PRODUCTION, TEMPERATURE AND WATER LEVEL DATA FOR THE FOUR HEATING SYSTEMS IN THE BOISE FRONT LOW TEMPERATURE GEOTHERMAL RESOURCE AREA, 1977-1997

by

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Open File Report
June, 1998

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ABSTRACT

Water level declines in the Boise Front Low Temperature (85 to 212° Fahrenheit) Geothermal Resources Area (Boise Front geothermal area) prompted the Idaho Department of Water Resources (IDWR) to create a Ground Water Management Area in 1987 to discontinue the routine issuances of permits for geothermal development. Further restrictions were added to the Boise Front geothermal area in 1988 when the IDWR issued a five-year moratorium. The moratorium was extended for another five years in 1993. The moratorium is due to be reviewed in June, 1998.

Water level declines in the Boise Front geothermal area began to occur when the State of Idaho and City of Boise heating systems came on line in the mid-1980's. Prior to 1983, the Boise Warm Springs Water District was the only geothermal district heating system in the Boise area. The Veterans Administration Regional Hospital was permitted to begin withdrawing geothermal water in 1988 because substantial development of their system had been completed when the moratorium was issued. Production from the Boise Front geothermal system has increased from about 300 million gallons in water year 1984 to the current level of about 670 millions gallons per water year.

Currently, discharge does not appear to be exceeding recharge in this part of the Boise Front geothermal area based on water level data from the Bureau of Land Management (BLM) observation well and production data from the four heating systems. Water levels in the BLM well for the past 10 years indicate that the geothermal system has probably reached a new equilibrium, despite some minor fluctuations. The reasons for the new equilibrium are not fully understood but are probably related to: 1) stabilized withdrawal rates since the rapid increases of the 1980's, and 2) induced recharge which can occur when withdrawals from an aquifer increase.

The City of Boise's new injection well, which is scheduled to be operational for the 1998-1999 heating season, is expected to cause positive pressure effects in the geothermal aquifer. A modeling scenario by Montgomery Watson (1994) predicted that injection of spent

geothermal water near the new injection well location would result in no net changes to the water level at the BLM well assuming a 20 percent increase in production at the City and Boise Warm Springs Water District well fields.

Based on the current data, it is unknown whether production increases, if allowed by the IDWR, will adversely impact the water levels in this part of the Boise Front geothermal system, especially in combination with the new injection well. The historic data show that water level declines did occur after the State and City systems came on line. However, there were no observable water level declines with the addition of the VA production in the late 1980's.

INTRODUCTION

The four geothermal district heating systems in the Boise Front Low Temperature (85 to 212° Fahrenheit) Geothermal Resources Area (Boise Front geothermal area) are the: 1) Boise Warm Springs Water District (BWSWD), 2) State of Idaho Capitol Mall (State), 3) City of Boise (City), and 4) Veterans Administration Regional Hospital (VA) The BWSWD, which is the oldest heating district in the United States, has been supplying hot water to customers for space heating since 1892 (Rafferty, 1992) The State and City systems began producing geothermal water to heat public buildings in 1983. The VA system came on line in 1988 to heat the buildings on the VA complex. Combined, these systems provide clean and cost-efficient heat for several hundred private and public buildings. The cost savings of geothermal heat over conventional fossil fuel or hydropower electric heating for the four systems is at least one million dollars per year.

Water level declines in the Bureau of Land Management (BLM) observation well in the mid 1980's suggested that discharge may have been exceeding recharge in the Boise Front geothermal area. The Idaho Department of Water Resources (IDWR) created the Boise Front Low Temperature Geothermal Resource Ground Water Management Area (Boise Front GWMA) in 1987. The conditions of the Boise Front GWMA curtailed additional development of the geothermal resource in the Boise area. In 1988, a five-year moratorium was put in place by IDWR to further restrict withdrawals from the geothermal system. The moratorium was extended in 1993 for five more years. The moratorium is scheduled for review in June, 1998.

PURPOSE OF REPORT

The purpose of this report is to publish a summary of the production, temperature and water level data for the four heating systems in the Boise Front geothermal area for the years 1977 through 1997. The data in this report include: 1) annual production totals for each system by water year (October 1 of the previous year through September 30 of the designated water year), 2) cumulative annual production totals for the four systems, 3) monthly production graphs for each system, 4) cumulative monthly production totals for the four systems, 5) water level records, 6) water supply and return temperatures for the State of Idaho Capitol Mall system, 7) precipitation records for the Boise Airport rain gauge, and 8) heating day records for the Boise area. This report was written so that the Idaho Department of Water Resources, with input from the four major users and other interested parties, could determine whether the moratorium should be extended, modified or canceled in 1998.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is identical to the system used by the USGS in Idaho (Figure 1) The system indicates the location of wells within the official rectangular subdivision of the Public Land Survey System (PLSS) with reference to the Boise baseline and meridian. The first two segments of the number designate the township and range. The third segment gives the section number followed by three or four letters and a number The letters indicate the ¼ section (160 acre tract), ¼-¼ section (40 acre tract), ¼-¼-¼ section (10 acre tract), ¼-¼-¼-¼ section (2 5 acre tract), and the serial number of the well within the tract. Quarter sections are lettered A, B, C, and D in counterclockwise order beginning in the northeast quarter of the section. Successively smaller tracts are lettered in the same manner For example, well 01N 01E 11DBA1 corresponds to the PLSS location: NE¼, NW¼, SE¼, Section 11, Township 1 North, Range 1 East, and it was the first well inventoried by the USGS in that tract.

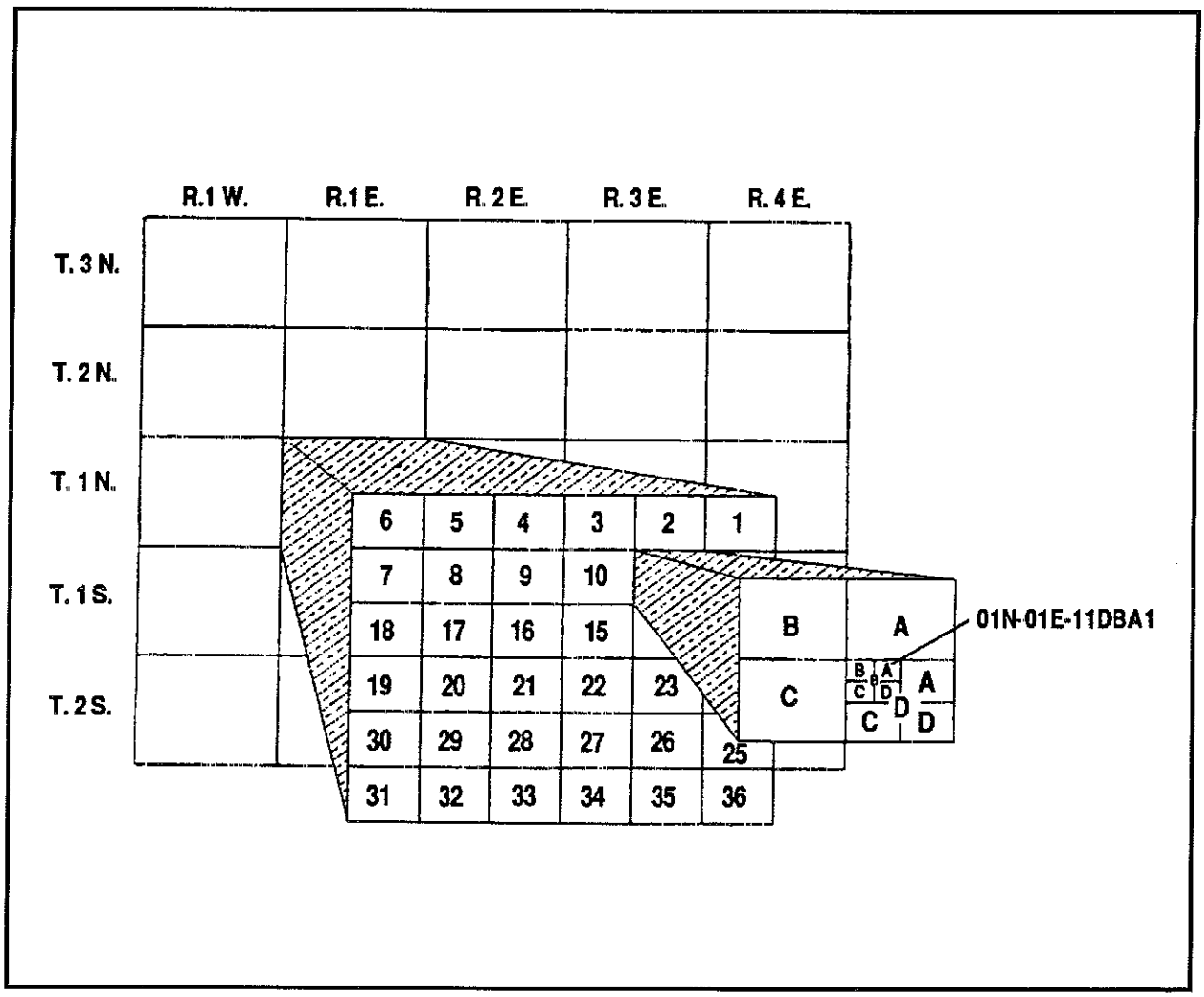

Figure 1. Well-numbering system

STUDY AREA

The Boise Front geothermal area is located along the northern edge of the Treasure Valley in the western part of the Snake River Plain of southwestern Idaho The Treasure Valley trends northwest-southeast with the Boise Mountains located to the northeast. The Boise and Snake Rivers dissect the Treasure Valley as they flow to the northwest. A band of hills known as the Boise Front Foothills lie between the Boise Mountains and the valley floor. The Boise Front geothermal area occurs in Ada county primarily along the toe of the Boise Front Foothills and extends a short distance into the Treasure Valley (Figure 2) Part of the Boise Front geothermal area is within the Boise City limits; the remainder of the area is located north, northeast and east of the city limits The study area for this report is the relatively small portion of the Boise Front geothermal area that contains the four district heating systems

PREVIOUS STUDIES

Numerous papers and reports have either described the geologic setting for the Boise Front geothermal system, documented the development of the four district heating systems or chronicled the production, water level and temperature data Reports that provided overviews of geothermal resources in Idaho, including the Boise Front geothermal area, are Mitchell and others (1980) and Dansart and others (1994)

Mink and Graham (1977) described the geothermal potential in the western part of the Boise Front geothermal area Anderson and Kelly (1983) evaluated the ground water flow conditions for the Boise Front geothermal aquifer. Waag and Wood (1987a and 1987b) discussed in detail the physical setting of the Boise geothermal hydrogeologic system, the chemical data and the analysis of drawdown and production data Wood and Burnham (1987) described the geological framework of the Boise Front geothermal system and developed a conceptual model

Reports and articles that provided information about the exploration and development history of the Boise Front geothermal resources included Stoker and others (1977), Nelson and others (1980), Worbois (1982), Higginson and Barnett (1987), and Neely (1996) Lithologic, hydrologic and chemical data were documented in reports by Young and others (1988), and Parliman and Young (1992). Burnham and Wood (1983) provided a field trip guidebook and road log for the Boise Front geothermal area.

A detailed aquifer study in the area of the four heating systems was conducted by the Berkeley Group, Inc. (1990) A two-part study was conducted by the City and the BWSWD in the early 1990's. The first part developed a conceptual model of the geothermal system (Montgomery, 1992) The second part described the hydraulic modeling of the aquifer which used the USGS MODFLOW and TST3D flow models (Montgomery Watson, 1994) A follow-up study used the numerical modeling results to evaluate potential sites for the City system's injection well (Montgomery Watson, 1996)

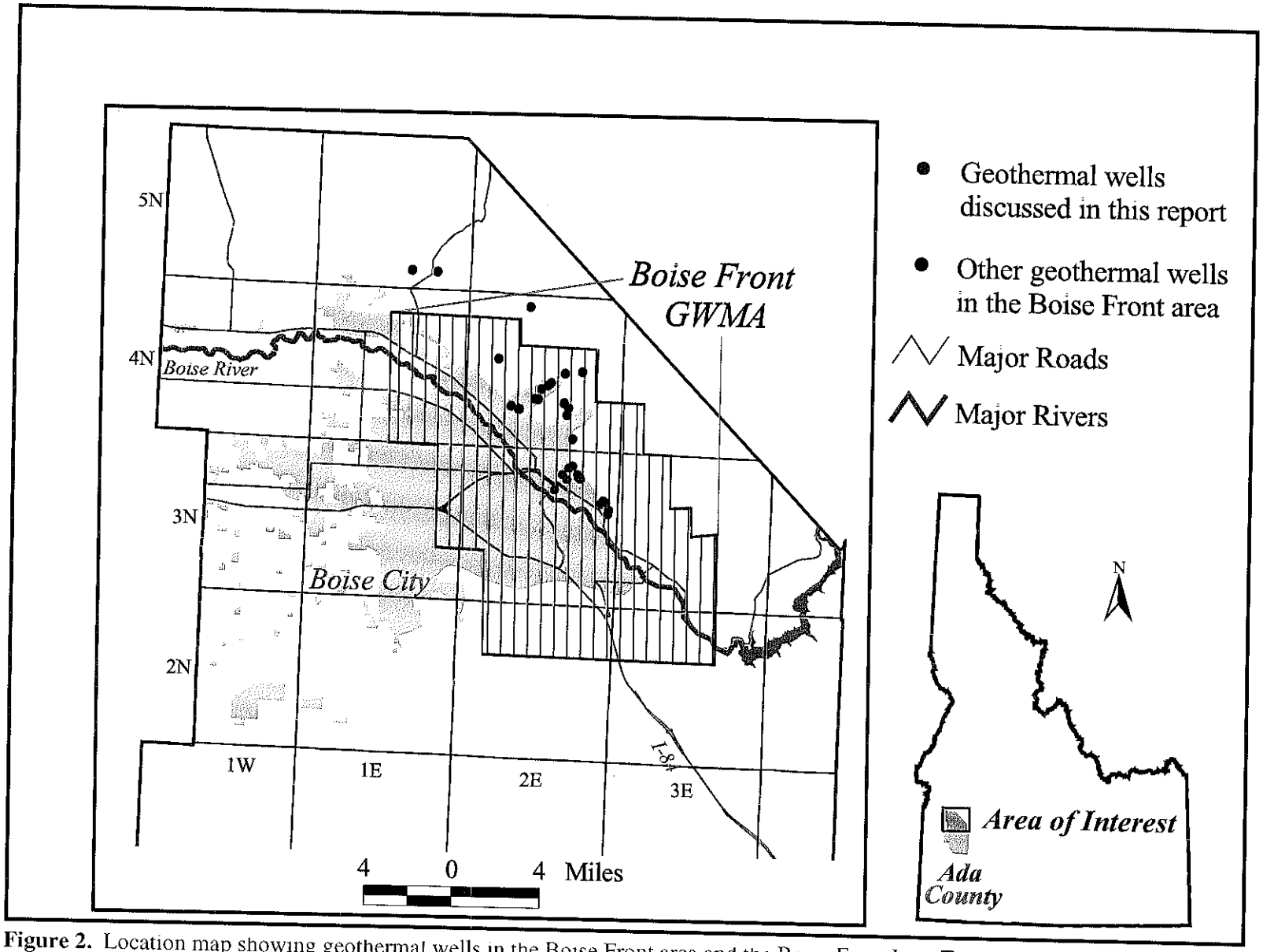

Figure 2. Location map showing geothermal wells in the Boise Front area and the Boise Front Low Temperature Geothermal Resource Ground Water Management Area (Boise Front GWMA).

Some reports have been written specifically about one of the systems The geothermal production for the BWSWD from 1977 through 1989 was documented by Robert Griffiths (Boise Warm Springs Water District, 1989) Rafferty (1992) presented the history of the BWSWD system Mink (1976) summarized the testing of the Statehouse well which is located beside the State Capitol building. Austin (1978) described a demonstration project for the State of Idaho which used geothermal water from the BWSWD to heat three buildings in the State Laboratory complex. Anderson and Kelly (1981) reported the drilling and testing of the State Capitol Mall #2 well Neely (1995) reported production and temperature data for the State system for 1983 through 1994

CLIMATE AND HEATING DATA

The 30-year average precipitation (water years 1968 through 1997) for the Boise Airport rain gauge station was 12.19 inches (National Oceanic and Atmospheric Administration) (Figure 3) The data for the last 20 water years, which is the time period that we have monitoring data for the Boise Front geothermal system, show that: 1) water years 1978 through 1986 were

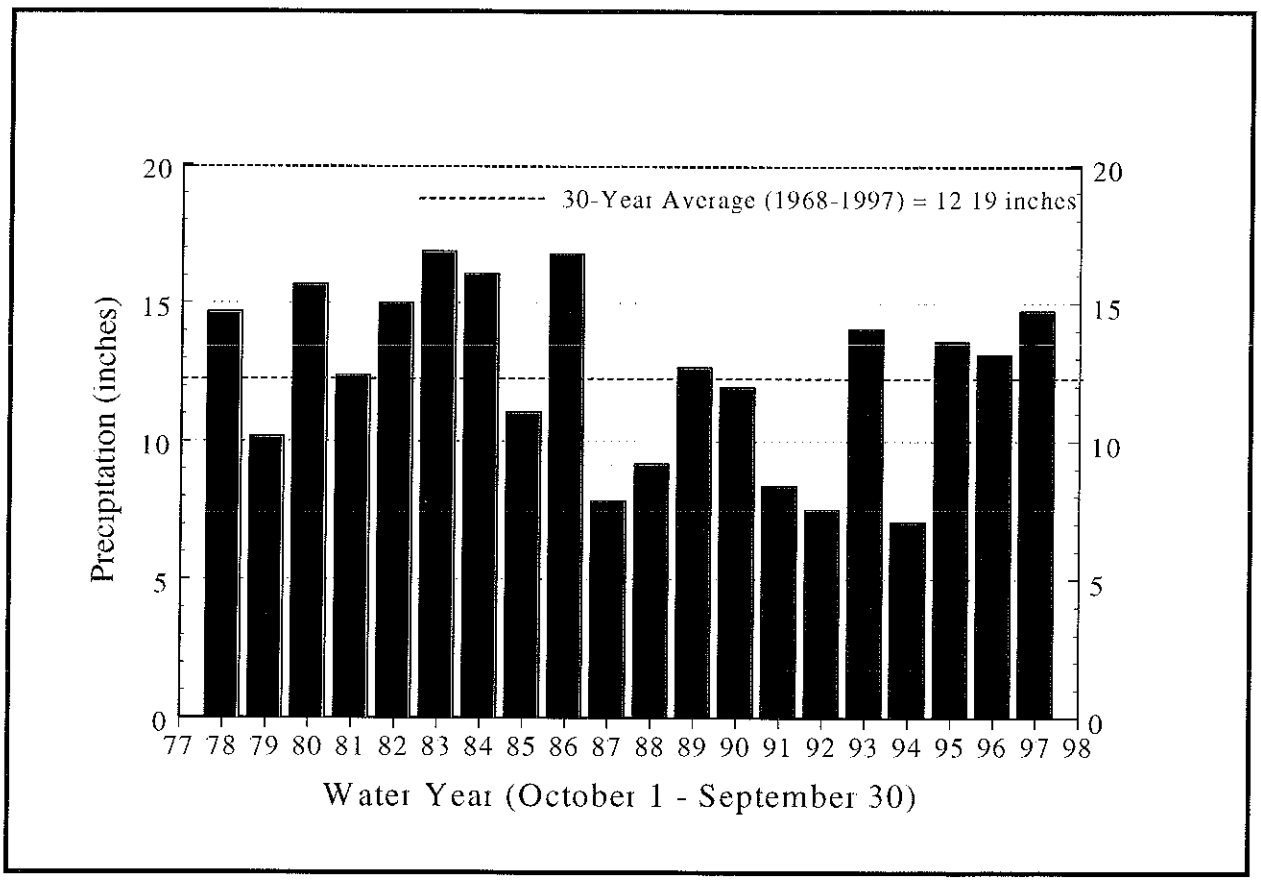

Figure 3. Precipitation records for the Boise Airport rain gauge station for water years 1978 through 1997

generally wetter than average, 2) water years 1987 through 1994 were generally dryer than average, and 3) water years 1995 through 1997 were slightly wetter than average (Figure 3).

The 30-year heating degree day average (heating years 1968 through 1997) for Boise was 5757 heating degree days (National Oceanic and Atmospheric Administration). The data for the last 20 years show that: 1) annual heating degree days were generally less than the 30-year average for heating years 1978 though 1983, 2) annual heating degree days were significantly more than the 30-year average for heating years 1984 through 1986, and 3) annual heating degree days were generally less than the 30-year average for heating years 1987 through 1997 (Figure 4).

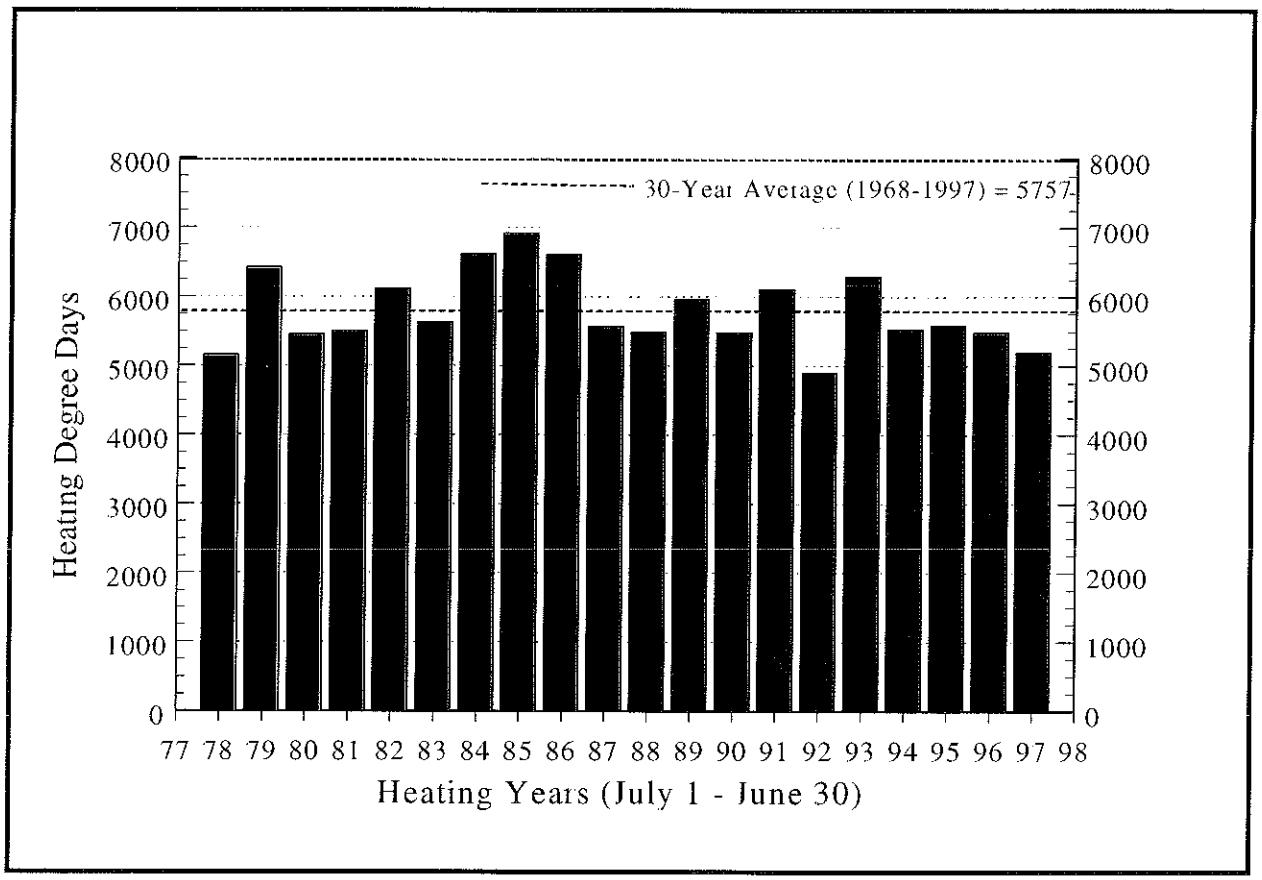

Figure 4. Heating degree day data for Boise for heating years 1978 through 1997

GEOTHERMAL DEVELOPMENT IN THE BOISE AREA

The first two geothermal wells in the United States were drilled near Boise, Idaho, in 1890 and 1891 (Boise City Public Works, 1993) The wells were completed near some thermal springs located about two miles east of Boise (Figure 5) Both wells were drilled to depths of 400 feet (Table 1) Although there are no well driller's reports for the two wells, it is assumed that the wells were completed in the rhyolite rocks of the Idavada Group The wells are believed to have been drilled through a major down-to-the-southwest normal fault that trends northwest/southeast along the toe of the Boise Front Foothills This fault and other associated faulting are interpreted to be the conduits for upward migration of geothermal water along the Boise Front

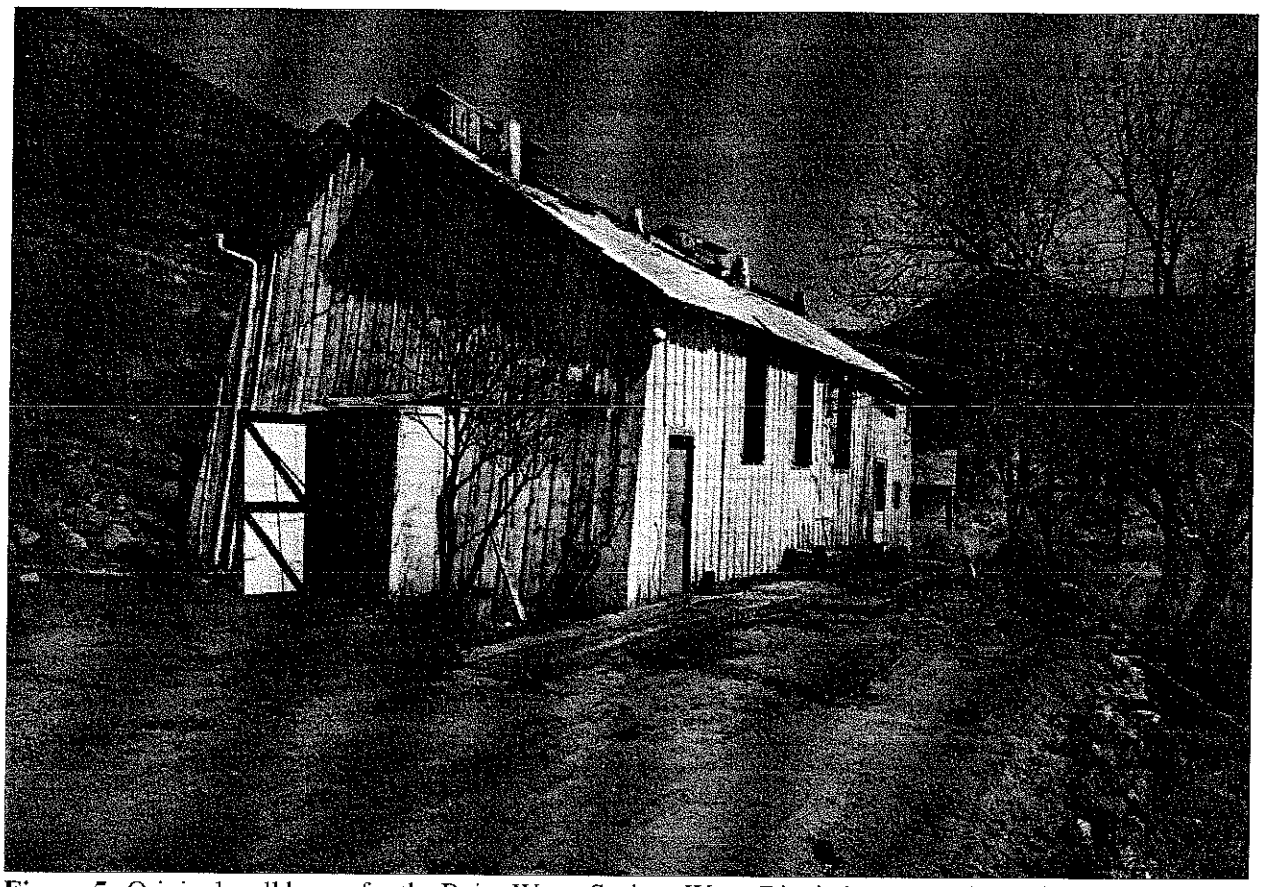

Figure 5. Original well house for the Boise Warm Springs Water District's two geothermal production wells (from Burnham and Wood, 1983).

By 1892, the water from the wells was being used to heat homes, businesses and a 15,000 square foot Natatorium in east Boise. The Natatorium no longer exists but the

geothermal water is still being used to heat 226 homes and 36 commercial buildings on and near Warm Springs Avenue and in part of the downtown Boise area (Figure 6) Today, the Boise Warm Springs Water District (BWSWD) maintains the production wells and delivers the water to the customers The used geothermal water is discharged to the Boise River through the city sewer system (Berkeley Group, Inc., 1990) BWSWD drilled a third well in 1981 about 650 feet northwest of the two production wells The well, which is believed to be on the upthrown side of the fault, did not encounter sufficient quantities of geothermal water for production. The well is being used for monitoring water levels

Table 1. Selected wells in the Boise Front geothermal area.

System	Well Name	Location	Reported Depth (feet below land surface)	Year Drilled	Use[1]
Boise Warm Springs Water District (BWSWD)	BWSWD West	3N 2E 12CDDD1	400	1891	A
	BWSWD East	3N 2E 12CDDD2	400	1891	A
	BWSWD #3	3N 2E 12CDDC1	587	1981	U,M
State of Idaho Capitol Mall (State or CM)	CM #1	3N 2E 10AADA1	2,152	1981	I
	CM #2	3N 2E 10AABB1	3,030	1981	A
City of Boise (previously owned by Boise Geothermal Limited (BGL))	BGL #1	3N 2E 11ABCA1	2,008	1981	U
	BGL #2	3N 2E 11ABBC1	880	1981	A
	BGL #3	3N 2E 11BAAA1	1,897	1981	A
	BGL #4	3N 2E 11ABCB2	1,103	1981	A
Veterans Administration Regional Hospital (VA)	VA #1	3N 2E 02CDCD1	1,666	1983	A
	VA #2	3N 2E 02CBCC2	1,840	1983	U
	VA #3	3N 2E 02CBCC3	2,300	1987	I
Other	BLM	3N 2E 11BABD1	1,222	1976	M

[1] Use codes: A = heating; I = injection; M = monitoring; U = unused

In the mid-1970's, the increasing cost of heating created new interests in alternate heat sources such as geothermal. In 1976, EGG /INEL drilled the Bureau of Land Management (BLM) and Beard exploration wells, along with three geothermal test holes, in the downtown Boise area. At about the same time, the State of Idaho Capitol Mall complex was expanding This development prompted then-Governor Andrus to request a federal study to determine the feasibility of geothermal heat for the State's building in downtown Boise (Austin, 1978).

The State Health Laboratory was retrofitted for geothermal heat as a pilot project in 1977 The success of the State Health Laboratory project motivated the State of Idaho to drill

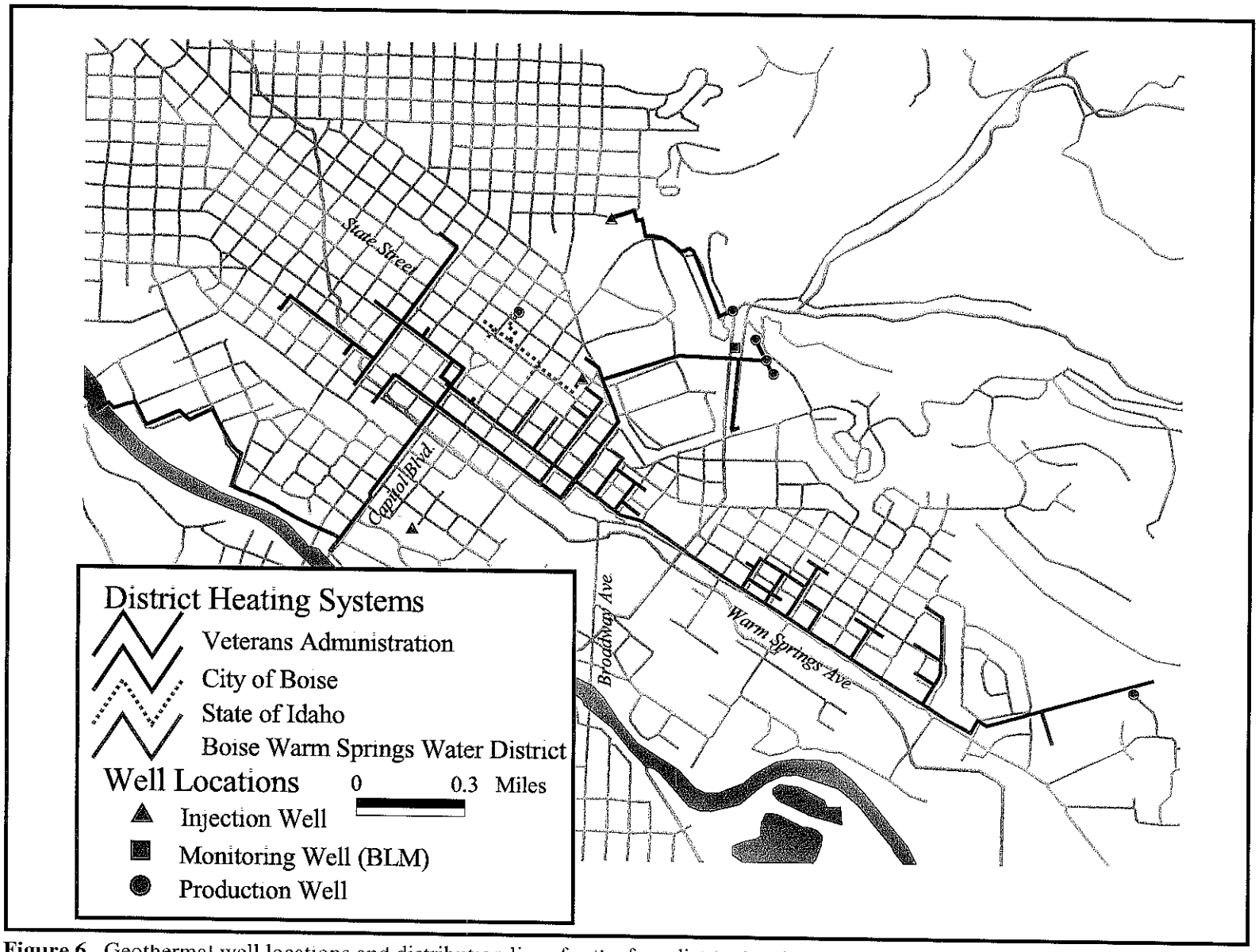

Figure 6. Geothermal well locations and distribution lines for the four district heating systems in the Boise area (This map was modified from a map received from the City of Boise Public Works Department in 1996).

the Capitol Mall #1 exploration well about three blocks from the State Capitol in 1981. Capitol Mall #2 was drilled about two blocks north of the Capitol (Figure 7). Capitol Mall #2, which is 3,030 feet deep, is being used as the production well; Capitol Mall #1 is 2,150 feet deep and is used as the injection well (Figure 6). The wells were completed in volcanic rock and sand (Idavada Group) according to the well driller's reports. By 1982, the State of Idaho geothermal system was suppling heat to eight building in the Capitol Mall complex, including the State Capitol. The Alexander House was added to the system in about 1992. Currently, the system is used to heat about 1,500,000 square feet

In 1981, a company named Boise Geothermal Limited (BGL) had four geothermal wells drilled an area northeast of downtown Boise and along the edge of the Boise Front Foothills (Figure 6). The well names and well depths are: 1) BGL-1, 2,008 feet, 2) BGL-2, 880 feet, 3) BGL-3, 1,897 feet (Figure 8), and 4) BGL-4, 1,103 feet. The wells were completed in the rhyolite and interbedded sandstones of the Idavada Group.

BGL began supplying geothermal water for space heating to downtown Boise customers in 1983 (Berkeley Group, Inc., 1990). In 1988, the City of Boise purchased BGL. Today, the City geothermal system is used to heat about 1.8 million square feet which includes the City

Figure 7. Well house for the State of Idaho Capitol Mall #2 geothermal production well. The top of the State Capitol building is in the background

Hall and 42 customers (Tensen, 1996, personal communication). Used geothermal water is currently disposed of in the Boise River. However, the City of Boise has recently completed a 3,200-foot well in Julia Davis Park which will be used for injecting spent geothermal water (Figure 9). The well is to be operational by the beginning of the 1998-1999 heating season.

Two geothermal wells were drilled for the Veterans Administration (VA) Regional Hospital on their properties in 1983. A third geothermal well was drilled for the VA in 1986. The production well, which was the first well drilled for the VA, is 1,666 feet deep (Figures 6 and 10). The injection well, which was the third well drilled for the VA, is 2,300 feet deep (Figure 6). The second well, which was drilled primarily for exploration, is currently unused. The wells were completed in rhyolite, tuff, basalt and sand (Idavada Group) according to the well driller's report. The VA geothermal system provides heat to about 400,000 square feet in 22 buildings on the hospital grounds which include patient care, clinical support, outpatient and ancillary support facilities.

Several other deep geothermal wells have been drilled in the Boise Front geothermal area (Berkeley Group, Inc., 1990; Neely, 1995). The names of the wells located nearest to the four

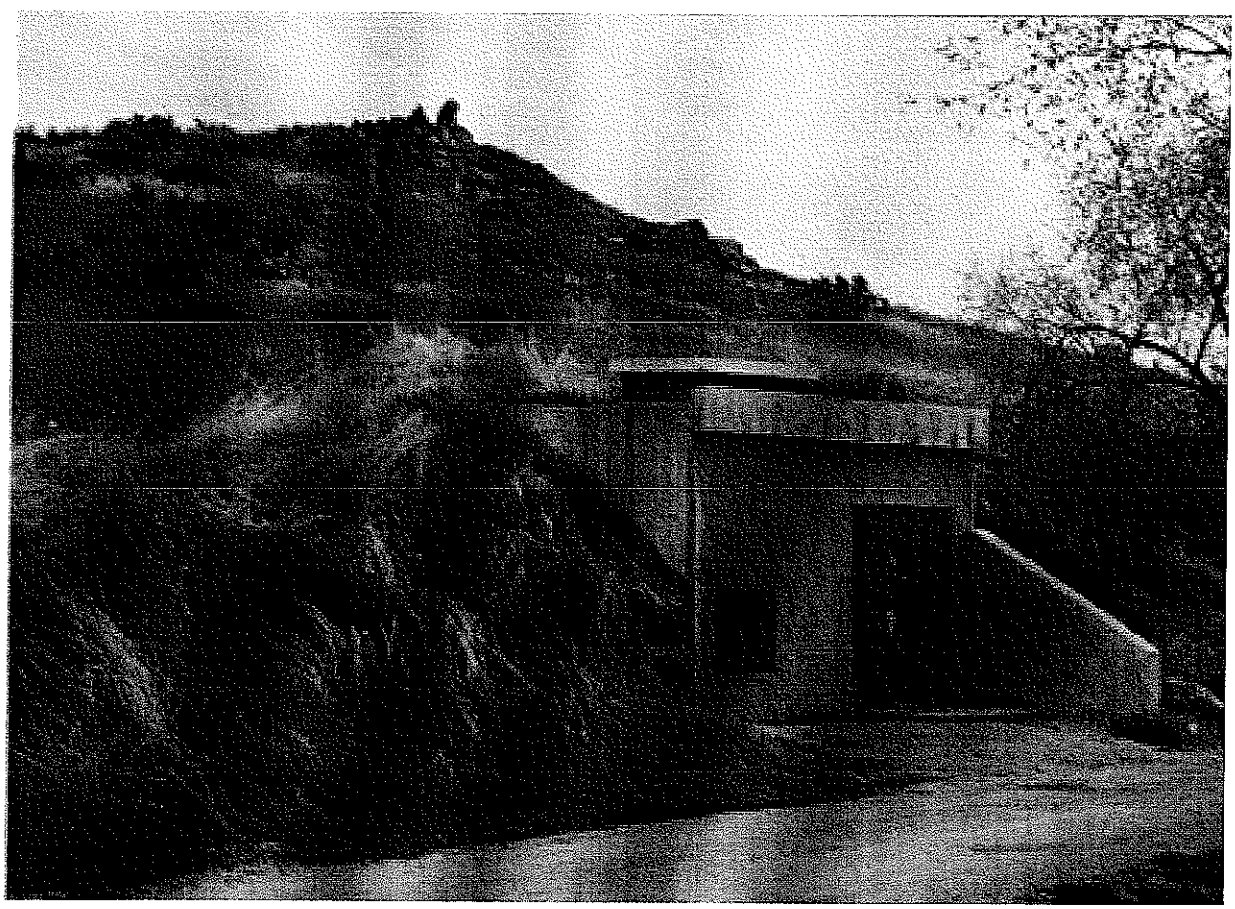

Figure 8. Well house for the City of Boise's BGL #3 geothermal production well

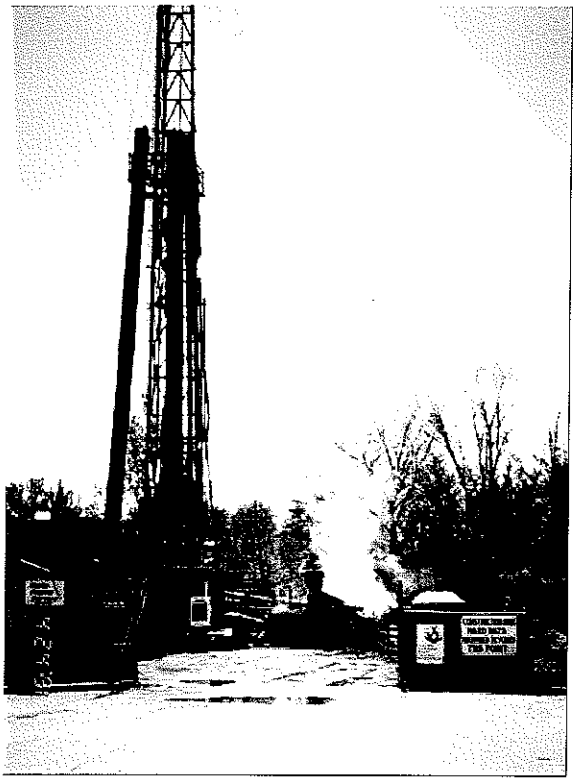

Figure 9. Drilling the injection well for the City of Boise, April 1998

heating systems are: Behrman, BLM, Fort Boise Park, Kanta, Koch, Old Penitentiary (Botanical Gardens) and Quarry View. The Fort Boise Park and Koch wells produce small quantities of geothermal water; the other wells are not being used for withdrawals. The BLM well, located close to the VA and City of Boise production wells, is the primary observation well for the Boise geothermal system.

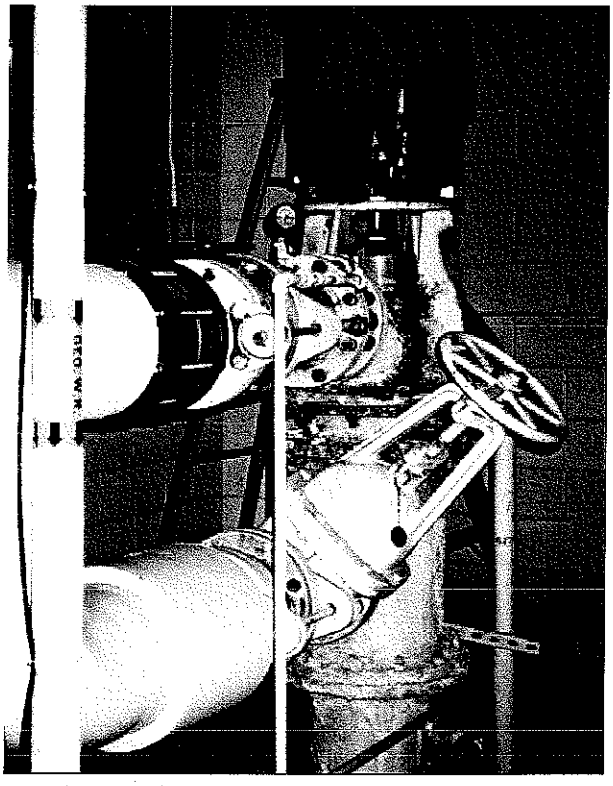

Figure 10. Production well for the Veterans Administration Regional Hospital.

GEOTHERMAL MONITORING DATA

Data collection for the four systems is accomplished through manual readings and computer data loggers The BWSWD and the State systems currently use electronic devices to capture monitoring data Automation of data collection using data loggers has been discussed for the City and Va systems but has not been implemented yet.

The BWSWD began recording production data in September, 1977 (Boise Warm Springs Water District, 1989) Production data are currently being recorded using two methods: 1) hand-written daily logs, and 2) a data logger The BWSWD submits a summary of the hand-written logs to IDWR that lists production by month and by year The data logger captures a production value once every 10 minutes IDWR downloads the datalogger every three months.

Maximum monthly production for the BWSWD has decreased over the past 20 years from almost 50 million gallons per month to about 30 million gallons (Figure 11) Annual production by water year for the BWSWD has decreased from a peak of over 300 million gallons to about 220 million gallons (Table 2; Figure 12) The reasons for the decline are: 1) better heating efficiencies because of the addition of new pipe insulation on main and service

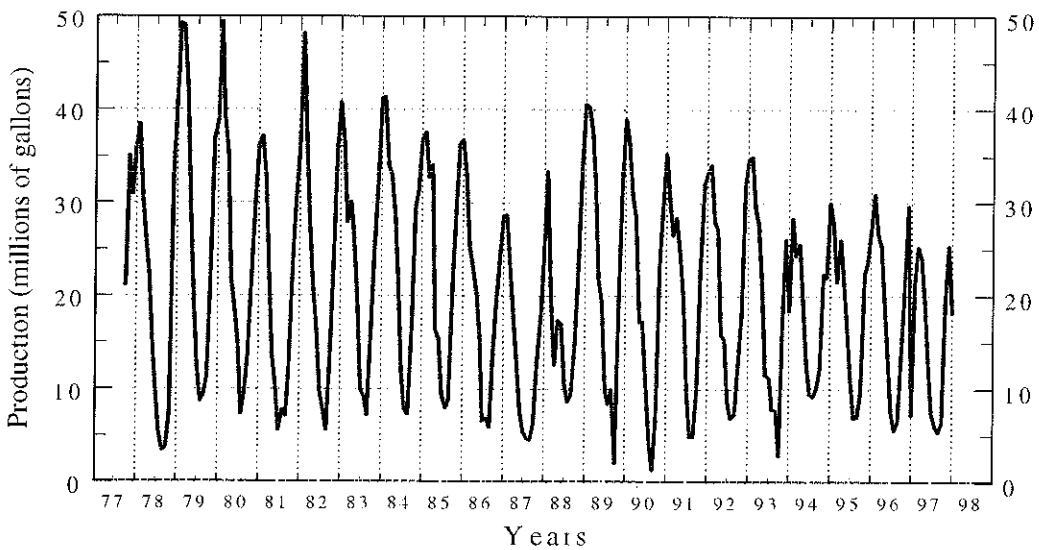

Figure 11. Monthly production for the Boise Warm Springs Water District heating system, 1977-1997.

Table 2. Production By Water Year[1] For The Four Heating Systems In The Boise Front Geothermal Area.

PRODUCTION IN MILLIONS OF GALLONS					
Water Year	**BWSWD**	**State**	**City**	**VA**	**Total**
1978	256 0				256 0
1979	312 2				312 2
1780	308 1				308 1
1981	239 4				239 4
1982	276 0				276 0
1983	283 5				283 5
1984	300 1	162 9	166 7		629 7
1985	281 1	175 4	121 4		577 9
1986	253 2	192 0	176 8		622 0
1987	183 3	169 1	188 9		541 3
1988	199 4	138 8	123 8		462 0
1989	278 0	120 0	158 0		556 0
1990	244 6	68 3	122 3	118 2	553 4
1991	245 7	177 6	121 3	115 4	660 0
1992	243 3	139 0	123 3	116 7	622 3
1993	239 3	177 6	156 0	137 0	709 9
1994	214 7	179 6	122 5	137 4	654 2
1995	221 2	150 8	129 9	151 4	653 3
1996	226 6	119 6	132 1	186 2	664 5
1997	212 8	112 2	130 7	203 6	659 3
Average production	250 9 (1978-1997)	155 0 (1984-1997, minus 1990)	141 0 (1984-1997)	145 7 (1990-1997)	660 5 (1991-1997)

[1]Water year runs from October 1 to September 30 For example, water year 1978 started on October 1, 1977 and ended on September 30, 1978

lines, 2) reduced demand by some of the service units, and 3) reduction in the number of service units. The addition of new pipe insulation is considered the primary factor for the reduction in withdrawals. Water supply temperatures have remained constant at about 175° Fahrenheit (F)

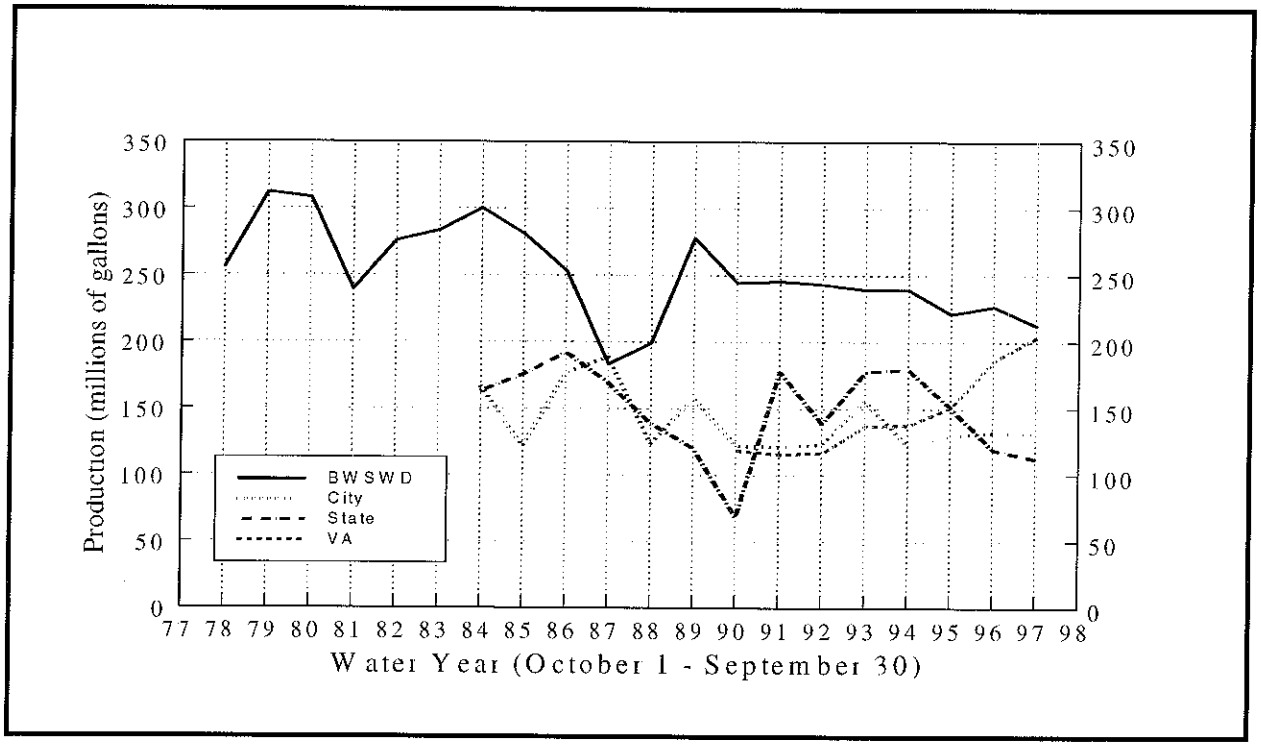

Figure 12. Geothermal production by water year for the Boise Warm Springs Water District (BWSWD), City of Boise (City), State of Idaho Capitol Mall (State) and Veterans Administration Regional Hospital (VA) heating systems

The State of Idaho geothermal system went on line in November, 1982. The first production data recorded for the system were from May, 1983. Monitoring data were initially recorded by hand on daily logs with only one entry for each day. Data were usually recorded in the mornings (between 5:00 and 8:00 am). The Berkeley Group, Inc., (1990) reported that the daily logs reflect higher than average discharges because the readings were taken during peak flow times. Data have been recorded on computer trend logs since 1991. Data were initially recorded once every six hours; since 1995, data have been recorded once every two hours.

Maximum monthly production for the State of Idaho geothermal system was about 30 million gallons in 1985, 1986 and 1993 (Figure 13). Production data for half of water year 1990 was missing; therefore, the total of 68.3 million gallons is considerably too low.

Production appears to have declined in 1996 and 1997 (Table 2; Figures 12 and 13). However, there are missing data intervals in the computer trend logs during those years due to equipment failure and data capture errors. To minimize data loss in the future, the State Department of Administration is now submitting data updates to IDWR once every three

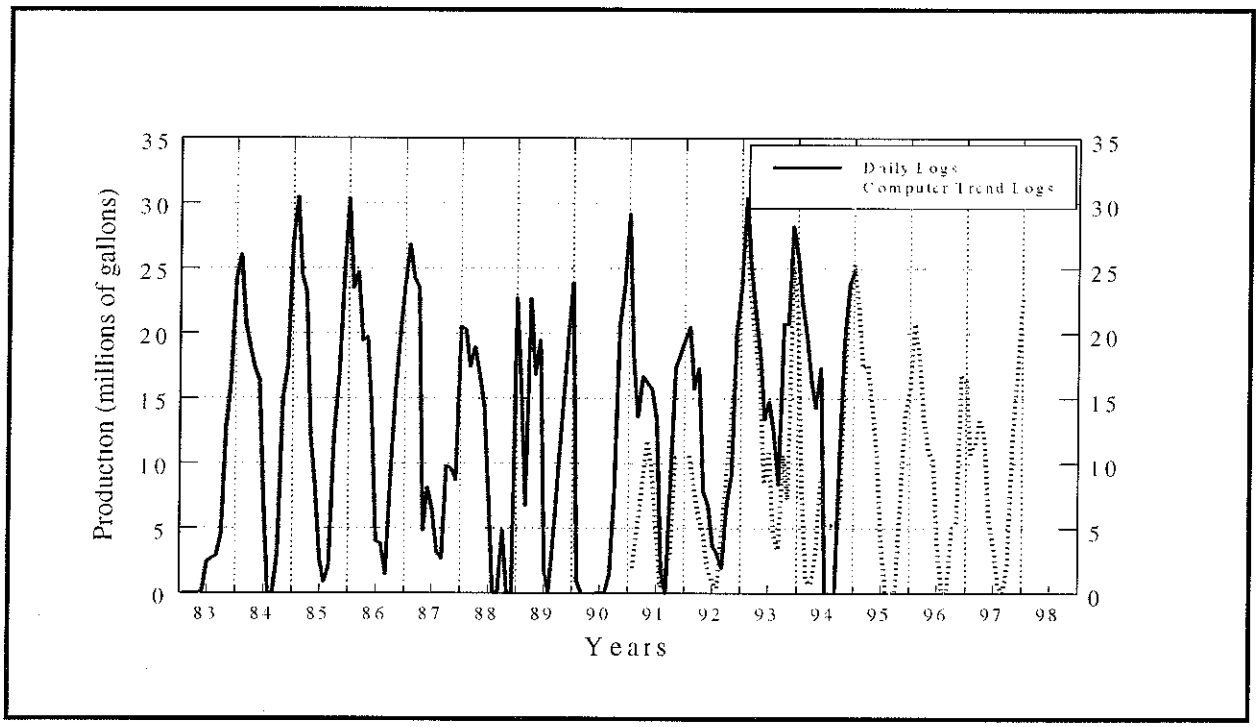

Figure 13. Monthly production for the State of Idaho Capitol Mall heating system, 1983-1997

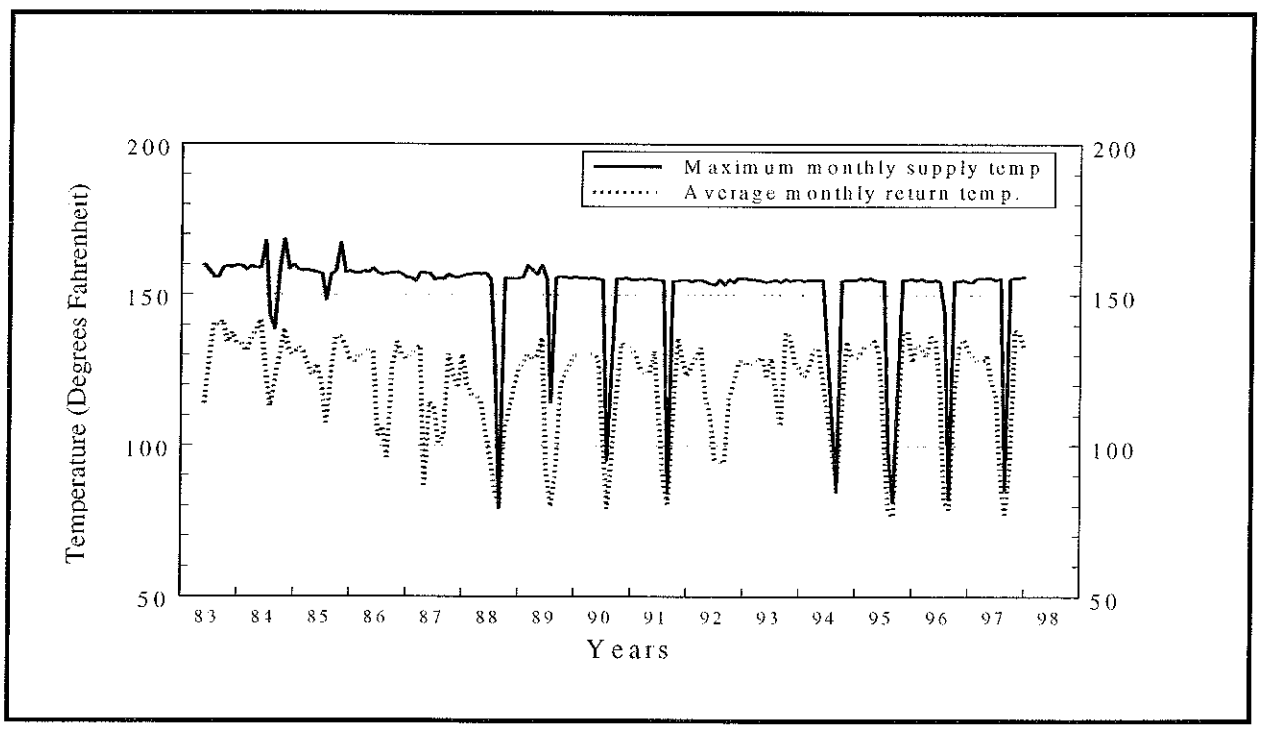

Figure 14. Maximum monthly supply and average monthly return temperatures for the State of Idaho Capitol Mall heating system, 1983-1997

months Maximum monthly supply temperatures decreased from about 160° F in 1983 to about 155° F in 1992 and have since risen slightly (Figure 14)

The City of Boise records monitoring data using flow rate and temperature charts The City also has a totalizer meter that is read weekly Since 1988, the City has supplied the IDWR with a production total for each month Production data prior to 1988 were documented in the Berkeley Group, Inc., (1990) and Montgomery (1992) reports.

Production for the City of Boise geothermal system was variable from water years 1984 through 1989 (Table 2; Figure 12). Beginning in water year 1990, production has been consistently in the 121-130 million of gallons per year range with the exception of a slight

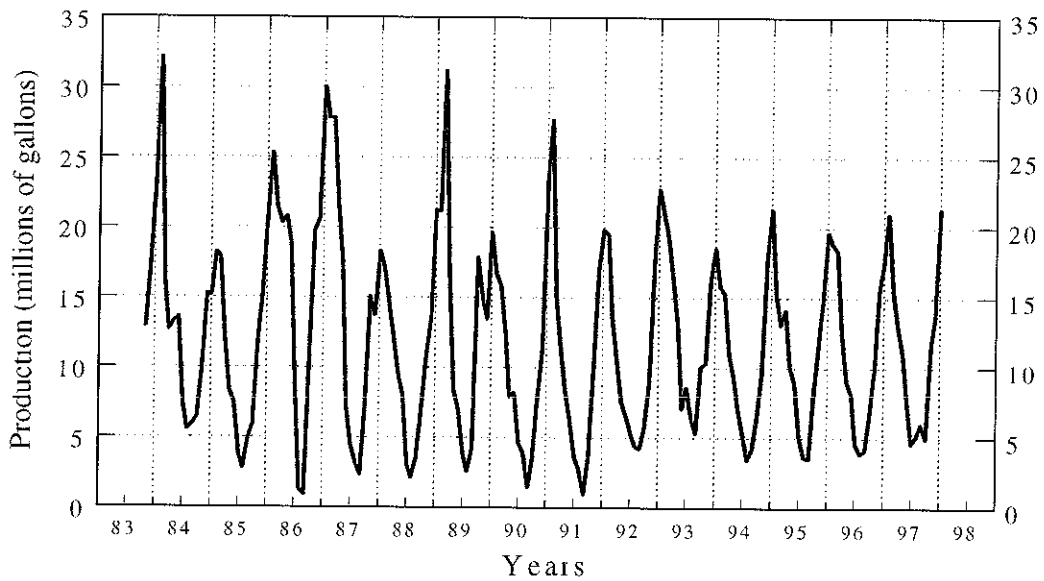

Figure 15. Monthly production for the City of Boise heating system, 1983-1997.

increase in water year 1993 (Figure 12). Maximum monthly production was generally higher during the 1980's than it was in the 1990's (Figure 15) Supply temperatures have remained constant at about 175° F.

VA technicians record totalizer, instantaneous discharge, temperature and water level data daily (except for weekend days and holidays) on handwritten log sheets Production has increased steadily from water years 1990 through 1997 (Table 2; Figure 12) Maximum monthly production has increased during this time period from about 16 million gallons to about

25 million gallons (Figure 16). The reason(s) for the increase is unknown (Doug Lamb, VA; personal communication) Supply temperatures have remained constant at about 162° F.

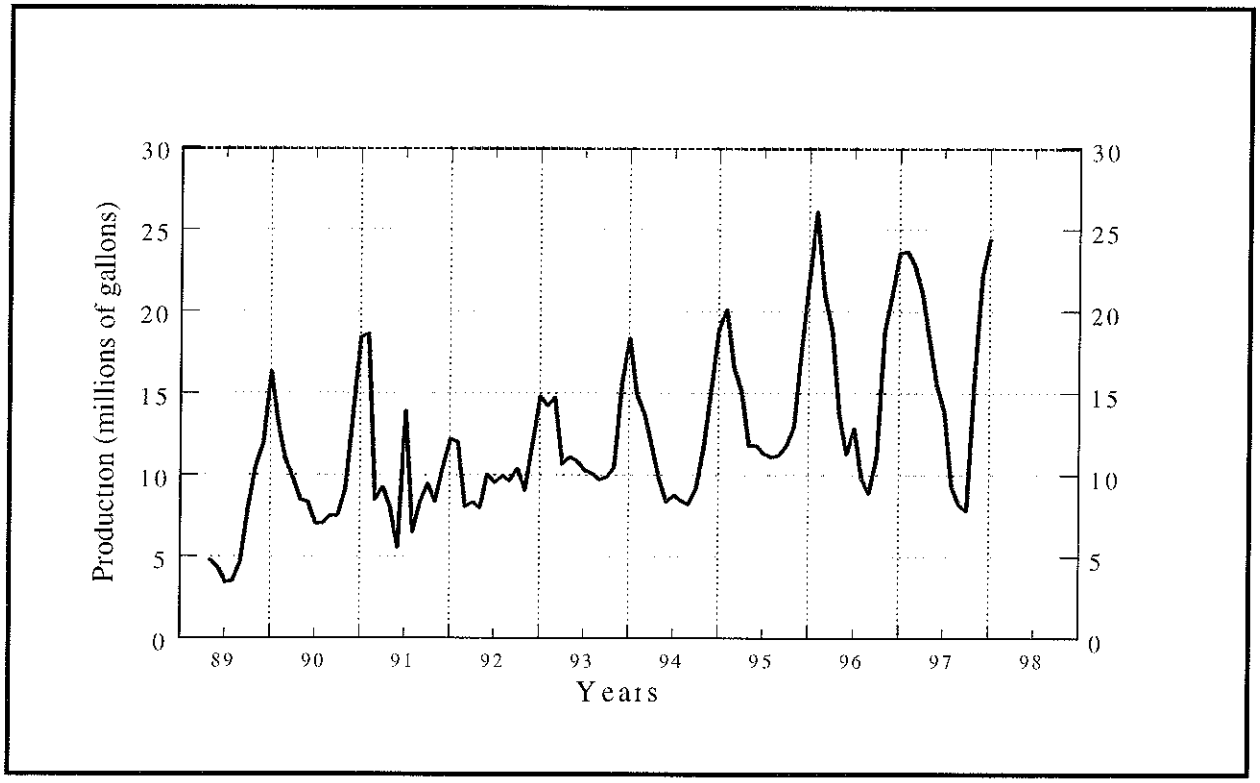

Figure 16. Monthly production for the Veterans Administration Regional Hospital heating system, 1989-1997

Figure 17 shows that total production for the four geothermal heating systems jumped dramatically in water year 1984 when the State and City systems came on line The average annual production for water years 1978 through 1983, when the BWSWD was the only system withdrawing geothermal water, was 279 million gallons The average annual production for water years 1984 through 1989 was 565 million gallons A second but smaller increase occurred in the early 1990's water years when the VA began production The average annual production for water years 1991 through 1997, when all four systems were on line, was 661 million gallons (Calculations did not include 1990 because a considerable amount of data were not available for the State system that year) The average for 1991-1997 is estimated to be 670 million gallons after adding in the estimated amount of withdrawals that are missing from the State system in 1996 and 1997

Overall, production has more than doubled since the time when only the BWSWD was withdrawing geothermal water Maximum monthly production, which occurs in January, for the

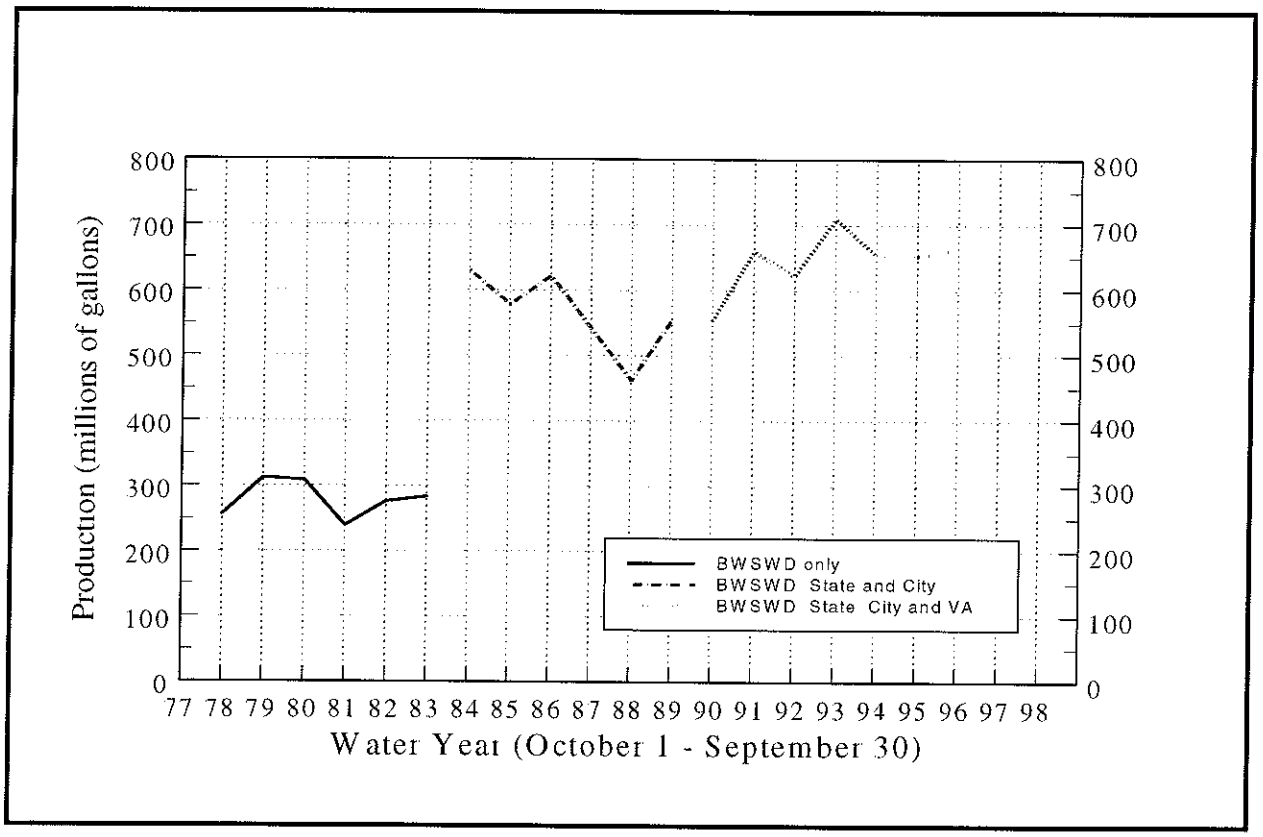

Figure 17. Total production by water year for the four heating systems in the Boise Front geothermal area, 1978-1997

four systems, has been as much as 106 million gallons (Figure 18) Figure 19 shows the average annual production and percentage of total for each heating system for water years 1991-1997.

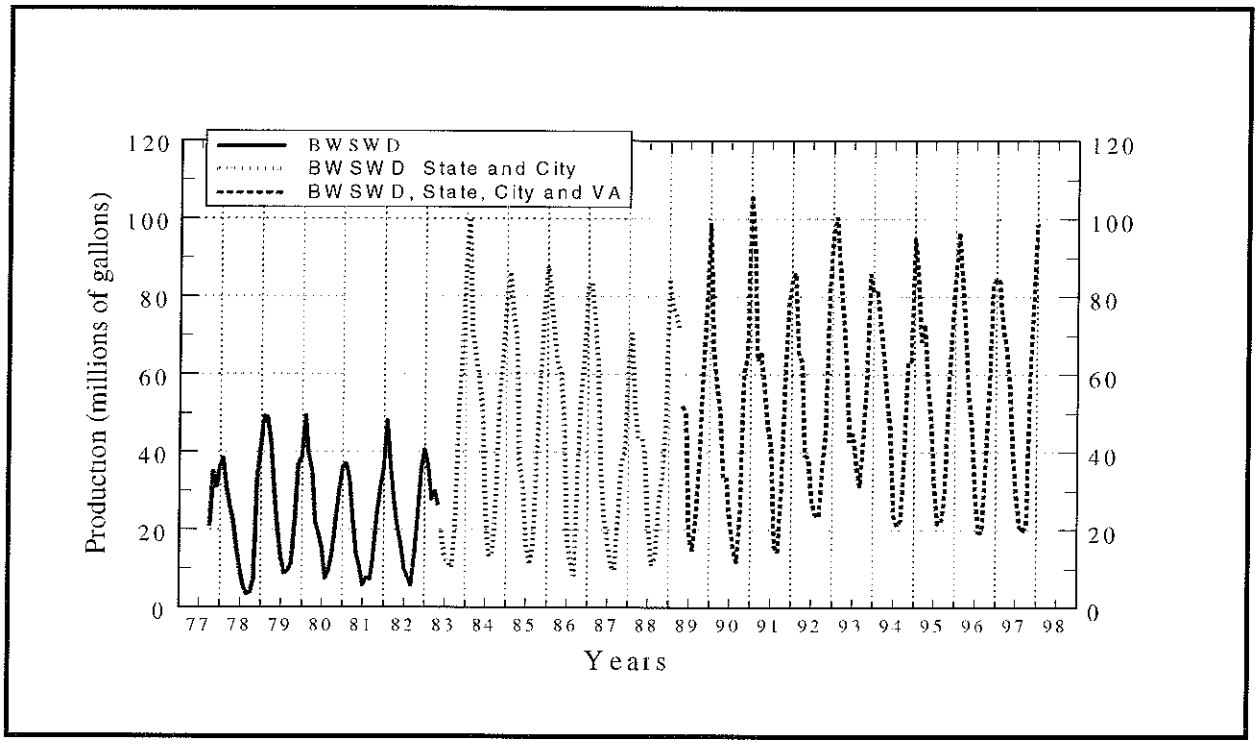

Figure 18. Monthly production for the four heating systems in the Boise Front geothermal area, 1977-1997

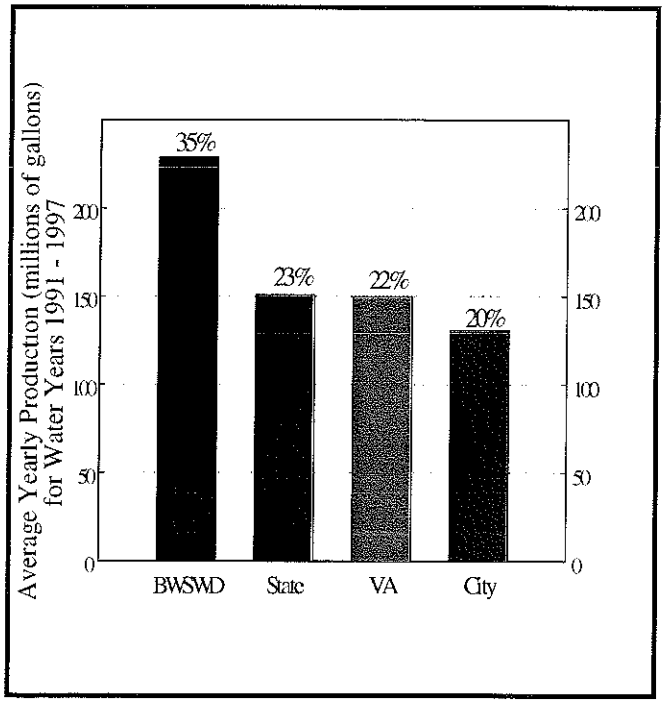

Figure 19. Average yearly geothermal production for the four heating systems in the Boise area for water years 1991 through 1997 Individual percentages of the total production are given for each system

GROUND WATER MANAGEMENT AREA AND MORATORIUM

Water levels in the BLM well, which is the primary monitoring well for the Boise Front geothermal area, declined about 25 feet from 1984 to 1989 (Figure 20) Comparing Figures 17 and 18 to Figure 20 shows that the plummeting levels in the mid to late 1980's were related to new production from the State and City heating systems Geothermal production in this portion of the Boise Front geothermal area increased about 100 percent when these two systems went on line The addition of the VA system in 1989 did not cause observable declines in the BLM well despite a 15 percent increase in total production The VA production well and the BLM well are believed to be in the same fault zone based on similar water level responses (Berkeley Group, 1990)

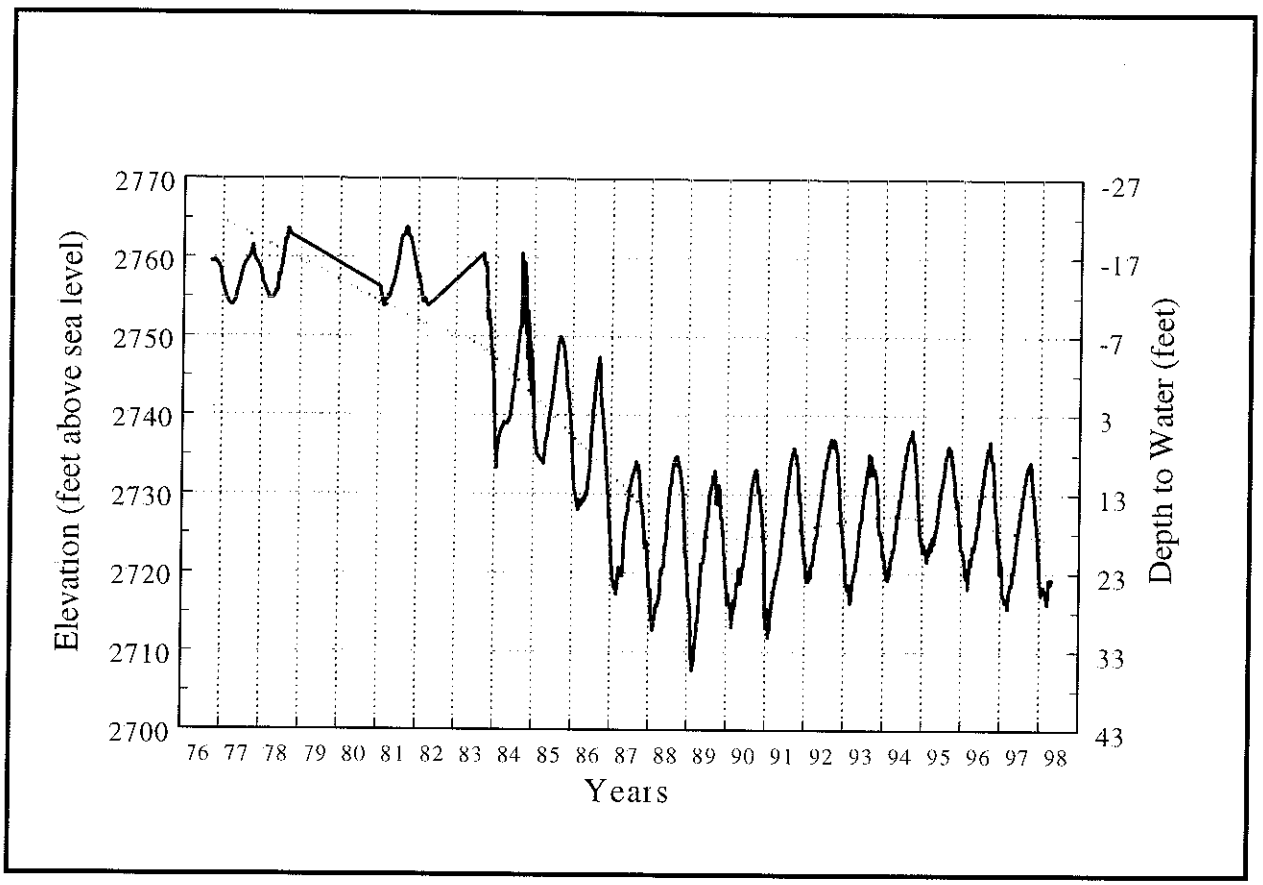

Figure 20. Hydrograph for the BLM observation well, 1976-1998 The solid line connects actual data points The dotted line was added using the locally weighted scatterplot smoothing (LOWESS) method to show the general middle trend of the data (Helsel and Hirsch, 1992)

On June 15, 1987, the IDWR designated the Boise Front Low Temperature Geothermal Resource Ground Water Management Area (Boise Front GWMA) which stopped routine issuances of permits for geothermal development in the designated area (Figure 2) The description of the Boise Front GWMA is:

> From a point of beginning at the Northeast corner of Sec. 8, T4N, R2E; thence southerly 1 mile to the southeast corner of Sec 8; thence easterly approximately 3 miles to the northeast corner of Sec. 14; then southernly 2 miles to the southeast corner of Sec 23; then easterly 2 miles to the northeast corner of Sec. 30, T4N, R3E; thence southerly 2 miles to the southeast corner of Sec. 31; thence easterly approximately 1 mile to the southeast corner of Sec. 32; thence southerly approximately 2 miles to the northwest corner of Sec 16, T3N, R3E, thence easterly 1 mile to the northeast corner of Sec. 16; thence southerly 1 mile to the southeast corner of Sec 16, thence easterly 1 mile to the southeast corner of Sec. 15; thence southerly approximately 5 miles to the southeast corner of Sec 10, T2N, R3E; thence westerly approximately 9 miles to the southwest corner of Sec. 8, T2N, R2E; thence northerly 4 miles to the southwest corner of Sec. 20, T3N, R2E; thence westerly approximately 2 miles to the southwest corner of Sec. 24, T3N, R1E; thence northerly approximately 4 miles to the southwest corner of Sec. 36, T4N, R1E; thence westerly 2 miles to the southwest corner of Sec. 34; thence northerly approximately 5 miles to the northwest corner of Sec. 10; thence easterly approximately 5 miles to the point of beginning (Idaho Department of Water Resources, 1987)

On June 10, 1988, the IDWR issued a five-year moratorium for the Boise Front GWMA whose main conditions were: 1) the prohibition of further development or additional use pursuant to undeveloped or partially developed permits (unless certain information is provided), and 2) the rejection of pending and future applications (unless certain information is provided)(Idaho Department of Water Resources, 1998) The Veterans Administration Regional Hospital was allowed to bring their system on line in 1988 because substantial development had been completed when the moratorium was issued In 1993, the IDWR extended the moratorium for another five years (Idaho Department of Water Resources, 1993). The moratorium is due to be reviewed in June, 1998. The dramatic water level declines in the BLM well ceased in 1989 Water levels rose slightly from 1989 to 1994 and have decreased a small amount since 1994 (Figure 20).

DATA ANALYSES

The following observations are based on reviewing and analyzing the geothermal monitoring data and other ancillary data for the Boise Front GWMA:

1. The rapid water level declines that occurred in the BLM well in the mid-1980's ceased after early 1989. Water levels increased in the BLM well from 1989 through 1994 (Figure 20). Since 1994, water levels have declined slightly.
2. Average annual total production for the four heating systems for water years 1991-1997 was 661 million gallons (Figure 17). The data from 1990 were not used because much of the State data for that year was missing. Some data were also missing from the State records for 1996 and 1997. The adjusted average total production for 1991-1997 was estimated to be 670 million gallons after the State records were modified with estimated values for the missing data intervals in 1996 and 1997.
3. Some correlations occurred between heating degree days and production data during water years 1991 through 1997 (Figures 4 and 17). For example, the number of heating degree days for water year 1993 was slightly higher than both the preceding and succeeding years. Total production was also higher in 1993. Both the number of heating degree days and the total production have remained fairly constant since 1994. However, missing State data for 1996 and 1997 make these correlations less reliable.
4. Correlations between water levels in the BLM well and total production are not clear. Water levels increased from 1990 through 1992 despite total production increases during these years. Water levels declined slightly in 1993 when heating degree days and total production were at their highest in the last 10 years. Water levels in the BLM well declined 3-4 feet from 1994 through1997 despite the apparent flat trend in total production. However, if we assume that total production was slightly higher in1996 and 1997 than shown in Figure 17 (based on the adjustments for missing data), then water level declines may be related to production increases for those years. In any event, fluctuations in water levels and total production have been minor in the last five years.
5. The average precipitation at the Boise Airport rain gauge station for water years 1987 through 1997 was about 10 percent lower than the 30 year average for water years 1968 through 1997 (Figure 3). These data suggest that recharge from precipitation to the ground water systems in the Boise area has been slightly less than average during the last decade. However, it is uncertain how fluctuations in precipitation affect water levels in the deep geothermal aquifer. Water levels in the BLM well did not responded immediately to precipitation fluctuations. For example, water levels in the BLM well increased slightly from 1990 through1992

despite below average precipitation during these years Water levels declined slightly in the BLM well from 1994 through 1997 despite above average precipitation in water years 1995-1997 Presently, it cannot be determined if the water level declines in the 1994-1997 interval were related to below average precipitation in some of the mid 1980's and early 1990's water years or to slight increases in total production

In conclusion, discharge does not appear to be exceeding recharge based on the water level data in the BLM well and the production data from the four geothermal heating systems. Water levels in the BLM observation well for the past 10 years indicate that the geothermal system has probably reached a new water level equilibrium, despite some minor fluctuations The reason(s) for the new equilibrium is not fully understood but it is probably caused by: 1) stabilized withdrawal rates since the rapid increases of the 1980's, and/or 2) induced recharge related to the increase in production from the geothermal system.

A model developed by Montgomery Watson (1994) predicted that water levels will decline if production is increased at the City and Boise Warm Springs well fields. However, the City of Boise recently completed an injection well that is expected to reduce or completely offset the predicted water declines caused by increased withdrawals. The new well will inject most of the City's spent geothermal water that is currently being disposed in the Boise River. This well, which is to be operational for the 1998-1999 heating season, is predicted to cause positive pressure effects assuming there is hydraulic connectivity between it and the geothermal aquifer (Montgomery Watson, 1996). A modeling scenario by Montgomery Watson (1994) predicted that injection of spent geothermal water near the new injection well location would result in no net changes to the water level at the BLM well assuming a 20 percent increase in production at the City and Boise Warm Springs Water District well fields

Based on the current data, it is uncertain how production increases, if allowed by the IDWR, will adversely impact the water levels in this part of the Boise Front geothermal system, especially in combination with the new injection well The historic data show that water level declines did occur after the State and City systems came on line. However, there were no observable water level declines with the addition of the VA production.

ACKNOWLEDGMENTS

The author would like to thank the following people who have faithfully recorded monitoring data for the four district heating system over the years: Rod Baldwin and Robert Giffiths (Boise Warm Springs Water District); Bill Hudson and Monty Leinberger (State of Idaho Capitol Mall System); Kent Johnson, Neal Oldemeyer and Dave Turner (City of Boise System); and Larry Post (Veterans Administration Regional Hospital)

The persons who provided technical reviews for this report were: Hal Anderson, Paul Castelin, Wayne Haas, Glen Saxton and Norman Young who are all employed at the Idaho Department of Water Resources. Thank you for taking the time to add valuable comments to this effort. Appreciation is also extended to Jessica Larson who helped with some of the graphics.

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