HYDROLOGIC IMPACTS OF THE SNOWCREEK GOLF COURSE EXPANSION ON THE AB AND CD HEADWATER SPRINGS

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SECTION 1
INTRODUCTION

PURPOSE

The purpose of this study is to estimate the impacts, if any, of present and future groundwater extraction in the Mammoth Basin area on the AB and CD headsprings near the Hot Creek Fish hatchery. The AB and CD spring discharge channels are habitats for the endangered Owens Valley tui chub (Gila bicolor snyderi). The biologic assessment of spring flow impacts will be done by others and is not included in this report. The specific impacts that are to be investigated include:

> "the effect of groundwater pumping on spring flows at the AB and CD headsprings. For the analysis, spring flows include the discharge, timing of discharge and water quality parameters." (July 1, 1996 letter from Dennis Martin, United States Department of Agriculture, Forestry Service to Diane Noda, Fish and Wildlife Service).

This analysis will examine the direct, indirect and cumulative effects of the Snowcreek golf course and current extractions by the Mammoth Community Water District (MCWD) and will include:

> "Determination of golf course groundwater extraction and timing.
>
> Determination of Water District extraction and timing
>
> Characterization of Mammoth Creek surface flows focusing on volume and timing.
>
> Characterization of the flows at the AB and CD headsprings, including flow volume, timing and water quality parameters" (July 1, 1996 letter from Dennis Martin, United States Department of Agriculture, Forestry Service to Diane Noda, Fish and Wildlife Service).

This report describes the hydrologic impacts of the proposed Snowcreek golf course expansion. Expansion of the Snowcreek golf course will require an increase in irrigation supply to the golf course that in turn may require: an increase in groundwater extraction, use of reclaimed water, or both. The California Department of Fish and Game and the U. S. Fish and Wildlife Service have expressed concern regarding potential changes in spring flow at the AB and CD headsprings that could be caused by future increases in groundwater extraction that may be caused specifically by expansion of the Snowcreek golf course, and in general by expanded urban and recreational land uses in the Mammoth Basin area.

MCWD is the principal water purveyor and wastewater treatment entity in the Mammoth Basin area. MCWD has developed a water supply plan to meet all future water demands using a combination of local water resources, reclaimed water and imported water. This plan includes potential for long term increases in groundwater extraction, some of which could be used for irrigation at the proposed expansion of the Snowcreek golf course (MCWD,1996).

SCOPE

The scope described herein was developed to evaluate the potential hydrologic impacts described above. The scope includes the following tasks:

Task 1 Collect, compile and review reports and data.

Task 2 Conduct assessments of the available reports and data to: characterize surface water discharges in the AB and CD headsprings and Mammoth Creek; and to develop relationships, if possible, of historical groundwater extraction in the Mammoth Basin and discharge at the AB and CD headsprings.

Task 3 Describe future and ultimate water demands in the Mammoth Basin.

Task 4 Describe impacts, if any, of increased groundwater extraction from the proposed expansion of the Snowcreek golf course and for ultimate development, on the AB and CD headsprings.

SECTION 2
MAMMOTH BASIN GEOLOGIC AND HYDROLOGIC SETTING

STUDY AREA

The general study area, shown in Figure 1, is located on the eastern flank of the Sierra Nevada mountain range approximately 30 miles north of the community of Bishop and almost directly west of Lake Crowley. The study area encompasses a total area of about 175 square miles, of which 155 square miles lay within and forms the Long Valley Caldera and some 20 square miles that are south and outside the caldera boundary (see Figure 2). Of primary interest to this study is the watershed area of the Mammoth Creek and Hot Creek which extends 13 miles eastward from Mammoth Mountain to a surface flow gaging station on lower Hot Creek. This area is shown in Figure 2. The topographically defined area of the Mammoth Basin is about 71 square miles and has maximum west-east and north-south dimensions of 13 and 9 miles respectively. Plate 1 shows the locations of wells, springs and other important features

The Mammoth Basin occupies a topographically diverse area on the eastern flank of the Sierra Nevada Mountain Range. Surface elevations range from about 12,500 ft-msl at Bloody Mountain in the southern part of the Basin to about 6,900 ft-msl at the far eastern extreme of the Basin. Surface topography ranges from flat to undulating in the Mammoth valley to sharp and craggy in the western mountainous elevations. The topography may be characterized as an alpine glaciated surface superimposed with extrusive volcanic terrain.

PRECIPITATION AND CLIMATIC VARIABILITY

Studies by the California Department of Water Resources (DWR, 1973) indicated that about 85 percent of all precipitation in the study area occurs during the period of October 1 through April 1. Figure 3 is an isohyetal map of average annual precipitation for the Mammoth Basin developed by DWR (DWR, 1973). Average annual precipitation ranges from about 60 inches in the

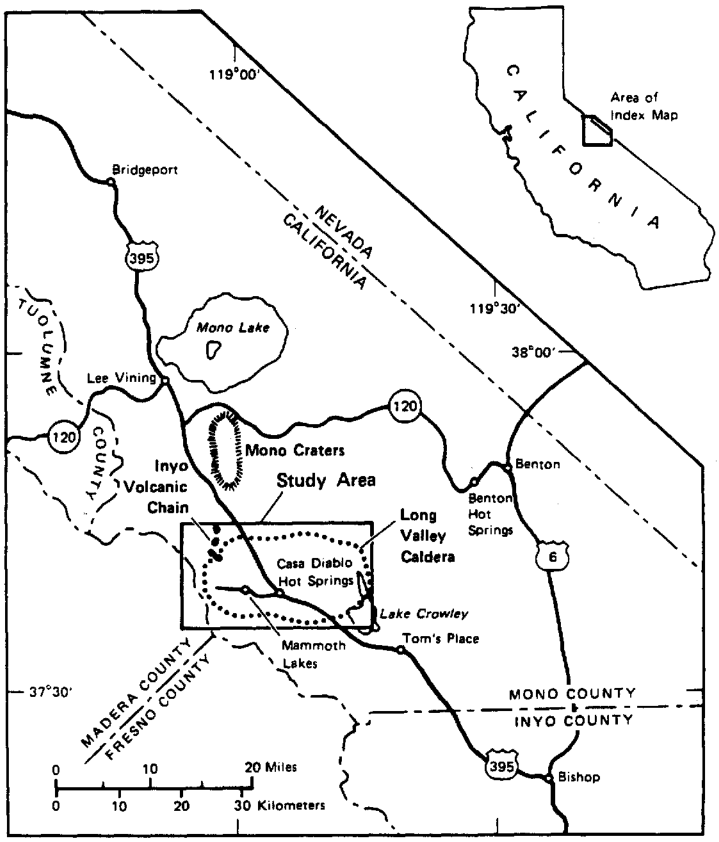

FIGURE 1
MAMMOTH BASIN
LOCATION MAP

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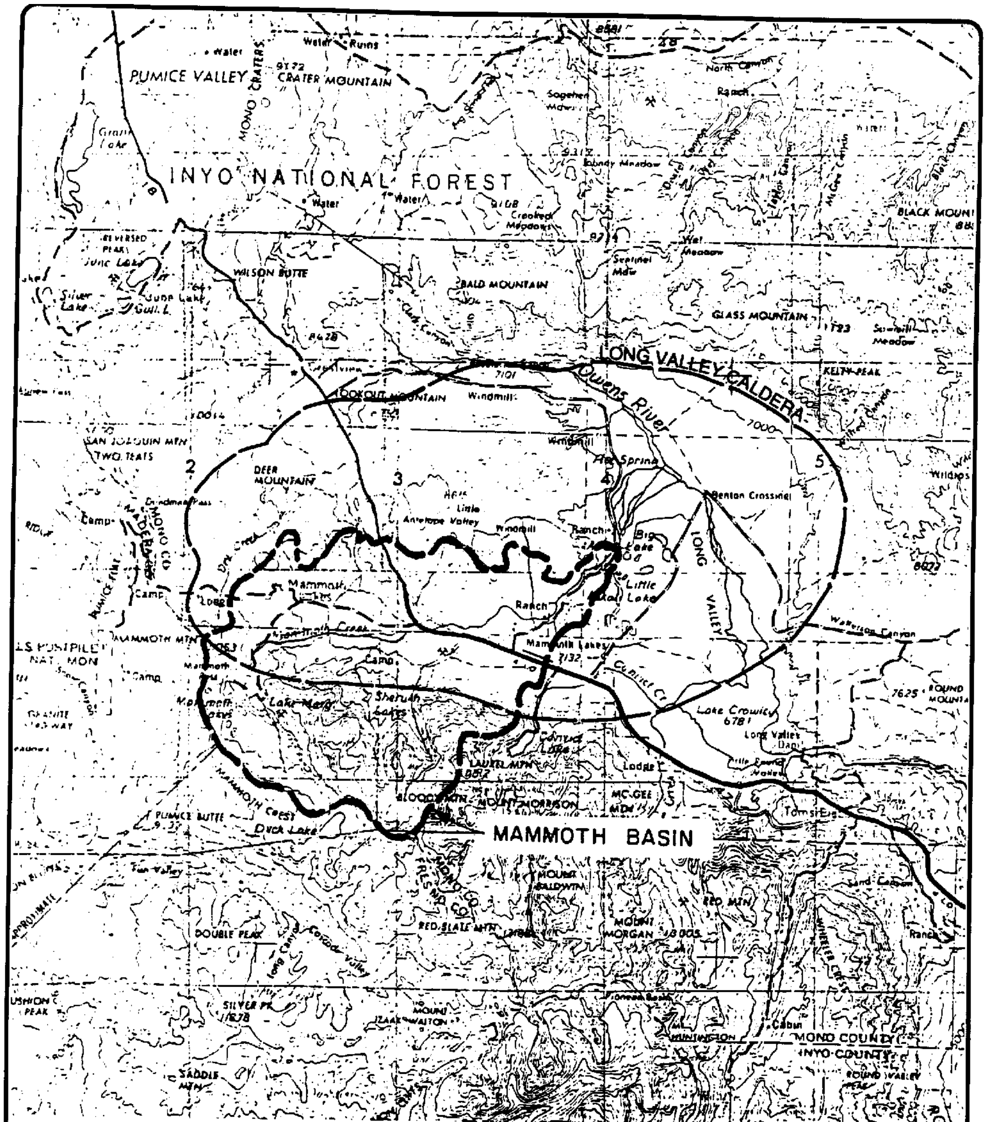
REFERENCE: U.S. Geological Survey Water-Resources Investigations Report 85-4183, 1985.



N

0 1 2 3

Approximate Scale: 1"= 3 Miles

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FIGURE 2
MAMMOTH BASIN
VICINITY MAP

REFERENCE: Brown & Caldwell and Triad Engineering, July, 1984.

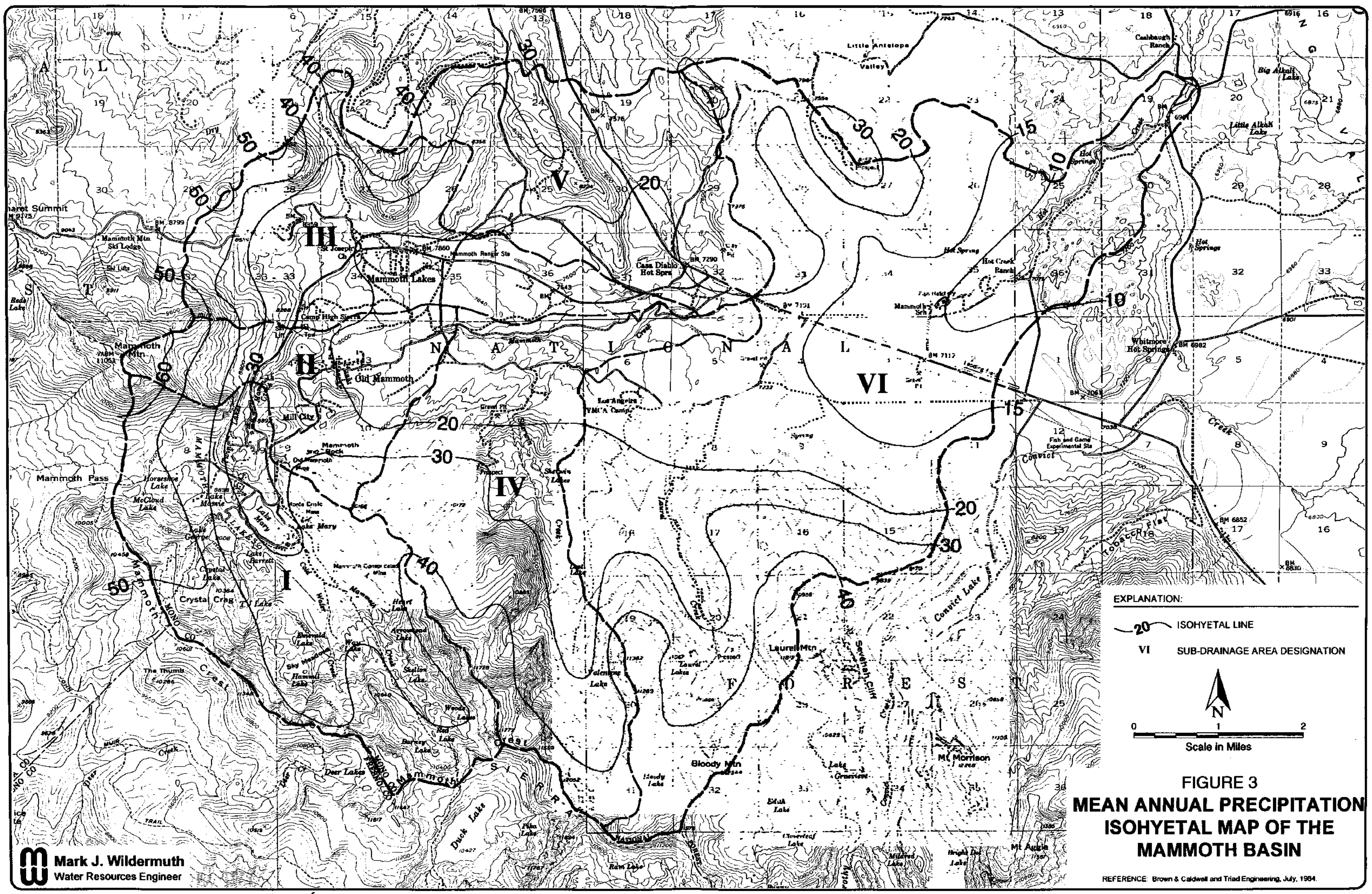

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FIGURE 3
MEAN ANNUAL PRECIPITATION ISOHYETAL MAP OF THE MAMMOTH BASIN

REFERENCE: Brown & Caldwell and Triad Engineering, July, 1984.

western mountainous area to about 10 inches in the extreme eastern part of the Basin. Precipitation occurs as snow and rain. Table 1 lists the annual precipitation totals at the Lake Mary Store station and the water content from the April 1 snow course survey. The Lake Mary Store precipitation data and April 1 snow survey data are collected by the Los Angeles Department of Water and Power (LADWP). Precipitation records at Lake Mary Store started in 1948 and runs to the present. Annual precipitation at Lake Mary Store averages about 28 inches per year and ranges from a high of about 56 inches per year to a low of about 17 inches per year. April 1 snow survey records start in 1943. Snow water content from the April 1 snow surveys average about 43 inches per year and range from a high of about 89 inches per year to a low of about 9 inches per year.

Figure 4 is a plot of the accumulated departure from the mean for precipitation at Lake Mary Store and the April 1 snow survey. The accumulated departure from the mean (ADFM) plot is useful in characterizing wet and dry climatic periods. Negative sloped line segments indicate periods of below mean precipitation, and positively sloped line segments indicate period of above normal precipitation. For example, the period from 1978 to 1986 was a wet period and the period from 1987 to 1992 was a dry period. Review of the entire record for Lake Mary Store and the April 1 snow surveys indicate that the 1978 to 1986 period was the wettest period in the 50-year precipitation record; and that the following dry period of 1987 to 1992 was the most severe drought of record. In fact, applying the ADFM approach to the LADWP/USGS stream flow history for Mammoth Creek at Old 395 indicates that the 1978 to 1986 period was the wettest period in the last 63 years; and that the dry period of 1987 to 1992 was the most severe drought period (in terms of magnitude and length) in the last 63 years. Stream discharge data will be characterized later in this section.

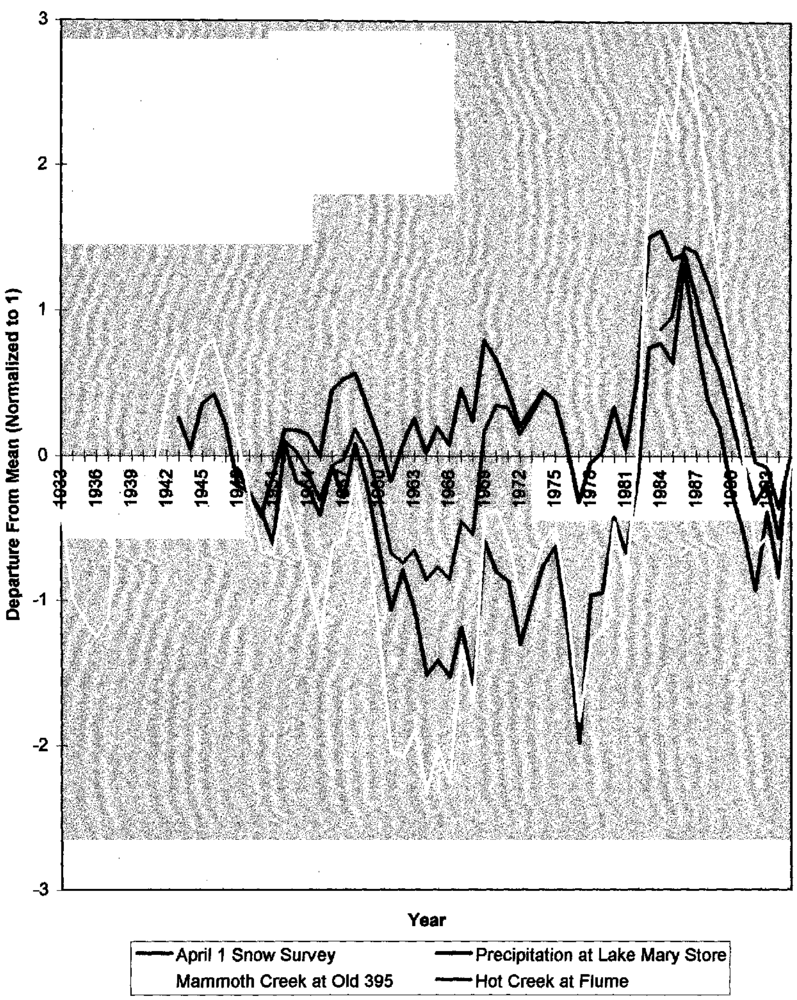
Geology and Hydrogeology of the Mammoth Basin Area

The Mammoth Basin watershed straddles the southern boundary of the Long Valley Caldera. Figure 5 depicts the general surface geology in the project area. Approximately one half of the basin lies inside the downdropped caldera feature and one half is south of and outside the caldera. Mammoth Basin is generally formed by elevated areas on the north and west that are comprised largely of Tertiary extrusive igneous rocks; a central trough filled with Quaternary alluvial and

Table 1
Precipitation and Surface Discharge at Major Stations
Mammoth Basins

Year	Apr 1 Snow Surveys (inches/yr)	Precip at Lake Mary Stores (inches/yr)	Mammoth Creek at Old 395 (acre-ft/yr)	Hot Creek at Flume (acre-ft/yr)
1933			9,860	
1934			6,136	
1935			13,650	
1936			14,125	
1937			18,069	
1938			32,544	
1939			10,193	
1940			15,628	
1941			21,655	
1942			23,873	
1943	54.70		19,990	
1944	34.30		12,314	
1945	57.30		20,914	
1946	46.20		16,806	
1947	34.50		11,210	
1948	25.30	25.93	9,982	
1949	41.30	23.54	9,461	
1950	37.90	24.05	9,612	
1951	33.60	36.44	15,741	36,915
1952	73.70	37.50	22,986	51,491
1953	32.30	28.35	11,574	38,958
1954	41.60	27.60	10,449	36,180
1955	35.20	24.12	9,561	33,860
1956	58.40	41.50	25,935	52,246
1957	34.20	30.75	16,411	43,655
1958	59.60	29.65	23,128	50,971
1959	30.80	22.00	8,261	35,454
1960	24.30	22.05	5,264	29,221
1961	25.60	20.00	3,487	25,437
1962	55.40	35.65	15,358	39,060
1963	31.40	33.75	18,965	45,759
1964	24.20	21.69	9,114	33,531
1965	48.00	33.60	20,877	45,942
1966	38.50	24.90	12,159	38,482
1967	58.50	39.50	30,780	59,016
1968	26.50	22.25	9,724	38,314
1969	86.50	44.30	36,702	72,128
1970	34.10	24.65	16,453	49,658
1971	41.00	22.65	12,773	41,322
1972	24.50	21.10	9,034	34,429
1973	56.10	32.15	18,041	47,743
1974	54.80	31.95	20,823	48,326
1975	49.10	26.50	17,468	
1976	18.80	19.68	7,388	
1977	9.20	17.28	3,151	
1978	87.80	36.18	24,617	
1979	44.40	30.61	17,246	
1980	66.30	37.37	27,877	
1981	32.70	20.11	9,566	
1982	65.40	42.58	30,091	
1983	83.70	55.90	45,812	
1984	44.70	29.90	24,077	60,786
1985	37.70	22.88	12,103	45,835
1986	72.90	29.57	28,699	62,096
1987	21.40	19.94	8,110	40,632
1988	24.90	19.46	5,973	33,506
1989	35.50	22.58	5,845	31,389
1990	24.10	19.30	5,074	27,953
1991	31.10	20.00	6,918	29,317
1992	26.30	20.40	5,842	27,291
1993	67.10	32.60	17,449	40,499
1994	24.00	17.55	7,487	30,100
1995	80.00	44.60	33,224	57,366
Average	43.06	28.44	15,929	42,495
Std. Dev.	18.33	8.35	8,838	10,963
Coef of Var.	43%	29%	55%	26%
Max	87.80	55.90	45,812	72,128
Min	9.20	17.28	3,151	25,437

Figure 4 Accumulative Departure From Mean For Key Hydrologic Time Series in the Mammoth Basin



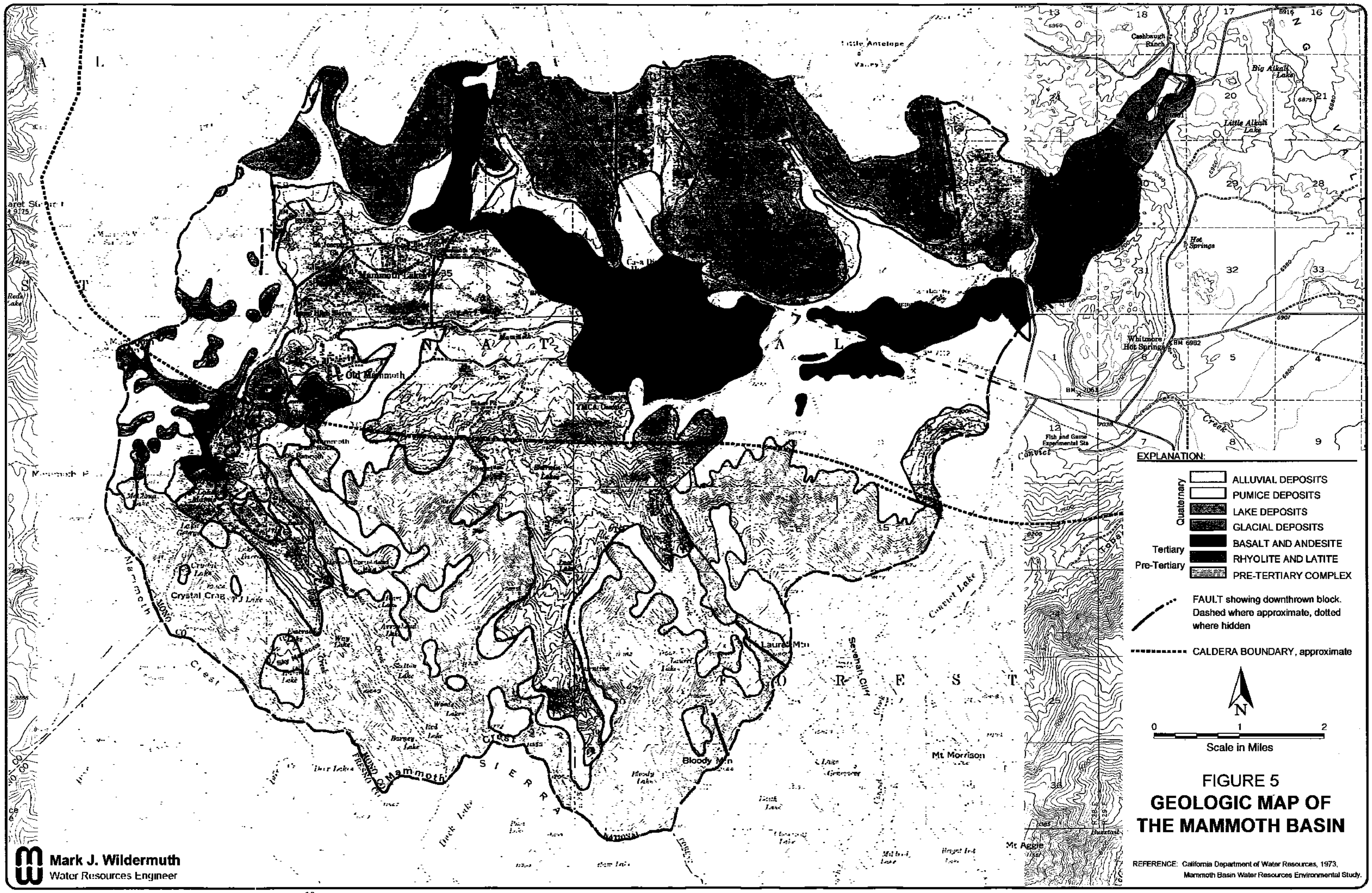


FIGURE 5
GEOLOGIC MAP OF THE MAMMOTH BASIN

REFERENCE: California Department of Water Resources, 1973, Mammoth Basin Water Resources Environmental Study.

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glacial debris; and an abrupt southern flank of Pre-Tertiary igneous intrusive and metamorphic rocks. The central trough area opens and drains to the east through Quaternary glacial and alluvial deposits to the Owens River and Lake Crowley. Quaternary lake deposits occur sporadically within the eastern portion of the Basin. Numerous faults occur in the extrusive igneous rocks along the northern flank of the basin, while few faults have been mapped in the central and southern parts of the basin

Rock Formation Water Bearing Characteristics

Previous studies have indicated more than 20 geologic rock units are present in the project area. For hydrogeologic purposes, these rock units can be grouped into five general formation categories. The relative water bearing characteristics of the rock formations exposed and underlying Mammoth Basin are described herein for the rocks from youngest to oldest in age.

Quaternary Alluvial Deposits (Qad) - This formation is comprised of detritus derived from all other rock formations in the project area. Such deposits are comprised of clay, silt, sand, cobbles and boulders that are generally unconsolidated and range in thickness from a thin wedge to an estimated 60 feet (DWR, 1973). These alluvial deposits range in permeability from low to moderate, and do not constitute large groundwater reservoirs because of their limited thickness and areal occurrence.

Quaternary Lake Deposits (Ql) - These lake sediments were deposited during the upper Pleistocene epoch in a large regional lake that was created by the damming of the upper Owens River Valley by volcanic and glacial rock materials. The lake deposits are most frequently comprised of unconsolidated fine grained sediments that are of low permeability and produce only small-to-moderate quantities of water. Depths of these deposits range to over 200 feet regionally. However, in the Mammoth Basin, depths appear to reach only to a few tens of feet in localized areas and therefore do not appear to constitute significant aquifers.

Quaternary Glacial Deposits (Qg) - During the Quaternary (Pleistocene) epoch, alpine glaciation was active throughout a large area of the Sierra Nevada Ranges. Remnants of this glaciation continue to persist today in some of the higher mountainous elevations. Within the project area, features related to glaciation and glacial deposition are present, for the most part, in the southern and central sectors of Mammoth Basin. The glacial deposits are slightly to moderately consolidated, consist of clay to boulder size fragments and provide locally good groundwater sources and storage. Such materials were deposited at several glacial and inter-glacial intervals throughout the Pleistocene epoch and vary in thickness from a few feet to more than 100 feet.

Quaternary through Tertiary Igneous Rocks (Vb), (Vr) - These rock formations consist of lava flows, breccias and tuffs inter-bedded with glacial debris. Types of rock include basalt, rhyolite, latite and andesite. These formations occur mainly in the northern and western parts of the basin and largely within the southern part of the Long Valley Caldera. Secondary porosity in these volcanic rocks along with the inter-bedded glacial sediments produce significant aquifers in the central part of the Mammoth Basin. These rocks range in depth to more than 3,000 feet.

Pre-Tertiary Rocks (pT) - This complex of rocks includes Paleozoic Metasediments, Mesozoic Metavolcanics and Cretaceous intrusive rocks. The rocks contained within this complex include a wide variety of igneous and metamorphic types which occur exclusively in the southern part of the Mammoth Basin. Groundwater in the pre-tertiary rocks is generally associated with the secondary porosity of faults, joint systems and crush and fracture zones. The quantity of groundwater yielded from these rocks in the Mammoth Basin vicinity is usually small. The Pre-Tertiary rocks are the basement complex of the Sierra Nevada.

The Mammoth Basin Groundwater Regime

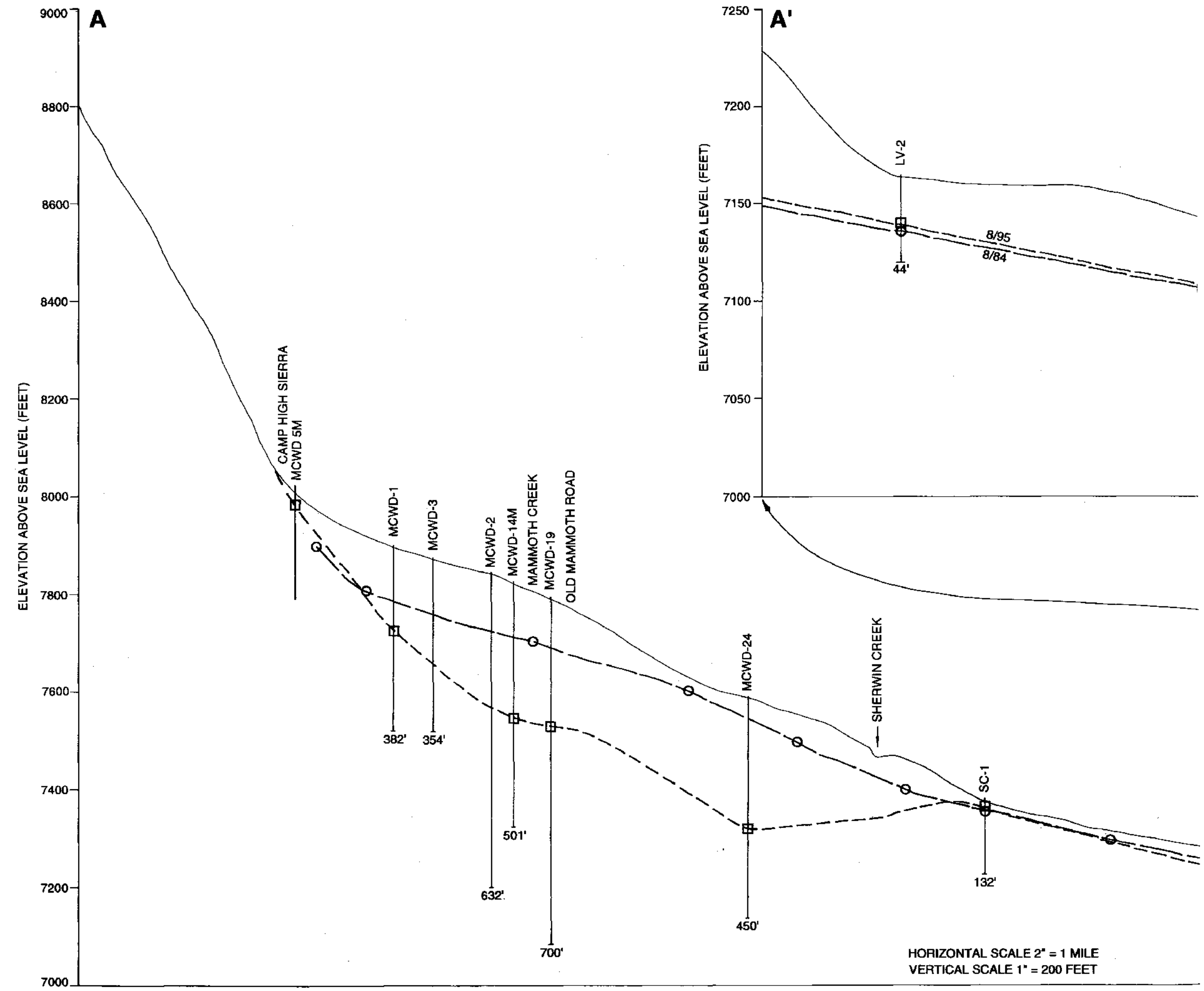
Underlying the Mammoth Basin is a groundwater regime that does not correspond to the boundaries of the surface drainage systems. Previous studies in the project vicinity have implied that the Mammoth Basin groundwater regime is a part of the Long Valley Caldera groundwater system. It is doubtful, however, that a single system prevails throughout the caldera and/or the Mammoth Basin considering the complex geology, hydrology and hydrogeology of the area. It also appears from earlier studies that two, and perhaps more, groundwater regimes are present.

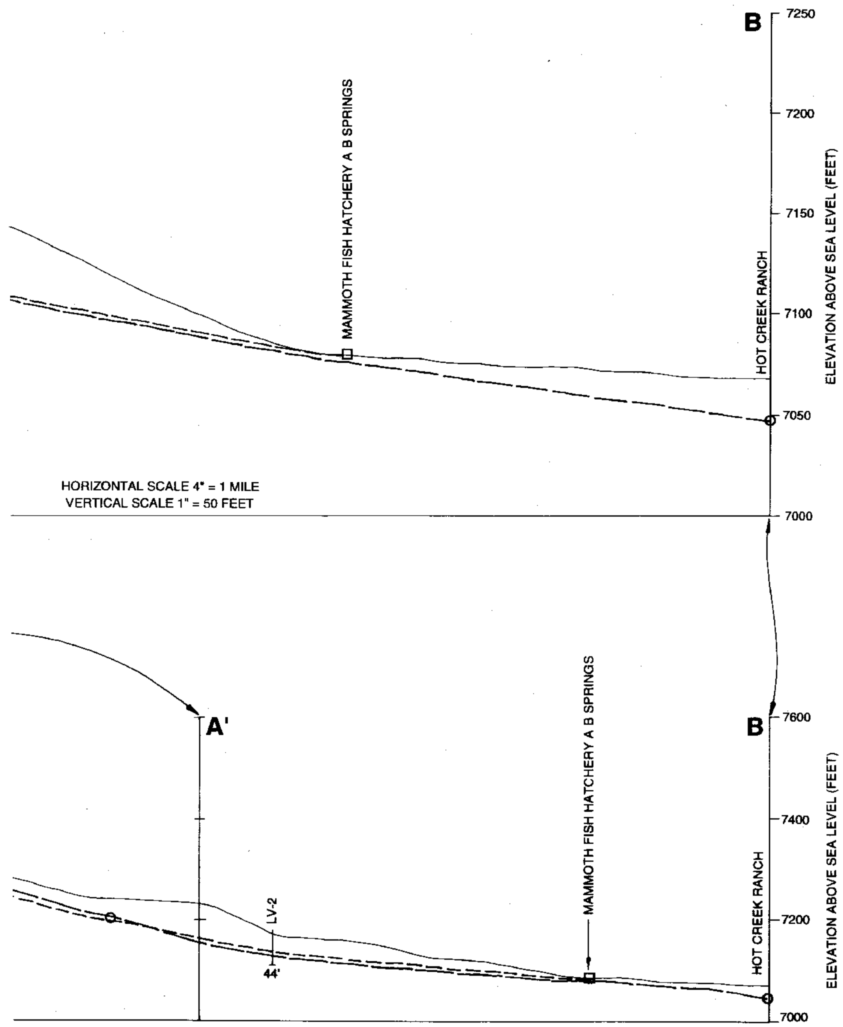
The groundwater basin lies largely within the central part of the Mammoth Basin watershed. Boundaries of the groundwater basin have not been specifically defined due to the complex hydrogeologic conditions of the basin. Nevertheless, a general outline of the basin can be made considering surface drainages, ground elevations, surface geology and earlier subsurface exploration. A generalized outline of the Mammoth-Hot Creek groundwater basin is shown on Plate 1. The basin as shown extends from near Mammoth Mountain Ski Lodge in the west, through the areas of Old Mammoth and Mammoth Lakes, on eastward past the Casa Diablo Hot Springs and the fish hatchery, then continues eastward across the Mammoth Basin boundary into Long Valley. The southern boundary of the Long Valley Caldera appears to closely parallel the southern groundwater basin boundary. The width of the basin varies from about 1.5 to 4.0 miles along its 11 mile east-west course. This area is about 28 square miles. Both surface and groundwater enter the groundwater basin area from the north, west and south. Gradients of surface flows follow stream course elevations, while groundwater gradients are a function of saturated basin cross section, hydraulic conductivity of the rocks, and the rate groundwater is passing through the basin

Figure 6 shows two cross sections (A-B and A'-B;) that pass through a part of Mammoth groundwater basin. The locations of these cross sections are shown on Plate 1. Cross section A-B originates approximately 1 mile west of Camp High Sierra and extends eastward about 9.5 miles to the Hot Creek Ranch. Cross Section A'-B is an expanded scale of a part of section A-B that starts 0.35 mile west of well LV-2 and extends eastward to Hot Creek Ranch. Both sections indicate the ground surface configuration as determined from published topographic maps and recorded elevations of well heads. Extraction and monitoring wells are shown in their relative locations along the section lines. Two water level profiles are plotted:

- Summer 1984, taken from interpretations of estimated water level contours by the USGS in Water Resources Investigation 85-4183 (USGS, 1985).
- Summer 1995, data from records of the USGS and MCWD.

Groundwater level and well construction data were obtained from MCWD and the USGS. The summer 1984 profile is partly from actual water level data and partly from the USGS generalized interpretations that produced a regional water level map (USGS, 1985). The USGS 1984 groundwater levels in the western basin sector are a composite of unconfined, partially confined and confined aquifers. A gap in data occurs in the vicinity of MCWD-24 where a major difference of


A
A'
ELEVATION ABOVE SEA LEVEL (FEET)
9000
8800
8600
8400
8200
8000
7800
7600
7400
7200
7000
CAMP HIGH SIERRA
MCWD 5M
MCWD-1
MCWD-3
MCWD-2
MCWD-14M
MAMMOTH CREEK
MCWD-19
OLD MAMMOTH ROAD
MCWD-24
SHERWIN CREEK
SC-1
382'
354'
632'
501'
700'
450'
132'
7250
7200
7150
7100
7050
LV-2
8/95
8/84
44'
HORIZONTAL SCALE 2" = 1 MILE
VERTICAL SCALE 1" = 200 FEET



EXPLANATION:

- ○ USGS Data- 1984
- —— 1984 Groundwater Levels
- □ USGS and MCWD Data- 1995 (8/95)
- – – – 1995 Groundwater Levels

FIGURE 6.

WATER LEVEL ELEVATIONS ALONG CROSS SECTIONS A-A'-B EAST-WEST THROUGH MAMMOTH VALLEY GROUNDWATER BASIN

water levels can be noted. Such levels were interpreted to be between 7,500 and 7,600 feet in 1984 by he USGS, while an actual measurement in 1995 at MWD-24 had a static level of about 7,330 feet It is probable that errors in the interpretations of water levels for 1984 made by the USGS account, at least partially, for the water level differences observed in Figure 6 between summer 1984 and summer 1995. Another possibility is that the 1984 water levels represent those of a shallow unconfined aquifer while those of 1995 are represent deeper confined and semi-confined aquifers. The latter condition appears to be confirmed by 1990 through 1996 water level measurements that rise and fall seasonally and annually within a relatively narrow range, as shown in the groundwater level hydrographs on Plate 2.

DWR divided the Mammoth groundwater basin into eastern and western areas. The dividing point used by DWR is located near the Los Angeles YMCA Camp along the northern boundary of Section 7, T4S/R28E. Figure 7 is a surface water drainage map of the Mammoth Basin (Brown and Caldwell - Triad Engineering, 1994). For purposes of this investigation, the Basin was divided into eastern and western areas -- the dividing line across the groundwater basin being the eastern boundary of sub-drainage areas IV and V of the Mammoth Basin. This subdivision of drainage occurs at the location of the Mammoth Creek at Old 395 stream gage. The eastern drainage boundary of sub-drainage areas IV and V divides the Mammoth-Hot Creek Groundwater Basin into areas designated herein as *Basin West* and *Basin East*.

Basin West - *Basin West* receives surface drainage from sub-drainage areas I, II, III, IV and V which includes about 34.5 square miles. Of that total acreage, approximately 14.4 square miles are included within the groundwater basin in *Basin West*. Numerous extraction and monitoring wells have been constructed in Basin West, primarily by MCWD. These wells have drilled to depths of more than 700 feet. Geothermal groundwater is extracted and re-injected in the vicinity of Casa Diablo Hot. The operations of the Casa Diablo facilities are in the extreme eastern part of *Basin West* and probably outside the hydraulic influence of the MCWD wells that are located about three miles west of the Casa Diablo facilities.

Lithologic logs of wells indicate that inter-bedded alluvium, glacial till and various types of extrusive volcanic rocks comprise the *Basin West* aquifers. *Basin West* aquifers appear, from

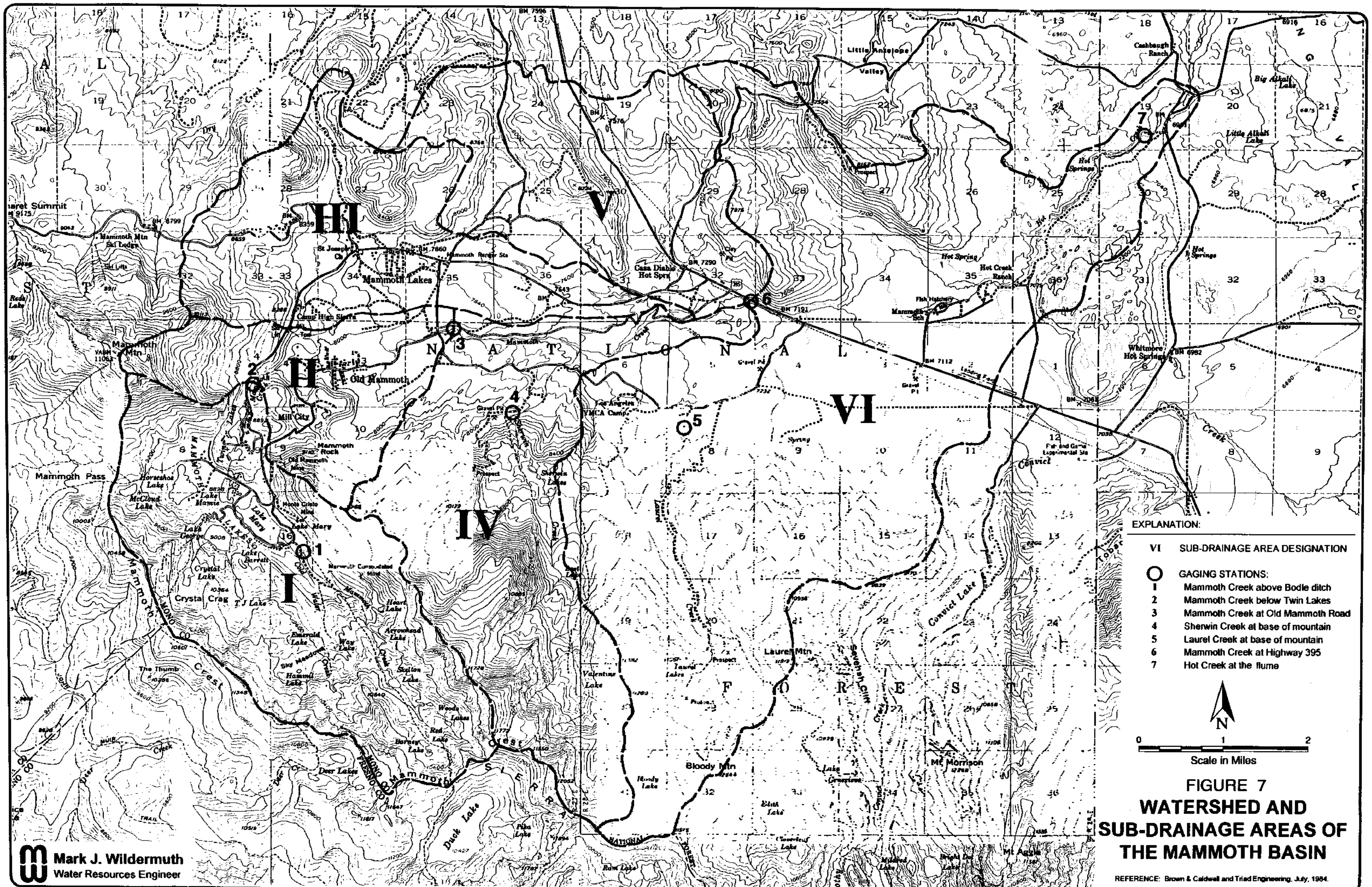


FIGURE 7
WATERSHED AND SUB-DRAINAGE AREAS OF THE MAMMOTH BASIN

REFERENCE: Brown & Caldwell and Triad Engineering, July, 1984.

pumping responses and other data to be confined, semi-confined and unconfined water bearing zones to at least the total depth to which wells have been drilled. Essentially all well extraction in *Basin West* is by MCWD.

The highly variable nature of the subsurface lithology, complex stratigraphic and structural conditions result in a complex aquifer system. Groundwater recharge to the basin is derived from direct percolation of precipitation, and infiltration along Mammoth Creek and other minor streams tributary to the basin. This part of the groundwater basin can potentially receive substantial subsurface recharge because of its western location where basin precipitation is greatest. The location of MCWD wells is shown in Plate 1. Plate 2 contains groundwater elevation time histories (hydrographs) for MCWD extraction wells (shown in pink) located in *Basin West*. The response of the groundwater levels in these wells indicate that groundwater levels recover almost completely each year, even during periods of lower than normal precipitation.

Outflow to the east from the *Basin West* is by surface outflow and subsurface flow through the eastern boundary of sub-drainage areas III, IV and V into sub-drainage area VI.

Basin East - *Basin East* is in the surface watershed of sub-drainage area VI and receives surface inflow from sub-drainage III, IV and V via Mammoth Creek. Exclusive of the Mammoth Creek inflow, all surface flows are derived from sub-drainage area VI which includes 33.8 square miles.

The most significant inflowing stream to the *Basin East* drainage, with the exception of Mammoth Creek, is Laurel Creek which issues from the southern flank of sub-drainage VI. Laurel Creek has a mountainous tributary area of some 5.3 square miles. After leaving the mountain slopes the stream finds its way across the Mammoth valley floor to Mammoth Creek during times of high runoff. During moderate and low flow periods the stream disappears into the alluvial deposits that mantle the valley surface. A number of other streams also enter the valley primarily from springs on the flanking slopes that seasonally cause marshes to form on the surface flats of the basin.

Several extraction wells and test wells have been constructed within *Basin East*. Boring logs for these wells indicate that the subsurface lithology is similar to that found in *Basin West*, i.e., inter-bedded alluvium, glacial till and volcanic extrusives and agglomerates. The Hot Creek headsprings and geothermal waters occur in *Basin East*. The aquifers in the *Basin East* groundwater basin are as complex, or more so, than those in *Basin West*; since they are unconfined, semi-confined and confined, as well as having hot and cold water components.

Recharge in *Basin East* is derived from direct percolation of precipitation, infiltration along stream courses and subsurface inflows from the south, west and north. The seasonal presence of marshes and shallow groundwater over a large area of the valley surface suggests that this basin, under normal conditions, is refilled completely in most years. The USGS has several monitoring wells in *Basin East*, the locations of which are shown in Plate 1. Groundwater level hydrographs for wells in *Basin East* are shown in Plate 2 (green hydrographs). Groundwater levels in *Basin East* change vary slightly over time in response to climatic variability.

A number of hot springs issue from the surface in sub-drainage area VI. Most significant to this project are those springs in the vicinity of the Hot Creek Fish Hatchery which are designated AB, CD, H1, H23 (see Figure 8). These springs comprise the headwaters of Hot Creek. The USGS (USGS,1987) conducted a detailed analyses of the springs in *Basin East* of the groundwater basin and continues to collect such data that may be relevant to Long Valley Caldera seismic activity, and hydrologic conditions.

Groundwater Development in the Mammoth Basin

Except for possible activities of Native Americans, development of groundwater in the Mammoth Basin did not commence until the late 1800's. This limited early development included the construction of shallow hand-dug wells and the improvement of cool and hot springs. Many of these springs continue to yield water for various uses. Recent groundwater extraction began in January 1976 with the completion of well No. 1 by the Mammoth County Water District (now Mammoth Community Water District). This well was tested to produce at a rate of 512 gallons per minute (gpm) with a specific capacity of 9.4 gallons per minute per foot of drawdown (gpm/ft). Two other wells, Nos. 2 and 3, constructed in the same year were poor producers and not outfitted with pumps. Wells Nos. 6 and 10 were completed in 1988, penetrating fractured basalts

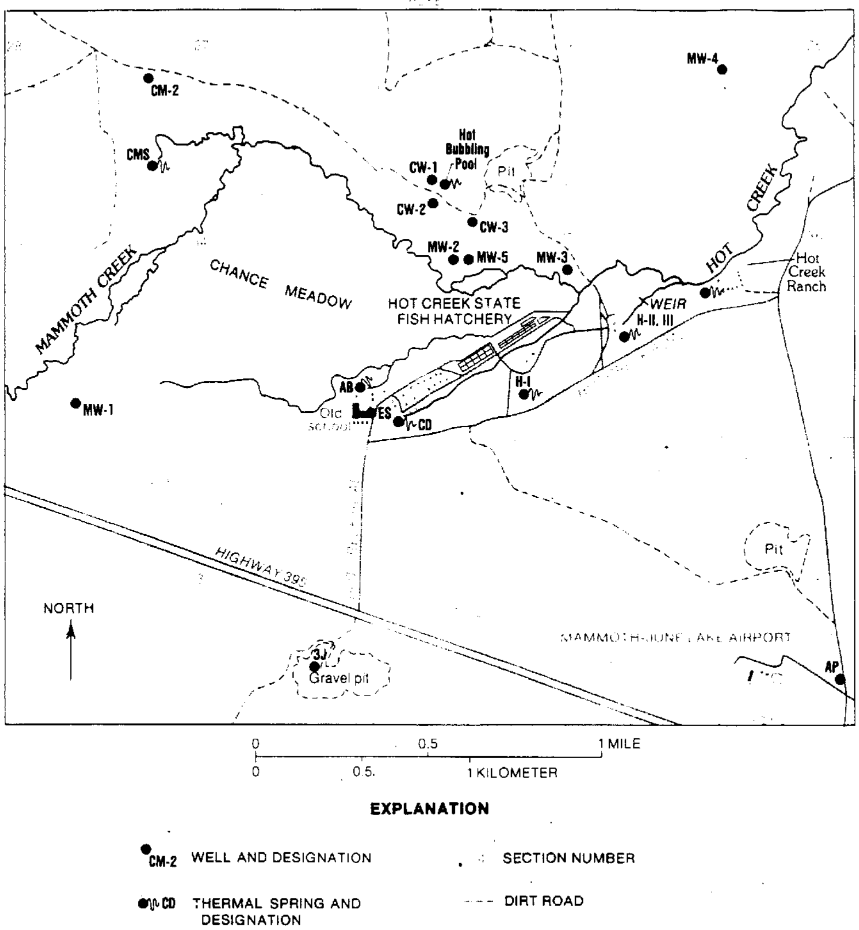


FIGURE 8

SPRINGS AND TEST WELLS IN THE VICINITY OF THE HOT CREEK STATE FISH HATCHERY

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REFERENCE: From U.S.G.S. (1987) Water Resources Investigations Report No. 87-4090.

to depths of about 700 feet. Seven wells have been added to the MCWD system since the construction of well No. 1. The recent groundwater extraction history is listed in Table 2. Groundwater extraction has increased from 48 acre-ft/yr in calendar year 1983 to 1,133 acre-ft/yr in 1995. Groundwater extraction peaked at 2,385 acre-ft/yr in 1992 during the 1987 to 1992 drought. A few private wells also produce from the Mammoth Basin, the most significant of which is the Snowcreek golf course well which produced 165 acre-ft in 1995.

Groundwater Storage

The DWR estimated the available groundwater storage in the Mammoth groundwater basin to be about 57,000 acre-ft (DWR, 1973). This estimate is based on useful groundwater occurred only in unconsolidated sediments, specific yield range of 7 to 10 percent, and groundwater level data from only a few wells. Since the DWR completed it study, MCWD has constructed several successful extraction wells into the fractured basalts that underlie the unconsolidated sediments. Useful groundwater storage extends to the basalts that underlie the unconsolidated sediments. For this study, we estimated the useful groundwater storage tributary to the AB and CD headsprings. *Useful groundwater storage tributary to the AB and CD headsprings* is defined herein as the groundwater in storage that could flow by gravity to AB and CD headwater springs and consists of all drain-able groundwater up-gradient of the headwater springs. The Mammoth Basin up-gradient of the AB and CD headsprings is about 65.9 square miles. For storage analysis, this area can be divided into three areas:

- Mammoth valley area from the fish hatchery westward about 7 miles and averaging about 1.5 miles wide;
- the area defined as the difference between the Mammoth groundwater basin as shown in Plate 1, and the Mammoth valley area described above; and
- the area defined by the difference between the Mammoth Basin drainage area upgradient of the AB and CD headsprings, and the Mammoth groundwater basin.

The Mammoth valley area is about 10.5 square miles. The aquifer in this area consists of relatively thin deposits of alluvium and glacial debris underlain by layers of various types of volcanic rocks to depths of more than 700 feet in the western part of the Mammoth valley area. The surface

Table 2
Total Groundwater Use in Mammoth Basin Area

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1983	3	0	4	0	0	6	26	2	1	0	0	6	48
1984	7	0	11	0	11	22	55	5	19	0	2	25	157
1985	22	6	20	13	36	26	39	62	38	18	13	22	313
1986	14	11	10	3	18	30	42	66	10	0	28	32	264
1987	40	28	40	41	44	68	79	70	57	23	27	47	563
1988	47	54	58	24	40	58	49	51	54	29	59	72	595
1989	88	71	83	6	9	24	193	169	138	46	57	73	958
1990	51	56	38	72	43	118	141	160	192	96	71	84	1,142
1991	171	132	0	98	95	47	120	180	178	99	163	80	1,364
1992	80	121	111	147	76	160	297	413	309	261	158	251	2,385
1993	191	232	115	131	89	224	240	238	182	46	1	24	1,714
1994	76	30	83	65	90	124	244	317	198	51	35	100	1,412
1995	114	99	108	101	61	58	140	239	132	18	12	50	1,133
1996	37	39	34	14	32								
Average	67	63	51	51	46	74	128	153	116	53	48	66	918
Max	191	232	115	147	96	224	297	413	309	261	163	251	2,385
Min	3	0	0	0	0	6	26	2	1	0	0	6	48
% of Annual	7.3%	6.8%	5.6%	5.6%	5.0%	8.1%	14.0%	16.7%	12.6%	5.8%	5.3%	7.2%	100%

Note: Includes all pumpage from wells for pump testing, golf course water, and for use by community.

elevation at the fish hatchery springs is about 7,075 ft-msl. From review of Figure 6, the average saturated thickness in this area is about 250 feet. The specific yield of the aquifer materials in this area is estimated to be about 6 percent. The useful groundwater in storage in this area is about 100,800 acre-ft. The remaining part of the groundwater basin area is irregular in shape and does not lend itself to the analysis described above due to a lack of lithologic data and groundwater level data. The area of the remaining part of the groundwater basin area is about 9.5 square miles. Assuming an average saturated thickness of 100 feet and a specific yield of 4 percent the useful groundwater storage in this area is estimated to be about 24,300 acre-ft. The total useful storage in the Mammoth groundwater basin is about 135,100.

The Mammoth Basin drainage area outside the Mammoth groundwater basin is about 45.9 square miles and consists of fractured rock. Assuming an average saturated thickness of 200 feet and specific yield of 2 percent, the useful storage is estimated to be about 117,500 acre-ft. The total useful groundwater storage tributary to the AB and CD headsprings is estimated to be about 242,600 acre-ft.

Surface Water Discharge and Spring Discharge Characterization

Mammoth Creek drains the western part of the Mammoth Basin flowing in a generally easterly direction past Highway 395. Mammoth Creek changes its name to Hot Creek near the Hot Creek Fish Hatchery. Hot Creek leaves the Basin near Cashbaugh Ranch at the eastern end of the Basin and continues about three miles to the northeast to a confluence with the Owens River. Surface flows have been measured at seven gaging stations within the Basin. These stations are listed below.

Station Name	Drainage Area (square miles)
Mammoth Creek above Bodle Ditch	2.8
Mammoth Creek below Twin Lakes	8.3
Laurel Creek at base of mountain	5.6
Sherwin Creek at base of mountain	4.7
Mammoth Creek at Old Highway 395	34.5
Hot Creek at the Flume	68.3

The locations of these stations are shown in Figure 7. Mammoth Creek at Old 395 and Hot Creek at the Flume are long period stations with daily flow records of 40 years or longer. The USGS and others have measured spring discharge from AB, CD and H23 springs since about 1985. The location of the AB and CD headsprings and Owens Valley Tui Chub habitat are shown in Figure 9. Table 3 lists the monthly and annual discharges for Mammoth Creek at Old 395 for the period 1951 through mid 1996; Table 4 lists the monthly and annual discharges for AB, CD, H23 springs for the period of about 1985 through mid 1996; Table 5 lists the monthly and annual discharges for Hot Creek at the Flume for the period 1951 through mid 1996.

Figure 10 shows the average monthly distribution of discharge for Mammoth Creek at Old 395 and for Hot Creek at the Flume. Discharge in Mammoth Creek upstream of the AB, CD and H23 headsprings is seasonal with just over 70 percent of the annual flow occurring in the period May through August. Most of the discharge during this period comes from snow melt. Average annual discharge for the Mammoth Creek at Old 395 averages about 16,000 acre-ft/yr and has ranged from a low of about 3,000 acre-ft/yr to a high of about 46,000 acre-ft/yr.

Downstream at the Hot Creek at the Flume gaging station, about 46 percent of the annual discharge occurs during the May to August snow melt period. In contrast to the upstream Mammoth Creek at Old 395 gaging station, Hot Creek has a significant base flow component fed in part by discharges from the AB, CD and H23 headsprings. Average annual discharge for the Hot Creek at the Flume averages about 42,000 acre-ft/yr and has ranged from a low of about 25,000 acre-ft/yr to a high of about 72,000 acre-ft/yr.

Figure 11 is a graphical comparison of the equivalent water depth from the April 1 snow surveys and the annual runoff for Mammoth Creek at Old 395 and Hot Creek at Flume. The trend lines for annual discharge versus April 1 snow survey is also plotted in Figure 10. The observed annual discharge for Hot Creek at Flume is more scattered about its trend line than the observed annual discharges for Mammoth Creek at Old 395. The coefficient of determination for Hot Creek at flume trend is 0.65 and 0.79 for Mammoth Creek at Old 395. The coefficient of variation (R^2) is the fraction of the variance in discharge that can be explained by the variance in April 1 snow surveys. The difference in the trends is due to Hot Creek having a significant groundwater component that can sustain Hot Creek surface discharges in years with low precipitation.

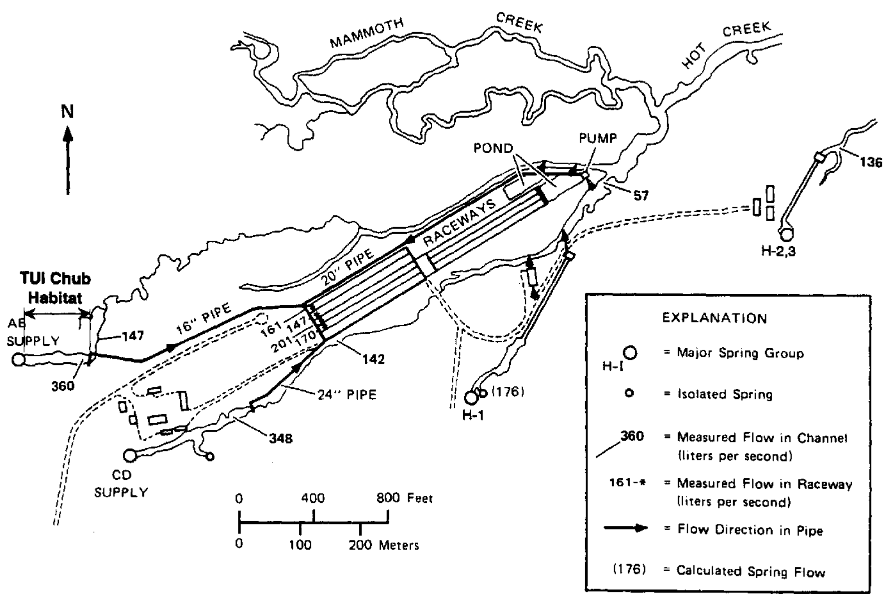


FIGURE 9

OWEN'S VALLEY TUI CHUB HABITAT AT THE AB HEADSPRING

REFERENCE: HYDROLOGIC AND GEOCHEMICAL MONITORING IN LONG VALLEY CALDERA, MONO COUNTY, CALIFORNIA 1982-1984, by C.D. Farrar, M.L. Sorey, S.A. Rojstaczer, C.J. Janik, R.H. Mariner, and T.L. Winnett (U.S. Geological Survey) and by M.D. Clark (U.S. Forest Service). U.S. Geological Survey Water-Resources Investigations Report 85-4183.

Mark J. Wildermuth
Water Resources Engineer

Table 3
Monthly Distribution of Discharge for Mammoth Creek at Old 395

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1950-1951	250	1,660	2,160	770	575	505	743	2,355	3,399	1,854	994	475	15,741
1951-1952	437	340	646	607	480	372	708	3,788	6,158	5,724	2,579	1,147	22,986
1952-1953	748	423	536	651	354	410	821	1,021	2,979	2,725	616	289	11,574
1953-1954	307	295	251	212	278	521	1,088	3,123	2,500	1,221	391	261	10,449
1954-1955	144	336	294	323	223	271	497	1,217	4,239	1,355	462	198	9,561
1955-1956	281	274	1,556	808	446	440	944	3,324	8,526	5,872	2,279	1,186	25,935
1956-1957	1,024	765	577	565	569	532	700	1,642	6,343	2,471	807	415	16,411
1957-1958	475	382	389	309	341	439	853	4,662	6,959	4,634	2,419	1,265	23,128
1958-1959	644	522	429	439	371	502	828	1,447	1,900	586	228	366	8,261
1959-1960	348	222	241	356	369	412	598	864	1,371	302	95	87	5,264
1960-1961	136	144	179	188	145	220	192	604	970	332	201	175	3,487
1961-1962	138	148	227	231	357	349	1,094	2,092	5,548	3,358	1,209	605	15,356
1962-1963	542	393	426	336	1,048	422	590	2,187	6,232	4,333	1,581	874	18,985
1963-1964	639	853	636	425	308	471	600	1,492	2,271	723	406	286	9,114
1964-1965	154	347	1,317	937	348	521	836	2,025	5,118	4,438	3,367	1,469	20,877
1965-1966	842	777	587	556	472	566	1,015	3,230	2,321	990	459	345	12,159
1966-1967	340	303	857	469	475	610	519	3,232	8,411	10,195	3,387	1,983	30,780
1967-1968	1,124	818	592	598	599	531	568	1,640	1,993	753	376	131	9,724
1968-1969	232	368	323	277	106	248	962	8,572	11,634	8,808	3,691	1,488	38,702
1969-1970	1,367	879	697	680	665	779	909	2,548	4,342	2,151	751	485	16,453
1970-1971	453	590	519	425	333	496	593	1,811	4,300	2,099	751	403	12,773
1971-1972	494	516	418	416	296	399	586	1,584	2,766	702	190	664	9,034
1972-1973	519	361	453	430	514	340	518	4,798	6,306	2,314	996	491	18,041
1973-1974	522	1,049	562	593	395	526	801	4,346	7,104	3,006	1,313	606	20,823
1974-1975	516	338	362	368	392	340	477	2,700	7,110	3,118	1,058	694	17,468
1975-1976	1,017	572	460	400	395	468	419	1,805	927	382	326	215	7,388
1976-1977	272	195	127	139	220	225	261	299	904	287	117	107	3,151
1977-1978	83	77	64	68	46	169	423	3,019	8,894	6,287	2,769	2,719	24,617
1978-1979	1,138	768	457	727	537	606	1,047	4,063	4,366	1,948	947	642	17,246
1979-1980	421	352	312	782	517	463	969	3,770	8,173	7,892	2,918	1,308	27,877
1980-1981	810	469	372	380	392	361	648	2,145	2,679	760	301	259	9,566
1981-1982	393	483	414	155	346	297	1,553	4,978	7,983	6,933	3,447	3,109	30,091
1982-1983	2,553	1,999	1,318	857	755	782	668	4,475	13,277	11,024	5,554	2,551	45,812
1983-1984	1,813	1,466	1,162	1,218	631	758	1,093	4,828	5,178	3,496	1,640	796	24,077
1984-1985	1,211	736	618	446	378	343	999	2,722	2,853	988	420	388	12,103
1985-1986	352	341	413	367	392	967	1,668	5,582	10,659	4,839	1,998	1,122	28,699
1986-1987	1,244	555	494	442	337	390	427	1,888	1,330	549	262	193	8,110
1987-1988	219	345	276	422	297	306	464	1,038	1,306	812	302	195	5,973
1988-1989	188	172	200	271	203	385	589	1,376	1,417	497	294	253	5,845
1989-1990	292	341	218	260	225	245	423	845	1,065	560	385	214	5,074
1990-1991	156	195	112	81	98	262	259	592	3,050	1,291	480	341	6,918
1991-1992	319	401	307	234	226	167	336	1,541	1,046	621	370	275	5,842
1992-1993	235	272	135	172	198	348	616	3,418	5,555	4,132	1,559	810	17,449
1993-1994	544	445	433	362	350	345	489	1,541	1,828	548	313	288	7,487
1994-1995	354	326	409	436	394	585	892	2,773	8,224	11,412	5,199	2,220	33,224
1995-1996	1,303	807	821	354	437	399	713	2,784					
Average	600	531	529	451	388	437	718	2,648	4,700	3,096	1,338	764	16,169
Stan Dev	497	390	404	244	181	167	307	1,608	3,161	3,049	1,371	742	9,839
Coef of Var	83%	73%	76%	54%	47%	38%	43%	61%	67%	98%	102%	97%	61%
Max	2,553	1,999	2,160	1,218	1,048	967	1,668	8,572	13,277	11,412	5,554	3,109	45,812
Min	83	77	64	68	46	167	192	299	904	287	95	87	3,151
% of Annual	3.7%	3.3%	3.3%	2.8%	2.4%	2.7%	4.4%	16.4%	29.1%	19.1%	8.3%	4.7%	100.0%

Table 4
Headspring Flow in Fish Hatchery Area

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
						AB Spring							
1985				516	583	684	700	626	574	552	519	516	
1986	528	470	574	641	715	810	911	829	703	669	580	559	7,988
1987	525	448	497	479	522	531	525	503	442	430	399	393	5,693
1988	374	347	368	350	359	433	436	399	341				
1989													
1990													
1991	203	184	209	196	203	344	402	381	301	252	224	203	3,100
1992	167	163	172	169	196	279	230	193	178	157	132	132	2,188
1993	163	172	178	273	322	463	562	562	473	390	313	264	4,134
1994	233	172	206	175	221	365	344	227	175	166	147	147	2,578
1995	175	144	196	322	424	580	789	862	770	632	543	470	5,908
1996	436	393	420	414									
Average	314	277	313	354	394	499	544	509	440	406	357	335	4,741
Max	528	470	574	641	715	810	911	862	770	669	580	559	7,988
Min	163	144	172	169	196	279	230	193	175	157	132	132	2,188
% of Annual	6.6%	5.8%	6.6%	7.5%	8.3%	10.5%	11.5%	10.7%	9.3%	8.6%	7.5%	7.1%	100%
						CD Spring							
1988											424	494	
1989	506	460	506	534	503	503	577	565	470	396	365	479	5,865
1990	513	411	537	488	470	482	531	494	473	552	540	526	6,015
1991	485	460	497	454	439	509	583	651	574	485	439	457	6,033
1992	460	433	470	445	448	470	485	460	420	436	399	414	5,340
1993	433	405	509	526	519	568	746	680	644	617	485	500	6,610
1994	516	448	476	457	466	543	565	519	473	454	362	368	5,647
1995	356	316	374	408	491	559	678	675	657	626	549	531	6,221
1996	506	457	482	466									
Average	472	424	461	472	477	519	595	575	530	509	445	471	5,971
Max	516	460	537	534	519	568	746	675	657	626	549	531	6,610
Min	356	316	374	408	439	470	485	460	420	396	362	368	5,340
% of Annual	7.9%	7.1%	8.1%	7.9%	8.0%	8.7%	10.0%	9.6%	8.9%	8.5%	7.5%	7.9%	100%
						H23 Spring							
1987	218	206	224	218	224	224	230	227	215	209	203	203	2,599
1988	206	193	215	203	209	206	218	218	196	199	190	193	2,446
1989	187	153	178	184	184	187	206	203	190	193	184	184	2,234
1990	181	160	181	169	184	184	190	193	203	209	199	206	2,259
1991	196	184	184	178	181	181	209	221	167	166	160	169	2,216
1992	160	157	166	163	172	181	181	175	153	169	166	172	2,013
1993	178	163	184	193	221	230	249	255	233	221	215	190	2,532
1994	184	172	196	187	252	242	246	236	233	227	181	190	2,547
1995	187	169	196	187	193	212	246	249	246	242	215	230	2,572
1996	221	224	227	196									
Average	192	178	195	188	202	205	219	220	206	204	190	193	2,393
Max	221	224	227	218	252	242	249	255	246	242	215	230	2,599
Min	160	153	166	163	172	181	181	175	153	166	160	169	2,013
% of Annual	8.0%	7.4%	8.2%	7.8%	8.5%	8.6%	9.2%	9.2%	8.6%	8.5%	8.0%	8.1%	100%

Table 6
Monthly Distribution of Discharge for Hot Creek at Flume

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1950-1951	2,274	3,432	3,912	2,678	2,352	2,411	2,257	3,617	5,190	3,637	2,746	2,437	36,943
1951-1952	2,401	2,177	2,411	2,548	2,228	2,377	3,306	6,623	9,779	8,451	5,267	3,912	51,480
1952-1953	3,448	2,892	2,899	3,030	2,410	2,863	2,877	2,936	4,825	5,493	2,955	2,521	38,948
1953-1954	2,471	2,382	2,307	2,274	2,171	2,764	3,080	4,961	4,724	3,974	2,652	2,407	36,188
1954-1955	2,340	2,276	2,366	2,375	2,110	2,496	2,433	3,167	5,961	3,337	2,673	2,325	33,859
1955-1956	2,327	2,207	3,712	3,219	2,634	2,842	3,290	4,993	9,663	8,606	4,931	3,808	52,232
1956-1957	3,742	3,320	3,111	2,965	2,794	3,001	2,967	3,431	7,770	4,716	3,111	2,913	43,840
1957-1958	2,959	2,752	2,656	2,490	2,380	2,720	3,797	6,732	8,453	7,060	5,019	3,955	50,964
1958-1959	3,400	3,109	2,960	2,905	2,474	3,015	3,021	3,149	3,628	2,727	2,514	2,539	35,443
1959-1960	2,437	2,371	2,437	2,478	2,362	2,533	2,482	2,380	3,025	2,377	2,193	2,146	29,221
1960-1961	2,120	2,060	2,091	2,082	1,980	2,269	2,074	2,173	2,386	2,121	2,021	2,051	25,407
1961-1962	2,173	2,095	2,184	2,168	2,103	2,368	3,576	3,844	7,016	5,371	3,233	2,926	39,072
1962-1963	2,958	2,583	2,585	2,351	3,529	2,675	2,768	4,152	8,312	6,511	3,896	3,428	45,749
1963-1964	3,235	3,185	2,810	2,570	2,354	2,565	2,579	3,021	3,994	2,568	2,379	2,272	33,522
1964-1965	2,309	2,272	2,988	2,824	2,319	2,622	2,868	3,534	7,096	7,172	5,815	4,114	45,933
1965-1966	3,573	3,342	3,097	3,018	2,493	2,972	3,073	4,622	4,209	2,973	2,596	2,503	38,472
1966-1967	2,581	2,397	3,155	2,598	2,434	3,168	3,250	5,108	9,860	12,523	6,643	5,269	59,003
1967-1968	4,262	3,644	3,438	3,263	3,042	2,977	2,835	3,349	3,729	2,791	2,567	2,378	38,294
1968-1969	2,456	2,525	2,500	2,497	2,300	2,890	4,214	11,513	16,151	12,686	7,364	5,018	72,114
1969-1970	4,789	3,863	3,663	3,718	3,260	3,578	3,528	4,686	6,758	5,190	3,456	3,164	49,653
1970-1971	3,148	3,191	3,235	3,066	2,721	2,923	2,681	4,189	6,056	4,300	3,090	2,710	41,308
1971-1972	2,936	2,923	2,665	2,694	2,473	2,786	2,504	3,119	4,566	2,655	2,284	2,797	34,424
1972-1973	2,801	2,619	2,697	2,710	2,511	2,656	3,564	7,173	8,704	5,488	3,669	3,138	47,732
1973-1974	3,059	3,541	3,068	3,095	2,622	2,995	2,944	5,998	8,784	5,390	3,747	3,072	48,315
1974-1975	3,106	2,745	2,709	2,692	2,272	2,658	2,554						
1983-1984	5,568	5,009	4,811	4,343	3,893	3,899	3,736	6,905	7,644	6,403	4,688	3,795	60,694
1984-1985	4,002	3,930	3,893	3,617	3,126	3,387	3,710	4,910	5,205	3,724	3,207	3,056	45,766
1985-1986	3,091	3,040	3,262	3,306	3,337	4,654	4,662	8,067	10,199	8,275	5,610	4,499	62,002
1986-1987	4,561	3,708	3,456	3,282	2,976	3,294	2,856	4,008	3,706	3,155	2,899	2,679	40,570
1987-1988	2,602	2,637	2,703	2,820	2,655	2,802	2,637	3,020	3,441	3,008	2,669	2,465	33,457
1988-1989	2,526	2,542	2,384	2,399	2,271	2,566	2,463	3,329	3,329	2,625	2,499	2,388	31,341
1989-1990	2,378	2,346	2,284	2,306	2,118	2,417	2,185	2,437	2,649	2,358	2,374	2,068	27,911
1990-1991	2,016	2,005	1,945	1,969	1,858	2,239	2,384	2,358	4,156	3,099	2,731	2,514	29,273
1991-1992	2,316	2,237	2,094	2,086	1,995	2,150	2,106	2,931	2,647	2,473	2,203	2,013	27,250
1992-1993	2,060	1,991	1,818	1,963	1,814	2,409	2,967	4,710	7,032	6,476	3,982	3,214	40,437
1993-1994	2,937	2,600	2,499	2,378	2,102	2,318	2,249	3,072	3,250	2,520	2,191	1,939	30,054
1994-1995	1,955	1,929	2,090	2,213	2,048	2,731	3,197	4,848	9,487	13,161	8,305	5,515	57,279
1995-1996	4,158	3,429	3,550	1,622	1,592	1,647	1,811	1,233					
Average	2,986	2,824	2,854	2,700	2,477	2,775	2,934	4,327	6,205	5,149	3,616	3,054	42,059
Stan Dev	847	676	641	545	489	519	616	1,967	2,970	3,014	1,567	937	11,117
Coef of Var	28%	24%	22%	20%	20%	19%	21%	45%	48%	59%	43%	31%	26%
Max	5,568	5,009	4,811	4,343	3,893	4,654	4,662	11,513	16,151	13,161	8,305	5,515	72,114
Min	1,955	1,929	1,818	1,622	1,592	1,647	1,811	1,233	2,386	2,121	2,021	1,939	25,407
% of Annual	7.1%	6.7%	6.8%	6.4%	5.9%	6.6%	7.0%	10.3%	14.8%	12.2%	8.6%	7.3%	100.0%

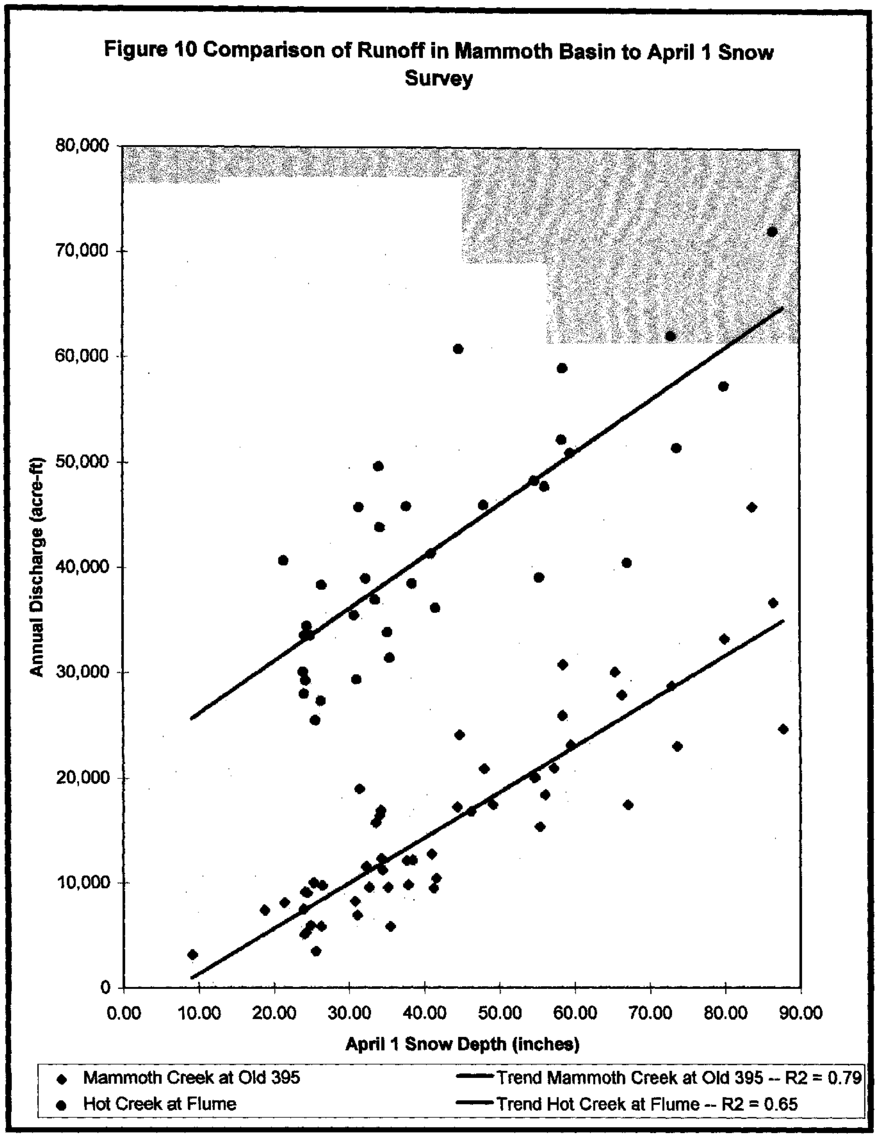


Figure 10 Comparison of Runoff in Mammoth Basin to April 1 Snow Survey
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Annual Discharge (acre-ft)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
April 1 Snow Depth (inches)
Mammoth Creek at Old 395
Hot Creek at Flume
Trend Mammoth Creek at Old 395 -- R2 = 0.79
Trend Hot Creek at Flume -- R2 = 0.65

Figure 11
Monthly Distribution of Surface Water Flow

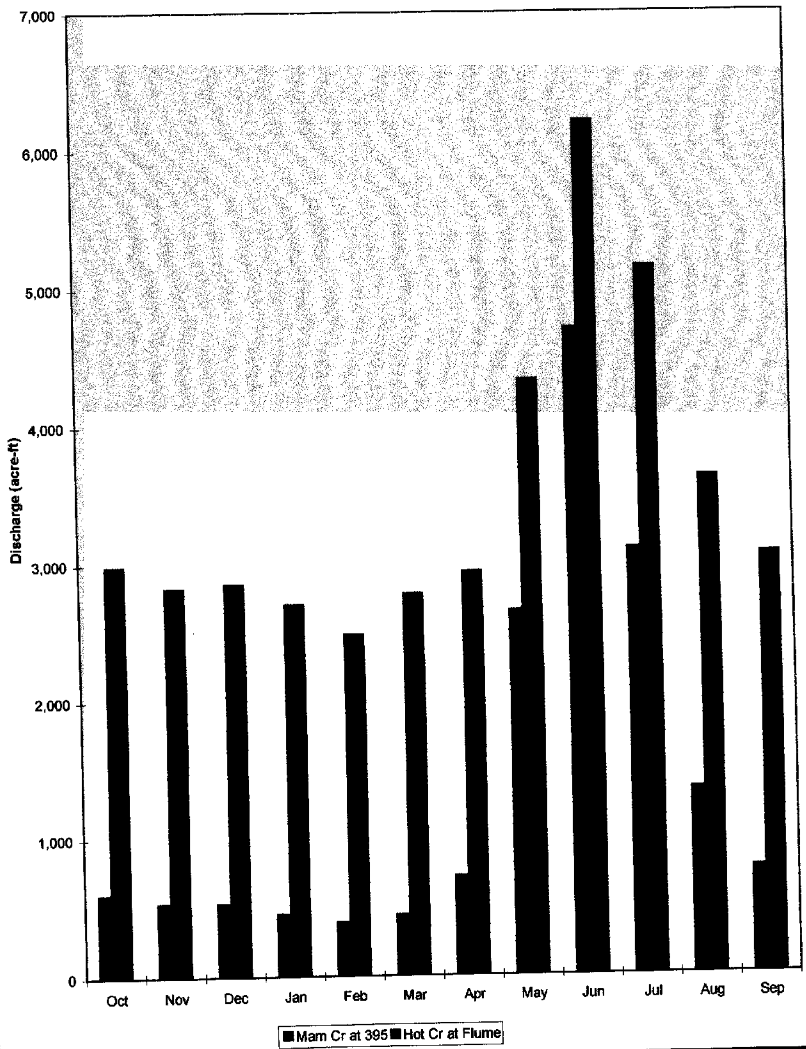


Figure 12 shows the monthly distribution of discharge for the AB, CD and H23 headsprings located at the fish hatchery. Daily discharge data for these springs are plotted in Plate 3 for their period of record along with the daily discharge data for Mammoth Creek at Old 395 and Hot Creek at the Flume. Comparable data does not exist for the H1 spring. The AB spring shows a definitive seasonal pattern that consists of two components – a seasonal component that responds rapidly to the magnitude and timing of snow melt runoff (as observed in the Mammoth Creek at Old 395 record; and a more steady base flow component that responds to changes in long term groundwater storage and climatic cycles. Analysis of the daily discharge data for the AB spring and Mammoth Creek indicates that the peak discharge from the AB spring lags behind the Mammoth Creek peak discharge by a period one to two months; and that the AB seasonal component has a recession period of about a five to six months where the Mammoth Creek recession period usually lasts two to three months. This can clearly be seen in Plate 3 by comparing the daily flow hydrograph for the AB headspring and Mammoth Creek at Old 395. In contrast, the CD and H23 springs show only a slight seasonal component with most of the discharge variation coming from changes in long term groundwater storage and climatic cycles. The recorded discharge history for the springs is heavily influenced by the drought of 1987 through 1992 and therefore estimates of average annual discharges based on the available history are probably low. The average annual discharge for the AB, CD and H23 springs for the existing records is 4,700 acre-ft/yr, 6,000 acre-ft/yr and 2,400 acre-ft/yr, respectively.

Table 6 lists the annual discharge of Hot Creek at the Flume, the associated base flow and storm flow components, and the annual flows for the AB, CD and H23 headsprings. The total flow at Hot Creek at the Flume was divided into base flow and storm flow components through a detailed analysis of daily flow data for the period October 1950 to May 1996. Base flow is numerically equal to the total flow minus surface runoff and is comprised of spring flow and other groundwater that discharge to Hot Creek. The base flow estimated for the discharge at the Hot Creek at the Flume gage averages about 27,000 acre-ft/yr and ranges from a low of 16,000 acre-ft/yr to a high of about 42,000 acre-ft/yr. The average fraction of the base flow at the Hot Creek gage contributed by the AB, CD and H23 springs during the 1986 to 1995 period is estimated at 18 percent, 23 percent and 9 percent, respectively.

Figure 12 Monthly Distribution of Flow at Hot Creek Headsprings

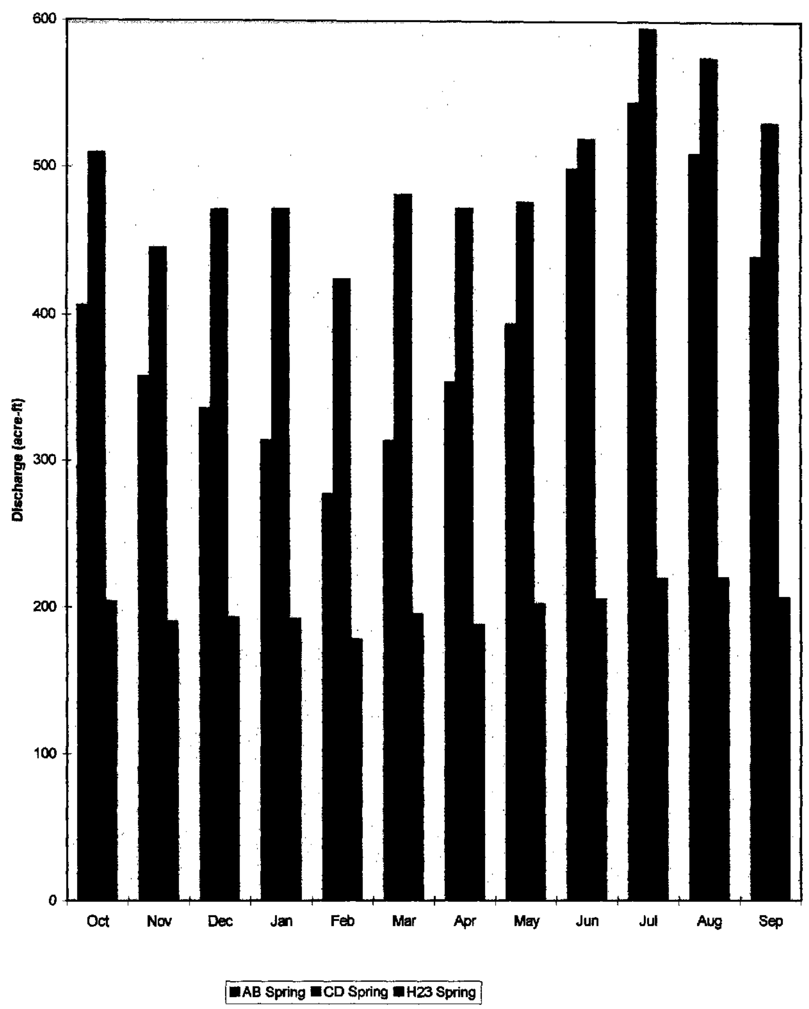


Table 6
Flow Components for Hot Creek at Flume
(acre-ft/yr)

Year	Flow In Hot Creek at Flume Total	Base	Storm	Flow in Springs AB	CD	H23
1950 / 1951	36,943	23,161	13,781			
1951 / 1952	51,403	21,984	29,419			
1952 / 1953	38,948	29,060	9,888			
1953 / 1954	36,168	25,007	11,161			
1954 / 1955	33,859	25,260	8,599			
1955 / 1956	52,153	25,369	26,784			
1956 / 1957	43,840	15,851	27,989			
1957 / 1958	50,963	27,450	23,514			
1958 / 1959	35,443	30,576	4,867			
1959 / 1960	29,136	24,774	4,362			
1960 / 1961	25,407	22,365	3,041			
1961 / 1962	39,072	23,270	15,802			
1962 / 1963	45,749	28,409	17,340			
1963 / 1964	33,411	27,142	6,268			
1964 / 1965	45,933	26,853	19,080			
1965 / 1966	38,472	29,676	8,797			
1966 / 1967	59,003	26,624	32,379			
1967 / 1968	38,141	34,524	3,617			
1968 / 1969	72,114	27,577	44,537			
1969 / 1970	49,653	34,501	15,151			
1970 / 1971	41,308	30,508	10,801			
1971 / 1972	34,331	26,998	7,333			
1972 / 1973	47,732	26,527	21,205			
1973 / 1974	48,315	29,784	18,531			
1983 / 1984	60,495	42,066	18,429			
1984 / 1985	45,879	35,596	10,282			
1985 / 1986	64,501	33,791	30,710	7,988		
1986 / 1987	40,570	36,624	3,946	5,693		2,599
1987 / 1988	33,374	28,409	4,965			2,446
1988 / 1989	31,341	26,744	4,597		5,865	2,234
1989 / 1990	27,911	24,609	3,302		6,015	2,259
1990 / 1991	29,273	22,632	6,641	3,100	6,033	2,216
1991 / 1992	27,171	22,691	4,480	2,188	5,340	2,013
1992 / 1993	40,437	22,712	17,726	4,134	6,610	2,532
1993 / 1994	30,054	25,405	4,649	2,578	5,647	2,547
1994 / 1995	57,279	21,346	35,933	5,908	6,221	2,572
Average (acre-ft/yr)	42,105	27,385	14,720	4,513	5,962	2,380
Min (acre-ft/yr)	25,407	15,851	3,041	2,188	5,340	2,013
Max (acre-ft/yr)	72,114	42,066	44,537	7,988	6,610	2,599
Coefficient of Variation	27%	19%	73%	47%	7%	9%
Fraction of Total Spring Flow (1986 to 1995)				18%	23%	9%

TEMPERATURE AND WATER QUALITY

Temperature and water quality data for the period of the early to mid 1980' to the present is available for Mammoth Creek at Old 395, the AB headsprings, CD headspring, H23 headspring and Hot Creek at the Flume. These data were collected by the USGS and were obtained from the USGS for this study. These data are summarized in Table 7. A detailed tabular listing of temperature and water quality data for these sites is included in the Appendix. Parameters of interest for the AB and CD headsprings include total dissolved solids (TDS), hardness, total inorganic nitrogen (ammonia plus nitrite plus nitrate expressed as nitrogen), phosphorus (orthophosphate-phosphorus) and arsenic. Temperature, total inorganic nitrogen and phosphorus are parameters of concern for the aquatic habitat. TDS and hardness are general indices of water chemistry. Total inorganic nitrogen and arsenic are human health concerns for the employees of the fish hatchery that use the springs as a domestic supply.

The temperature at the AB spring averages about 16.9 degrees centigrade and ranges from a low of 15.5 degrees centigrade to a high of about 18.0 degrees centigrade. The temperature at the CD spring averages about 15.6 degrees centigrade and ranges from a low of 14.0 degrees centigrade to a high of about 17.0 degrees centigrade. The temperature at the H23 spring averages about 11.3 degrees centigrade and ranges from a low of 10.0 degrees centigrade to a high of about 13.0 degrees centigrade. Plots of discharge versus temperature are included in the appendix for each spring. There is a weak relationship between spring discharge and temperature for the AB spring. Linear regression for temperature as a function of discharge for each spring yielded the following parameters:

Spring	Slope	Intercept	Coefficient of Determination (R2)
AB	-0.1737	17.86	0.4160
CD	0.1294	14.50	0.0966
H23	0.2217	10.54	0.0296

The coefficient of determination is the fraction of the variance in temperature that is explained by the variance in discharge. About 40 percent of the variation in temperature in the AB spring can be attributed to variation in AB spring discharge. The temperature variations in the CD and H23 springs are not significantly influenced by variations in discharge at these springs.

Table 7
Water Quality Data
At Selected Stream and Spring Locations
(Data from USGS)

Date	Instan. Flow (cfs)	Water Temp (°C)	pH	EC (umho/cm)	TDS (mg/l)	Cations — Ca (mg/l)	Cations — Mg (mg/l)	Cations — Na (mg/l)	Cations — K (mg/l)	Anions — HCO3 (mg/l)	Anions — Cl (mg/l)	Anions — SO4 (mg/l)	Anions — TIN (mg/l N)	Anions — F (mg/l)	Anions — B (mg/l)	Total Alkalinity (mg/l as CACO3)	Total Hardness (mg/l as CACO3)
10265130 Mammoth Creek at Old 395																	
Minimum	1.4	0.5	7.1	42	30	5.1	0.9	2.1	0.6	41	0.1	1.7	0.01	0.10	0.01	28	18
Maximum	76.9	18.0	8.4	165	136	14.0	6.9	13.0	3.0	99	1.2	9.2	0.50	0.30	0.05	86	61
Average	16.2	8.3	7.8	118	82	10.2	4.4	8.0	1.9	77	0.5	5.1	0.08	0.15	0.01	61	44
Std. Dev.	19.4	5.6	0.3	34	25	2.3	1.6	2.8	0.6	18	0.2	1.5	0.11	0.07	0.01	16	12
10265150 Hot Creek at Flume																	
Minimum	38.0	16.5	7.3	153	193	7.9	2.9	20.0	2.5	207	8.9	8.3	0.02	0.50	0.42	60	32
Maximum	283.0	37.0	8.7	591	408	13.0	6.3	100.0	9.0	234	57.0	32.0	3.90	2.50	2.60	192	58
Average	91.2	25.6	7.8	424	305	11.9	5.4	66.6	6.3	221	34.9	21.4	0.56	1.50	1.57	144	52
Std. Dev.	63.0	6.3	0.4	123	58	1.5	0.9	23.4	1.7	19	13.5	6.3	1.11	0.63	0.59	31	7
373822118514401 003S028E34R801M - AB Springs																	
Minimum	2.5	15.5	7.1	212	164	9.4	7.1	21.0	4.5	104	7.1	9.1	0.21	0.20	0.36	85	53
Maximum	13.0	18.0	7.7	302	230	15.0	11.0	31.0	6.7	143	18.0	19.0	0.79	0.40	0.70	116	83
Average	5.7	16.9	7.3	267	197	13.1	9.5	26.8	5.8	130	11.8	13.3	0.37	0.30	0.54	107	72
Std. Dev.	2.9	0.7	0.2	22	17	1.6	1.1	2.9	0.6	11	2.9	2.5	0.13	0.05	0.11	8	8
373818118513301 003S028E35N803M - CD Springs																	
Minimum	5.7	14.0	7.1	185	154	11.0	8.0	21.0	4.4	120	3.8	9.4	0.24	0.10	0.20	98	60
Maximum	12.9	17.0	8.1	263	204	14.0	10.0	27.0	5.5	137	8.2	15.0	0.47	0.40	0.32	113	74
Average	8.3	15.6	7.5	237	179	12.2	9.2	23.9	5.1	131	5.8	11.1	0.34	0.31	0.27	107	68
Std. Dev.	1.5	0.6	0.3	18	10	0.7	0.5	1.3	0.3	4	1.1	1.2	0.06	0.06	0.03	3	4
373829118505801 003S028E35K801M - H23 Springs																	
Minimum	2.6	10.0	6.9	166	105	16.0	5.2	13.0	3.0	93	5.2	6.0	0.25	0.10	0.09	73	61
Maximum	4.1	13.0	7.7	241	168	21.0	6.9	18.0	4.1	115	11.0	13.0	0.70	0.40	0.13	94	81
Average	3.2	11.3	7.3	205	145	17.4	5.9	15.4	3.6	102	7.5	11.6	0.41	0.20	0.11	82	68
Std. Dev.	0.4	0.5	0.2	20	15	1.4	0.5	1.4	0.3	7	1.5	1.3	0.13	0.06	0.01	6	6

Note flow values correspond to observed flows when water quality samples were taken

The TDS concentration at the AB spring averages about 197 mg/L and ranges from a low of 164 mg/L to a high of about 203 mg/L. The TDS concentration at the CD spring averages about 237 mg/L and ranges from a low of 185 mg/L to a high of about 263 mg/L. The TDS concentration at the H23 spring averages about 205 mg/L and ranges from a low 166 mg/L to a high of about 241 mg/L. Plots of TDS versus discharge are included in the appendix for each spring. There is a weak relationship between spring discharge and TDS for the AB spring. Linear regression for TDS as a function of discharge for each spring yielded the following parameters:

Spring	Slope	Intercept	Coefficient of Determination (R2)
AB	-3.80	218	0.3700
CD	-1.44	191	0.0454
H23	7.24	121	0.0328

About 37 percent of the variation in TDS in the AB spring can be attributed to variation in AB spring discharge. The TDS variations in the CD and H23 springs are not significantly influenced by variations in discharge at these springs.

The hardness at the AB spring averages about 72 mg/L (expressed as mg/L of CaCO3) and ranges from a low of 53 mg/L to a high of about 82 mg/L. The hardness at the CD spring averages about 68 mg/L and ranges from a low of 60 mg/L to a high of about 74 mg/L. The hardness at the H23 spring averages about 68 mg/L and ranges from a low 61 mg/L to a high of about 81 mg/L. Plots of hardness versus discharge are included in the appendix for each spring. There is a weak relationship between spring discharge and hardness for the AB and CD springs. Linear regression for hardness as a function of discharge for each spring yielded the following parameters:

Spring	Slope	Intercept	Coefficient of Determination (R2)
AB	-1.76	81	0.3367
CD	-1.60	81	0.4545
H23	6.18	48	0.1837

About 34 percent of the variation in hardness in the AB spring can be attributed to variation in AB spring discharge; 45 percent of the variation in hardness in the CD spring can be attributed to variation in CD spring discharge; and 18 percent of the variation in hardness in the H23 spring can be attributed to variation in H23 spring discharge.

Total inorganic nitrogen concentration (expressed as mg/L of nitrogen) at the AB spring averages about 0.30 mg/L and ranges from a low of 0.28 mg/L to a high of about 0.31 mg/L. Total inorganic nitrogen concentration at the CD spring averages about 0.33 mg/L and ranges from a low of 0.28 mg/L to a high of about 0.39 mg/L. Total inorganic nitrogen concentration at the H23 spring averages about 0.43 mg/L and ranges from a low 0.26 mg/L to a high of about 0.68 mg/L. Ammonia levels range from <0.01 to 0.04 mg/L. Plots of total inorganic nitrogen versus discharge are included in the appendix for each spring. There is a weak relationship between spring discharge and total inorganic nitrogen for the AB spring. Linear regression total inorganic nitrogen a function of discharge for each spring yielded the following parameters:

Spring	Slope	Intercept	Coefficient of Determination (R2)
AB	0.0210	0.25	0.2162
CD	0.0048	0.30	0.0151
H23	-0.0099	0.44	0.0009

About 20 percent of the variation in total inorganic nitrogen in the AB spring can be attributed to variation in AB spring discharge. The total inorganic nitrogen variations in the CD and H23 springs are not significantly influenced by variations in discharge at these springs. Essentially all the total inorganic nitrogen is nitrate. The maximum contaminant level nitrate in drinking water is 10 mg/L as nitrogen. During the period of record, nitrate, as a component of total inorganic nitrogen, has always been measured far below the nitrate maximum contaminant level.

The phosphorus concentration (orthophosphate phosphorus) at the AB spring averages about 0.44 mg/L and ranges from a low of 0.34 mg/L to a high of about .049 mg/L. The phosphorus concentration at the CD spring averages about 0.52 mg/L and ranges from a low of .034 mg/L to a high of about 0.58 mg/L. The phosphorus concentration at the H23 spring averages about 0.3 mg/L and ranges from a low 0.25 mg/L to a high of about 0.34 mg/L. Plots of discharge versus phosphorus concentration are included in the appendix for each spring. There is no apparent relationship between flow and phosphorus. Linear regression for each spring yield coefficient of determinations of ranging from 0.0001 to 0.001.

The arsenic concentration at the AB spring averages about 0.047 mg/L and ranges from a low of 0.020 mg/L to a high of about 0.077 mg/L. The arsenic concentration at the CD spring averages about 0.052 mg/L and ranges from a low of 0.030 mg/L to a high of about 0.085 mg/L The arsenic concentration at the H23 spring averages about 0.022 mg/L and ranges from a low 0.015 mg/L to a high of about 0.048 mg/L. The maximum contaminant level for arsenic in drinking water is 0.050 mg/L. There are times when the discharge from the AB and CD headsprings are not potable. Plots of discharge versus arsenic concentration are included in the appendix for each spring. There is no apparent relationship between flow and arsenic. Linear regression for each spring yield coefficient of determinations ranging from 0.0005 to 0.03.

RELATIONSHIP BETWEEN HISTORICAL GROUNDWATER EXTRACTION AND DISCHARGE AT THE AB AND CD HEADSPRINGS

Prior investigations (USFS, 1990) presumed that groundwater extraction in the western part of the Mammoth Basin would cause a comparable reduction in spring flow at the headwater springs. Presumption of this impact is based on the assumption that groundwater storage is small, and that all groundwater eventually leaves the basin as surface flow in Hot Creek. If these assumptions were true then we should be able to observe groundwater level and stream discharge changes caused by groundwater extraction.

The groundwater extraction area in question is located about seven miles west and hydraulically up-gradient of the headsprings. Groundwater elevations in the vicinity of the significant groundwater extraction ranges from about 7,600 to 7,800 ft-msl. The groundwater elevation in the vicinity of the AB and CD headwater springs is about 7,075 ft-msl. A necessary condition for the groundwater extraction in the west Mammoth Basin area to influence the springs would be a change in the hydraulic gradient from the groundwater extraction area in the west extending continuously to the headsprings. Figure 6 shows a groundwater profile extending from the MCWD groundwater extraction area in the western part of the mammoth groundwater basin through the AB and CD headspring area. Plate 2 shows the groundwater level histories at wells extending from the MCWD groundwater extraction area in the west through the headspring area.

The drop in groundwater level in the groundwater extraction area due to pumping in the west can be clearly seen in and Plate 2 (pink hydrographs) to range between 40 to 60 feet during the period 1987 to 1992. Storage depletion during part of the drought can be seen in MCWD well hydrographs in the far western end of the groundwater basin. Some down-gradient monitoring wells with ambient groundwater elevations above 7,400 ft-msl show slight groundwater level declines during the drought and may have been influenced by the accumulated up-gradient groundwater extraction during the drought. Groundwater elevations and the gradient below groundwater elevation 7,300 ft-msl show no significant changes due to drought or up-gradient groundwater extraction. Review of groundwater level data in Figure 6 and Plate 2 show that aquifer stresses originating in the western part of the Mammoth Basin from groundwater extraction did not extend to the area of the headsprings where groundwater levels are about elevation 7,075 ft-msl.

The streamflow records for Mammoth Creek at Old 395 and Hot Creek at Flume were studied to see if groundwater extraction in the western part of the Mammoth Basin could have impacted the aggregate of spring flows. Double mass curves were developed for these stream discharge gaging stations. Double mass curves are plots of accumulative mass or flow at one station versus a similar accumulative term for another nearby station. Double mass curves are used to determine if significant changes have occurred at precipitation and stream discharge gages due to such activities as relocation of gages or construction of stream diversions. Changes in discharge due to drought or wet periods are filtered out in double mass curve analysis. Each point on the curve corresponds to a point in time. If data on the plot occurs after a change in the flow regime then the trend represented by the later data will diverge from the trend described by the data representing the period prior to a change. Figures 13 and 14 contain double mass curve plots for the Mammoth Creek at Old 395 gage versus April 1 snow survey, and the Hot Creek at the Flume gage versus the same index. Review of the Mammoth Creek plot shows a fairly straight line with no divergence. Groundwater extraction has not impacted the surface discharge measured at this location – groundwater levels are too deep to influence stream flows. The Hot Creek plot shows divergence corresponding to after 1986 -- the point in time that the drought occurred. If groundwater pumping were the source of the divergence, then the divergence would have been down to the right indicating that the stream discharge would be accumulating at a lessor rate than before significant groundwater extraction occurred. The Hot Creek mass curve diverges slightly

Figure 13 Double Mass Curve for Mammoth Creek at Old 395 and April 1 Snow Survey

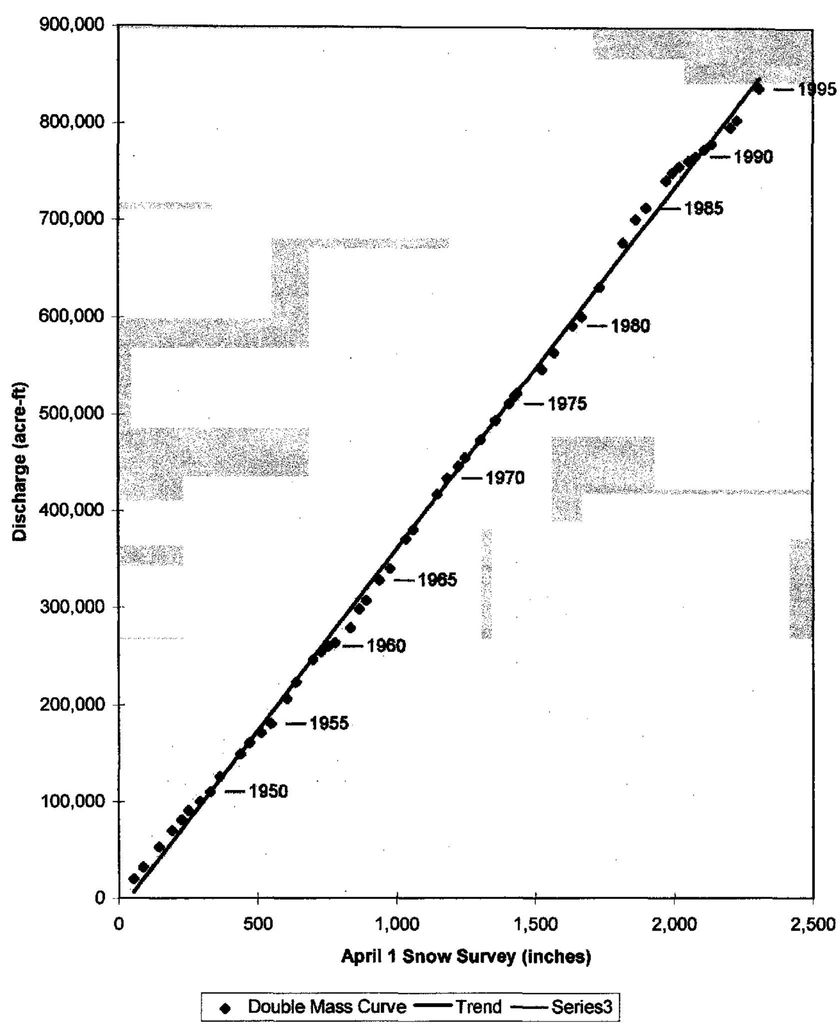
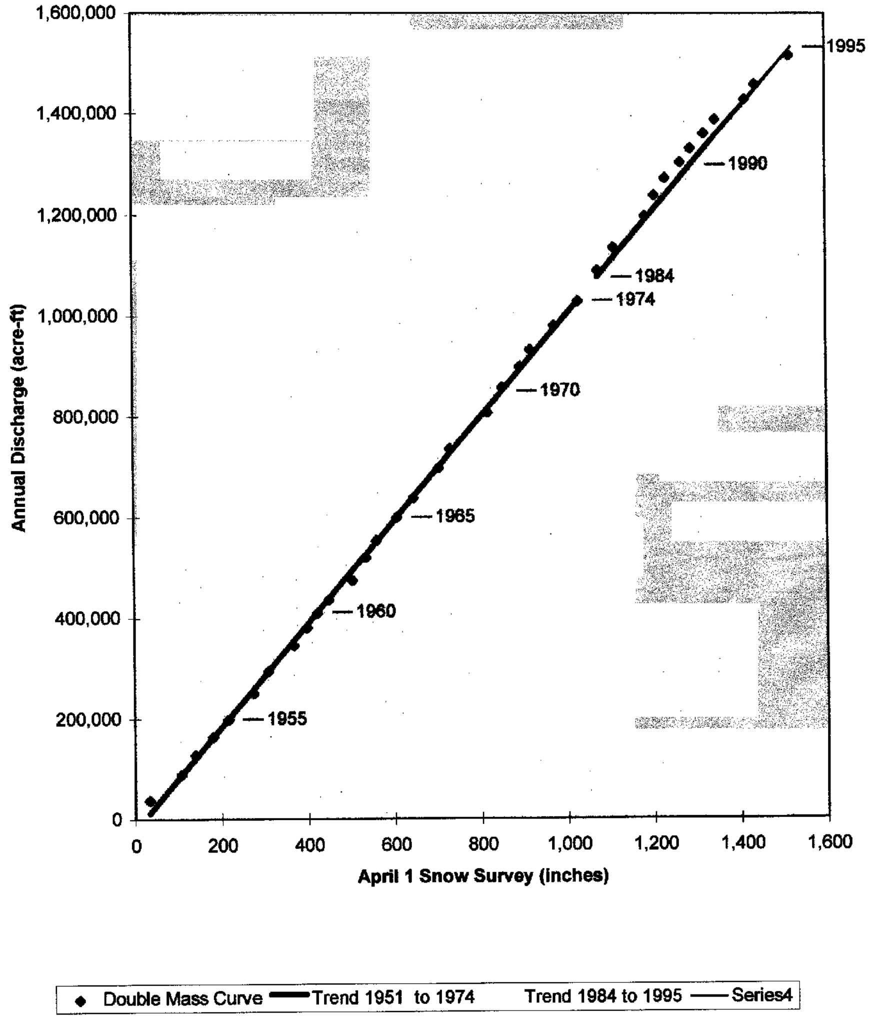


Figure 14 Double Mass Curve for Hot Creek at Flume and April 1 Snow Survey



the opposite way, that is, Hot Creek <u>coincidentally</u> has more discharge than would historically have been expected, after significant groundwater extraction began. We checked with the USGS to see if there were any changes in flow measuring at the Hot Creek station that could have caused this apparent anomaly – they stated that to the best of their knowledge there were no such changes (telephone discussions with G. Rockwell of USGS, 7/30/96). The lack of downward divergence at the Hot Creek gage indicates that there has been no observed depletion of spring flows due to past groundwater pumping.

There is a significant amount of recent groundwater level data in the area between the MCWD groundwater extraction area in the western part of the Mammoth Basin and the AB and CD headwater springs. Review of the groundwater level data in Figure 6 and Plate 2 show that the changes in hydraulic gradient caused by groundwater extraction area in the western part of the Mammoth Basin did not extend to anywhere near the area of the headsprings. Review of the double mass curve for Hot Creek indicate that there has been no observed depletion of the aggregate spring discharge measured at the Hot Creek at the Flume gage. From these two observations we conclude that historical groundwater extraction in western part of the Mammoth Basin has not noticeably impacted the discharge at the AB and CD headspring.

The Mammoth Basin is hydrologically more complex than described by the simple conceptual model developed by the DWR in 1973. The DWR conceptual model of the Mammoth Basin was based on very simplistic assumptions, the most significant being that the yield of the Basin is directly equatable to average annual basin precipitation minus average consumptive use. Runoff, recharge and evapotranspiration processes are non linear with respect to precipitation – translated, average precipitation is not equatable to yield. The yield of the Mammoth groundwater basin can only be determined by studying hydrologic process over a historically-representative range of precipitation. Conceptual errors aside, the DWR analysis suffers from a lack of precipitation data, groundwater level and historical extraction data. The groundwater basin had never been significantly stressed prior to the late 1980's. The DWR estimated that the total outflow of the basin, surface and groundwater, to be about 40,600 acre-ft/yr. Based on review of historical groundwater levels, spring discharge and surface water discharge, the combined surface and groundwater yield of Mammoth basin should be much larger than the yield estimate developed by the DWR.

The DWR estimated that useful groundwater storage to be about 57,000 acre-ft based on groundwater stored only in unconsolidated deposits. In the 1980's MCWD developed extraction wells in fractured basalts which demonstrated that the useful storage includes fractured rocks that underlie and are adjacent to the unconsolidated deposits. The useful groundwater storage up-gradient and tributary to the AB and CD headsprings is estimated to be about 242,700 acre-ft.

The lack of noticeable spring flow and stream flow depletions in the late 1980's and early 1990's is likely due to the yield being significantly larger than the MCWD groundwater extractions and AB and CD headspring discharges; and due to the large amount of storage relative to MCWD groundwater extractions and AB and CD headspring discharges. Yield in excess of MCWD groundwater extraction and spring discharge leaves the basin as subsurface outflow.

SECTION 3
FUTURE WATER DEMANDS AND SUPPLIES

CURRENT DEMANDS AND WATER SUPPLY SOURCES

Estimates of existing and future water demands in the Mammoth basin are listed in Table 8. These estimates are based in part on published estimates from MCWD (*1996 Urban Water Management Plan,* MCWD, May 1996) and other estimates for water users either not served by MCWD or not included in the *1996 Urban Water Management Plan.* Table 9 shows the monthly demand pattern for water supplied by MCWD and the existing Snow Creek golf course.

Water supplies in the Mammoth lakes area comes from a combination of surface water diverted from Lake Mary and groundwater. Table 10 lists historical water extraction by MCWD (1983 to 1995) and groundwater extraction by the Snowcreek golf course. Domestic use at the Casa Diablo geothermal plant is estimated at 0.35 acre-ft/yr.

The capacity of MCWD supplies for existing conditions is:

Sources of Supply Existing System	Non Drought	Drought
Lake Mary	2,450	800
Well 1	500	315
GWTP1*	2,000	1,685
GWTP2**	1,500	1,450
Snowcreek G.W.	165	165
Total	6,615	4,415

* MCWD wells 6, 10, 15 and 18
** MCWD wells 16, 17 and 20

Table 8
Projected Water Demands for Mammoth Lakes Area
Including Mammoth Community Water District and Adjacent Privately Served Lands
(acre-ft/yr)

Water Use Category	Existing Water Demand: Units of Use	Existing Water Demand: Number of Units of Use	Existing Water Demand: Water Use per Unit (acre-ft/yr/unit)	Water Demand (acre-ft/yr)	Incremental Demand to Buildout: Units of Use	Incremental Demand to Buildout: Number of Units of Use	Incremental Demand to Buildout: Water Demand (acre-ft/yr)	Ultimate Demand at Buildout (acre-ft/yr)
MCWD Municipal Service								
Single Family Residential	edu	1,677	0.22	361	edu	707	152	514
Condominium	edu	4,623	0.19	894	edu	1,544	298	1,192
Multi-Family/Apartment	edu	539	0.17	92	edu	470	80	173
Mobile Home	edu	144	0.24	35	edu	11	3	38
Motel/Hotel	room	998	0.12	116	room	4,964	579	695
Commercial	ft*ft	1,056,069	0.000161	170	ft*ft	379,642	61	231
Industrial	ft*ft	106,635	0.000054	6	ft*ft	124,582	7	12
Recreation/Parks	ea	1	56.68	57	ea	1	34	91
Public Sector	ea	1	20.48	20	ea	1	12	33
Irrigation (billed separately)	ea	1	60.60	61	ea	1	36	97
Other Residential	ea	1	20.85	21	ea	0	0	21
Fire Use, Maintenance	ea	1	75.49	75	ea	0	45	121
Audit Corrections	15% of existing			286	10% of existing		131	417
Conservation Devices							(111)	(111)
Growth in Occupancy	25% of existing + audit corr.			549	25% of existing +		332	881
Subtotal MCWD Municipal Service				2,743			1,660	<u>4,403</u>
Other Demands								
Snowcreek Golf Course (1)				165			165	330
Lodestar Golf Course (2)				0			300	300
Snowcreek Ski Area (3)				0			145	145
Geothermal Domestic(4)				0.35			0.12	0.47
Subtotal Other Demands				165			610	<u>775</u>
Total Ultimate Annual Demand Under Normal Climatic Conditions								<u>5,179</u>
Total Ultimate Annual Demand Under Drought Conditions (5)								<u>3,884</u>

Notes (1) Existing 165 acre-ft/yr supplied by private wells, new 165 acre-ft/yr can be supplied with reclaimed water.
(2) Total demand will be met with reclaimed water when reclaimed water is available; MCWD will supply potable water until reclaimed water is available.
(3) 125 acre-ft/yr for snowmaking (50 af in Nov, 50 af in Dec and 25 af in Feb; 20 acre-ft/yr for domestic uses; and 125 acre-ft/yr for first 2 to 3 years for re-vegetation. Re-vegetation demand not included because it is short term and small.
(4) Currently there are three geothermal plant in the area using a total of about 0.35 acre-ft/yr. One more plant is proposed. Assume new plant uses about 0.12 acre-ft/yr (source Jim Anderson, plant manager for Mammoth Pacific, 8/6/96).
(5) Assumed water demands reduced by 25% during droughts.

Table 9
Monthly Water Demand by Water User Group

Existing Demand Time Histories

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Basic Muni Demand	2,744	206	193	208	184	227	278	344	330	245	181	150	198
%	100.0%	7.5%	7.0%	7.6%	6.7%	8.3%	10.1%	12.5%	12.0%	8.9%	6.6%	5.5%	7.2%
Ex. Snowcreek G.C.	165	0	0	0	0	23	28	34	34	28	18	0	0
Tot Dem, Norm Clim	2,909	206	193	208	184	250	306	378	364	273	199	150	198
Reclaimed Water Prod Norm Clim Cond	1,656	158	146	163	150	148	130	146	145	117	103	106	145
Ratio of Recl Wat Prod To Mun Supply		77%	75%	78%	81%	65%	47%	42%	44%	48%	57%	71%	73%

Ultimate Demand Time Histories

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Basic Muni Demand	4,404	331	310	334	295	365	446	551	530	393	290	241	318
%	100.0%	7.5%	7.0%	7.6%	6.7%	8.3%	10.1%	12.5%	12.0%	8.9%	6.6%	5.5%	7.2%
Lodestar GC	300	0	0	0	0	42	51	62	62	51	33	0	0
Ex. Snowcreek G.C.	165	0	0	0	0	23	28	34	34	28	18	0	0
Snowcreek GC Expansion	165	0	0	0	0	23	28	34	34	28	18	0	0
-wcreek snow making	125		25	0	0	0	0	0	0	0	0	50	50
-wcreek domestic	20	4	4	2	1	0	0	0	0	0	2	3	4
Tot Dem, Norm Clim	5,179	335	339	336	296	452	553	681	659	500	361	294	372
Reclaimed Water Prod Norm Clim Cond	2,673	257	237	263	241	237	209	234	232	188	167	173	235
Ratio of Recl Wat Prod To Mun Supply		77%	75%	78%	81%	65%	47%	42%	44%	48%	57%	71%	73%

Table 10
Water Production by MCWD and Snowcreek
(acre-ft/yr)

Year	MCWD Production Surface Water	MCWD Production Groundwater	MCWD Production Total	Snowcreek Groundwater Production	Total Groundwater Production
1983	2,221	48	2,269		48
1984	2,450	157	2,607		157
1985	2,196	313	2,509		313
1986	2,164	264	2,428		264
1987	1,537	563	2,100		563
1988	1,605	595	2,200		595
1989	1,780	958	2,738		958
1990	1,485	1,143	2,628		1,143
1991	1,048	1,337	2,385	27	1,364
1992	804	2,285	3,089	100	2,385
1993	1,653	1,677	3,330	37	1,714
1994	1,364	1,257	2,621	155	1,412
1995	1,726	968	2,695	165	1,133
Average 1991 to 1995	1,319	1,505	2,824	97	1,602

Source: MCWD Summary.xls

FUTURE WATER DEMANDS AND WATER SUPPLY SOURCES

Demands for ultimate buildout are listed in Table 8. These demand projections are based on the same references cited above for existing demand. The increase in water demand due to the expansion of the Snowcreek golf course from a 9-hole course to an 18-hole course, is estimated to be the same as the existing 9-hole demand – 165 acre-ft/yr. That is, upon completion of the expansion, the Snowcreek golf course demand will have increased from 165 to 330 acre-ft/yr. Ultimate demand is projected to be about 5,200 acre-ft/yr, an increase of about 2,200 acre-ft/yr or 73 percent.

Sources of Supply Ultimate Water System	Non Drought	Drought
Lake Mary	2,300	800
Well 1	500	315
GWTP1*	2,000	1,685
GWTP2**	1,500	1,450
Dry Creek (on line 2010 or sooner)	1,500	1,400
Snowcreek G.W.	330	330
Total	8,100	5,980

* MCWD wells 6, 10, 15 and 18
** MCWD wells 16, 17 and 20

FUTURE WATER SUPPLY SCENARIOS

Two basic scenarios were developed to investigate the potential impacts of groundwater extraction in the Mammoth area for ultimate (corresponding cumulative impacts) and project specific (direct) impact of Snowcreek golf course expansion. These scenarios are distinguished by the inclusion or exclusion of the Dry Creek Project. The Dry Creek project is essentially an importation project to bring supplemental waters from outside the Mammoth Basin to meet future water demands. MCWD has completed extensive testing in the Dry Creek area to determine the integrity of the supply. MCWD is also investigating other importation projects to bring in additional supplies from outside the Mammoth Basin should the Dry Creek project not be implemented. Sub-scenario's were developed to include or exclude the direct use of reclaimed water as a water supply for the Snowcreek golf course expansion and for the Lodestar golf course. The scenario's studied herein include:

Scenario 1a	Supplies for ultimate or buildout conditions comes from within and outside of the Mammoth Basin and exclude reclaimed water.
Scenario 1b	Supplies for ultimate or buildout conditions comes from within and outside of the Mammoth Basin and include reclaimed water.
Scenario 2a	Supplies for ultimate or buildout conditions comes from within the Mammoth Basin and exclude reclaimed water.
Scenario 2b	Supplies for ultimate or buildout conditions comes from within the Mammoth Basin and include reclaimed water.

A water supply allocation plan was developed for each scenario for drought and non-drought conditions. The supply allocation plan is listed in Table 11. Table 11 also lists the annual Mammoth Basin groundwater extraction, ratio of supply to demand, additional (new) Mammoth Basin groundwater extraction, and the incremental Snowcreek demand for potable supplies. Total Mammoth Basin groundwater extraction is projected to range from a low of about 900 acre-ft/yr for Scenario 1b (includes Dry Creek and direct use of 465 acre-ft/yr of reclaimed water) to a high of 3,780 acre-ft/yr for Scenario 2a (excludes Dry Creek and direct use of reclaimed water).

Baseline groundwater extraction, as used herein, is the annual groundwater extraction representative of existing conditions. Groundwater extraction in excess of the baseline groundwater extraction is additional groundwater extraction due to the increased water demands (including expansion of the Snowcreek golf course) and or drought conditions. Baseline groundwater extraction is estimated to be 2,385 acre-ft/yr which is the largest annual groundwater extraction to occur in Mammoth Basin. Additional new groundwater extraction is projected to range from a low of about -1,500 acre-ft/yr for Scenario 1b (includes Dry Creek and direct use of 465 acre-ft/yr of reclaimed water) to a high of 1,400 acre-ft/yr for Scenario 2a (excludes Dry Creek and direct use of reclaimed water). The negative value of additional groundwater extraction means that local groundwater extraction declined from the baseline.

Table 11
Water Sources and Allocation for MCWD

Sources of Supply	Scenario 1a With Dry Creek No Reclamation		Scenario 1b With Dry Creek With Reclamation		Scenario 2a No Dry Creek No Reclamation		Scenario 2b No Dry Creek With Reclamation	
	Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought
Sources of Supply								
Lake Mary	2,300	800	2,300	800	2,300	800	2,300	800
Well 1	500	315	500	315	500	315	500	315
GWTP1	2,000	1,685	2,000	1,685	2,000	1,685	2,000	1,685
GWTP2	1,500	1,450	1,500	1,450	1,500	1,450	1,500	1,450
Dry Creek Wells	1,500	1,400	1,500	1,400	0	0	0	0
Reclamation	0	0	465	465	0	0	465	465
Private Wells	330	330	165	165	330	330	165	165
Total Supplies	8,130	5,980	8,430	6,280	6,630	4,580	6,930	4,880
Total Mammoth GW	4,330	3,780	4,165	3,615	4,330	3,780	4,165	3,615
Allocation of Supplies								
Lake Mary	2,300	800	2,300	800	2,300	800	2,300	800
Well 1	131	242	94	214	319	315	281	315
GWTP1	524	1,294	374	1,147	1,274	1,685	1,124	1,685
GWTP2	393	1,113	281	987	956	1,450	843	1,450
Dry Creek Wells	1,500	1,400	1,500	1,400	0	0	0	0
Reclamation	0	0	465	465	0	0	465	465
Private Wells	330	330	165	165	330	330	165	165
Total Allocated	5,179	5,179	5,179	5,179	5,179	4,580	5,179	4,880
Total Mammoth GW	1,379	2,979	914	2,514	2,879	3,780	2,414	3,615
Ratio of Supply to Demand	100%	100%	100%	100%	100%	88%	100%	94%
Baseline Groundwater Production	2,385	2,385	2,385	2,385	2,385	2,385	2,385	2,385
Additional Groundwater Production	(1007)	593	(1472)	128	493	1395	28	1230
Incremental Snowcreek Potable Demand	165	165	0	0	165	165	0	0
Increment of Additional Groundwater Prod Due to SnowCreek Golf Course Exp.	NA	28%	NA	0%	33%	12%	0%	0%

The incremental Snowcreek potable demand is the additional demand required by the expansion of the Snowcreek golf course when reclaimed water is not available. This demand is either 165 acre-ft/yr or zero – 165 acre-ft/yr when reclaimed water is not available and zero when reclaimed water is available.

The ratio of supply to demand is ratio of available supply to demand. A value of less than 100 percent means that a shortage occurred. During the period of 1987 to 1992, demand was reduced from 65 to 75 percent of normal. In the present analysis, shortages occur only Scenarios 2a and 2b during drought conditions, due to the exclusion of Dry Creek Project. It is assumed that under shortage conditions, MCWD will impose waster use restrictions up to a maximum of 25 percent of normal water use.

Tables 12a through 12d show the water supply allocations on a monthly basis, monthly use of Mammoth Basin groundwater and the monthly flow of reclaimed water to Laurel Pond.

Table 12a
Monthly Water Supply Allocations for Scenario 1a
(acre-ft)

Scenario 1a	**Ultimate Buildout, Dry Creek Operational, No Reclamation, and Non-Drought Conditions**												
Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Mary	2,300	192	192	192	179	192	192	192	192	192	192	178	192
Well 1	131	2	3	2	0	11	23	37	34	16	1	0	8
GWTP1	524	9	11	10	0	45	90	148	137	64	4	0	32
GWTP2	393	7	8	7	0	34	68	111	103	48	3	0	24
Dry Creek Wells	1,500	125	125	125	117	125	125	125	125	125	125	116	116
Reclamation	0	0	0	0	0	0	0	0	0	0	0	0	0
Private Wells	330	0	0	0	0	46	56	68	68	56	36	0	0
Total Supplied	5,179	335	339	336	296	452	553	681	659	500	361	294	372
Mammoth GW	1,379	18	22	20	0	136	237	365	343	183	44	0	64
Recl Water to Laurel Pond	2,673	257	237	263	241	237	209	234	232	188	167	173	235

Scenario 1a	**Ultimate Buildout, Dry Creek Operational, No Reclamation, and Drought Condition**												
Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ke Mary	800	67	67	67	67	67	67	67	67	67	67	67	67
ell 1	242	14	14	14	10	20	29	39	37	24	13	10	17
GWTP1	1,294	74	76	75	55	109	153	210	199	127	69	54	92
GWTP2	1,113	64	65	64	47	94	132	181	171	110	59	46	79
Dry Creek Wells	1,400	117	117	117	117	117	117	117	117	117	117	117	117
Reclamation	0	0	0	0	0	0	0	0	0	0	0	0	0
Private Wells	330	0	0	0	0	46	56	68	68	56	36	0	0
Total Supplied	5,179	335	339	336	296	452	553	681	659	500	361	294	372
Mammoth GW	2,979	151	156	153	113	269	370	498	476	317	178	110	189
Recl Water to Laurel Pond	2,673	257	237	263	241	237	209	234	232	188	167	173	235

Table 12b
Monthly Water Supply Allocations for Scenario 1b
(acre-ft)

Scenario 1b — **Ultimate Buildout, Dry Creek Operational, With Reclamation, Non-Drought Conditions**

Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Mary	2,300	192	192	192	179	192	192	192	192	192	177	178	192
Well 1	94	2	3	2	0	7	17	30	28	11	0	0	7
GWTP1	374	9	11	10	0	28	69	121	110	42	0	0	28
GWTP2	281	7	8	7	0	21	52	91	83	32	0	0	21
Dry Creek Wells	1,500	125	125	125	117	117	117	117	117	117	115	116	125
Reclamation	465	0	0	0	0	65	79	96	96	79	51	0	0
Private Wells	165	0	0	0	0	23	28	34	34	28	18	0	0
Total Supplied	5,179	335	339	336	296	452	553	681	659	500	361	294	372
Mammoth GW	914	18	22	20	0	79	166	277	255	112	18	0	55
Recl Water to Laurel Pond	2,208	257	237	263	241	173	130	138	137	109	116	173	235

Scenario 1b — **Ultimate Buildout, Dry Creek Operational, With Reclamation, Drought Conditions**

Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ke Mary	800	67	67	67	67	67	67	67	67	67	67	67	67
Well 1	214	14	14	14	10	17	24	34	32	19	10	10	17
GWTP1	1,147	74	76	75	55	88	129	180	169	102	53	54	92
GWTP2	987	64	65	64	47	76	111	155	146	88	46	46	79
Dry Creek Wells	1,400	117	117	117	117	117	117	117	117	117	117	117	117
Reclamation	465	0	0	0	0	65	79	96	96	79	51	0	0
Private Wells	165	0	0	0	0	23	28	34	34	28	18	0	0
Total Supplied	5,179	335	339	336	296	452	553	681	659	500	361	294	372
Mammoth GW	2,514	151	156	153	113	204	291	402	380	238	127	110	189
Recl Water to Laurel Pond	2,208	257	237	263	241	173	130	138	137	109	116	173	235

Table 12c
Monthly Water Supply Allocations for Scenario 2a
(acre-ft)

Scenario 2a — **Ultimate Buildout, No Dry Creek Project, No Reclamation, and Non-Drought Conditions**

Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Mary	2,300	192	192	192	192	192	192	192	192	192	192	192	192
Well 1	319	20	21	20	15	24	36	51	48	29	14	14	26
GWTP1	1,274	81	84	82	59	98	144	204	191	114	57	58	102
GWTP2	956	61	63	61	44	73	108	153	144	86	43	43	77
Dry Creek Wells	0	0	0	0	0	0	0	0	0	0	0	0	0
Reclamation	0	0	0	0	0	0	0	0	0	0	0	0	0
Private Wells	330	0	0	0	0	46	56	68	68	56	36	0	0
Total Supplied	5,179	354	359	356	310	434	536	667	643	476	342	307	396
Mammoth GW	2,879	162	167	164	118	242	345	476	451	284	150	116	204
Recl Water to Laurel Pond	2,673	257	237	263	241	237	209	234	232	188	167	173	235

Scenario 2a — **Ultimate Buildout, No Dry Creek Project, No Recimation and Drought Conditions**

Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
κe Mary	800	67	67	67	67	67	67	67	67	67	67	67	67
Well 1	315	22	22	22	20	26	32	39	38	28	21	19	25
GWTP1	1,685	118	120	119	104	140	171	211	203	152	112	104	131
GWTP2	1,450	102	103	102	90	120	147	182	175	131	96	89	113
Dry Creek Wells	0	0	0	0	0	0	0	0	0	0	0	0	0
Reclamation	0	0	0	0	0	0	0	0	0	0	0	0	0
Private Wells	330	0	0	0	0	46	56	68	68	56	36	0	0
Total Supplied	4,580	308	311	309	281	399	473	567	551	434	332	279	335
Mammoth GW	3,780	242	245	243	214	332	406	500	484	368	265	212	269
Recl Water to Laurel Pond	2,364	227	209	233	213	210	185	207	206	166	147	153	208

Table 12d
Monthly Water Supply Allocations for Scenario 2b
(acre-ft)

Scenario 2b — **Ultimate Buildout, No Dry Creek Project, With Reclamation, and Non-Drought Conditions**

Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Mary	2,300	192	192	192	192	192	192	192	192	192	192	192	192
Well 1	281	18	18	18	13	22	32	45	42	25	13	13	23
GWTP1	1,124	72	74	72	52	86	127	180	169	101	50	51	90
GWTP2	843	54	55	54	39	65	96	135	127	76	38	38	68
Dry Creek Wells	0	0	0	0	0	0	0	0	0	0	0	0	0
Reclamation	465	0	0	0	0	65	79	96	96	79	51	0	0
Private Wells	165	0	0	0	0	23	28	34	34	28	18	0	0
Total Supplied	5,179	335	339	336	296	452	553	681	659	500	361	294	372
Mammoth GW	2,414	143	147	145	105	196	283	394	372	229	118	102	180
Recl Water to Laurel Pond	2,208	257	237	263	241	173	130	138	137	109	116	173	235

Scenario 2b — **Ultimate Buildout, No Dry Creek Project, With Reclamation, and Drought Conditions**

Source	Annual Allocation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ake Mary	800	67	67	67	67	67	67	67	67	67	67	67	67
ell 1	315	24	24	24	21	25	30	37	36	26	20	21	27
GWTP1	1,685	128	129	128	113	132	162	200	191	141	106	112	142
GWTP2	1,450	110	111	111	97	114	139	172	165	122	91	97	122
Dry Creek Wells	0	0	0	0	0	0	0	0	0	0	0	0	0
Reclamation	465	0	0	0	0	65	79	96	96	79	51	0	0
Private Wells	165	0	0	0	0	23	28	34	34	28	18	0	0
Total Supplied	4,880	328	332	330	298	425	504	606	588	463	352	296	358
Mammoth GW	3,615	262	265	263	232	293	359	443	426	317	235	230	291
Recl Water to Laurel Pond	2,105	245	226	251	230	164	124	132	130	104	111	165	224

SECTION 4

IMPACT OF NEW GROUNDWATER EXTRACTION ON HOT CREEK HEADSPRINGS

ASSUMPTIONS AND METHODOLOGY

It was concluded in Section 2 that there has been no discernible impact on Hot Creek headsprings from historical groundwater extraction in the western part of the Mammoth Basin. The hydrologic and geologic complexities of the Basin preclude the development and use of precise groundwater flow model for impact analysis. A conservative approach was developed to estimate impacts of future new groundwater extraction on the headsprings. We assumed that all new groundwater extraction would impact the springs directly with the impact allocated to the springs based on their relative contribution to the Hot Creek base flow. Groundwater extraction impacts would normally be buffered or attenuated due to groundwater storage – we assumed attenuation from storage to be negligible. We further assumed that the seasonal variation in groundwater extraction would not propagate through the groundwater basin to the headsprings. This assumption is reasonable due to the great distance between the extraction area and the headsprings (about 7 miles) and the observation that the historical extraction has not noticeably influenced the headsprings.

The results of this analytical approach is shown in Table 13. New extraction, if positive, is assumed to deplete the springs with 18 percent allocated to the AB spring, 23 percent to the CD spring and 9 percent to H23 spring. The remaining depletion is assumed to occur in aggregate at other springs from the Hot Creek Fish Hatchery to the Hot Creek gage. This is a "worst' case analysis in that spring flows are assumed to respond immediately and in direct proportion to new groundwater extraction.

IMPACTS ON SPRING DISCHARGE

Table 13 contains the average spring discharge in the column titled "non drought" and the

Table 13
Projected Worst-Case Impacts From Cumulative and Incremental New Water Production MCWD Service and Surrounding Areas Spring Discharge (cfs)

	Spring Flow Non-Drought	Spring Flow Drought	Fraction of Spring Flow Depletion Assigned to Spring	Flow in Springs: Scenario 1a With Dry Creek No Reclamation Non-Drought	Scenario 1a Drought	Scenario 1b With Dry Creek With Reclamation Non-Drought	Scenario 1b Drought	Scenario 2a No Dry Creek No Reclamation Non-Drought	Scenario 2a Drought	Scenario 2b No Dry Creek With Reclamation Non-Drought	Scenario 2b Drought
Cumulative New Groundwater Production				(1,007)	593	(1,472)	128	493	1,395	28	1,230
New Snowcreek Production				165	165	0	0	165	165	0	0
AB Spring	6.5	2.1	18%								
Cumulative				*na*	*2.0*	*na*	*2.1*	*6.4*	*1.8*	*6.5*	*1.8*
Snowcreek				*na*	*2.1*	*na*	*2.1*	*6.4*	*2.1*	*6.5*	*2.1*
CD Spring	8.3	5.5	23%								
Cumulative				*na*	*5.3*	*na*	*5.5*	*8.2*	*5.1*	*8.3*	*5.1*
Snowcreek				*na*	*5.4*	*na*	*5.5*	*8.3*	*5.4*	*8.3*	*5.5*
H23 Spring	3.3	2.4	9%								
Cumulative				*na*	*2.3*	*na*	*2.4*	*3.2*	*2.2*	*3.3*	*2.2*
Snowcreek				*na*	*2.4*	*na*	*2.4*	*3.3*	*2.4*	*3.3*	*2.4*
All Other Springs Below Hot Creek Fish Hatchery	19.7	8.8	50%								
Cumulative				*na*	*8.4*	*na*	*8.7*	*19.4*	*7.8*	*19.7*	*8.0*
Snowcreek				*na*	*8.7*	*na*	*8.8*	*19.6*	*8.7*	*19.7*	*8.8*
Total All Springs (1)	37.8	18.8									
Cumulative				na	18.0	na	18.6	37.2	16.9	37.8	17.1
Snowcreek				na	18.6	na	18.8	37.6	18.8	37.8	18.8

(1) Base flow for Hot Creek at Flume form Table 6.

estimated lowest average daily discharge observed at the spring in the column titled "drought." The spring flow depletions, assumed to occur due to new groundwater extraction, are deducted from these flows for the cumulative new groundwater extraction and the incremental extraction from expansion of Snowcreek golf course. The resulting spring discharge are listed in Table 13. The cumulative impacts vary with scenario and climatic assumptions, ranging from zero up to 0.4 cfs at individual springs. The incremental impacts of the Snowcreek golf course expansion are always less than 0.1 cfs at individual springs. These impacts are conservative, will probably be much less than estimated herein, and most likely not measurable.

IMPACTS ON SPRING DISCHARGE TEMPERATURE

A linear relationship for temperature for the AB spring discharge as a function of discharge was developed by regression and is described in Section 2. This relationship was used to estimated the spring discharge temperature when groundwater extractions are increased in the future. Table 14 lists the estimated spring discharge temperatures for average and drought discharge conditions, for the Snowcreek golf course expansion and for ultimate buildout conditions. For the AB, CD and H23 springs, cumulative and incremental temperature impacts for all scenarios range from zero to less than 0.1 degrees-C for all water development scenarios.

IMPACTS ON SPRING DISCHARGE WATER QUALITY

Tables 15, 16 and 17 lists the projected TDS, hardness and total inorganic nitrogen concentrations in spring discharges, for average and drought discharge conditions, for the Snowcreek golf course expansion and for ultimate buildout conditions. The estimated TDS, hardness and total inorganic nitrogen concentrations are based on the linear regressions described in Section 2. The TDS and hardness concentrations change by 1 mg/L or less for all water development scenarios. The total inorganic nitrogen changes than 0.1 mg/L or less for all water development scenarios. The coefficient of determination phosphorous and arsenic are so low that the projected change in discharge of the springs due to new groundwater extraction will have no impact on their respective concentrations.

Table 14
Projected Worst-Case Impacts From Cumulative and Incremental New Water Production MCWD Service and Surrounding Areas
Temperature (degrees Centegrade)

	Spring Flow		Fraction of Spring Flow Depletion Assigned to Spring	Temperature in Springs							
				Scenario 1a With Dry Creek No Reclamation		Scenario 1b With Dry Creek With Reclamation		Scenario 2a No Dry Creek No Reclamation		Scenario 2b No Dry Creek With Reclamation	
	Non-Drought	Drought		Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought
AB Spring	16.7	17.5	18%								
Cumulative				*na*	17.5	*na*	17.5	16.6	17.6	16.7	17.5
Snowcreek				*na*	17.5	*na*	17.5	16.7	17.5	16.7	17.5
CD Spring	15.6	15.2	23%								
Cumulative				*na*	15.2	*na*	15.2	15.6	15.2	15.6	15.2
Snowcreek				*na*	15.2	*na*	15.2	15.6	15.2	15.6	15.2
H23 Spring	11.3	11.1	9%								
Cumulative				*na*	11.1	*na*	11.1	11.3	11.0	11.3	11.0
Snowcreek				*na*	11.1	*na*	11.1	11.3	11.1	11.3	11.1

Table 15
Projected Worst-Case Impacts From Cumulative and Incremental New Water Production MCWD Service and Surrounding Areas Total Dissolved Solids (mg/L)

	Spring Flow		Fraction of Spring Flow Depletion Assigned to Spring	Total Dissolved Solids in Springs							
				Scenario 1a With Dry Creek No Reclamation		Scenario 1b With Dry Creek With Reclamation		Scenario 2a No Dry Creek No Reclamation		Scenario 2b No Dry Creek With Reclamation	
	Non-Drought	Drought		Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought
AB Spring	194	210	18%								
Cumulative				*na*	211	*na*	210	194	211	194	211
Snowcreek				*na*	210	*na*	210	194	210	194	210
CD Spring	179	184	23%								
Cumulative				*na*	184	*na*	184	180	184	179	184
Snowcreek				*na*	184	*na*	184	180	184	179	184
H23 Spring	145	139	9%								
Cumulative				*na*	138	*na*	139	145	138	145	138
Snowcreek				*na*	139	*na*	139	145	139	145	139

Table 16
Projected Worst-Case Impacts From Cumulative and Incremental New Water Production MCWD Service and Surrounding Areas
Hardness (mg/L as $CaCO_3$)

	Spring Flow Non-Drought	Spring Flow Drought	Fraction of Spring Flow Depletion Assigned to Spring	Hardness in Springs: Scenario 1a With Dry Creek No Reclamation Non-Drought	Scenario 1a Drought	Scenario 1b With Dry Creek With Reclamation Non-Drought	Scenario 1b Drought	Scenario 2a No Dry Creek No Reclamation Non-Drought	Scenario 2a Drought	Scenario 2b No Dry Creek With Reclamation Non-Drought	Scenario 2b Drought
AB Spring	70	78	18%								
Cumulative				*na*	78	*na*	78	70	78	70	78
Snowcreek				*na*	78	*na*	78	70	78	70	78
CD Spring	68	73	23%								
Cumulative				*na*	73	*na*	73	68	73	68	73
Snowcreek				*na*	73	*na*	73	68	73	68	73
H23 Spring	68	63	9%								
Cumulative				*na*	62	*na*	63	68	62	68	62
Snowcreek				*na*	63	*na*	63	68	63	68	63

Table 17
Projected Worst-Case Impacts From Cumulative and Incremental
New Water Production MCWD Service and Surrounding Areas
Total Inorganic Nitrogen (NH3+NO2+NO3 as mg/L of N)

	Spring Flow		Fraction of	Hardness in Springs							
			Spring Flow	Scenario 1a		Scenario 1b		Scenario 2a		Scenario 2b	
			Depletion	With Dry Creek		With Dry Creek		No Dry Creek		No Dry Creek	
			Assigned	No Reclamation		With Reclamation		No Reclamation		With Reclamation	
	Non-Drought	Drought	to Spring	Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought	Non-Drought	Drought
AB Spring	0.39	0.29	18%								
Cumulative				*na*	0.29	*na*	0.29	0.38	0.29	0.39	0.29
Snowcreek				*na*	0.29	*na*	0.29	0.39	0.29	0.39	0.29
CD Spring	0.34	0.32	23%								
Cumulative				*na*	0.32	*na*	0.32	0.33	0.32	0.33	0.32
Snowcreek				*na*	0.32	*na*	0.32	0.33	0.32	0.34	0.32
H23 Spring	0.41	0.42	9%								
Cumulative				*na*	0.42	*na*	0.42	0.41	0.42	0.41	0.42
Snowcreek				*na*	0.42	*na*	0.42	0.41	0.42	0.41	0.42

SECTION 5
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Appendix

Water Quality Data
At Selected Stream and Spring Locations
(Data from USGS)

Date	Flow (cfs)	Water Temp (°C)	pH	EC (umho/cm)	TDS (mg/l)	Cations: Ca (mg/l)	Cations: Mg (mg/l)	Cations: Na (mg/l)	Cations: K (mg/l)	Anions: HCO3 (mg/l)	Anions: Cl (mg/l)	Anions: SO4 (mg/l)	Anions: NO3-N (mg/l N)	Anions: F (mg/l)	Anions: B (mg/l)	Total Ion Balance: Cations (meq/l)	Total Ion Balance: Anions (meq/l)	Total Ion Balance: Error (%)	Total Alkalinity (mg/l as CACO3)	Total Hardness (mg/l as CACO3)	Inorganic Nitrogen (mg/l)	Ortho Phosph (mg/l)	As (ug/l)
10265130 Mammoth Creek at Old 395																							
8/14/83	76.9	12.0	7.8	55		5.1	1.7	3.4	1.1		0.4	<5		<0.1	<0.01					20			5
10/3/83	37.5	9.0	7.8	89	55	7.4	2.7	5.2	1.3		0.3	3.5		0.10	0.01				39	30			3
11/2/83	20.4	6.0	7.6	99	77	9.2	3.5	6.2	1.7		1.2	4.9		<0.1	0.05				47	37			2
12/15/83	24.5	1.5	8.4	102	79	11.0	4.2	7.1	1.6		0.6	5.1		0.30	0.01					45			3
1/17/84	15.5	0.5	7.8	150	100	12.0	5.6	9.9	2.3		0.4	5.9		0.10	0.02					53			5
4/5/84	13.0	5.0	8.2	165	136	13.0	8.9	12.0	2.5		0.6	7.9		0.20	0.02				82	61	0.2		6
5/10/84	35.0	13.0	8.0	121	77	10.0	4.1	6.7	2.1		0.4	5.1		0.10	0.01				54	42	<0.1		2
6/20/84	76.3	14.5	7.6	58	33	5.7	1.4	2.8	0.7		0.3	3.1		<0.1	0.02					20	<0.1		<1
7/24/84	45.3	13.0	8.1	58	37	6.1	1.8	3.6	0.8		0.3	3.5		<0.1	<0.01				28	23	<0.1		2
9/2/84	13.7	13.5	7.9	74	61	7.3	2.6	5.8	1.6		<0.1	4.0		0.30	0.01				40	29	<0.1		4
10/10/84	18.4	10.5	7.8	128	69	11.0	4.4	7.2	1.9		0.5	4.8		<0.1	0.01				58	48	<0.1		2
11/11/84	15.6	2.0	8.4	140	85	12.0	5.1	8.9	2.4		0.5	5.4		0.15	<0.01					51			3
10/19/85	4.7	3.0	8.3	124	89	9.7	5.2	9.6	2.2		0.5	6.5		<0.1	0.01				64	46	<0.1		4
4/11/86	22.8	8.0	8.1	153	111	13.0	5.8	9.9	2.2		0.4	9.2		0.10	0.01				73	56	<0.1		8
7/13/88	13.7	13.0	8.1	82	50	7.8	2.4	4.8	1.1		0.3	3.1	0.09	0.20	<0.01				42	29	0.11	0.08	3
10/18/88	3.6	5.5	7.6	140	95	11.0	5.6	9.3	2.3		0.4	5.8		0.10	<0.01				73	51	<0.1	0.09	4
1/11/89			7.1	165	109	13.0	8.3	11.0	2.6		0.4	6.8		0.30	0.02				78	58	<0.1	0.15	4
4/11/89	8.8	5.5	7.8	143	108	11.0	6.0	11.0	2.4		0.4	6.3		0.20	0.01				69	52	0.01	0.18	21
7/18/89	7.8	13.5	7.8	90	86	8.5	2.9	5.8	1.2		0.3	4.0		0.10	<0.01				49	33	0.02	0.03	4
10/18/89	3.7	4.0	7.8	137	76	11.0	4.8	9.3	2.1		1.0	6.0		0.10	0.01					47	<0.1	0.09	3
1/9/90	4.9		7.8	143	116	14.0	5.2	11.0	3.0		0.4	6.0		0.10	0.01				86	61	0.02	0.12	29
4/25/90	10.3	3.0		124	88	10.0	4.7	8.6	2.0		0.5	5.1	0.48	0.10	<0.01				64	44	0.5	0.12	4
7/17/90	8.0	17.5	7.8	84	63	8.5	2.8	6.0	1.1	54	<0.1	3.8		0.20	<0.01	0.94	0.97	3%	45	33	0.02	0.09	3
10/16/90	1.6	8.0	7.9	103	81	11.0	5.0	9.6	2.2	79	1.2	4.3		0.30	<0.01	1.44	1.43	0%	64	48	<0.1	0.12	3
1/17/91	1.4		7.7	165	99	14.0	6.4	12.0	2.8	98	0.2	5.9		<0.1	0.01	1.82	1.74	5%	81	61	0.04	0.12	4
4/16/91	2.9	1.0	7.9	161	109	13.0	6.7	13.0	2.8	99	0.2	7.4		0.10	<0.01	1.84	1.79	3%	82	60	0.11	0.12	4
7/22/91	15.5	17.0	8.1	71	46	7.8	2.1	4.9	1.0	41	<0.1	3.1		0.10	0.02	0.80	0.74	7%	35	28	0.02	0.03	4
10/22/91	3.2	9.5	7.7	119	66	9.7	4.4	7.5	1.9	77	0.7	5.1		0.20	<0.01	1.22	1.40	14%	63	42	0.02	0.09	4
1/13/92	3.5	0.5	7.9	137	95	12.0	5.1	9.4	2.1	86	0.5	5.3		0.20	<0.01	1.48	1.54	4%	70	51	0.09	0.12	2
4/14/92	5.3	10.0	8.1	159	108	12.0	6.8	13.0	2.6	98	0.1	8.6		<0.1	0.02	1.79	1.75	2%	80	58	0.02	0.18	5
7/6/92	10.1	15.0	7.9	88	48	8.3	2.6	5.3	1.1	49	<0.1	3.5		<0.1	<0.01	0.89	0.88	1%	42	31	0.01	0.06	2
10/19/92	3.3	9.5	7.7	121	99	11.0	4.3	7.9	2.0	76	0.4	4.3		0.10	<0.01	1.30	1.35	4%	62	45	0.02	0.06	3
1/25/93	2.9		7.8	121	80	11.0	4.4	8.3	1.9	77	0.4	5.4		0.10	<0.01	1.32	1.39	5%		46	0.07	0.25	3
4/12/93	7.1	4.5	8.0	161	98	12.0	6.3	12.0	2.6	96	0.7	7.2		0.10	0.01	1.71	1.75	3%	79	56	0.22	0.15	5
7/12/93	71.7	17.0	7.7	42	30	5.5	0.9	2.1	0.8		0.2	1.7		<0.1	0.01					18	0.02	0.06	2
10/13/93	9.2	9.0	7.6	101	70	9.1	3.7	6.1	1.6		0.3	4.1		0.10	<0.01				49	38	0.03	0.06	3
1/10/94	6.1		7.4	128	88	11.0	5.0	8.9	2.1	74	0.4	5.0		<0.1	<0.01	1.40	1.33	5%	60	48	0.09	0.12	3
4/12/94	7.4	2.0	7.5	148	108	12.0	6.1	10.0	2.3	92	0.4	6.0		0.10	<0.01	1.60	1.65	3%	75	55	0.03	0.12	3
7/11/94	10.1	18.0	7.6	86	54	8.1	2.7	5.1	1.4	48	0.3	3.5		<0.1	<0.01	0.88	0.87	2%	40	31	<0.05	0.06	3
10/19/94	5.3	2.0	7.4	133	88	11.0	4.8	9.0	2.0	78	0.3	4.1		0.10	0.01	1.39	1.38	1%	64	47	<0.05	0.09	3
1/17/95	6.7		7.3	130	88	11.0	4.5	8.4	2.2	73	0.5	4.9		<0.1	0.02	1.34	1.31	2%	60	46	0.06	0.09	2
4/17/95	11.1	0.5	7.8	148	104	12.0	5.5	10.0	2.2	87	0.7	5.8		0.10	0.01	1.54	1.57	2%	71	53	0.06	0.12	3
No of Data	41	36	41	42	41	42	42	42	42	18	38	41	2	29	23				34	42	23	26	41
Minimum	1.4	0.5	7.1	42	30	5.1	0.9	2.1	0.6	41	0.1	1.7	0.09	0.10	0.01				28	18	0.01	0.03	2
Maximum	76.9	18.0	8.4	165	136	14.0	8.9	13.0	3.0	99	1.2	9.2	0.48	0.30	0.05				86	61	0.50	0.25	29
Average	16.2	8.3	7.8	118	82	10.2	4.4	8.0	1.9	77	0.5	5.1	0.29	0.15	0.01				61	44	0.08	0.11	5
Std. Dev.	19.4	5.6	0.3	34	25	2.3	1.6	2.8	0.6	18	0.2	1.5	0.28	0.07	0.01				16	12	0.11	0.05	5
10265150 Hot Creek at Flume																							
11/16/82		19.5	7.7	340	235	10.0	4.8	53.0	5.3		28.0	20.0		1.20	1.30					45			140
6/3/83	213.0	17.0	7.5	216		10.0	4.0	28.0	3.4		13.0	12.0		0.60	0.59					41			70
7/6/83	283.0	22.5	7.3	153		7.9	2.9	20.0	2.5		8.9	8.3		0.50	0.42				60	32			52
8/8/83	173.0	18.5	7.4	246		9.5	4.2	33.0	4.6		17.0	12.0		0.70	0.74					41			88
10/3/83	97.0	21.5	7.7	363	235	12.0	5.6	55.0	5.8		27.0	19.0		1.00	1.30				120	53			120
11/2/83	80.0	20.5	7.5	410	276	12.0	5.6	60.0	6.3		31.0	19.0		1.40	1.40				133	53			150
12/14/83	88.0	16.5	7.5	416	282	13.0	6.1	59.0	6.0		29.0	20.0		1.40	1.40					58			130
4/5/84	60.0	23.5	7.6	490	331	13.0	6.3	77.0	7.8		41.0	25.0		1.90	1.80				151	58	0.33		170
5/10/84	69.0	25.5	7.6	444	288	13.0	5.9	64.0	6.1		34.0	24.0		1.60	1.50				139	57	0.15		160
6/20/84	114.0	21.0	7.5	297	193	9.9	4.5	44.0	4.1		23.0	15.0		1.10	0.98					43	<0.1		83
7/24/84	98.0	27.5	8.2	382	233	13.0	5.0	51.0	5.0		25.0	18.0		1.20	1.20				122	53	0.2		120
9/2/84	68.0	24.5	7.9	445	303	12.0	5.7	72.0	7.2		37.0	22.0		1.80	1.70				144	54	0.37		160
10/10/84	84.0	24.5	7.5	471	313	13.0	6.2	78.0	7.4		37.0	23.0		1.80	1.60				156	58	0.22		160
11/11/84	70.0	24.0	8.6	460	311	13.0	5.8	77.0	7.5		39.0	23.0		1.70	1.90				156	57	3.9		150
10/19/85	49.0	32.5	8.0	552	362	13.0	5.8	93.0	7.8		51.0	26.0		2.20	2.20				168	57			240
4/12/86	74.0	25.0	7.6	447	306	12.0	6.2	69.0	6.3		40.0	18.0		1.80	1.60					56			180
7/27/87	49.0	36.0	8.7	579	369	13.0	6.0	95.0	8.5		50.0	30.0		0.50	2.30					57	0.29		
7/12/88	53.0	34.0	7.7	470	323	12.0	5.5	78.0	7.0		40.0	24.0	0.41	1.60	1.70				140	53	0.43	0.49	230
7/19/89	43.0	37.0	7.8	586	388	13.0	5.7	98.0	8.2		52.0	28.0		2.40	2.30				171	56	0.12	0.52	270
7/18/90	38.0	33.0	7.7	591	406	13.0	6.0	100.0	9.0	234	57.0	32.0		2.50	2.60	5.72	6.48	13%	192	57	0.02	0.74	280
7/8/92	40.0	33.5	7.9	561	346	12.0	5.9	96.0	7.3	207	54.0	31.0	0.14	2.50	2.40	5.45	5.92	9%	188	54	0.18	0.58	280
No of Data	20	21	21	21	18	21	21	21	21	2	21	21	2	21	21				14	21	11	4	20
Minimum	38.0	16.5	7.3	153	193	7.9	2.9	20.0	2.5	207	8.9	8.3	0.14	0.50	0.42				60	32	0.02	0.49	52
Maximum	283.0	37.0	8.7	591	406	13.0	6.3	100.0	9.0	234	57.0	32.0	0.41	2.50	2.60				192	58	3.90	0.74	280
Average	91.2	25.6	7.8	424	305	11.9	5.4	68.6	6.3	221	34.9	21.4	0.28	1.50	1.57				144	52	0.56	0.58	162
Std. Dev.	63.0	6.3	0.4	123	58	1.5	0.9	23.4	1.7	19	13.5	6.3	0.19	0.63	0.59				31	7	1.11	0.11	68

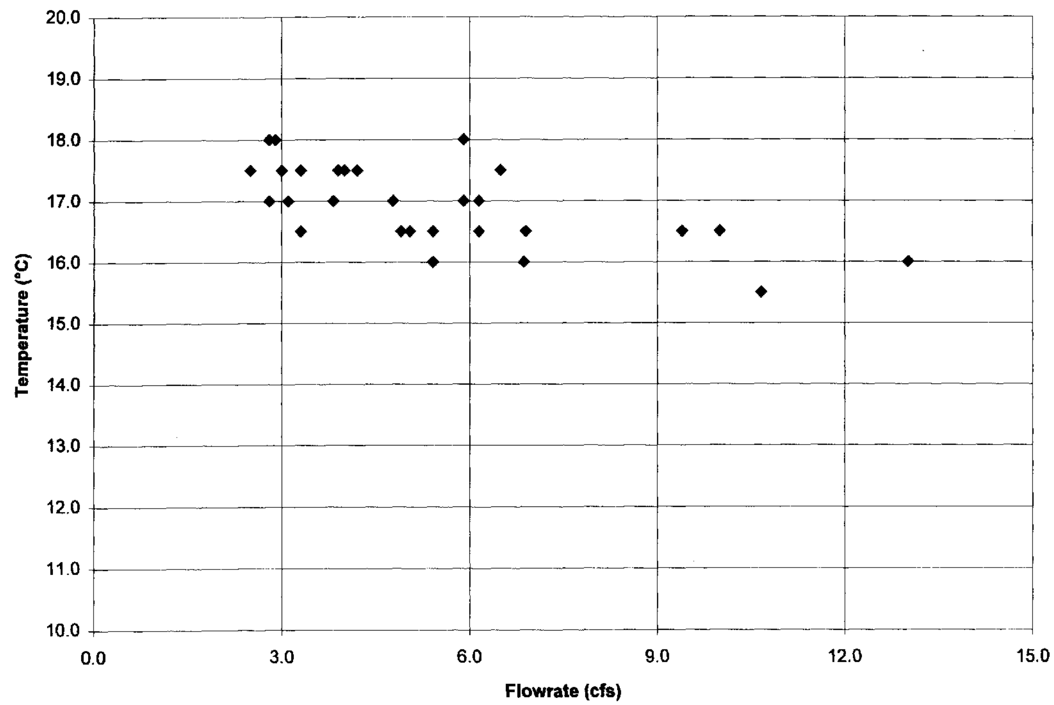
Water Quality Data
At Selected Stream and Spring Locations
(Data from USGS)

Date	Flow (cfs)	Water Temp (°C)	pH	EC (umho/cm)	TDS (mg/l)	Cations: Ca (mg/l)	Cations: Mg (mg/l)	Cations: Na (mg/l)	Cations: K (mg/l)	Anions: HCO3 (mg/l)	Anions: Cl (mg/l)	Anions: SO4 (mg/l)	Anions: NO3-N (mg/l N)	F (mg/l)	B (mg/l)	Total Ion Balance: Cations (meq/l)	Total Ion Balance: Anions (meq/l)	Total Ion Balance: Error (%)	Total Alkalinity (mg/l as CACO3)	Total Hardness (mg/l as CACO3)	Inorganic Nitrogen (mg/l)	Ortho Phosph (mg/l)	As (ug/l)
373818118513301 003S028E35NS03M - CD Springs																							
10/21/88	7.4	15.0	7.4	185	181	12.0	9.4	24.0	4.4		4.5	11.0		0.30	0.23				108	69	0.32	0.49	57
1/10/89	8.2	14.0	7.5	229	171	12.0	9.0	22.0	5.1		5.6	11.0		0.30	0.24				108	67	0.34	0.55	62
4/12/89	9.3	15.0	7.5	231	181	12.0	9.0	23.0	4.7		5.6	11.0		0.30	0.24				108	67	0.29	0.55	54
7/20/89	9.5	15.5	8.0	236	188	12.0	9.0	23.0	5.1		5.7	10.0		0.40	0.26				108	67	0.26	0.52	49
10/19/89	6.2	15.0	7.6	232	154	12.0	8.6	23.0	4.6		5.4	11.0		0.30	0.27					65	0.29	0.52	54
1/8/90	8.7	15.5	7.6	213	180	12.0	9.0	24.0	5.5		5.2	11.0		0.30	0.26				105	67	0.47	0.52	30
4/24/90	7.8	15.5	7.5	243	182	12.0	9.1	25.0	5.2		7.2	10.0	0.28	0.30	0.27				99	67	0.3	0.58	54
7/17/90	8.8	15.5	7.4	230	187	12.0	8.8	24.0	5.1	127	7.0	11.0		0.10	0.28	2.50	2.54	2%	104	66	0.31	0.58	55
10/16/90	9.2	15.5	7.4	222	181	12.0	9.1	24.0	4.9	131	6.3	11.0		0.30	0.27	2.52	2.59	3%	108	67	0.32	0.52	66
1/17/91	7.7	16.0	7.6	246	163	13.0	9.5	25.0	5.1		8.2	14.0		0.40	0.32	2.65	0.57	78%		72	0.31	0.55	48
4/16/91	7.7	16.0	7.6	263	176	13.0	9.6	25.0	5.1	131	8.0	10.0		0.30	0.31	2.66	2.63	1%	108	72	0.3	0.49	52
7/23/91	9.7	16.0	7.6	235	184	12.0	8.9	25.0	5.0	130	6.9	11.0		0.30	0.28	2.55	2.60	2%	105	67	0.36	0.52	85
10/23/91	7.3	15.5	7.5	239	173	12.0	9.4	26.0	5.2	135	6.1	13.0		0.30	0.26	2.64	2.70	2%	111	69	0.44	0.34	46
1/14/92	7.5	16.0		243	170	12.0	9.2	24.0	5.1	130	7.3	15.0		0.40	0.30	2.53	2.70	7%	106	68	0.32	0.55	50
4/15/92	7.5	16.0	7.9	240	194	12.0	9.3	24.0	5.1	132	6.4	13.0		0.40	0.30	2.54	2.66	5%	109	68	0.34	0.58	56
7/7/92	8.0	16.5	7.7	246	182	12.0	9.1	25.0	5.2	129	6.5	12.0		0.40	0.32	2.57	2.60	1%	106	67	0.36	0.55	54
10/20/92	7.1	15.5	7.4	244	204	12.0	9.3	25.0	5.3	132	5.9	11.0		0.40	0.29	2.59	2.61	1%	107	68	0.31	0.55	53
1/26/93	7.1	16.0	7.9	250	190	13.0	10.0	27.0	5.3	137	5.9	11.0	0.32	0.30	0.28	2.78	2.71	3%	113	74	0.34	0.55	55
4/13/93	9.0	15.5	7.6	255	180	14.0	9.5	23.0	5.2	132	8.7	11.0	0.39	0.30	0.30	2.62	2.65	1%	107	74	0.42	0.55	51
7/13/93	12.9	17.0	8.1	214	166	11.0	8.1	22.0	4.5		4.2	11.0	0.32	0.30	0.25	2.29	0.41	82%		61	0.36	0.55	46
10/13/93	10.4	15.0	7.4	237	174	11.0	8.0	23.0	5.3		4.3	11.0		0.30	0.21	2.34	0.39	84%	104	60	0.32	0.46	40
1/11/94	8.5	15.5	7.3	242	184	12.0	9.3	24.0	5.2	123	4.6	11.0		0.30	0.24	2.54	2.41	5%	102	68	0.3	0.46	50
4/13/94	7.7	16.0	7.1	247	186	12.0	9.4	23.0	5.2	136	5.3	11.0		0.30	0.26	2.51	2.65	6%	111	69	0.31	0.49	48
7/12/94	9.3	16.5	7.2	250	168	12.0	9.5	24.0	5.5	133	5.2	11.0		0.30	0.27	2.57	2.60	1%	109	69	0.24	0.49	45
10/19/94	7.5	15.5	7.2	251	180	13.0	9.6	25.0	5.3	134	5.1	10.0		0.30	0.26	2.66	2.59	3%	109	72	0.27	0.52	55
1/17/95	5.7		7.2		184	13.0	10.0	24.0	5.1	133	5.2	11.0		0.30	0.26	2.65	2.60	2%		74	0.26	0.52	48
4/18/95	7.1	15.0	7.5	249	186	13.0	9.4	23.0	5.1	133	5.2	9.5		0.30	0.25	2.55	2.56	0%	108	71	0.43	0.52	48
4/18/95	7.1	15.0	7.3	250	186	13.0	9.3	23.0	5.1	135	5.2	9.4		0.30	0.25	2.55	2.59	2%	109	71	0.42	0.52	49
7/11/95	11.0	15.5	7.2	223	168	11.0	8.5	21.0	4.7	120	3.8	10.0		0.30	0.20	2.28	2.32	1%	98	62	0.41	0.46	45
No of Data	29	28	28	28	29	29	29	29	28	19	29	29	4	29	29				25	29	29	29	29
Minimum	5.7	14.0	7.1	185	154	11.0	8.0	21.0	4.4	120	3.8	9.4	0.28	0.10	0.20				98	60	0.24	0.34	30
Maximum	12.9	17.0	8.1	263	204	14.0	10.0	27.0	5.5	137	8.2	15.0	0.39	0.40	0.32				113	74	0.47	0.58	85
Average	8.3	15.8	7.5	237	179	12.2	9.2	23.9	5.1	131	5.8	11.1	0.33	0.31	0.27				107	68	0.34	0.52	52
Std. Dev.	1.5	0.6	0.3	16	10	0.7	0.5	1.3	0.3	4	1.1	1.2	0.05	0.06	0.03				3	4	0.06	0.05	9
373822118514401 003S028E34RS01M - AB Springs																							
6/21/84		16.0	7.1	251	187	13.0	9.7	24.0	5.1		8.0	10.0		0.40	0.37					73	0.36		20
4/8/86	10.7	15.5	7.3	255	211	14.0	10.0	25.0	5.3		11.0	12.0		0.30	0.40				111	76	0.45		36
4/8/86	10.7		7.3		197	14.0	11.0	26.0	6.1		9.0	12.0		0.30	0.39					80			38
7/11/88	5.9	16.0	7.4	270	201	14.0	10.0	28.0	5.0		10.0	14.0		0.20	0.44					76	0.36	0.46	56
10/16/88	5.4	16.5	7.3	267	203	14.0	11.0	29.0	5.2		11.0	13.0		0.30	0.47				114	80	0.34	0.43	51
1/10/89	5.4	16.0	7.4	272	192	14.0	10.0	26.0	6.0		11.0	14.0		0.30	0.46				116	76	0.35	0.49	56
4/12/89	5.4	16.0	7.5	278	209	14.0	10.0	27.0	5.6		11.0	14.0		0.20	0.55				115	76	0.32	0.46	26
7/20/89	6.2	16.5	7.7	276	214	14.0	9.9	26.0	6.0		15.0	13.0		0.30	0.59				105	76	0.27	0.43	50
10/19/89	6.2	17.0	7.2	280	191	14.0	9.7	28.0	6.0		12.0	13.0		0.30	0.56					75	0.3	0.46	48
1/8/90	6.2	16.5	7.4	254	210	14.0	10.0	29.0	6.4		13.0	14.0		0.30	0.59				111	76	0.34	0.46	39
4/24/90	4.8	17.0	7.4	290	209	14.0	10.0	29.0	6.3		14.0	14.0	0.28	0.30	0.59				103	76	0.3	0.46	52
7/17/90	5.0	16.5	7.2	273	215	15.0	10.0	31.0	6.4	135	14.0	9.5		0.20	0.66	3.08	2.88	7%	111	79	0.31	0.49	59
10/17/90	3.8	17.0	7.3	281	206	14.0	10.0	29.0	6.0	139	18.0	14.0		0.30	0.66	2.94	3.15	7%	113	76	0.32	0.43	50
1/16/91	3.3	17.5	7.4	295	203	15.0	11.0	30.0	6.1	131	18.0	18.0		0.30	0.69	3.12	3.11	0%	109	83	0.31	0.4	46
4/16/91	3.3	16.5	7.5	302	227	15.0	11.0	30.0	6.2	140	16.0	16.0		0.20	0.66	3.12	3.15	1%	113	83	0.31	0.4	45
7/23/91	6.9	16.5	7.3	264	194	13.0	9.0	29.0	5.6	125	13.0	14.0		0.30	0.64	2.80	2.78	0%	102	70	0.4	0.46	77
10/23/91	3.9	17.5	7.3	275	196	14.0	9.2	26.0	6.7	128	15.0	17.0		0.30	0.62	2.76	2.95	7%	105	73	0.53	0.4	38
1/14/92	3.1	17.0	7.4	274	200	13.0	9.3	28.0	6.0	126	12.0	18.0		0.30	0.62	2.79	2.85	2%	106	71	0.28	0.46	50
4/15/92	2.8	17.0	7.5	276	216	14.0	9.9	29.0	5.8	134	14.0	19.0		0.40	0.62	2.92	3.07	5%	108	76	0.29	0.49	53
7/7/92	4.2	17.5	7.6	268	168	12.0	8.8	28.0	5.9	123	16.0	16.0		0.30	0.70	2.69	2.88	7%	101	66	0.32	0.46	47
10/20/92	2.5	17.5	7.5	289	230	14.0	10.0	31.0	6.6	143	14.0	15.0		0.30	0.67	3.04	3.13	3%	115	76	0.31	0.46	50
1/26/93	3.0	17.5	7.5	287	211	14.0	11.0	31.0	6.4	143	13.0	14.0	0.31	0.30	0.62	3.12	3.10	1%	116	80	0.32	0.48	55
4/13/93	4.9	16.5	7.4	269	186	14.0	10.0	26.0	6.0	132	14.0	16.0		0.30	0.62	2.89	2.96	2%	105	76	0.79	0.49	47
7/13/93	9.4	16.5	7.5	226	160	9.4	7.1	21.0	4.6		9.1	12.0		0.30	0.50					53	0.45	0.49	40
10/13/93	6.5	17.5	7.3	239	182	12.0	8.9	22.0	5.1		7.5	12.0		0.30	0.39				97	67	0.36	0.43	47
1/11/94	4.0	17.5	7.4	254	200	12.0	8.8	26.0	5.8	119	9.4	13.0		0.30	0.43	2.60	2.54	2%	97	66	0.26	0.34	44
4/12/94	2.9	18.0	7.1	264	200	12.0	8.6	25.0	5.3	129	10.0	13.0		0.30	0.47	2.53	2.73	8%	107	65	0.3	0.4	44
7/12/94	5.9	18.0	7.2	232	164	10.0	7.7	23.0	5.9	109	9.9	11.0		0.30	0.51	2.29	2.36	3%	90	57	0.21	0.37	43
10/19/94	2.8		7.1		192	13.0	9.1	28.0	6.0		12.0	12.0		0.30	0.54					70	0.25	0.43	52
10/18/94	2.8	18.0	7.1	287	192	13.0	9.2	28.0	6.0	124	11.0	13.0		0.30	0.53	2.78	2.68	4%	101	70	0.25	0.43	52
1/17/95	2.9	18.0	7.1	291	208	14.0	10.0	28.0	6.0	140	10.0	12.0		0.30	0.49	2.89	2.89	0%	114	76	0.26	0.46	45
4/18/95	5.9	17.0	7.3	287	214	14.0	10.0	27.0	5.9	142	11.0	11.0		0.30	0.52	2.85	2.93	3%	115	76	0.89	0.46	46
6/20/95	10.0	16.5	7.1	217	166	10.0	7.5	22.0	4.9		8.2	9.4		0.30	0.41					56	0.54	0.37	42
7/11/95	13.0	16.0	7.2	212	164	9.4	7.2	21.0	4.5	104	7.1	9.1		0.40	0.36	2.09	2.15	3%	85	53	0.51	0.43	43
7/11/95	13.0		7.3		164	9.4	7.3	21.0	4.8		7.1	9.1		0.30	0.36					54	0.49	0.43	48
No of Data	34	32	35	32	35	35	35	35	35	19	35	35	2	35	35				27	35	34	32	35
Minimum	2.5	15.5	7.1	212	164	9.4	7.1	21.0	4.5	104	7.1	9.1	0.28	0.20	0.36				85	53	0.21	0.34	20
Maximum	13.0	18.0	7.7	302	230	15.0	11.0	31.0	6.7	143	18.0	19.0	0.31	0.40	0.70				116	83	0.79	0.49	77
Average	5.7	16.9	7.3	267	197	13.1	9.5	26.8	5.8	130	11.8	13.3	0.30	0.30	0.54				107	72	0.37	0.44	47
Std. Dev.	2.9	0.7	0.2	22	17	1.8	1.1	2.9	0.6	11	2.9	2.5	0.02	0.05	0.11				8	8	0.13	0.04	10

Water Quality Data
At Selected Stream and Spring Locations
(Data from USGS)

Date	Flow (cfs)	Water Temp (°C)	pH	EC (umho/cm)	TDS (mg/l)	Cations: Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Anions: HCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l N)	F (mg/l)	B (mg/l)	Total Ion Balance: Cations (meq/l)	Anions (meq/l)	Error (%)	Total Alkalinity (mg/l as CACO3)	Total Hardness (mg/l as CACO3)	Inorganic Nitrogen (mg/l)	Ortho Phosph (mg/l)	As (ug/l)
373829118505801 003S028E35K501M - H2,3 Springs																							
7/11/88	3.5	11.0	7.8	193	141	16.0	5.6	13.0	3.0		6.2	12.0		0.30	0.12					63	0.32	0.25	20
10/18/88	3.2	11.0	7.4	187	143	16.0	5.9	15.0	3.2		5.4	12.0		0.20	0.09					64	0.29	0.28	22
1/10/89	3.1	11.0	7.4	182	137	16.0	5.4	13.0	3.4		5.4	12.0		0.20	0.09					62	0.29	0.28	26
4/11/89	3.1	11.0	7.4	186	139	16.0	5.4	13.0	3.3		5.4	12.0		0.20	0.10				73	62	0.33	0.31	48
7/20/89	3.3	11.0	7.2	190	156	16.0	5.5	14.0	3.5		5.4	11.0		0.30	0.11				77	63	0.27	0.28	20
10/18/89	3.2	11.0	7.3	190	122	16.0	5.3	14.0	3.5		5.6	11.0	0.26	0.20	0.10					62	0.27	0.31	23
1/9/90	2.9	11.0	7.5	179	134	16.0	5.3	14.0	3.8		5.2	6.0		0.20	0.10				73	62	0.36	0.28	19
4/24/90	2.9	11.0	7.4	199	147	18.0	5.6	15.0	3.5		7.1	13.0	0.68	0.20	0.11				74	63	0.7	0.31	23
7/17/90	3.1	11.5	7.3	192	150	17.0	5.5	15.0	3.4	94	8.0	11.0		0.10	0.10	2.04	2.01	2%	77	65	0.52	0.31	21
10/18/90	3.5	11.5	7.4	186	129	16.0	5.4	14.0	3.4	96	7.3	12.0		0.40	0.10	1.94	2.06	6%	79	62	0.3		24
1/16/91	3.1	11.5	7.3	177	105	16.0	5.2	14.0	3.2		5.7	11.0		<0.1	0.10					61	0.3	0.31	20
4/16/91	3.0	11.0	7.4	190	146	16.0	5.4	15.0	3.5	93	6.9	11.0		0.20	0.11	1.99	1.97	1%	76	62	0.63	0.25	22
7/23/91	3.6	13.0	7.3	198	140	17.0	5.7	16.0	3.5	96	7.9	13.0		0.20	0.12	2.10	2.09	1%	79	66	0.54	0.28	22
10/23/91	2.7	11.5	7.2	201	142	17.0	5.8	16.0	3.7	94	8.0	12.0		0.20	0.11	2.12	2.04	4%	75	66	0.56	0.25	19
1/14/92	2.6	11.5	7.3	200	116	17.0	5.6	15.0	3.5	95	7.0	12.0		0.20	0.11	2.05	2.03	1%	79	66	0.33	0.31	21
4/15/92	2.8	11.0	7.7	210	158	18.0	6.2	16.0	3.5	101	9.4	12.0		0.10	0.12	2.20	2.19	0%	82	70	0.5	0.31	21
7/7/92	3.0	11.0	7.3	213	130	18.0	5.9	16.0	3.8	105	8.1	12.0		0.10	0.12	2.17	2.22	2%	84	69	0.42	0.31	23
10/20/92	2.8	11.5	7.2	210	167	18.0	5.9	16.0	3.7	104	8.3	12.0		0.20	0.11	2.18	2.21	2%	85	69	0.53	0.31	22
1/28/93	3.0	11.5	7.3	213	149	18.0	6.3	18.0	3.7	106	8.2	12.0	0.34	0.20	0.12	2.30	2.26	1%	88	71	0.35	0.31	24
4/13/93	3.3	11.5	7.3	241	158	20.0	6.8	17.0	3.8	106	11.0	13.0		0.20	0.12	2.40	2.34	2%	86	78	0.53	0.31	21
7/13/93	4.0	11.5	7.4	230	164	21.0	6.9	17.0	3.8		8.6	13.0		0.20	0.13					81	0.48	0.31	20
10/13/93	3.6	12.0	7.2	234	166	19.0	6.5	17.0	3.9		8.3	12.0		0.20	0.11				92	74	0.47	0.31	22
1/11/94	2.9	11.5	7.2	219	152	18.0	6.2	16.0	4.1	102	7.5	12.0		0.20	0.11	2.21	2.15	3%	83	70	0.3	0.28	15
4/12/94	3.0	11.0	6.9	216	148	18.0	6.1	18.0	3.7	105	8.3	12.0		0.20	0.12	2.19	2.23	2%	87	70	0.36	0.28	21
7/12/94	4.1	11.0	7.1	221	132	18.0	6.1	16.0	4.1	109	7.4	11.0		0.20	0.13	2.20	2.25	2%	88	70	0.25	0.28	23
1/18/95	3.0	10.0	7.1	224	152	18.0	6.1	17.0	3.6	104	8.3	11.0		0.20	0.12	2.23	2.19	2%	85	70	0.32	0.34	25
4/18/95	3.3	11.0	7.1	236	168	19.0	6.4	17.0	3.9	112	10.0	10.0		0.20	0.12	2.32	2.35	1%	91	74	0.43	0.34	19
7/11/95	4.0	11.0	7.1	237	158	20.0	6.7	17.0	3.9	115	8.7	11.0		0.20	0.12	2.39	2.38	0%	94	78	0.62	0.31	23
No of Data	28	28	28	28	28	28	28	28	28	17	28	28	3	27	28				22	28	28	27	28
Minimum	2.6	10.0	6.9	166	105	16.0	5.2	13.0	3.0	93	5.2	6.0	0.26	0.10	0.09				73	61	0.25	0.25	15.00
Maximum	4.1	13.0	7.7	241	168	21.0	6.9	18.0	4.1	115	11.0	13.0	0.68	0.40	0.13				94	81	0.70	0.34	48.00
Average	3.2	11.3	7.3	205	145	17.4	5.9	15.4	3.6	102	7.5	11.6	0.43	0.20	0.11				82	68	0.41	0.30	22.43
Std. Dev.	0.4	0.5	0.2	20	15	1.4	0.5	1.4	0.3	7	1.5	1.3	0.22	0.06	0.01				6	8	0.13	0.02	5.49

Water Temperature versus Flow
AB Springs



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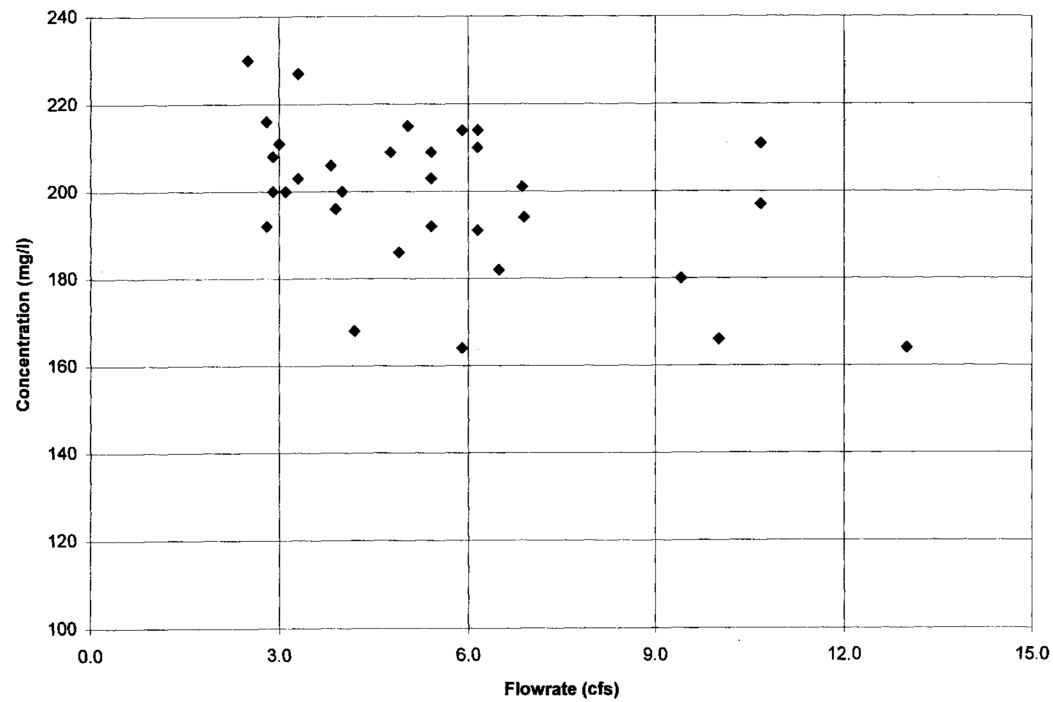
9/24/96

Total Dissolved Solid Concentration versus Flow
AB Springs



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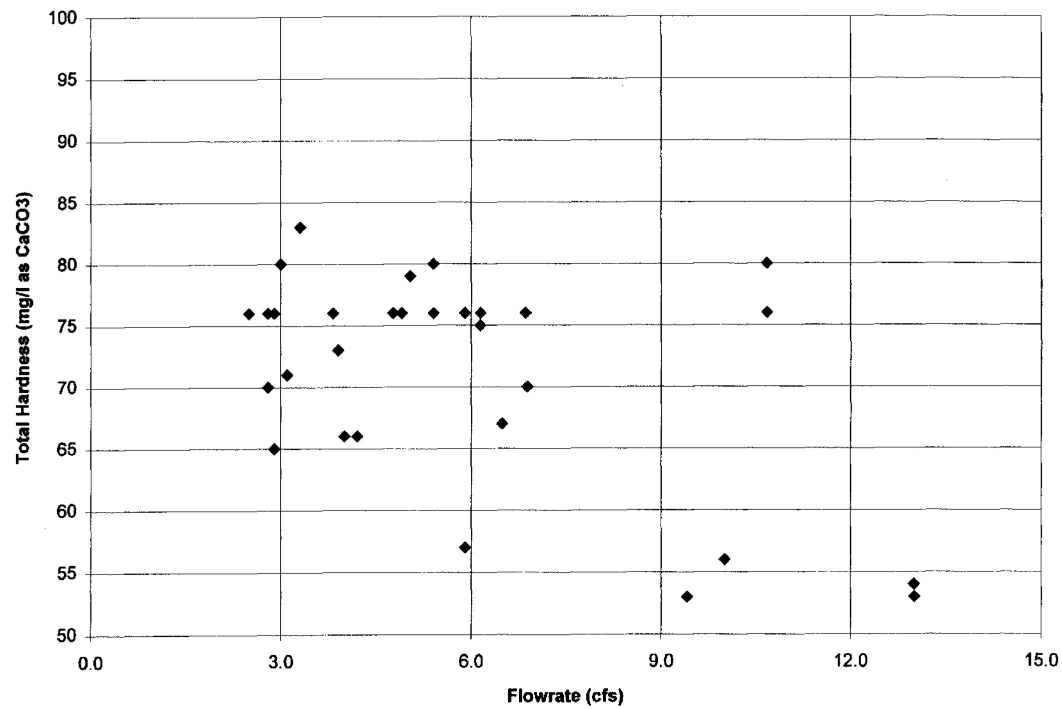
9/24/96

Total Hardness versus Flow
AB Springs



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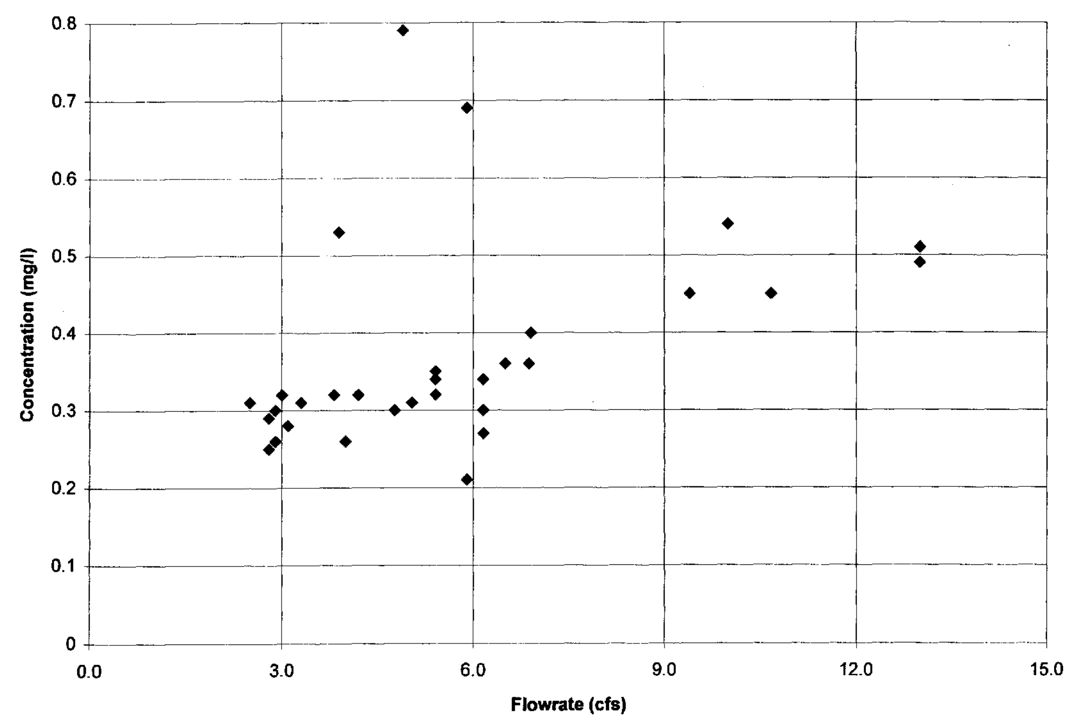
9/24/96

Inorganic Nitrogen Concentration versus Flow
AB Springs



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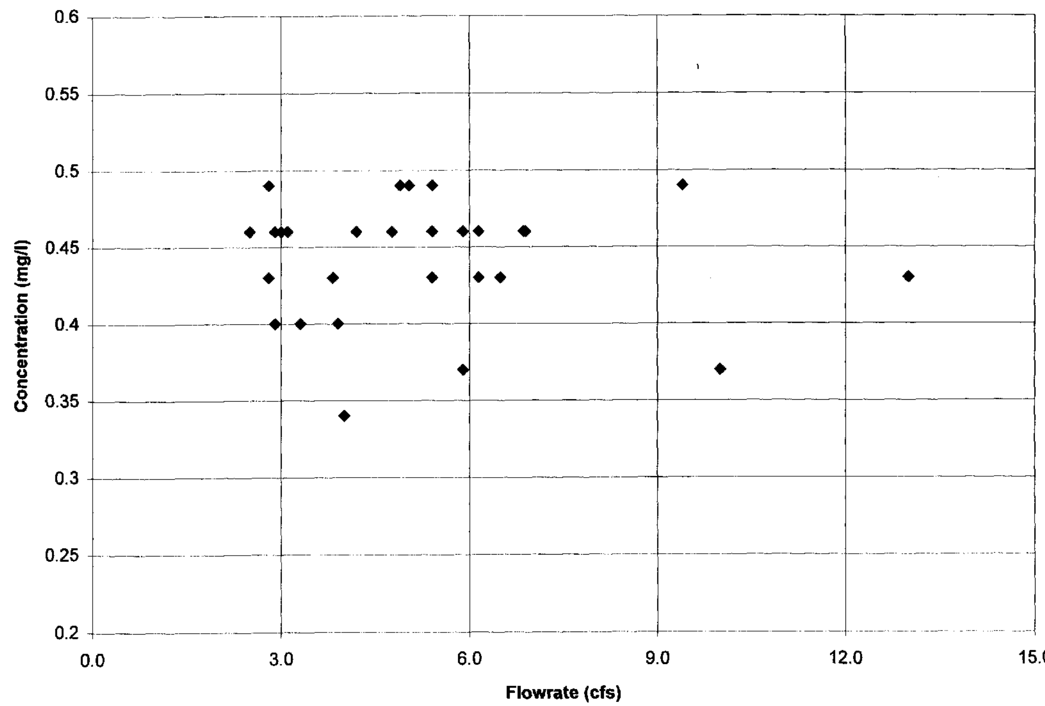
9/24/96

Ortho Phosphate Concentration versus Flow
AB Springs



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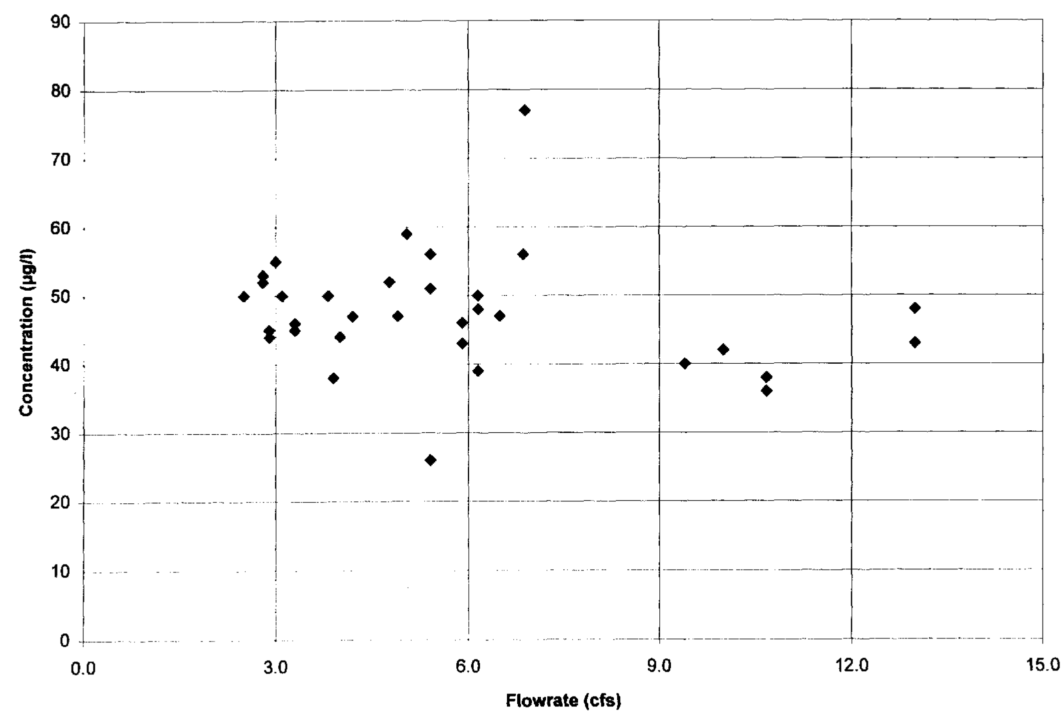
9/24/96

Arsenic Concentration versus Flow
AB Springs



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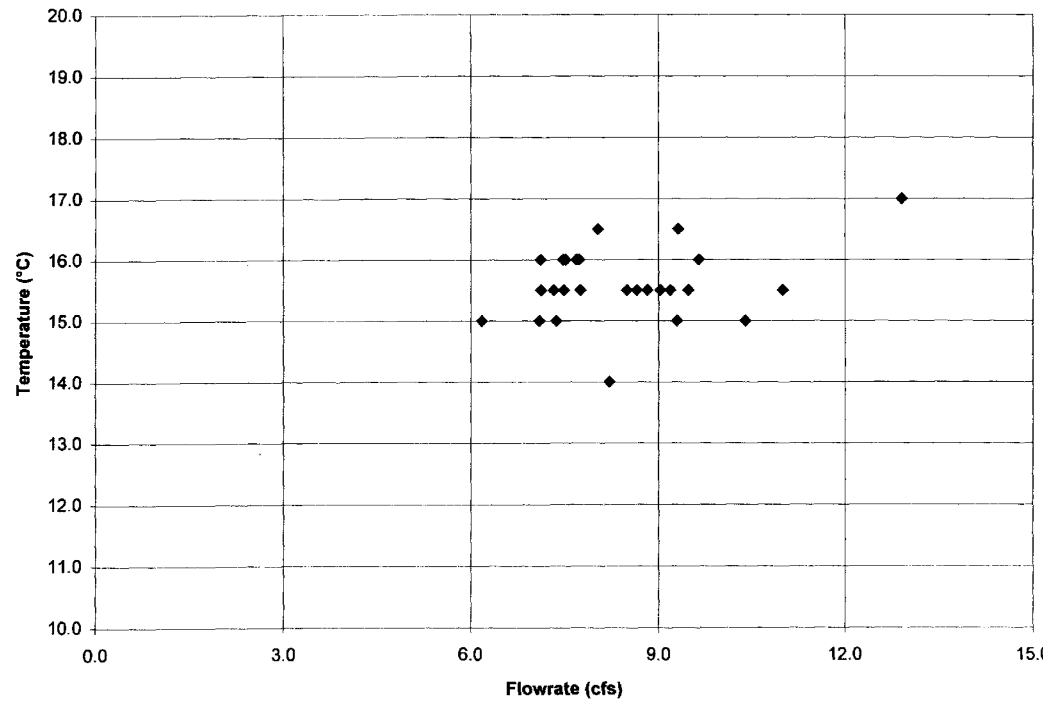
9/24/96

Water Temperature versus Flow
CD Springs



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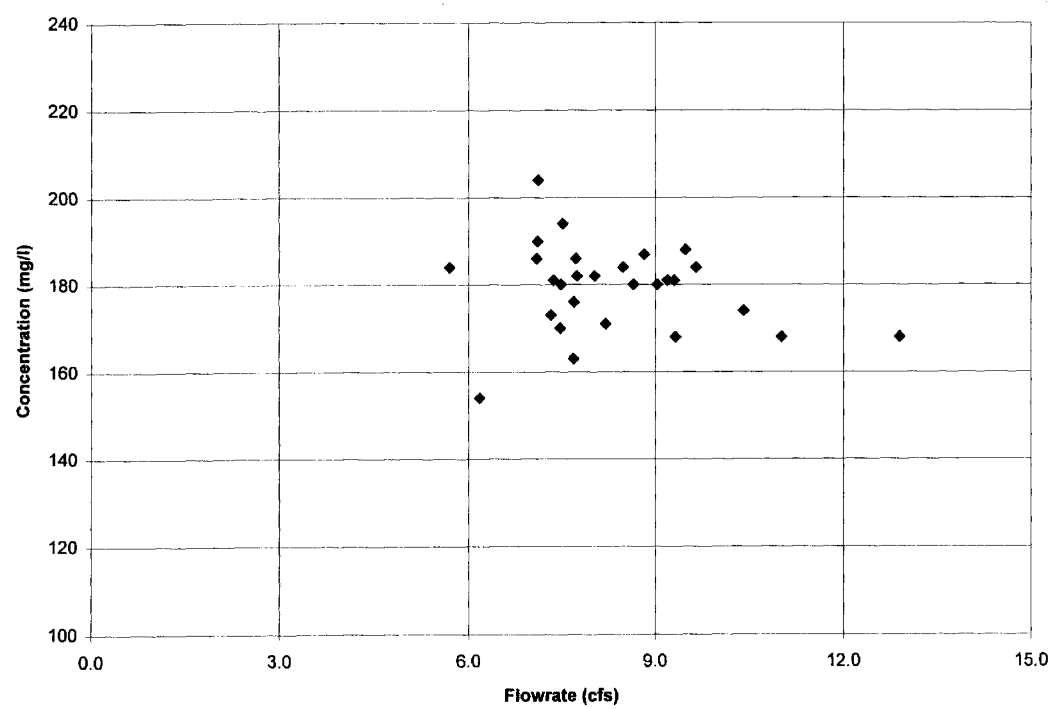
9/24/96

Total Dissolved Solid Concentration versus Flow
CD Springs



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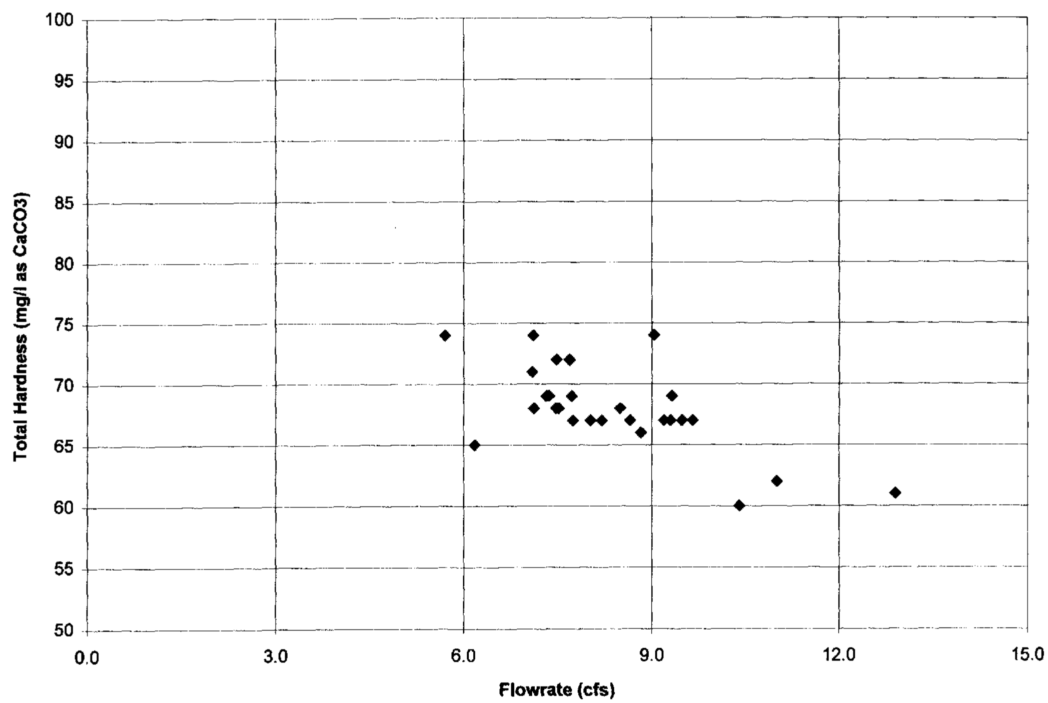
9/24/96

Total Hardness versus Flow
CD Springs



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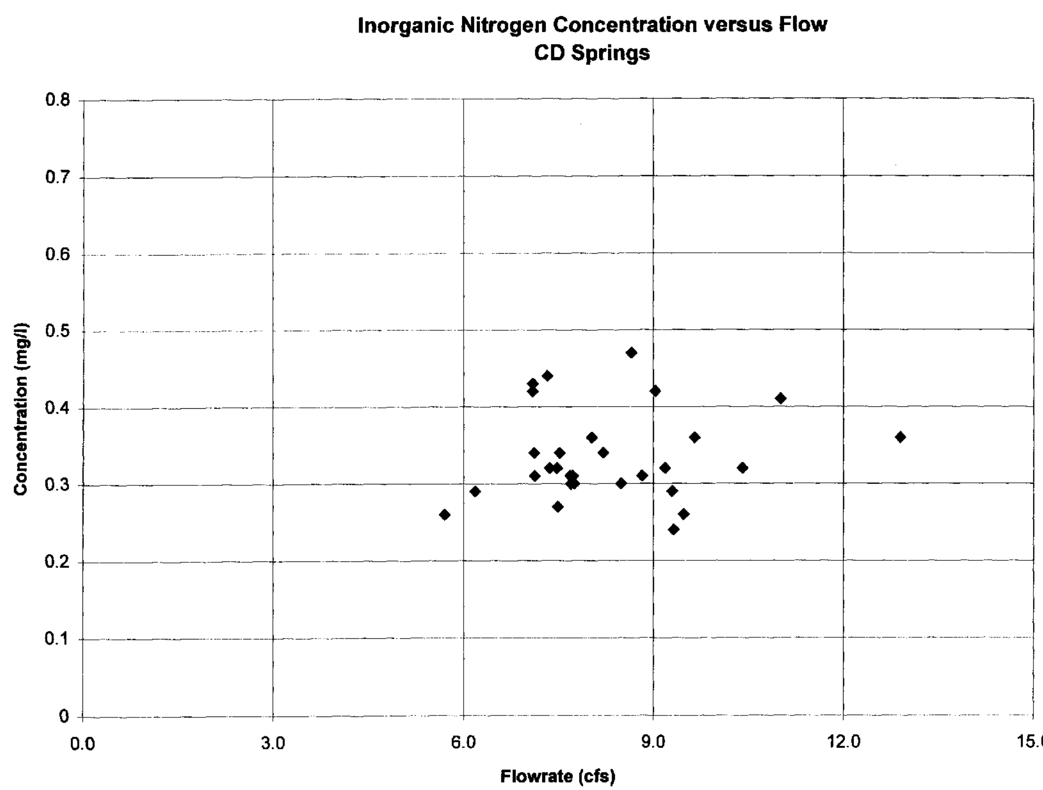
9/24/96



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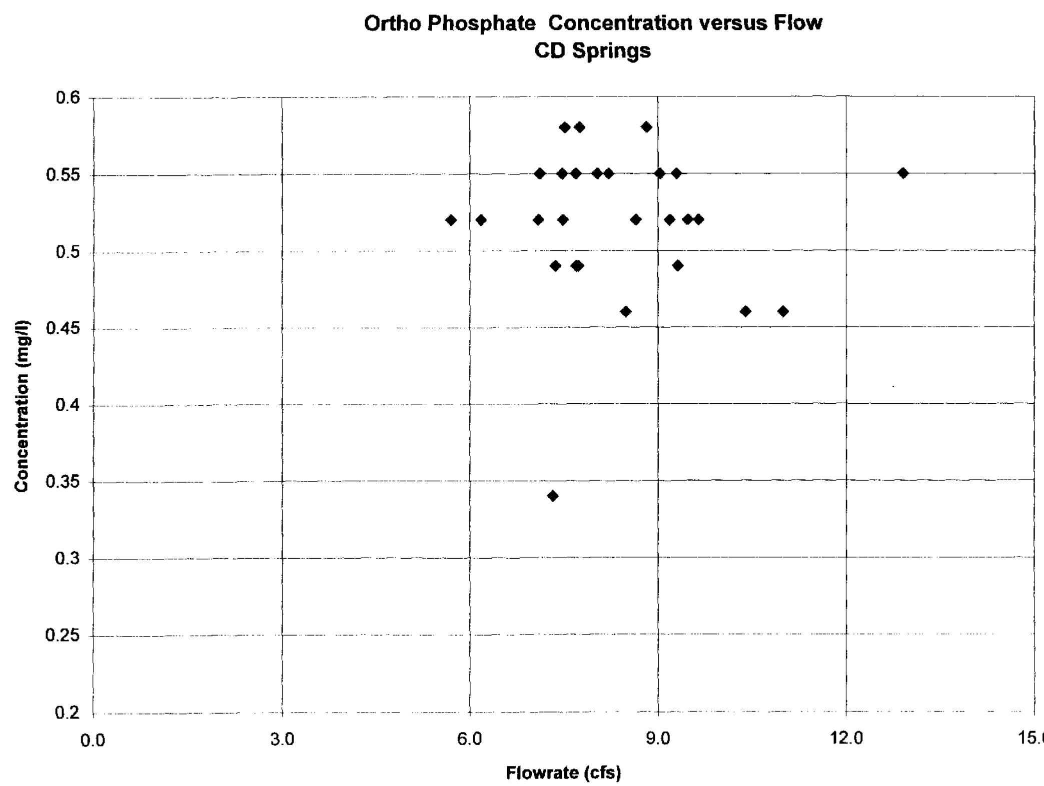
9/24/96



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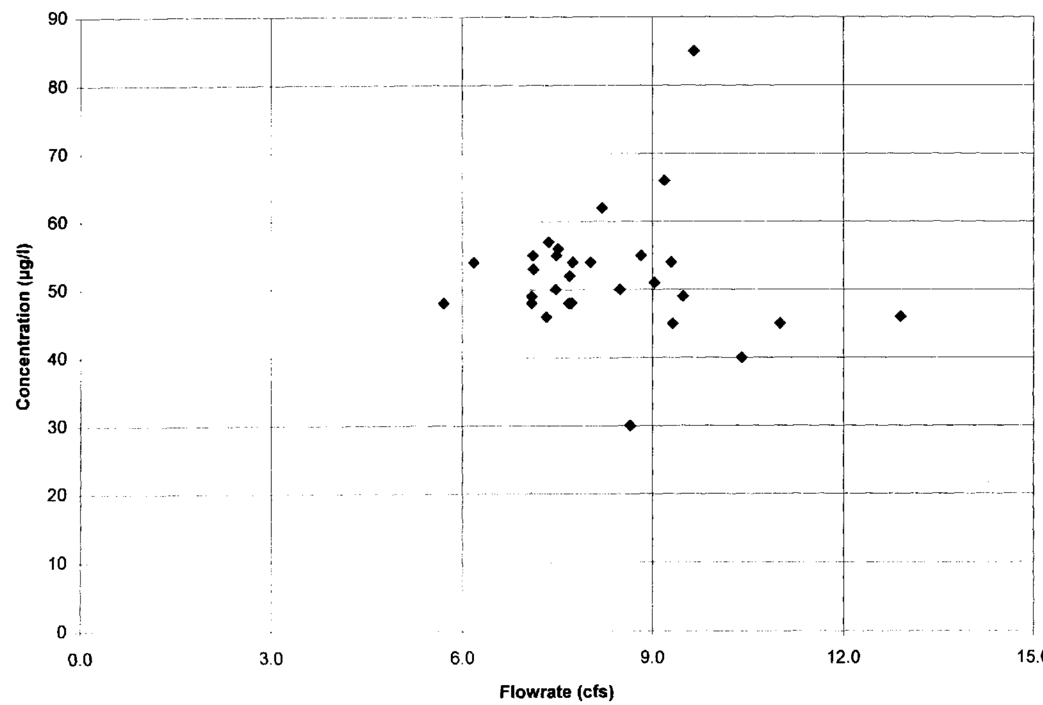
9/24/96

Arsenic Concentration versus Flow
CD Springs



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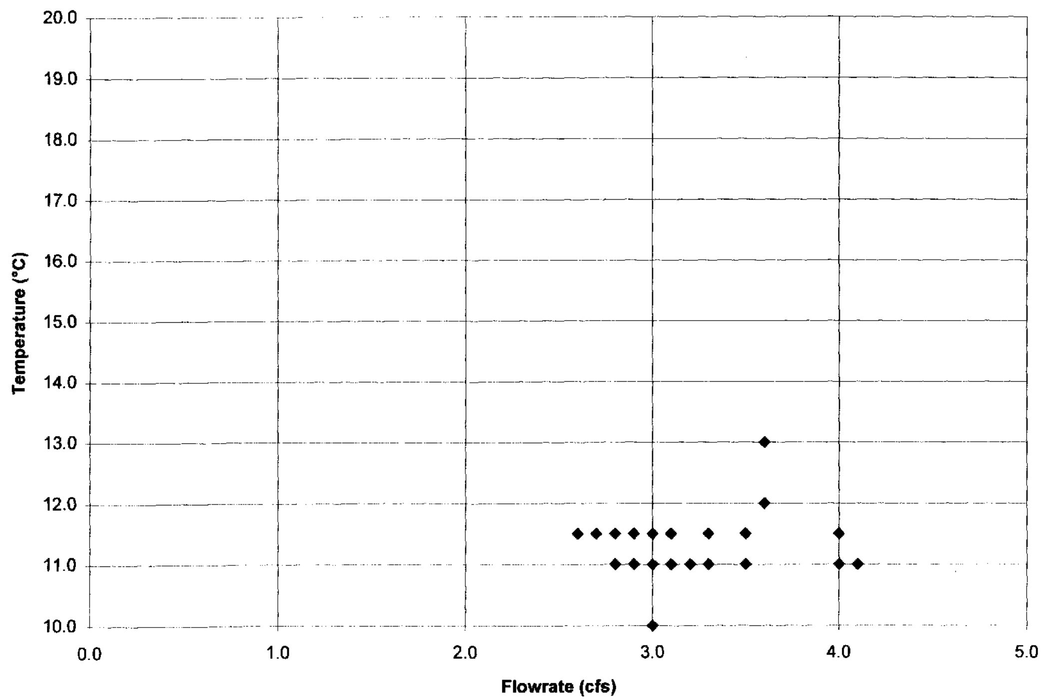
9/24/96

Water Temperature versus Flow
H2,3 Springs



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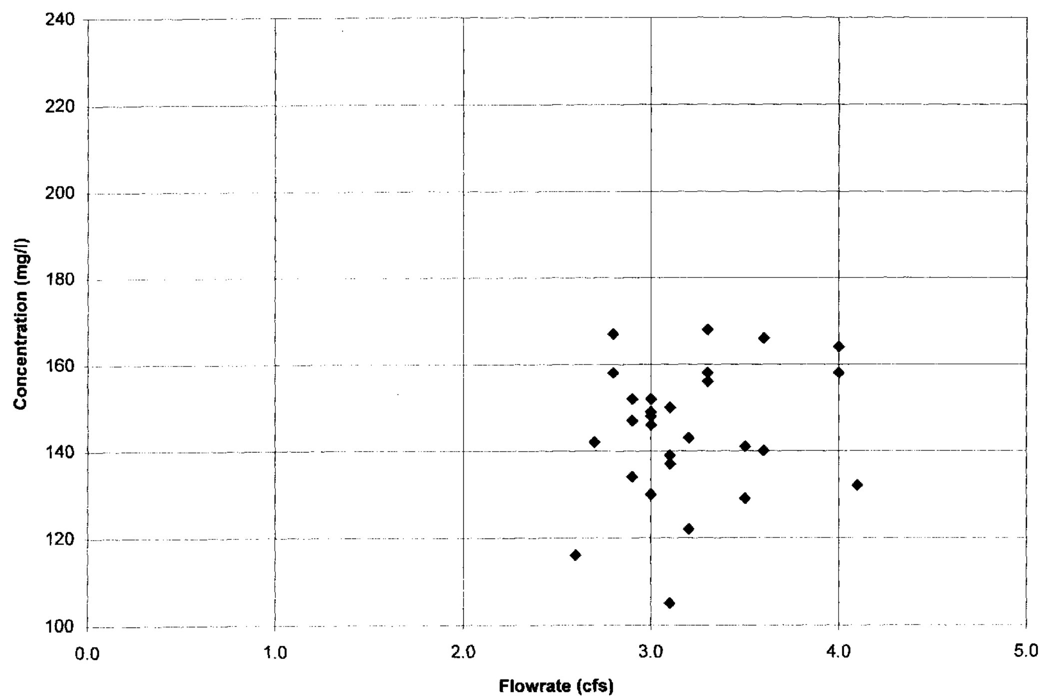
9/24/96

Total Dissolved Solid Concentration versus Flow
H2,3 Springs



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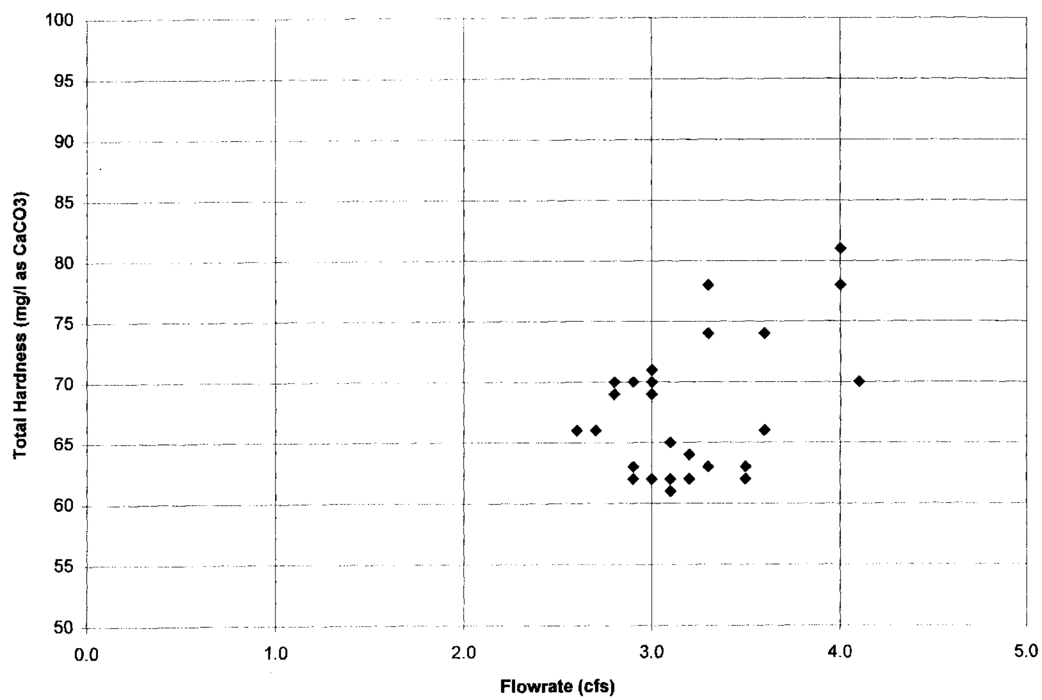
9/24/96

Total Hardness versus Flow
H2,3 Springs



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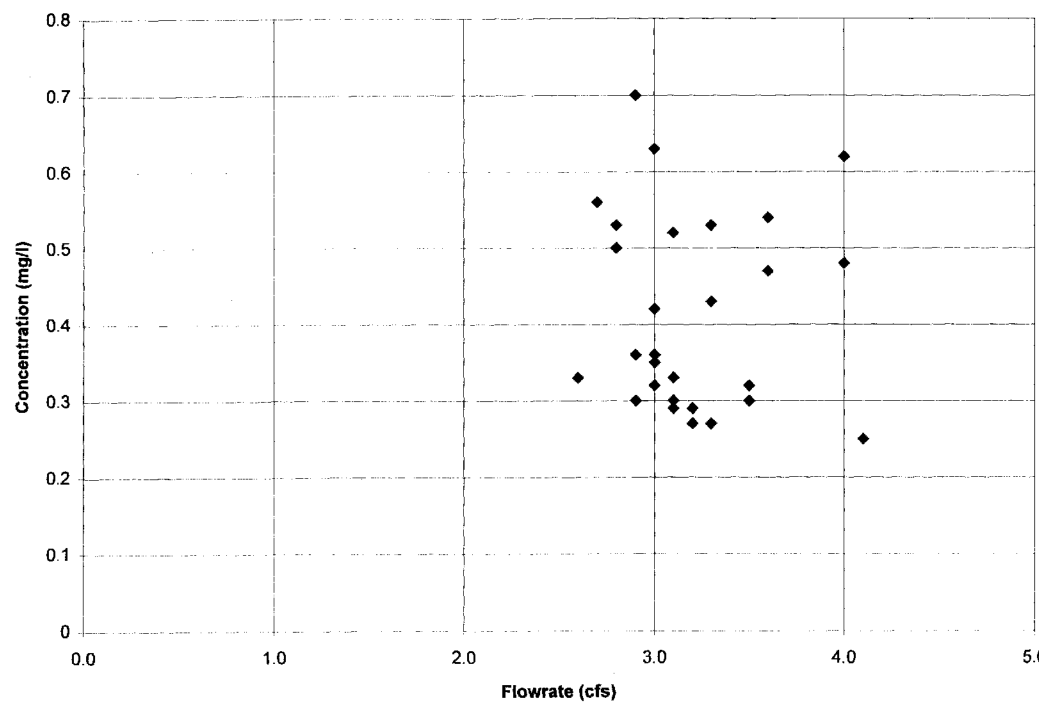
9/24/96

Inorganic Nitrogen Concentration versus Flow
H2,3 Springs



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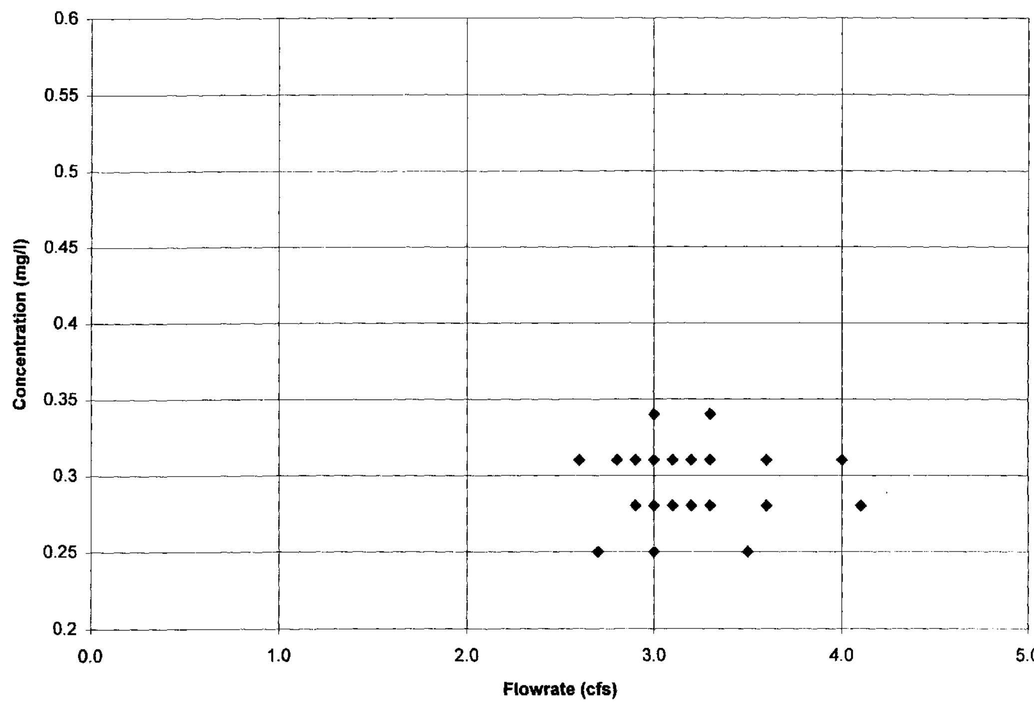
9/24/96

Ortho Phosphate Concentration versus Flow
H2,3 Springs



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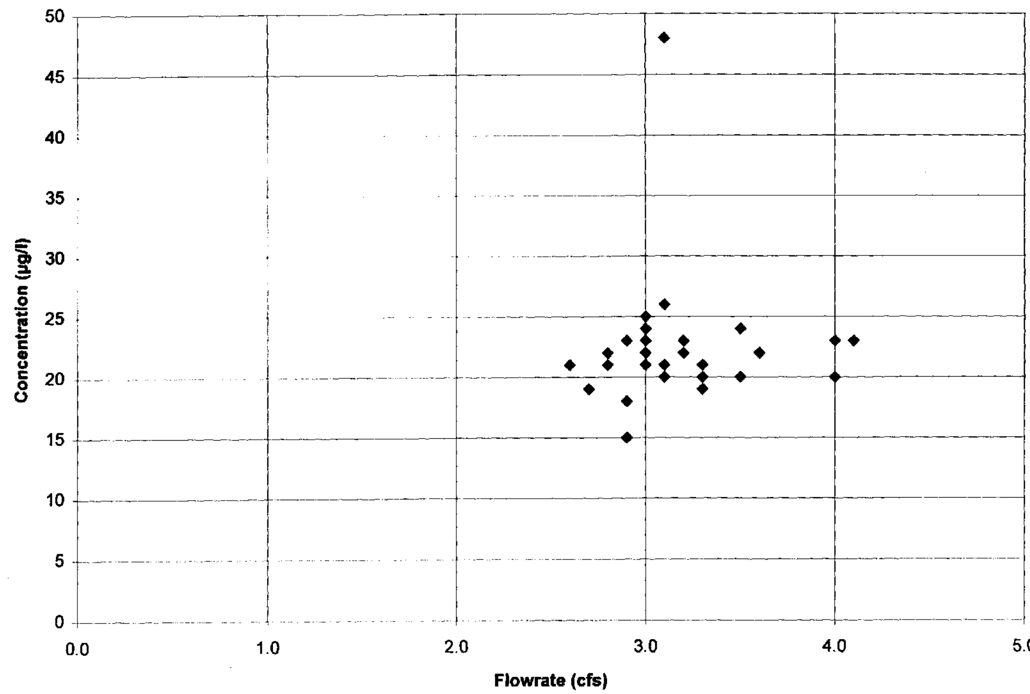
9/24/96

Arsenic Concentration versus Flow
H2,3 Springs



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9/24/96