WATER QUALITY STATUS REPORT NO. 84

# WARM SPRINGS CREEK GEOTHERMAL STUDY

## Blaine County, Idaho

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Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau
Boise, Idaho

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## ABSTRACT

The development and use of geothermal resources can potentially impact public health and the environment. Drinking water aquifers may be contaminated as may surface waters depending upon wastewater disposal practices. The Warm Springs Creek drainage near Ketchum, Idaho, is one area of Idaho where use of geothermal water may be impacting public health and aquatic resources. A leaking pipeline conveys geothermal water through this valley to heat nearby homes as well as to supply a resort's swimming pool. Several domestic wells in close proximity to this line have exhibited increasing fluoride levels since 1979. As alternatives to replacing this line, developers have also proposed constructing various types of resort facilities near the main geothermal source, Guyer Hot Springs. Water currently being collected by the pipeline (about 450 gpm) and additional geothermal water obtained by developing the spring system (possibly as much as 600 gpm) may be used by such facilities. Disposal of the waste geothermal water has not been addressed, but discharge to nearby surface waters will likely be proposed.

During 1987, groundwater and surface water studies were conducted in the Warm Springs Creek area. The groundwater research was designed to characterize the valley aquifer and groundwater flows, to assess background fluoride levels, to assess sources of fluoride to the aquifer, and to determine the effect of pipeline leaks on the groundwater and domestic well contamination. Surface water research was designed to assess water quality impacts due to existing geothermal discharges as well as to evaluate potential impacts from proposed geothermal developments. Warm Springs Creek, Trail Creek, and the Big Wood River were included in this research.

Groundwater monitoring documented fluoride levels in excess of the current state Maximum Contaminant Level (MCL) of 2.4 mg/l at several public and private wells. The research indicated that leakage from the pipeline does enter the Warm Springs Creek valley aquifer, and that it has a demonstrated effect on fluoride levels in several public community drinking water systems. Removal of the leakage is expected to reduce fluoride levels in these wells by 1-2 mg/l on average, and possibly as much as 5 mg/l during periods when the pipeline is pressurized. It is recommended that this leakage be eliminated to protect public health from fluoride impacts. The public should be notified of existing hazards and informed on measures to take to reduce exposure as the aquifer recovers from past discharges. New well construction in the valley should follow guidelines and standards to assure that the aquifer is not contaminated by other geothermal intrusions.

Surface water data indicate that fluoride levels in the Big Wood River, Trail Creek, and Warm Springs Creek all increase in the Ketchum area as a result of geothermal water accrual. Under existing conditions, fluoride levels in Warm Springs Creek meet or exceed the recommended limit (1.8 mg/l) to protect cold water biota during base flow conditions. Fluoride levels in Trail Creek do not approach this limit during base flows, but due to low winter flows (about 2-5 cfs), additional geothermal discharges to this creek may exceed this standard as well as create potential thermal problems. Big Wood River fluoride levels increase on the average of about 0.4 mg/l through the Ketchum area due to geothermal discharges to the river and its tributaries.

Recreational developments will likely propose geothermal wastewater discharges from existing and developed sources to Warm Springs Creek. These discharges may elevate instream fluoride levels to 2-4 mg/l during baseflow conditions. Existing spring temperatures (March - May) in lower Warm Springs Creek near the salmonid spawning standard of 13°C suggest that increased geothermal discharges to Warm Springs Creek during this period might impact this activity. In addition, a thermal barrier may be created that might prevent fish movement from the Big Wood River into the Warm Springs Creek system. The magnitude and seasonal timing of any new geothermal discharges from developed sources to Warm Springs Creek must be carefully evaluated to prevent toxic and thermal impacts to resident fisheries.

The Big Wood River is designated a special resource water by Idaho Water Quality Standards and Wastewater Treatment Requirements (IDHW 1985). As such, no new point source discharges from developed geothermal sources should be allowed to the Big Wood River or its tributaries that would result in increased fluoride levels or temperature above ambient in the Big Wood River. Any new proposed geothermal point source discharges to these surface waters should be reviewed and permitted through the federal NPDES permit program to insure that all potential water quality impacts are evaluated. Geothermal wastewater treatment and/or re-injection should be considered. The State of Idaho should begin developing a surface water standard for fluoride, specific for the physical and chemical conditions of Idaho streams, to insure protection of beneficial uses.

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# INTRODUCTION

Geothermal resources in Idaho continue to be developed for a number of beneficial uses. These uses include space heating of commercial and residential buildings, power generation, aquaculture, industrial uses, and recreational/health facilities. Geothermal wastewater is often discharged to surface waters.

The Warm Springs Creek valley near Ketchum, Idaho, is one area where geothermal resource development may be impacting public health and aquatic resources. The Guyer Hot Springs system (i.e., Guyer, Lloyd, Greyhawk, and un-named springs) is a diffuse geothermal system that includes a number of springs which discharge to Warm Springs Creek along a quarter-mile reach of the creek. This geothermal source also discharges to the valley floor alluvium as evident through seepage from alluvial deposits in several locations. Geothermal water is also discharged directly to the streambed. Historically, these springs discharged about 1200 gpm of geothermal water to the Warm Springs Creek valley. In the late 1930s a portion of the major spring source, Guyer Hot Springs, was collected and diverted through a pipeline system to deliver geothermal water to Ketchum. The pipeline is presently used to heat nearby residences and as a water source for a resort's swimming pool. The three mile long pipeline eventually discharges to Trail Creek after flowing through the Bald Mountain Hot Springs pool.

Water samples submitted for chemical analysis by public community drinking water systems in the Warm Springs Creek valley since 1979 have indicated a trend towards increasing fluoride levels. Concentrations have approached or exceeded the State of Idaho maximum contaminant level (MCL) for fluoride at some of these systems. The aquifer tapped by these wells consists of very permeable alluvial sands and gravels underlain by limestone bedrock. Most wells in the valley are less than 60 feet deep, with depth to groundwater varying from 9 to 30 feet. Since this leaking geothermal pipeline passes in close proximity to a number of wells impacted by fluoride, it has been postulated that the pipeline might be a source of the fluorides.

In addition, several alternative development proposals have been made regarding the Guyer Hot Springs system. These proposals involve further development of the spring to obtain additional geothermal water for recreational facilities. Disposal of the geothermal wastewater generated by these proposed facilities has not been addressed. It is likely that proposals will be made to discharge this wastewater to surface waters in the area including Warm Springs Creek, Trail Creek, and the Big Wood River. The impact of additional geothermal discharges on the beneficial uses of surface waters in this area are unknown.

All streams studied are protected for cold water biota and salmonid spawning under the Idaho Water Quality Standards and Wastewater Treatment Requirements. Maximum water temperatures are limited to 22°C during non-spawning periods and 13°C during the spawning season. The Big Wood River is also designated a special resource water. As such, discharges causing detectable increases in fluoride levels or temperature above ambient are not allowed.

## PAST WATER QUALITY STUDIES

A number of studies concerning sewage disposal impacts on surface water and groundwater resources in the Ketchum-Hailey area have been conducted by consulting engineering firms (see Castelin and Winner 1975). In addition, resource agencies have also examined the same problem (e.g., Castelin and Winner 1975; Luttrell and Brockway 1982, 1984) as well as evaluated the water resources in the valley (e.g., Smith 1959, 1960; Castelin and Chapman 1972). Most recently (1987 water year), the United States Geological Survey (USGS) conducted a study to develop a water budget for the Big Wood River, and to assess existing sewage disposal practices on surface water quality (Frenzel 1989).

A preliminary survey of fluoride levels in Warm Spring Creek and the Big Wood River was conducted as part of an Idaho Department of Health and Welfare, Division of Environmental Quality (IDHW-DEQ) study in 1984 (Renk 1986). Sampling was conducted on a quarterly basis and did not include Trail Creek. Recommendations included no additional year-round geothermal discharges to Warm Springs Creek, that all geothermal discharges be permitted through the U.S. Environmental Protection Agency to control water quality impacts, that additional monitoring be conducted to assess thermal impacts during the summer, and that a bioassay study be performed.

$CH_2M$ Hill has evaluated the economic value of the Guyer Hot Springs system geothermal resource ($CH_2M$ Hill 1986). This report examined various alternatives for developing these springs for space heating, as well as identified areas favorable for exploratory drilling to increase geothermal flows. An exploratory drilling program and cost alternatives were presented.

A number of Idaho Department of Fish and Game studies have examined the fisheries in Warm Springs Creek, Trail Creek, and the Big Wood River including most recently a three year study on fisheries populations in the Big Wood River (Bell 1989). Data indicate wild spawning populations of rainbow trout, brook trout, and mountain whitefish are present in this system. Brown trout are also present in lower reaches of the Big Wood River below Hailey. Fish and Game also stocks this system with catchable rainbows during the summer.

## OBJECTIVES

This study may be subdivided into two main sections, groundwater and surface water. The overall objective of the groundwater portion of this research was to evaluate sources of fluorides impacting public community drinking water wells and to recommend corrective actions. The surface water portion of this research was to examine fluoride levels in Trail Creek, Warm Springs Creek, and the Big Wood River to address potential water quality impacts of proposed commercial uses of geothermal resources.

Specific objectives in each area include:

A. Groundwater

1. Characterize regional groundwater flows.
2. Determine background fluoride levels in groundwater.
3. Determine the effect of geothermal intrusions on groundwater fluoride levels.
4. Determine the effect of Guyer Hot Springs pipeline leaks on groundwater fluoride levels.
5. Prepare an implementation strategy for regulation of existing and proposed commercial activities to protect beneficial uses of the aquifer.

B. Surface water

1. Characterize surface water flows.
2. Determine background fluoride levels.
3. Determine the effect of geothermal intrusions on surface water fluoride concentrations.
4. Determine the effect of current and proposed commercial activities on surface water quality.
5. Prepare an implementation strategy for regulation of existing and proposed commercial activities to protect beneficial uses of Warm Springs Creek, Trail Creek, and the Big Wood River.

## DRAINAGE BASIN DESCRIPTION

The study was conducted in northern Blaine County in the Upper Big Wood River drainage basin near Ketchum, Idaho. This region is characterized by narrow to broad alluvial valleys which contrast sharply with the surrounding mountains. The area is bordered on the east by the Pioneer Mountains, on the west by the Smokey Mountains, and by the Boulder Mountains on the north. Bedrock consists of sandstone, quartzite, limestone, dolomite, and conglomerate of the Wood River Formation ($CH_2M$ Hill 1986). Well logs from the Idaho Department of Water Resources (IDWR) indicate alluvium depths of 60-120 feet in upper Warm Springs Creek valley.

This area is characterized by moderately cold winters and warm, dry summers. At Sun Valley, winter temperatures reach a mean minimum of -1.2$^{o}$F in January, and summertime mean maximum of 82.4$^{o}$F in July. The mean altitude of the Warm Springs Creek drainage is about 7,560 feet Mean Sea Level (MSL). The 48 year average precipitation at Ketchum, elevation 5,870 feet MSL, is 18.1 inches (Sawtooth National Forest 1989), 60% of which falls from November through March.

The economy of this area is dependent primarily on tourism and recreation, particularly winter sports. The resident population is employed in service-oriented industries, merchandising, lumbering, mining, construction and agriculture. A residental population of about 2,000 may increase 200% or more during the ski season. Many seasonal recreation homes, cabins and condominiums have been built along and near Warm Springs Creek, Trail Creek, and the Big Wood River.

### MONITORING STATIONS

Water chemistry and flow were monitored at eight surface water stations identified in Figure 1 and referenced in Table 7. Warm Springs Creek monitoring stations were located above and below major spring sources. Similarly, stations on Trail Creek were located above and below the Bald Mountain Hot Springs pool and pipeline outfalls. Stations on the Big Wood River were above and below confluences of each of these tributaries.

Fifteen wells were included in the groundwater portion of this research (Table 3). In addition, water samples were collected at Guyer Hot Springs and at the pipeline and pool outfalls to Trail Creek during each sampling run.

## MATERIALS AND METHODS

### GROUNDWATER METHODS

Groundwater samples for chemical analysis were collected from hose bibs at the individual sampling wells. In general, outside taps were used from May through October and indoor faucets were utilized during freezing weather. Samples were collected in one liter cubitainers, stored on ice in coolers, and shipped on the day of collection to the IDHW-Bureau of Laboratories, Boise. Analytical methods followed Standard Methods (American Public Health Association 1985).

Well water levels were monitored using a Fisher M-Scope water level indicator. True groundwater elevations were determined by subtracting measured water depths from casing elevations corrected to MSL.

Several chemical tracing experiments were conducted to assess relationships between the leaking geothermal pipeline water and domestic well contamination. Each of these experiments used sodium chloride as the tracer. Also, the geothermal pipeline was shut down for a brief period (about 2 days) in September 1987 to assess possible impacts of the geothermal pipeline on domestic wells. Throughout the period of each test, water samples were collected periodically for chemical analysis. Specifics of each test are discussed in the "Results and Discussion" section.

### SURFACE WATER METHODS

Field parameters were monitored with portable meters that were calibrated prior to each survey. Dissolved oxygen and temperature were measured with a YSI Model 54A meter. The pH was measured with a Model 640A Accumet mini-pH meter. Specific conductance was measured with a YSI Model 33 SCT Meter. Measured conductances were standardized to 25°C for reporting purposes. Current velocity measurements were made with a Marsh-McBirney Model 201D flow meter and used to calculate stream discharge.

Water samples for chemical analysis were depth integrated and composited across transects at well mixed locations at each station. A churn splitter was used to collect representative subsamples in 1 liter cubitainers. Samples were placed on ice and cooled to 4°C. Chemical analyses were performed by the IDHW-Bureau of Laboratories, Boise, following Standard Methods (American Public Health Association 1985).

Accute and chronic toxicity tests were conducted on Guyer Hot Springs geothermal water and Warm Springs Creek water in August 1987 to assess potential fluoride toxicity impacts on fisheries. This work was performed by EA Engineering, Science, and Technology, Inc., Sparks, MD, under contract to the U.S. Environmental Protection Agency, Region X. Test organisms included the fathead minnow (Pimpephales promelas) and a cladoceran (Ceriodaphnia dubia). Water samples for this research were collected from the Guyer Hot Springs outfall and from Warm Springs Creek above the hot spring confluence.

## QUALITY ASSURANCE

Duplicate (split) and spiked water samples were collected during the study to assess precision and accuracy, respectively, of the data. The quality assurance (QA) component of this research follows the recommendations of Bauer (1986) and Bauer et al. (1986a, 1986b).

Since the primary contaminant of interest in this study was fluoride, spiked samples were collected from two stations in December 1986 to assess the accuracy of these data prior to initiating this research. Previous work has indicated extremely poor (20.7%) recovery of fluorides from spiked field quality assurance (QA) samples (Clark 1985). Interferences might include calcium and phosphorus. Chemical spikes were prepared by the IDHW-Bureau of Laboratories, Boise, and sealed in Kimble 10 ml glass ampules. In the field, ampules were opened and their contents mixed with 900 ml of sample water in 1 liter cubitainers.

Duplicate samples were collected to assess precision. At a given station, these QA samples were collected from the same cross-composite prepared for routine water chemistry samples.

All QA samples were stored on ice at 4°C and shipped to the IDHW-Bureau of Laboratories in Boise for analysis following Standard Methods (American Public Health Association 1985). Percent recovery for spikes was determined by subtracting background concentrations (as determined from duplicate or routine samples) from known spike values.

## RESULTS AND DISCUSSION

This section of the report is divided into two parts. The first section discusses findings of the groundwater investigation, while the second part examines the surface water research.

### GROUNDWATER INVESTIGATION

The groundwater, stream flows, and geothermal discharges for the Warm Springs Valley were monitored and characterized to provide a basis for assessment of the impacts of various sources of pollution . Data gathered from field measurements and literature review are presented in Figures 1-14 and Tables 1-6. Characterizations of the systems were accomplished in accordance with the procedures contained in this section to assess the effects of pollution sources on groundwater fluoride levels.

#### GROUNDWATER FLUORIDE STANDARDS

Fluoride is a groundwater contaminant regulated by the Environmental Protection Agency and the Idaho, Department of Health and Welfare, Division of Environmental Quality. The Idaho Regulations for Public Drinking Water Systems, July, 1985 (IDAPA 16.01.8900,03) and the Idaho Water Quality Standards and Wastewater Treatment Requirements (IDAPA 16.01.2200 and 16.01.2250,07) establishes fluoride maximum contaminant levels between 1.4 and 2.4 mg/l. These levels vary depending on the annual average of the daily maximum air temperature of the area. They are established for protection of ground and drinking waters from the effects of fluoride in causing dental mottling and skeletal fluorosis.

The United States Environmental Protection Agency has established a maximum contaminant level for fluoride in drinking water of 4.0 mg/l for protection of skeletal fluorosis and a secondary maximum contaminant level of 2.0 mg/l to protect against objectionable dental fluorosis (40 CFR Parts 141, 142, AND 143; Wednesday April 2, 1986).

#### GROUNDWATER FLOWS

Groundwater flows for this study were determined using the following method:

$Q = T \times W_S \times S$ (Water Supply and Control; Clark, Viesman, and Hammer: 3-14, pg 78, 1971)

Where:

- $Q$ is the aquifer discharge in gallons per day (gpd)
- $T$ is the aquifer transmissibility in gpd/ft
- $W_S$ is the section width in ft
- and $S$ is the water table slope in ft/ft

The aquifer transmissibility was estimated at 15,000-20,000 gpd/ft from well yield testing at Ketchum Municipal well#1 (Brockway 1988).

The aquifer width was determined from U.S. Department of the Interior Geological Survey topographic maps (see Figure 1). A geologic cross-section of Warm Springs Creek valley is presented in Figure 2.

The water table slope was determined from field surveys and Ketchum City plat maps (Figure 6). Well casing elevations were surveyed using the top of the fire hydrant 25 feet south of Greyhawk well "A" as an assumed datum of 100.00 feet. (This datum was later corrected to Mean Sea Level by adding 5813.3 feet). Well water levels were monitored by M-Scope on a monthly basis throughout the study (Table 3 and Figure 7). Groundwater elevations were determined by subtracting the measured water depths from the casing elevations (Table 1).

Using this analysis method a flow of approximately 500,000 gpd was estimated for the aquifer:

Q= 20,000 g/ft/d x 3200 ft x 0.00682 ft/ft = 436,480gpd

It is important to note that this method of estimation is not precise and that actual flows may vary by an order of magnitude from the calculated value.

STREAM FLOWS

A 17 year (1941-58) average flow for Warm Springs Creek was estimated at 87.4 cubic feet per second (cfs) by the U.S. Geological Survey (U.S.G.S. 1963). Stream flows in Warm Springs Creek were monitored on a monthly basis at stations S-1 and S-3 from February 1987 to January 1988 (Figure 1). The average flows for this period were 37 and 41 cfs, respectively. This indicates that the stream gains approximately 4 cfs (1800 gpm) from spring flows and groundwater discharges through the valley (Figure 3).

GEOTHERMAL DISCHARGES

Several geothermal springs have been identified in the Warm Springs System. Measured and estimated data are summarized on Table 2. Total geothermal inflows to Warm Springs Creek and the groundwater system were estimated to be 1200 gpm ($CH_2$MHILL1986).

FLUORIDE MONITORING

Fluoride concentrations were monitored in the groundwater, surface water, and geothermal water on a routine basis. Data from field sampling is summarized in Table 3 and mass balance calculations for the prepared data presented in Table 4. A systems simulation representing the collated data is presented in Figure 3.

## SYSTEM ANALYSIS

Figure 3 indicates that during 1987 the Guyer pipeline lost 200 gpm of geothermal water at 16 mg/l fluoride to pipe leakage. This leakage was represented in the analysis to occur uniformly over the length of the pipeline. One and one half miles of the three mile pipeline is within the Warm Springs System (Figure 4). Therefore, one half of the total 200 gpm was estimated to enter that aquifer.

The Guyer pipeline is pressurized throughout the Warm Springs valley to deliver water to its users. The lower portion of the pipeline is also pressurized to provide water from an elevation of 5800 ft MSL near the mouth of the valley to the Bald Mountain Swimming Pool in Ketchum at an elevation of 5830 ft MSL.

The field data, estimates, and calculations indicate that a pipeline leakage of 0.14 mgd is lost into the Warm Springs Aquifer . This leakage with a concentration of 16 mg/l fluoride could elevate background levels of the entire aquifer by 3.5 mg/l.

From Figure 3 it can be estimated that 72 pounds per day (ppd) of fluoride is available to enter the groundwater. This quantity has the potential to elevate background levels to 17 mg/l for the estimated 0.5 mgd aquifer flow. Field measurements of groundwater fluoride concentrations suggest a significantly lower average level of about 1.5 mg/l (Figure 5). This indicates that either there is a significant loss of fluoride through undetected sources, such as chemical precipitation, or that the input quantities have been misrepresented. A detailed study beyond the scope of this investigation would be required to quantify and identify these parameters in sufficient detail to determine the exact processes involved.

This analysis does indicate that sufficient sources are available to sustain the aquifer fluoride concentrations observed and that leaks from the Guyer pipeline system have the potential to substantially influence a considerable portion of the aquifer.

## FIELD TESTS

Four field tests were conducted to determine a correlation between pipeline leakage and groundwater fluoride concentrations.

### Test One - Pipeline Depressurization

Test one consisted of a 32 hour depressurization of the Guyer pipeline September 8th, 9th, and 10th, 1987. Fluoride levels at four wells ; Limelight, Four Seasons, Ketchum #1, and Ketchum #2 were monitored for response to the test (Figure 8 and Table 5).

Tests for Limelight, Ketchum #1, and Four Seasons showed slightly elevated concentrations of fluoride prior to the depressurization and a slight post test suppression. The test duration was limited due to Guyer Pipeline Company obligations in delivering water to its users and did not yield results statistically significant at the 95% confidence level except at Ketchum well #2. An exception to this observation occurred at Ketchum well #2.

A pronounced increase in fluoride levels occurred during the test at Ketchum well #2, elevating concentrations from a background level of 0.2 mg/l to 4.6 mg/l. The cause can be attributed to the bypassing of geothermal water from the pipeline to the Big Wood River during depressurization. The discharged geothermal water entered the groundwater as leakage through the gravel riverbed, increasing the fluoride levels in the aquifer in the vicinity of well #2.

Test Two (Salt #1)

Test two consisted of dissolving 200 pounds of block salt (NaCl) into the wetwell of the Guyer Pipeline Company collection system over a period of 8 hours on November 10th. Four wells ; Limelight, 320 Georgina, Four Seasons, and Ketchum #1 were monitored for response (Figure 9 and Table 6).

The introduction of the salt was designed to increase the chloride concentrations in the geothermal water in the pipeline to differentiate it from other geothermal waters. Both chloride and fluoride ions are negatively charged and therefore act similarly in groundwater systems. The groundwater was monitored for chloride and fluoride concentrations to assess the relative impacts from the two geothermal sources.

All four wells exhibited the same characteristic response to the test. Groundwater chloride levels increased while fluoride levels remained constant or in some cases were slightly suppressed. The results indicate that pipeline leakage is affecting groundwater fluoride concentrations.

The State Bureau of Laboratories determined chloride concentrations for this study using a titration method of analysis. Precision tolerances for this method in the reported range are ±1.2 mg/l. Only one well, Limelight, responded with chloride concentrations greater than the 1.2 mg/l tolerance. For this reason a second salt test was conducted.

Test Three (Salt #2)

Test three consisted of introducing 400 pounds of salt into the wetwell at the Guyer Hot Springs collection point over a period of 8 hours on Tuesday, December 15th. Water from three wells Limelight, Four Seasons, and Ketchum #1 were monitored for response to the test (Figure 10 and Table 6). Chloride levels responded in a manner similar to those noted in the salt tracing test #1.

Pre and post samples of the pipeline water tested at chloride levels of 9 and 267 mg/l, respectively, indicating that the salt was effectively introduced in the pipeline water. Doubling the salt amount from 200 to 400 pounds did not result in a doubling of the responses at the monitored wells. However, comparison of data means for the two tests did indicate a significant response (See data analysis section below). Data from wells monitored exhibited a statistically significant increase in the chloride to fluoride ratio indicating a direct correlation between pipeline leakage and aquifer fluoride concentrations.

Test Four (No Salt)

A no salt test was conducted from 1/22/88 through 1/28/88 for the Limelight, Four Seasons, and Ketchum#1 wells. This test was conducted to correlate chloride accumulated in the aquifer with results from the three previous tests. Test results are presented in Figure 11 and Table 6.

A detectable increase over background levels in the chloride to fluoride ratio for this test was demonstrated when statistical mean values for the data were compared. This ratio increase indicates that aquifer response to the pipeline leakage is cumulative and not confined to a temporary localized reaction from dosing. The effects of upstream chloride discharges were carried downstream affecting a significant area in the aquifer.

## DATA ANALYSIS

Graphical presentation of the data at the individual wells is presented in Figures 12, 13, and 14 for the No Salt, Salt#1, and Salt#2 tests. Increased chloride levels were observed on the 4th, 3rd, 7th, and 6th sampling days for the Ketchum #1, Limelight, Four Seasons, and Georgina wells respectively for the Salt #1 test. The control well at 405 Sage did not exhibit the same characteristics. Peaks were also indicated in data collected from the Salt #2 test for the monitored wells, supporting the observations from the Salt #1 tracing test.

Test #3 also indicated that salt in the form of chlorides had accumulated in the groundwater from the Salt #1 and Salt #2 tests. A statistical test was used to validate the observed responses. Analysis of the groundwater data for the tests was accomplished by comparison of data mean values to eliminate the variability induced by laboratory error in determining chloride concentrations (± 1.2 mg/l). Field fluoride levels, which have a laboratory variance of ± 0.04 mg/l, were used to predict field chloride values according to the following formula:

$$Cl = 2.3 + (F/16.2) \times 10.9$$

Where:
- Cl = Calculated chloride concentration
- F = Field fluoride concentration
- 2.3 = Groundwater background chloride concentration with no geothermal water present (405 Sage)
- 16.2 = Geothermal water fluoride concentration and 10.9 = Geothermal water chloride concentration

*(All values in mg/l)

Mean values were calculated for each of the four tests for the difference between calculated chloride values and actual field data. Data means for the Salt#1, Salt#2, and No Salt tests were compared with the mean for the depressurization test using the Student's "t" test (Zar 1974). Significant responses were recorded at the 95% confidence level for all tests except Salt#1-Four Seasons and No Salt-Ketchum #1.

The Four Seasons well did not respond to the Salt #1 test until the 7th monitoring day (Figure 12). For this reason only two of the samples collected were influenced by the test. This was not sufficient to change the test mean values enough to be significant at the 95% confidence level.

The absence of a statistically significant response at the Ketchum #1 well may be attributed to the first sample collected in the No Salt series. This field sample of 3.5 mg/l did not correlate with the other samples collected and skewed the mean value out of the confidence range of the test (Figure 14).

## SURFACE WATER INVESTIGATION

Fluoride is found in most fresh water systems in low concentrations ranging from 0.1-1 mg/l. Most of this fluoride arises from leaching of cryolite, apatite, rhyolite, and sedimentary phosphate rocks by groundwater and precipitation (U.S. EPA 1973). A certain amount of fluoride may also enter surface waters through atmospheric fallout.

Elevated fluoride levels in the streams examined in this study arise from groundwater accrual, particularly geothermal intrusions into the valley floor and streambeds, as well as by direct discharges of geothermal wastewater. In addition to direct fluoride toxicity, the heat content of geothermal water may increase stream temperatures and thereby impact fisheries.

### FLUORIDE TOXICITY TO FRESHWATER SYSTEMS

Tolerance of freshwater organisms to fluoride is variable. Generally, salmonids tend to be most sensitive, while invertebrates, algae, and bacteria are apparently quite tolerant (North Carolina Department of Natural Resources and Community Development 1986). Fluoride tolerance by fish is generally increased by high levels of calcium hardness, low temperatures, and low concentrations of chloride ions (Sigler et al. 1972, Wright 1977, Pimentel and Bulkley 1983, Smith et al. 1985).

Fluoride has a varying toxicity impact on salmonids depending upon species, life stage, and physiological condition of the fish, in addition to the environmental factors mentioned above. Fluoride has a low potential for bioaccumulation which is reflected in relatively high chronic:acute ratios for most species. Most of the fluoride uptake in rainbow trout occurs in both soft tissues and bone (Sigler and Neuhold 1972).

Generally, smaller salmonids tend to be less resistant to fluoride impacts than larger fish (Wright 1977). This may relate to the higher metabolic rates of smaller fish or a greater surface area per weight, both of which would result in increased fluoride uptake. Rainbow trout eggs appear to be somewhat tolerant of fluoride (Neuhold 1958, Neuhold and Sigler 1960). For example, Neuhold (1958) found fluoride levels of 100 mg/l not to impact egg hatching. Only one report for this species indicates otherwise, and this report outlines only undocumented observations that hatching was delayed and hatching success was reduced at a fluoride level of 1.5 mg/l (Ellis et al. 1946).

## SURFACE WATER FLUORIDE STANDARD

Fluoride is not an EPA priority pollutant. As a result, individual states have adopted their own standards in order to protect beneficial uses. These standards range from 1.0 mg/l in states such as Oregon and Pennsylvania, to values as high as 15 mg/l in Minnesota (North Carolina Department of Natural Resources and Community Development 1986). Some states have recognized a need to link their standard to chemical and physical properties of surface waters such as hardness and temperature. Idaho does not have a surface water standard for fluoride.

North Carolina conducted the most extensive literature review to date of information related to fluoride toxicity of freshwater organisms, as part of a water quality standards review process (North Carolina Department of Natural Resources and Community Development 1986). When this review began, North Carolina had a freshwater standard of 1.8 mg/l measured at 7Q10 flow. This review process yielded substantially more acute, rather than chronic, toxicity data. Following EPA guidelines, they calculated a preliminary Final Acute Value (FAV) of 15.6 mg/l fluoride for surface waters with salmonids (North Carolina Department of Natural Resources and Community Development 1986). To determine an actual instream standard, this FAV would have to be lowered by an appropriate chronic:acute ratio. The ratio used by North Carolina was 0.05; however, based upon the limited chronic data available they indicate that this may be too low. Based upon their literature review, North Carolina concluded that their 1.8 mg/l standard would remain in effect until additional acute and chronic toxicity tests were conducted in order to refine chronic:acute ratios following EPA protocols.

Until a freshwater fluoride standard is developed nationally or for Idaho surface waters, the North Carolina standard may be used for comparative purposes. When a standard is developed for Idaho, it should be linked to hardness and temperature. A fluoride standard developed for Idaho may ultimately be greater than North Carolina's and reflect a reduced toxicity of fluoride in Idaho streams due to lower water temperatures and higher hardness levels. In addition, separate standards should probably be developed for Idaho salmonid and non-salmonid waters since salmonids appear to be more sensitive to fluoride than other species.

## EXISTING SURFACE WATER QUALITY CONDITIONS

### Fluoride Levels

During the study, fluoride levels generally increased in Warm Springs Creek with downstream progression from S-1, and reflect accrual of geothermal water from the Guyer Hot Springs system (Tables 8-10). Mean values for Warm Springs Creek for the study range from 0.78 mg/l at S-1 to 1.28 mg/l at S-3. During base flow conditions (winter months), instream fluoride levels ranged from 1.4-1.9 mg/l downstream of Guyer Hot Springs (Tables 9 and 10).

Fluoride levels in Trail Creek and the Big Wood River were generally less than those observed in Warm Springs Creek and reflect less geothermal accrual or increased flows. In Trail Creek, mean concentrations for the study period increased from 0.18 at S-6 to 0.51 mg/l at S-7. Discharges from the geothermal pipleline and pool therefore increased instream fluoride levels about threefold. Maximum concentrations observed at S-6 and S-7 were 0.26 and 1.18 mg/l, respectively (Tables 13 and 14). The peak value at S-7 may have occurred when the pool was being flushed and the total geothermal wastewater flow to Trail Creek increased. Outfall flows and contaminant levels are summarized in Table 16. Trail Creek could conceivably assimilate additional geothermal wastewater during elevated flows without exceeding the 1.8 mg/l recommended standard. However, due to base flows as low as 2.1 cfs (Table 14) discharges during this period may result in toxicity problems as well as potential thermal impacts on the stream system.

Fluoride levels also increase in the Big Wood River with downstream progression from above the Warm Springs Creek confluence (annual mean of 0.2 mg/l) to below the Trail Creek confluence (annual mean of 0.57 mg/l). The highest fluoride level observed in the Big Wood River during this research was 0.82 mg/l at S-8 under base flow conditions. As a special resource water, no new geothermal point source discharges should be allowed to the Big Wood River that would increase fluoride levels above ambient as a result of existing or natural spring sources. Additional geothermal discharges to the Big Wood River or its tributaries from developed spring sources should not be allowed if these discharges would result in increases in fluoride levels above ambient.

### Temperature

According to Idaho Water Quality Standards and Wastewater Treatment Requirements the surface waters examined in this research are all protected for cold water biota and salmonid spawning. Water temperatures are therefore limited to a maximum of 22°C during the non- spawning season (June-Sept.) and a maximum 13°C during the spawning season (Oct.-May). The potential impact of geothermal wastewater on stream temperature is significant since Guyer Hot Springs water has a temperature of about 70°C.

All of the streams examined in this study were in compliance with these temperature limits (Tables 8-15). Note however, that temperatures observed at Warm Springs Creek station S-3 in March, April, and May approached the salmonid spawning standard and ranged from 11-12°C (Table 10). Additional geothermal discharges to this stream might result in a violation of this standard and an impact on resident fish populations.

## POTENTIAL GEOTHERMAL DEVELOPMENTS AND POSSIBLE WATER QUALITY IMPACTS

Most of the following discussion focuses on Warm Springs Creek. Recently proposed development projects have focused on geothermal resources located along lower Warm Springs Creek. At present, no additional geothermal discharges have been proposed for Trail Creek. However, as noted above, geothermal discharges to any Big Wood River tributaries have potential for impacting tributary and Big Wood River water quality depending upon their magnitude and seasonal timing.

The Guyer Hot Springs pipeline is an old, decaying, geothermal conveyance system that will require considerable expense to replace or repair ($CH_2M$ Hill 1986). Several alternatives for use of this water in various types of developments have been proposed. One such proposal involves development of a resort complex near Guyer Hot Springs where the geothermal water would be used for space heating, health spas, etc. Discharge of the existing spring flow now entering the pipeline to Warm Springs Creek (about 450 gpm) will likely be proposed. It has also been proposed that the spring system could be developed to obtain an additional 600 gpm of geothermal water that is probably not currently entering Warm Springs Creek or the shallow alluvial aquifer. The total potential discharge to Warm Springs Creek might then be about 1050 gpm (2.3 cfs) in addition to the existing geothermal spring flows.

### Potential Fluoride Impacts

During the base flow period of this study (August-March) mean fluoride levels and flow at S-2 were 1.5 mg/l and 29.9 cfs, respectively. An additional 450 gpm geothermal discharge would raise this average fluoride level to about 2 mg/l. Similarly, if the spring system was developed to obtain an additional 600 gpm, the total discharge would elevate this fluoride level to about 2.5 mg/l. Similar calculations for S-3 result in potential instream fluoride levels of 2.1 and 2.7 mg/l for discharges of 450 gpm and 1050 gpm, respectively.

The lowest flow measured at S-2 in this study was 23.8 cfs. However, Renk (1986) measured flows as low as 12.5 cfs at this station in November 1984. Potential additional geothermal discharges to Warm Springs Creek during such drought flows could result in fluoride levels as high as 3-4 mg/l.

Therefore, additional geothermal discharges to Warm Springs Creek will likely result in exceedances of the 1.8 mg/l recommended criteria during base flow conditions. This will probably occur if the historical flows of Guyer Hot Springs are returned to the creek, and certainly occur if the spring system is developed and additional spring flows discharged to the creek. Clearly, the magnitude and timing of any additional geothermal discharges to Warm Springs Creek must be carefully evaluated to prevent potential toxic impacts.

Potential Thermal Impacts

As noted previously, all streams examined in this study were in compliance with temperature standards to support existing beneficial uses of cold water biota and salmonid spawning. However, as previously noted, water temperatures in lower Warm Springs Creek (station S-3, Table 10) approached the 13°C salmonid spawning standard in March, April, and May. Additional geothermal discharges during this period could result in a violation of this standard.

Such an increase in water temperature could adversely affect salmonid spawning success in this reach of Warm Springs Creek and may also create a thermal barrier to upstream movement of fish from the Big Wood River into the Warm Springs Creek system.

## TOTAL EFFLUENT BIOASSAY RESULTS

Acute and chronic toxicity tests were conducted on water samples from Guyer Hot Springs and from Warm Springs Creek above the Guyer Hot Springs system. Water quality data for these samples are summarized in Appendix A. Generally, these data indicate that the geothermal water had elevated dissolved solids, chloride, fluoride, sulphate, silica, and boron levels in comparison to creek water.

This water was used to conduct 7-d larval survival and growth tests and two 24-hr acute toxicity tests with fathead minnows (Pimpephales promelas). In addition, a 7-d survival and reproduction test, and two 24-hr acute toxicity tests were conducted with a cladoceran (Ceriodaphnia dubia). Test procedures and results are summarized in Appendix B.

The data indicate that for these organisms, under the test conditions specified, that 100% effluent (i.e., Guyer Hot Springs water) was not acutely toxic (24 hr $LC_{50}$ > 100% effluent), nor were chronic toxicity effects (growth, reproduction) observed. These results must be interpreted with caution, since as indicated previously, salmonids are the most sensitive group of organisms with respect to fluoride toxicity. Before extrapolating these results to imply that additional geothermal discharges to Warm Springs Creek will not affect salmonid populations, bioassay tests involving various salmonid species need to be conducted. More specifically, chronic tests (for at least 21 d) involving rainbow and brook trout need to be conducted. In addition, tests should be conducted to assess fluoride impacts on brook trout egg development and hatching success. Because of hardness, temperature, and chloride effects on fluoride toxicity, these tests should be designed to mimic water quality conditions in Idaho mountain streams. These data would enable Idaho to develop a fluoride standard to protect the cold water biota and salmonid spawning beneficial uses.

Even though these bioassay results indicate no effects on Pimpephales promelas and Ceriodaphnia dubia at 100 percent effluent (i.e., 17 mg/l fluoride), the 1.8 mg/l North Carolina standard should be applied as a conservative standard to protect salmonids until additional data are available for the species of concern.

## QUALITY ASSURANCE

Fluoride spiked and duplicate samples were collected during this study to assess data quality. These samples were used to determine if laboratory reported values were equivalent to environmental values at the time of collection. Accuracy (or bias) and precision estimates may be utilized to assess how close these two values are for a given data set.

### Accuracy

Accuracy is a measure of the agreement between a given measurement and a true value for that parameter. Percent recovery of a spike from quality assurance samples may be used to estimate accuracy. Percent recovery is calculated as the ratio of a spiked sample to the true value. Average percent recoveries may be calculated for comparison when a number of spiked samples are analyzed for a given parameter.

As indicated previously, at the onset of this research there was concern regarding underestimating fluoride levels due to the possible poor recovery of fluoride as had been observed in previous studies (see Clark 1985). For this reason spiked samples were collected from Guyer Hot Springs and Warm Springs Creek prior to initiating the study.

The data generally indicate good recovery of fluoride from the spiked QA samples (Table 17). Statistically, the Guyer Hot Spring data indicate a slight low bias since the range of recoveries (84.2 to 90.3%) that encompases the true value, is below 100%. For the Warm Springs Creek data, the range of recoveries in which the true value lies includes 100 % so neither type of bias is really defined.

### Precision

Precision is a measure of the agreement between duplicate measurements of a given parameter under the same environmental conditions (Bauer 1986). The average relative range is used to describe the precision for duplicate samples. Precision was generally good for most of the parameters examined (Table 18). Average relative range was less than or equal to 10% for all parameters except chloride. Precision was not very good for chloride, with an average relative range of 26.2%.

## CONCLUSIONS

### GROUNDWATER

The test mean values exhibit a significant and repeated pattern in response to the salt added to the aquifer. This confirms that leakage from the pipeline does enter the Warm Springs Creek groundwater and that it has a demonstrated effect on fluoride concentrations at Limelight, Four Seasons, and Ketchum #1. Removal of the pipeline leakage is expected to result in reductions of fluoride at the monitored public wells by 1-2 mg/l on average and up to 5 mg/l for peak periods. Private wells, adjacent to the pipeline will experience similar responses to those predicted for the public systems.

### SURFACE WATER

Fluoride levels increase in the Big Wood River through the Ketchum area as a result of geothermal spring water feeding its tributaries. Some of this geothermal water naturally enters tributaries such as Warm Springs Creek, while discharges from a geothermal pipeline transfers water from the Warm Springs Creek drainage to the Trail Creek drainage and Trail Creek.

Under existing conditions, fluoride levels in Warm Springs Creek meet or exceed the recommended limit (1.8 mg/l) to protect cold water biota during base flow periods. These elevated levels reflect geothermal water accrual from the Guyer Hot Springs system. Fluoride levels in Trail Creek were below this limit even during base flow periods. However, due to the low flow in Trail Creek during the winter months (2-5 cfs) additional geothermal discharges or pool flushing during these periods might exceed this standard as well as create thermal problems.

Plans to develop the Guyer Hot Springs system for a recreational development may result in proposals to discharge 450-1050 gpm additional geothermal water to Warm Springs Creek. About 450 gpm of this water historically entered the creek and would elevate fluoride levels to about 2 mg/l during base flow. Developing this spring source to obtain additional geothermal water that ultimately might be discharged to Warm Springs Creek would raise base flow fluoride levels even higher. In addition to fluoride toxicity problems, this additional geothermal water might elevate water temperatures and impact salmonid spawning in lower Warm Springs Creek. Elevated water temperatures in this reach might create a thermal barrier to fish movement. This study supports Renk's (1986) conclusion that Warm Springs Creek should not receive additional geothermal discharges in excess of normal spring flows, except during runoff conditions. Any new geothermal discharges from developed sources must be carefully evaluated to assess toxicity and thermal impacts.

Although impacts from proposed developments would most likely focus on Warm Springs Creek at this time, impacts from any proposed geothermal development on Big Wood River water quality must also be considered. As a special resource water, no new point sources can discharge to the Big Wood River if pollutants significant to the designated uses contained in the discharged wastewater (i.e., fluoride, heat) can or will result in a reduction of the ambient water quality and thereby affect beneficial uses. Obviously, development of spring sources to increase geothermal flows with subsequent discharges to Big Wood River tributaries might result in a reduction of ambient Big Wood River water quality.

Development of a fluoride standard at the national or state level should be pursued. Many acute fluoride toxicity studies have been conducted with various organisms (see North Carolina Department of Natural Resources and Community Development 1986 ). However, there is a need for additional chronic and acute data before a final standard can be developed following EPA protocols. In particular, a longer term (21 d) chronic study for salmonids is needed. Ideally, to apply such research to Idaho, test conditions should approximate environmental conditions in Idaho surface waters. Separate standards for trout and non-trout surface waters are warranted. With this information, a more accurate assessment of potential beneficial use impacts due to geothermal discharges could be made.

## RECOMMENDATIONS

GROUNDWATER

1. Leakage from the Guyer Pipeline System should be eliminated to stop the discharge of geothermal waters to the aquifer to protect the public health from fluoride contamination as required in the Idaho Water Quality Standards and Wastewater Treatment Requirements.

2. The public utilizing the aquifer as a drinking water source should be informed of the existing hazards and given information on methods for reducing their exposures during the period that the aquifer takes to recover from past discharges.

3. New systems developed in the Warm Springs Creek valley should be constructed with designs and materials compatible with the characteristics of the geothermal water.

SURFACE WATER

1. The Idaho Department of Water Resources and the U.S. EPA should work together to oversee development of geothermal resources and disposal of geothermal wastewater.

2. All new geothermal discharges to surface waters from developed sources should be permitted through the federal NPDES permit program to ensure potential water quality impacts are addressed. Geothermal wastewater treatment and/or re-injection should be considered.

3. No new point source geothermal discharges to Warm Springs Creek from developed sources should be allowed until potential toxicity and thermal impacts of the proposed discharge are thoroughly evaluated. No new point source geothermal discharges should be allowed that will increase ambient fluoride levels or temperature in the Big Wood River.

4. Additional chronic and acute bioassays should be conducted to permit development of a fluoride water quality standard. This research should include a chronic study with rainbow trout and brook trout under physical and chemical conditions similar to Idaho streams.

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Table 1. Well survey data, Warm Springs Creek Valley, 1987.

| Well Location | Casing Elevation | Datum Correction* | Water Depth | Groundwater Elevation |
|---|---|---|---|---|
| Greyhawk | 99.98 | 5913.3 | 21.0 | 5892.3 |
| 405 Sage | 101.14 | 5914.4 | 30.9 | 5883.5 |
| 2810 W.S. Rd. | 84.93 | 5898.2 | 56.1 | 5842.1 |
| 320 Georgina | 61.86 | 5875.2 | 22.0 | 5853.2 |
| 220 Cedar | 55.10 | 5868.4 | 42.4 | 5826.0 |
| 2512 W.S. Rd. | 71.75 | 5885.1 | 59.7 | 5825.4 |
| 2206 W.S. Rd. | 61.18 | 5874.5 | 54.3 | 5820.2 |
| Limelight | 55.90 | 5869.2 | 49.5 | 5819.7 |
| 401 Bald Mt. Rd. | 34.25 | 5847.6 | 26.8 | 5820.8 |
| Four Seasons | 47.90 | 5861.2 | 48.7 | 5812.5 |
| W.S. Ranch | 12.20 | 5825.5 | 20.2 | 5805.3 |
| 410 Riverrun | 29.50 | 5842.8 | 40.5 | 5802.3 |
| Greyhawk Geothermal well | 73.20 | 5886.5 | 2.5 | 5884.0 |

*5813.3 ft

Table 2. Flow estimates, Warm Springs Creek Valley groundwater study, 1987.

| SPRING | FLOW | SOURCE |
|---|---|---|
| GUYER SPRINGS | 625 gpm | $CH_2M$ Hill (1986) |
| GUYER PIPELINE | 450 gpm | IDWR unpubl. data |
| LLOYD SPRINGS | 200 gpm | $CH_2M$ Hill (1986) |
| GREYHAWK AND UNNAMED SPRINGS | 350 gpm | $CH_2M$ Hill (1986) |
| GUYER PIPELINE DISCHARGES | 50 gpm | Present study |
| GUYER PIPELINE LEAKS | 100 gpm | Present study |

Table 3 Well Monitoring Data. Fluoride in mg/l and Depth in ft.

| Greyhawk | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | | | | | | | | | | |
| Depth | 20.90 | 21.20 | 21.50 | 21.10 | 21.00 | | 21.50 | 21.60 | 21.80 | | |
| | | | | | | | | | | | |
| **2206** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | 3.43 | 3.64 | 3.95 | 3.97 | 3.37 | 3.40 | 3.10 | 3.33 | 3.10 | | |
| Depth | 56.70 | 56.10 | 54.60 | 54.40 | 54.20 | | 55.60 | 57.00 | 57.60 | | |
| | | | | | | | | | | | |
| **401 Bald Mountain** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | | | 1.56 | 1.35 | 1.35 | 1.49 | 1.44 | 1.41 | | |
| Depth | 34.30 | 28.80 | 27.10 | 27.00 | 26.70 | | 28.10 | 29.60 | 30.00 | | |
| | | | | | | | | | | | |
| **4 Seasons** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | 3.30 | 3.26 | 3.39 | 3.31 | 3.23 | 3.00 | 3.40 | 3.43 | 3.43 | 4.08 | 4.70 |
| Depth | 50.40 | 49.70 | 48.40 | 48.60 | 48.60 | | 49.40 | 50.60 | 50.60 | | |
| | | | | | | | | | | | |
| **410 Riverrun** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | 0.95 | 1.01 | 1.11 | 1.08 | 1.14 | 1.30 | 1.31 | 1.37 | | |
| Depth | 40.60 | 40.20 | 39.60 | 40.10 | 40.40 | | 40.60 | 41.40 | 41.90 | | |
| | | | | | | | | | | | |
| **Limelight** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | 1.96 | 1.82 | 2.09 | 2.25 | 2.68 | 2.15 | 1.51 | 1.34 | 1.51 | 4.03 | 3.20 |
| Depth | | 51.10 | 49.60 | 49.50 | | 50.60 | 50.50 | 52.00 | 52.50 | | |
| | | | | | | | | | | | |
| **405 Sage** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | 0.04 | 0.13 | 0.17 | 0.11 | 0.15 | 0.09 | 0.19 | 0.01 | | |
| Depth | | | 31.10 | 31.00 | 30.90 | 30.90 | 31.30 | 31.70 | 32.90 | | |
| | | | | | | | | | | | |
| **320 Georginia** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | 5.33 | 5.36 | 5.53 | 5.25 | 6.60 | 6.05 | 5.64 | 5.08 | 5.24 | |
| Depth | | 22.20 | 21.80 | 21.80 | 22.00 | | 22.80 | 22.60 | 22.70 | | |
| | | | | | | | | | | | |
| **115 Corrock** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | | | 3.50 | 3.90 | 3.21 | 0.89 | 3.63 | 3.50 | | |
| Depth | | | | | 48.20 | 48.90 | 48.60 | 49.10 | 48.70 | | |
| | | | | | | | | | | | |
| **WS Ranch** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | | | 1.12 | 0.95 | 0.99 | 0.96 | 1.08 | 1.04 | | |
| Depth | | | | 20.20 | 20.20 | 21.20 | 20.60 | 21.60 | 21.30 | | |

Table 3 Well Monitoring Data. Fluoride in mg/l and Depth in ft.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2512 WS** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | 1.01 | 0.79 | 0.62 | 0.67 | 0.61 | 0.46 | 0.60 | 0.55 | | |
| Depth | | | 60.20 | 59.80 | 59.60 | | 62.20 | | 62.90 | | |
| | | | | | | | | | | | |
| **Ketchum #1** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | 2.76 | 2.20 | 2.23 | 2.60 | 3.35 | 6.00 | 3.36 | 3.66 | | | |
| Depth | | | | | | | | | | | |
| | | | | | | | | | | | |
| **Ketchum #2** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | 0.04 | 0.11 | 0.22 | 0.17 | 0.18 | 1.40 | 0.16 | 0.27 | 0.24 | 0.21 | |
| Depth | | | | | | | | | | | |
| | | | | | | | | | | | |
| **2810 Sage** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | | | | | | | | | | |
| Depth | 56.10 | 56.50 | 56.60 | 56.30 | 56.10 | | 58.20 | 58.30 | 61.10 | | |
| | | | | | | | | | | | |
| **220 Cedar** | | | | | | | | | | | |
| **Sample Date** | **2/25** | **3/25** | **4/22** | **5/13** | **6/24** | **7/22** | **8/25** | **9/22** | **10/20** | **11/17** | **12/21** |
| Fluoride | | | 2.84 | | 2.56 | 2.71 | 2.86 | 3.02 | 2.84 | | |
| Depth | | | | | 42.30 | 43.60 | 44.00 | 44.70 | 45.40 | | |

Table 4

FLUORIDE MASS BALANCE CALCULATIONS

Warm Springs Creek (outflow)

27mgd x 8.34 lbs/gal x 1.07mg/l = 241lbs/day

Groundwater (outflow)

0.5mgd x 8.34lbs/gal x 2.0mg/l *1 = 8lbs/day

Guyer Pipeline (outflow)

(450 - 50*2- 100gpm*3) x 1440min/day / 1,000,000 x 8.34lbs/gal x 16mg/l = 58lbs/day

Warm Springs Creek (inflow)

24mgd x 8.34lbs/gal x 0.69mg/l = 138lbs/day

Guyer Hot Springs (inflow)

630gpm x 1440 min/day / 1,000,000 x 8.34lbs/gal x 16.2mg/l = 123lbs/day

Groundwater (inflow)

2.2mgd x 8.34lbs/day x 0.07mg/l = 1lb/day

Table 4. Continued.

Lloyd Hot Springs (inflow)

200gpm x 1440min/day / 1,000,000 x 8.34lbs/gal x 16mg/l = 38lbs/day

Greyhawk and Unknown Springs (inflow)

(1200*4 - 630 - 200gpm) x 1440min/day / 1,000,000 x 8.34lbs/gal x 16mg/l = 71lbs/day

*1 See Figure 6 for field data summary
*2 IDHW-DEQ estimate
*3 Leakage in lower one half of the pipeline
*4 CH2M Hill estimate of available geothermal water(1986)

ABBREVIATIONS

mgd = million gallons per day

cfs = cubic feet per day

ppd = pounds per day

mg/l = milligrams per litre

ppm = parts per million

lbs = pounds

gal = gallons

Table 5 Pipeline Depressurization Data. Values reported in mg/l.

| System | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Four Seasons | 9/1 | 9/2 | 9/3 | 9/4 | 9/5 | 9/6 | 9/7 | 9/8 | 9/9 | 9/11 | 9/13 | 9/15 | 9/17 | 9/19 | 9/21 | 9/23 | 9/25 | 9/27 | |
| Fluoride | 3.88 | 3.16 | 3.36 | 3.52 | 3.56 | 3.58 | 3.50 | 3.54 | 3.66 | 3.36 | 3.44 | 3.44 | 3.36 | 2.88 | 3.26 | 3.16 | 3.81 | 3.92 | |
| Chloride | 4.4 | 4.4 | 3.9 | 3.9 | 4.4 | 3.9 | 4.2 | 4.1 | 3.2 | 3.0 | 3.0 | 2.8 | 3.4 | 3.0 | 3.2 | 4.3 | 4.3 | 4.0 | |
| Calculated Cl | 4.9 | 4.4 | 4.6 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.8 | 4.6 | 4.6 | 4.6 | 4.6 | 4.2 | 4.5 | 4.4 | 4.9 | 4.9 | |
| Cl/F Ratio | 1.13 | 1.39 | 1.16 | 1.11 | 1.24 | 1.09 | 1.20 | 1.16 | 0.87 | 0.89 | 0.87 | 0.81 | 1.01 | 1.04 | 0.98 | 1.36 | 1.13 | 1.02 | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Limelight | 9/1 | 9/2 | 9/3 | 9/4 | 9/5 | 9/6 | 9/7 | 9/8 | 9/10 | 9/12 | 9/14 | 9/16 | 9/18 | 9/20 | 9/22 | 9/24 | 9/26 | 9/28 | 9/30 |
| Fluoride | 1.40 | 1.51 | 1.51 | 1.51 | 1.54 | 1.51 | 1.48 | 1.48 | 1.67 | 1.36 | 1.45 | 1.44 | 1.45 | 1.45 | 1.34 | 1.47 | 1.55 | 1.32 | 1.41 |
| Chloride | 3 | 3.5 | 2.6 | 3.3 | 3.3 | 2.2 | 3.0 | 2.6 | 2.1 | 2.3 | 2.1 | 1.8 | 2.5 | 2.3 | 2.2 | 3.2 | 2.3 | 2.5 | 3.0 |
| Calculated Cl | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.2 | 3.3 | 3.3 | 3.2 | 3.2 |
| Cl/F Ratio | 2.14 | 2.32 | 1.72 | 2.19 | 2.14 | 1.46 | 2.03 | 1.76 | 1.26 | 1.69 | 1.45 | 1.25 | 1.72 | 1.59 | 1.64 | 2.18 | 1.48 | 1.89 | 2.13 |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Ketchum #1 | | | 9/3 | 9/4 | 9/5 | 9/6 | 9/7 | 9/8 | 9/10 | 9/12 | 9/14 | 9/16 | 9/18 | 9/20 | | | | | |
| Fluoride | | | 3.56 | 3.60 | 3.66 | 3.08 | 3.38 | 3.60 | 3.82 | 3.14 | 3.48 | 3.38 | 3.20 | 3.18 | | | | | |
| Chloride | | | 4.6 | 4.6 | 5.2 | 5.2 | 4.6 | 5.2 | 3.9 | 4.3 | 4.2 | 4.5 | 4.2 | 4.0 | | | | | |
| Calculated Cl | | | 4.7 | 4.7 | 4.8 | 4.4 | 4.6 | 4.7 | 4.9 | 4.4 | 4.6 | 4.6 | 4.5 | 4.4 | | | | | |
| Cl/F Ratio | | | 1.29 | 1.28 | 1.42 | 1.69 | 1.36 | 1.44 | 1.02 | 1.37 | 1.21 | 1.33 | 1.31 | 1.26 | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Ketchum # 2 | | | | | | | | | 9/10 | 9/12 | 9/14 | 9/16 | 9/22 | 9/25 | 9/28 | 9/30 | | | |
| Fluoride | | | | | | | | | 1.50 | 4.60 | 0.36 | 0.16 | 0.27 | 0.34 | 0.21 | 0.22 | | | |
| Chloride | | | | | | | | | 1.7 | 1.9 | 1.7 | 1.5 | 1.3 | 1.0 | 1.0 | 0.7 | | | |
| Calculated Cl | | | | | | | | | 3.3 | 5.4 | 2.5 | 2.4 | 2.5 | 2.5 | 2.4 | 2.4 | | | |
| Cl/F Ratio | | | | | | | | | 1.13 | 0.41 | 4.72 | 9.38 | 4.81 | 2.94 | 4.76 | 3.18 | | | |

Table 6 Pipeline Salt Test Data. Values reported in mg/l.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Salt #1 | | | | | | | | | | | |
| Ketchum #1 | 11/10 | 11/11 | 11/12 | 11/13 | 11/14 | 11/15 | 11/16 | 11/17 | | | |
| Fluoride | 3.36 | .3.38 | 3.16 | 2.60 | 3.16 | 3.14 | 3.07 | 3.68 | | | |
| Chloride | 4.0 | 4.0 | 3.6 | 4.2 | 4.0 | 4.0 | 3.8 | 4.2 | | | |
| Calculated Cl | 4.6 | 4.6 | 4.4 | 4.0 | 4.4 | 4.4 | 4.4 | 4.8 | | | |
| Cl/F Ratio | 1.19 | 1.18 | 1.14 | 1.62 | 1.27 | 1.27 | 1.24 | 1.14 | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Limelight | 11/10 | 11/11 | 11/12 | 11/13 | 11/14 | 11/15 | 11/16 | 11/17 | | | |
| Fluoride | 3.32 | 3.66 | 3.70 | 3.78 | 3.79 | 3.80 | 3.83 | 4.03 | | | |
| Chloride | 3.8 | 4.2 | 5.5 | 4.7 | 4.7 | 4.2 | 4.7 | 4.8 | | | |
| Calculated Cl | 4.5 | 4.8 | 4.8 | 4.8 | 4.9 | 4.9 | 4.9 | 5.0 | | | |
| Cl/F Ratio | 1.14 | 1.15 | 1.49 | 1.24 | 1.24 | 1.11 | 1.23 | 1.19 | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Four Seasons | 11/10 | 11/11 | 11/12 | 11/13 | 11/14 | 11/15 | 11/16 | 11/16 | | | |
| Fluoride | 3.67 | 3.79 | 3.71 | 3.75 | 3.73 | 3.71 | 3.20 | 4.08 | | | |
| Chloride | 4.2 | 4.2 | 4.2 | 3.8 | 4.2 | 4.0 | 4.9 | 4.4 | | | |
| Calculated Cl | 4.8 | 4.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.5 | 5.0 | | | |
| Cl/F Ratio | 1.14 | 1.11 | 1.13 | 1.01 | 1.13 | 1.08 | 1.53 | 1.08 | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 405 Sage | 11/10 | 11/11 | 11/12 | 11/13 | 11/14 | 11/15 | 11/16 | | | | |
| Fluoride | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | | |
| Chloride | 2.8 | 2.6 | 2.1 | 2.1 | 2.5 | 2.1 | 2.8 | | | | |
| Cl/F Ratio | -------- | ------ | ------ | ------ | ------ | ------ | ------ | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 320 Georgina | 11/10 | 11/11 | 11/12 | 11/13 | 11/14 | 11/15 | 11/16 | | | | |
| Fluoride | 4.45 | 5.02 | 5.08 | 5.12 | 5.16 | 5.27 | 5.24 | | | | |
| Chloride | 4.9 | 5.1 | 5.3 | 5.1 | 5.5 | 6.0 | 5.1 | | | | |
| Calculated Cl | 5.3 | 5.7 | 5.7 | 5.7 | 5.8 | 5.8 | 5.8 | | | | |
| Cl/F Ratio | 1.10 | 1.02 | 1.04 | 1.00 | 1.07 | 1.14 | 0.97 | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Salt #2 | | | | | | | | | | | |
| | | | | | | | | | | | |
| Ketchum #1 | 12/15 | 12/16 | 12/17 | 12/18 | 12/19 | 12/20 | 12/21 | | | | |
| Fluoride | 3.50 | 3.10 | 3.20 | 3.30 | 3.30 | 3.40 | 3.40 | | | | |
| Chloride | 5.0 | 4.8 | 4.8 | 4.6 | 5.2 | 5.5 | 5.2 | | | | |
| Calculated Cl | 4.7 | 4.4 | 4.5 | 4.5 | 4.5 | 4.6 | 4.6 | | | | |
| Cl/F Ratio | 1.43 | 1.55 | 1.50 | 1.39 | 1.58 | 1.62 | 1.53 | | | | |
| | | | | | | | | | | | |
| Four Seasons | 12/15 | 12/16 | 12/17 | 12/18 | 12/19 | 12/20 | 12/21 | 12/22 | 12/23 | | |
| Fluoride | 4.60 | 4.30 | 4.40 | 3.90 | 4.50 | 4.50 | 4.70 | 4.60 | 4.50 | | |
| Chloride | 4.2 | 5.4 | 5.2 | 5.6 | 5.4 | 5.4 | 5.5 | 5.7 | 5.7 | | |
| Calculated Cl | 5.4 | 5.2 | 5.3 | 4.9 | 5.3 | 5.3 | 5.5 | 5.4 | 5.3 | | |
| Cl/F Ratio | 0.91 | 1.26 | 1.18 | 1.44 | 1.20 | 1.20 | 1.17 | 1.24 | 1.27 | | |

Table 6 Pipeline Salt Test Data. Values reported in mg/l.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| Salt #2 Continued | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Limelight | 12/15 | 12/16 | 12/17 | 12/18 | 12/19 | 12/20 | 12/21 | | | | |
| Fluoride | 4.20 | 3.70 | 3.70 | 3.70 | 3.40 | 3.80 | 3.20 | | | | |
| Chloride | 5.4 | 6.1 | 5.5 | 5.2 | 4.6 | 4.6 | 5.2 | | | | |
| Calculated Cl | 5.1 | 4.8 | 4.8 | 4.8 | 4.6 | 4.9 | 4.5 | | | | |
| Cl/F Ratio | 1.29 | 1.65 | 1.49 | 1.41 | 1.35 | 1.21 | 1.63 | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| No Salt | | | | | | | | | | | |
| | | | | | | | | | | | |
| Limelight | 1/22 | 1/23 | 1/24 | 1/25 | 1/26 | 1/27 | 1/28 | | | | |
| Fluoride | 1.42 | 1.46 | 1.40 | 1.48 | 1.54 | 1.48 | 1.59 | | | | |
| Chloride | 3.6 | 2.9 | 3.1 | 3.8 | 3.5 | 2.7 | 3.5 | | | | |
| Calculated Cl | 3.3 | 3.3 | 3.2 | 3.3 | 3.3 | 3.3 | 3.4 | | | | |
| Cl/F Ratio | 2.54 | 1.99 | 2.21 | 2.57 | 2.27 | 1.82 | 2.20 | | | | |
| | | | | | | | | | | | |
| Ketchum #1 | 1/22 | 1/23 | 1/24 | 1/25 | 1/26 | 1/27 | 1/28 | | | | |
| Fluoride | 3.72 | 3.89 | 3.97 | 3.91 | 3.91 | 3.48 | 3.55 | | | | |
| Chloride | 3.5 | 4.8 | 5.2 | 5.4 | 5.4 | 5.2 | 5.6 | | | | |
| Calculated Cl | 4.8 | 4.9 | 5.0 | 4.9 | 4.9 | 4.6 | 4.7 | | | | |
| Cl/F Ratio | 0.94 | 1.23 | 1.31 | 1.38 | 1.38 | 1.49 | 1.58 | | | | |
| | | | | | | | | | | | |
| Four Seasons | 1/22 | 1/23 | 1/24 | 1/25 | 1/26 | 1/27 | 1/28 | | | | |
| Fluoride | 4.79 | 5.36 | 5.49 | 5.47 | 5.44 | 5.45 | 5.47 | | | | |
| Chloride | 5.8 | 5.8 | 6.0 | 5.8 | 5.8 | 5.6 | 5.8 | | | | |
| Calculated Cl | 5.5 | 5.9 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | | | | |
| Cl/F Ratio | 1.21 | 1.08 | 1.09 | 1.06 | 1.07 | 1.03 | 1.06 | | | | |

Table 7. Summary of surface water monitoring stations.

| Station | Description | Latitude | Longitude | River Mile | Elevation | STORET# |
|---|---|---|---|---|---|---|
| S-1 | Warm Springs Creek 3.5 miles above mouth | 43 40 55 | 114 25 07 | 324.3/571.4/96.8/2.4 | 5960 | 2060198 |
| S-2 | Warm Springs Creek 1 mile above mouth | 43 41 25 | 114 23 50 | 324.3/571.4/103.5/1.4 | 5880 | 2060199 |
| S-3 | Warm Springs Creek above mouth | 43 41 03 | 114 22 38 | 324.3/571.4/97.0/.3 | 5791 | 2060203 |
| S-4 | Big Wood River 0.5 mi above Warm Springs creek confluence | 43 41 17 | 114 22 20 | 324.3/571.4/97.4 | 5800 | 2060190 |
| S-5 | Big Wood River above Trail Ck. confluence | 43 40 15 | 114 21 58 | 324.3/571.4/96.6 | 5760 | 2060204 |
| S-6 | Trail Creek above Ketchum | 43 41 04 | 114 21 24 | 324.3/571.4/96.2/1.0 | 5960 | 2060205 |
| S-7 | Trail Creek above mouth | 43 40 27 | 114 21 40 | 324.3/571.4/96.2/.7 | 5760 | 2060206 |
| S-8 | Big Wood River at Highway 93 | 43 39 20 | 114 20 55 | 324.3/571.4/94.4 | 5706 | 2060191 |

Table 8. Summary of water quality data for station S-1, Warm Springs Creek 3.5 miles above mouth, 1987

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 224 | 252 | 162 | 146 | 193 | 199 | 239 | 251 | 222 | 193 | 163 | 11 | 204.00 | 146-252 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 250 | 250 | 169 | 155 | 198 | 177 | 236 | 254 | 298 | 260 | 271 | 11 | 228.91 | 155-298 |
| Hardness (mg/l as CaCO3) | | | | | | 92 | 108 | 103 | 103 | 107 | 107 | 6 | 103.33 | 92-108 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 92 | 105 | 109 | 105 | 107 | 104 | 6 | 103.67 | 92-109 |
| Calcium (mg/l) | 30 | 33.7 | 20 | 22 | 28 | 28 | 33 | 32.4 | 34 | 33 | 33 | 11 | 29.74 | 20-34 |
| Potassium (mg/l) | | | | | | | | 1 | 0.6 | 0.9 | 0.9 | 4 | 0.85 | 0.6-1 |
| Chloride (mg/l) | | | | | | 1.9 | 2.44 | 1.7 | 1.3 | 1.8 | 1.8 | 6 | 1.82 | 1.3-2.4 |
| Fluoride (mg/l) | 0.76 | 0.83 | 0.58 | 0.42 | 0.56 | 0.71 | 0.98 | 0.86 | 0.91 | 0.91 | 1.1 | 11 | 0.78 | 0.42-1.1 |
| Silica (mg/l) | 17 | 17 | 17 | 15 | 17.3 | 18.1 | 19 | 19 | 17 | 17 | 17 | 11 | 17.31 | 15-19 |
| pH (field- SU) | 9.1 | 8.4 | 8.1 | 8.1 | 7.7 | 8.1 | 8.1 | 8.4 | 9.4 | 8 | 8 | 11 | 8.31 | 7.7-9.4 |
| Filterable Residue (mg/l) | 131 | 148 | 112 | 88 | 115 | 116 | 147 | 142 | 137 | 138 | 143 | 11 | 128.82 | 88-148 |
| Boron (mg/l) | | | | | | | | 82 | 91 | 77 | 102 | 4 | 88.00 | 77-102 |
| Flow (cfs) | 28.02 | 21.8 | 72 | 91 | 48 | 45 | 24 | 20.2 | 18.7 | 18.5 | 23.2 | 11 | 37.31 | 18.5-91 |
| Temperature (oC) | 1 | 8 | 9.5 | 9 | 13 | 11 | 11.5 | 11 | 3 | 0.1 | 1 | 11 | 7.10 | 0.1-13 |
| Dissolved Oxygen (mg/l) | 8.5 | 7.6 | 9.4 | 9.5 | 8.3 | 8.4 | 9.3 | 8.1 | 9.4 | 11 | 10.4 | 11 | 9.08 | 7.6-11 |

Table 9. Summary of water quality data for station S-2, Warm Springs Creek 1 mile above mouth, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 234 | 269 | 172 | 160 | 213 | 223 | 254 | 265 | 232 | 203 | 174 | 11 | 218.09 | 160-269 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 270 | 265 | 188 | 170 | 220 | 238 | 261 | 267 | 349 | 234 | 271 | 11 | 248.45 | 170-271 |
| Hardness (mg/l as CaCO3) | | | | | | 88 | 104 | 105 | 104 | 104 | 110 | 6 | 102.50 | 88-110 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 97 | 113 | 113 | 111 | 112 | 108 | 6 | 109.00 | 97-113 |
| Calcium (mg/l) | 30 | 33.7 | 21 | 23 | 30 | 29 | 34 | 35.5 | 34 | 33 | 32 | 11 | 30.47 | 21-35.5 |
| Potassium (mg/l) | | | | | | | | 1.1 | 0.8 | 1 | 0.9 | 4 | 0.95 | 0.8-1.1 |
| Chloride (mg/l) | | | | | | 1.7 | 2.44 | 1.7 | 2.1 | 2.1 | 2.6 | 6 | 2.11 | 1.7-2.6 |
| Fluoride (mg/l) | 1.19 | 1.45 | 0.75 | 0.62 | 0.91 | 1.05 | 1.45 | 1.59 | 1.48 | 1.57 | 1.8 | 11 | 1.26 | 0.62-1.8 |
| Silica (mg/l) | 20 | 19 | 17 | 16 | 19 | 19.3 | 21 | 20 | 18 | 20 | 18 | 11 | 18.85 | 16-21 |
| pH (field- SU) | 9 | 8.5 | 7.8 | 8.1 | 7.8 | 8.2 | 8.1 | 8.15 | 8.4 | 8 | 7.9 | 11 | 8.18 | 7.8-9.0 |
| Filterable Residue (mg/l) | 142 | 153 | 117 | 97 | 121 | 125 | 156 | 150 | 148 | 147 | 149 | 11 | 136.82 | 97-156 |
| Boron (mg/l) | | | | | | | | 73 | 104 | 75 | 80 | 4 | 83.00 | 73-104 |
| Flow (cfs) | 36.8 | 31 | 90 | 100 | 54 | 49 | 33 | 23.8 | 29.6 | 24.6 | 31.1 | 11 | 45.72 | 23.8-100 |
| Temperature (oC) | 4 | 10.5 | 10.5 | 11 | 13 | 12.5 | 13.5 | 14.8 | 6 | 8 | 2 | 11 | 9.62 | 2-14.8 |
| Dissolved Oxygen (mg/l) | 7.7 | 7.3 | 8.3 | 9.3 | 7.2 | 8.4 | 9.2 | 8.8 | 8.5 | 9.8 | 10.1 | 11 | 8.60 | 7.2-10.1 |

Table 10. Summary of water quality data for station S-3, Warm Springs creek above its confluence with the Big Wood River, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 241 | 274 | 172 | 155 | 206 | 223 | 257 | 272 | 232 | 203 | 174 | 11 | 219.00 | 155-274 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 280 | 263 | 185 | 175 | 213 | 235 | 268 | 274 | 349 | 249 | 271 | 11 | 251.09 | 175-349 |
| Hardness (mg/l as CaCO3) | | | | | | 92 | 108 | 107 | 106 | 104 | 108 | 6 | 104.17 | 92-108 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 98 | 119 | 112 | 111 | 112 | 107 | 6 | 109.83 | 98-119 |
| Calcium (mg/l) | 32.5 | | 21 | 23 | 29 | 29 | 34 | 33.4 | 34 | 32 | 33 | 10 | 30.09 | 21-34 |
| Potassium (mg/l) | | | | | | | | 1.1 | 0.8 | 1 | 0.9 | 4 | 0.95 | 0.8-1.1 |
| Chloride (mg/l) | | | | | | 1.9 | 3.4 | 1.5 | 2.8 | 2.7 | 2 | 6 | 2.38 | 1.5-3.4 |
| Fluoride (mg/l) | 1.26 | 1.41 | 0.78 | 0.61 | 0.87 | 1.09 | 1.52 | 1.58 | 1.42 | 1.65 | 1.9 | 11 | 1.28 | 0.61-1.9 |
| Silica (mg/l) | 20 | 20 | 18 | 16 | 0.754 | 19.4 | 21 | 19 | 18 | 20 | 18 | 11 | 17.29 | 16-21 |
| pH (field- SU) | 8.6 | 8.4 | 8.24 | 8.16 | 8.2 | 8 | 8.1 | 8.1 | 7.8 | 7.8 | 8 | 11 | 8.13 | 7.8-8.6 |
| Filterable Residue (mg/l) | 146 | 172 | 116 | 94 | 123 | 121 | 151 | 151 | 145 | 151 | 153 | 11 | 138.45 | 94-172 |
| Boron (mg/l) | | | | | | | | 60 | 87 | 91 | 90 | 4 | 82.00 | 60-91 |
| Flow (cfs) | 30.6 | 29.6 | 79 | 94 | 48 | 44 | 28 | 27.9 | 23.9 | 21.8 | 24.9 | 11 | 41.06 | 21.8-94 |
| Temperature (oC) | 4.5 | 12 | 11 | 11.5 | 13 | 13 | 13.5 | 14.8 | 6 | 4 | 2 | 11 | 9.57 | 2-14.8 |
| Dissolved Oxygen (mg/l) | 8 | 6.9 | 8.3 | 8.9 | 8.8 | 9.4 | 8.2 | 7.6 | 8.4 | 10.2 | 10 | 11 | 8.61 | 6.9-10.2 |

Table 11. Summary of water quality data for station S-4, Big Wood River 0.5 miles above Warm Springs Creek confluence, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 212 | 247 | 181 | 136 | 186 | 199 | 220 | 237 | 216 | 190 | 162 | 11 | 198.73 | 136-247 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 250 | 234 | 190 | 151 | 195 | 201 | 225 | 240 | 236 | 246 | 244 | 11 | 219.27 | 151-250 |
| Hardness (mg/l as CaCO3) | | | | | | 92 | 106 | 108 | 106 | 108 | 105 | 6 | 104.17 | 92-108 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 98 | 102 | 113 | 102 | 104 | 106 | 6 | 104.17 | 98-113 |
| Calcium (mg/l) | 32.5 | 35.2 | 26 | 24 | 29 | 29 | 34 | 34.8 | 35 | 34 | 36 | 11 | 31.77 | 24-36 |
| Potassium (mg/l) | | | | | | | | 0.4 | 0.3 | 0.4 | 0.4 | 4 | 0.38 | 0.3-0.4 |
| Chloride (mg/l) | | | | | | 0.6 | 0.56 | 1.5 | 1 | 1.3 | 1.4 | 6 | 1.06 | 0.56-1.5 |
| Fluoride (mg/l) | 0.07 | 0.23 | 0.17 | 0.21 | 0.18 | 0.19 | 0.2 | 0.2 | 0.26 | 0.24 | 0.3 | 11 | 0.20 | 0.07-0.3 |
| Silica (mg/l) | 10 | 10 | 10 | 8.5 | 0.399 | 10.2 | 11 | 9 | 10 | 10 | 9 | 11 | 8.92 | 8.5-11 |
| pH (field- SU) | 9 | 8.3 | 7.8 | 8.1 | 7.8 | 7.7 | 7.8 | 8.1 | 7.6 | 8.3 | 7.6 | 11 | 8.01 | 7.6-9.0 |
| Filterable Residue (mg/l) | 127 | 132 | 111 | 83 | 102 | 102 | 128 | 124 | 123 | 124 | 134 | 11 | 117.27 | 83-134 |
| Boron (mg/l) | | | | | | | | 70 | 66 | 115 | 65 | 4 | 79.00 | 65-115 |
| Flow (cfs) | 64.5 | 83.9 | 208 | 496 | 213 | 203 | 91 | 73.7 | 62.5 | 49.5 | 65.5 | 11 | 146.42 | 49.5-496 |
| Temperature (oC) | 1.5 | 8 | 10 | 8.2 | 10.5 | 11 | 12 | 12 | 4 | 1.5 | 0.5 | 11 | 7.20 | 0.5-12 |
| Dissolved Oxygen (mg/l) | 8.6 | 7.8 | 9.2 | 9.3 | 7 | 9.5 | 8.4 | 7.4 | 9.4 | 10.2 | 11 | 11 | 8.89 | 7.4-11 |

Table 12. Summary of water quality data for station S-5, Big Wood River above Trail Creek confluence, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 218 | 257 | 184 | 148 | 202 | 212 | 246 | 269 | 260 | 198 | 172 | 11 | 215.09 | 148-269 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 280 | 268 | 201 | 184 | 229 | 239 | 272 | 279 | 269 | 302 | 262 | 11 | 253.18 | 184-302 |
| Hardness (mg/l as CaCO3) | | | | | | 100 | 122 | 114 | 122 | 112 | 108 | 6 | 113.00 | 100-122 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 107 | 113 | 116 | 117 | 106 | 111 | 6 | 111.67 | 106-117 |
| Calcium (mg/l) | 32.5 | 33.2 | 25 | 24 | 31 | 31 | 37 | 38.7 | 39 | 36 | 36 | 11 | 33.04 | 24-39 |
| Potassium (mg/l) | | | | | | | | 0.8 | 0.9 | 0.7 | 0.6 | 4 | 0.75 | 0.6-0.9 |
| Chloride (mg/l) | | | | | | 1.1 | 1.5 | 1.1 | 1.9 | 1.3 | 1.8 | 6 | 1.45 | 1.1-1.9 |
| Fluoride (mg/l) | 0.58 | 0.5 | 0.35 | 0.25 | 0.33 | 0.42 | 0.48 | 0.25 | 0.52 | 0.59 | 0.63 | 11 | 0.45 | 0.25-0.63 |
| Silica (mg/l) | 15 | 12 | 13 | 9.5 | 11.2 | 11.9 | 13 | 13 | 12 | 12 | 12 | 11 | 12.24 | 11.2-15 |
| pH (field- SU) | 9.2 | 8.2 | 8.1 | 8.1 | 7.6 | 7.8 | 7.8 | 8.1 | 7.5 | 8.3 | 8 | 11 | 8.06 | 7.5-9.2 |
| Filterable Residue (mg/l) | 133 | 142 | 118 | 87 | 111 | 116 | 145 | 143 | 147 | 139 | 146 | 11 | 129.73 | 87-147 |
| Boron (mg/l) | | | | | | | | 47 | 73 | 185 | 61 | 4 | 91.50 | 47-185 |
| Flow (cfs) | 86.3 | 116.4 | 315 | 559 | 289 | 247 | 138 | 109.1 | 99.9 | 84.2 | 112.2 | 11 | 196.01 | 84.2-559 |
| Temperature (oC) | 2.5 | 8 | 11 | 11.2 | 14 | 13.5 | 14 | 14 | 9 | 4 | 2 | 11 | 9.38 | 2-14 |
| Dissolved Oxygen (mg/l) | 7.8 | 7.2 | 9 | 8.8 | 10.6 | 8.7 | 8 | 7.3 | 8.6 | 9 | 10.2 | 11 | 8.65 | 7.2-10.6 |

Table 13. Summary of water quality data for station S-6, Trail Creek above Ketchum, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 416 | 485 | 459 | 293 | 390 | 414 | 458 | 489 | 465 | 354 | 314 | 11 | 412.45 | 293-489 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 475 | 490 | 501 | 338 | 406 | 424 | 474 | 505 | 431 | 488 | 497 | 11 | 457.18 | 338-505 |
| Hardness (mg/l as CaCO3) | | | | | | 188 | 232 | 223 | 249 | 236 | 200 | 6 | 221.33 | 188-249 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 173 | 189 | 196 | 199 | 95 | 197 | 6 | 174.83 | 95-199 |
| Calcium (mg/l) | 52.5 | 58.5 | 55 | 38 | 49 | 50 | 61 | 60.4 | 62 | 56 | 58 | 11 | 54.58 | 38-62 |
| Potassium (mg/l) | | | | | | | | 1.9 | 1.9 | 1.5 | 1.4 | 4 | 1.68 | 1.4-1.9 |
| Chloride (mg/l) | | | | | | 1.1 | 3.4 | 0.9 | 2.3 | 2.1 | 1.7 | 6 | 1.92 | 0.9-3.4 |
| Fluoride (mg/l) | 0.03 | 0.16 | 0.22 | 0.17 | 0.18 | 0.22 | 0.17 | 0.16 | 0.18 | 0.25 | 0.26 | 11 | 0.18 | 0.03-0.26 |
| Silica (mg/l) | 7 | 6 | 7.7 | 6.5 | 8.25 | 8.6 | 11 | 10 | 9 | 7 | 7 | 11 | 8.00 | 6-11 |
| pH (field- SU) | 9.1 | 8.4 | 8.1 | 8.25 | 7.7 | 7.9 | 8.4 | 8.34 | 7.8 | 8.1 | 8.1 | 11 | 8.20 | 7.7-9.1 |
| Filterable Residue (mg/l) | 250 | 257 | 264 | 165 | 219 | 215 | 267 | 268 | 263 | 252 | 264 | 11 | 244.00 | 165-268 |
| Boron (mg/l) | | | | | | | | 92 | 84 | 104 | 131 | 4 | 102.75 | 84-131 |
| Flow (cfs) | 12.5 | 13.8 | 18 | 89 | 32 | 32 | 4 | 2.5 | 7.5 | 9.2 | | 10 | 22.05 | 2.5-89 |
| Temperature (oC) | 0.1 | | 7.5 | 8.2 | 12 | 11 | 14.5 | 13 | 7 | 3.5 | 0.1 | 10 | 7.69 | 0.1-14.5 |
| Dissolved Oxygen (mg/l) | 8.5 | | 9.9 | 10 | 11 | 8.7 | 9.7 | 9.7 | 8.8 | 11.2 | 11.4 | 10 | 9.89 | 8.5-11.4 |

Table 14. Summary of water quality data for station S-7, Trail Creek above its confluence with the Big Wood River, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 409 | 487 | 459 | 297 | 404 | 421 | 416 | 452 | 454 | 348 | 328 | 11 | 406.82 | 297-487 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 520 | 460 | 428 | 342 | 418 | 416 | 458 | 452 | 475 | 378 | 506 | 11 | 441.18 | 342-506 |
| Hardness (mg/l as CaCO3) | | | | | | 192 | 212 | 199 | 226 | 168 | 198 | 6 | 199.17 | 168-226 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 177 | 177 | 174 | 190 | 156 | 200 | 6 | 179.00 | 156-200 |
| Calcium (mg/l) | 52.5 | | 55 | 38 | 50 | 51 | 50 | 49.5 | 58 | 40 | 58 | 10 | 50.20 | 38-58 |
| Potassium (mg/l) | | | | | | | | 1.9 | 1.9 | 1.5 | 1.6 | 4 | 1.73 | 1.5-1.9 |
| Chloride (mg/l) | | | | | | 1.7 | 1.5 | 1.5 | 2.5 | 4.6 | 2.8 | 6 | 2.43 | 1.5-4.6 |
| Fluoride (mg/l) | 0.29 | 0.45 | 0.41 | 0.19 | 0.23 | 0.28 | 0.79 | 1.18 | 0.83 | 0.52 | 0.5 | 11 | 0.52 | 0.19-1.18 |
| Silica (mg/l) | 10 | 7 | 8 | 6 | 8.5 | 8.6 | 13 | 14 | 12 | 27 | | 10 | 11.41 | 6-27 |
| pH (field- SU) | 8.8 | 8.5 | 8.3 | 8.3 | 8.2 | 7.9 | 8.3 | 8.4 | 8.2 | 8.8 | 8.1 | 11 | 8.35 | 7.9-8.8 |
| Filterable Residue (mg/l) | 259 | 263 | 268 | 163 | 227 | 228 | 243 | 322 | 259 | 269 | 275 | 11 | 252.36 | 163-322 |
| Boron (mg/l) | | | | | | | | 108 | 119 | 119 | 112 | 4 | 114.50 | 108-119 |
| Flow (cfs) | 14.5 | 13.96 | 18 | 108 | 33 | 30 | 5 | 2.9 | 2.1 | 9.2 | 4.9 | 11 | 21.96 | 2.1-108 |
| Temperature (oC) | 0.1 | 6 | 10 | 9 | 13 | 11 | 14 | 15.8 | 10 | 7 | 0.1 | 11 | 8.73 | 0.1-15.8 |
| Dissolved Oxygen (mg/l) | 8.8 | 8 | 9.4 | 9.4 | 7.7 | 9.4 | 10.2 | 9.1 | 8.7 | 9.6 | 11.1 | 11 | 9.22 | 7.7-11.1 |

Table 15. Summary of water quality data for station S-8, Big Wood River at Highway 93, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Conductance (lab-umhos/cm at 25oC) | 246 | 290 | 210 | 184 | 239 | 249 | 269 | 289 | 279 | 230 | 185 | 11 | 242.73 | 184-289 |
| Sp. Conductance (Field-umhos/cm at 25oC) | 270 | 300 | 218 | 207 | 247 | 257 | 251 | 298 | 280 | 316 | 292 | 11 | 266.91 | 207-316 |
| Hardness (mg/l as CaCO3) | | | | | | 116 | 136 | 124 | 132 | 130 | 118 | 6 | 126.00 | 116-136 |
| T. Alkalinity (mg/l as CaCO3) | | | | | | 98 | 119 | 120 | 120 | 121 | 120 | 6 | 116.33 | 98-121 |
| Calcium (mg/l) | 35 | | 28 | 28 | 34 | 34 | 38 | 38.2 | 37 | 39 | 38 | 10 | 34.92 | 28-39 |
| Potassium (mg/l) | | | | | | | | 1.1 | 1 | 0.9 | 0.9 | 4 | 0.98 | 0.9-1.1 |
| Chloride (mg/l) | | | | | | 1.9 | 2.4 | 1.7 | 2.8 | 2.7 | 3.3 | 6 | 2.47 | 1.7-3.3 |
| Fluoride (mg/l) | 0.63 | 0.56 | 0.43 | 0.78 | 0.33 | 0.43 | 0.56 | 0.64 | 0.54 | 0.82 | 0.54 | 11 | 0.57 | 0.33-0.82 |
| Silica (mg/l) | 15 | 12 | 13 | 9 | 12.4 | 13.1 | 14 | 13 | 12 | 12 | 12 | 11 | 12.50 | 9-15 |
| pH (field- SU) | 9 | 8.2 | 7.8 | 8.1 | 7.7 | 7.6 | 8.2 | 8.2 | 7.9 | 8 | 8.2 | 11 | 8.08 | 7.6-9 |
| Filterable Residue (mg/l) | 152 | 164 | 136 | 102 | 131 | 137 | 167 | 155 | 159 | 165 | 161 | 11 | 148.09 | 102-165 |
| Boron (mg/l) | | | | | | | | 66 | 94 | 147 | 101 | 4 | 102.00 | 66-147 |
| Flow (cfs) | 96.8 | 128.2 | 338 | 650 | 315 | 283 | 132 | 126.1 | 102.4 | 110.5 | 104.7 | 11 | 216.97 | 102.4-650 |
| Temperature (oC) | 3 | 8 | 12 | 11.2 | 14.5 | 14.1 | 15 | 14.2 | 8.5 | 6 | 2 | 11 | 9.86 | 2-15 |
| Dissolved Oxygen (mg/l) | 7.8 | 6.9 | 9 | 8.7 | 11.5 | 8.3 | 7.8 | 7.5 | 8.8 | 8 | 10.5 | 11 | 8.62 | 6.9-11.5 |

Table 16. Summary of water quality data for Guyer Hot Springs pipeline outfalls "A" and "B" into Trail Creek, 1987.

| | 2/25 | 3/26 | 4/22 | 5/13 | 6/24 | 7/22 | 8/25 | 9/22 | 10/20 | 11/17 | 12/21 | n | mean | range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OUTFALL 'A'** | | | | | | | | | | | | | | |
| Sp. Conductance (Field-umhos/cm at 25oC) | | 435 | 422 | 414 | 442 | 446 | 440 | 447 | 383 | 282 | 294 | 10 | 400.50 | 282-447 |
| Hardness (mg/l as CaCO3) | | | | | | 48 | | 31 | 14 | 42 | 10 | 5 | 29.00 | 10-48 |
| Alkalinity (mg/l as CaCO3) | | | | | | 90 | | 82 | 74 | 92 | 75 | 5 | 82.60 | 74-92 |
| Calcium (mg/l) | | 3.7 | 2.3 | 3.2 | 12 | 13.4 | 24.4 | 8.27 | 3.7 | 11 | 3.7 | 10 | 8.60 | 2.3-24.4 |
| Potassium (mg/l) | | | | | | | | 1.7 | 1.7 | 1.8 | 2 | 4 | 1.80 | 1.7-2.0 |
| Chloride (mg/l) | | | | 3.8 | | 14.8 | | 11.2 | 11 | 9.2 | 12.2 | 6 | 10.40 | 3.8-14.8 |
| Fluoride (mg/l) | | 14.7 | 16.8 | 14.3 | 12 | 12.9 | 9.63 | 13.8 | 14.4 | 16.5 | 15.4 | 10 | 14.04 | 9.63-16.8 |
| Silica (mg/l) | | 77 | 81 | 80 | 74 | 66 | 52 | 66 | 72 | 65 | 76 | 9 | 70.90 | 52-81 |
| Filterable Residue (mg/l) | | 292 | 308 | | 278 | 292 | 285 | | 299 | 296 | 301 | 8 | 294.00 | 278-308 |
| Boron (mg/l) | | | | | | | | 223 | 322 | 263 | 278 | 4 | 271.50 | 223-322 |
| Flow (cfs) | 0.138 | 0.33 | 0.408 | 0.369 | 0.61 | 1.11 | 0.35 | 0.48 | 0.32 | 0.23 | 0.175 | 11 | 0.41 | .138-1.11 |
| **Outfall "B"** | | | | | | | | | | | | | | |
| Sp. Conductance (Field-umhos/cm at 25oC) | | 439 | 425 | 415 | 434 | 446 | 440 | 447 | 392 | 282 | 294 | 10 | 401.40 | 282-447 |
| Hardness (mg/l as CaCO3) | | | | | | 52 | | 30 | 12 | 48 | 12 | 5 | 30.80 | 12-52 |
| Alkalinity (mg/l as CaCO3) | | | | | | 88 | | 82 | 73 | 98 | 74 | 5 | 83.00 | 73-98 |
| Calcium (mg/l) | | 3.7 | 2.4 | 3.3 | 12 | 12.8 | 24.4 | 8.36 | 3.9 | 13 | 3.8 | 10 | 8.80 | 2.4-24.4 |
| Potassium (mg/l) | | | | | | | | 1.7 | 1.7 | 1.9 | 2 | 4 | 1.80 | 1.7-2.0 |
| Chloride (mg/l) | | | | 8.6 | | 14.6 | | 10.8 | 11 | 8.3 | 10.5 | 6 | 10.60 | 8.3-14.6 |
| Fluoride (mg/l) | | 15.3 | 17 | 15.6 | 12 | 13.6 | 10.2 | 14 | 15.3 | 14.1 | 16.3 | 10 | 14.30 | 10.2-17.0 |
| Silica (mg/l) | | 77 | 81 | 77 | 68 | 70 | 52 | 68 | 72 | 62 | | 8 | 69.67 | 52-81 |
| Filterable Residue (mg/l) | | 295 | 306 | | 286 | 295 | 283 | | 298 | 294 | 306 | 8 | 295.00 | 283-306 |
| Boron (mg/l) | | | | | | | | | 316 | 285 | 321 | 3 | 307.00 | 285-321 |
| Flow (cfs) | 0.014 | 0.025 | 0.004 | 0.001 | 0.007 | 0.013 | 0.035 | 0.0011 | | 0.004 | 0.0035 | 10 | 0.01 | .0011-0.03 |

Table 17. Average percent recovery for fluoride spiked samples from Guyer Hot Springs and Warm Springs Creek.

**Guyer Hot Springs**

| Sample | Percent Recovery |
|---|---|
| 1 | 83 |
| 2 | 87.4 |
| 3 | 88 |
| 4 | 88.6 |
| 5 | 89.2 |
| Ave. % recovery | 87.2 + 3.1 |

**Warm Springs Creek**

| Sample | Percent Recovery |
|---|---|
| 1 | 84 |
| 2 | 131 |
| 3 | 121 |
| 4 | 116 |
| 5 | 84 |
| Ave. % recovery | 107.2 + 27.0 |

Table 18. Precision of duplicate samples from Warm Springs Creek, 1987.

| STORET # | Parameter | n | Average Relative Range (%) |
|---|---|---|---|
| 00951 | Fluoride | 22 | 10 |
| 00900 | Hardness | 12 | 3.4 |
| 00410 | Total Alkalinity | 12 | 1.12 |
| 70300 | Filterable Residue | 22 | 2.16 |
| 00095 | Specific Conductance | 22 | 1.07 |
| 00956 | Silica | 22 | 0.8 |
| 00940 | Chloride | 12 | 26.2 |
| 00916 | Calcium | 22 | 1.4 |

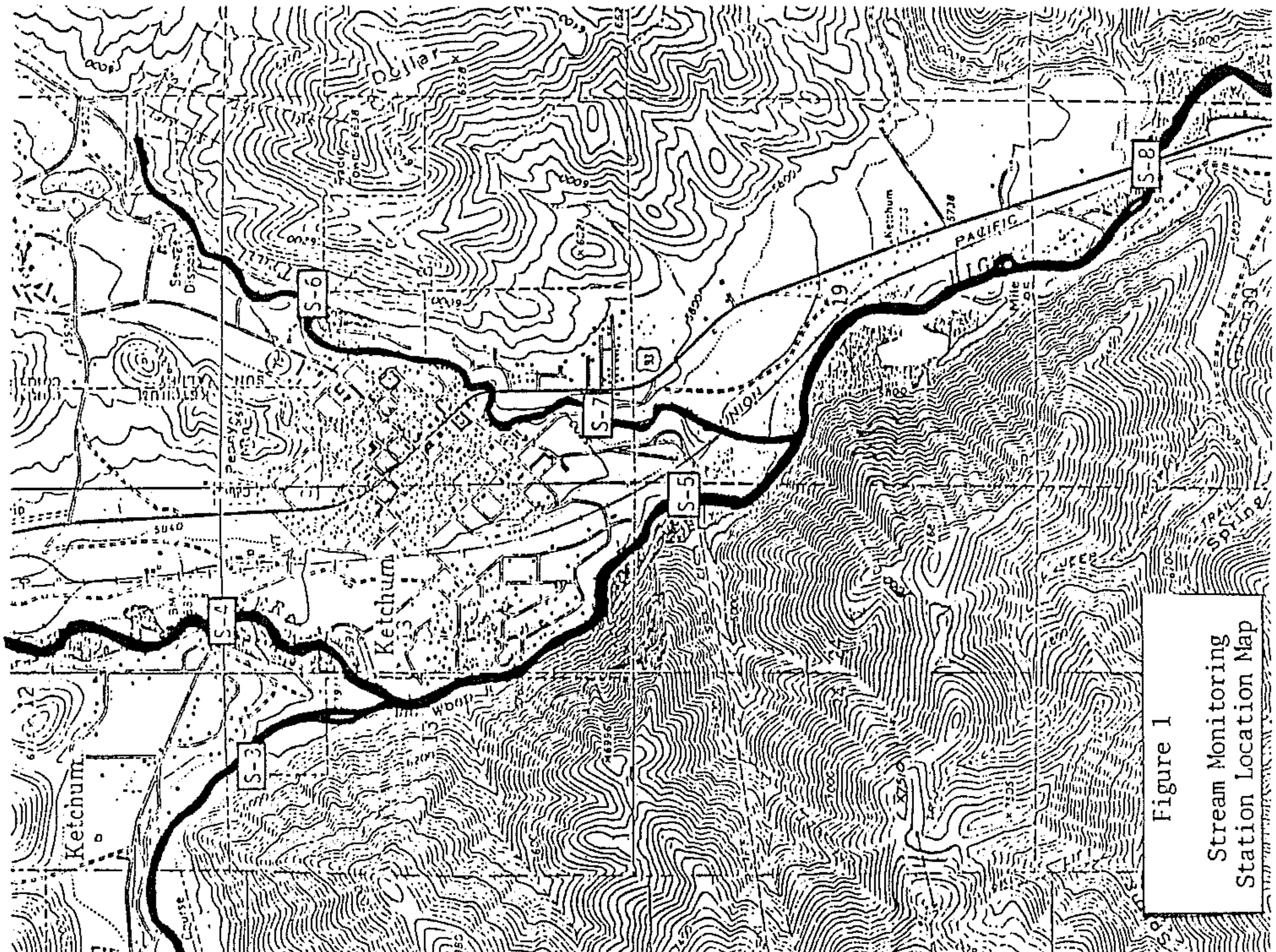



Figure 1

Stream Monitoring
Station Location Map

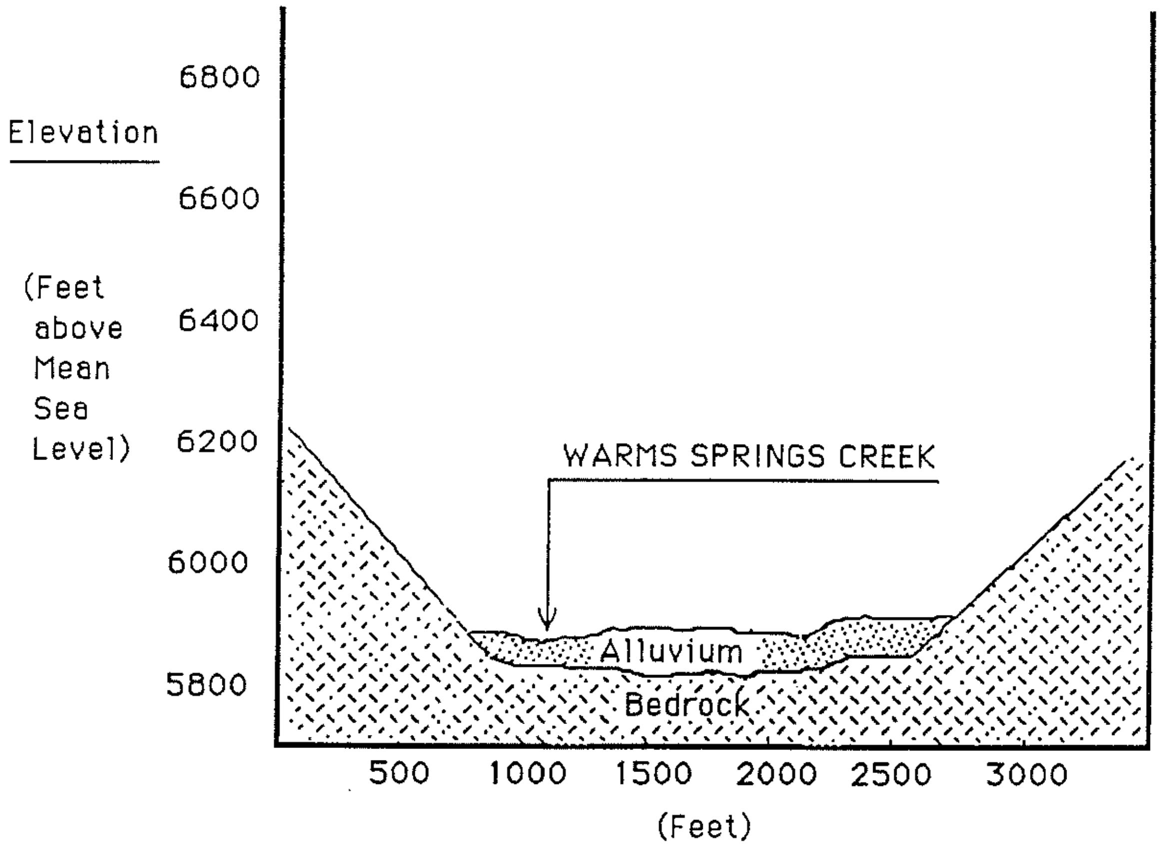
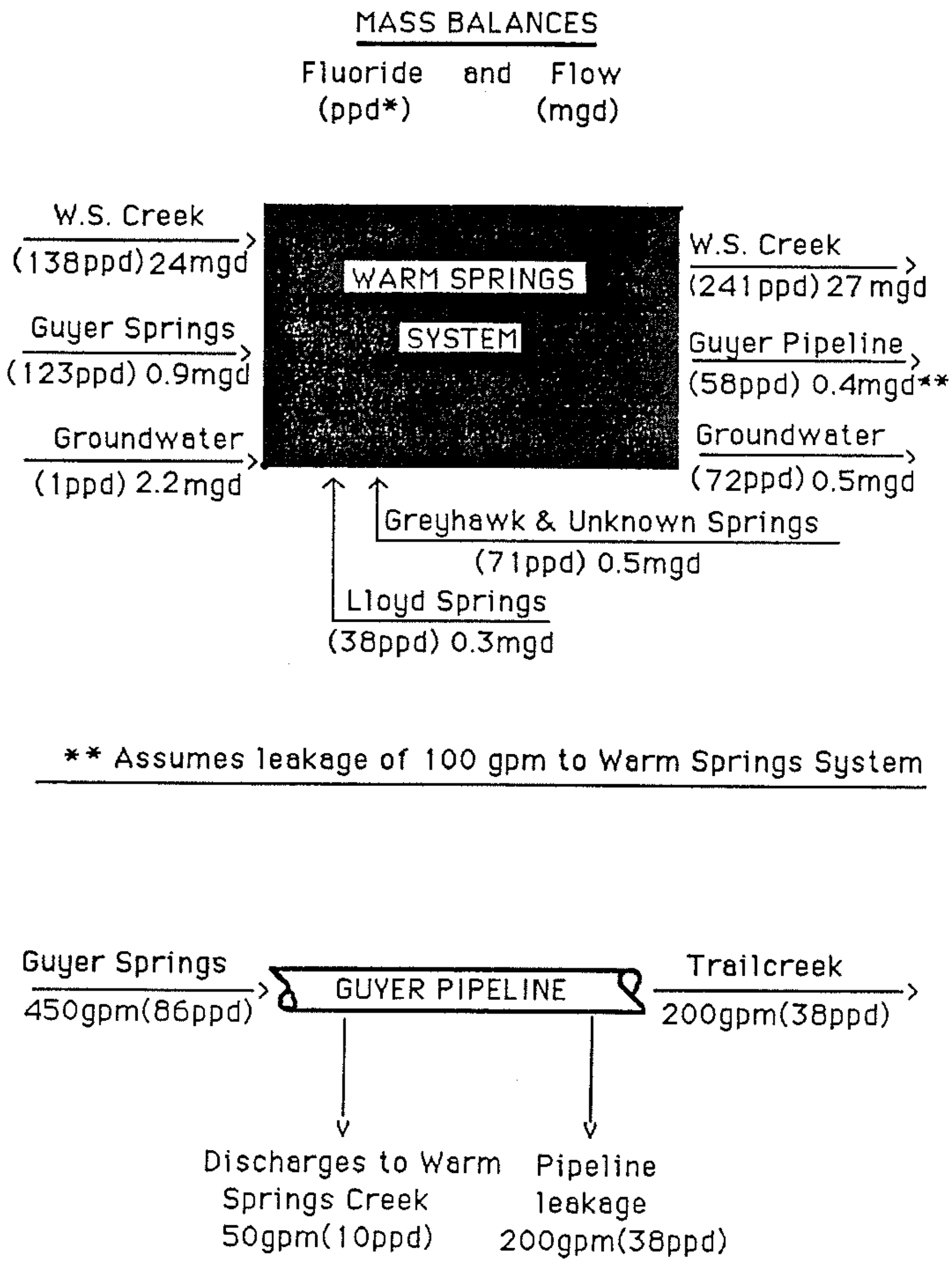



Figure 2. Geologic cross-section of the Warm Springs Creek Valley.




* ppd - pounds per day
mgd - million gallons per day
gpm - gallons per minute

Figure 3. Mass balances for fluoride and flow, Warm Springs Creek Valley aquifer system, 1987.

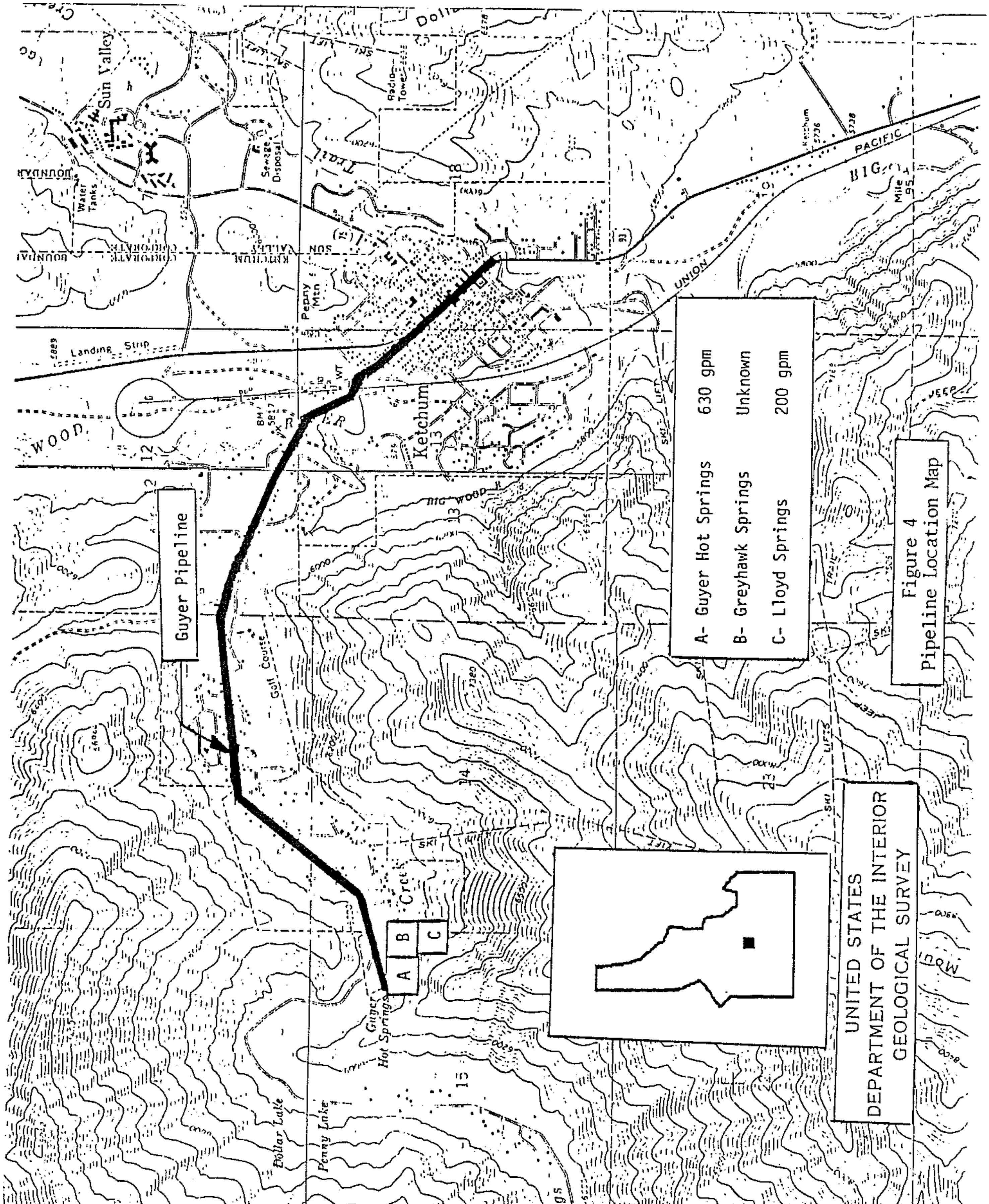
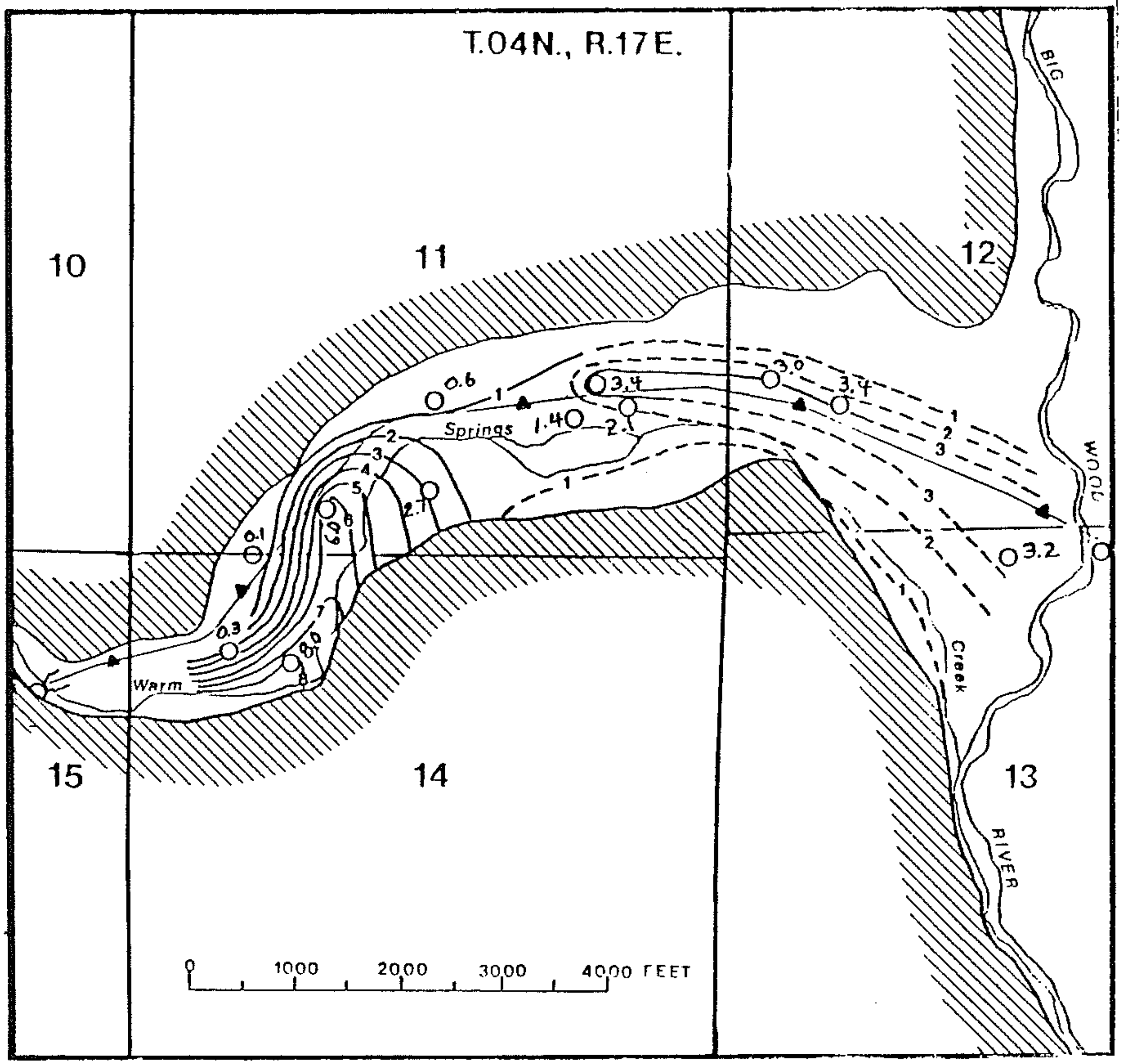
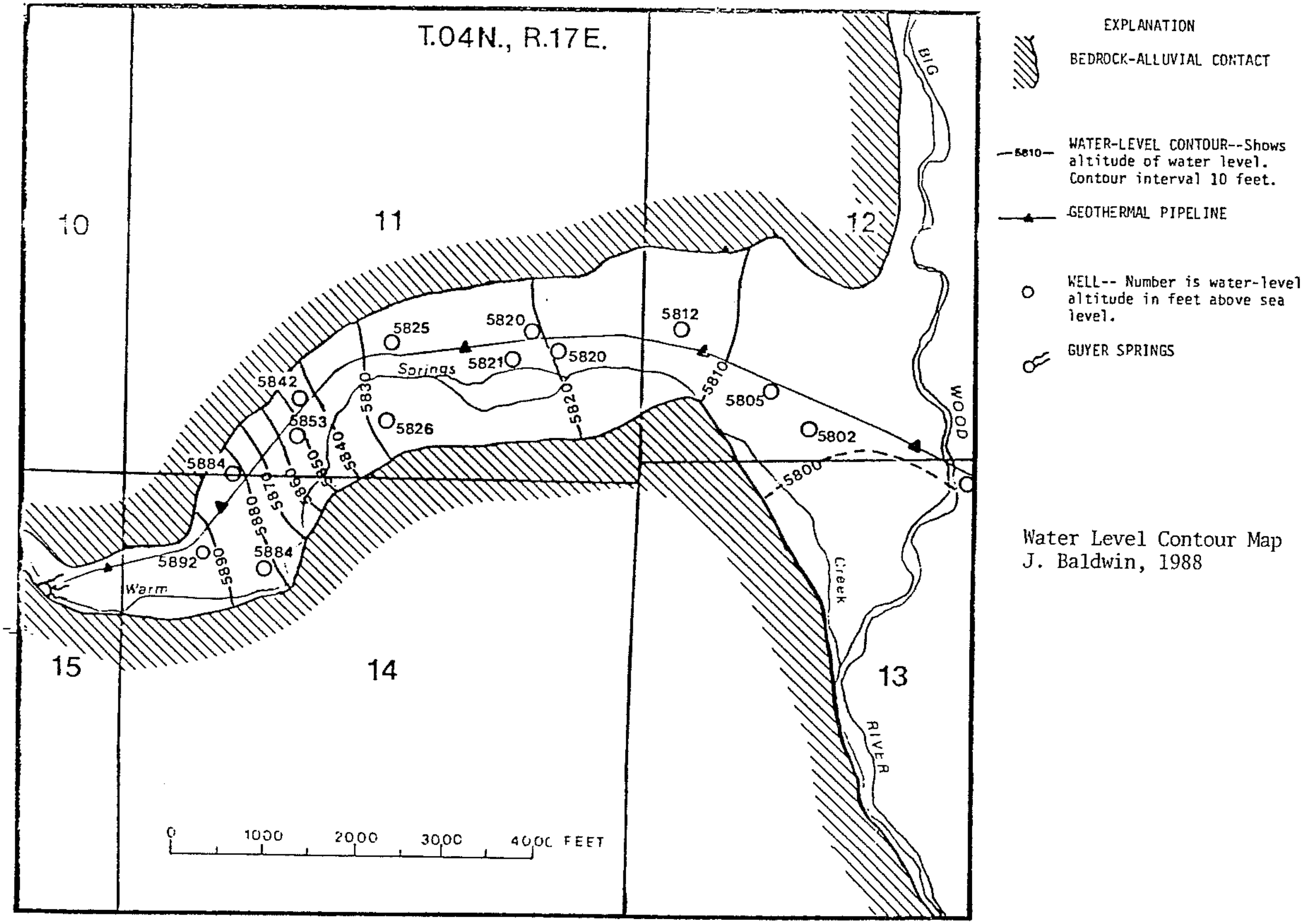



Figure 4
Pipeline Location Map




Groundwater Fluoride Concentration Contour Map, July, 1987 Data
J. Baldwin, 1988

Figure 5




Water Level Contour Map
J. Baldwin, 1988

Figure 6

Figure 7.
Fluoride concentration (mg/l) vs. depth of groundwater (ft)
in selected wells.

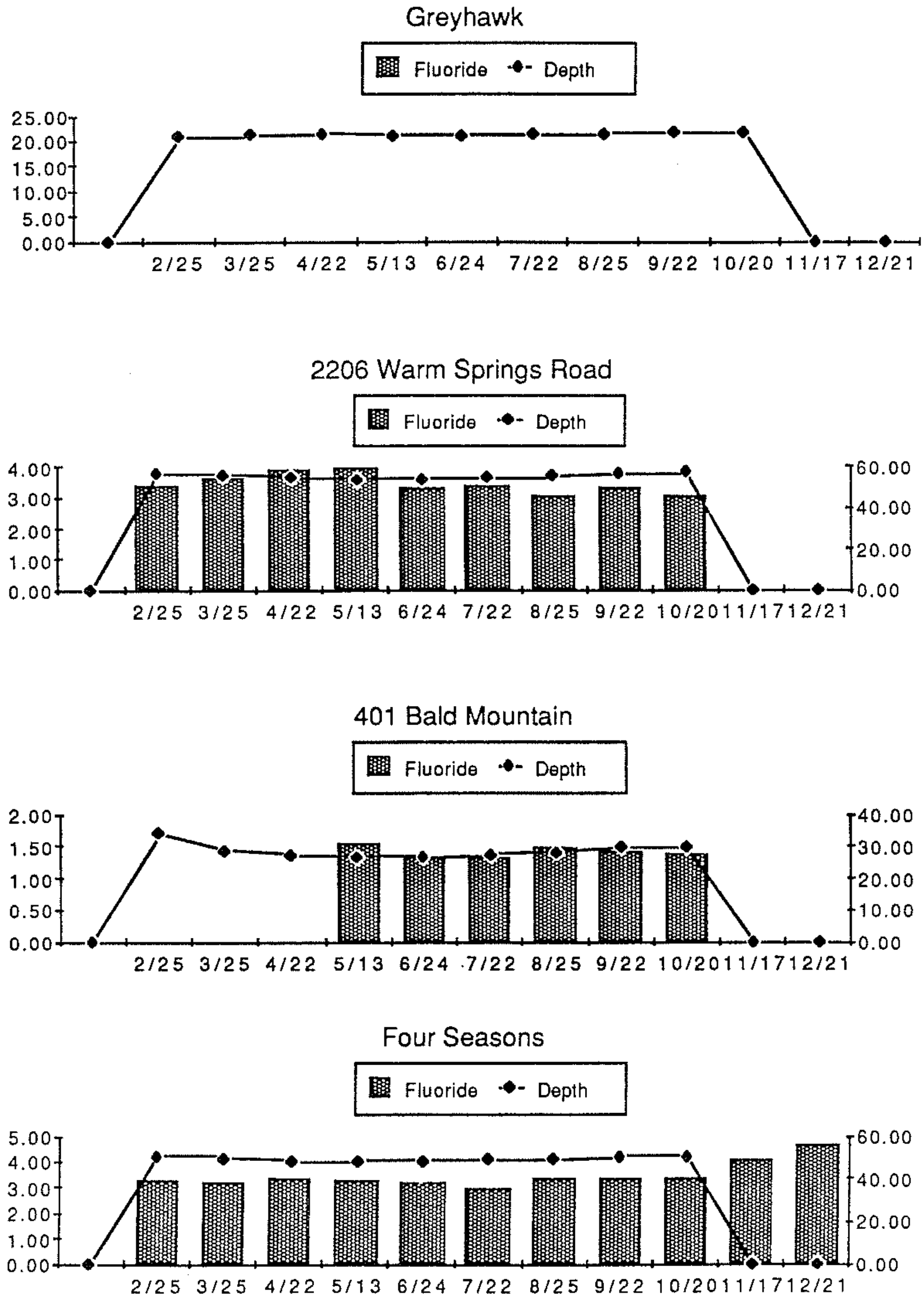
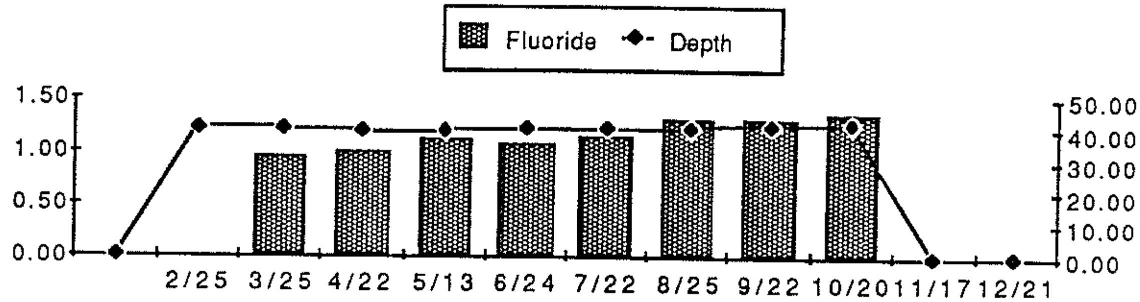
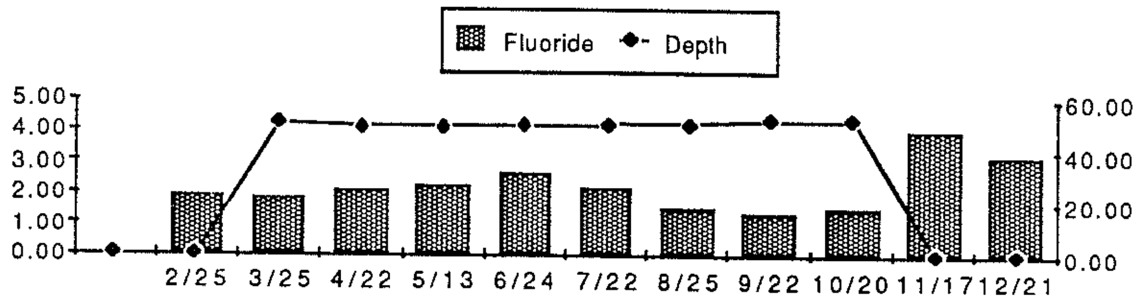


Figure 7. Continued

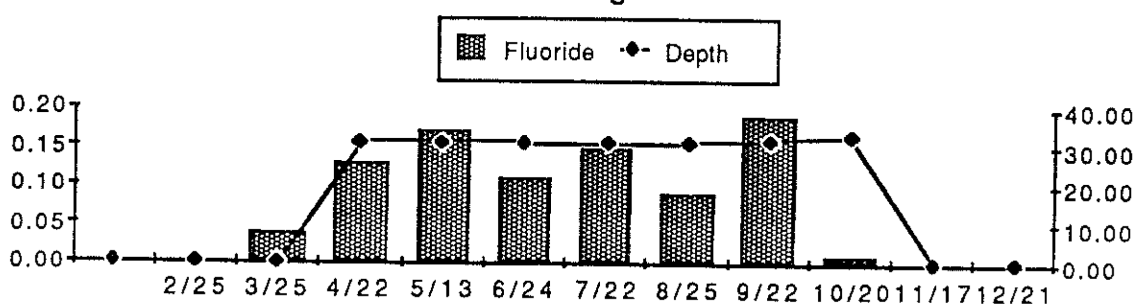
410 Riverrun




Limelight




405 Sage




320 Georgina

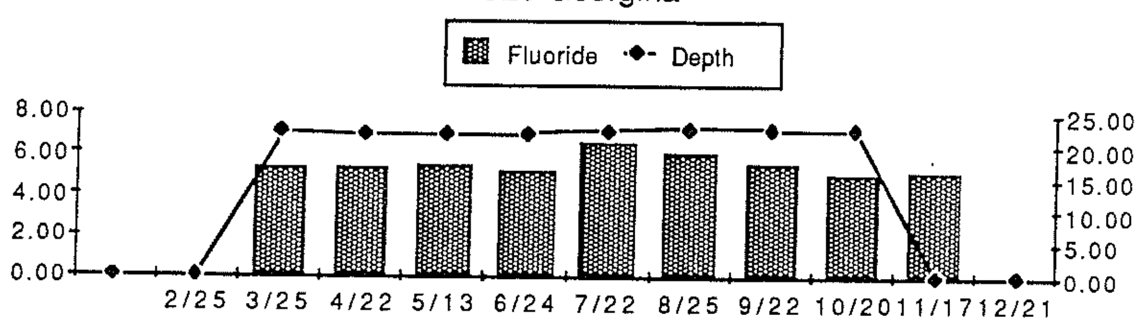
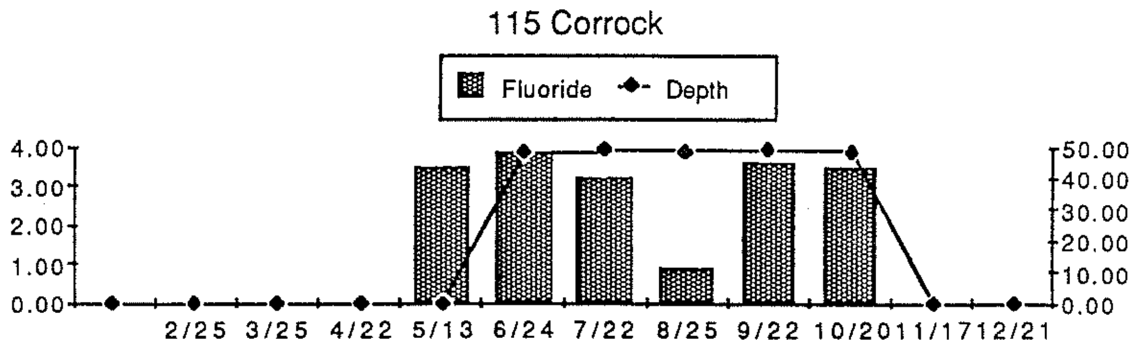
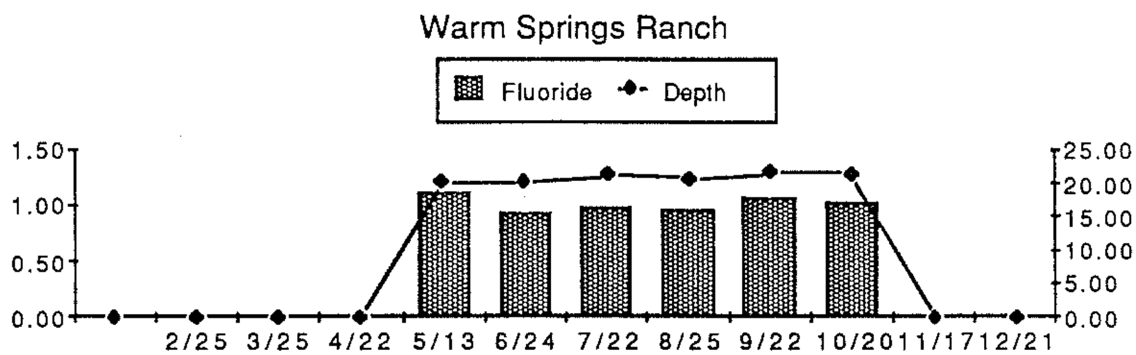
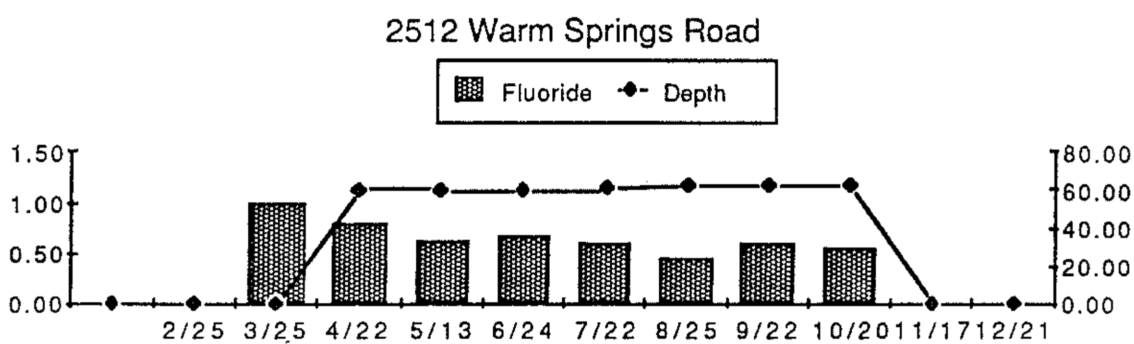


Figure 7. Continued



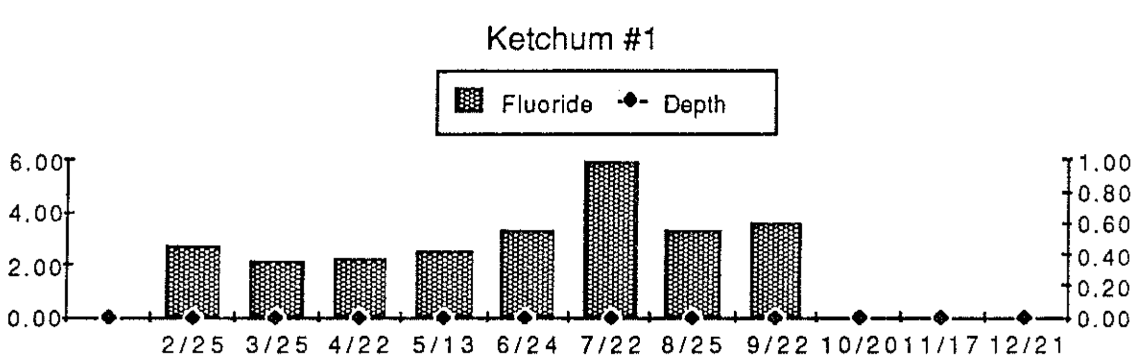
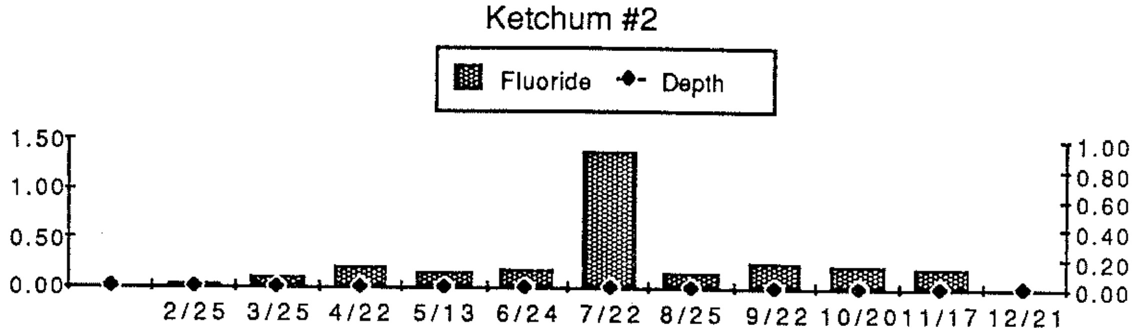
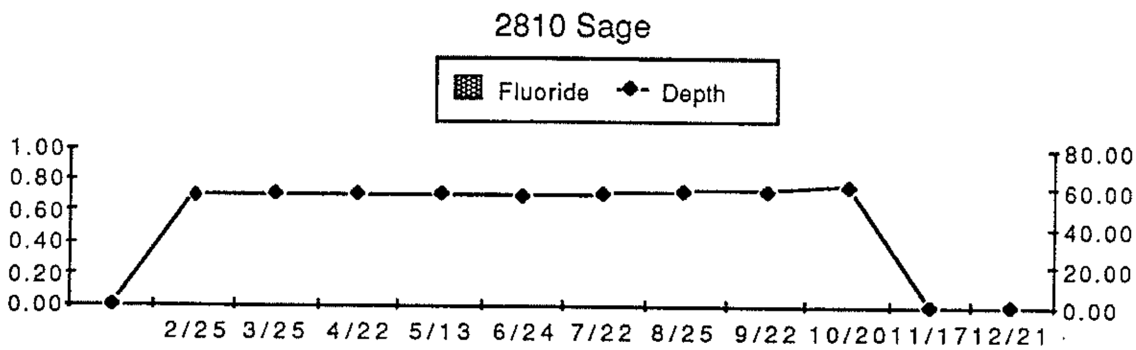



Figure 7. Continued



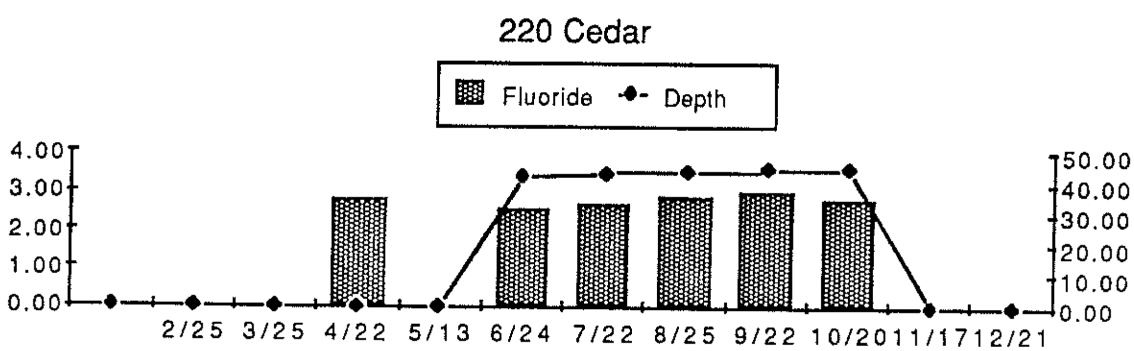
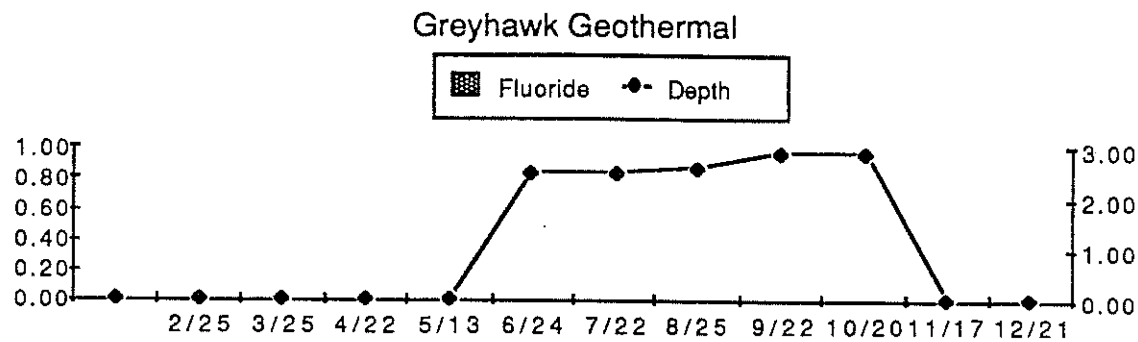



Figure 7. Continued



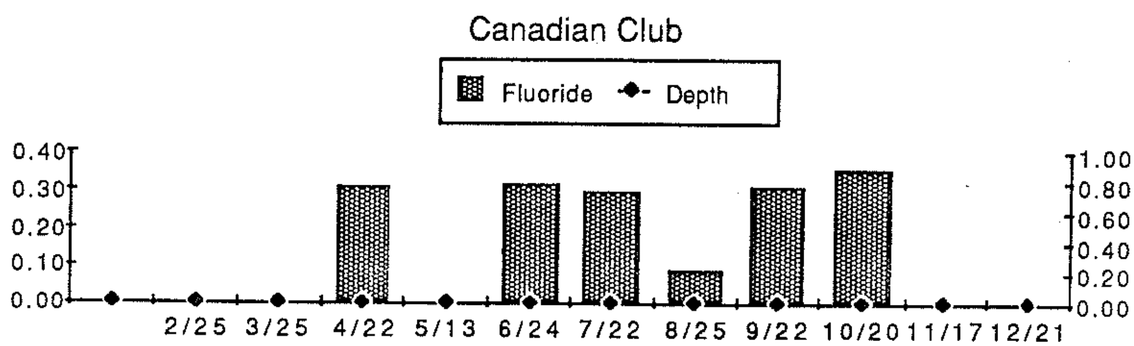
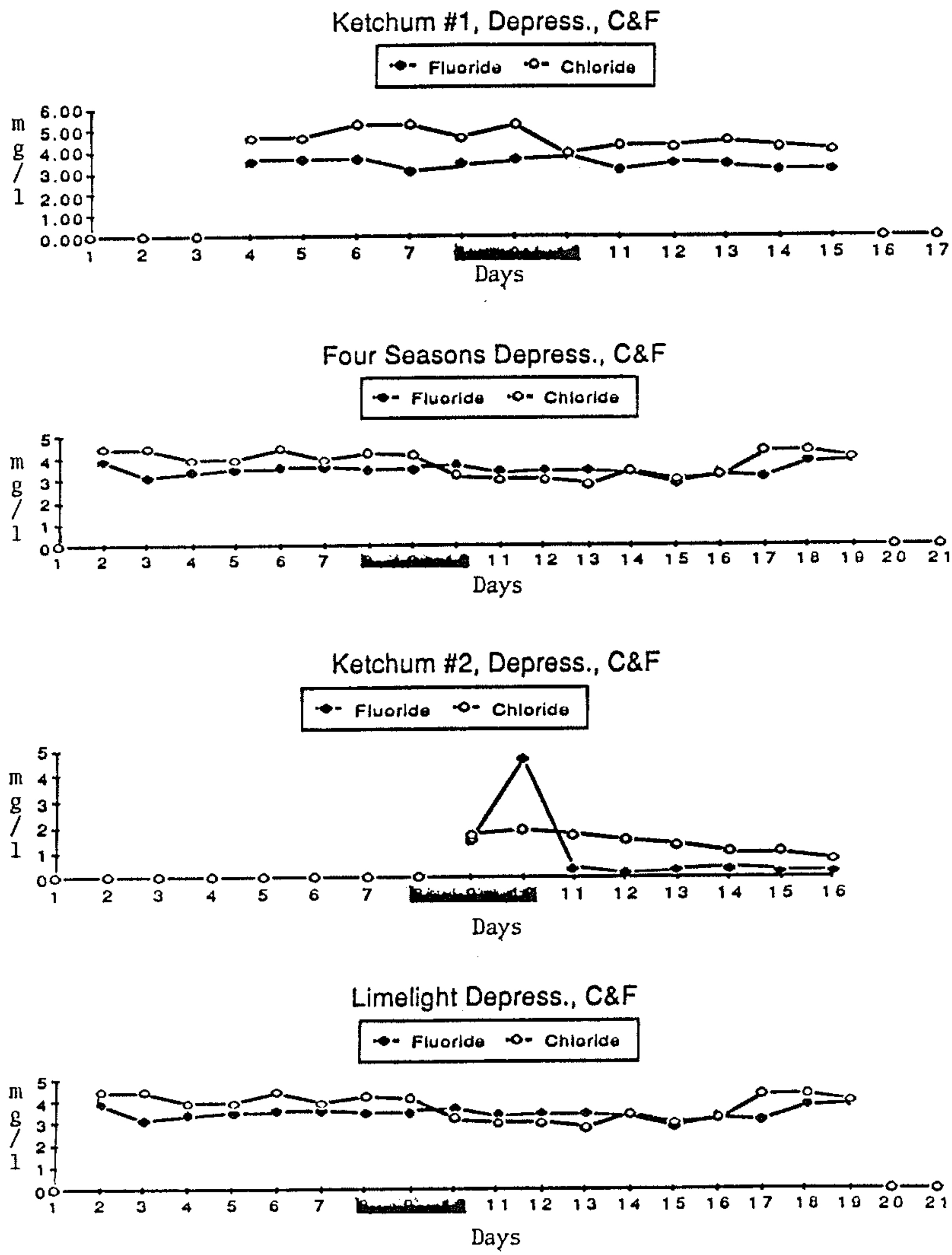



Figure 8 Depressurization Test.
Fluoride & chloride concentrations (mg/l) vs. days.




Denotes depressurization period

Figure 9 Salt #1 Tracing Test.
Fluoride & chloride concentrations (mg/l) vs. date.

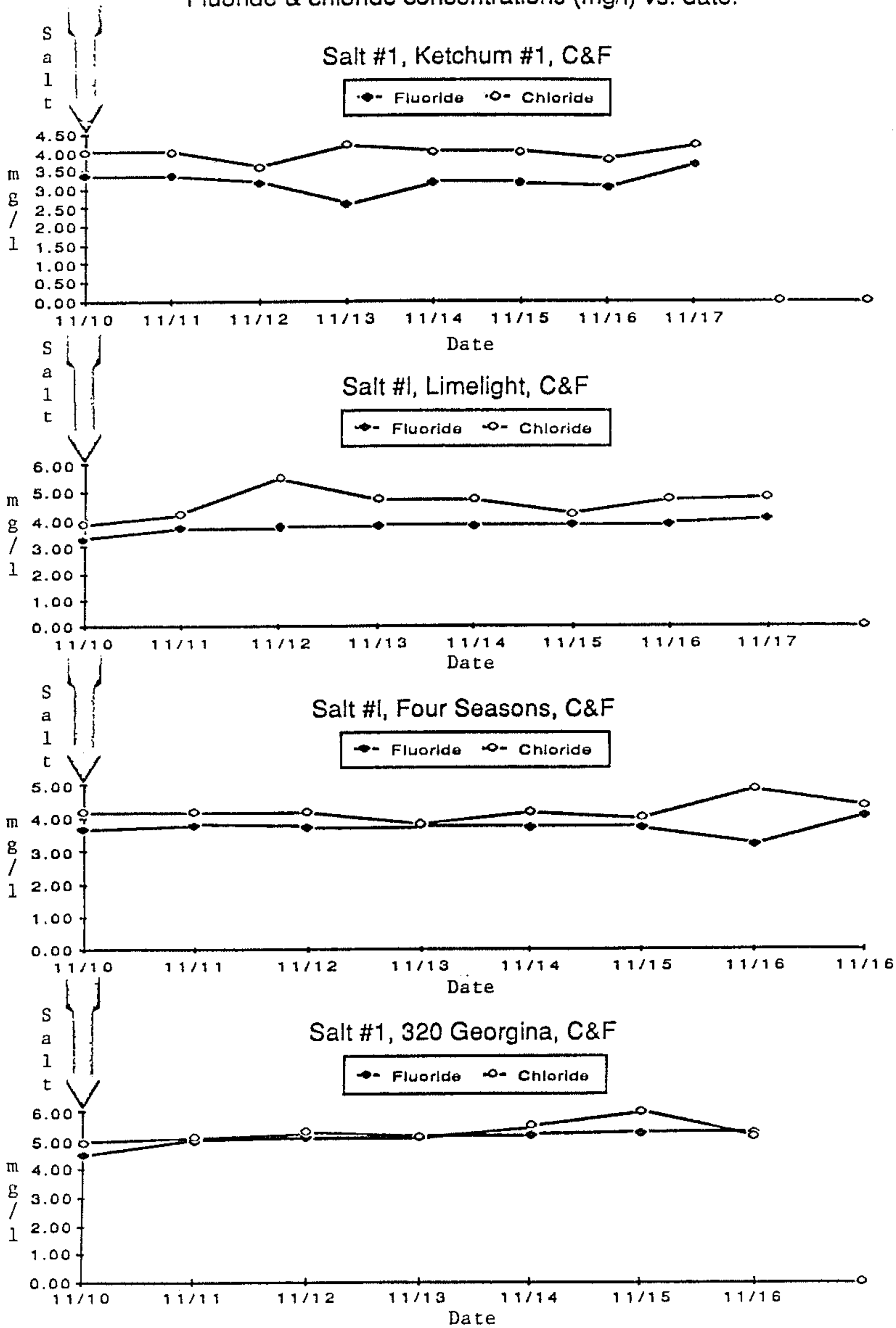


Figure 10 Salt #2 Tracing Test.
Fluoride & chloride concentrations (mg/l) vs. date.

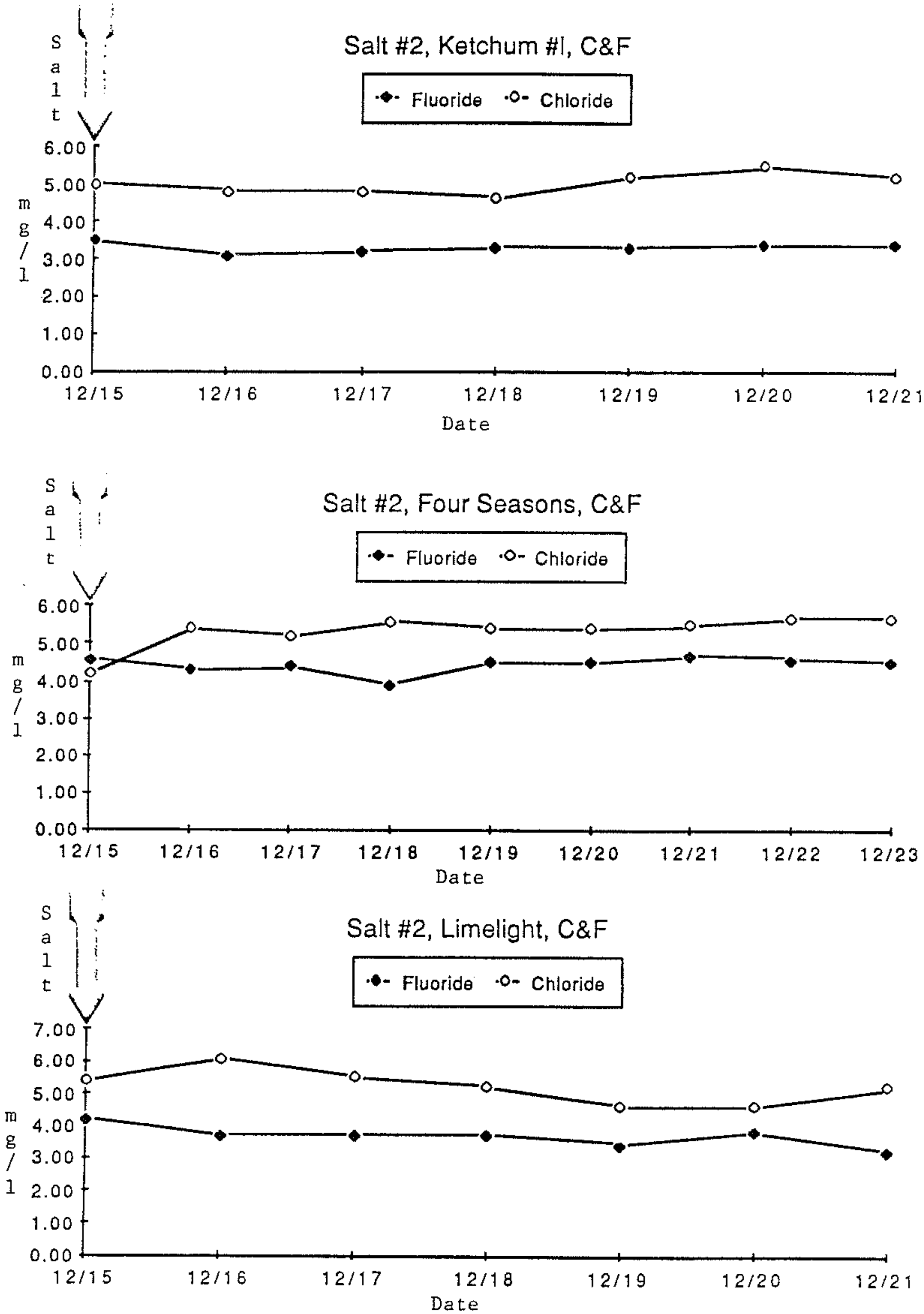
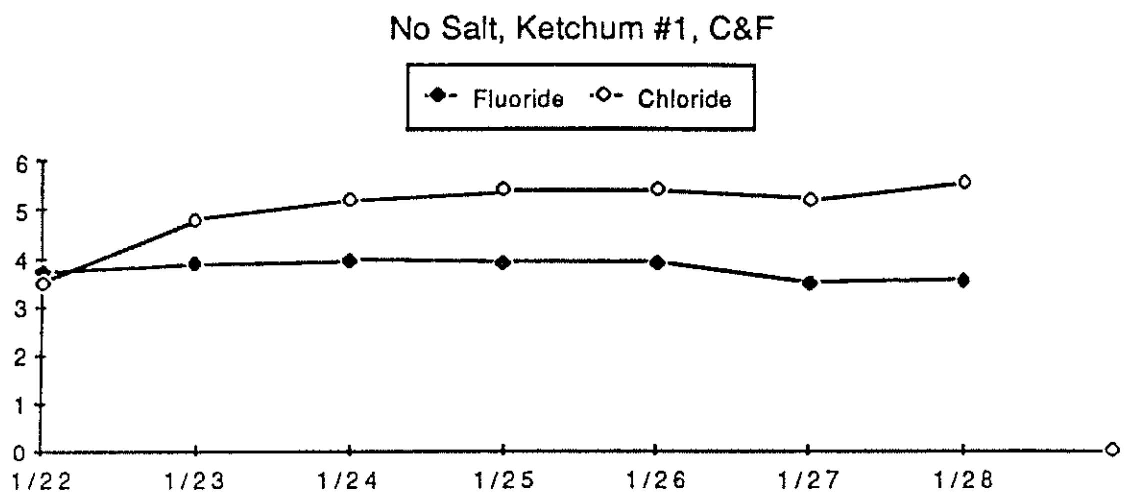
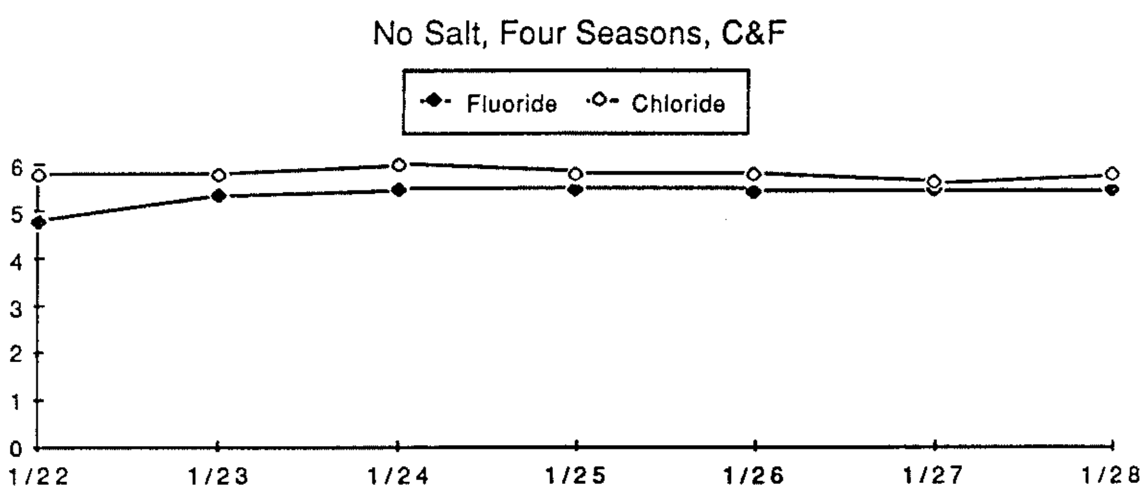


Figure 11 No Salt Test.
Fluoride & chloride concentrations (mg/l) vs. date.



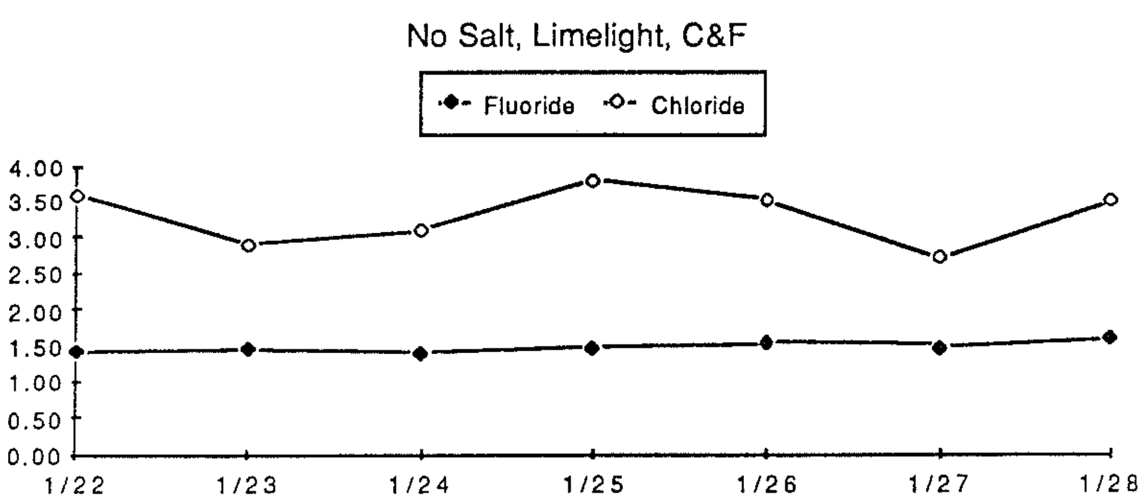



Figure 12 Salt #1 Tracing Test.
Calculated chloride concentrations (mg/l) & field values vs. days.

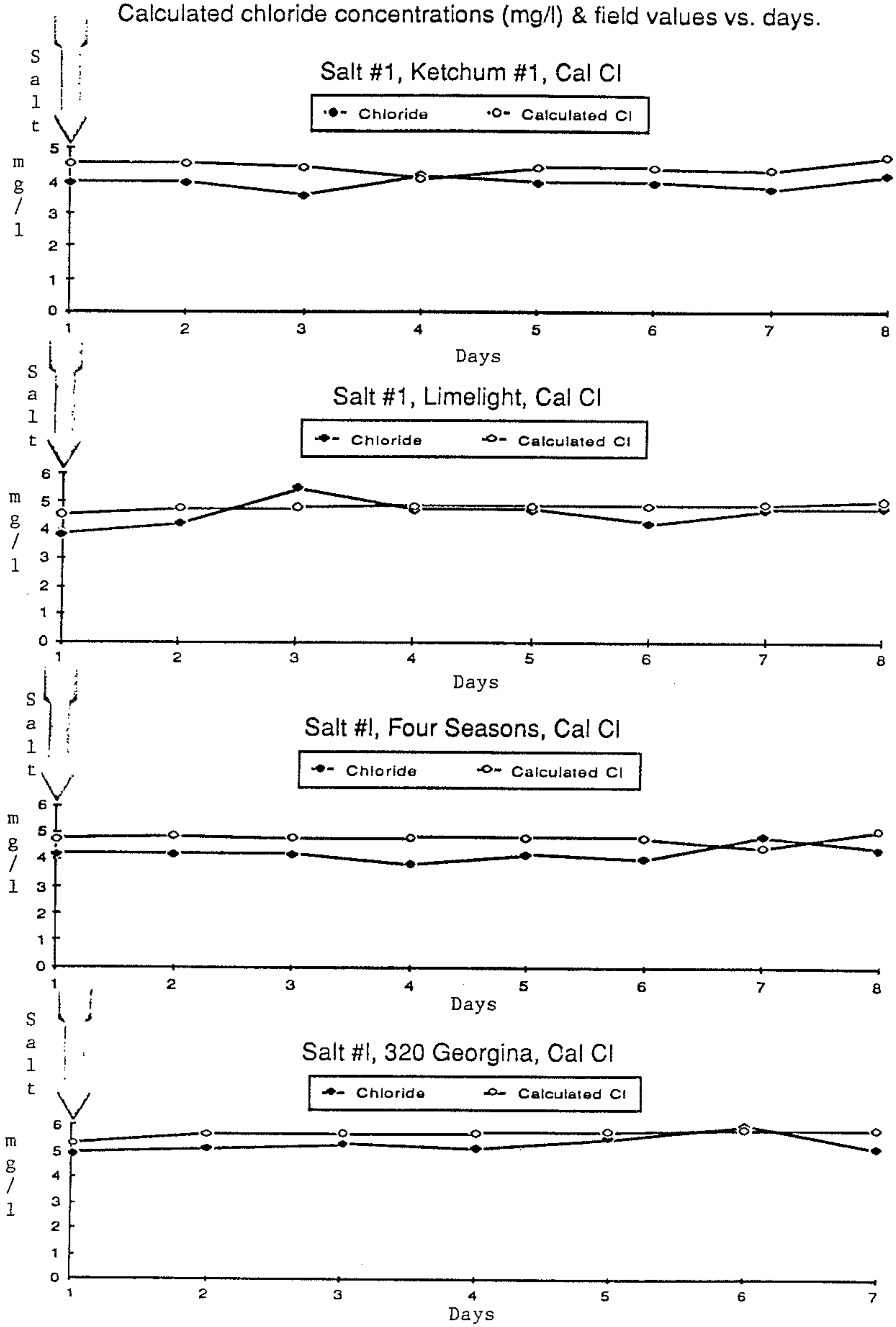


Figure 13 Salt #2 Tracing Tests.
Calculated chloride concentrations & field values (mg/l) vs. days.

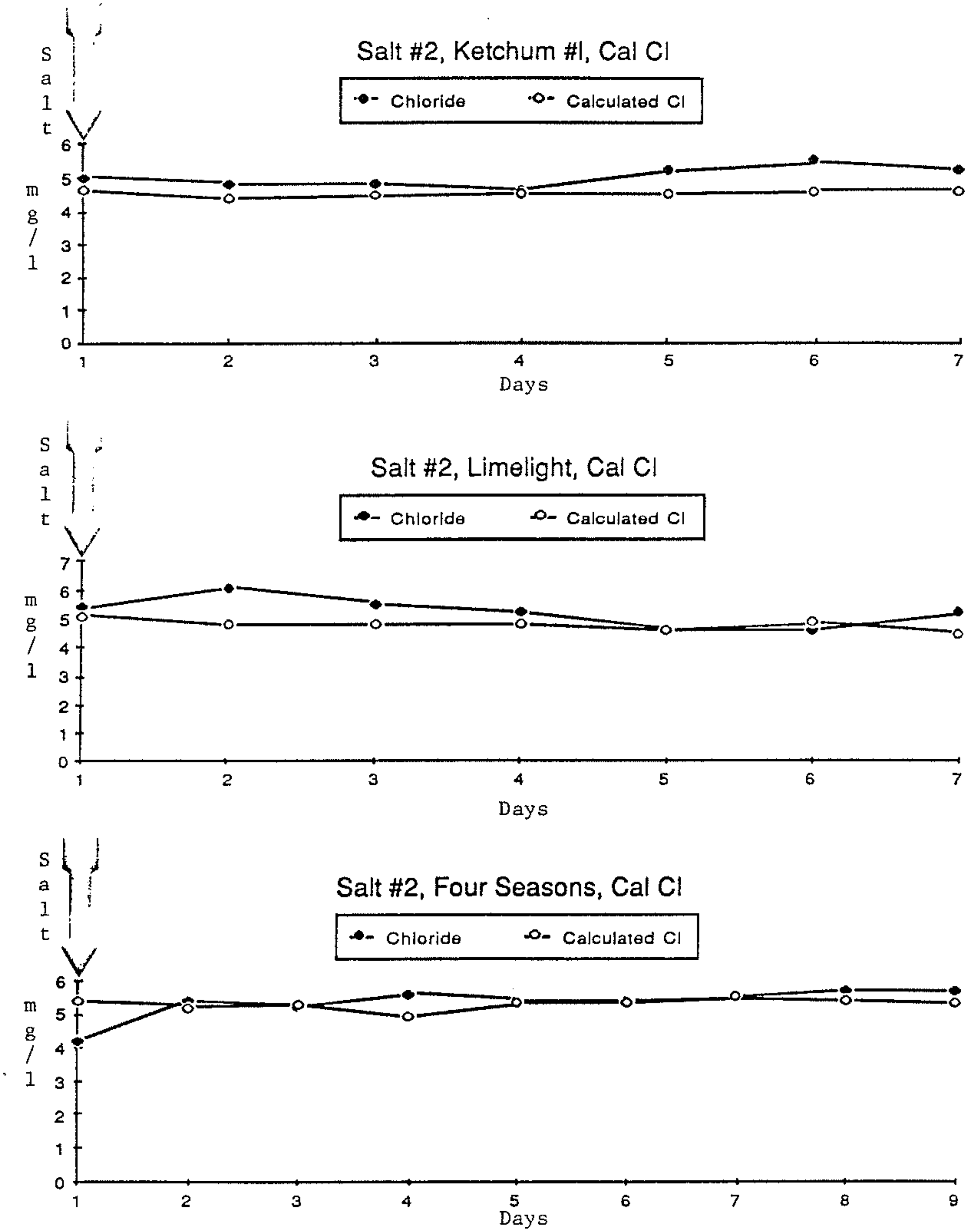
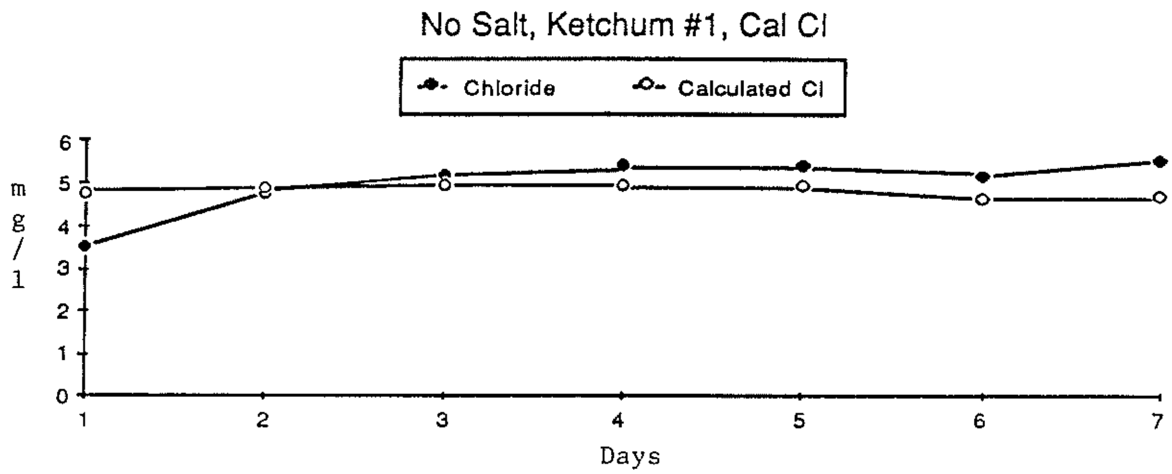
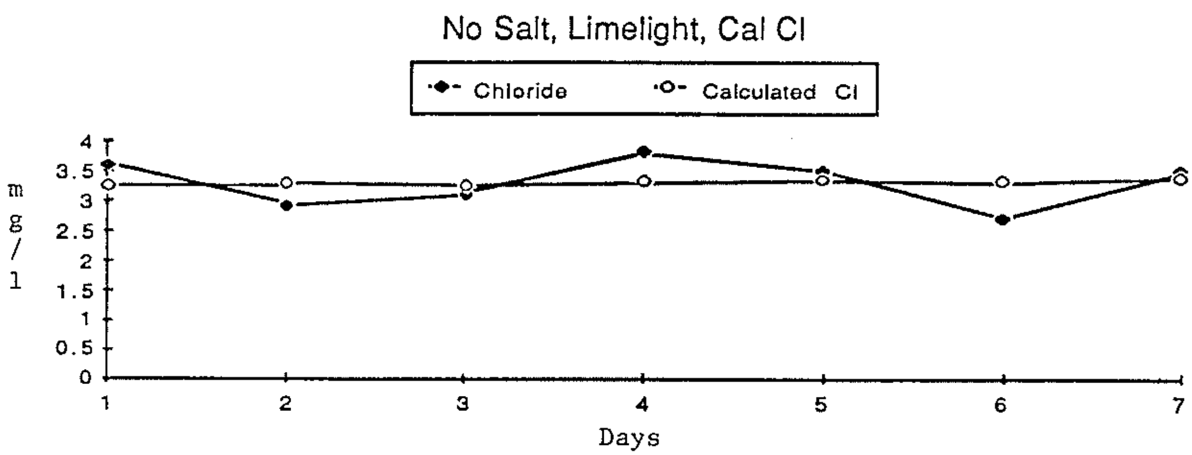
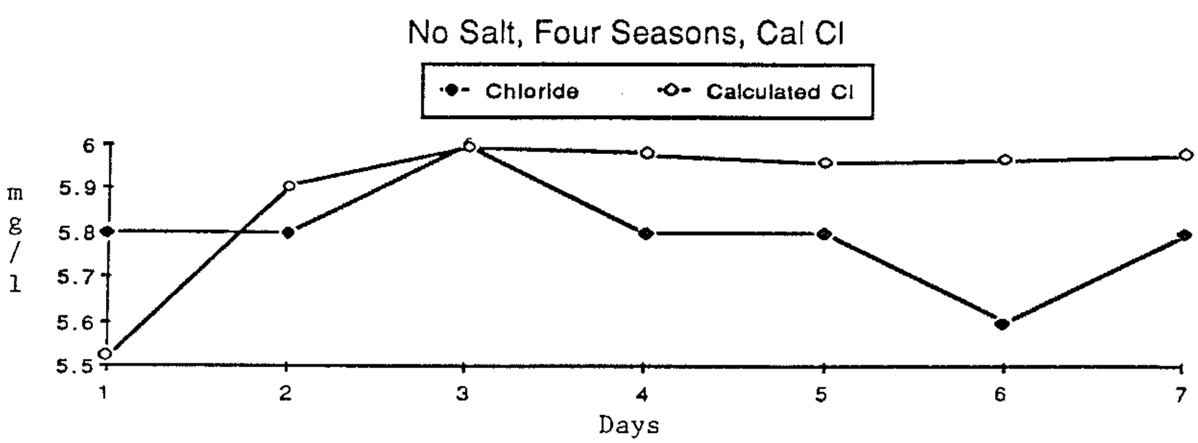


Figure 14 No Salt Test.
Calculated chloride concentrations & field values vs. days.



## APPENDIX A

87-8-135

HWR 0293 RECEIVED Sep 02 '87 ... OF ENVIRONMENT

State of Idaho
Department of Health & Welfare
BUREAU OF WATER QUALITY
BUREAU OF LABORATORIES

# WATER QUALITY REPORT
# CHEMICAL REPORT

See Back For Instructions

COPY DISTRIBUTION
White - Person requesting test
Canary - Lab
Pink - Water Quality Bureau (Storet)
Goldenrod - Extra as needed

LAB NAME (Check One): [X] Boise [ ] Coeur d'Alene [ ] Idaho Falls [ ] Lewiston [ ] Pocatello [ ] Twin Falls

STORET No.
NPDES No.
Date of Collection (Yr., Mo., Day) 87-08-11
Time of Collection (24 Hr. Clock) 1230 Depth (Meters) Circle One DM DBM DVM

Sampling Point Location GUYER HOT SPRINGS AT SOURCE
Date Submitted (Yr., Mo., Day) 87-08-12
Submitted By LITKE

PURPOSE OF SAMPLE (Check one): [X] Intensive Survey [ ] Trend [ ] Compliance [ ] Other

TYPE OF SAMPLES (Check appropriate boxes): [ ] Wastewater [ ] Raw [ ] Final [ ] Chlorinated [X] Grab [ ] Cross Composite [ ] Depth Integrated [ ] Composite Begin End

SAMPLE TAKEN FROM (Check one): [X] Spring [ ] Creek [ ] River [ ] Reservoir [ ] Well [ ] Lake [ ] Lagoon [ ] STP [ ] Industrial [ ] Drain

PRESERVED SAMPLES SUBMITTED: [X] Cooled, 4° C [X] $HNO_3$ [X] $H_2SO_4$ [ ] NaOH [ ] Other

| STORET Code | | DEMAND (mg/L) | |
|---|---|---|---|
| (00310) | [ ] | $BOD_5$ (Est ...) | |
| (00335) | [ ] | COD Low Level | |
| (00340) | [ ] | High Level | |
| (00680) | [ ] | TOC | |
| | | **NUTRIENTS (mg/L)** | |
| (00610) | [X] | T Ammonia as N | .024 |
| (00615) | [ ] | T Nitrite as N | |
| (00620) | [ ] | T Nitrate as N | |
| (00630) | [X] | T $NO_2 + NO_3$ as N | .014 |
| (00625) | [X] | T Kjeldahl Nitrogen as N | <.05 |
| (00665) | [X] | T Phosphorus as P | <.05 |
| (00669) | [ ] | T Hydrolyzable Phosphorus as P | |
| (70507) | [ ] | Ortho Phosphate as P | |
| (00671) | [ ] | Dissolved o-Phosphate as P | |
| | | **MINERALS (mg/L)** | |
| (00095) | [X] | Sp. Conductance (umhos/cm) | 414 |
| (00900) | [X] | Hardness as $CaCO_3$ | 8 |
| (00410) | [X] | T Alkalinity as $CaCO_3$ | 78 |
| (00425) | [ ] | Bicarbonate Alk. as $CaCO_3$ | |
| (00430) | [ ] | Carbonate Alk. as $CaCO_3$ | |
| (00916) | [ ] | Calcium | |
| (00927) | [ ] | Magnesium | |
| (00929) | [ ] | Sodium | |
| (00937) | [ ] | Potassium | |
| (00940) | [X] | Chloride | 12.1 |
| (00951) | [X] | Fluoride | 17 |
| (00945) | [X] | Sulphate as $SO_4$ | 68.7 |
| (00956) | [X] | Silica as $SiO_2$ | 83 |
| | | **MISCELLANEOUS** | |
| (00076) | [X] | Turbidity (NTU) | 0.20 |
| (00403) | [ ] | pH (SU) | |
| (00720) | [ ] | Total Cyanide (mg/L) | |
| (00116) | [ ] | Intensive Survey No. | |

| STORET Code | | RESIDUE (mg/L) | |
|---|---|---|---|
| (00500) | [X] | Total Residue | 322 |
| (00530) | [X] | Non-Filterable Residue (105° C) (Suspended Solids) | 8 |
| (70300) | [ ] | Filterable Residue | |
| (80154) | [ ] | Non-Filterable Residue (110° C) (Susp. Sediment) | |
| ( ) | [ ] | Other Residue | |
| | | **TRACE METALS (ug/L)** | |
| | | **DISSOLVED METALS** | |
| (01000) | [ ] | Arsenic, Dissolved | |
| (01020) | [ ] | Boron, Dissolved | |
| (01025) | [ ] | Cadmium, Dissolved | |
| (01030) | [ ] | Chromium, Dissolved | |
| (01040) | [ ] | Copper, Dissolved | |
| (01046) | [ ] | Iron, Dissolved | |
| (01049) | [ ] | Lead, Dissolved | |
| (01056) | [ ] | Manganese, Dissolved | |
| (71890) | [ ] | Mercury, Dissolved | |
| (01065) | [ ] | Nickel, Dissolved | |
| (01075) | [ ] | Silver, Dissolved | |
| (01090) | [ ] | Zinc, Dissolved | |
| ( ) | [ ] | Other | |
| ( ) | [ ] | Other | |
| | | **TOTAL METALS** | |
| (01002) | [X] | Arsenic, Total | <10 |
| (01022) | [X] | Boron, Total | 348 |
| (01027) | [X] | Cadmium, Total | <1 |
| (01032) | [ ] | Chromium, +6 | |
| (01034) | [X] | Chromium, Total | <10 |
| (01042) | [X] | Copper, Total | <10 |
| (01045) | [X] | Iron, Total | 10 |
| (01051) | [X] | Lead, Total | <10 |
| (01055) | [X] | Manganese, Total | <10 |
| (71900) | [X] | Mercury, Total | <.5 |
| (01067) | [X] | Nickel, Total | <50 |
| (01077) | [X] | Silver, Total | <1 |
| (01092) | [X] | Zinc, Total | <2 |
| ( ) | [ ] | Other | |
| ( ) | [ ] | Other | |

Date Completed SEP 01 1987 Date Reported 8-3-87
Chemist
Remarks:

RETURN TEST RESULTS TO
Name IDHW-DOE
Address P.O. Box 1626
City TWIN FALLS State ID Zip Code 83303

RECEIVED SEP 01 '87 DIVISION OF ENVIRONMENT

State of Idaho
Department of Health & Welfare
BUREAU OF WATER QUALITY
BUREAU OF LABORATORIES

# WATER QUALITY REPORT
# CHEMICAL REPORT

See Back For Instructions

87-8-134

COPY DISTRIBUTION
White - Person requesting test
Canary - Lab
Pink - Water Quality Bureau (Storet)
Goldenrod - Extra as needed

LAB NAME (Check One): [x] Boise [ ] Coeur d'Alene [ ] Idaho Falls [ ] Lewiston [ ] Pocatello [ ] Twin Falls

STORET No. ______
NPDES No. ______
Date of Collection (Yr., Mo., Day) 87-08-11
Time of Collection (24 Hr. Clock) 1300 Depth (Meters) ______ Circle One DM DBM DVM

Sampling Point Location WARM SP. CK 5-1
Date Submitted (Yr., Mo., Day) 87-08-12
Submitted By LITKE

PURPOSE OF SAMPLE (Check one): [x] Intensive Survey [ ] Trend [ ] Compliance [ ] Other ______

TYPE OF SAMPLES (Check appropriate boxes): [ ] Wastewater [ ] Raw [ ] Final [ ] Chlorinated [x] Grab [ ] Cross Composite [ ] Depth Integrated [ ] Composite: Begin ______ End ______

SAMPLE TAKEN FROM (Check one): [ ] Spring [x] Creek [ ] River [ ] Reservoir [ ] Well [ ] Lake [ ] Lagoon [ ] STP [ ] Industrial [ ] Drain

PRESERVED SAMPLES SUBMITTED: [x] Cooled, 4° C [x] $HNO_3$ [x] $H_2SO_4$ [ ] NaOH [ ] Other ______

| STORET Code | | DEMAND (mg/L) | |
|---|---|---|---|
| (00310) | [ ] | $BOD_5$ (Est ______) | |
| (00335) | [ ] | COD Low Level | |
| (00340) | [ ] | High Level | |
| (00680) | [ ] | TOC | |
| | | **NUTRIENTS (mg/L)** | |
| (00610) | [x] | T. Ammonia as N | .016 |
| (00615) | [ ] | T. Nitrite as N | |
| (00620) | [ ] | T. Nitrate as N | |
| (00630) | [x] | T. $NO_2 + NO_3$ as N | .034 |
| (00625) | [x] | T. Kjeldahl Nitrogen as N | <.05 |
| (00665) | [x] | T. Phosphorus as P | <.05 |
| (00669) | [ ] | T. Hydrolyzable Phosphorus as P | |
| (70507) | [ ] | Ortho Phosphate as P | |
| (00671) | [ ] | Dissolved o-Phosphate as P | |
| | | **MINERALS (mg/L)** | |
| (00095) | [x] | Sp. Conductance (umhos/cm) | 227 |
| (00900) | [x] | Hardness as $CaCO_3$ | 104 |
| (00410) | [x] | T. Alkalinity as $CaCO_3$ | 107 |
| (00425) | [ ] | Bicarbonate Alk. as $CaCO_3$ | |
| (00430) | [ ] | Carbonate Alk. as $CaCO_3$ | |
| (00916) | [ ] | Calcium | |
| (00927) | [ ] | Magnesium | |
| (00929) | [ ] | Sodium | |
| (00937) | [ ] | Potassium | |
| (00940) | [x] | Chloride | 2.0 |
| (00951) | [x] | Fluoride | .80 |
| (00945) | [x] | Sulphate as $SO_4$ | 10.6 |
| (00956) | [x] | Silica as $SiO_2$ | 18 |
| | | **MISCELLANEOUS** | |
| (00076) | [x] | Turbidity (NTU) | 0.40 |
| (00403) | [ ] | pH (SU) | |
| (00720) | [ ] | Total Cyanide (mg/L) | |
| (00116) | [ ] | Intensive Survey No. | |

| STORET Code | | RESIDUE (mg/L) | |
|---|---|---|---|
| (00500) | [x] | Total Residue | 141 |
| (00530) | [x] | Non-Filterable Residue (105° C) (Suspended Solids) | 8 |
| (70300) | [ ] | Filterable Residue | |
| (80154) | [ ] | Non-Filterable Residue (110° C) (Susp. Sediment) | |
| ( ) | [ ] | Other Residue | |
| | | **TRACE METALS (ug/L)** | |
| | | **DISSOLVED METALS** | |
| (01000) | [ ] | Arsenic, Dissolved | |
| (01020) | [ ] | Boron, Dissolved | |
| (01025) | [ ] | Cadmium, Dissolved | |
| (01030) | [ ] | Chromium, Dissolved | |
| (01040) | [ ] | Copper, Dissolved | |
| (01046) | [ ] | Iron, Dissolved | |
| (01049) | [ ] | Lead, Dissolved | |
| (01056) | [ ] | Manganese, Dissolved | |
| (71890) | [ ] | Mercury, Dissolved | |
| (01065) | [ ] | Nickel, Dissolved | |
| (01075) | [ ] | Silver, Dissolved | |
| (01090) | [ ] | Zinc, Dissolved | |
| ( ) | [ ] | Other | |
| ( ) | [ ] | Other | |
| | | **TOTAL METALS** | |
| (01002) | [x] | Arsenic, Total | <10 |
| (01022) | [x] | Boron, Total | 86 |
| (01027) | [x] | Cadmium, Total | <1 |
| (01032) | [ ] | Chromium, + 6 | |
| (01034) | [x] | Chromium, Total | <10 |
| (01042) | [x] | Copper, Total | <10 |
| (01045) | [x] | Iron, Total | 20 |
| (01051) | [x] | Lead, Total | <10 |
| (01055) | [x] | Manganese, Total | <10 |
| (71900) | [x] | Mercury, Total | <.5 |
| (01067) | [x] | Nickel, Total | <50 |
| (01077) | [x] | Silver, Total | <1 |
| (01092) | [x] | Zinc, Total | 3 |
| ( ) | [ ] | Other | |
| ( ) | [ ] | Other | |

Date Completed SEP 01 1987 Date Reported 8-31-87
Chemist ______
Remarks:

RETURN TEST RESULTS TO
Name IDHW - DOE
Address P.O. Box 1626
City TWIN FALLS State ID Zip Code 83303

## APPENDIX B

Test: 7-day fathead minnow (Pimephales promelas) larval survival and growth test

Client name: EPA Region X

Test procedure or protocol followed: EA protocol ATS-STC-FH-02, 7-day larval survival and growth test with fathead minnows (Pimephales promelas)

Sample description: Grab sample from the outfall of Guyer Hot Springs, Blaine County, Idaho[(a)]

Client sample number: NA    EA accession number: AT7-433

Time and date of sample collection: 1230 hours, 11 August 1987

Time and date of sample receipt: 1130 hours, 13 August 1987

EA QC test number: FG-08-13-87-483

Test initiation time and date: 1610 hours, 13 August 1987

Test completion time and date: 1630 hours, 20 August 1987

Dilution water: Dechlorinated municipal tap water

Organism lot number: FH-087

Source: EA Middletown

Age: <24 hours

Acclimation: NA

Length: NA

Range: NA

Weight: NA

Reference toxicant: SDS

EA QC test number: RT-08-14-87-485

Dilution water: Dechlorinated municipal tap water

(a) A grab sample of water from a "well mixed area" of Warm Springs Creek above the outfall was collected at 1245 hours, 11 August 1987 (EA Accession No. AT7-432) and tested as an additional concentration.

Note: Results of this test are provided in Tables 1 and 2.

Test: Day 0 and Day 6 24-hour fathead minnow (Pimephales promelas) acute tests

Client name: EPA Region X

Test procedure or protocol followed: Modification of EA Protocol ATS-SAF-FM-03, static acute 96-hour LC50 assay with fathead minnows (Pimephales promelas)

Sample description: Grab sample from the outfall of Guyer Hot Springs, Blaine County, Idaho

Client sample number: NA EA accession number: AT7-433

Time and date of sample collection: 1230 hours, 11 August 1987

Time and date of sample receipt: 1130 hours, 13 August 1987

| | Day 0 | Day 6 |
|---|---|---|
| QC Test Number: | SA-08-13-87-482 | SA-08-19-87-490 |
| Test initiation time and date: | 1523 hours, 13 AUG 87 | 1420 hours, 19 AUG 87 |
| Test completion time and date: | 1511 hours, 14 AUG 87 | 1356 hours, 20 AUG 87 |
| Dilution water: | Dechlorinated municipal tap water | |
| Organism lot #: | FH-084 | FH-084/086 |
| Source: | EA Middletown | EA Middletown |
| Age: | 13 days | 19 days |
| Acclimation: | 9 days | 13-15 days |
| Length: | $\bar{x}$ = 8.20 mm<br>S.D. = 1.10 mm | $\bar{x}$ = 8.52<br>S.D. = 1.07 |
| Length range: | 5.70-10.15 mm | 6.51-11.29 mm |
| Average of pooled weight: | 3.74 mg | 7.22 mg |
| Reference Toxicant Test #: | RT-08-04-87-448 | RT-08-04-87-448 (FH-084)<br>RT-08-10-87-469 (FH-086) |

Note: Results of these tests are provided in Tables 1 and 3.

Test: 7-day _Ceriodaphnia dubia_ survival and reproduction test

Client name: EPA Region X

Test procedure or protocol followed: EA protocol ATS-STC-CD-03, 7-day survival and reproduction test with cladoceran (_Ceriodaphnia dubia_)

Sample description: Grab sample from the outfall of Guyer Hot Springs, Blaine County, Idaho[a]

Client sample number: NA    EA accession number: AT7-433

Time and date of sample collection: 1230 hours, 11 August 1987

Time and date of sample receipt: 1130 hours, 13 August 1987

EA QC test number: RP-08-13-87-476

Test initiation time and date: 1500 hours, 13 August 1987

Test completion time and date: 1530 hours, 20 August 1987

Dilution water: Patapsco River water    EA accession number: AT7-427

Organism lot number: NA

Source: EA cultures

Age: <8 hours

Acclimation: NA

Length: NA

Range: NA

Weight: NA

Reference toxicant: SDS

EA QC test number: RT-08-11-87-471

Dilution water: Patapsco River water

Organism lot number: NA

(a) A grab sample of water from a "well mixed area" of Warm Springs Creek above the outfall was collected at 1245 hours, 11 August 1987 (EA Accession No. AT7-432) and tested as an additional concentration.

Note: Results of this test are provided in Tables 4 and 5.

Test: Day 0 and Day 6 24-hour *Ceriodaphnia dubia* acute tests
Client name: EPA Region X
Test procedure or protocol followed: Modification of EA protocol ATS-SAI-CD-02, static acute 48-hour LC50 assay with *Ceriodaphnia*

Sample description: Grab sample from the outfall of Guyer Hot Springs, Blaine County, Idaho
Client sample number: NA EA accession number: AT7-433
Time and date of sample collection: 1230 hours, 11 August 1987
Time and date of sample receipt: 1130 hours, 13 August 1987

| | Day 0 | Day 6 |
|---|---|---|
| QC Test Number: | SA-08-13-87-478 | SA-08-19-87-489 |
| Test initiation time and date: | 1520 hours, 13 AUG 87 | 1535, 19 AUG 87 |
| Test completion time and date: | 1541 hours, 20 AUG 87 | 1523 hours, 20 AUG 87 |
| Dilution water: | Patapsco River water (EA Accession No. AT7-427) | Patapsco River water (EA Accession No. AT7-434) |
| Organism lot #: | NA | NA |
| Source: | EA cultures | EA cultures |
| Age: | <24 hours | <24 hours |
| Reference Toxicant Test #: | RT-08-11-87-471 | RT-08-11-87-471 |

Note: Results of these tests are provided in Tables 4 and 6.

TABLE 1 WATER QUALITY SUMMARY FOR FATHEAD MINNOW TESTS CONDUCTED 13-20 AUGUST 1987

| | 7-Day Chronic FG-08-13-87-483 | | | |
|---|---|---|---|---|
| | Test Conc. | Upstream Receiving Water | Day 0 Acute SA-08-13-87-482 | Day 6 Acute SA-08-19-87-490 |
| Temperature range (degrees C) | 23.2-26.8 | 23.3-26.9 | 19.3-22.0 | 19.4-20.8 |
| pH range | 7.5-9.6 | 7.7-8.5 | 7.7-9.2 | 8.0-9.5 |
| DO range (mg/L) | 3.7-9.0 | 4.7-9.1 | 7.3-8.5 | 7.6-9.0 |
| Conductivity (μmhos/cm) | 250-461 | 220-270 | 255-390 | 260-390 |

Additional parameters:

Ammonia-nitrogen in whole effluent: 0.05 mg/L

Total residual chlorine: <0.1 mg/L

TABLE 2 RESULTS OF FATHEAD MINNOW (*Pimephales promelas*) 7-DAY GROWTH TEST (QC# FG-08-13-87-483)

| Test concentration (percent effluent) | Mean survival (percent)[a] | Average Dry Weight (mg)[b] |
|---|---|---|
| Control | 65[c] | 0.43 |
| 1 | 88 | 0.38 |
| 3 | 85 | 0.44 |
| 10 | 87.5 | 0.40 |
| 30 | 97.5 | 0.39 |
| 100 | 90 | 0.36 |
| Receiving water | 85 | 0.40 |

NOEC = 100%

LOEC = >100%

ChV = >100%

Reference Toxicant (SDS) Results

24 hour LC50: 28.3 (binomial method)

Laboratory control chart acceptability range for 24-hour LC50: 22.1-37.6 mg/L.

(a) Percent survival is based on an arithmetic mean calculated directly from data set and may differ slightly from the mean calculated after arc sine transformation (Dunnetts Test).
(b) The average dry weight is the pooled dry weight of fathead minnow fry from each of four replicates per test concentration. These values are expressed as mean total weight per fry and not daily increases.
(c) Although control mortality was greater than 20 percent, this test can still be considered acceptable since less than 20 percent mortality occurred in the low test concentrations.

TABLE 3 RESULTS OF FATHEAD MINNOW 24-HOUR ACUTE TESTS CONDUCTED ON 13-14 AND 19-20 AUGUST 1987

| Test Concentration (percent effluent) | Mean Percent Survival Day 0 SA-08-13-87-482 | Day 6 SA-08-19-87-490 |
|---|---|---|
| Control | 100 | 100 |
| 18 | 100 | 100 |
| 28 | 100 | 95 |
| 42 | 95 | 95 |
| 65 | 100 | 100 |
| 100 | 100 | 100 |
| 24-hour LC50 value: (method of calculation): | >100% (NA) | >100% (NA) |

Reference Toxicant (SDS) Results

| | | |
|---|---|---|
| 24-hour LC50: | 28.3 mg/L | 28.3 mg/L (FH-084)<br>28.3 mg/L (FH-086) |

Laboratory control chart acceptability range for 24-hour LC50: 18.8-34.7 mg/L.

TABLE 4 WATER QUALITY SUMMARY FOR *Ceriodaphnia dubia* TESTS CONDUCTED FROM 13-20 AUGUST 1987

| | 7-Day Chronic RP-08-13-87-476 | | Day 0 Acute | Day 6 Acute |
|---|---|---|---|---|
| | Test Conc. | Receiving Water | SA-08-13-87-478 | SA-08-19-87-489 |
| Temperature range (degrees C) | 23.0-26.3 | 24.0-24.8 | 24.2-25.5 | 23.4-24.1 |
| pH range | 7.3-9.3 | 7.4-8.3 | 7.2-9.2 | 7.9-9.4 |
| DO range (mg/L) | 7.1-9.9 | 7.2-8.3 | 7.2-8.8 | 6.2-8.3 |
| Conductivity (µmhos/cm) | 205-440 | 215-248 | 220-425 | 251-430 |

Additional parameters:

| | Sample | Patapsco River Water | |
|---|---|---|---|
| | AT7-433 | AT7-427 | AT7-434 |
| Conductivity (µmhos/cm) | 500 | 218 | 280 |
| Hardness (mg/L as $CaCO_3$) | 40 | 56 | 60 |
| Alkalinity (mg/L as $CaCO_3$) | 75 | 44 | 44 |

TABLE 5 RESULTS OF *Ceriodaphnia dubia* 7-DAY SURVIVAL AND REPRODUCTION TEST (QC# RP-08-13-87-476)

| Test concentration (% effluent) | n | Percent survival | Young per female Total | Mean (± S.D) |
|---|---|---|---|---|
| Control | 10 | 80 | 101 | 10.1 (±6.4) |
| 1 | 10 | 80 | 107 | 10.7 (±7.4) |
| 3 | 10 | 70 | 125 | 12.5 (±9.6) |
| 10 | 9 | 67 | 79 | 8.8 (±7.5) |
| 30 | 10[a] | 90 | 130 | 14.4 (±10.5) |
| 100 | 10 | 100 | 53 | 5.3 (±4.5) |
| Receiving water | 9 | 89 | 86 | 9.6 (±4.6) |

NOEC = 100%

LOEC = >100%

ChV = >100%

Reference Toxicant (SDS) Results

24-hour LC50: 15.2 mg/L (binomial method)

Laboratory control chart acceptability range for 24-hour LC50: 4.2-37.6 mg/L.

(a) 9 females, 1 male.

TABLE 6 RESULTS OF *Ceriodaphnia dubia* 24-HOUR ACUTE TESTS CONDUCTED ON 13-14 AND 19-20 AUGUST 1987

| Test Concentration (percent effluent) | Mean Percent Survival Day 0 SA-08-13-87-478 | Mean Percent Survival Day 6 SA-08-19-87-489 |
|---|---|---|
| Control | 100 | 100 |
| 18 | 100 | 100 |
| 28 | 100 | 90 |
| 42 | 100 | 100 |
| 65 | 100 | 100 |
| 100 | 100 | 100 |
| 24-hour LC50 value: (method of calculation): | >100% (NA) | >100% (NA) |

Reference Toxicant (SDS) Results

24-hour LC50: 15.2 mg/L

Laboratory control chart acceptability range for 24-hour LC50: 4.2-37.6 mg/L.

TABLE 7 SUMMARY OF ACUTE AND CHRONIC ENDPOINTS

| Species | Acute Toxicity (24-hour LC50) Day 0 | Acute Toxicity (24-hour LC50) Day 6 | Chronic Toxicity NOEC | Chronic Toxicity ChV | Chronic Toxicity LOEC |
|---|---|---|---|---|---|
| *Pimephales promelas* | >100% | >100% | 100% | >100% | >100% |
| *Ceriodaphnia dubia* | >100% | >100% | 100% | >100% | >100% |