Research Technical Note 97-1

Depth and Temporal Variations in Water Quality of the Snake River Plain Aquifer in Well USGS-59 near the Idaho Chemical Processing Plant at the Idaho National Engineering and Environmental Laboratory

by

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ABSTRACT

In-situ measurements of the specific conductance and temperature of ground water in the Snake River Plain aquifer were collected in observation well USGS-59 near the Idaho Chemical Processing Plant at the Idaho National Engineering and Environmental Laboratory. These parameters were monitored at various depths in the aquifer from October 1994 to August 1995.

The specific conductance of ground water in well USGS-59, as measured in the borehole, ranged from about 450 to 900 μS/cm at standard temperature (25° C). The pumping cycle of the production wells at the Idaho Chemical Processing Plant causes changes in borehole circulation patterns, and as a result the specific conductance of ground water at some depths in the well varies by up to 50% over a period of about 14 hours. However, these variations were not observed at all depths, or during each pumping cycle. The temperature of ground water in the well was typically between 12.8 and 13.8° C.

The results of this study indicate that temporal variations in specific conductance of the ground water at this location are caused by an external stress on the aquifer - pumping of a production well approximately 4000 feet away. These variations are believed to result from vertical stratification of water quality in the aquifer and a subsequent change in intrawell flow related to pumping. When sampling techniques that do not induce a stress on the aquifer (i.e. thief sampling) are used, knowledge of external stresses on the system at the time of sampling may aid in the interpretation of geochemical data.

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LIST OF ACRONYMS AND ABBREVIATIONS

bls - below land surface

C - Celsius

DOE - U.S. Department of Energy

gpm - gallons per minute

ICPP - Idaho Chemical Processing Plant

INEEL- Idaho National Engineering and Environmental Laboratory

μS/cm - microsiemens per centimeter

mg/l - milligrams per liter

MSL - mean sea level

pCi/l - picocuries per liter

SC - specific conductance

USGS - U.S. Geological Survey

CHAPTER 1:

INTRODUCTION

Monitoring wells may be constructed such that they are open, or screened, over a thick vertical section of an aquifer. In some cases this may be desirable - for example, fully-penetrating monitoring wells or production wells for aquifer tests. However, in areas with vertical stratification of ground-water contaminants, natural or induced vertical gradients in the aquifer can result in circulation of ground water with varying chemical signatures within the borehole. As a result, analytical samples collected from wells open over a thick section of an aquifer with a bailer, thief sampler, or low-discharge pump may produce variable geochemical data, depending on the vertical flow regime at the time of sampling and the depth at which the sample is collected. This report describes measurements of a water-quality indicator (specific conductance) from a single well to serve as an example of intrawell variations that might occur.

Background

The Idaho National Engineering and Environmental Laboratory (INEEL)[1] is located in southeast Idaho and is operated by the U.S. Department of Energy (DOE). The INEEL encompasses 890 square miles of the Snake River Plain about 40 miles west of Idaho Falls. Since it was established in 1949 as the National Reactor Testing Station, 52 nuclear reactors have been constructed and tested at the INEEL.

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[1] From 1974 to January 1997, this facility was known as the Idaho National Engineering Laboratory, or INEL. The former name is used in the title of documents produced during that period.

There are several major facilities at the INEEL (Figure 1) which have served a range of uses associated with DOE operations, including nuclear-reactor research, waste disposal, and reprocessing of spent nuclear fuel. One of these facilities, the Idaho Chemical Processing Plant (ICPP), was constructed in the early 1950s to recover fissionable materials from spent nuclear fuel. Reprocessing of nuclear fuel at the ICPP began in 1952 and continued intermittently until 1994.

The Snake River Plain aquifer is present beneath nearly all of the eastern Snake River Plain, including the INEEL. The aquifer is comprised of interlayered basalt flows and sediments. Near the ICPP, the water table for the aquifer is about 460 feet below land surface (bls).

From 1952 to 1986, low-level radioactive, chemical, and sanitary waste water from the ICPP was discharged directly to the Snake River Plain aquifer via an injection well (CPP-03). Since 1984, waste water was also discharged to two unlined percolation ponds south of the ICPP (Figure 2), and discharge to the injection well decreased. In 1986, the injection well was taken out of service. Sanitary waste is discharged to treatment ponds located east of the ICPP (Figure 2).

Disposal of waste water at the ICPP has resulted in the formation of ground-water contaminant plumes which extend several miles downgradient (Barraclough and Jensen, 1976; Barraclough and others, 1982; Mann and Cecil, 1990). Contaminants detected in the aquifer include tritium, strontium-90, iodine-129, nitrate, and chloride, among others.

In 1994 and 1995, the INEEL Oversight Program and the Idaho Water Resources Research Institute collected in-situ measurements of the specific conductance and temperature of ground water in observation well USGS-59. This well is located about 2400 feet southeast of the

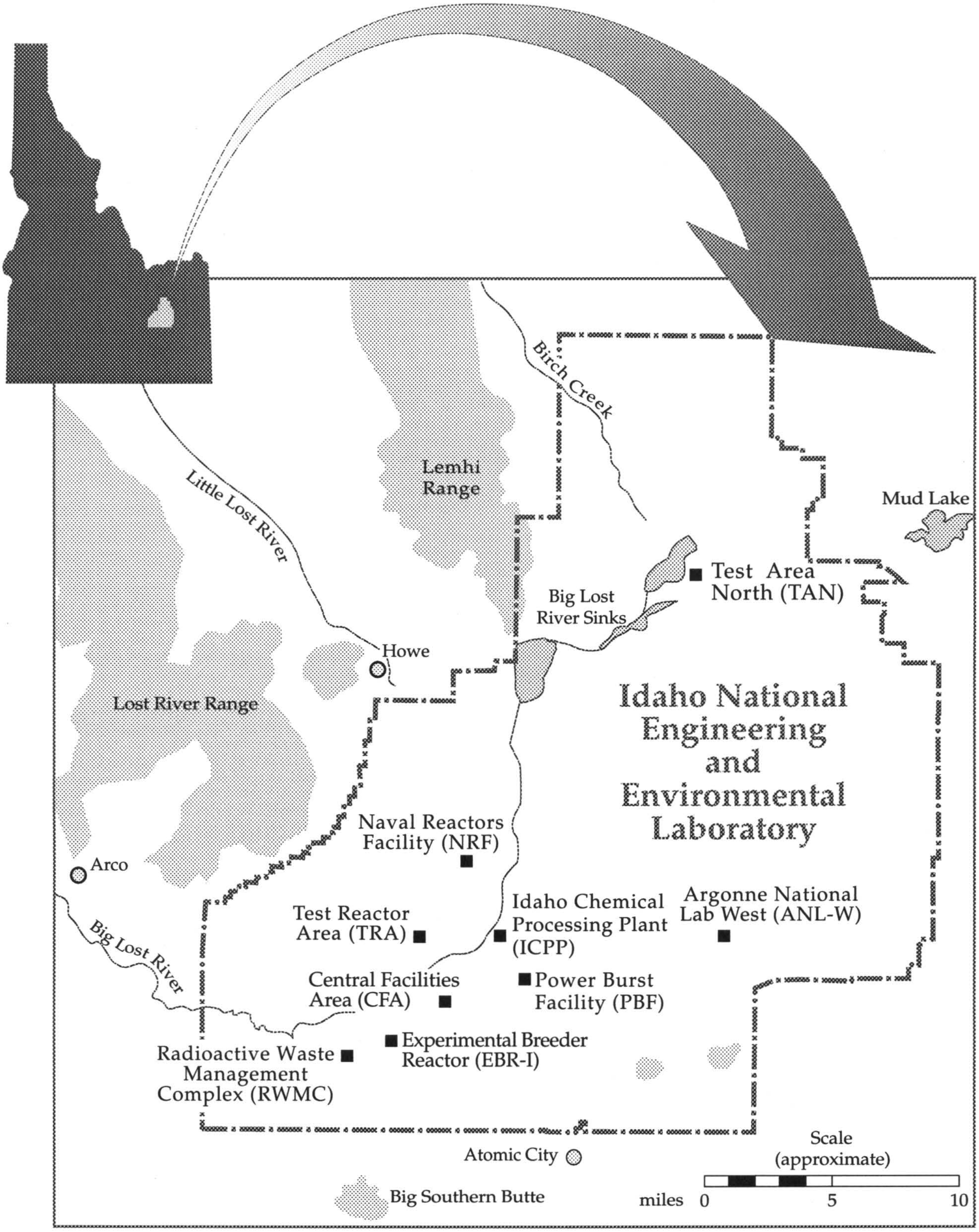


Figure 1. Location of selected facilities at the Idaho National Engineering and Environmental Laboratory.

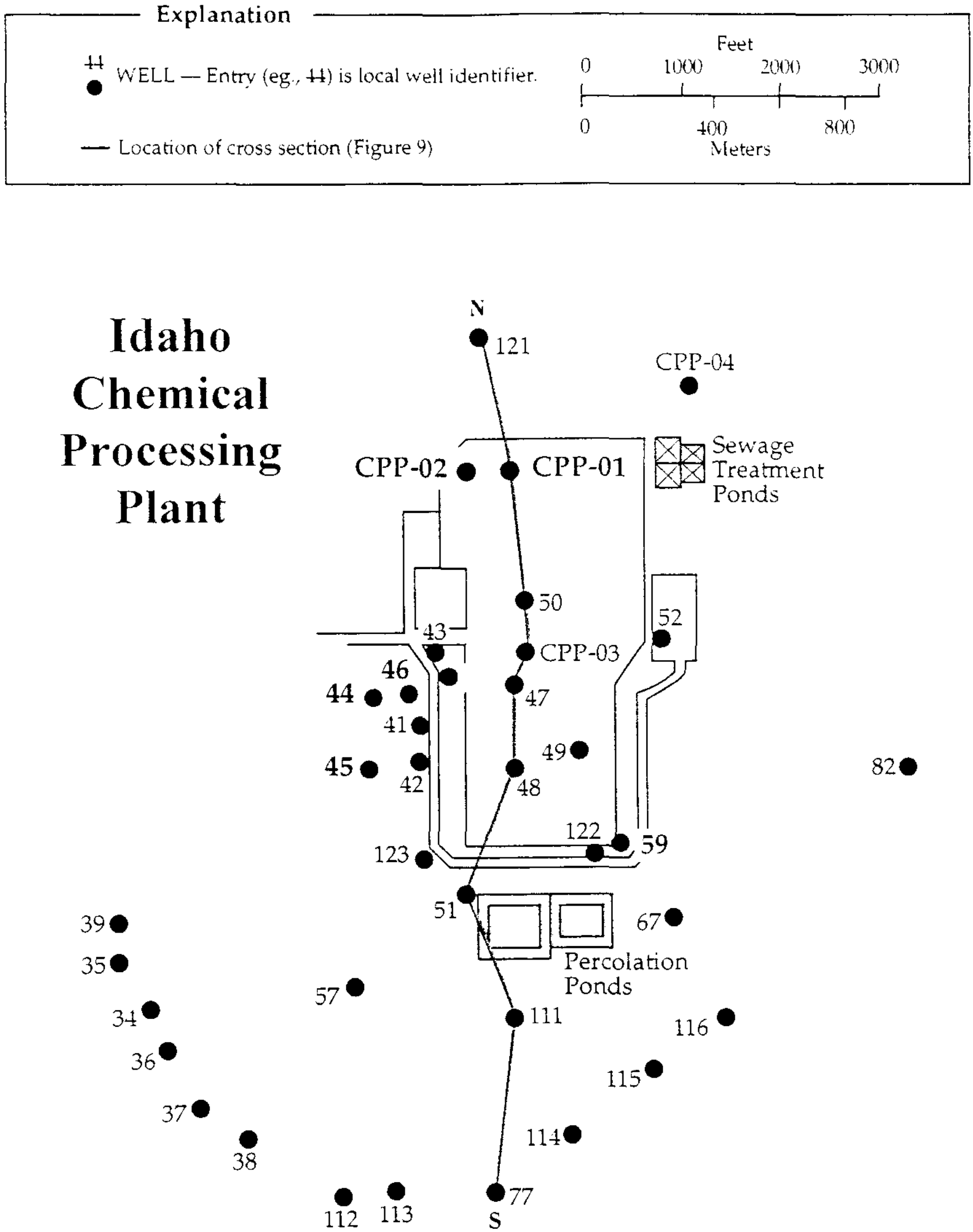


Figure 2. Locations of selected wells at the Idaho Chemical Processing Plant.

abandoned injection well, and approximately 400 feet northeast of the percolation ponds (Figure 2).

Specific conductance is a measure of electrical conductivity, and is approximately proportional to the quantity of dissolved chemicals in the water. Therefore, it serves as an indicator of water quality. Robertson and others (1974) reported that the natural specific conductance of water in the Snake River Plain aquifer near the Idaho Chemical Processing Plant was about 300 to 325 microsiemens per centimeter (μS/cm). In 1991, the most recent time for which an extensive data set is readily available, the median specific conductance of water from 100 wells at the INEEL was 425 μS/cm, and ranged from 254 to 1380 μS/cm (Bartholomay and others, 1995).

The water quality of the Snake River Plain aquifer near the ICPP has been adversely impacted by numerous processes. From 1952 to 1986, waste water was injected directly into the aquifer via well CPP-03. The average annual volume discharged to CPP-03 from 1953 to 1970 was estimated to be 300 million gallons; the specific conductance of the effluent was estimated to be 960 to 1140 μS/cm (Robertson and others, 1994).

Since 1984, much of the waste water at the ICPP has been discharged to percolation ponds south of the facility. During 1994 and 1995, the average annual volume of liquid effluent discharged to the percolation ponds was about 480 million gallons (LITCO, 1995; LITCO, 1996). The effluent, which is sampled monthly, had a specific conductance of 1200-1400 μS/cm in 1994 and 1142-1611 μS/cm in 1995 (LITCO, 1995; LITCO, 1996).

In addition to the percolation ponds and the injection wells, effluent to sewage treatment ponds and infiltration from perched water units may also impact the water quality of the Snake

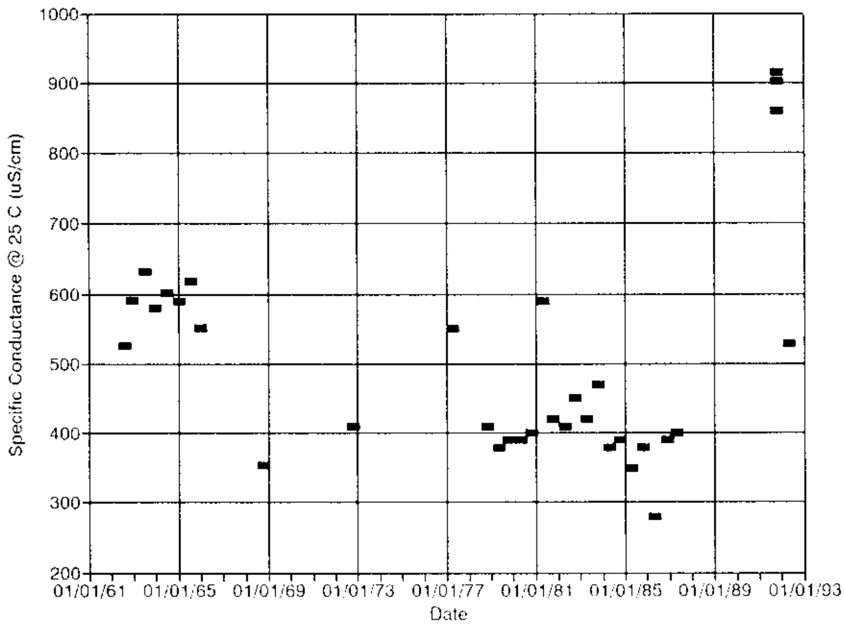
River Plain aquifer. During 1994 and 1995, 20 million to 30 million gallons of effluent was discharged annually to the sewage pond east of the ICPP (LITCO, 1995; LITCO, 1996); the specific conductance of the water was not available. There are also a number of perched water bodies in the vadose zone at the ICPP which may contribute relatively minor amounts of recharge to the aquifer. The specific conductance of water samples collected from the perched zones in 1995 ranged from 434 to 1290 μS/cm (Rodriguez and others, 1996; U.S. Geological Survey unpublished data).

Objectives

Over a thirty-year period, the specific conductance of ground-water samples collected from USGS-59 has ranged from less than 300 to more than 900 μS/cm (Figure 3). Short-term variations in specific conductance also occur, which may be a function of waste disposal or aquifer dynamics. For example, in 1981 the specific conductance of two ground-water samples from USGS-59 were roughly 400 to 600 μS/cm, respectively (Figure 3). The concentration of tritium also has varied by a few hundred percent between samples collected in a one-year period (Figure 3). This study was designed to demonstrate the variability in analytical results that can occur in open boreholes by evaluating the vertical and temporal changes in water chemistry in one well, USGS-59. Specifically, the objectives of this study were to:

1) Determine the magnitude of short-term variations in water quality at multiple depths in USGS-59. Specific conductance can be measured for minimal cost, therefore this parameter was selected as a general indicator of water quality.

2) Collect in-situ specific conductance data concurrently with sampling of the well with a dedicated pump to provide a qualitative evaluation of the variability in geochemical data which may occur in a stratified system.



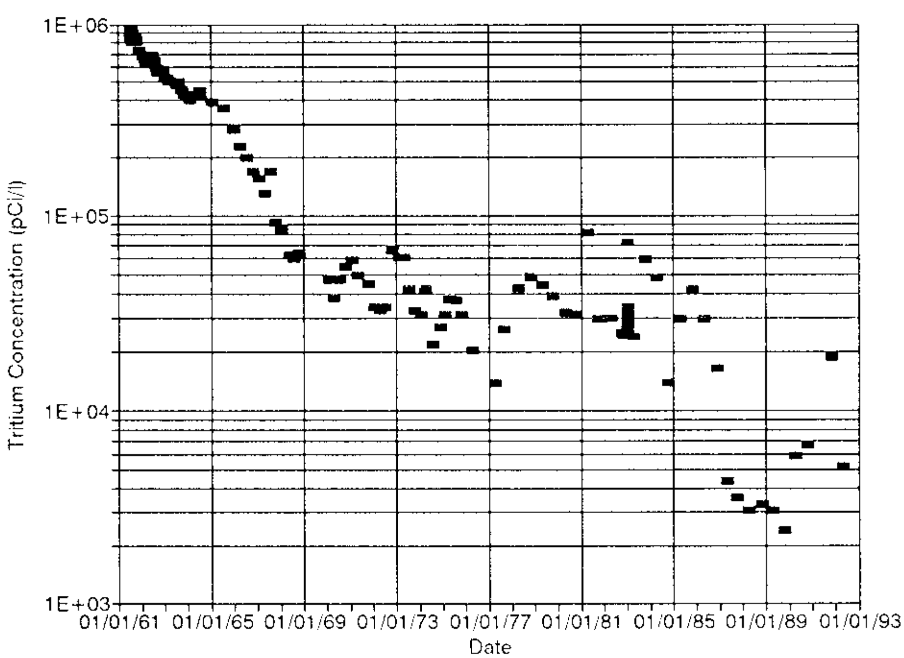


Figure 3. Tritium concentration and specific conductance of ground-water samples from USGS-59.

CHAPTER 2:

METHODOLOGY

Data Collection

A conductance/temperature probe was deployed at various depths in observation well USGS-59 from October 1994 to August 1995 (Table 1). Monitoring well USGS-59 is a eight-inch diameter well that was drilled in 1960. The well is cased to a depth of 459 feet bls, which is approximately the depth of the water table. Below this depth, the well has open-hole construction (i.e. uncased). A well construction log is in Appendix A.

The specific conductance and temperature of water in the Snake River Plain aquifer were measured at ten-minute intervals using an In-Situ Model CTS-100/DH[2] conductivity probe. The conductance was corrected to standard temperature (25° C) using Arp's equation. Barometric pressure readings were collected with a In-Situ barometric pressure transducer (Model PXD-360) located near the well. A pressure transducer was used to monitor the water level in USGS-59 from April to August 1995. Hydraulic head data and barometric pressure readings collected during the test are in Appendix B. Specific conductance and temperature data not discussed in the text are in Appendix C.

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[2] Use of trade names does not constitute an endorsement by the State of Idaho or it's employees.

Table 1. Dates and depths of ground water specific conductance monitoring in USGS-59.

Date Test Started	Date Test Ended	Water Level Data Collected?	Depth to Specific Conductance Probe (feet bls)	Barometric Pressure Data Collected?
10/28/94	12/6/94	No	550	Yes
12/22/94	2/8/95	No	600	Yes
4/12/95	5/4/95	Yes	499	Yes
5/10/95	5/26/95	Yes	499	Yes
6/7/95[2]	6/21/95	Yes	549	Yes
6/22/95	6/29/95	Yes	549	Yes
6/29/95	7/5/95	Yes	549	Yes
7/5/95	7/10/95	Yes	547	Yes
7/10/95	7/21/95	Yes	551	Yes
7/21/95[2]	8/8/95	Yes	588	Yes
8/8/95[2]	8/23/95	Yes	588	Yes

[2] During these tests, the temperature probe indicated that the ground water reached nearly 20° C on several occasions. In addition, in late August 1995 the barometric pressure transducer recorded peaks that did not correspond to barometric pressure data from the National Oceanic and Atmospheric Administration. The manufacturer of the data logger felt this data was erroneous, apparently related to problems with the power source. As a result, data collected on the following dates were discarded: 6/7/95-6/11/95; 6/19/95-6/21/95; 7/30/95-8/23/95.

Quality Assurance

The In-Situ specific conductance probe was calibrated on October 28, 1994, prior to deployment in the observation well. Specific conductance measurements of a 447 µS/cm standard solution and deionized water were taken with a hand-held meter (Orion Model 124) and the In-Situ probe. The conductance and temperature readings from the two instruments were typically within a few percent (Table 2).

Measurements taken from the In-Situ probe while deployed at 500 feet bls were compared to the conductance measured from purge water when the U.S. Geological Survey sampled the well on April 14, 1995. The intake for the sampling pump is at a depth of 490 feet bls (10 feet above the conductance probe), so in-situ measurements should be comparable to measurements of the purge water. The specific conductance values from the In-Situ probe were within three percent of the measurements taken from the purge water with a hand-held meter (Table 3). The temperature of the purge water at the surface was slightly more than 1° C higher than the in-situ temperature, possibly due to heating of the water by the pump.

Table 2. Results of the calibration of the specific conductance probe on October 28, 1994.

	Orion 124 Hand-held Meter		In-Situ Probe	
	Conductance @ 25° C (µS/cm)	Temperature (° C)	Conductance @ 25° C (µS/cm)	Temperature (° C)
Standard: 447 µS/cm	461	NA	465	NA
De-ionized water	74	13	74	13.3

Note: The Orion meter has an internal correction to covert the specific conductance measurement to standard temperature (25° C). Conductance readings from the In-Situ probe were corrected to 25° C using the Arp's equation.

Table 3. **Comparison of conductance and temperature measurements from In-Situ probe at 499 feet bls to measurements taken from purge water; April 14, 1995.**

Time	Purge Water		In-Situ Probe		Percent Difference in Conductance
	Conductance @ 25° C (μS/cm)	Temperature (° C)	Conductance @ 25° C (μS/cm)	Temperature (° C)	
12:13 pm	703	14.6	719	13.3	2.3
12:18 pm	699	14.6	718	13.3	2.7
12:23 pm	697	14.5	715	13.3	2.6
12:29 pm	695	14.4	714	13.3	2.7

Note: Conductance and temperature of purge water was measured with a hand-held meter with internal compensation to correct specific conductance to standard temperature. Conductance readings from the In-Situ probe were corrected to 25° C using the Arp's equation.

CHAPTER 3:

VERTICAL VARIATIONS IN SPECIFIC CONDUCTANCE

Three studies have been conducted in observation well USGS-59 to evaluate vertical variations in water quality in the Snake River Plain aquifer at this location. Depth-specific monitoring techniques used in this well include:

1) down-hole specific conductance logging on September 14, 1993.

2) ground-water samples collected with a straddle packer during the summer of 1994.

3) deployment of a specific conductance probe in the well during October 1994 to July 1995 (this study).

Each of these methods provides information on vertical and/or temporal variations in specific conductance. The samples collected with the straddle packer provide a specific conductance measurement for ground water in an interval of the aquifer at a point in time. The down-hole logging gives an "instantaneous" (less than one hour) profile of specific conductance values over the length of the open borehole, and the probe deployed in the well was used to measure the specific conductance at a point in the well over longer periods of time (days to months).

In the summer of 1994, a straddle packer was deployed at four intervals, each 18 feet thick, in USGS-59 to collect ground-water samples from specific depths of the aquifer (Table 4). The specific conductance of the sample collected at 517-535 feet bls was not reported. While the packer assembly was at a depth of 538 to 556 feet bls, a water sample was also collected with the lower packer deflated, and this sample is assumed to represent water chemistry from 538 feet bls to 651 feet bls (bottom of the well). The specific conductance of the ground-water samples ranged from 526 to 868 μS/cm (Table 4).

Vertical variations in the specific conductance of ground water in well USGS-59 were also recognized by Wood and Bennecke (1994). Using down-hole instruments, these authors collected a profile of specific conductance, water temperature, and vertical flow rates and directions in the well; whether the ICPP production wells were pumping during collection of the data was not documented. The water at 461-491 feet bls had a specific conductance of 550 uS/cm, a temperature of 13.8° to 14°C, and no vertical flow (Figure 4). At 521-537 feet bls , water entering the well increased the specific conductance to 1115 μS/cm, and the temperature decreased to 13.1°C. The flow log indicates that water flowed down the borehole to 624 feet, where it flowed out into the formation. Due to water entering the well at 575 feet bls, the specific conductance of the ground water decreased to about 850 μS/cm, and then gradually increased to 1020 μS/cm in the lower stagnant zone (Figure 4). The interval from 624-651 feet was stagnant (no flow).

The specific conductance of the ground water samples collected with the straddle packer is generally within the range of values measured with the in-situ probe at similar depths (Table 4). Measurements from the specific conductance logging (Wood and Bennecke, 1994) were comparable to the range of values from the in-situ probe at depths of 500 and 600 feet bls, but were considerable higher at 550 feet bls (Table 4). At depths of 538-556 feet bls and 538-651 feet bls the specific conductance values reported by Wood and Bennecke (1994) were higher than those reported for the samples collected with the straddle packer. The cause of the differences in specific conductance from the various studies cannot be determined with certainty because they were conducted over a two year period. Differences may be indicative of long-term trends (i.e. dilution of existing contaminant plume), or short-term variations (see Chapter 4).

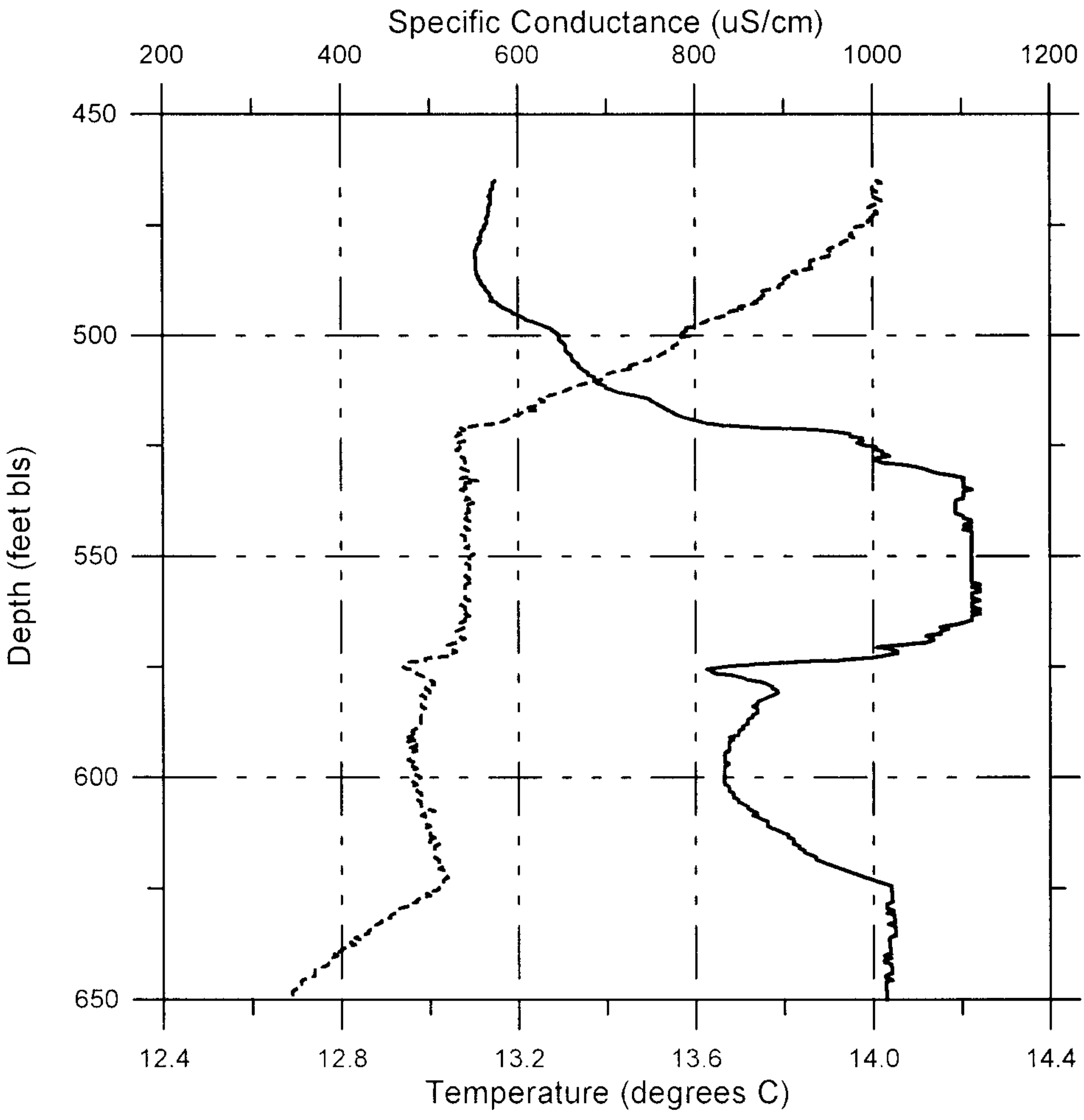

Figure 4. Temperature and specific conductance of ground water in USGS-59 (from Wood and Bennecke, 1994). Dashed line is temperature log, solid line is specific conductance log.

Table 4. **Specific conductance of ground water in USGS-59 at standard temperature (25° C). Columns 1 and 2 refer to ground-water samples collected with the straddle packer, and columns 3 and 4 are in-situ measurements from Wood and Bennecke (1994). Columns 5 and 6 are ranges measured with the In-Situ conductance probe (this study).**

Samples collected with straddle packer		Wood and Bennecke (1994)		In-situ probe	
Depth (ft bls)	SC (µS/cm)	Depth (ft bls)	SC (µS/cm)	Depth (ft bls)	SC (µS/cm)
462-480	560	462-480	550-580	---	---
484-502	540	484-502	550-650	500	580-600
517-535	---	517-535	770-1115	---	---
538-556	868	538-556	1090-1115	550	460-880
538-651	526	538-651	810-1090	---	---
---	---	600	830	600	510-920

SC = Specific conductance @ 25° C

CHAPTER 4:

TEMPORAL VARIATIONS IN SPECIFIC CONDUCTANCE

Temporal variations in the conductance of ground water at various intervals in well USGS-59 are believed to be related to changes in the intrawell flow patterns caused by:

1) the pumping cycle of the ICPP production wells,

2) changes in barometric pressure,

3) ground-water sampling of the well with a dedicated pump, and

4) an obstruction of the borehole which apparently occurred during the testing period.

The following sections discuss each of these findings.

Variations in Specific Conductance due to Operation of the ICPP Production Wells

The Idaho Chemical Processing Plant has two production wells, CPP-01 (or CPP 670) and CPP-02 (or CPP 671) for supplying process (non-potable) water. These wells are at the north end of the ICPP, approximately 4000 feet from USGS-59 (Figure 2). The pumping rate of the production wells is estimated to be 3,000 gallons per minute (gpm) (Daryl Hall, ICPP Utilities Dept., personal communication). These wells are utilized on a one month, alternating rotation.

The production wells were drilled in the early 1950s, and have a 16-inch diameter well screen. The depth to water in the wells is estimated to be 456 feet bls, based on measurements taken in nearby USGS wells in April 1994. CPP-01 is screened from 460-486 feet and 527-577 feet bls. CPP-02 also is screened over two intervals of the aquifer: 458-483 feet and 551-600 feet bls (Appendix A).

The most pronounced changes in the specific conductance of ground water in well USGS-59 were short-term variations which were attributed to pumping of the ICPP production wells, about 4000 feet away. This conclusion is supported by two lines of evidence:

1) A comparison of the known time of pumping to specific conductance data collected in July 1995 indicated that the specific conductance of ground water increased during pumping; however, this did not occur during each pumping cycle.

2) The duration of the pumping cycle is very similar to the cyclical changes in specific conductance observed during October 1994 to February 1995.

Comparison of Recorded Pumping Time to Specific Conductance Data

Records of the ICPP production well pumping cycle were obtained for July 17 to July 21, 1995, and compared to specific conductance data collected at 551 feet bls during this period (Figure 5). Note that, in contrast to the specific conductance at 550 feet bls in late 1994 (Figure 7), during July 1995 the ground water conductance was typically higher (850 μS/cm) and exhibited only occasional decreases to about 650 μS/cm. On three occasions between July 17 and July 21 the specific conductance decreased to about 625 μS/cm during the off cycle, and then increased to about 840 μS/cm during pumping of the ICPP production well; however during this period the specific conductance remained nearly constant during four other pumping periods (Figure 5).

On July 21, 1995, the specific conductance probe in well USGS-59 was lowered to 588 feet bls. A record of the ICPP production well cycles was available for July 21-29, 1995. During five pumping cycles between July 21 and July 25, when the production well was turned on the specific conductance rapidly decreased about 100 μS/cm, and then increased about 200 μS/cm during pumping (Figure 6). The fluctuations in specific conductance at 588 feet bls were relatively minor during the other nine pumping cycles (Figure 6).

Comparison of Cyclical Changes in Specific Conductance to the Pumping Cycle

Specific conductance measurements collected at 550 feet bls from October 28, 1994 to December 6, 1994, and at 600 feet bls from 600 feet bls from December 22, 1994 to February 8, 1995 had discrete cycles, with peaks in specific conductance occurring at about 14 hour intervals (Figures 7 and 8). The duration of these cycles, measured between peaks, ranged from 8.5 to 16.83 hours, and averaged about 13.8 hours (Table 5). The average duration of the specific conductance cycles is very similar (within about 0.2 hours) to the average duration of the pumping cycle for the ICPP production wells measured in July and August of 1995 (Table 5).

Table 5. Comparison of the pumping cycle of the ICPP production wells to the cycles observed in the specific conductance data.

Cycle	Number of Observations	Minimum Duration (hrs)	Maximum Duration (hrs)	Average Duration (hrs)
Pumping Cycle: 7/17/95 to 8/5/95				
On	32	4.08	4.32	4.18
Off	31	8.97	11.43	9.85
Total	31	13.13	15.53	14.04
Specific Conductance @ 550 feet bls: 10/28/94 to 12/6/94				
Low to Peak	64	4.00	6.17	4.87
Peak to Peak	65	11.83	15.83	13.81
Specific Conductance @ 600 feet bls: 12/22/94 to 2/8/95				
Low to Peak	84	2.83	6.17	4.53
Peak to Peak	83	8.50	16.83	13.77

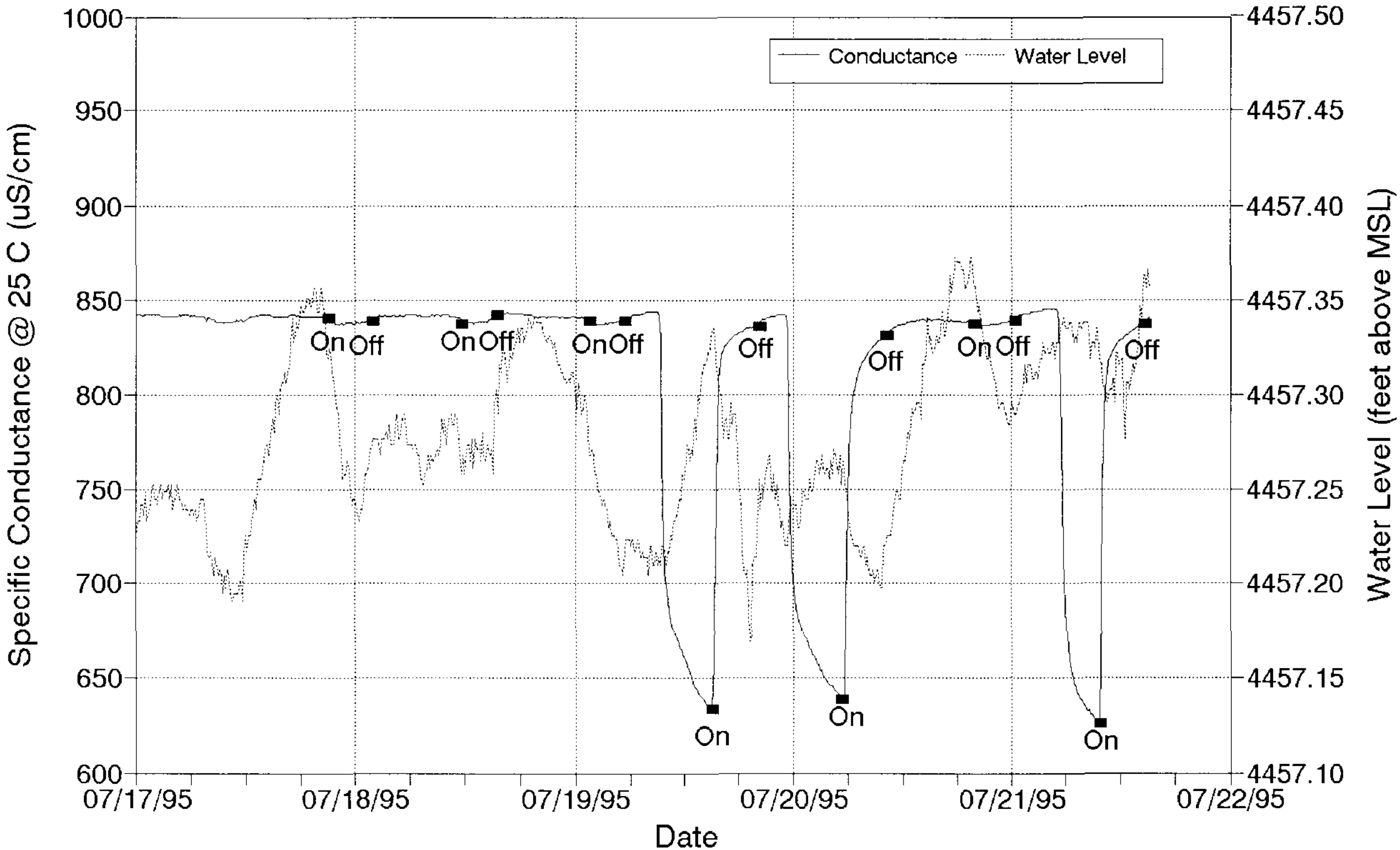

Figure 5. Specific conductance of ground water at 551 feet bls and water level in USGS-59. July 17-21, 1995. Pumping status of the ICPP production well is labeled on the graph.

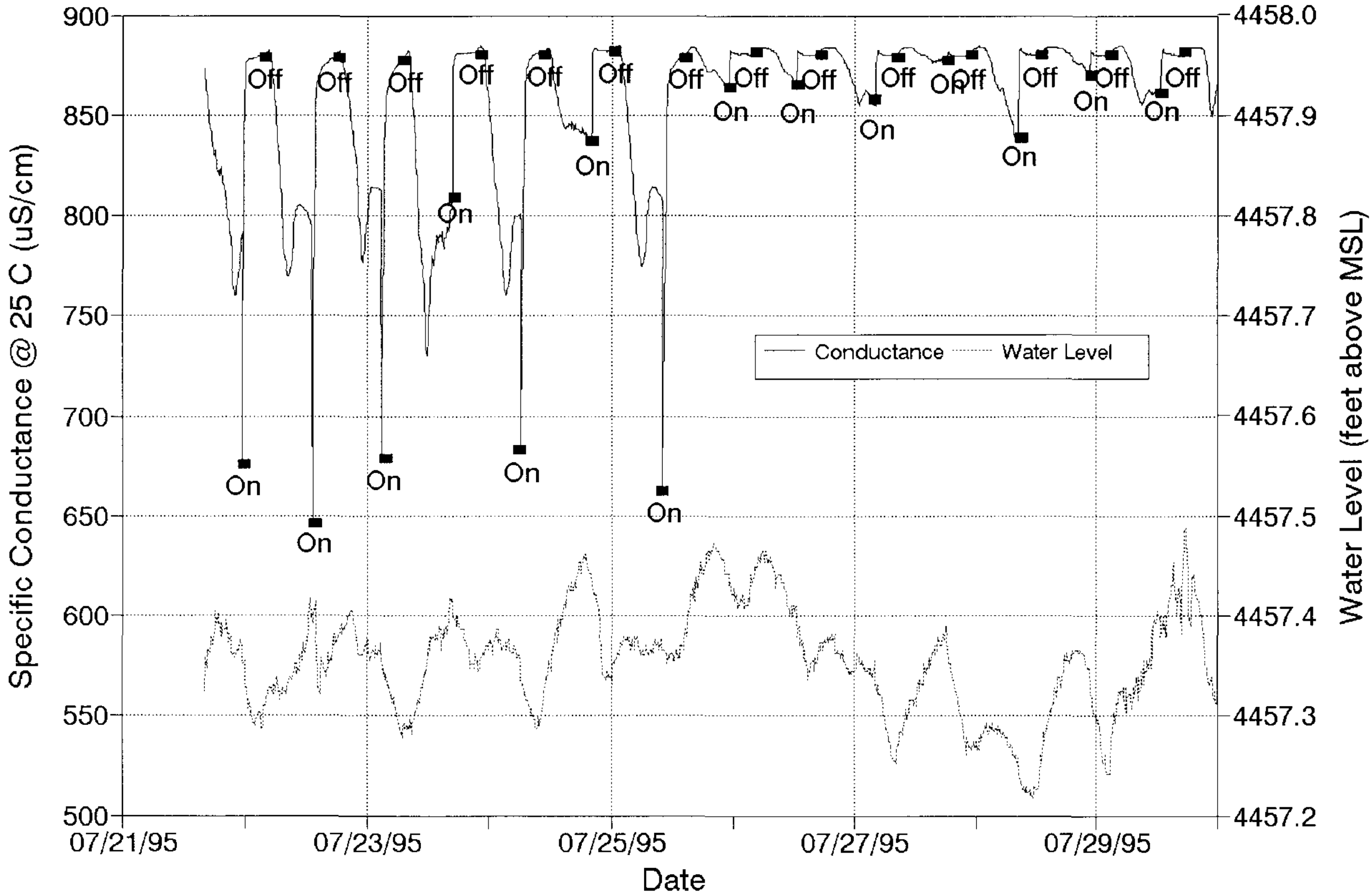

Figure 6. Specific conductance of ground water at 588 feet bls and water level in USGS-59. July 21-29, 1995. Pumping status of the ICPP production well is labeled on the graph.

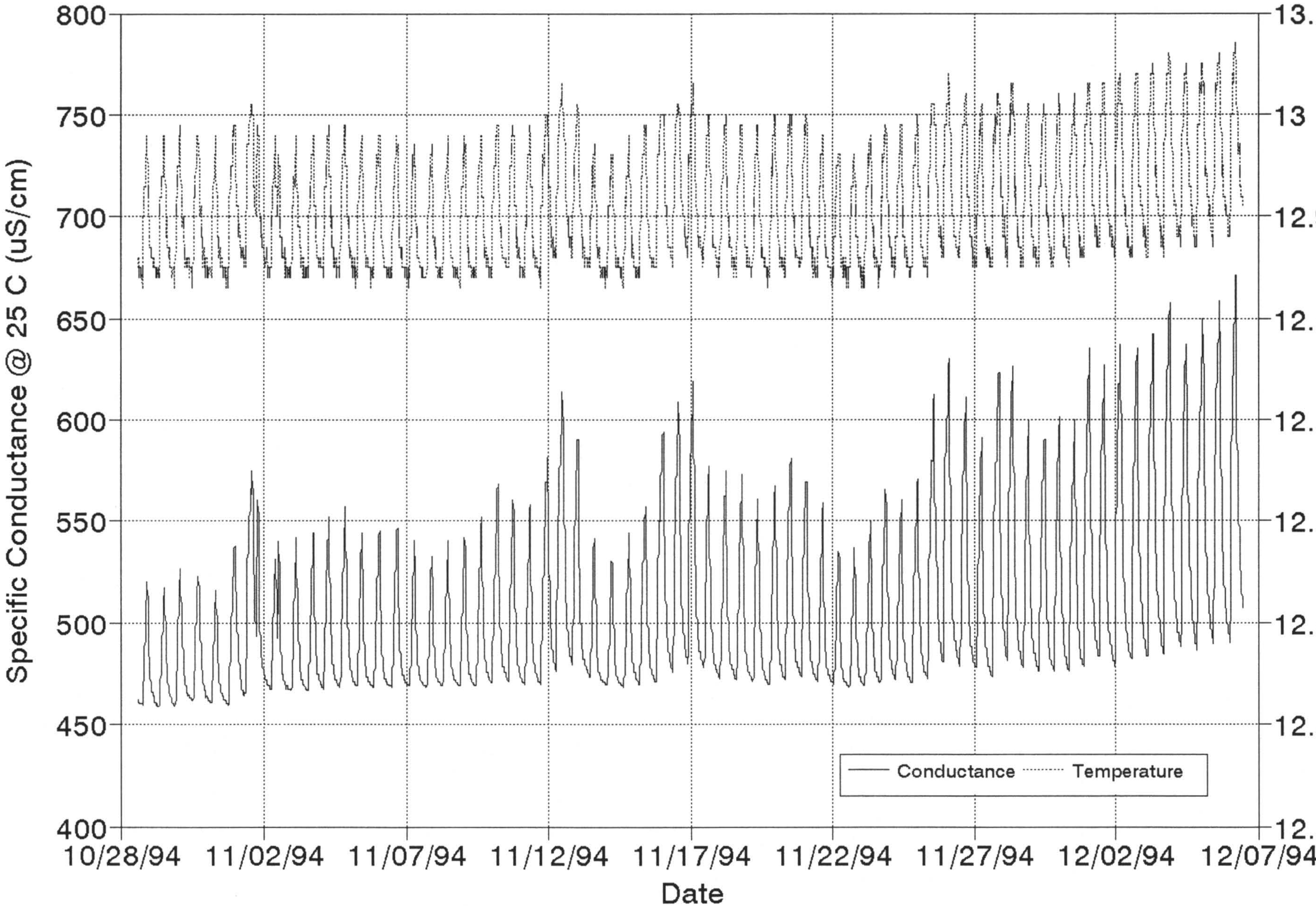

Figure 7. Specific conductance and temperature of ground-water at 550 feet bls in USGS-59, Oct. 28 to Dec. 6, 1994.

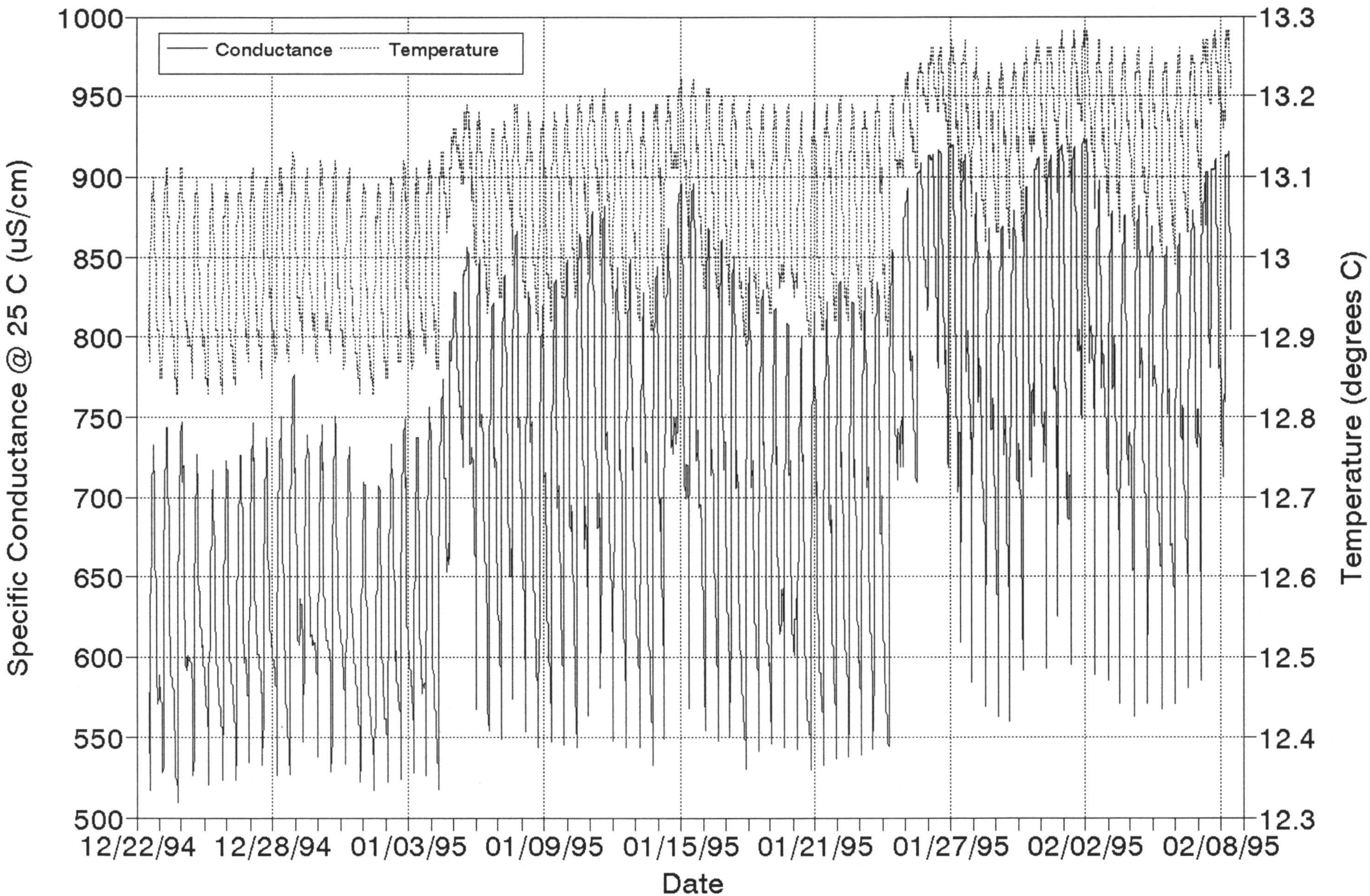

Figure 8. Specific conductance and temperature of ground water at 600 feet bls in USGS-59. December 22, 1994 to February 8, 1995.

The changes in specific conductance are asymmetric: most peaks show a rapid increase in specific conductance, followed by a more gradual decrease (Figures 7 and 8). The average period of increasing specific conductance, measured from a low to the following peak value, was 4.53 and 4.87 hours (Table 5). This is slightly longer than the average duration of the pumping in July and August 1995, which was 4.18 hours. While the cycles of the ICPP production wells and specific conductance readings are not identical, given the documented changes in specific conductance during pumping noted previously, it is compelling evidence that the variations in specific conductance observed during these monitoring periods are related to the ICPP production wells. The minor differences may be due to varying rates of water usage at the ICPP between the monitoring periods of the specific conductance data and the production well cycle.

Discussion

Frederick and Johnson (1996) used a straddle packer to monitor the water levels at various depths in well USGS-59 in response to pumping of the ICPP production wells. Given the observed drawdown, and the downward gradient in USGS-59 when a production well was operational; they interpreted the aquifer as a layered system (Frederick and Johnson, 1996). The sedimentary interbed (554 to 558 feet bls) at the top of the I-Flow was interpreted to be a leaky confining layer, which divided the system into an upper unconfined aquifer in Flow Groups E-G, and a lower, confined aquifer comprised of the I-Flow (Figure 9).

Ground-water samples collected with the straddle packer, and borehole logging conducted by Wood and Bennecke (1994), suggest that ground water with a high specific conductance ($\geq$770 μS/cm) occurs at a depth of about 520 to 558 feet bls in USGS-59 (Table 4). Wood and

Bennecke (1994) noted that ground water enters the borehole at 521 to 537 feet bls and flows down the well. Assuming that this downward gradient observed by Wood and Bennecke (1994) was during a period when an ICPP production well was operational, which would be consistent with the observations of Frederick and Johnson (1996), the fluctuations in specific conductance shown in Figures 7 and 8 could be the result of a change in the intrawell flow pattern related to pumping from a production well at ICPP. Specifically, the periodic increases in specific conductance that occurred at 550 feet bls and 600 feet bls (Figures 7 and 8) could be attributed to pumping, where an induced downward gradient draws ground water with a high specific conductance from the formation at 521 to 537 feet bls and down the borehole. When the pump is turned off, the conductance decreases to a baseline of about 500 μS/cm. This decrease apparently represents considerable mixing with lower conductance water above and/or below this interval. Presumably, upward flow occurs in the well when the pump is turned off, and the ground water with a lower specific conductance comes from deeper intervals in the well (see page 18).

In the fall of 1995, an impeller flow meter was deployed in USGS-59 to determine whether flow reversals occurred in the well in response operation of the ICPP production wells; however, the effort was unsuccessful due to the presence of an obstruction in the borehole at 588 feet bls. The obstruction was discovered when a video log of the well was taken in October 1995, and appears to be a fragment of columnar basalt that caved into the well, probably between February 1995 and June 1995.[3]

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[3] In contrast to the specific conductance data collected at 550 feet bls in October-December 1994, only occasional fluctuations in specific conductance occurred at this depth in June 1995 (compare Figures 7 and C3).

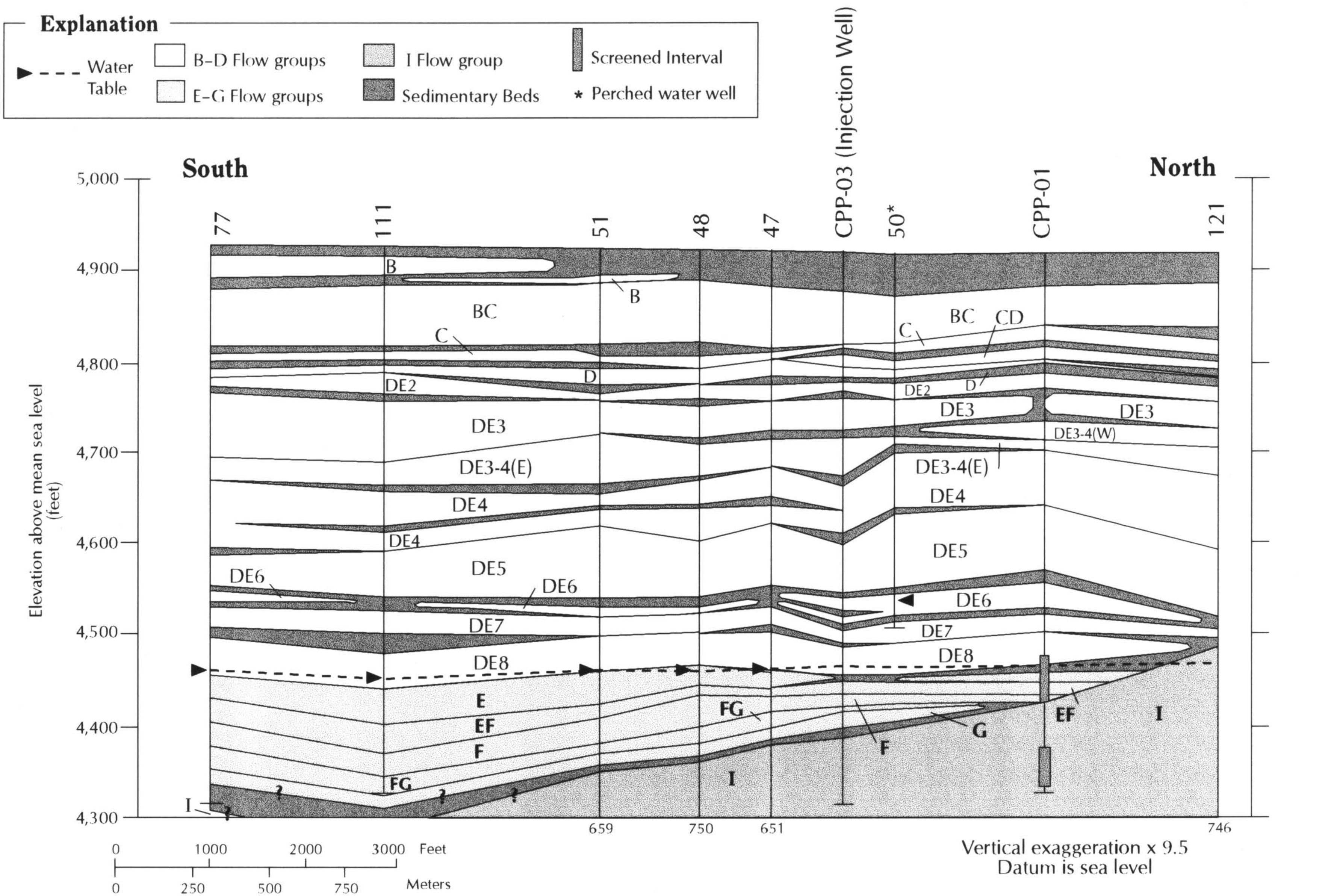

Figure 9. Geologic cross section at the Idaho Chemical Processing Plant (after Anderson, 1991). See figure 2 for location of cross section.

The specific conductance data collected at 551 and 588 feet bls in July 1995 is problematic for two reasons:

1) The specific conductance was generally higher in July 1995 than during October-December 1994.

2) Large fluctuations in specific conductance did not occur during each pumping cycle.

The higher specific conductance measurements in July 1995 may be related to a change in the intrawell flow regime resulting from the obstruction in the borehole. For example, the obstruction may impede vertical flow in the well, and the contrast between the specific conductance data collected during these periods may result from a lack of ground water with a lower specific conductance moving up the borehole when the production well is off.

The reason why the specific conductance remained nearly constant during some pumping cycles cannot be readily explained. Between July 17 and July 21, 1995, the production well was pumped seven times; the duration of pumping ranged from four hours and five minutes and four hours and eighteen minutes. The specific conductance at 551 feet bls increased markedly during only three of the seven pumping cycles (Figure 5). Similarly, from July 21 to July 29, 1995 the specific conductance at 588 feet bls did not fluctuate during each pumping cycle: large changes in specific conductance were only noted during five of the fourteen pumping cycles (figure 6). Whether or not a significant change in specific conductance occurs during the pumping cycle does not appear to be related to the water level in the well, or the magnitude of the change in water level during pumping. Furthermore, it does not appear to be a function of the duration of pumping, or the length of time which the pump was off prior to pumping (Figures 5 and 6). Because CPP-01 and CPP-02 are used on a monthly rotation, only one of these wells should have been operational during this period. Therefore the change in specific conductance does not appear to be related to use of a specific production well.

Relationship Between Barometric Pressure and Specific Conductance

The specific conductance data collected at 600 feet bls between December 1994 and February 1995 suggests that barometric pressure alters the intrawell flow patterns and, consequently, the specific conductance of ground water at some depths in the well. As illustrated in Figure 10, which is an 80-point moving average of the specific conductance at 600 feet bls versus barometric pressure, a decrease in the average specific conductance corresponded to an increase in barometric pressure, and vice versa.[4] This correlation was also observed at 550 feet bls.

The relationship between barometric pressure and specific conductance may indicate differing barometric efficiencies within discrete layers of the aquifer, provided there are differences in the specific conductance of ground water and the water levels in the layers. The first of these conditions, a layered aquifer with differing characteristics, has already been proposed. Frederick and Johnson (1996) described the Snake River Plain aquifer near the ICPP as a layered system, consisting of an unconfined aquifer in basalt Flow Groups E-G and a confined aquifer in Flow Group I (Figure 9). The unconfined aquifer would be expected to have a barometric efficiency near zero, and the barometric efficiency of the confined aquifer would be higher,

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[4] A moving average was used to smooth the short-term fluctuations in specific conductance (compare Figures 8 and 10).

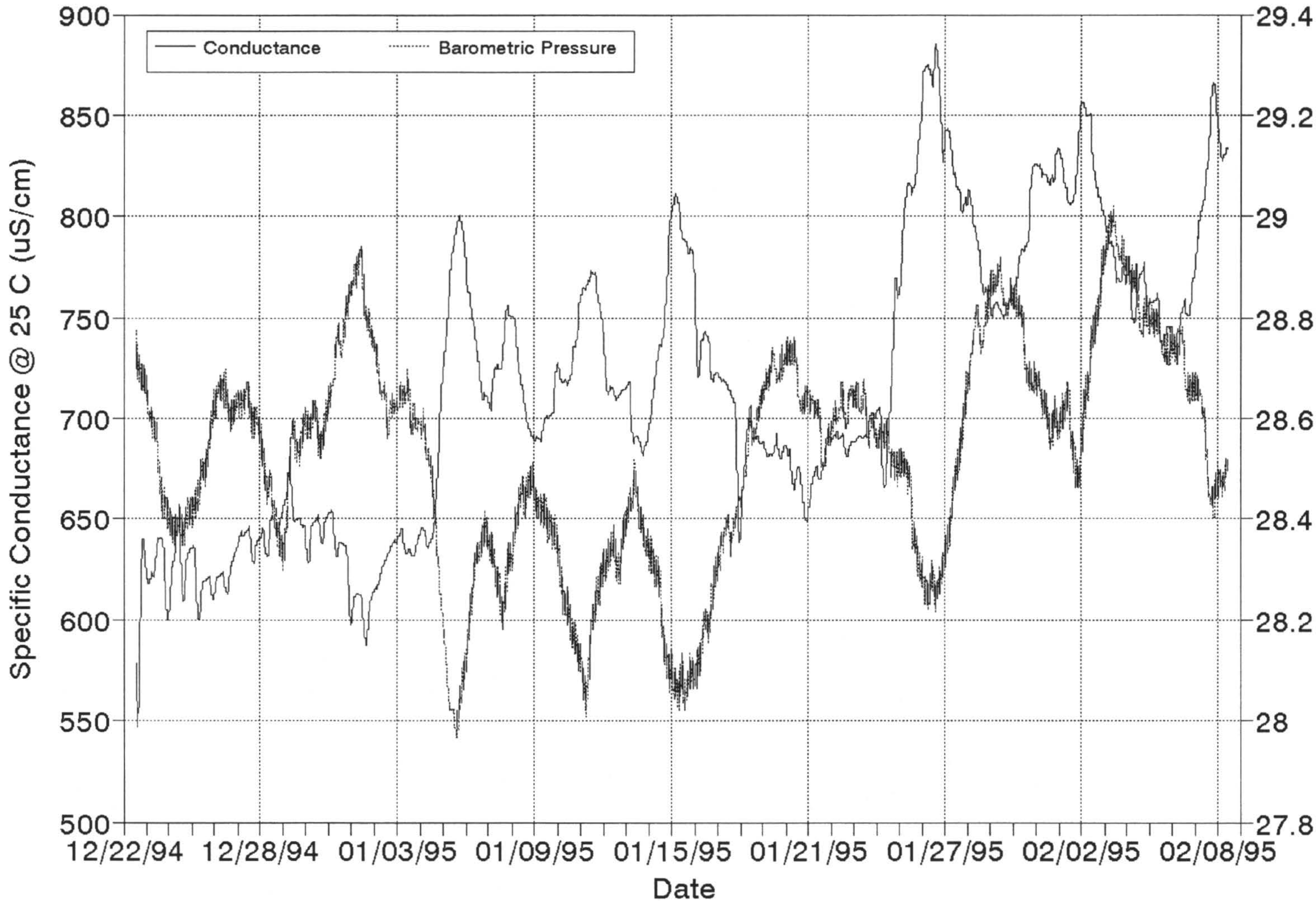

Figure 10. Specific conductance of ground water (80-point moving average) at 600 feet bls in USGS-59 and barometric pressure. December 22, 1994 to February 8, 1995.

presumably between 0.2 and 0.75 (Freeze and Cherry, 1979). Further, the ground water in the confined aquifer (depths greater than about 558 feet bls) generally has a lower specific conductance than the ground water in the unconfined aquifer (see Table 4).

Previous studies on vertical flow in wells near the ICPP suggest that the water level in the confined aquifer is higher than the water level in the unconfined aquifer when the production well is off (i.e. vertical flow component is from Flow Group I up to Flow Groups E-G). Morin and others (1993) documented upward flow in USGS-44, USGS-45, and USGS-46. Downward flow occurred in USGS-46 when CPP-02 was on; however the pumping status of the ICPP production wells was not known during testing of the other wells.

Observation well USGS-59 is open to the aquifer in both the unconfined and confined layers. Barometric pressure changes effect the water level of the confined system, therefore periods of low barometric pressure result in a higher water level in the well, and decrease the difference between the water level in the confined aquifer and that in the well. As such, the upward vertical gradient is smaller, resulting in less ground water with relatively low specific conductance moving up the borehole from Flow Group I. As a result, periods of low barometric pressure correspond to periods of higher specific conductance, and vice versa.

Variations in Specific Conductance During Sampling of USGS-59 with a Dedicated Pump

Contaminant plumes are generally mapped in two dimensions displaying areal extent. When vertical chemical gradients are present, this approach presents a limited view of the actual shape and character of the plume. Well USGS-59 is open over a saturated interval of nearly 200 feet, and exhibits vertical variations in water quality (Table 4). Because of the large open interval, it is not clear whether a ground-water sample collected with a dedicated pump represents the characteristics of formation water near the pump intake, or some average of the vertical stratification of contaminants in the aquifer. Where stratification exists, in-situ specific conductance measurements collected while the well is being purged and sampled can be beneficial during the interpretation of the analytical results.

Ground-water samples from USGS-59 were collected by personnel from the U.S. Geological Survey on April 14, 1995. The well was also sampled by a DOE contractor on May 18, 1995. During both sampling events, a specific conductance probe was deployed in the well at 499 feet bls. The submersible pump used to purge the well and collect the sample has an intake at 490 feet bls, and a pumping rate of three gpm (Mann, 1996). When the sampling pump was turned on, the specific conductance at 499 feet bls increased rapidly from about 600 μS/cm to over 850 μS/cm (Figures 11 and 12). The specific conductance at the time the sample was collected was about 700 μS/cm on April 14 and over 850 μS/cm on May 18. The samples from USGS-59 on April 14 and May 18 were both collected during a period when the ICPP production well was off.

During this study, the specific conductance of ground water in USGS-59 ranged from about 460 to 920 μS/cm (Table 4); the specific conductance of the ground-water samples collected in April and May of 1995 (700 μS/cm and 850 μS/cm) are near the middle to upper end of this range, suggesting that some portion of the water sample collected with the dedicated pump was drawn from levels of the aquifer with a high specific conductance, such as 521-537 feet bls (Chapter 3). Therefore, it appears that in observation well USGS-59 ground-water samples collected while the production well was off represent some average of the vertical water quality profile.

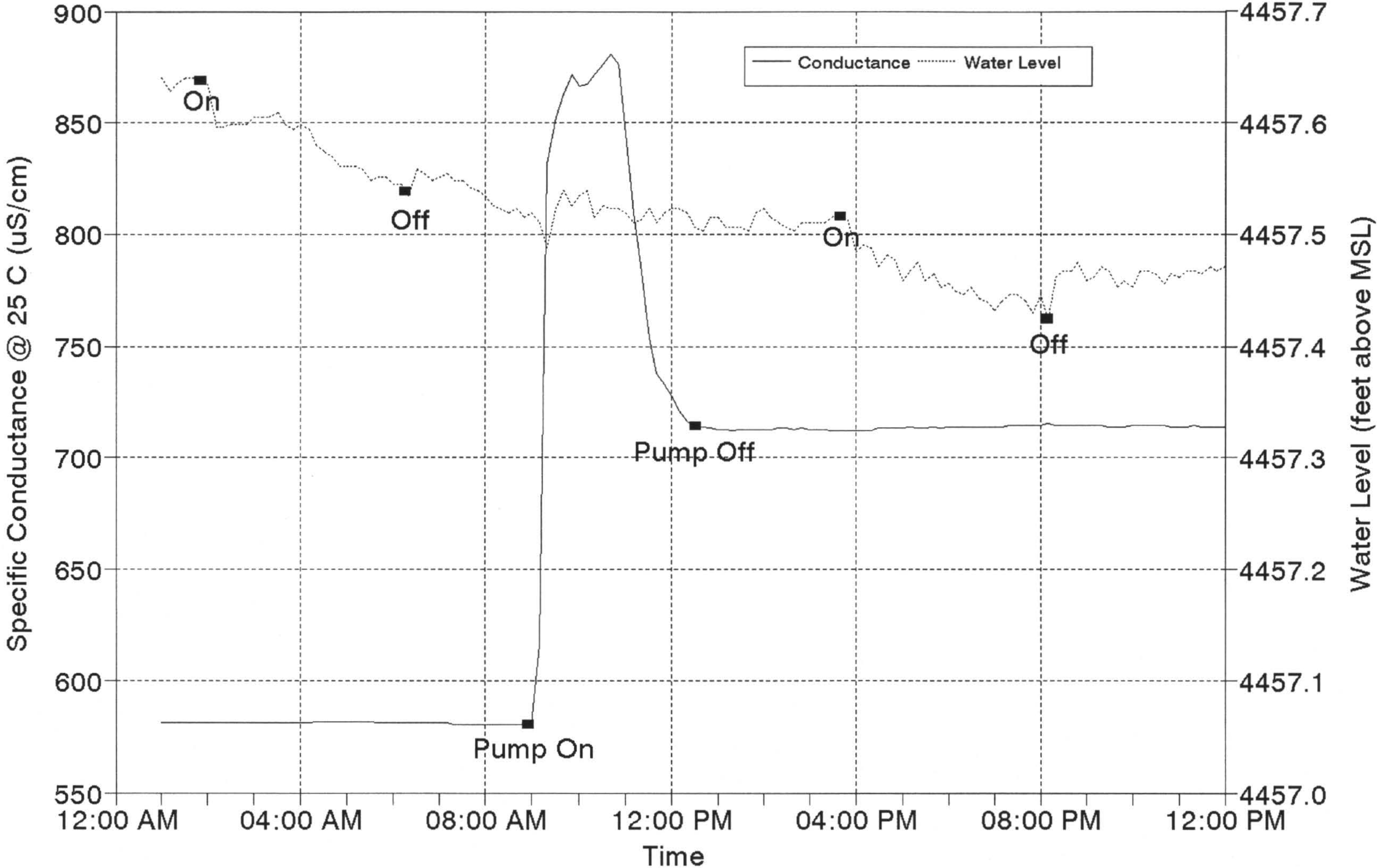

Figure 11. Specific conductance of ground water at 499 feet bls and water level in USGS-59 on April 14, 1995. "Pump On" and "Pump Off" refer to status of the sampling pump. "On" and "Off" refer to the pumping status of the ICPP production well. Note the production well has a more pronounced effect on hydraulic head than the sampling pump.

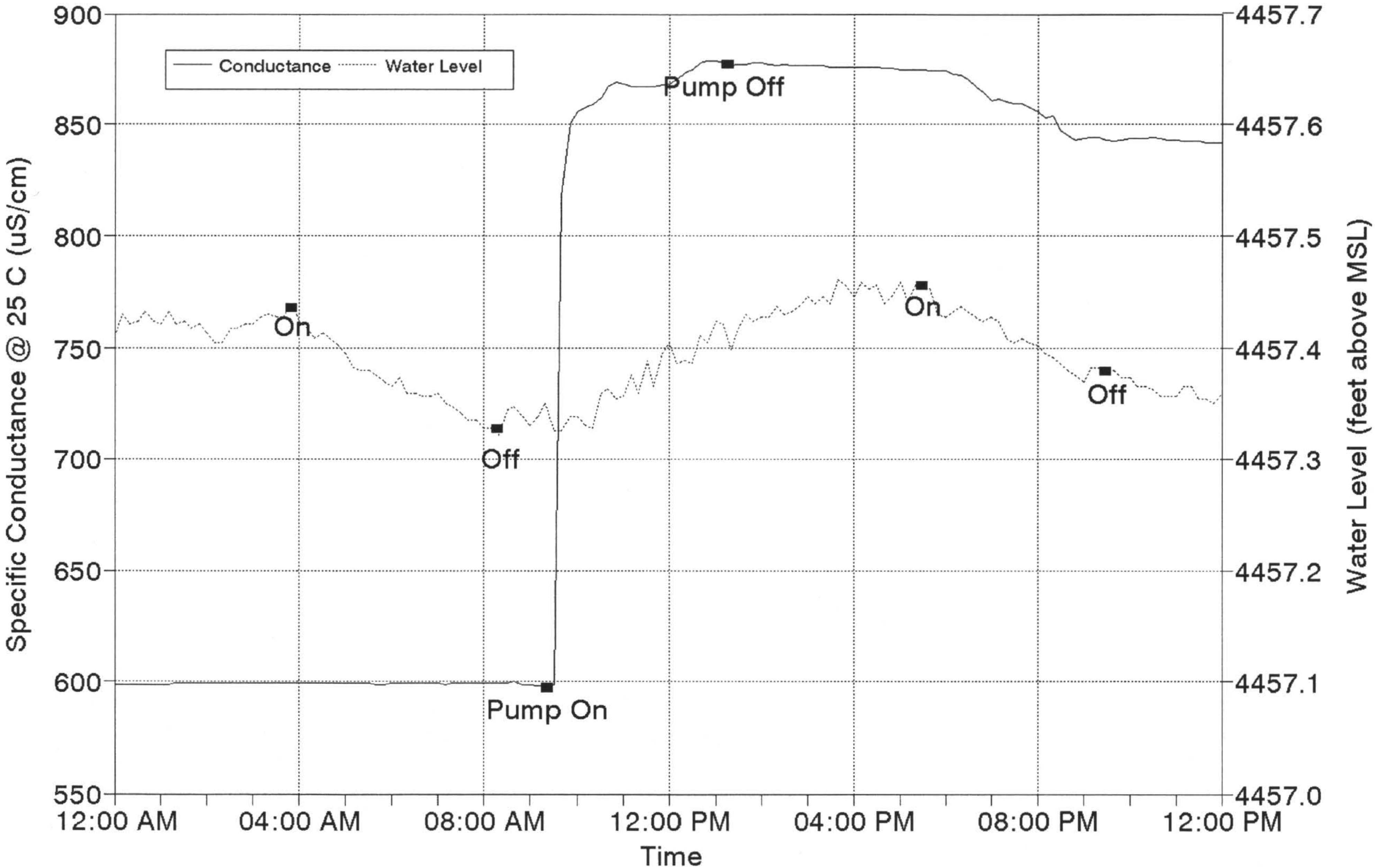

Figure 12. Specific conductance of ground water at 499 feet bls and water level in USGS-59 on May 18, 1995. "Pump On" and "Pump Off" refer to the status of the sampling pump. "On" and "Off" refer to the pumping status of the ICPP production well.

CHAPTER 5:

SUMMARY

The specific conductance (i.e. water quality) in observation well USGS-59 is subject to vertical and temporal variations. Measurements of the specific conductance of ground water at discrete depths in USGS-59 vary by more than 300 μS/cm, indicating considerable stratification in the water quality of the aquifer.

At some depths in USGS-59, temporal variations in specific conductance exceeded 200 μS/cm as a result of pumping from the ICPP production wells. The inverse relationship between specific conductance and barometric pressure is apparently related to variations in borehole flow resulting from differences in the barometric efficiency of the aquifer layers.

Variations in the vertical hydraulic gradient in USGS-59 induced by pumping from an ICPP production well could presumably affect sampling results by affecting intrawell flow patterns. Wood and Bennecke (1994) measured a downward flow rate of 10 to 15 gallons per minute (gpm) in USGS-59, presumably while an ICPP production well was operational. The intake of the dedicated submersible pump used to sample this well has an intake at 490 feet bls. The discharge rate of the sampling pump is three gpm, or 25-33% of the downward flow rate measured in the well by Wood and Bennecke (1994). As a result, ground-water samples collected while the production well is pumping may contain a smaller percentage of water from deeper intervals in the borehole.

The temperature of ground water in the observation well was typically between 12.8° and 13.8° C. Minor fluctuations in temperature (a few tenths of a degree) occurred as a result of pumping from one of the ICPP production wells.

Suggestions for Future Work

1) Remove the obstruction from USGS-59 and conduct flow logging to determine vertical gradients in the well throughout the pumping cycle. Continue in-situ specific conductance monitoring to determine whether the monitoring results during October 1994 to February 1995 are reproducible.

2) Compare/contrast analytical results of ground-water samples collected with a dedicated pump during periods of pumping versus non-pumping to quantify changes in contaminant concentrations resulting from the vertical gradient induced by the production well.

3) Compare/contrast new and existing analytical data from ground-water samples collected by the USGS and the DOE contractors to determine whether the variations in specific conductance can be related to a specific contaminant(s).

4) Monitor the specific conductance and temperature of ground water in nearby observation wells to determine whether the relationships between specific conductance and pumping from the ICPP production wells are unique to USGS-59.

5) Conduct additional flow logging in observation wells near the ICPP to further document vertical flow directions and rates in the wells.

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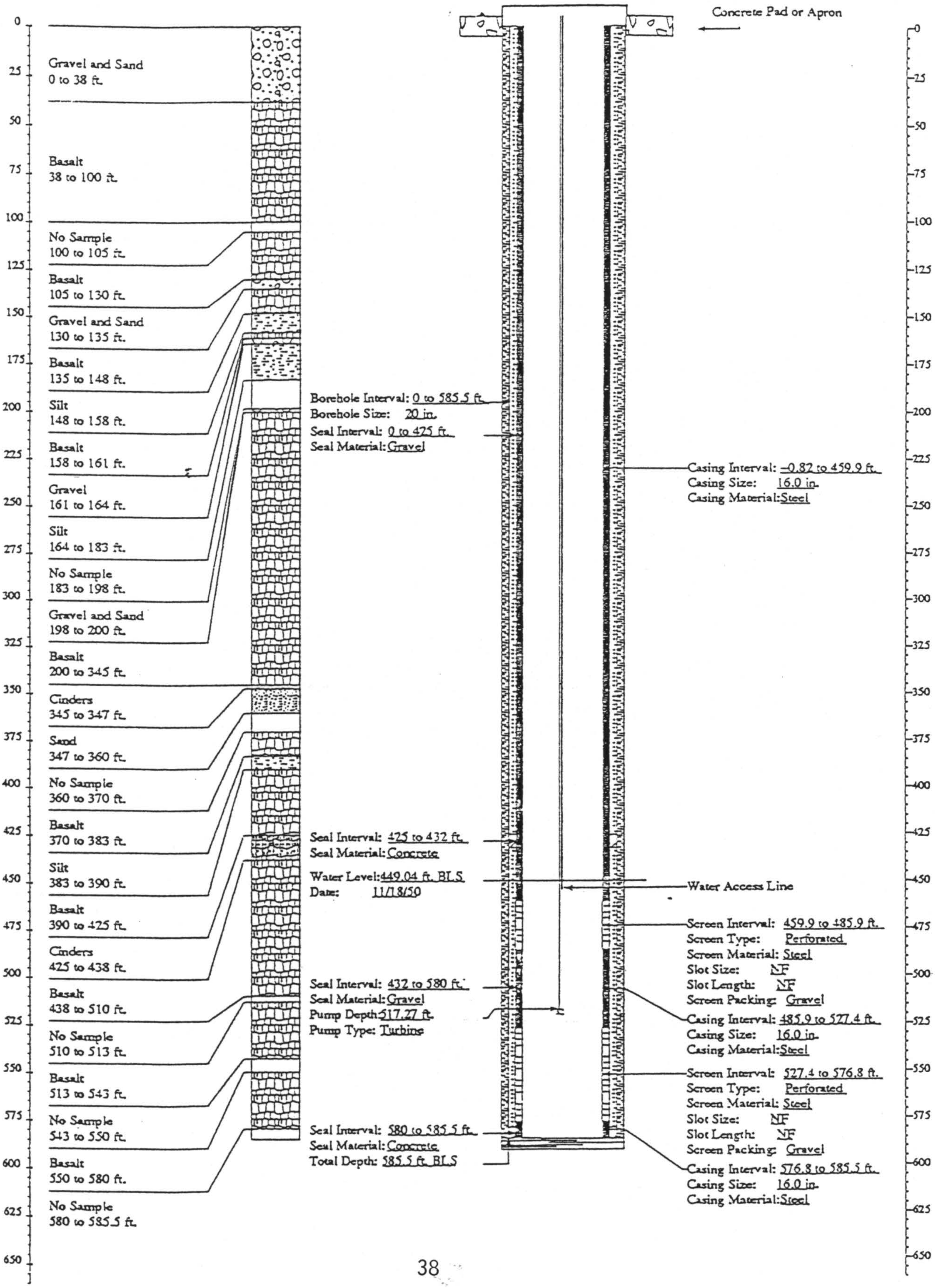
APPENDIX A

Well Construction Diagrams

and Lithology Logs

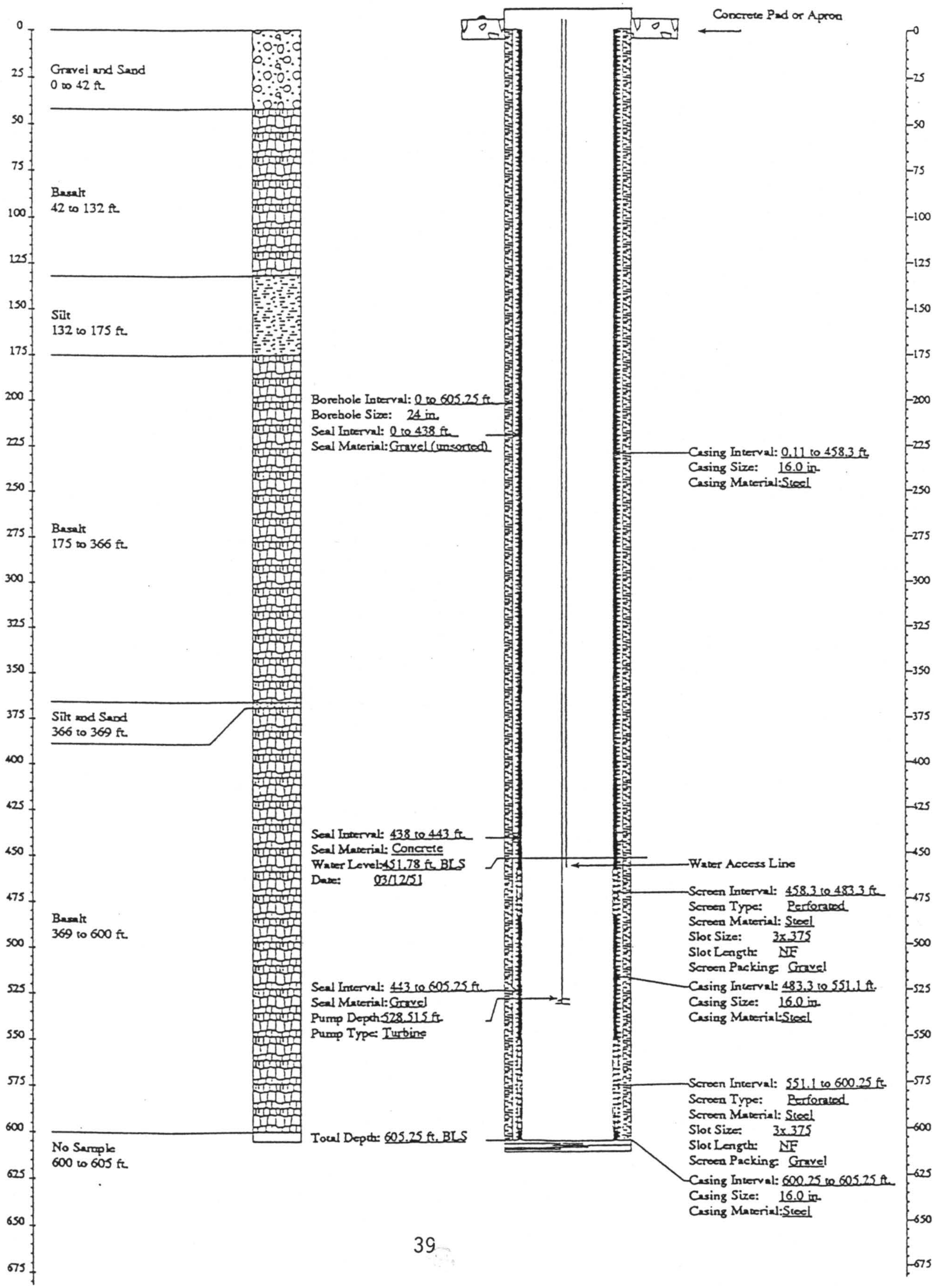
(from Sehlke and others, 1993)

CPP-01



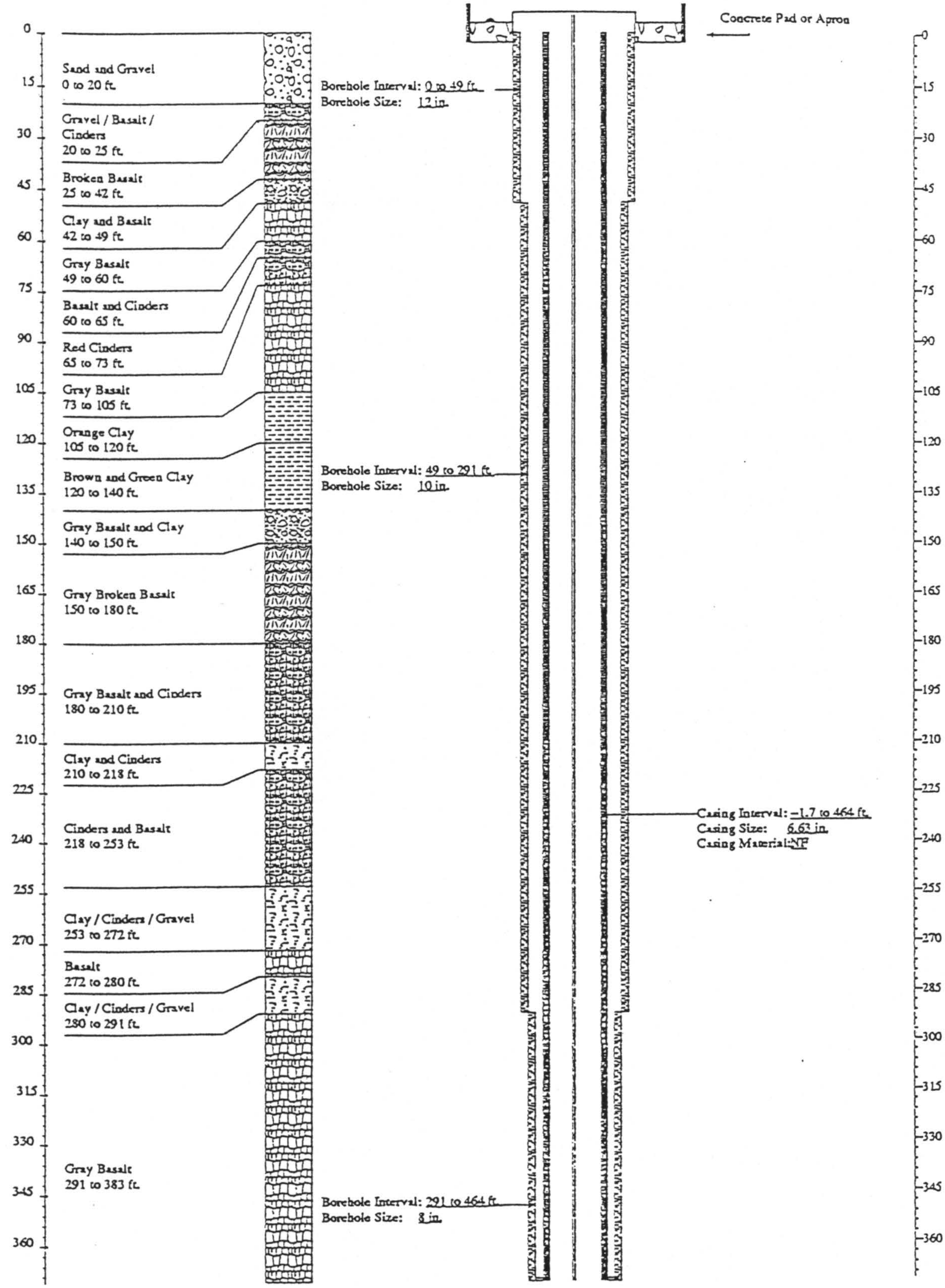
Concrete Pad or Apron
Gravel and Sand 0 to 38 ft.
Basalt 38 to 100 ft.
No Sample 100 to 105 ft.
Basalt 105 to 130 ft.
Gravel and Sand 130 to 135 ft.
Basalt 135 to 148 ft.
Silt 148 to 158 ft.
Basalt 158 to 161 ft.
Gravel 161 to 164 ft.
Silt 164 to 183 ft.
No Sample 183 to 198 ft.
Gravel and Sand 198 to 200 ft.
Basalt 200 to 345 ft.
Cinders 345 to 347 ft.
Sand 347 to 360 ft.
No Sample 360 to 370 ft.
Basalt 370 to 383 ft.
Silt 383 to 390 ft.
Basalt 390 to 425 ft.
Cinders 425 to 438 ft.
Basalt 438 to 510 ft.
No Sample 510 to 513 ft.
Basalt 513 to 543 ft.
No Sample 543 to 550 ft.
Basalt 550 to 580 ft.
No Sample 580 to 585.5 ft.
Borehole Interval: 0 to 585.5 ft.
Borehole Size: 20 in.
Seal Interval: 0 to 425 ft.
Seal Material: Gravel
Casing Interval: -0.82 to 459.9 ft.
Casing Size: 16.0 in.
Casing Material: Steel
Seal Interval: 425 to 432 ft.
Seal Material: Concrete
Water Level: 449.04 ft. BLS
Date: 11/18/50
Water Access Line
Screen Interval: 459.9 to 485.9 ft.
Screen Type: Perforated
Screen Material: Steel
Slot Size: NF
Slot Length: NF
Screen Packing: Gravel
Seal Interval: 432 to 580 ft.
Seal Material: Gravel
Pump Depth: 517.27 ft.
Pump Type: Turbine
Casing Interval: 485.9 to 527.4 ft.
Casing Size: 16.0 in.
Casing Material: Steel
Screen Interval: 527.4 to 576.8 ft.
Screen Type: Perforated
Screen Material: Steel
Slot Size: NF
Slot Length: NF
Screen Packing: Gravel
Seal Interval: 580 to 585.5 ft.
Seal Material: Concrete
Total Depth: 585.5 ft. BLS
Casing Interval: 576.8 to 585.5 ft.
Casing Size: 16.0 in.
Casing Material: Steel
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650

CPP-02

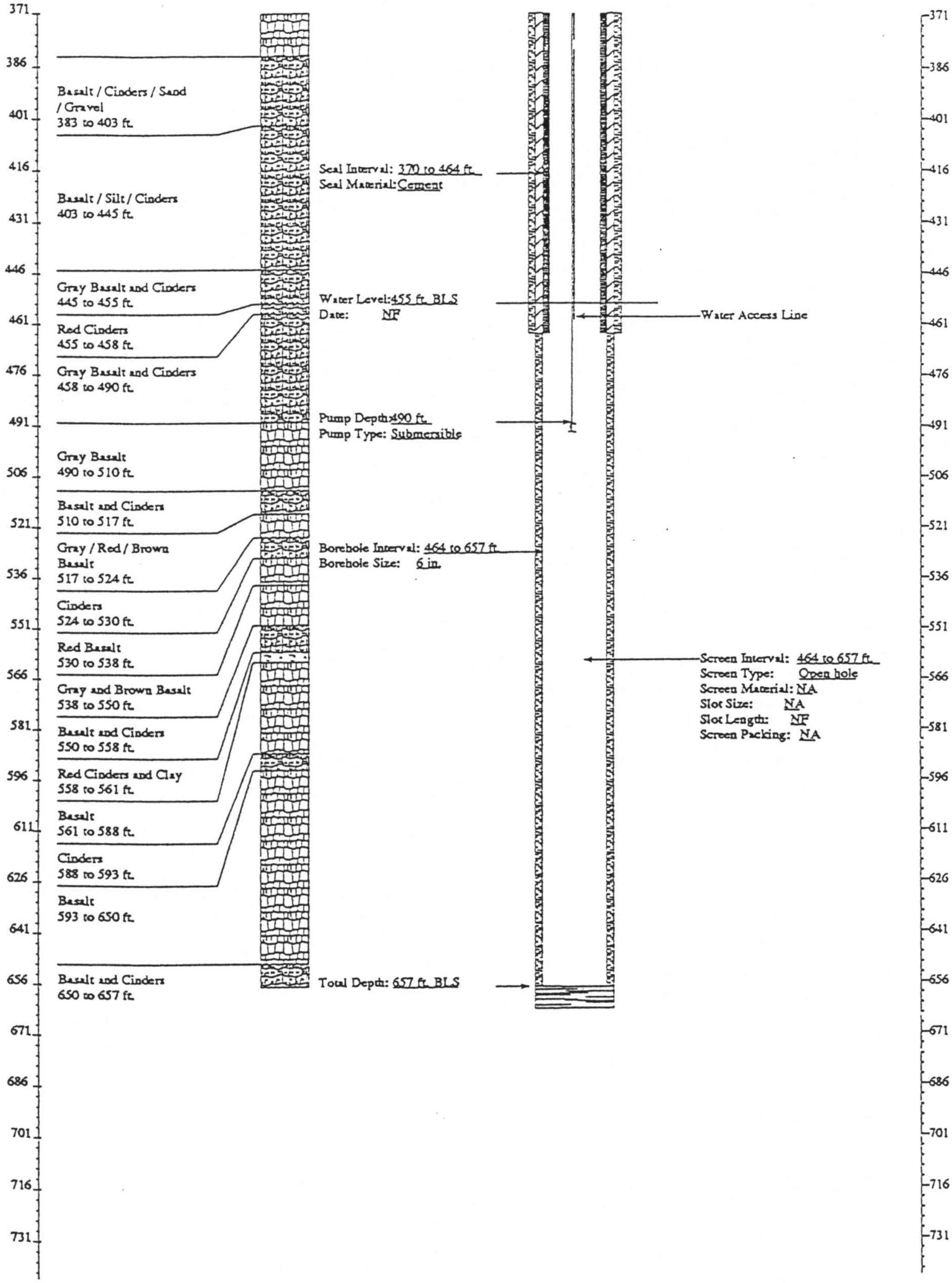


Gravel and Sand
0 to 42 ft.
Basalt
42 to 132 ft.
Silt
132 to 175 ft.
Basalt
175 to 366 ft.
Silt and Sand
366 to 369 ft.
Basalt
369 to 600 ft.
No Sample
600 to 605 ft.
Concrete Pad or Apron
Borehole Interval: 0 to 605.25 ft.
Borehole Size: 24 in.
Seal Interval: 0 to 438 ft.
Seal Material: Gravel (unsorted)
Casing Interval: 0.11 to 458.3 ft.
Casing Size: 16.0 in.
Casing Material: Steel
Seal Interval: 438 to 443 ft.
Seal Material: Concrete
Water Level: 451.78 ft. BLS
Date: 03/12/51
Water Access Line
Screen Interval: 458.3 to 483.3 ft.
Screen Type: Perforated
Screen Material: Steel
Slot Size: 3x.375
Slot Length: NF
Screen Packing: Gravel
Seal Interval: 443 to 605.25 ft.
Seal Material: Gravel
Pump Depth: 528.515 ft.
Pump Type: Turbine
Casing Interval: 483.3 to 551.1 ft.
Casing Size: 16.0 in.
Casing Material: Steel
Screen Interval: 551.1 to 600.25 ft.
Screen Type: Perforated
Screen Material: Steel
Slot Size: 3x.375
Slot Length: NF
Screen Packing: Gravel
Total Depth: 605.25 ft. BLS
Casing Interval: 600.25 to 605.25 ft.
Casing Size: 16.0 in.
Casing Material: Steel

USGS-59


Sand and Gravel 0 to 20 ft.
Gravel / Basalt / Cinders 20 to 25 ft.
Broken Basalt 25 to 42 ft.
Clay and Basalt 42 to 49 ft.
Gray Basalt 49 to 60 ft.
Basalt and Cinders 60 to 65 ft.
Red Cinders 65 to 73 ft.
Gray Basalt 73 to 105 ft.
Orange Clay 105 to 120 ft.
Brown and Green Clay 120 to 140 ft.
Gray Basalt and Clay 140 to 150 ft.
Gray Broken Basalt 150 to 180 ft.
Gray Basalt and Cinders 180 to 210 ft.
Clay and Cinders 210 to 218 ft.
Cinders and Basalt 218 to 253 ft.
Clay / Cinders / Gravel 253 to 272 ft.
Basalt 272 to 280 ft.
Clay / Cinders / Gravel 280 to 291 ft.
Gray Basalt 291 to 383 ft.
Concrete Pad or Apron
Borehole Interval: 0 to 49 ft.
Borehole Size: 12 in.
Borehole Interval: 49 to 291 ft.
Borehole Size: 10 in.
Borehole Interval: 291 to 464 ft.
Borehole Size: 8 in.
Casing Interval: -1.7 to 464 ft.
Casing Size: 6.63 in.
Casing Material: NF
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
255
270
285
300
315
330
345
360

USGS-59


371
386
401
416
431
446
461
476
491
506
521
536
551
566
581
596
611
626
641
656
671
686
701
716
731
Basalt / Cinders / Sand / Gravel
383 to 403 ft.
Basalt / Silt / Cinders
403 to 445 ft.
Gray Basalt and Cinders
445 to 455 ft.
Red Cinders
455 to 458 ft.
Gray Basalt and Cinders
458 to 490 ft.
Gray Basalt
490 to 510 ft.
Basalt and Cinders
510 to 517 ft.
Gray / Red / Brown Basalt
517 to 524 ft.
Cinders
524 to 530 ft.
Red Basalt
530 to 538 ft.
Gray and Brown Basalt
538 to 550 ft.
Basalt and Cinders
550 to 558 ft.
Red Cinders and Clay
558 to 561 ft.
Basalt
561 to 588 ft.
Cinders
588 to 593 ft.
Basalt
593 to 650 ft.
Basalt and Cinders
650 to 657 ft.
Seal Interval: 370 to 464 ft.
Seal Material: Cement
Water Level: 455 ft. BLS
Date: NF
Water Access Line
Pump Depth: 490 ft.
Pump Type: Submersible
Borehole Interval: 464 to 657 ft.
Borehole Size: 6 in.
Screen Interval: 464 to 657 ft.
Screen Type: Open hole
Screen Material: NA
Slot Size: NA
Slot Length: NF
Screen Packing: NA
Total Depth: 657 ft. BLS

APPENDIX B

Water Level in USGS-59

and Barometric Pressure

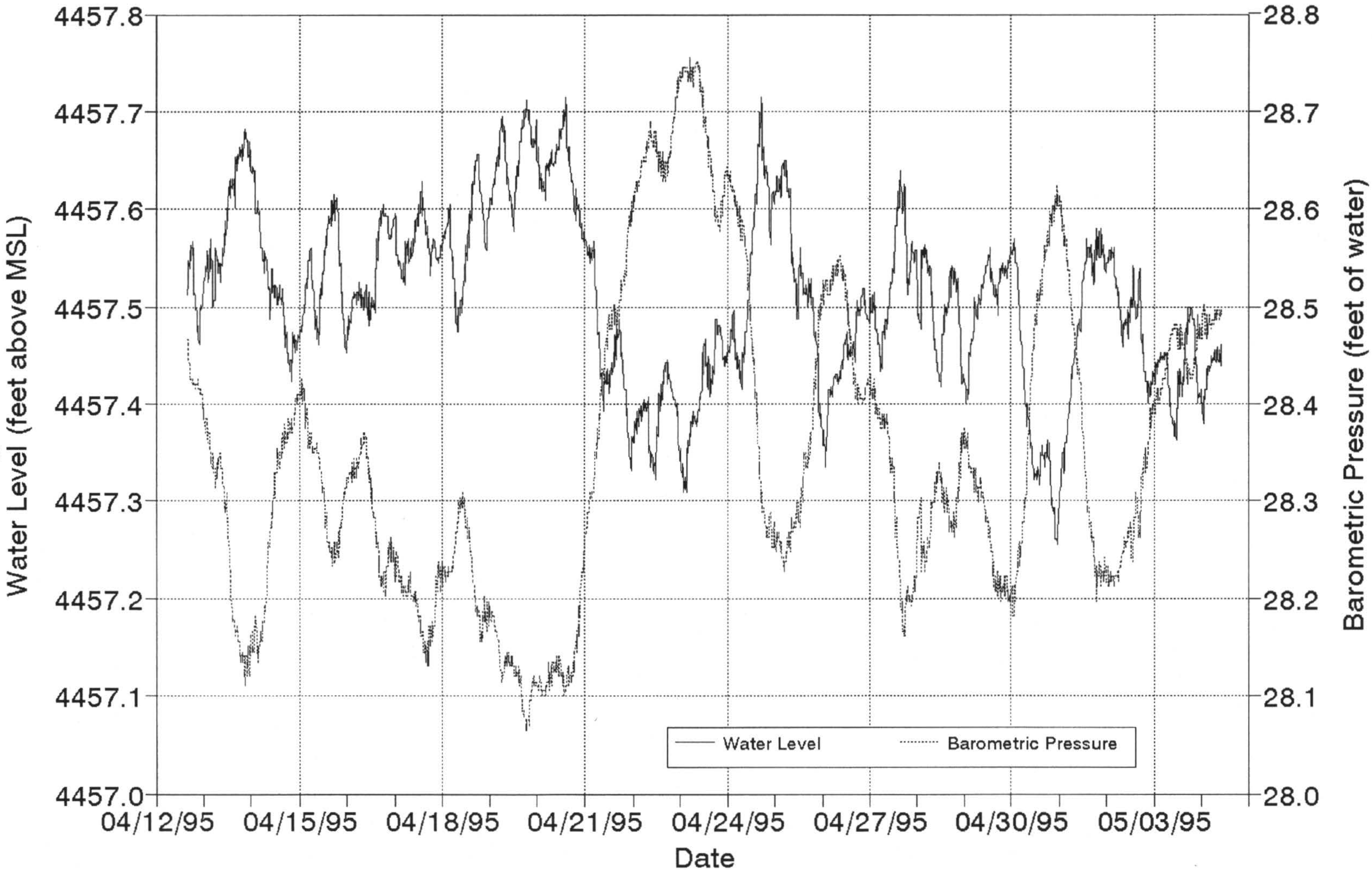


Figure B1. Water level in USGS-59 and barometric pressure, April 12 to May 4, 1995.

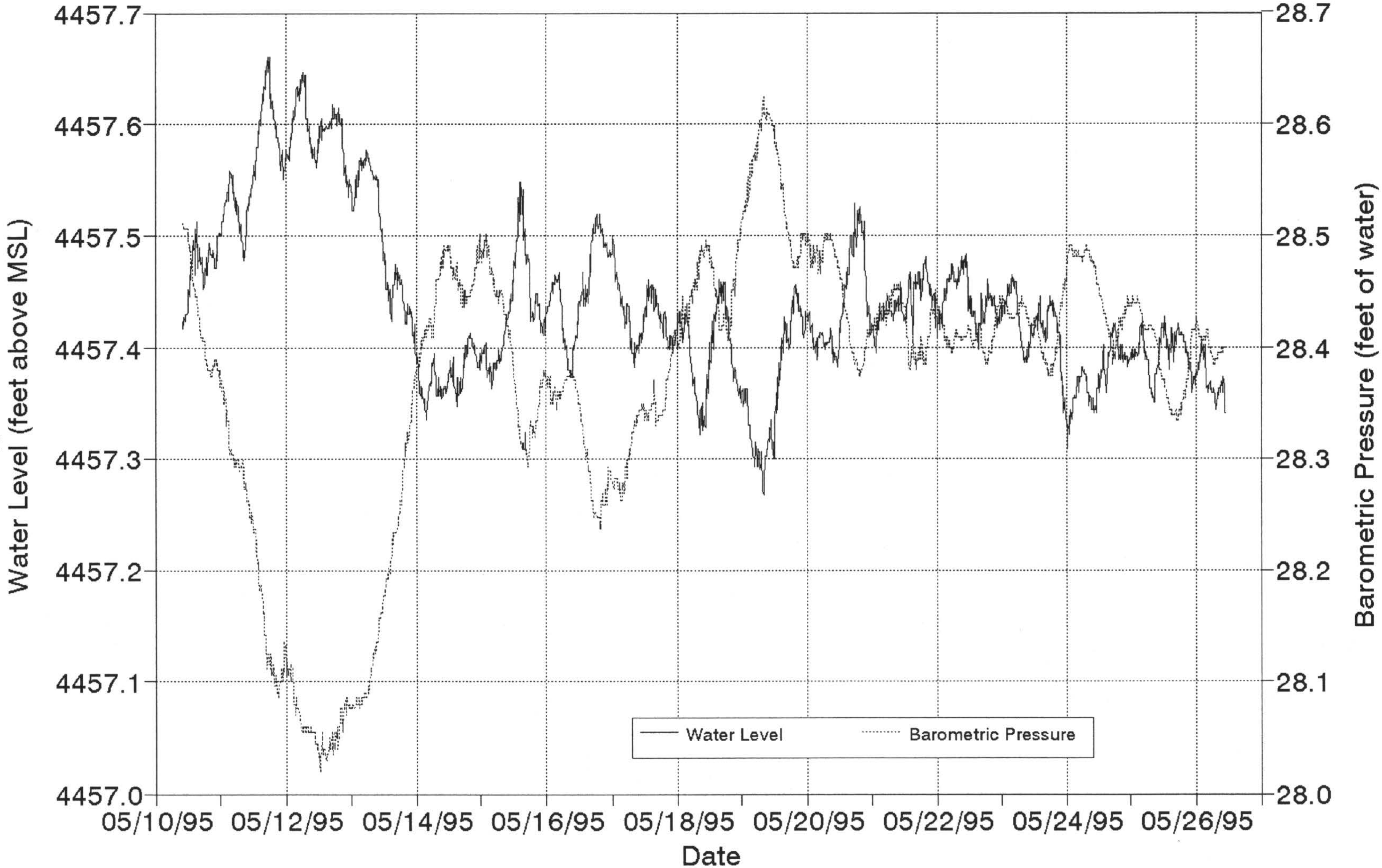


Figure B2. Water level in USGS-59 and barometric pressure, May 10-26, 1995.

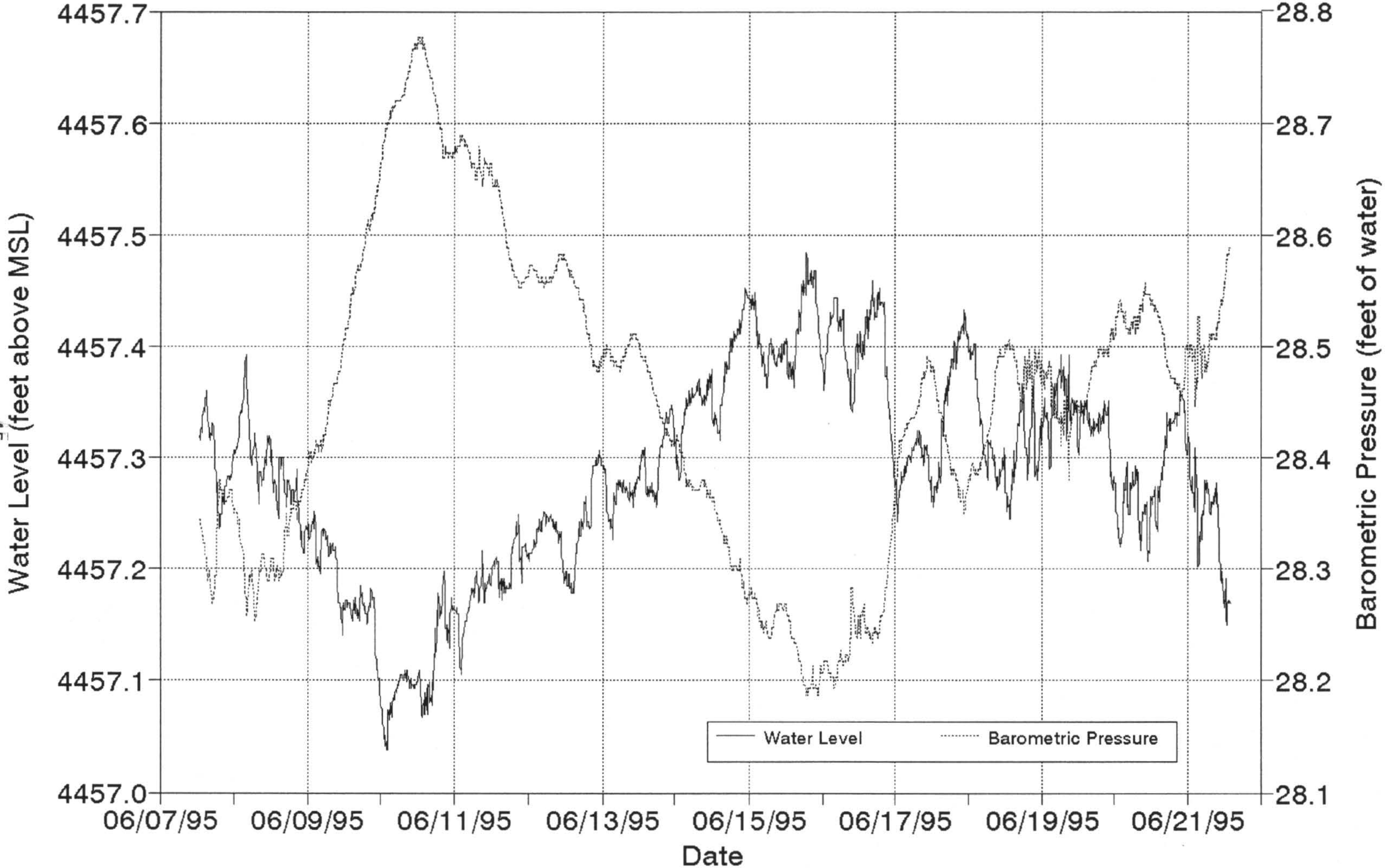


Figure B3. Water level in USGS-59 and barometric pressure, June 7-21, 1995.

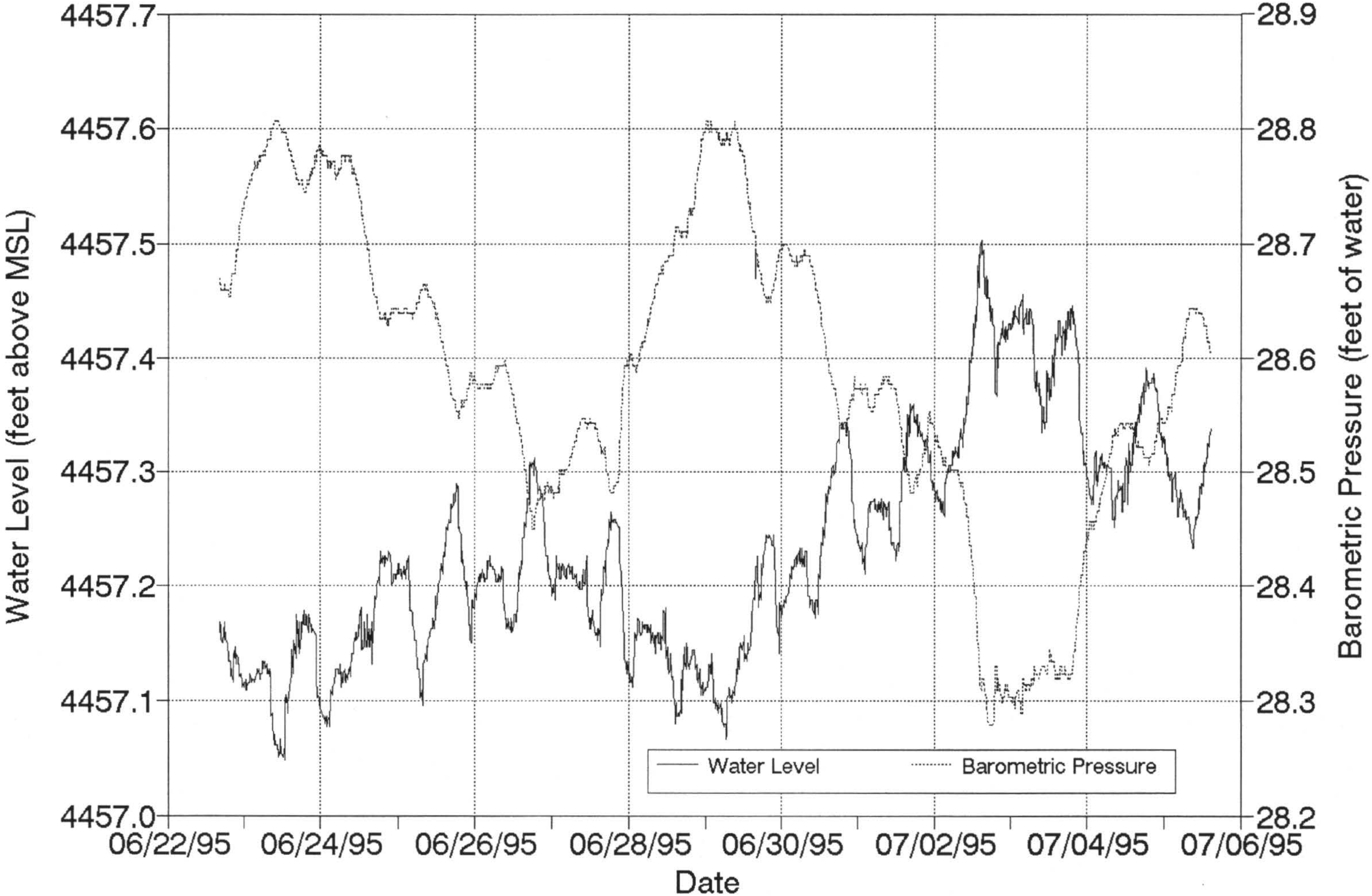


Figure B4. Water level in USGS-59 and barometric pressure, June 22 to July 5, 1995.

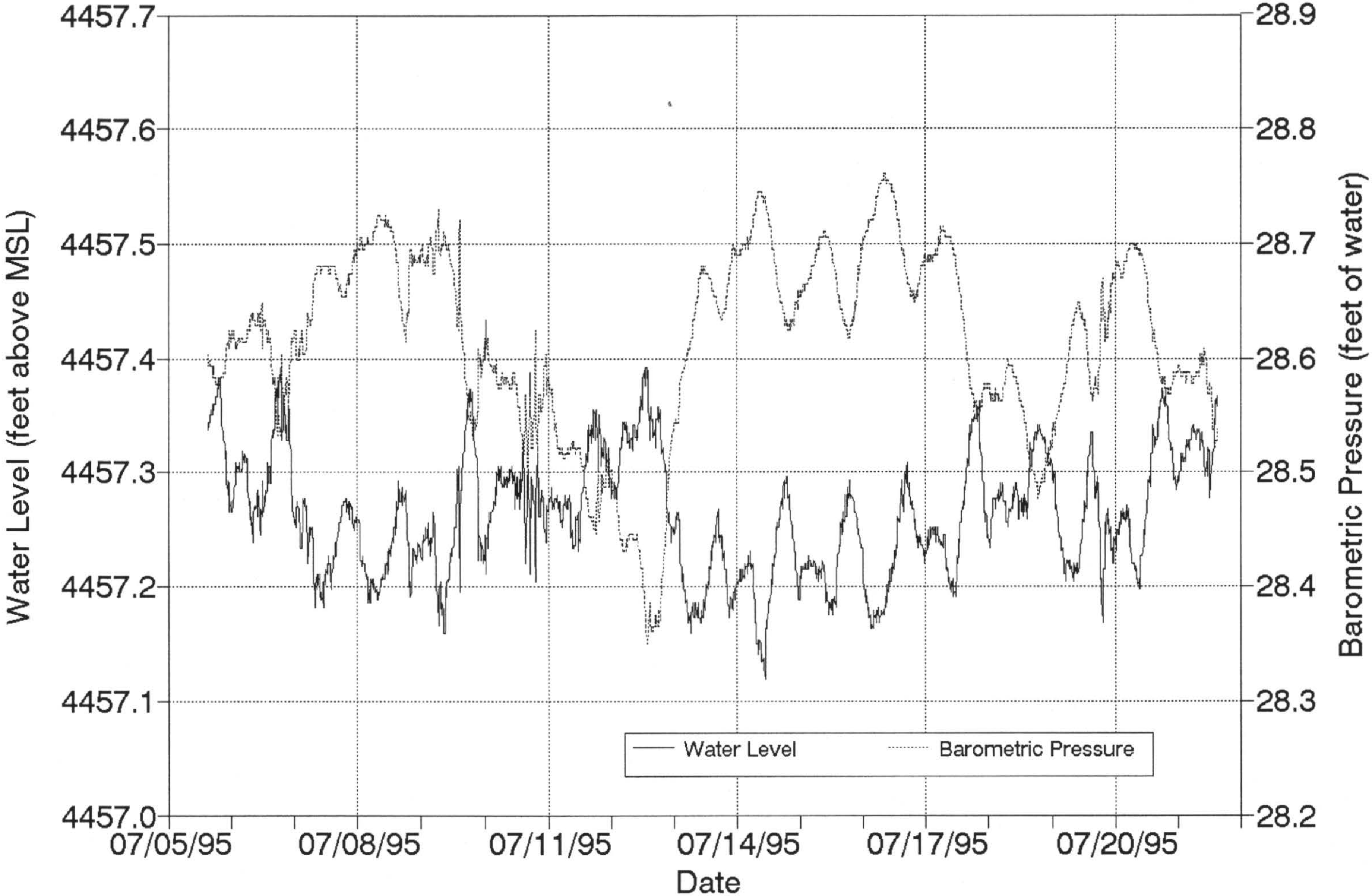


Figure B5. Water level in USGS-59 and barometric pressure, July 5-21, 1995.

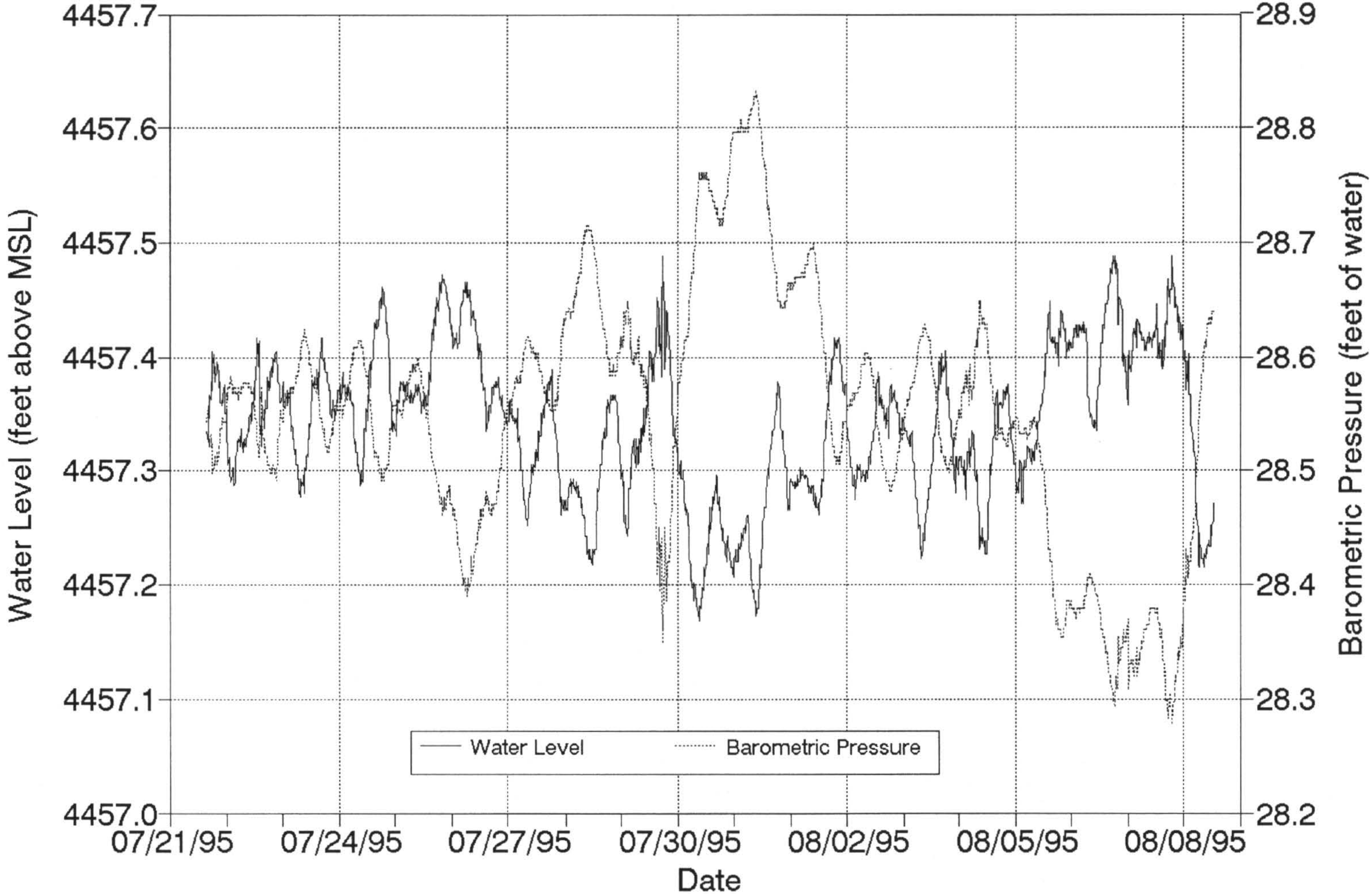


Figure B6. Water level in USGS-59 and barometric pressure, July 21 to August 8, 1995.

APPENDIX C

Specific Conductance and Temperature of Ground Water in USGS-59

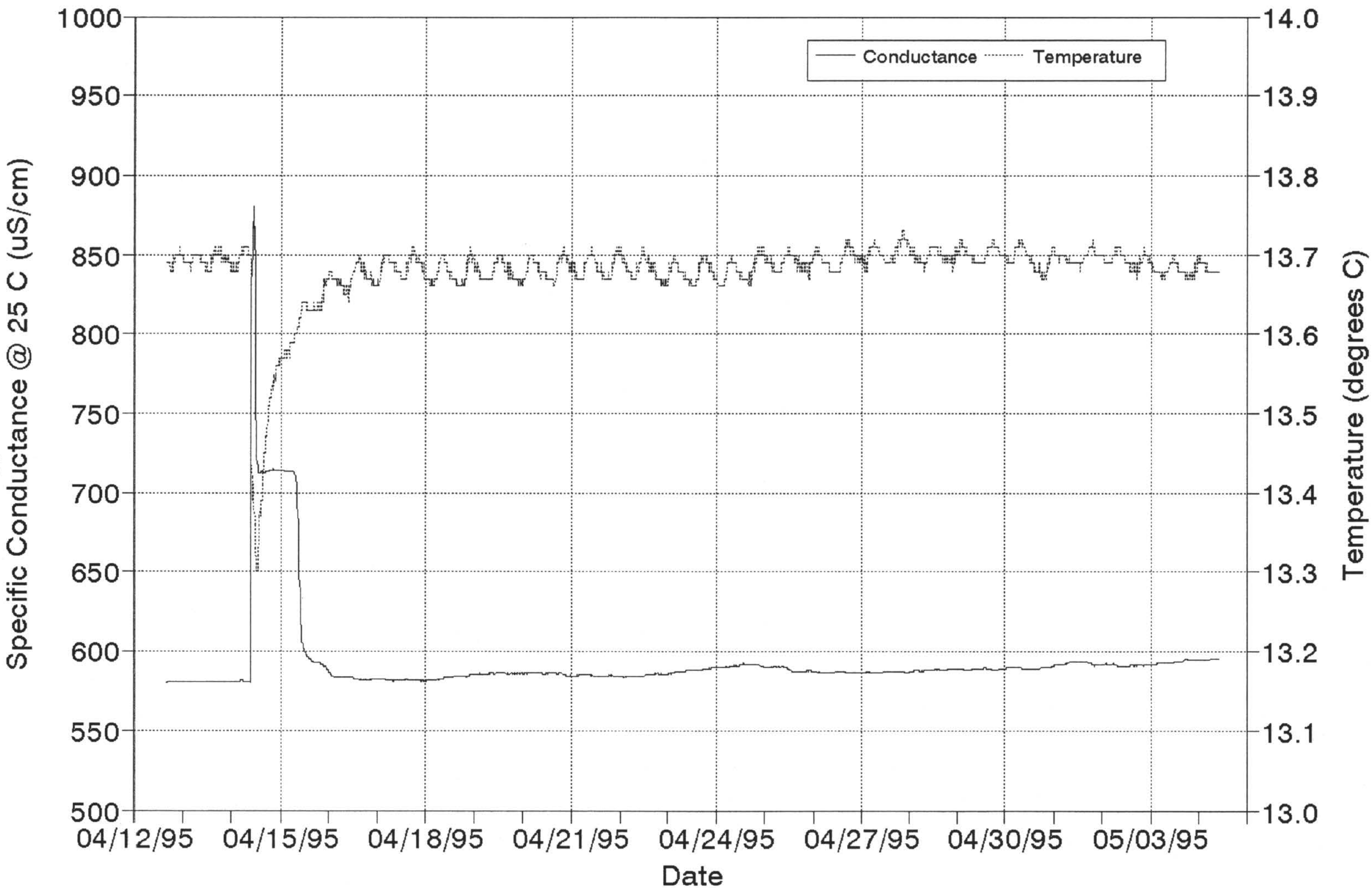


Figure C1. Specific conductance and temperature of ground water in USGS-59, 499 feet bls. The USGS sampled the well with a dedicated submersible pump on April 14.

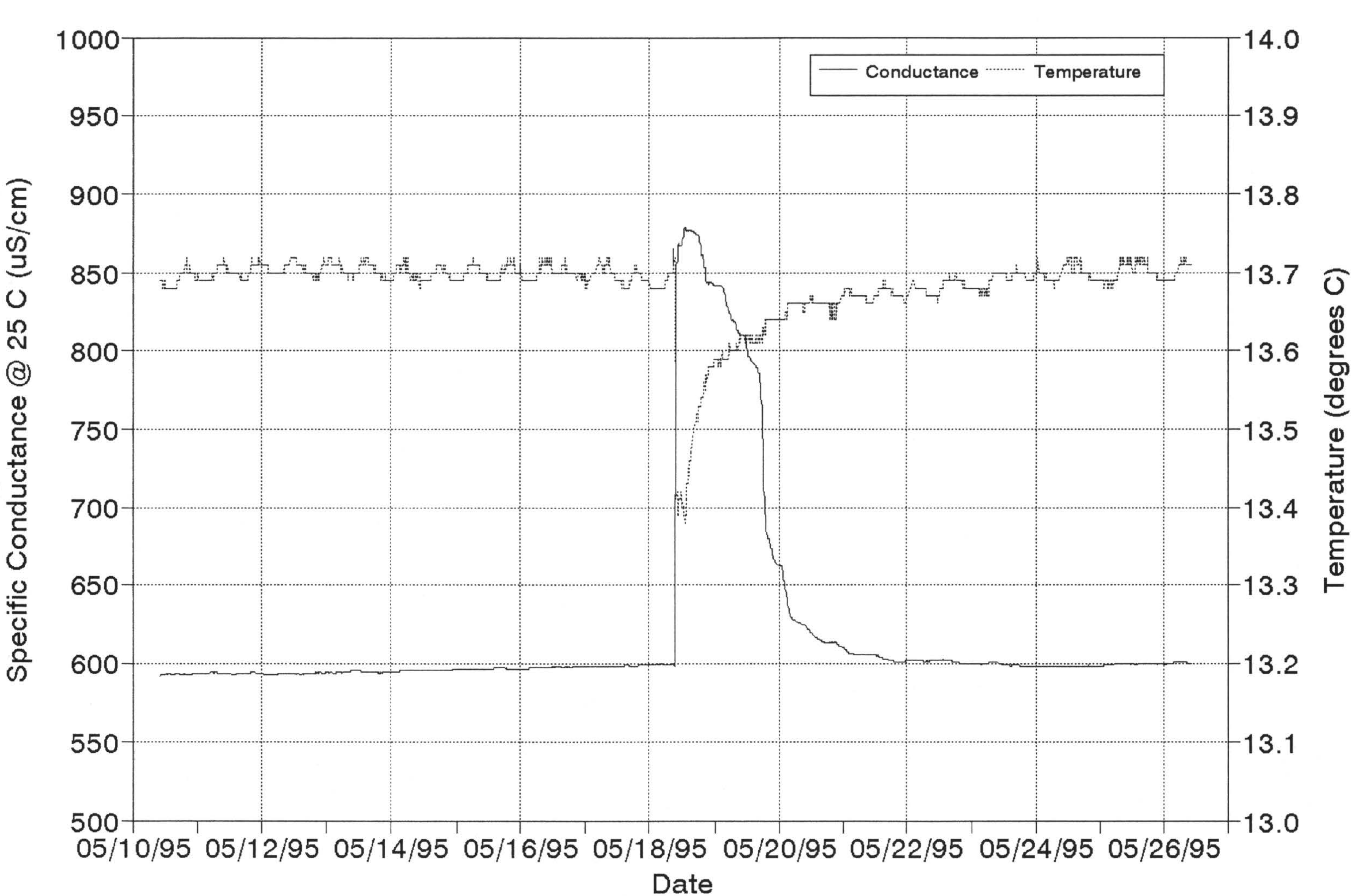


Figure C2. Specific conductance and temperature of ground water at 499 feet bls in USGS-59. The well was sampled with a dedicated sumbersible pump on May 18.

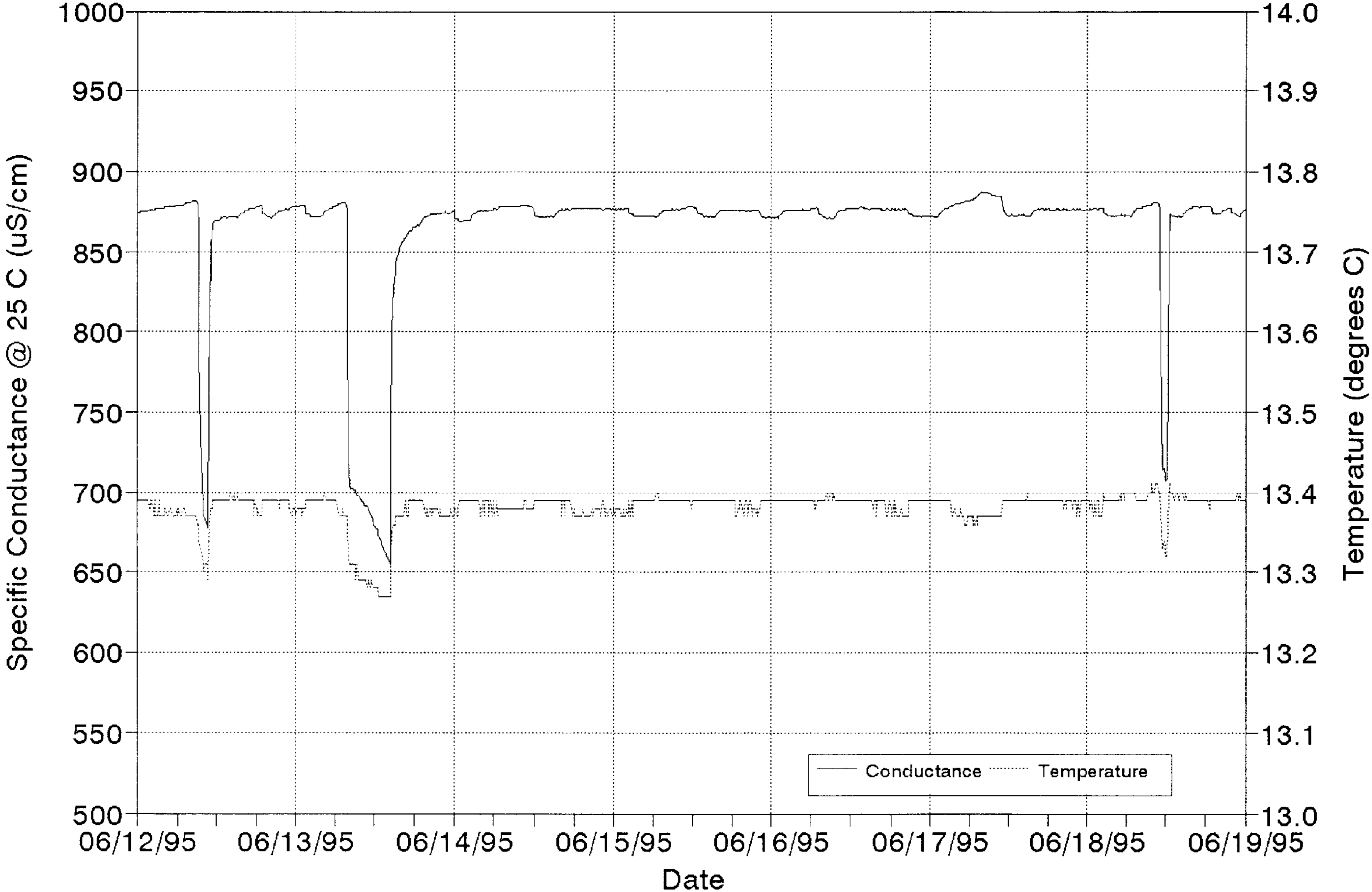


Figure C3. Specific conductance and temperature of ground water at 549 feet bls in USGS-59.

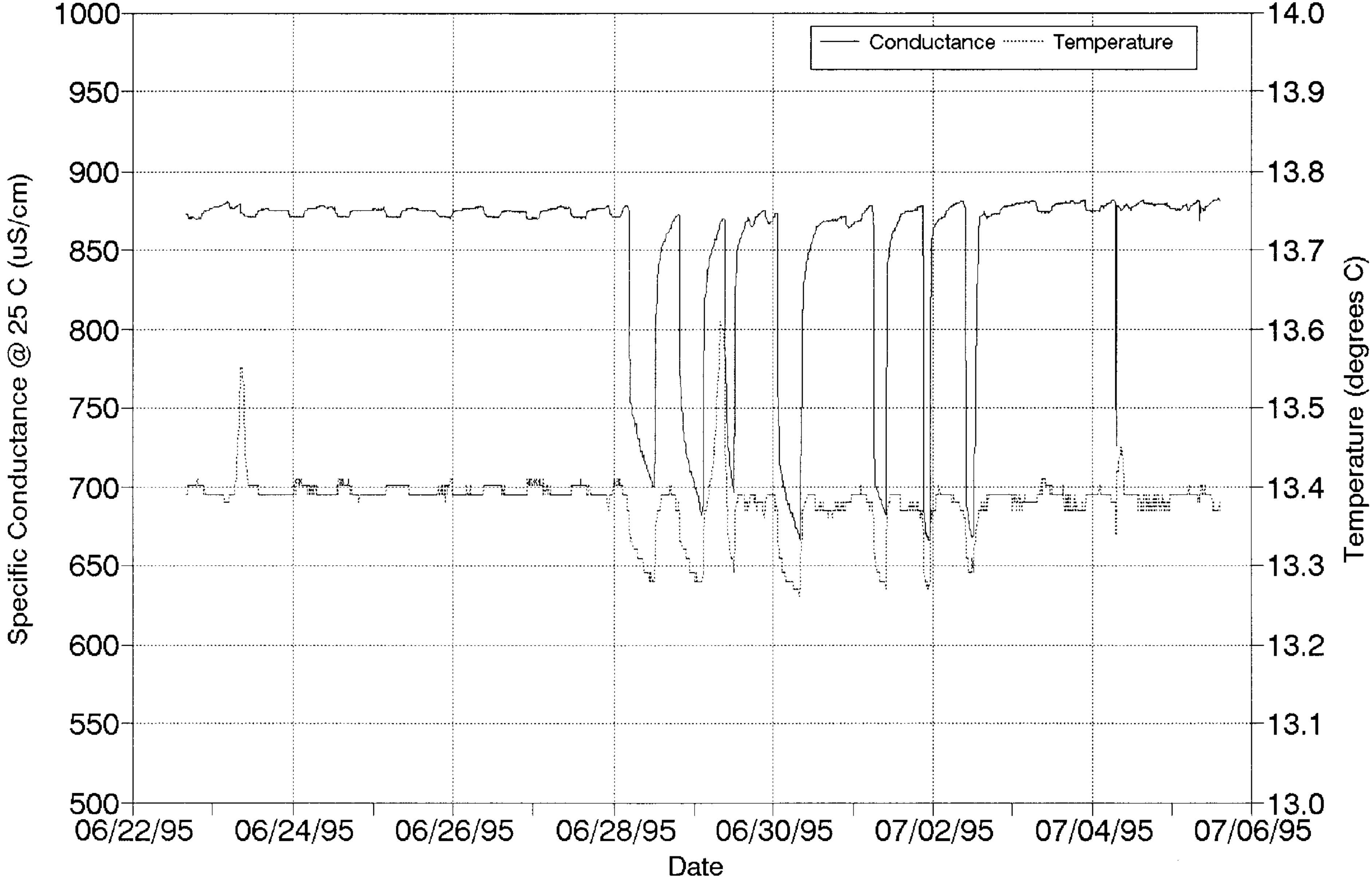


Figure C4. Specific conductance and temperature of ground water at 549 feet bls in USGS-59.

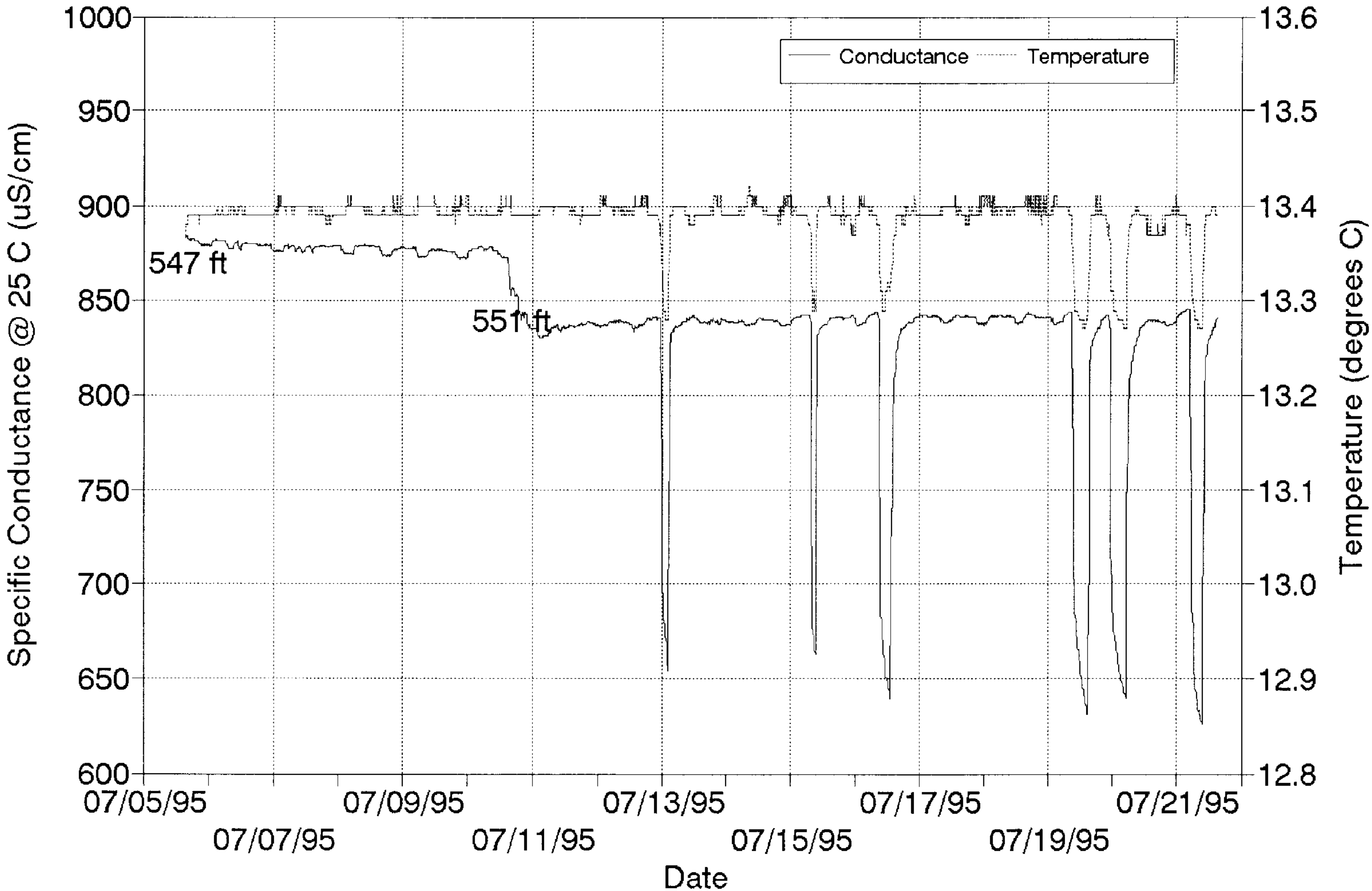


Figure C5. Temperature and specific conductance of ground water in USGS-59. In-situ probe was lowered from 547 feet bls to 551 feet bls on July 10.

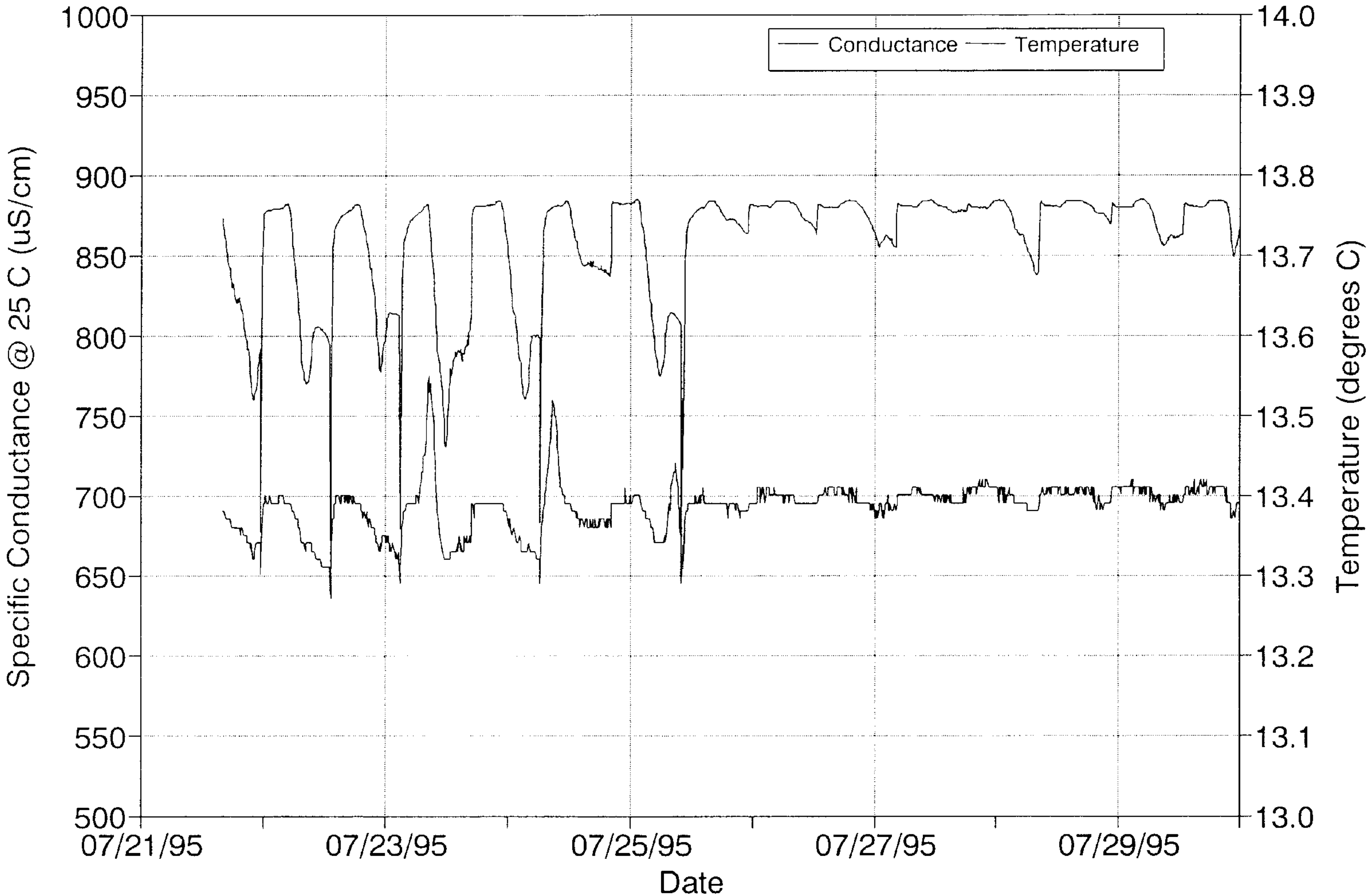


Figure C6. Specific conductance and temperature of ground water in USGS-59, 588 feet bls.