1.16	1.10	1.55	2.17	0.90	1.38
1988	October	1.20	0.84	1.78	1.20	1.00	1.20
1988	November	2.68	0.34	1.48	4.30	3.40	2.44
1[illegible]	December	1.91	1.44	1.77	3.70	2.70	2.30
	TOTAL	21.92	12.89	21.61	31.92	22.50	22.17

No Data Reported
Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1989 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1989	January	1.52	0.55	1.57	2.30	1.70	1.53
1989	February	1.99	0.44	1.48	1.90	2.00	1.56
1989	March	3.55	0.96	2.96	4.00	3.70	3.03
1989	April	0.35	0.40	1.18	1.70	1.00	0.93
1989	May	0.06	0.71	0.38	0.90	1.00	0.61
1989	June	1.54	0.78	0.24	1.20	1.80	1.11
1989	July	1.43	1.11	1.40	1.50	1.20	1.33
1989	August	1.37	2.21	1.28	1.60	3.00	1.89
1989	September	1.19	1.17	1.33	2.20	2.70	1.72
1989	October	1.21	0.32	1.30	1.80	2.10	1.35
1989	November	1.88	0.44	0.52	2.30	2.20	1.47
1989	December	0.70	0.07	2.20	1.90	1.20	1.21
	TOTAL	16.79	9.16	15.84	23.30	23.60	17.74

* No Data Reported

NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1990 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1990	January	2.00	0.55	*	2.00	1.70	1.25
1990	February	4.06	1.80	*	4.00	3.90	2.75
1990	March	2.30	1.36	*	3.00	1.70	1.67
1990	April	2.00	0.92	*	3.10	2.30	1.66
1990	May	0.81	0.57	*	0.50	0.40	0.46
1990	June	1.87	0.81	*	2.00	2.60	1.46
1990	July	1.08	0.61	*	2.00	0.90	0.92
1990	August	0.62	1.06	*	0.70	1.50	0.78
1990	September	1.87	2.20	*	2.90	1.80	2.59
1990	October	1.32	0.57	*	1.80	2.10	1.28
1990	November	*	*	*	2.30	2.20	1.78
1990	December	*	*	*	1.90	1.20	1.08
	TOTAL	NC	NC	NC	26.20	22.30	17.68

* No Data Reported
NC Not Calculated (Record Incomplete)

TABLE A-1 (Continued)

1991 PRECIPITATION DATA SUMMARY

YEAR	MONTH	ELECTRIC LAKE PRECIP.	HIAWATHA PRECIP.	STUART RANGER STATION PRECIP.	RED PINE RIDGE PRECIP.	MAMMOTH-COTTONWOOD PRECIP.	AVERAGE PRECIP.
1991	January	0.46	1.49	*	0.30	0.20	1.61
1991	February	0.19	1.61	*	0.80	0.20	0.70
1991	March	2.77	4.24	3.69	0.60	0.90	2.44
1991	April	0.41	3.06	2.57	0.30	0.60	1.39
1991	May	1.78	*	*	0.80	0.00	0.86
1991	June	0.94	*	*	0.00	0.50	0.48
1991	July	2.03	*	3.38	0.70	0.50	1.65
1991	August	1.78	*	*	0.50	0.50	0.93
1991	September	2.19	*	7.05	8.20	0.50	4.49
1991	October	0.29	*	*	0.50	0.70	0.50
1991	November	0.58	2.10	*	0.30	0.80	0.95
1991	December	*	*	*	0.20	0.60	0.40
	TOTAL	NC	NC	NC	13.20	6.00	16.40

* No Data Reported
NC Not Calculated (Record Incomplete)

Appendix 7N-B
Streamflow Data

TABLE B-1

HUNTINGTON CREEK AVERAGE MONTHLY FLOW (cfs)

YEAR	JAN AVG FLOW	FEB AVG FLOW	MAR AVG FLOW	APR AVG FLOW	MAY AVG FLOW	JUNE AVG FLOW	JULY AVG FLOW	AUG AVG FLOW	SEPT AVG FLOW	OCT AVG FLOW	NOV AVG FLOW	DEC AVG FLOW
1981	26.9	28.9	28.1	61.9	100.0	85.5	135.0	87.8	56.8	34.5	19.3	0.0
1982	20.5	21.4	27.7	42.9	270.0	374.0	173.0	97.5	92.8	95.1	70.9	0.0
1983	45.5	26.3	39.4	55.0	315.0	1003.0	324.0	138.0	105.0	85.7	72.7	52.2
1984	54.0	60.5	65.0	143.0	853.0	823.0	292.0	173.0	175.0	*	*	*
1985	*	*	*	*	*	*	*	*	*	61.1	36.0	35.3
1986	39.1	46.6	84.2	139.0	442.0	493.0	155.0	135.0	115.0	61.1	43.3	43.4
1987	43.4	48.6	45.8	97.2	171.0	125.0	85.6	73.6	82.5	69.4	46.3	40.4
1988	29.9	28.3	26.1	47.5	157.0	149.0	98.2	73.1	62.4	48.5	35.9	14.7
1989	29.5	25.7	33.1	72.4	77.6	83.5	103.0	91.5	87.7	19.2	18.7	16.6
1990	17.8	19.7	22.9	47.7	80.5	83.5	67.1	69.2	56.9	44.9	22.6	17.2
1991	13.7	11.4	16.5	31.9	115.0	188.0	91.9	65.7	65.5	*	*	*

* Data not available.

Appendix 7N-C

Water Rights Data

Table C-1

Summary of Water Rights

Water Right Number	User Name	Source Name	Quantity (cfs)	Water Use	Priority Date
93 1435	USA Forest Service	Left Fork Trail Canyon Spring	.0110	Stockwatering	1875
93 139	USA Forest Service	Trail Canyon Creek	.0000	Stockwatering	1875
93 1436	USA Forest Service	Surface Runoff Spring	.0110	Stockwatering	1875
93 1434	USA Forest Service	McCadden Ridge Spring	.0110	Stockwatering	1875
93 1432	USA Forest Service	Unnamed Spring	.0110	Stockwatering	1875
93 1433	USA Forest Service	Tuttle Spring	.0110	Stockwatering	1875
93 1431	USA Forest Service	Unnamed Stream	.0110	Stockwatering	1875
93 1430	USA Forest Service	Boundary Spring	.0110	Stockwatering	1875
93 151	USA Forest Service	Bear Creek	.0000	Stockwatering	1875
93 1429	USA Forest Service	Wild Horse Flat Spring	.0110	Stockwatering	1875
93 142	USA Forest Service	McCadden Hollow	.0000	Stockwatering	1875
[illegible]	Nevada Electric Investment Co.	McCadden Hollow Stream	.0000	Stockwatering	1875
93 12[illegible]	Nevada Electric Investment Co.	Huntington Creek	.0000	Stockwatering	1875
93 13[illegible]	Nevada Electric Investment Co.	Trail Canyon Creek	.0000	Domestic Stockwatering	1875

Table C-1 (Cont.)

Summary of Water Rights

Water Right Number	User Name	Source Name	Quantity (cfs)	Water Use	Priority Date
93 130	USA Forest Service	Huntington Creek	.0000	Stockwatering	1875
93 195	USA Forest Service	Mill Fork Huntington Creek	.0000	Stockwatering	1875
a15965	Co-op Mining Company	1) Spring 2) Mine Portal	.0000	Irrigation Domestic Mining	1991
93 1067	Charles W. Kingston	Underground Water Tunnel	.2500	Irrigation Mining	1964
93 1183	Utah Power & Light Co.	Huntington Creek	.0000	Stockwatering	1902
93 131	Peabody Coal Company Nevada Electric Investment Co.	Huntington Creek	.0000	Stockwatering	1875
93 144	USA Forest Service	Huntington Creek	.0000	Stockwatering	1875
93 390	Nevada Electric Investment Co.	Rilda Canyon	.0000	Stockwatering	1902
93 199	Utah Power & Light Co.	Rilda Canyon Creek	.0000	Stockwatering	1902
a7941	Huntington-Cleveland Irrigation Company	Huntington Creek and Tributaries	392.2500	Irrigation Domestic Stockwatering Power Other	1974
93 150	Nevada Electric Investment Co.	Bear Creek	.0000	Stockwatering	1875
a13694	Mrs. Charles W. Kingston (Laverda)	Bear Canyon Tunnel	.2500	Irrigation Domestic Mining Other	1985

Table C-1 (Cont.)

Summary of Water Rights

Water Right Number	User Name	Source Name	Quantity (cfs)	Water Use	Priority Date
E1621	Utah Power & Light Co.	Well	.1100	Other	1979
93 3208	USA Bureau of Land Management	Huntington Creek	.0000	Stockwatering	1860
E2504	Castle Valley Special Service District	Bear Spring	.0000	Municipal	1987
93 2196	Huntington Cleveland Irrigation Company	Birch Spring	45.0000	Irrigation Domestic Stockwatering Power Other	1879
93 2198	Huntington Cleveland Irrigation Company	Birch Spring	80.0000	Irrigation Domestic Stockwatering Power Other	1888
93 304	Huntington Cleveland Irrigation Company	Birch Spring	150.0000	Irrigation Domestic Stockwatering Power Other	1876
93 2197	Huntington Cleveland Irrigation Company	Birch Spring	77.2500	Irrigation Domestic Stockwatering Power Other	1884

Table C-1 (Cont.)

Summary of Water Rights

Water Right Number	User Name	Source Name	Quantity (cfs)	Water Use	Priority Date
93 2200	Huntington Cleveland Irrigation Company	Bear Canyon Spring	.0000	Irrigation Domestic Stockwatering Power Other	1884
93 253	Huntington Cleveland Irrigation Company	Bear Canyon Spring	150.0000	Irrigation Domestic Stockwatering Power Other	1876
93 1182	Peabody Coal Company	Bear Creek	.0000	Stockwatering	1902
93 2201	Huntington Cleveland Irrigation Company	Bear Canyon Spring	80.0000	Irrigation Domestic Stockwatering Power Other	1888
93 2199	Huntington Cleveland Irrigation Company	Bear Canyon Spring	45.0000	Irrigation Domestic Stockwatering Power Other	1879
93 3171	Northwest Carbon Corporation	Huntington Creek	.0000	Stockwatering	1875
93 3033	Northwest Carbon Corporation	Huntington Creek	.0000	Stockwatering	1875
93 143	Nevada Electric Investment Company	Birch Spring	.0110	Stockwatering	1875
93 3209	USA Bureau of Land Management	Huntington Creek	.0000	Stockwatering	1860

Table C-1 (Cont.)

Summary of Water Rights

Water Right Number	User Name	Source Name	Quantity (cfs)	Water Use	Priority Date
93 149	Nevada Electric Investment Company	Bear Creek	.0000	Stockwatering	1875
93 148	USA Bureau of Land Management	Bear Creek	.0000	Stockwatering	1902
93 3207	USA Bureau of Land Management	Huntington Creek	.0000	Stockwatering	1860
93 146	Nevada Electric Investment Company	Huntington Creek	.0000	Stockwatering	1875
93 303	Huntington Cleveland Irrigation Company	Spring	150.0000	Irrigation Domestic Stockwatering Power Other	1875
93 2202	Huntington Cleveland Irrigation Company	Unnamed Spring	45.0000	Irrigation Domestic Stockwatering Power Other	1879
93 2204	Huntington Cleveland Irrigation Company	Unnamed Spring	80.0000	Irrigation Domestic Stockwatering Power Other	1888
93 2203	Huntington Cleveland Irrigation Company	Unnamed Spring	77.2500	Irrigation Domestic Stockwatering Power Other	1884

Table C-1 (Cont.)

Summary of Water Rights

Water Right Number	User Name	Source Name	Quantity (cfs)	Water Use	Priority Date
t91-93-06	PacifiCorp Electric Operations	Huntington Creek 2) Rilda C	.0000	Other	1991
t91-93-07	Nielson Construction Company	Huntington Creek	.0000	Other	1991
t91-93-04	Minchey Digging	Huntington Creek	.0000	Other	1991
93 2210	Huntington-Cleveland Municipal	Gate Spring	80.0000	Domestic Municipal	1888
93 2209	Huntington-Cleveland Municipal	Gate Spring	77.2500	Domestic Municipal	1884
93 2208	Huntington-Cleveland Municipal	Gate Spring	45.0000	Domestic Municipal	1879
93 310	Huntington-Cleveland Municipal	Gate Spring	150.0000	Domestic Municipal	1875
93 2207	Huntington-Cleveland Irrigation Company	Unnamed Spring	80.0000	Domestic Municipal	1888
93 2206	Huntington-Cleveland Irrigation Company	Unnamed Spring	77.2500	Domestic Municipal	1884
93 2205	Huntington-Cleveland Irrigation Company	Unnamed Spring	45.0000	Domestic Municipal	1879
93 309	Huntington-Cleveland Irrigation	Unnamed Spring	150.0000	Domestic Municipal	1875

Appendix 7N-D

Spring Flow Data

TABLE D-1

BIG BEAR SPRING AVERAGE MONTHLY FLOW (gpm)

YEAR	JAN AVG FLOW	FEB AVG FLOW	MAR AVG FLOW	APR AVG FLOW	MAY AVG FLOW	JUNE AVG FLOW	JULY AVG FLOW	AUG AVG FLOW	SEPT AVG FLOW	OCT AVG FLOW	NOV AVG FLOW	DEC AVG FLOW
1980	223	228	226	225	228	340	365	304	245	230	239	233
1981	225	198	175	228	224	220	226	0	155	152	156	0
1982	161	159	155	152	154	213	243	198	174	168	167	0
1983	167	167	167	166	166	310	378	319	258	214	195	189
1984	189	191	187	187	198	335	321	299	245	209	203	202
1985	198	193	189	186	233	329	312	247	215	206	204	222
1986	171	190	186	182	208	304	305	249	211	198	197	193
1987	186	181	176	171	170	171	188	181	170	181	170	160
1988	153	151	147	143	147	151	157	152	151	155	151	146
1989	142	139	134	133	131	127	128	120	119	114	111	111
1990	110	110	112	109	104	104	104	105	107	110	108	125
1991	126	130	128	118	119	123	119	113	114	114	121	122

TABLE D-2

LITTLE BEAR SPRING AVERAGE MONTHLY FLOW (gpm)

YEAR	JAN AVG FLOW	FEB AVG FLOW	MAR AVG FLOW	APR AVG FLOW	MAY AVG FLOW	JUNE AVG FLOW	JULY AVG FLOW	AUG AVG FLOW	SEPT AVG FLOW	OCT AVG FLOW	NOV AVG FLOW	DEC AVG FLOW
1982	296	291	286	283	321	435	438	409	356	337	330	325
1983	320	316	316	311	325	424	430	395	358	339	330	326
1984	325	326	322	324	368	423	409	377	352	340	335	332
1985	332	329	324	227	379	379	357	341	341	331	327	322
1986	326	319	317	304	380	400	383	356	339	331	330	331
1987	326	322	321	315	320	380	388	364	345	345	328	321
1988	313	311	309	314	318	327	340	327	345	366	366	285
1989	256	356	363	363	341	333	332	330	340	334	326	319
1990	308	302	295	282	278	271	270	275	280	277	272	265
1991	257	249	241	229	225	236	296	302	302	298	291	281

TABLE D-3

TIE FORK SPRING AVERAGE MONTHLY FLOW (gpm)

YEAR	JAN AVG FLOW	FEB AVG FLOW	MAR AVG FLOW	APR AVG FLOW	MAY AVG FLOW	JUNE AVG FLOW	JULY AVG FLOW	AUG AVG FLOW	SEPT AVG FLOW	OCT AVG FLOW	NOV AVG FLOW	DEC AVG FLOW
1984	84	84	83	84	84	84	85	85	86	86	86	85
1985	85	85	84	85	85	85	85	85	86	87	86	85
1986	85	85	84	84	84	85	86	86	85	84	85	87
1987	85	85	86	85	86	86	86	85	84	89	85	83
1988	81	81	82	81	82	81	81	105	133	130	130	84
1989	104	106	104	102	101	101	99	98	98	97	96	96
1990	94	94	94	93	94	93	91	90	89	86	88	89
1991	88	89	88	89	88	89	86	86	86	85	85	84

TABLE D-4

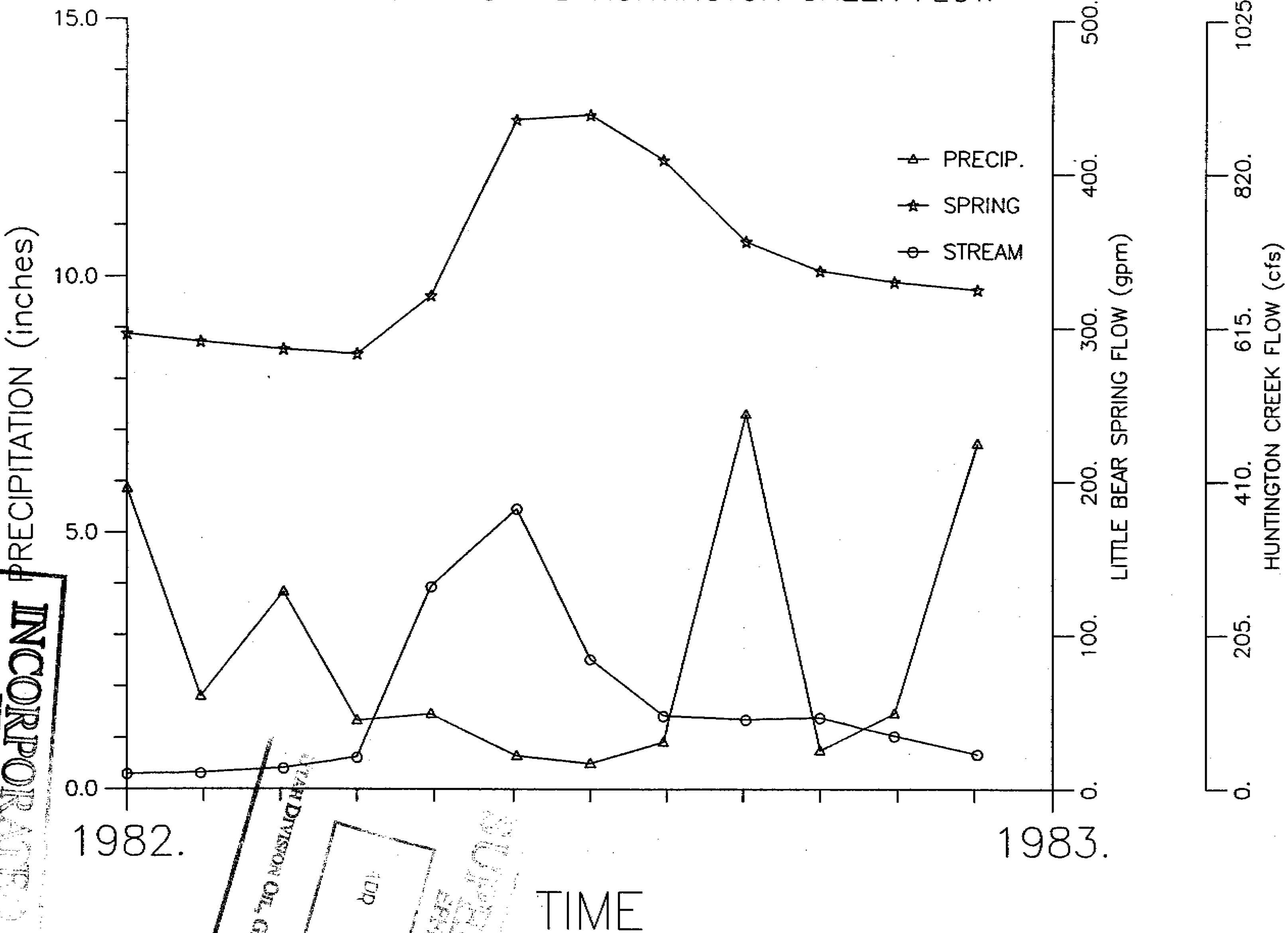
BIRCH SPRING AVERAGE MONTHLY FLOW (gpm)

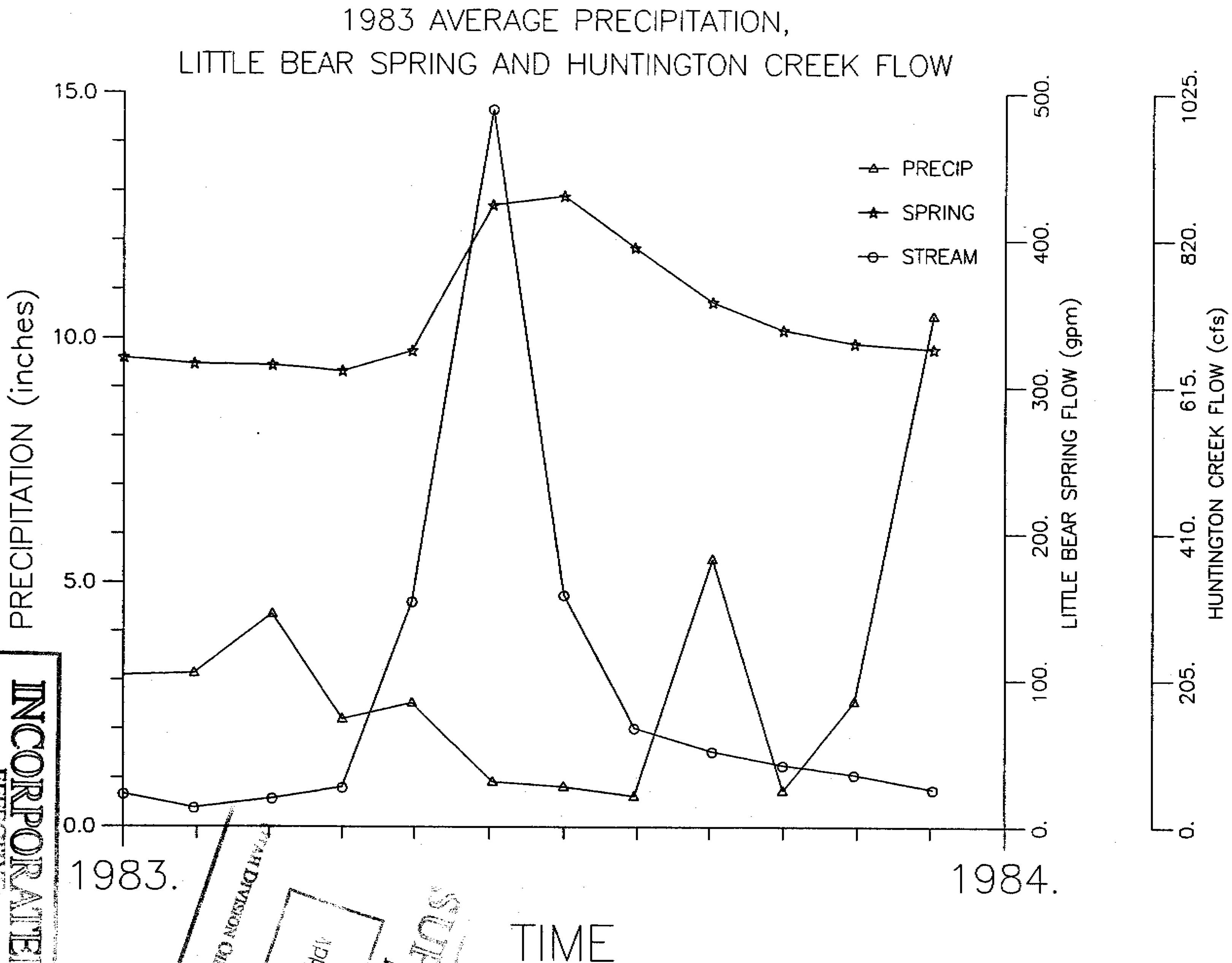
YEAR	JAN AVG FLOW	FEB AVG FLOW	MAR AVG FLOW	APR AVG FLOW	MAY AVG FLOW	JUNE AVG FLOW	JULY AVG FLOW	AUG AVG FLOW	SEPT AVG FLOW	OCT AVG FLOW	NOV AVG FLOW	DEC AVG FLOW
1989	70	65	60	55	85	100	90	85	80	230	230	230
1990	230	70	65	60	70	85	75	55	40	40	38	37
1991	35	33	33	33	34	34	36	31	33	33	33	33

Appendix 7N-E

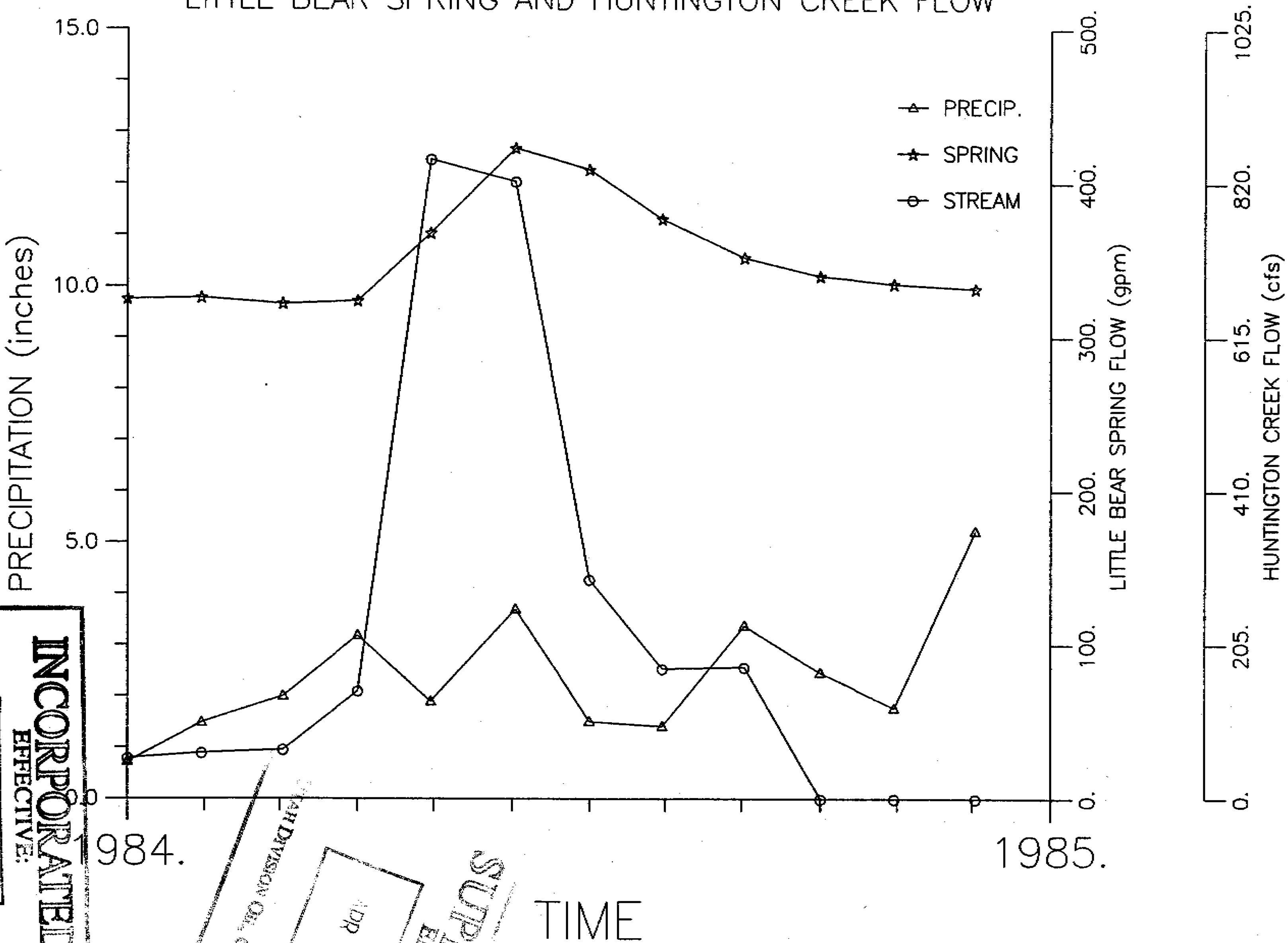
Spring Flow Plots

1982 AVERAGE PRECIPITATION, LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW

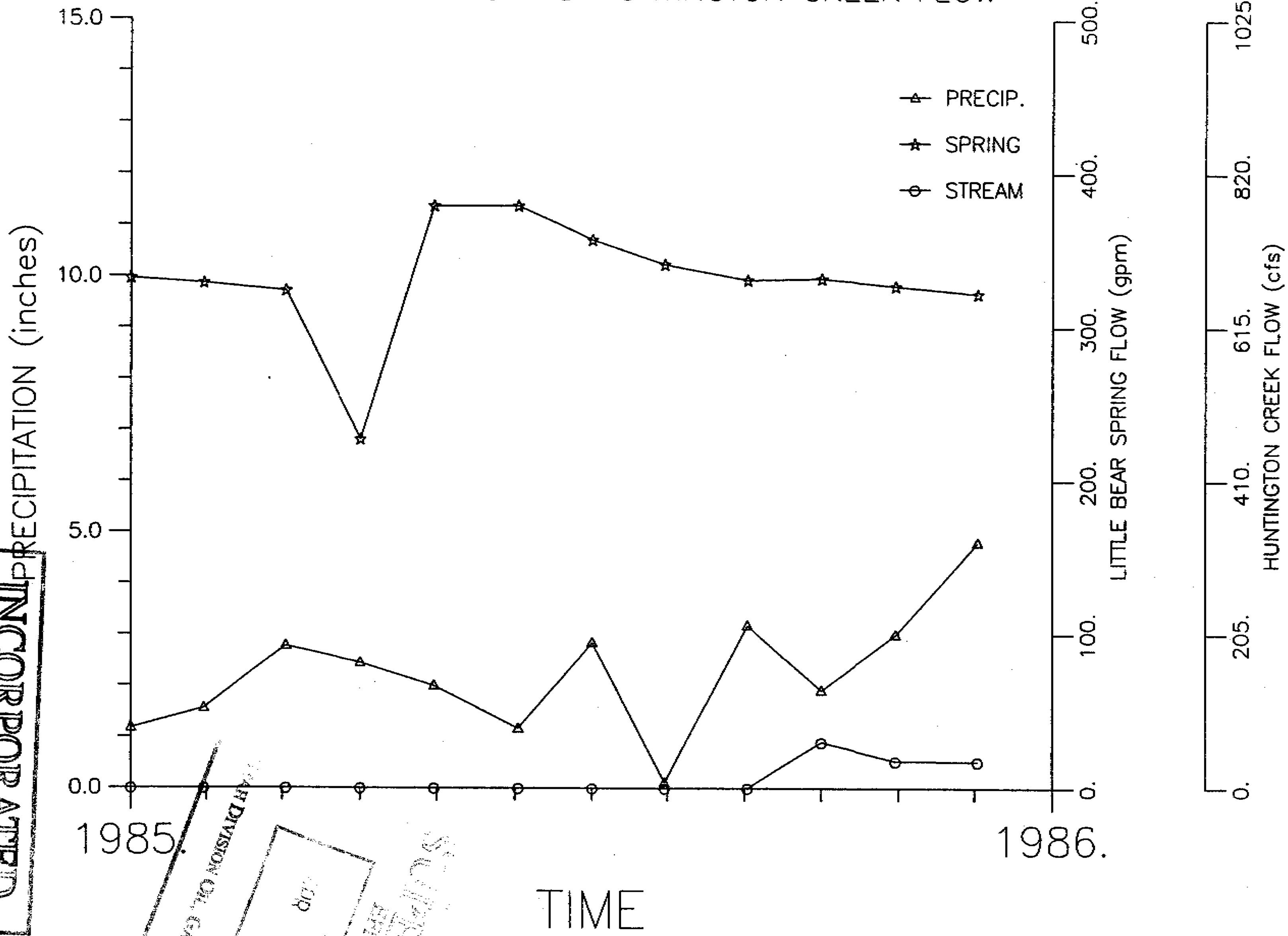



1983 AVERAGE PRECIPITATION,
LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW
PRECIPITATION (inches)
15.0
10.0
5.0
0.0
LITTLE BEAR SPRING FLOW (gpm)
500.
400.
300.
200.
100.
0.
HUNTINGTON CREEK FLOW (cfs)
1025.
820.
615.
410.
205.
0.
PRECIP
SPRING
STREAM
1983.
1984.
TIME

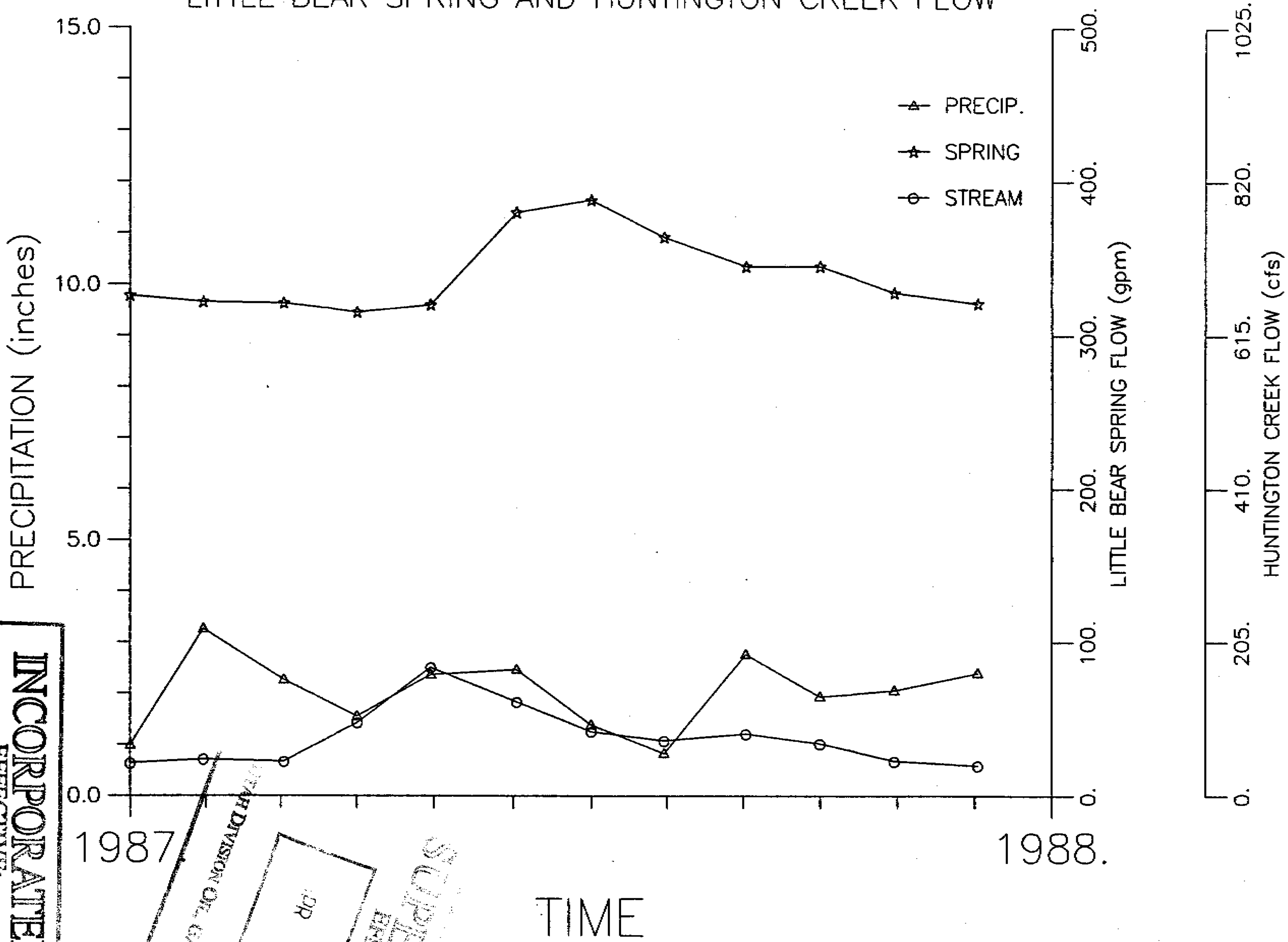
1984 AVERAGE PRECIPITATION,
LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW



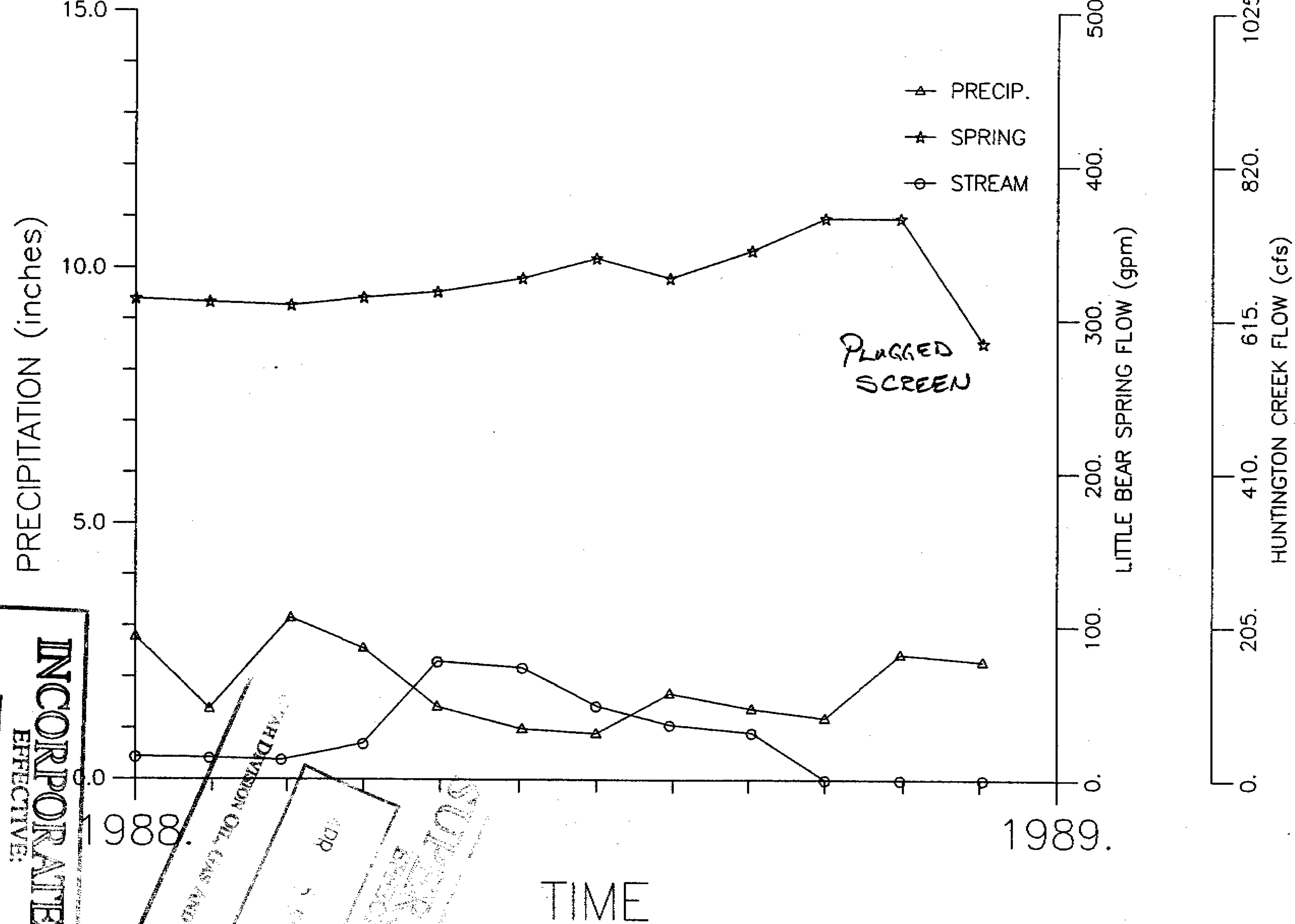
1985 AVERAGE PRECIPITATION, LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW



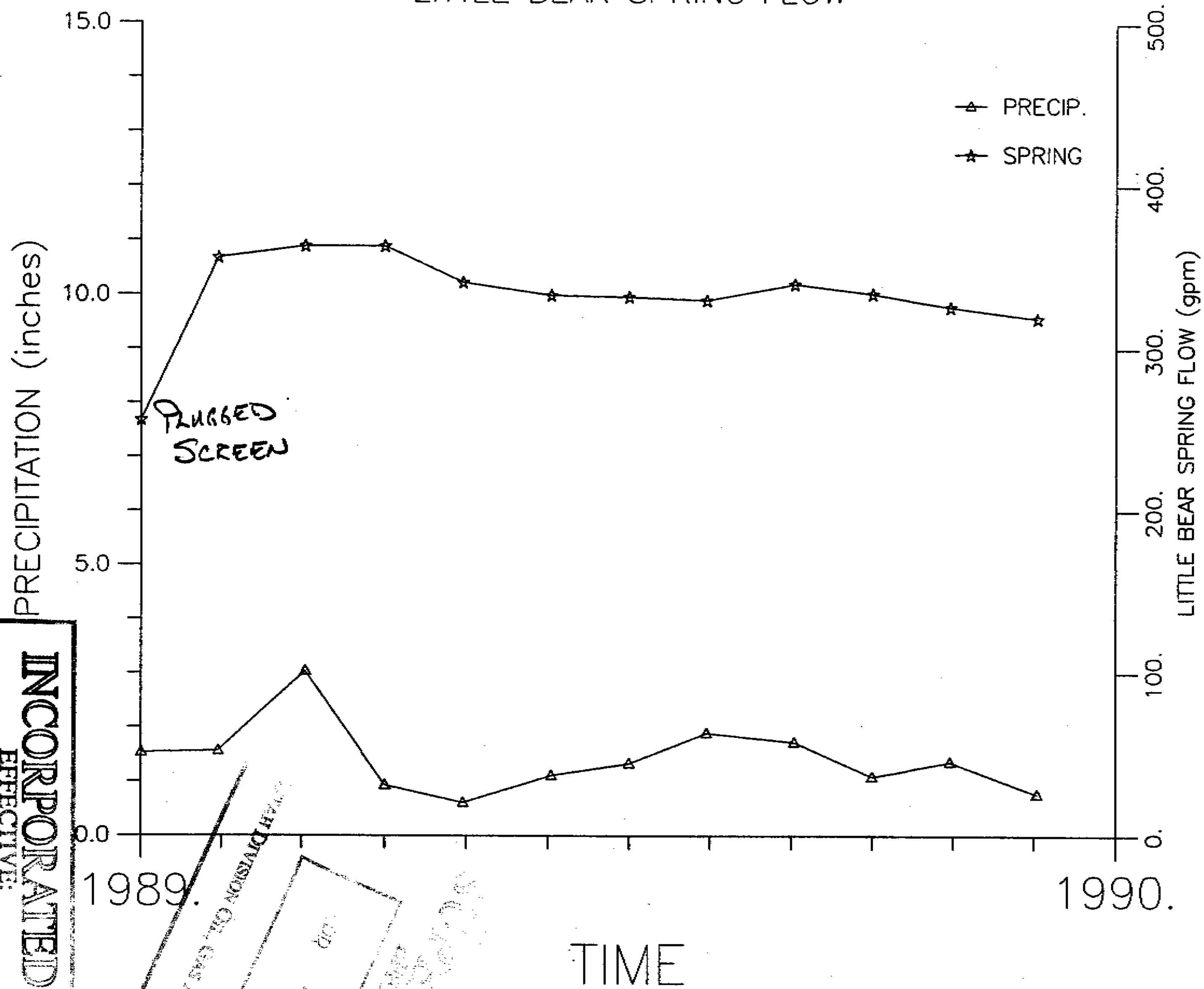
1987 AVERAGE PRECIPITATION,
LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW



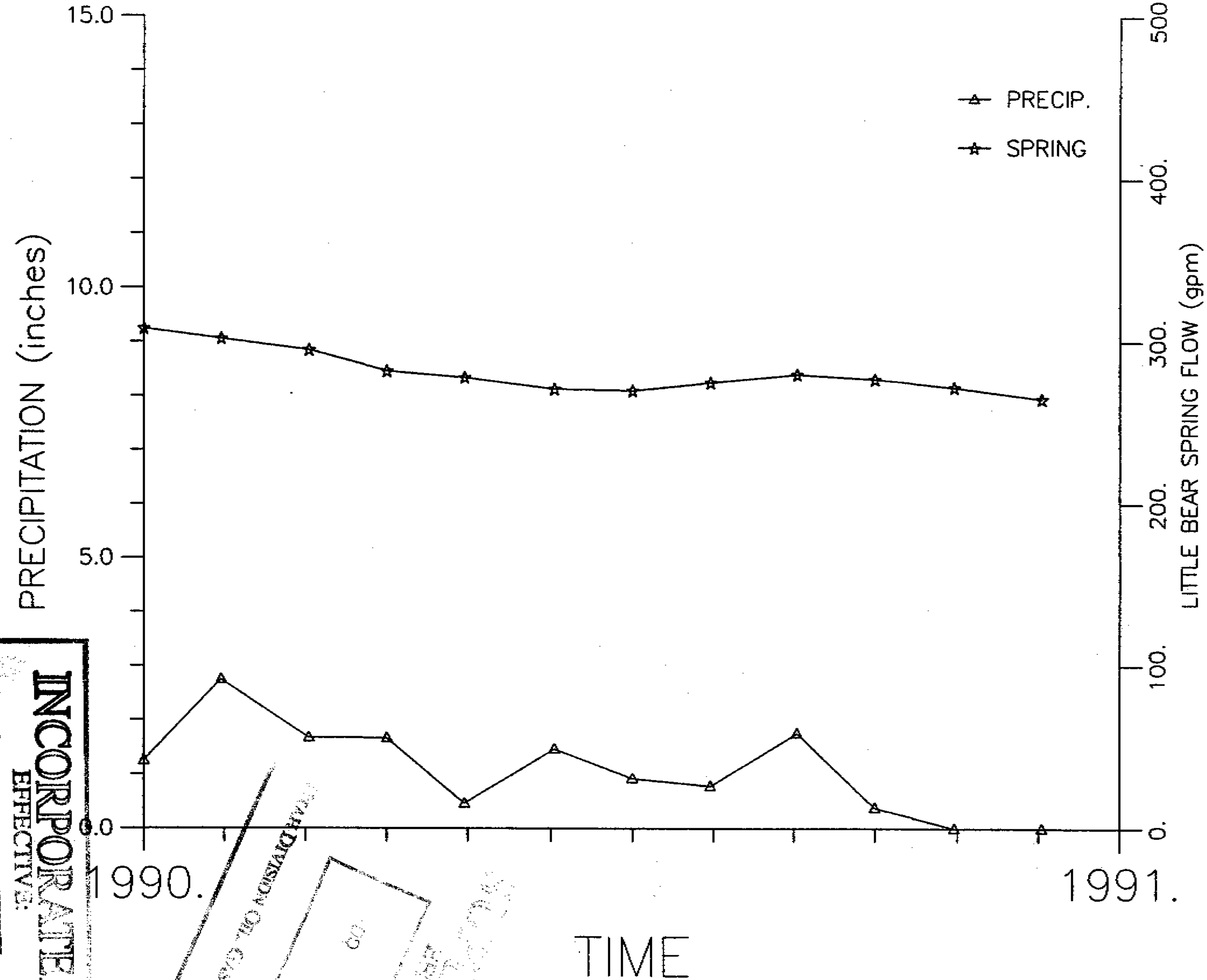
1988 AVERAGE PRECIPITATION, LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW

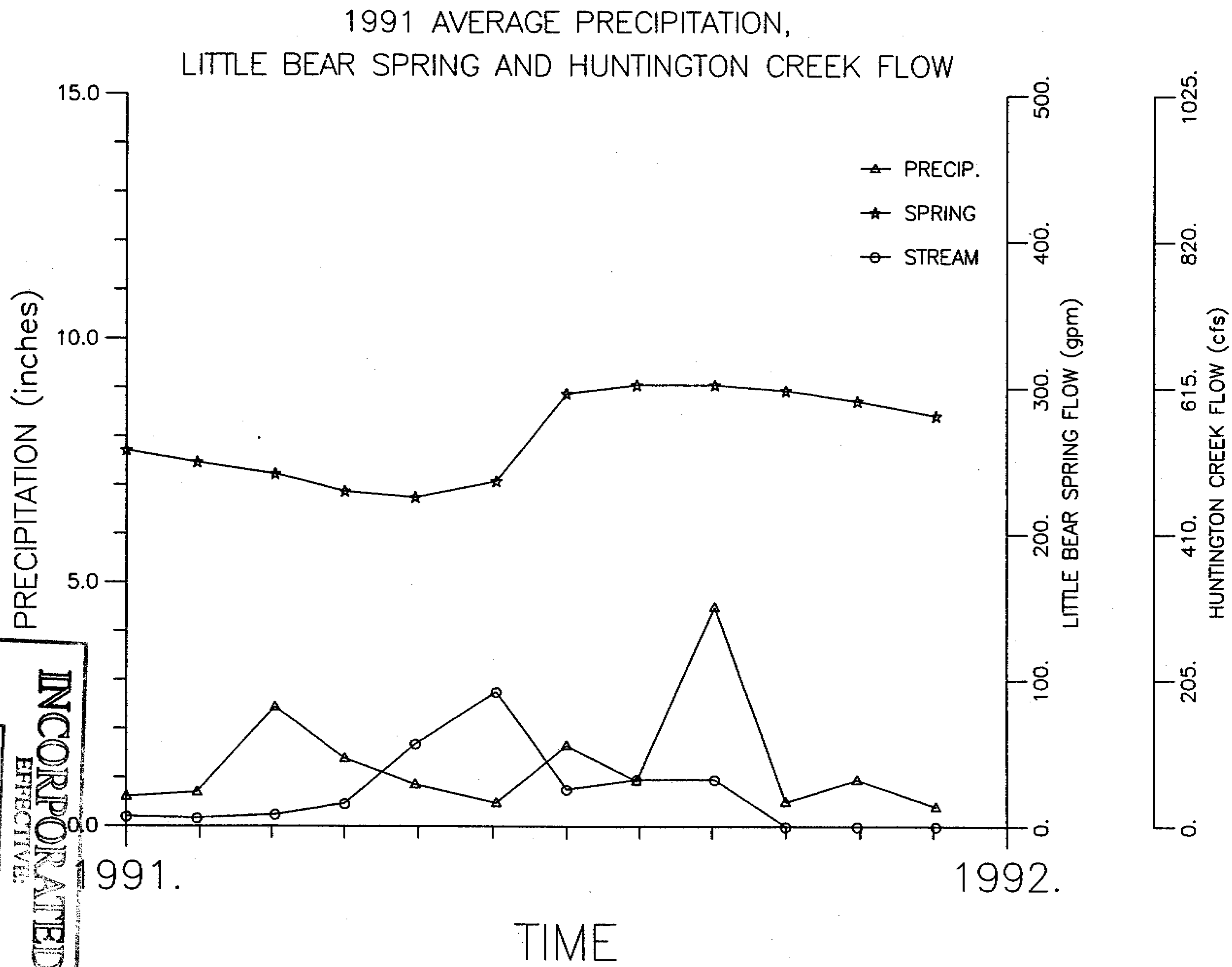


1989 AVERAGE PRECIPITATION AND
LITTLE BEAR SPRING FLOW



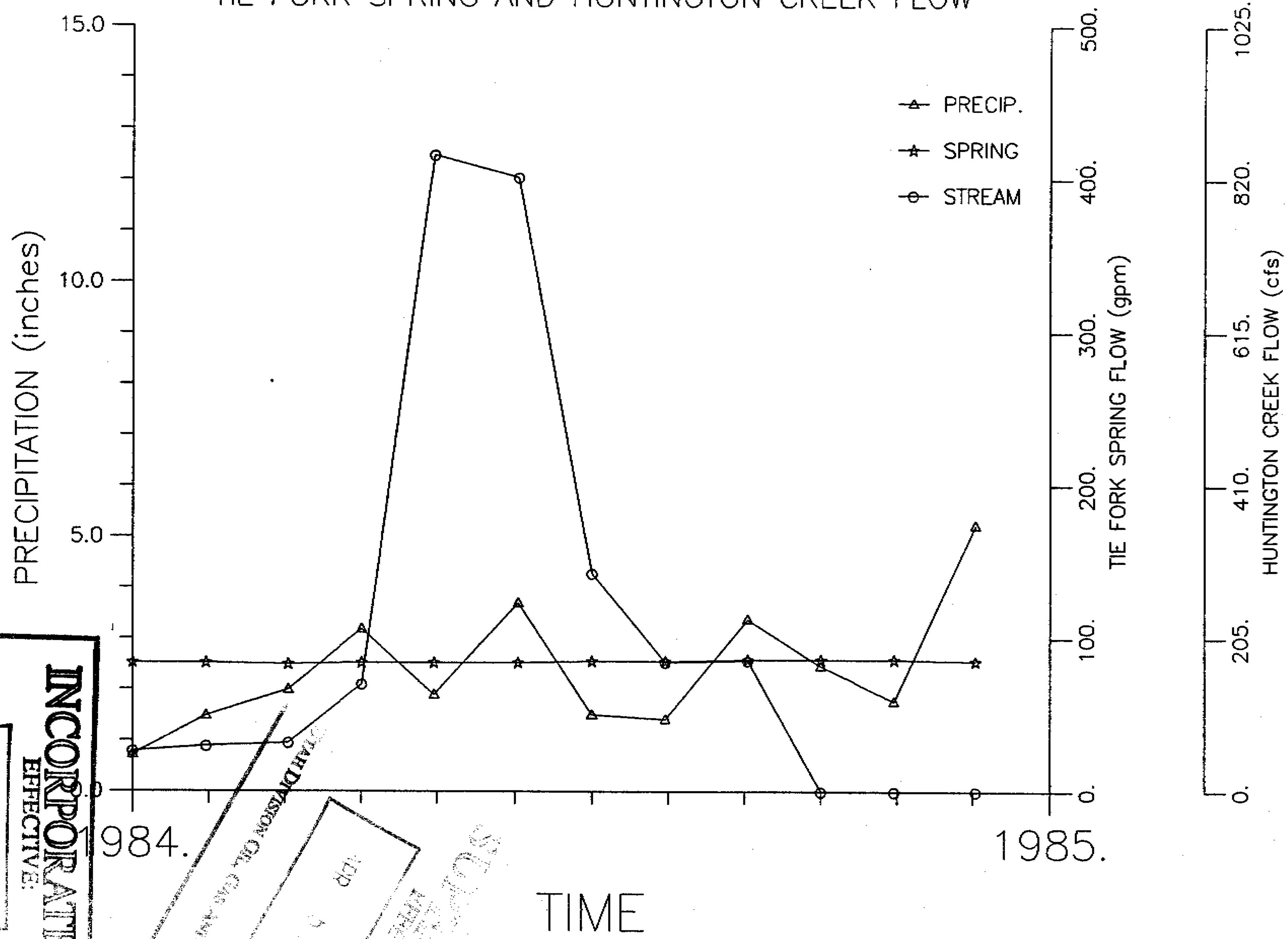
1990 AVERAGE PRECIPITATION AND LITTLE BEAR SPRING FLOW

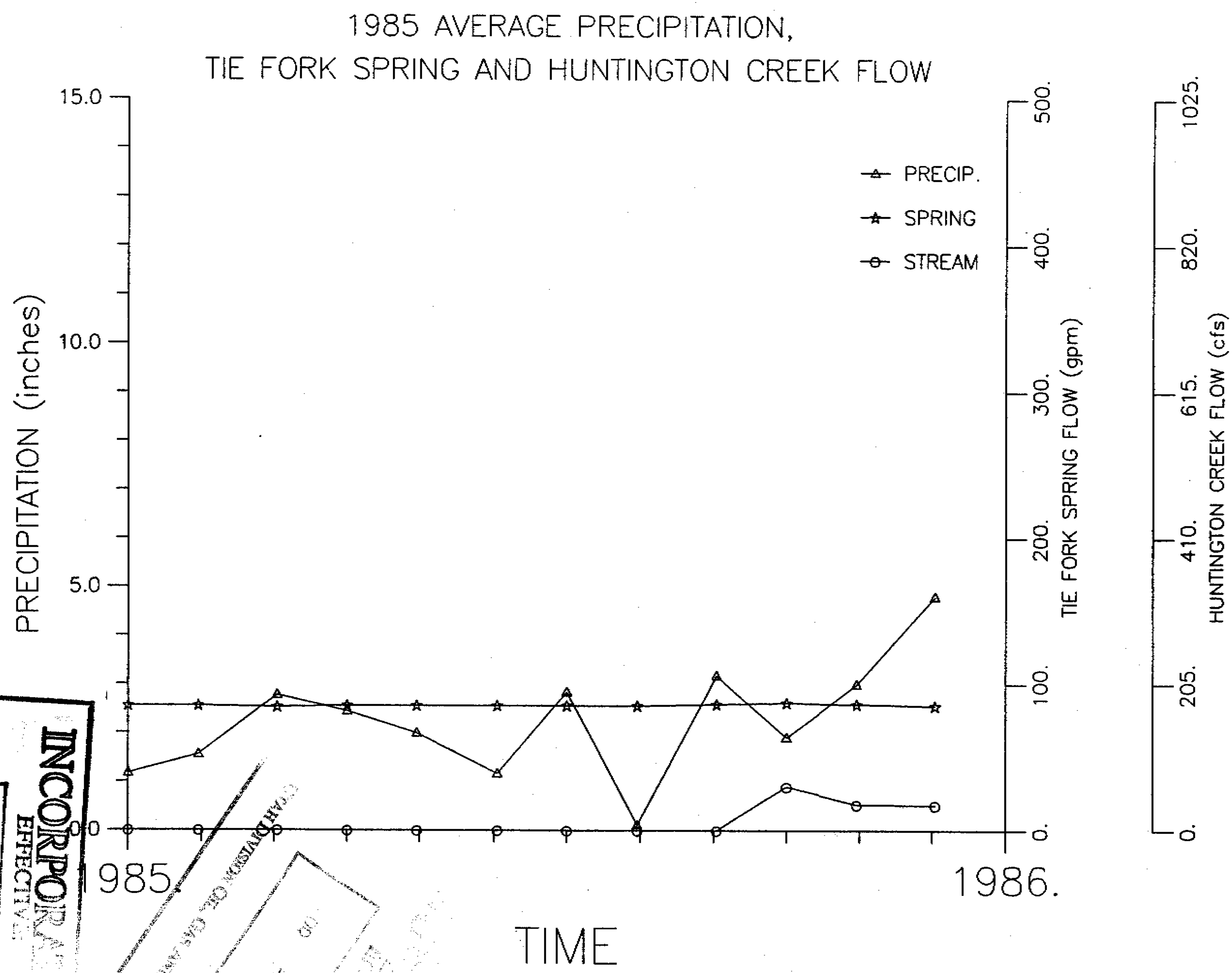




1991 AVERAGE PRECIPITATION,
LITTLE BEAR SPRING AND HUNTINGTON CREEK FLOW
PRECIP.
SPRING
STREAM
PRECIPITATION (inches)
15.0
10.0
5.0
0.0
LITTLE BEAR SPRING FLOW (gpm)
500.
400.
300.
200.
100.
0.
HUNTINGTON CREEK FLOW (cfs)
1025.
820.
615.
410.
205.
0.
1991.
1992.
TIME

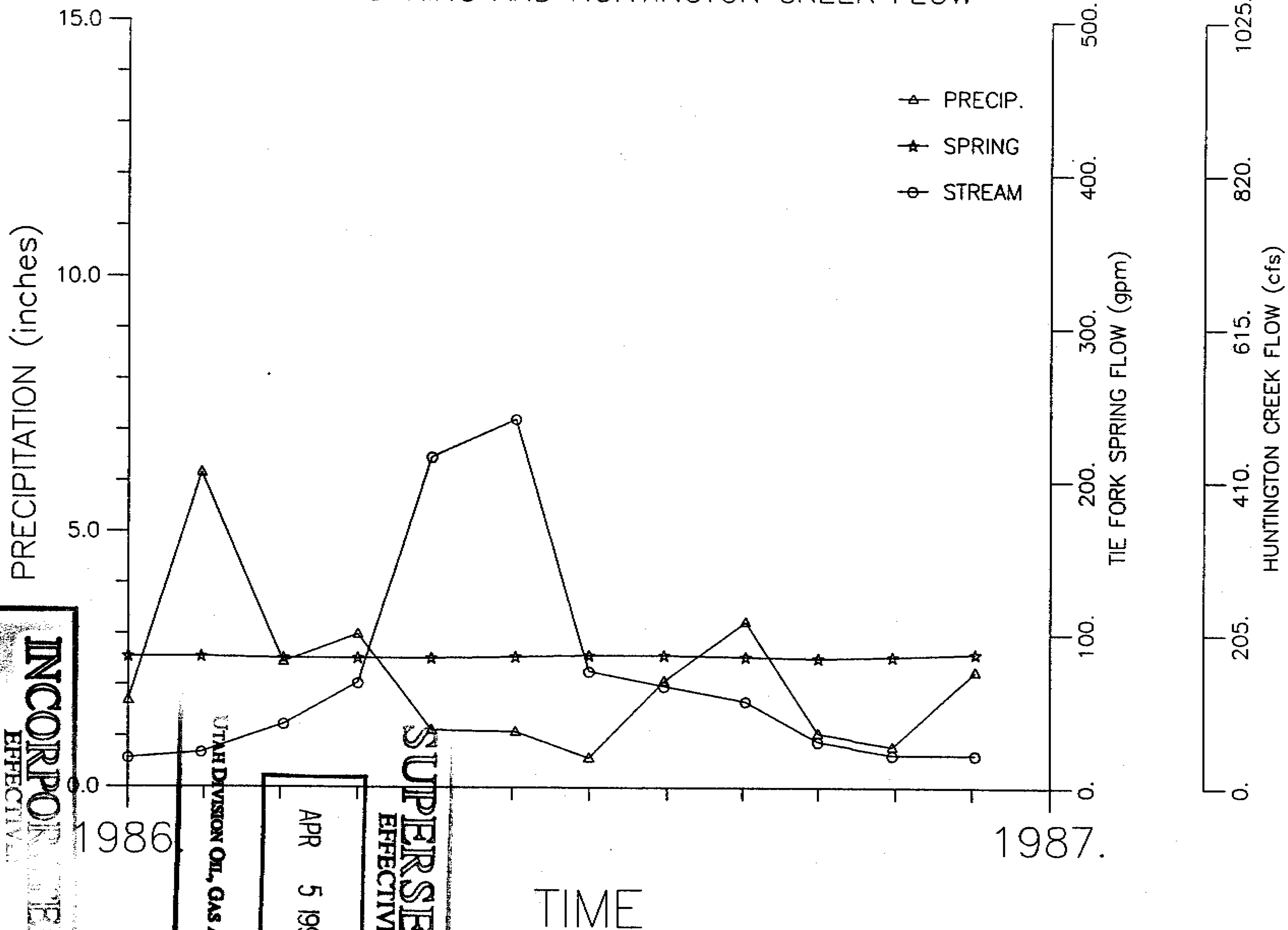
1984 AVERAGE PRECIPITATION, TIE FORK SPRING AND HUNTINGTON CREEK FLOW



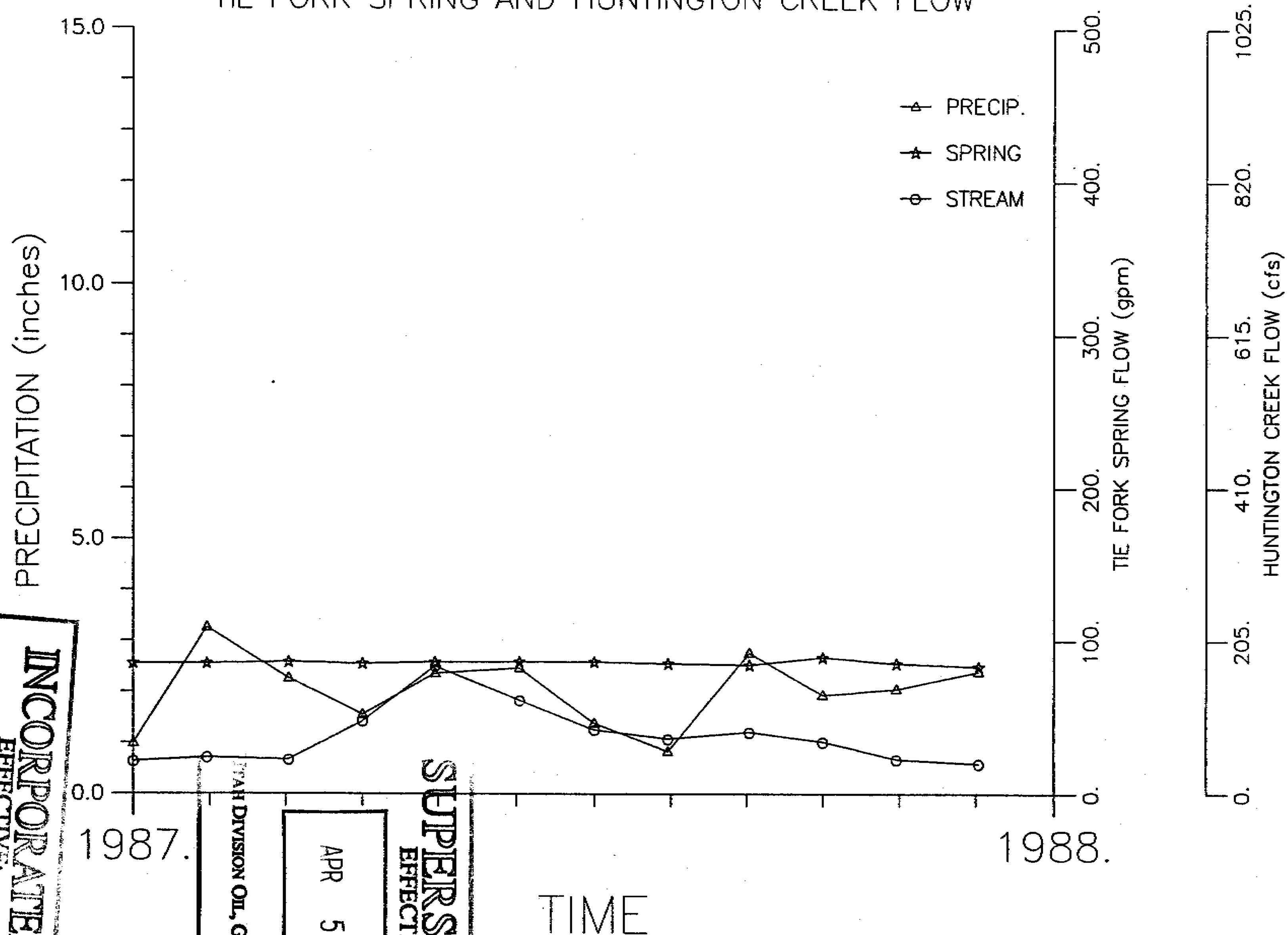


1985 AVERAGE PRECIPITATION,
TIE FORK SPRING AND HUNTINGTON CREEK FLOW
PRECIPITATION (inches)
15.0
10.0
5.0
0.0
PRECIP.
SPRING
STREAM
TIE FORK SPRING FLOW (gpm)
500.
400.
300.
200.
100.
0.
HUNTINGTON CREEK FLOW (cfs)
1025.
820.
615.
410.
205.
0.
1985.
1986.
TIME

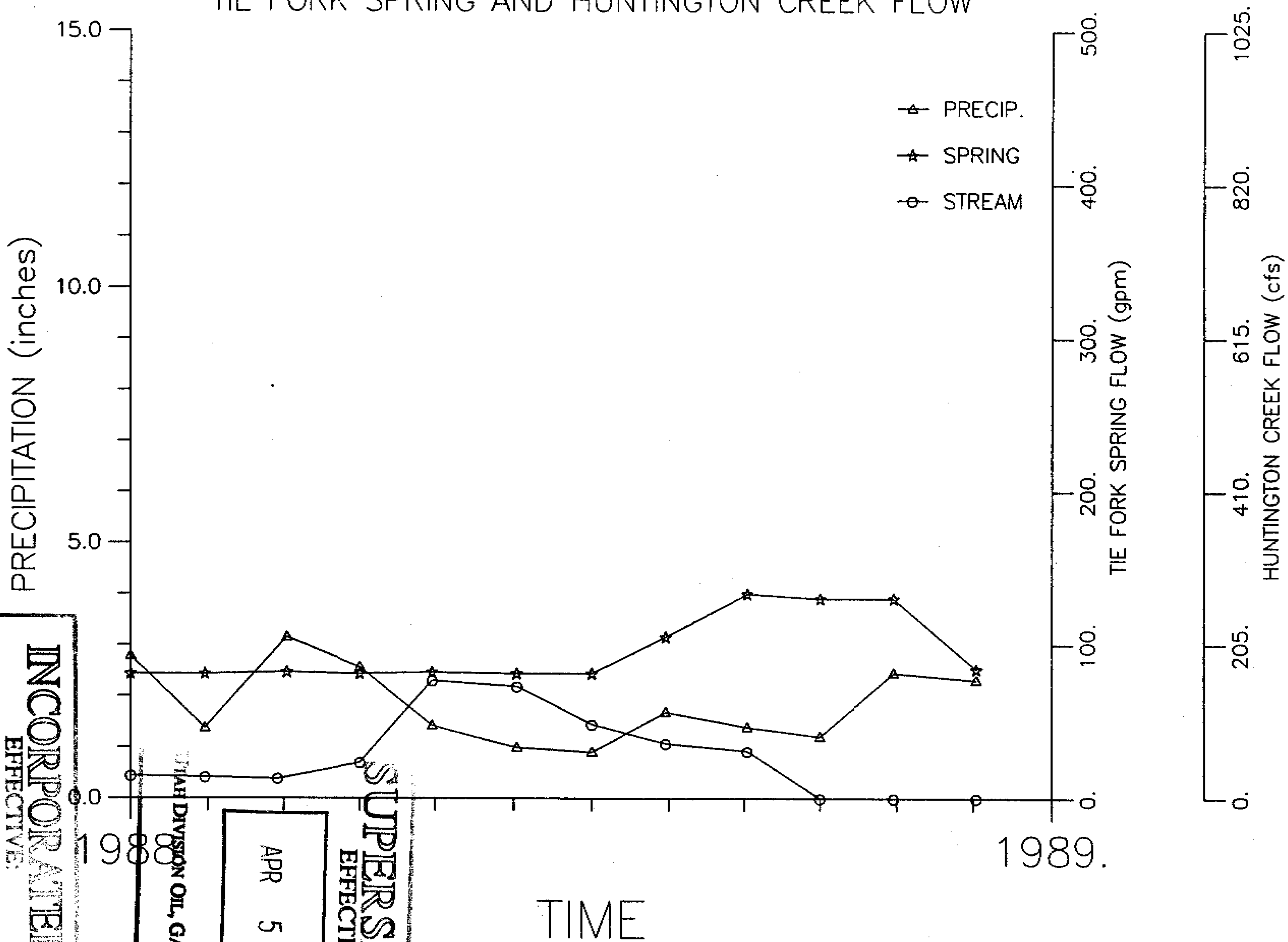
1986 AVERAGE PRECIPITATION,
TIE FORK SPRING AND HUNTINGTON CREEK FLOW



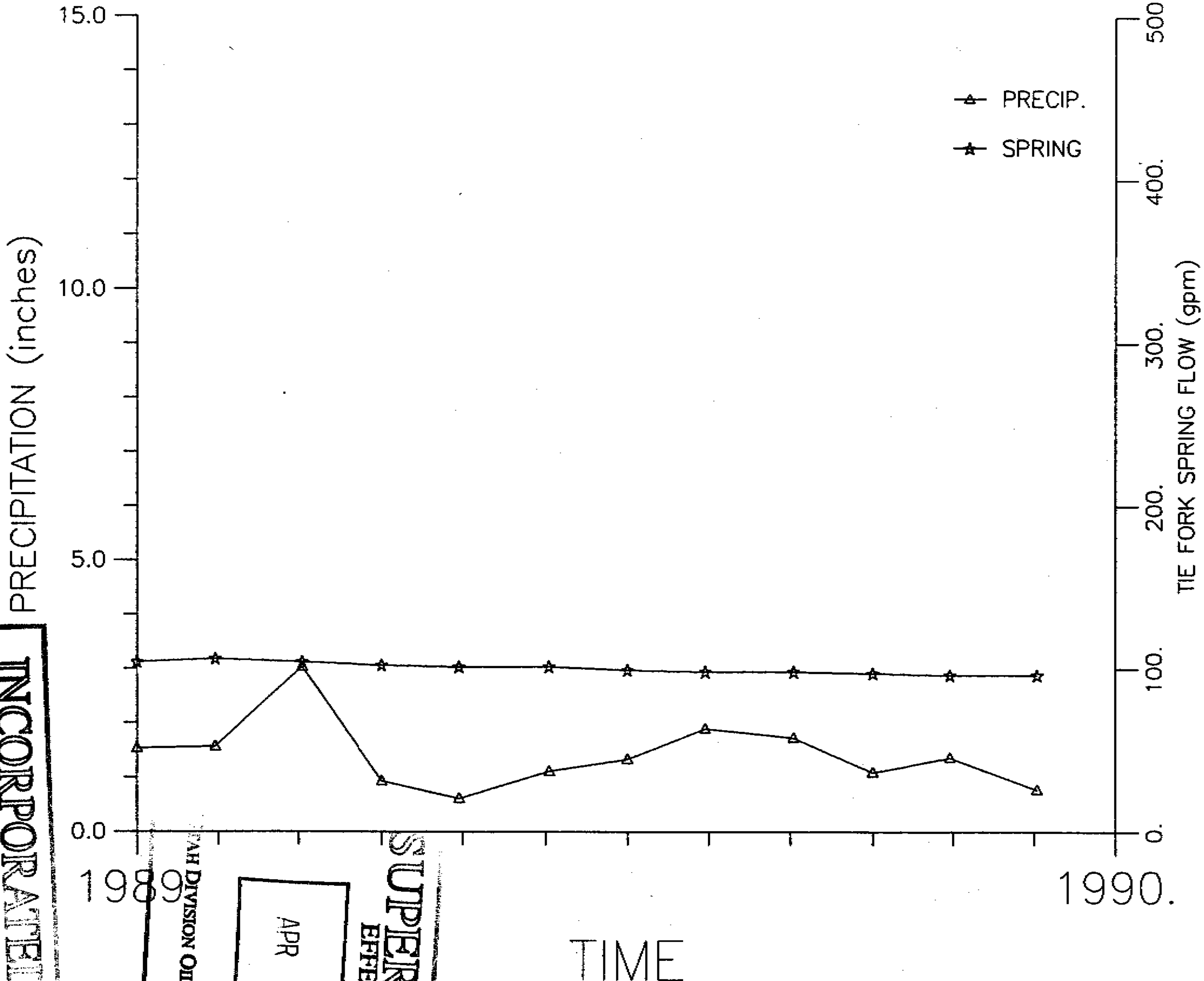
1987 AVERAGE PRECIPITATION, TIE FORK SPRING AND HUNTINGTON CREEK FLOW



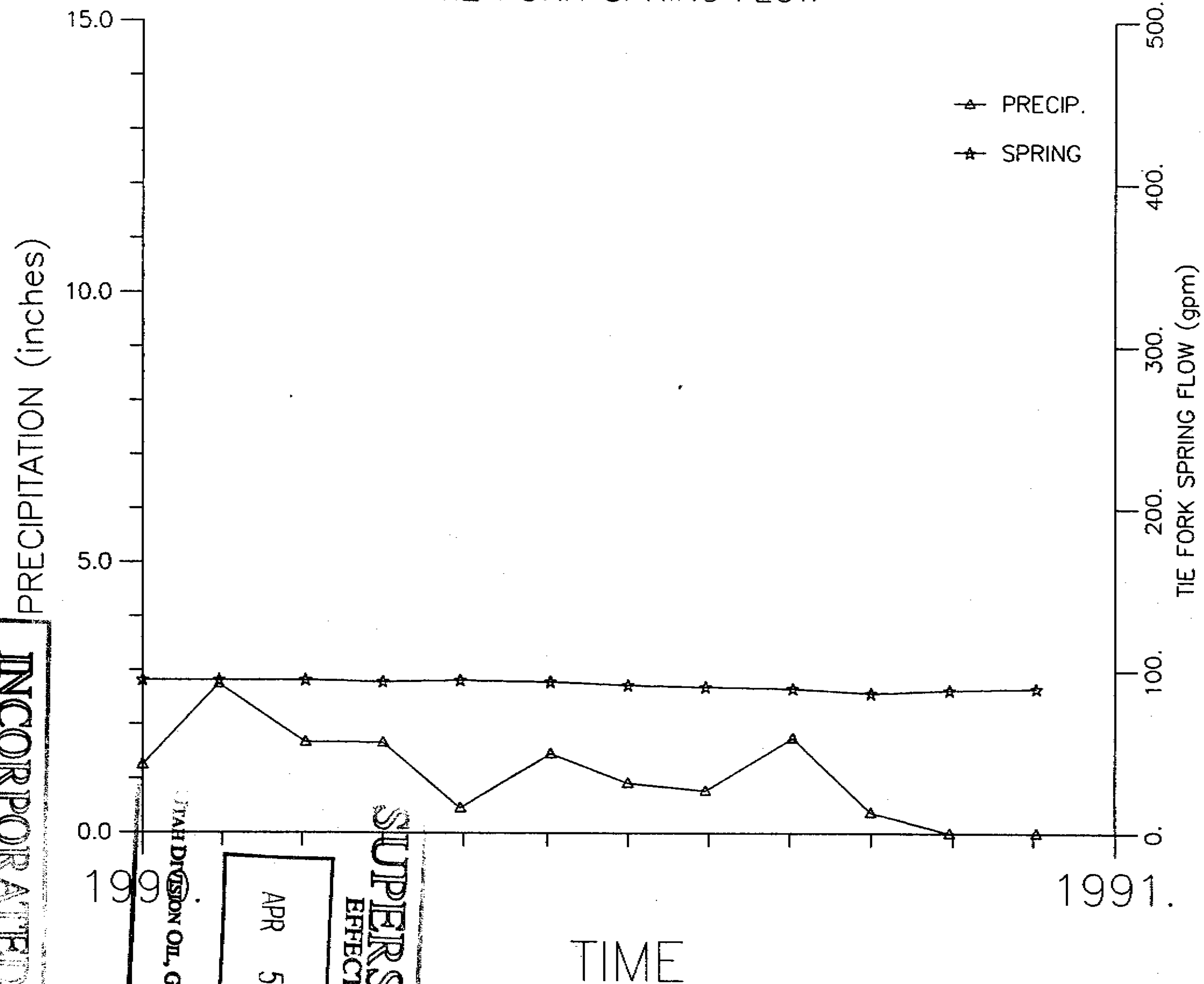
1988 AVERAGE PRECIPITATION, TIE FORK SPRING AND HUNTINGTON CREEK FLOW

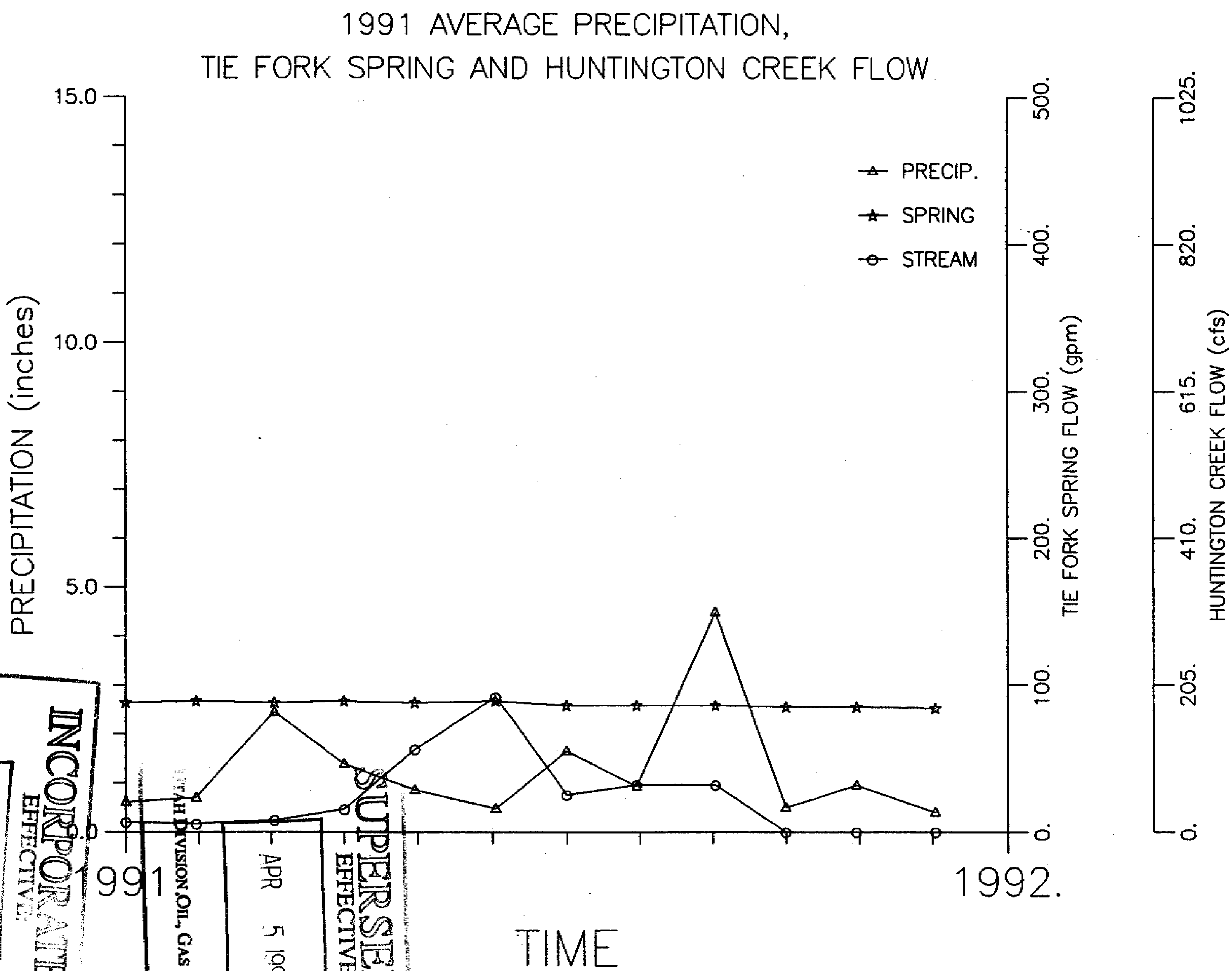


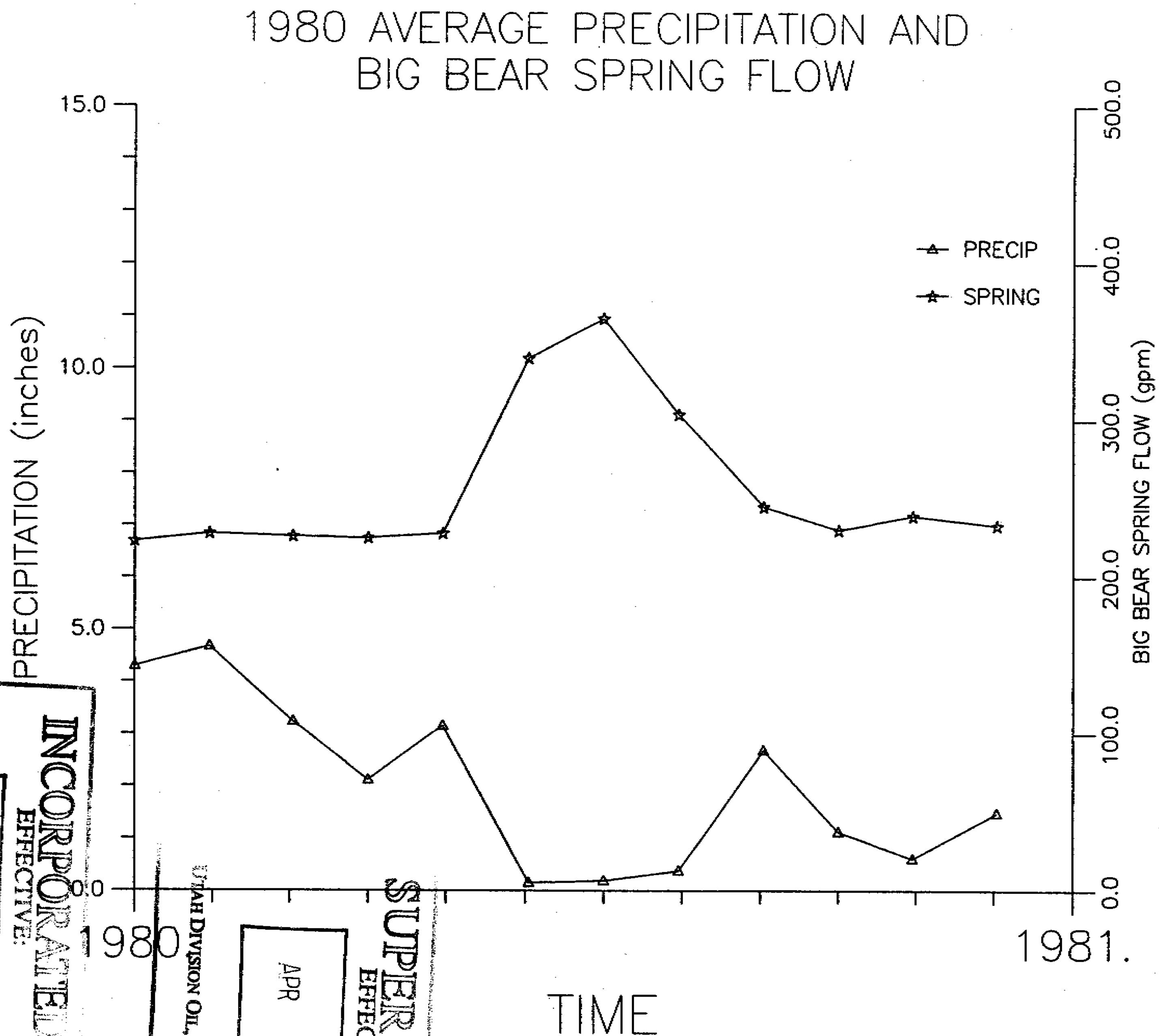
1989 AVERAGE PRECIPITATION AND
TIE FORK SPRING FLOW



1990 AVERAGE PRECIPITATION AND
TIE FORK SPRING FLOW

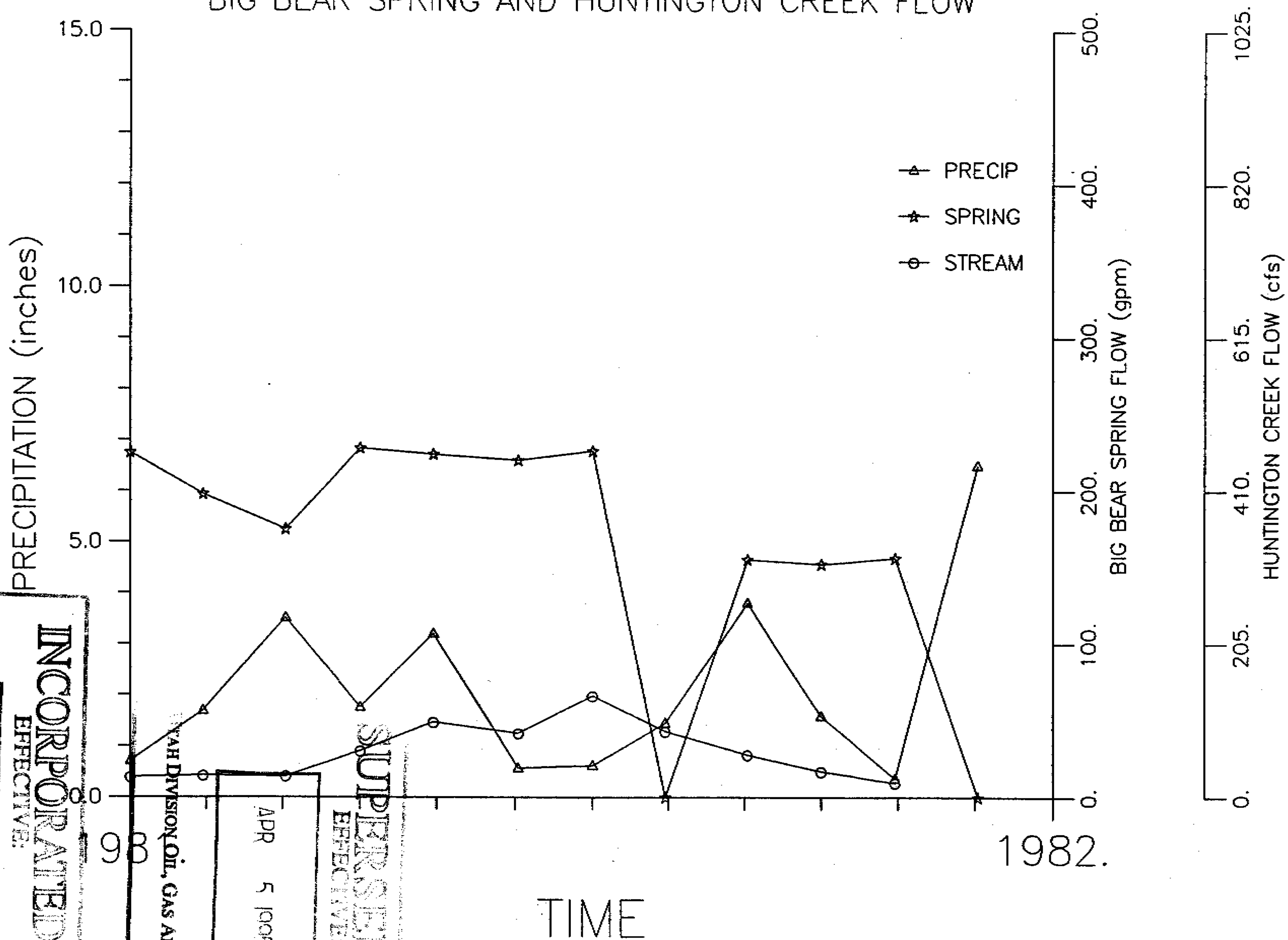



1991 AVERAGE PRECIPITATION,
TIE FORK SPRING AND HUNTINGTON CREEK FLOW
PRECIPITATION (inches)
15.0
10.0
5.0
0.0
PRECIP.
SPRING
STREAM
TIE FORK SPRING FLOW (gpm)
500.
400.
300.
200.
100.
0.
HUNTINGTON CREEK FLOW (cfs)
1025.
820.
615.
410.
205.
0.
1991
1992.
TIME

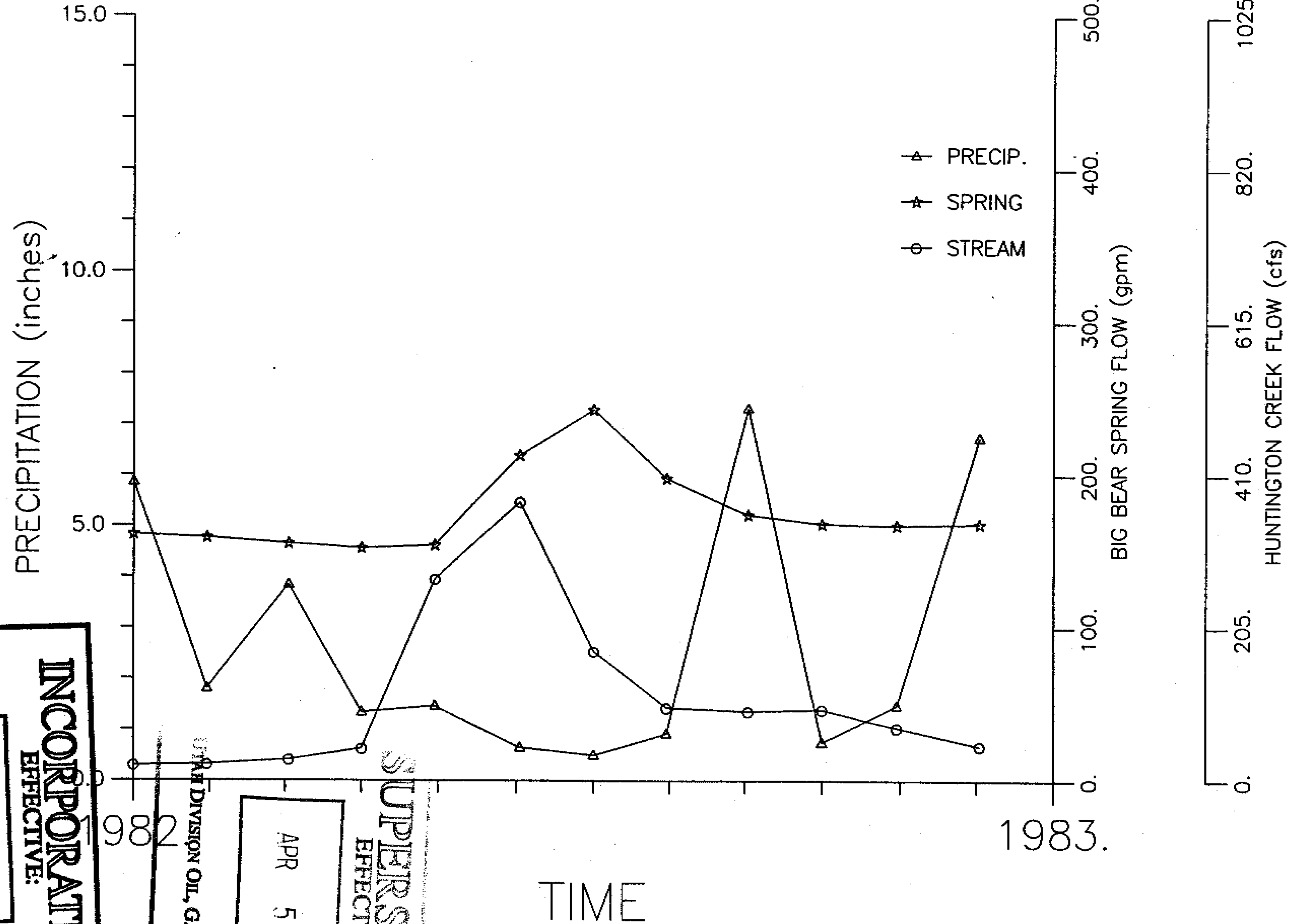


1980 AVERAGE PRECIPITATION AND
BIG BEAR SPRING FLOW
PRECIPITATION (inches)
15.0
10.0
5.0
0.0
BIG BEAR SPRING FLOW (gpm)
500.0
400.0
300.0
200.0
100.0
0.0
PRECIP
SPRING
1980
1981.
TIME

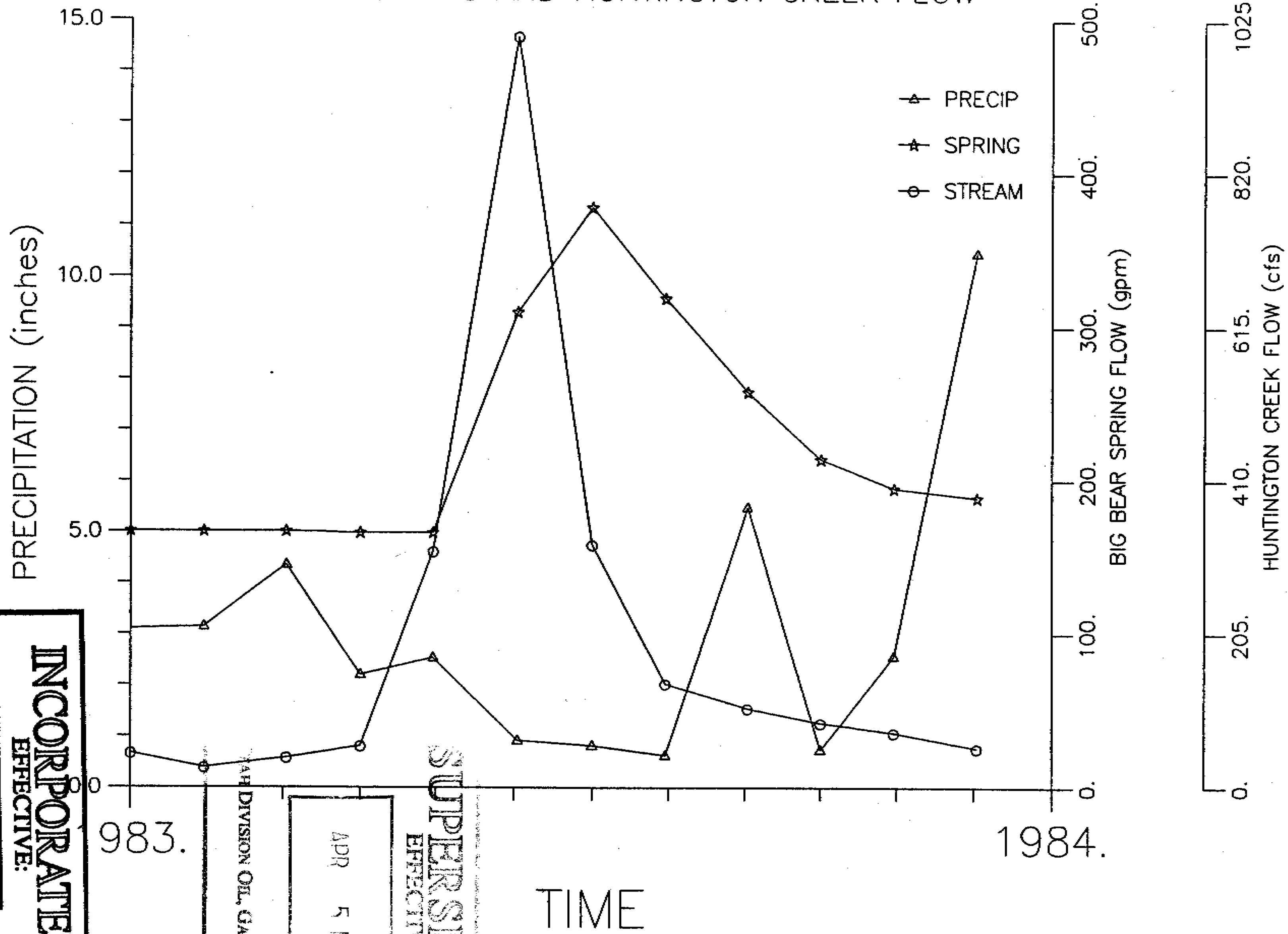
1981 AVERAGE PRECIPITATION,
BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



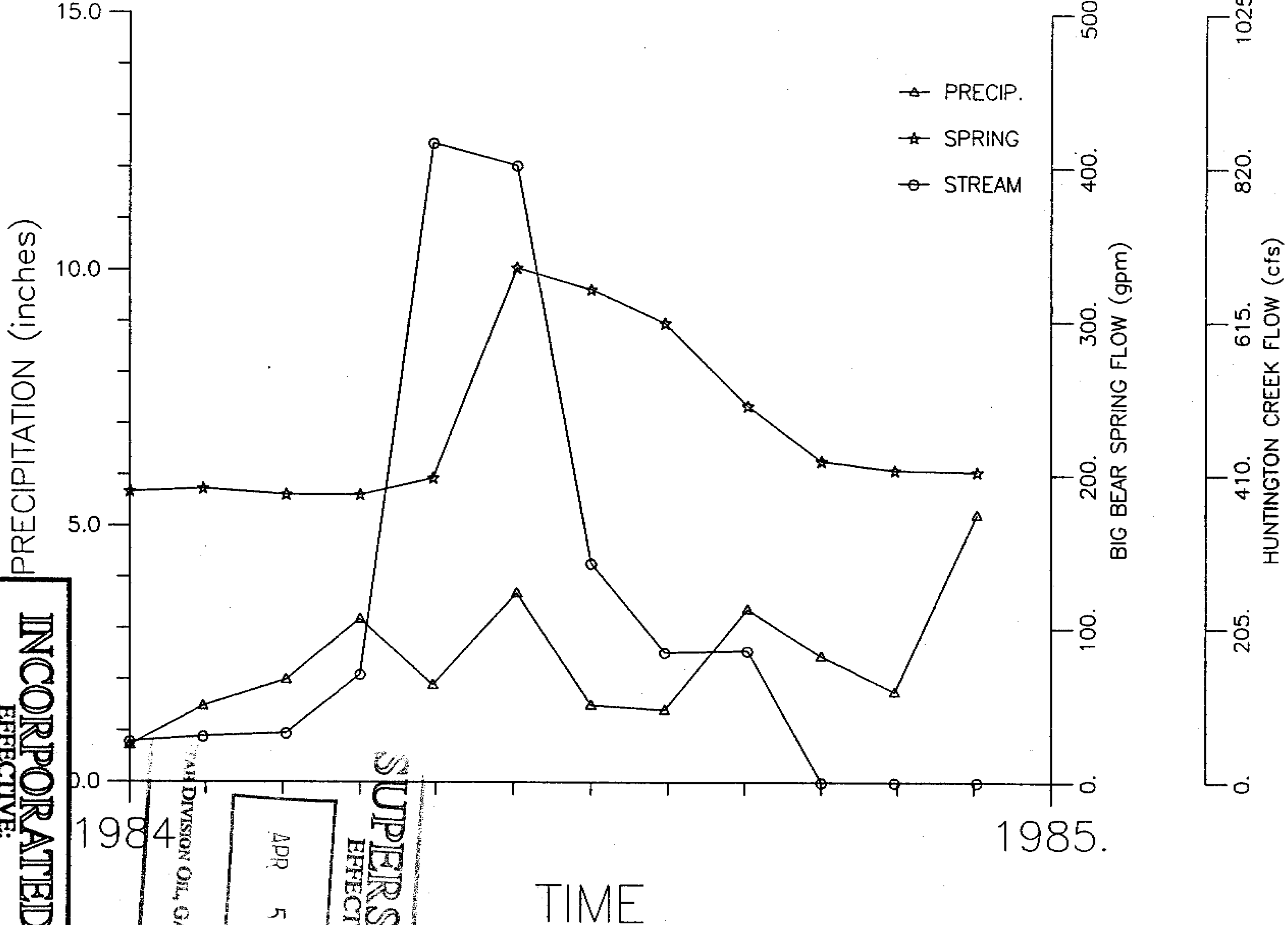
1982 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



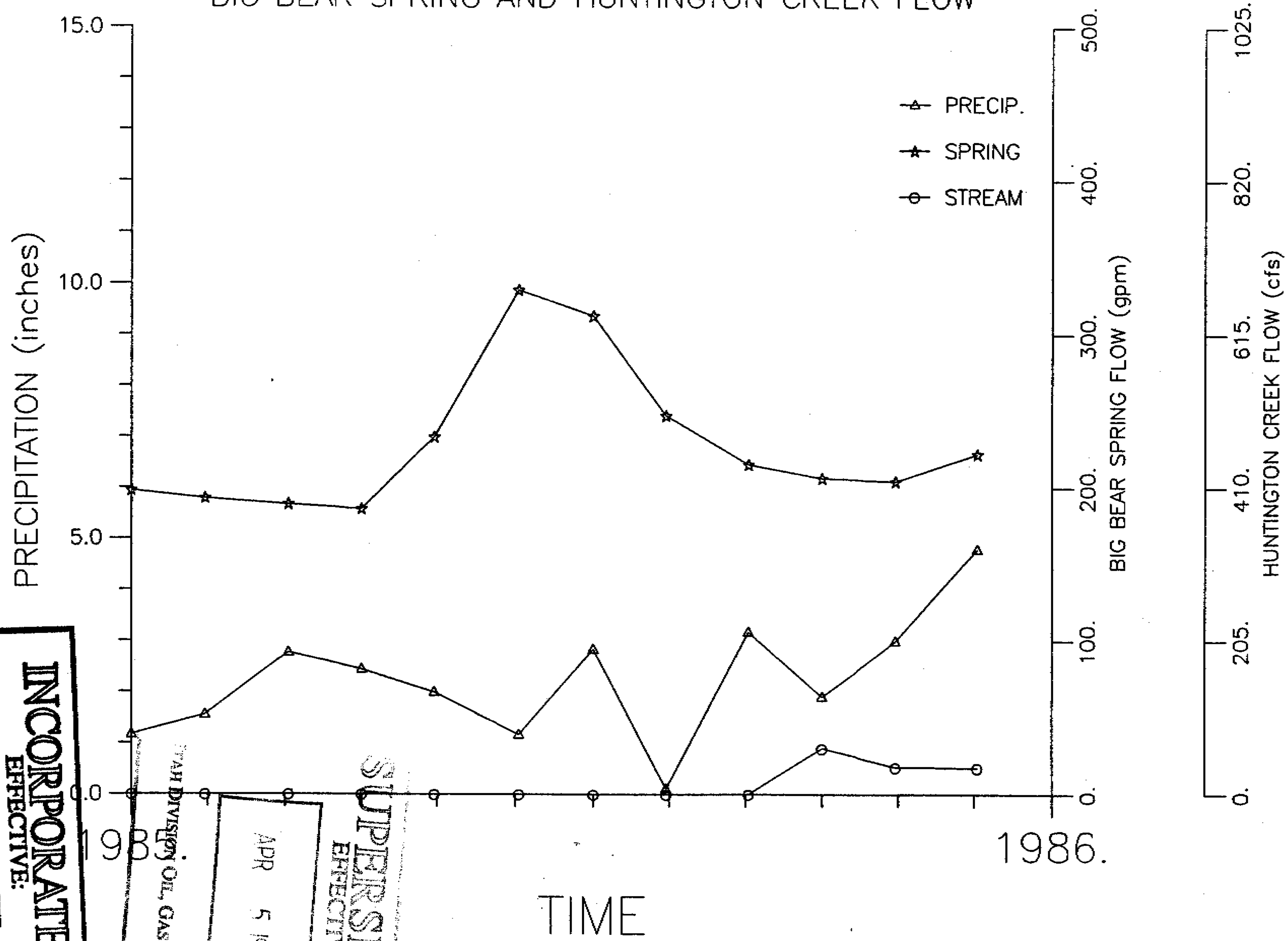
1983 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



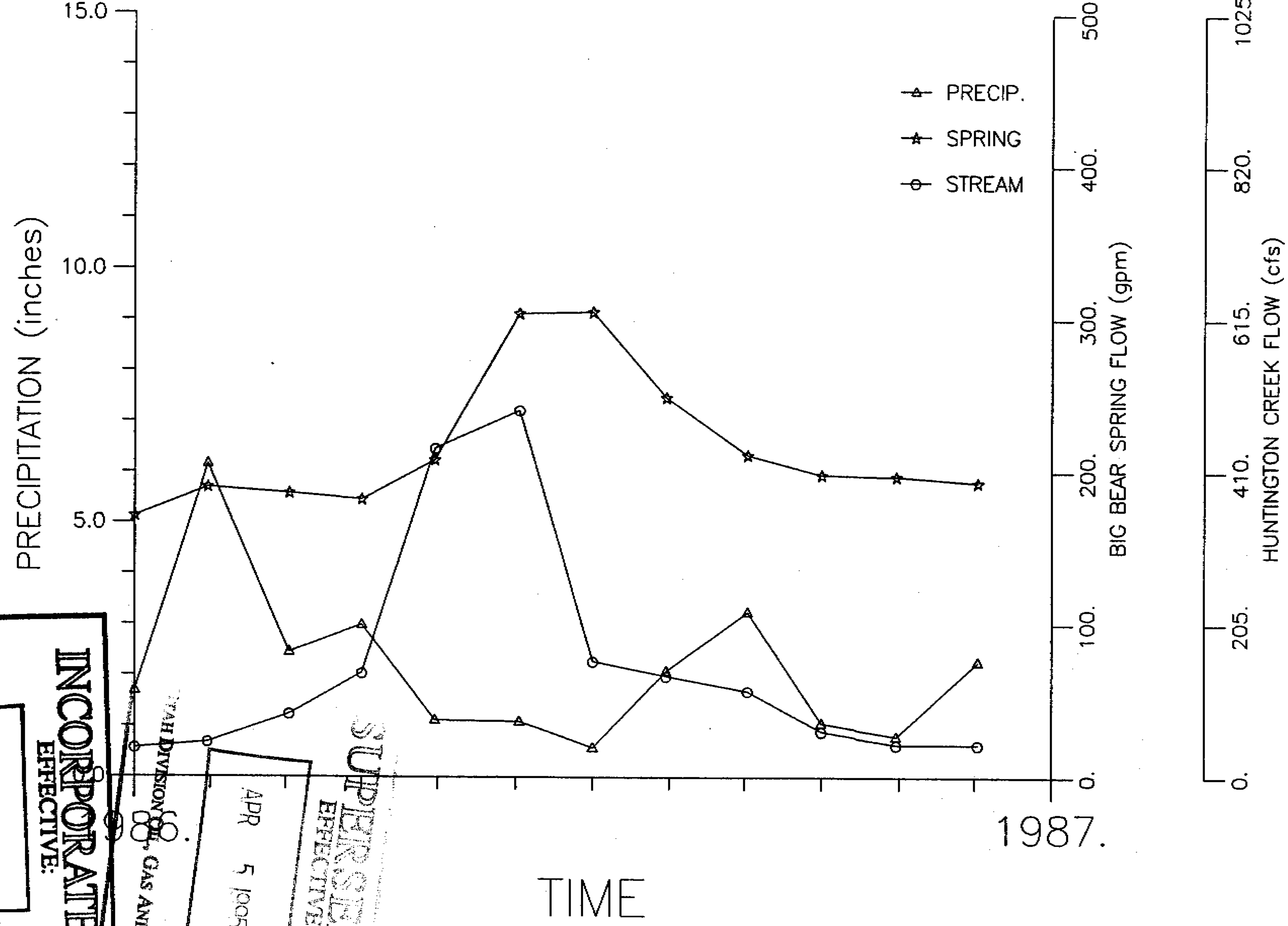
1984 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



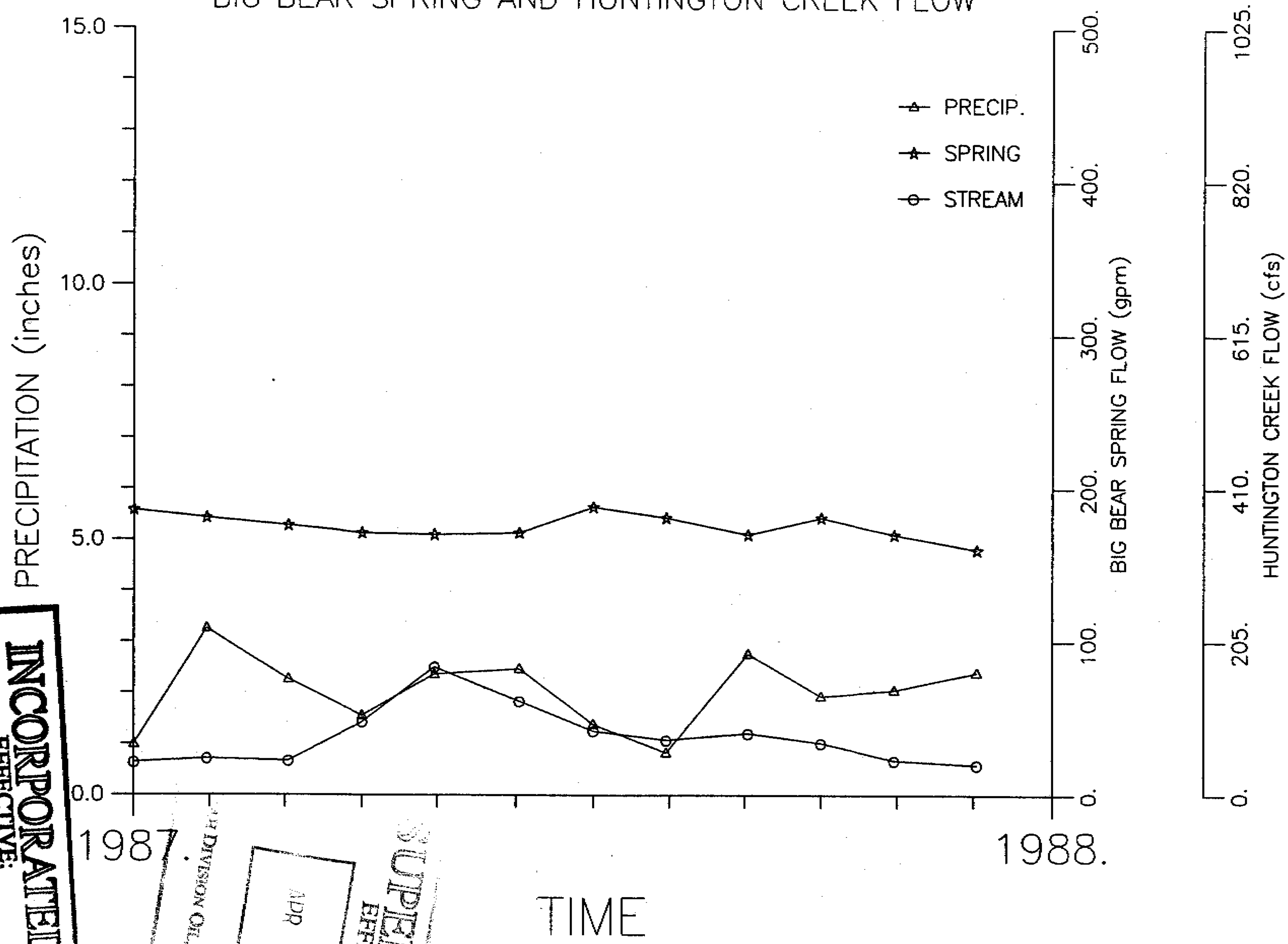
1985 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



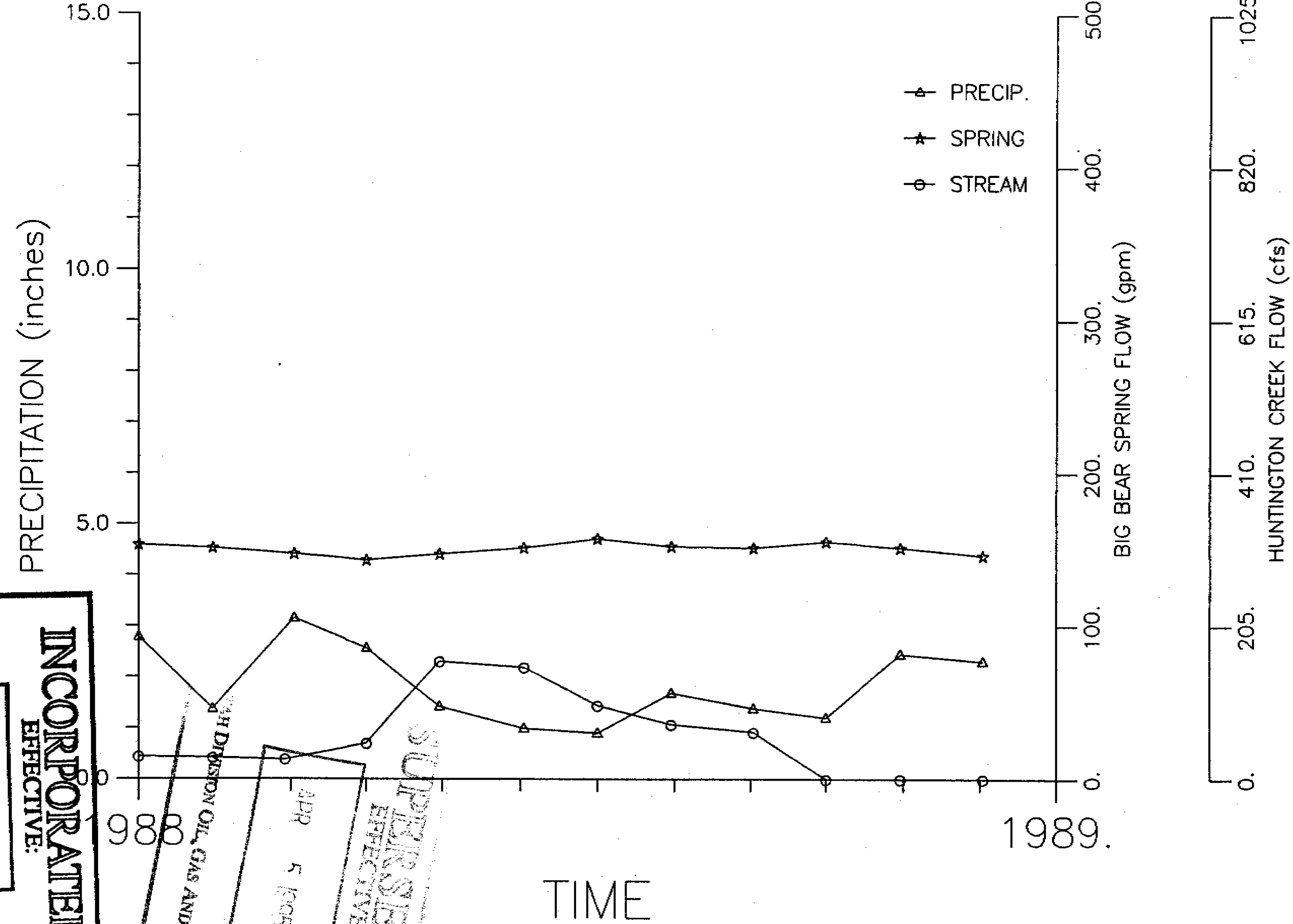
1986 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW

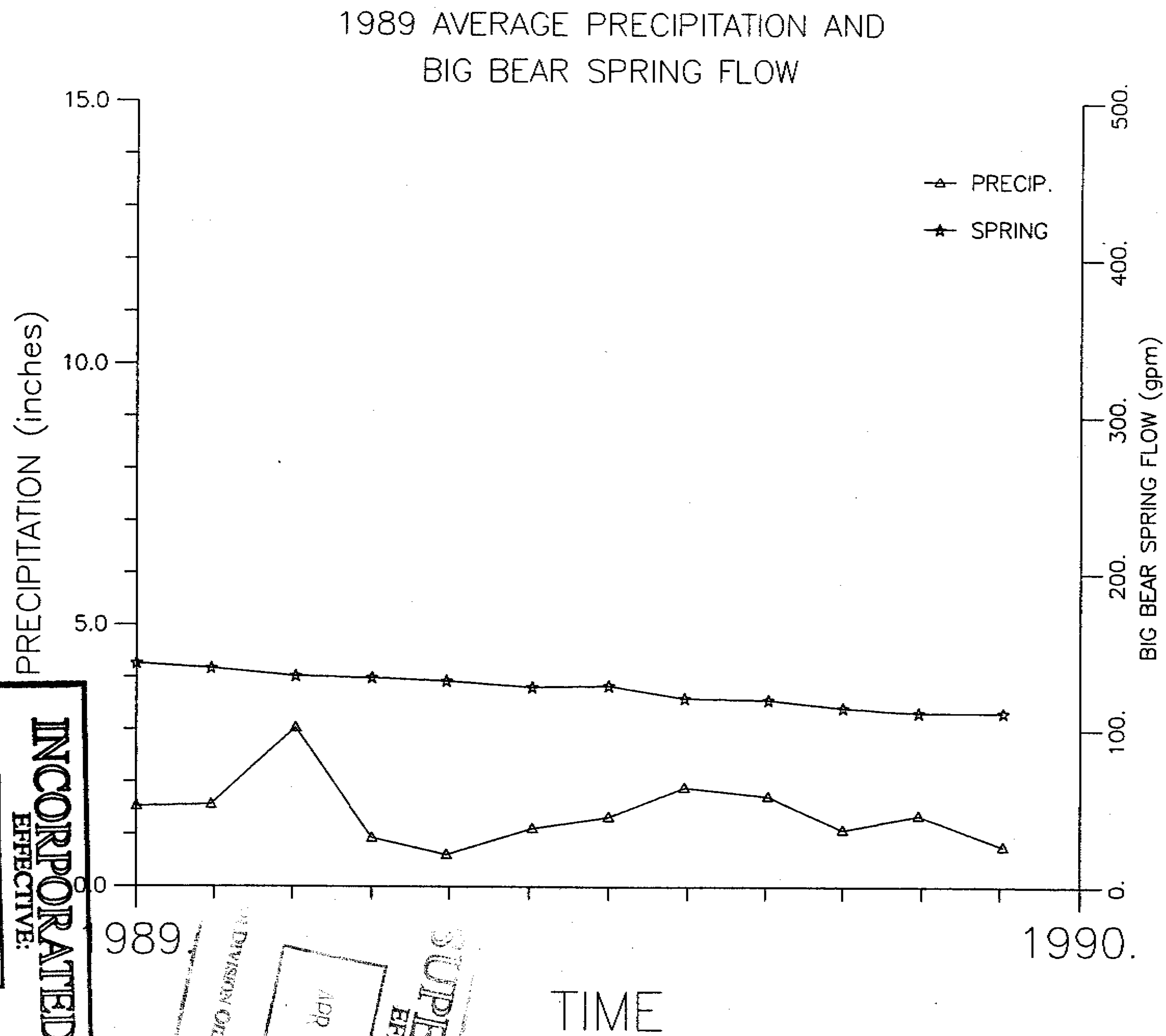


1987 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



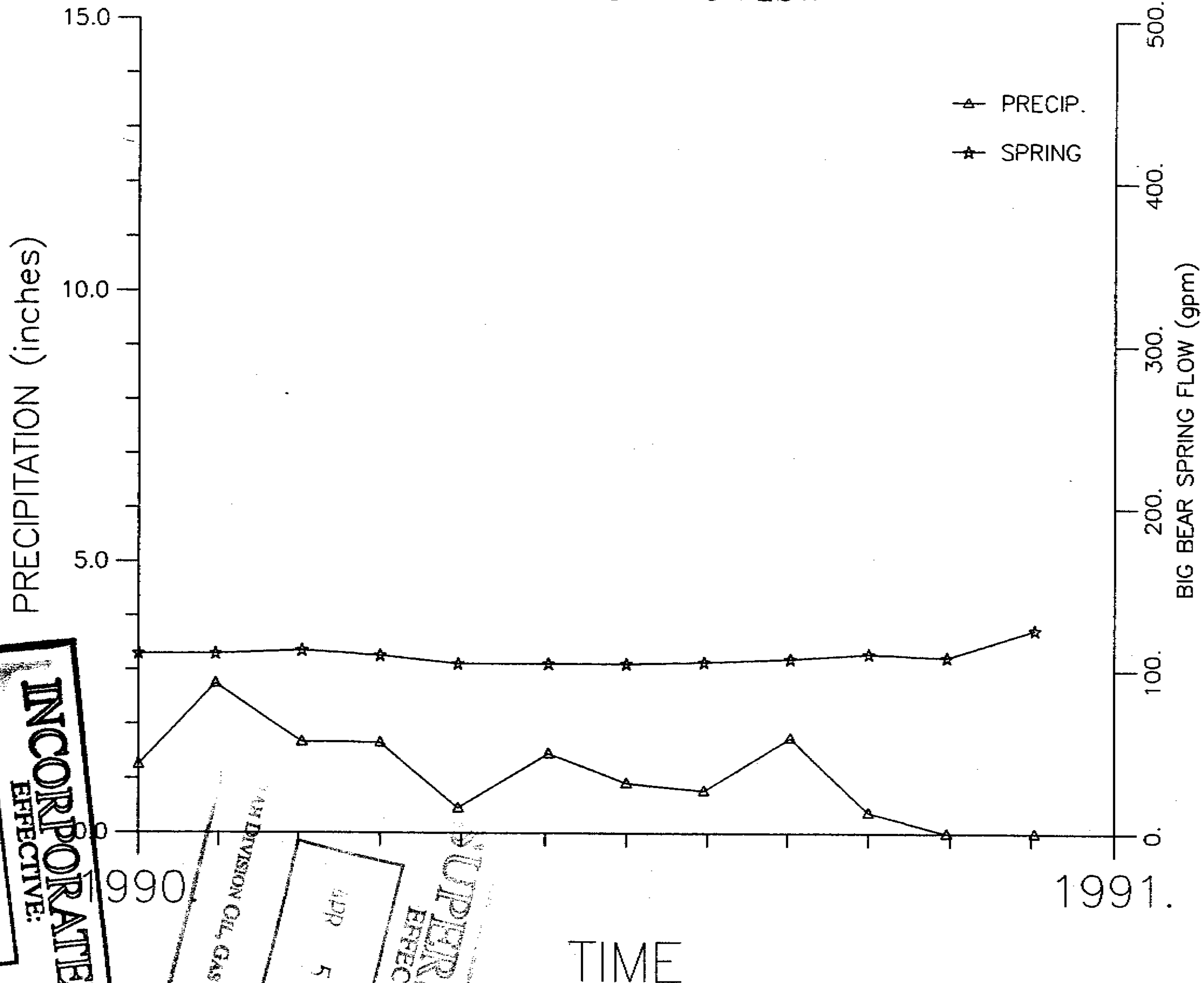
1988 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW



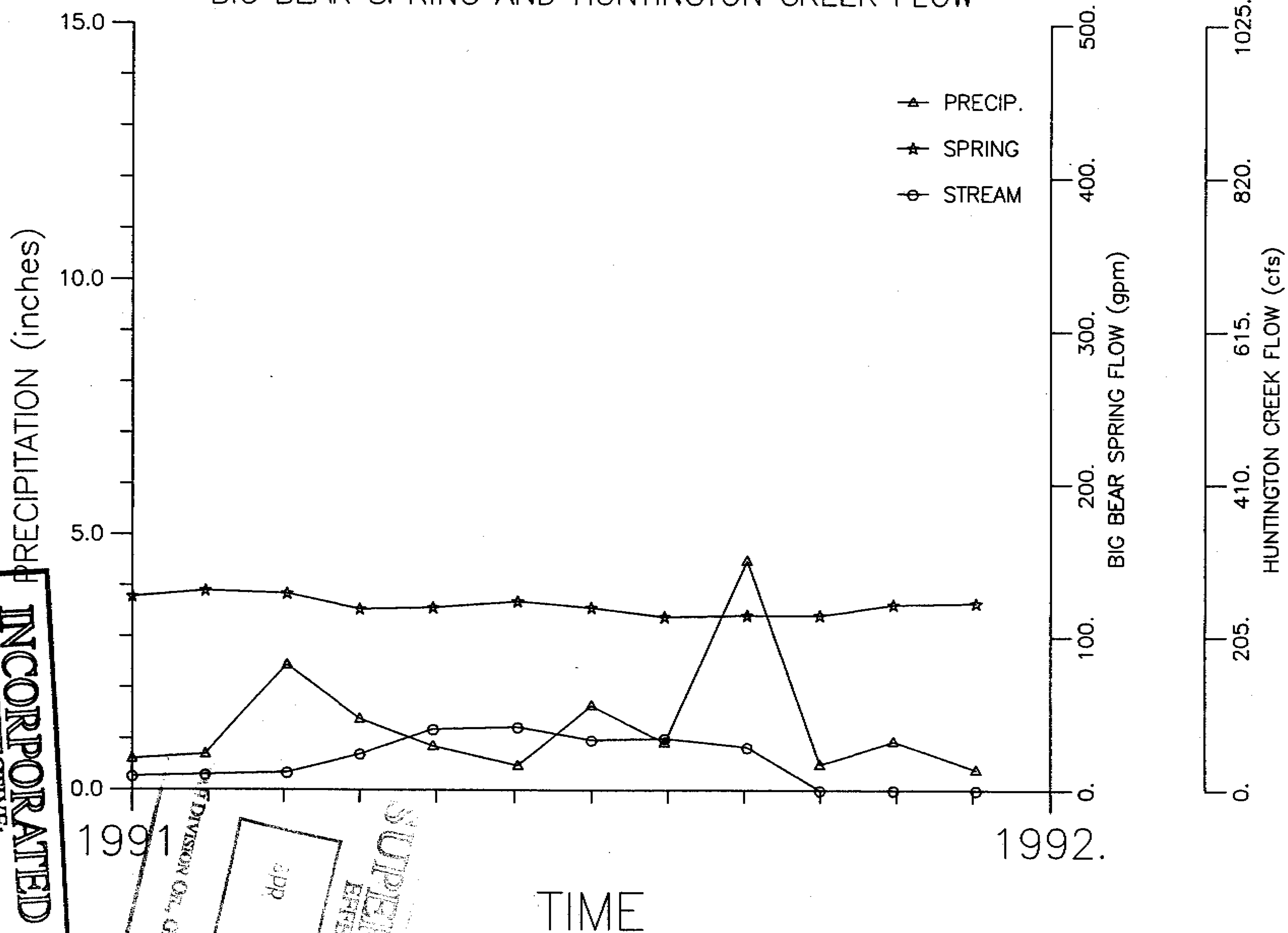


1989 AVERAGE PRECIPITATION AND
BIG BEAR SPRING FLOW
PRECIP.
SPRING
PRECIPITATION (inches)
BIG BEAR SPRING FLOW (gpm)
15.0
10.0
5.0
0.0
500.
400.
300.
200.
100.
0.
1989
1990.
TIME

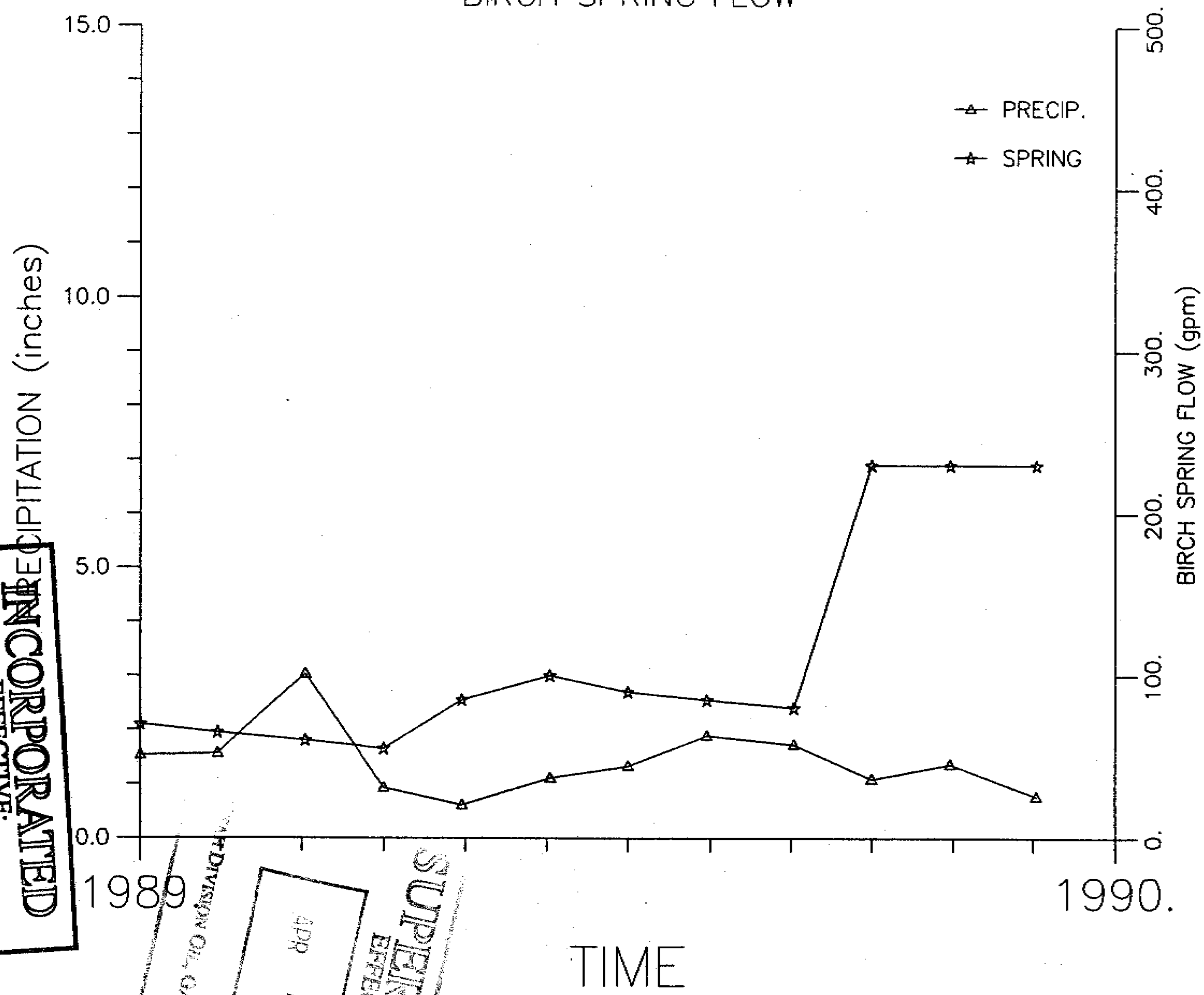
1990 AVERAGE PRECIPITATION AND
BIG BEAR SPRING FLOW



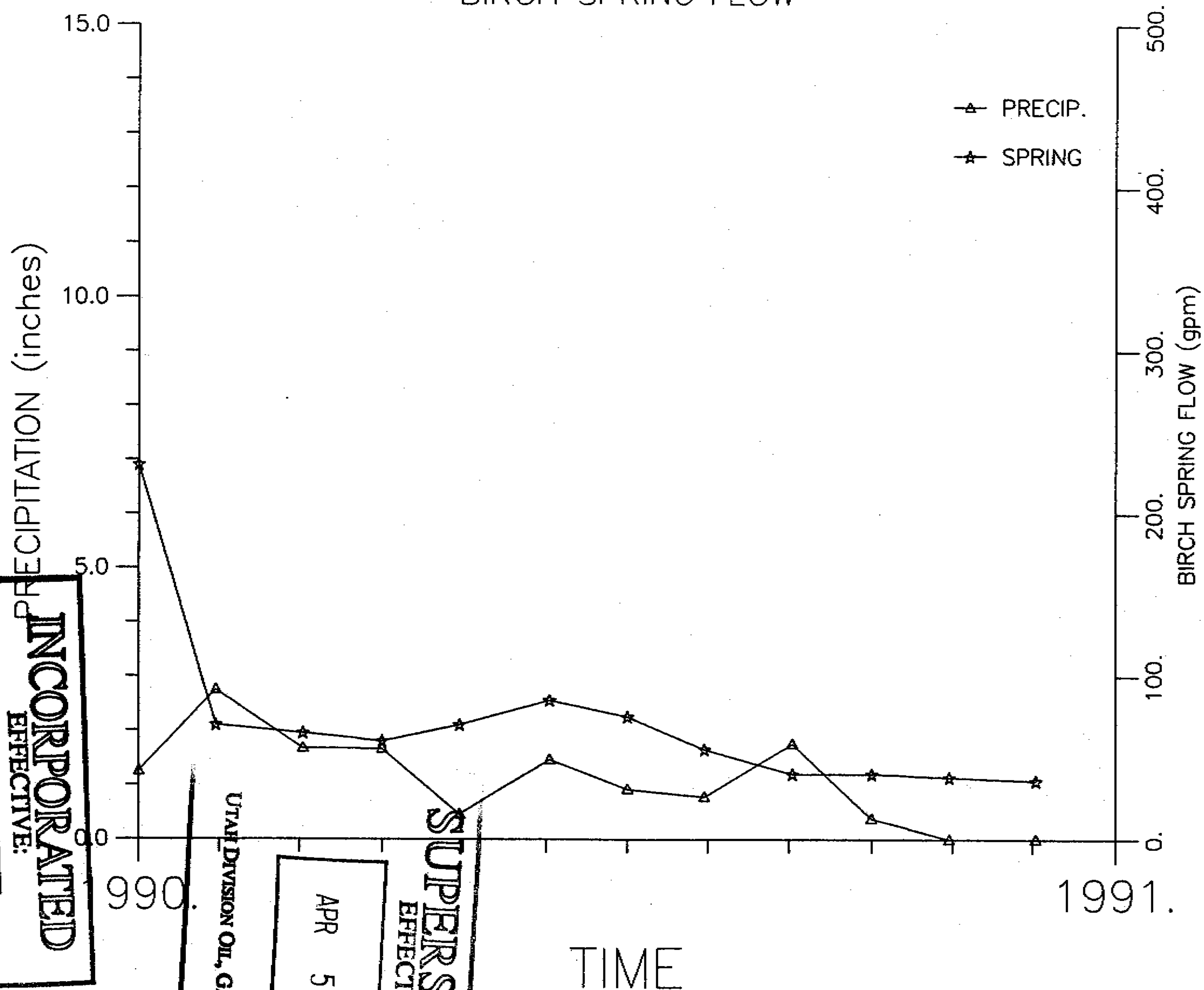
1991 AVERAGE PRECIPITATION, BIG BEAR SPRING AND HUNTINGTON CREEK FLOW

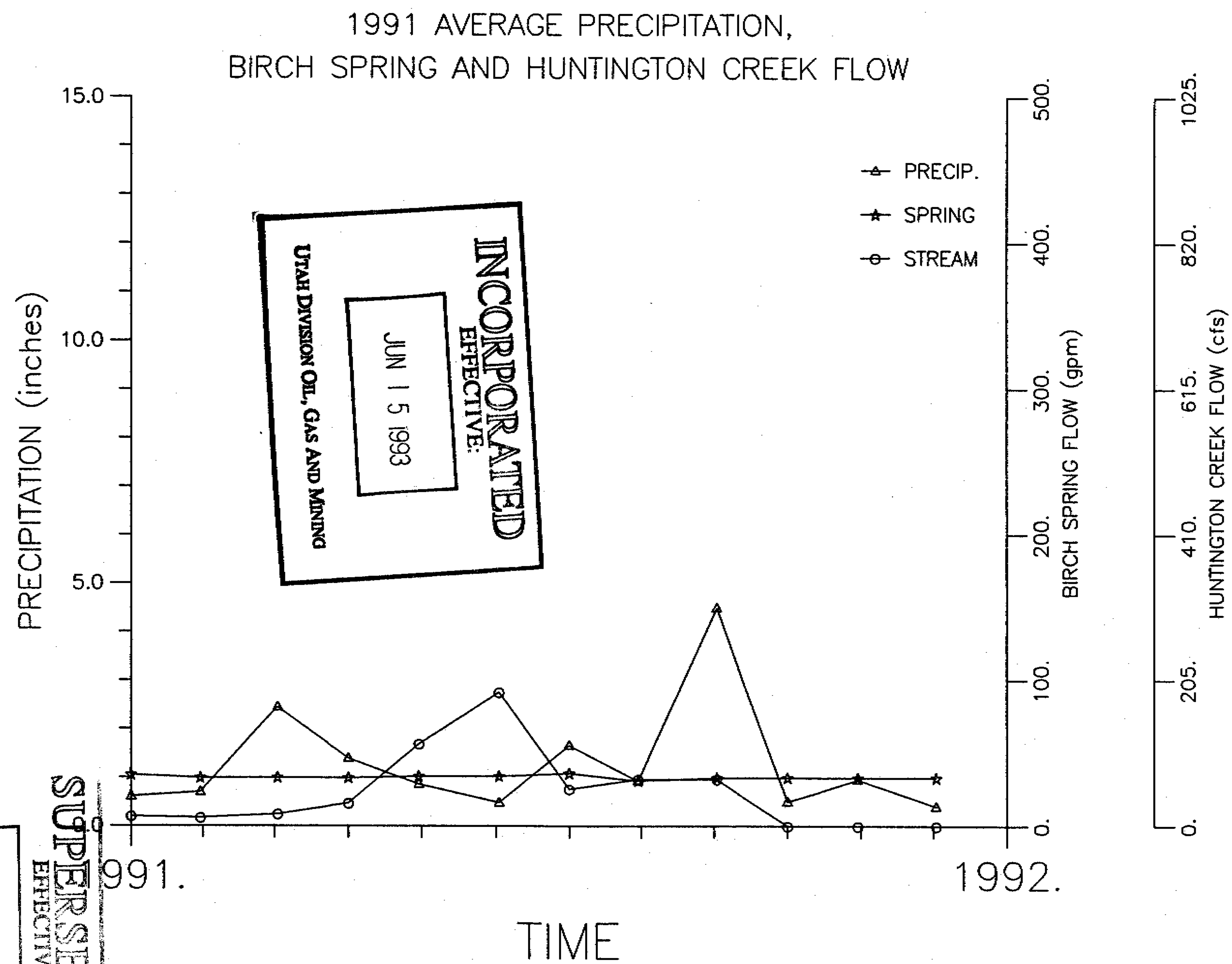


1989 AVERAGE PRECIPITATION AND
BIRCH SPRING FLOW



1990 AVERAGE PRECIPITATION AND BIRCH SPRING FLOW




1991 AVERAGE PRECIPITATION,
BIRCH SPRING AND HUNTINGTON CREEK FLOW
PRECIPITATION (inches)
15.0
10.0
5.0
0.0
BIRCH SPRING FLOW (gpm)
500.
400.
300.
200.
100.
0.
HUNTINGTON CREEK FLOW (cfs)
1025.
820.
615.
410.
205.
0.
PRECIP.
SPRING
STREAM
1991.
1992.
TIME