THE CONTINUED WARMING OF THE STOCKTON GEOTHERMAL WELL FIELD

Claude M. Epstein & Louise S. Sowers

Richard Stockton College of New Jersey
Natural and Mathematical Sciences, Pomona, NJ 08240, USA
609-652-4611
Claude.Epstein@stockton.edu, Louise.Sowers@stockton.edu

ABSTRACT

Temperatures within the Stockton College Geothermal well field have risen by as much as 11°C since it commenced operation in 1994. More heat is stored within the field during the air conditioning season than is removed during the heating season. Temperature increases have varied depending on whether the layers affected are aquifers or confining bed. Groundwater flow in the Upper and Lower Cohansey aquifers has functioned like a "stiff breeze", drawing cooler groundwater into the well field while advecting heat accumulated during its operation downflow. The deepest aquifer, the Rio Grande water-bearing zone, does not share this characteristic and seems merely to be accumulating heat.

INTRODUCTION

The geothermal well field commenced operations in 1994. But it soon became apparent that the college was air conditioning far more than it was heating. More heat was being added to the ground than was being removed. Consequently, ground temperatures slowly rose as time passed (Epstein, 1998; Epstein *et at*, 1996; Sowers *et al*, 1997). The purpose of this study is to document that rise in ground temperature over the last ten years.

HYDROGEOLOGIC SETTING

The well field contains three aquifers separated by confining beds. These are identified by means of three gamma radiation well logs (Figure 1). Aside from slight differences in surface elevation, the logs are similar. The first, or shallowest peak marks a confining bed at depths from approximately 75 to 115 feet, separating the **Upper and Lower Cohansey aquifers**. The **Upper Cohansey aquifer** lies between the surface and the top of the confining bed, while the **Lower Cohansey** lies beneath the base of the confining bed at depths of approximately 150 to 180 feet. A thick confining bed underlies the **Lower Cohansey**. Beneath this deeper confining bed lies the **Rio Grande water-bearing zone**, the third aquifer, at depths from 315 feet to 350 feet. This is followed by another still deeper confining bed beneath 350 feet.

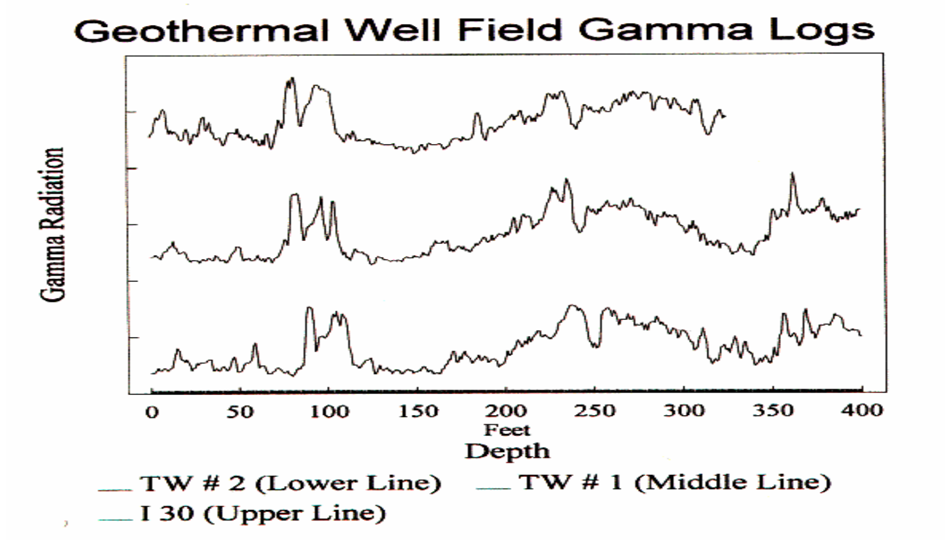


Figure 1. Geophysical Well Logs of the Geothermal Well Field

Groundwater flow in the region as a whole is from west to east (C. Epstein, 1994. 1995). Moreover, groundwater flow within the Cohansey aquifers is accelerated by the operation of the college's water supply wells east of the geothermal well field. The confining bed between the Upper and Lower Cohansey aquifers is thought to be discontinuous or leaky based on well tests conducted in nearby locations. Thus water withdrawn by the college not only affects the Lower Cohansey directly but the Upper Cohansey by leakage into the Lower Cohansey aquifer.

MONITORING WELLS

Eight wells were monitored for this study (Figure 2). EF 23 (Center) and CD 12,13 are within the well field. B1 (North), F46 (South), B26 (East) and L23 (West) wells occur just beyond the well field to the northwest, southeast, northeast and southwest respectively. The College Drive well occurs 475 feet northeast of the field while the USGS well (not shown in Figure 2) occurs 1200 feet east northeast.

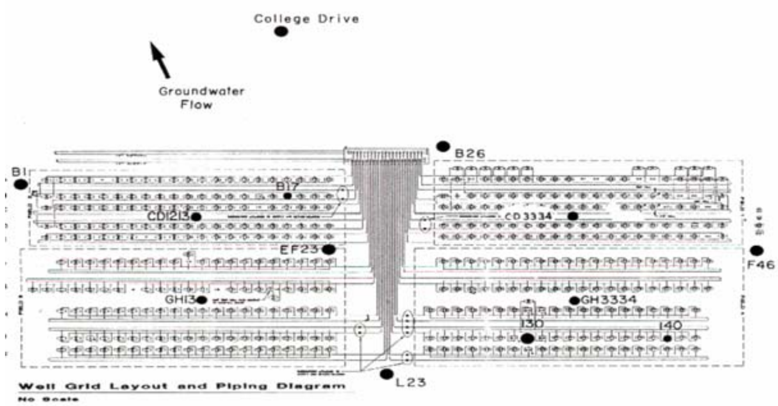


Figure 2. Location of Well Field Monitoring Wells

METHODS

Temperature profiles were determined for each monitoring well using a Solinst/Canada Model 201 water level/temperature meter. Temperatures were taken every five feet from the surface to the bottom of each well. These profiles were taken monthly from November 1994 through April 1997 and from October 2004 through August 2005. Then, average temperature was determined for each well for each reading starting at a depth of 30 feet and ending at the bottom of the well. This average was calculated to show the temperatures brought about by the operation of the well field. The upper 30 feet were not included in the calculation because weather conditions were a far greater influence on their temperatures.

TEMPERATURE CHANGES

Average Temperature Adjustments

The average temperature of the entire profile of each well is summarized in Table 1. The initial temperatures for most of these wells were recorded in November 1993 before the well field was in operation. The initial temperature of CD 12,13 was taken in February 1994 shortly after the field commenced operation but during the heating cycle and therefore unaffected by the addition of heat added during the air conditioning cycle. The initial temperatures of the college drive well (Col.Dr.) were recorded in January 1995 before advected heat from the well field reached it.

Well	Initial	Jan.'95	Jan'05	Change	Change
				'95-'05	'94-'05
CD 12,13	13.40	17.41	24.51	7.10	11.11
EF 23	13.77	16.04	21.93	5.89	8.16
L 23	13.35	13.92	13.36	-.56	0.01
B1	13.10	14.59	15.74	1.15	2.64
F 46	13.66	14.05	14.23	0.18	0.57
B26	13.59	15.26	21.04	5.78	7.45
Col.Dr.	13.69	13.85	15.98	2.13	2.29
USGS	12.76	12.75	12.65	-.10	-.11

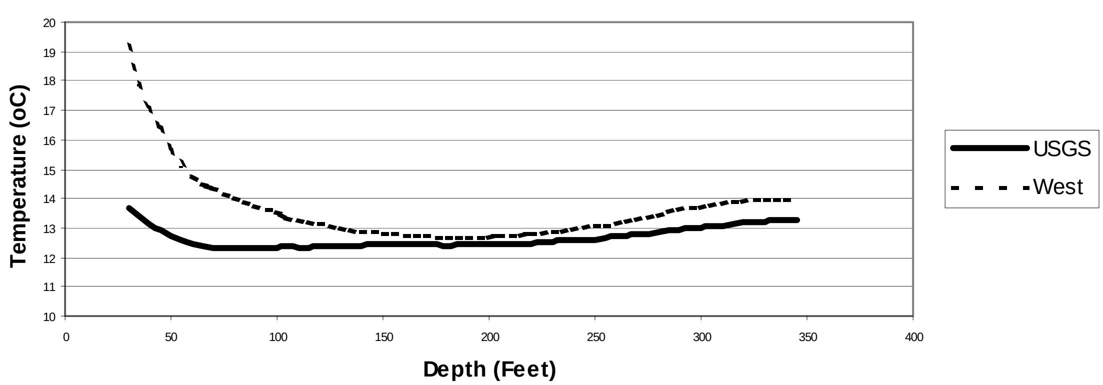
Table 1. Average Temperature (^{o}C)

Groundwater temperatures were not affected in L23 and the USGS wells. L23 is upflow of the well field while USGS is 1200 feet downflow and not aligned with the advected heat plume. There are modest heat increases from advected heat in B1 and F46 northwest and southeast of the well field. But the most substantial temperature increases occur within the well field at EF 23 and CD 12,13. CD 12,13 is downflow from EF 23 and therefore receives advected heat from upflow parts of the well field as well as its own direct heat load. (The highest temperatures recorded within the well field occurred in CD 12,13 where temperatures reached 25.57^{o}C at depths from 330 to 340 feet.) The advected heat plume is best seen in B26 and Col.Dr northwest of the well field.

Temperature Changes Within Aquifers and Confining Bed.

The temperature profiles in wells not affected by the operation of the well field show a natural profile. Here, the upper 30 to 50 feet show either a decrease or increase due to the change in seasons. But beneath this, temperature decreases slightly or is stable until approximately 175 feet when it increases modestly (Figure 3).

Figure 3. Beyond Well Field Impact
USGS L23
Jan. 2005



But the temperature profiles within the well field depart from the natural condition because of a.) the differences in heat storage between aquifers and the confining beds and b.) the advection of heat within aquifers due to groundwater flow. Unheated groundwater enters the well field through the underlying aquifers. Consequently, though temperature is elevated at all depths within the well field, the temperatures within the Upper and Lower Cohansey aquifers are lower than those in their adjacent confining beds. This is seen in both aquifers in wells CD 12,13 (Figure 4) and B1 (Figure 5) and in the Lower Coshansey aquifer in well EF 23 (Figure 4). The heat lost from the Cohansey aquifers in the well field elevates the temperature within these aquifers downflow. This is seen in both aquifers in B26 and in the Lower Cohansey in the college drive well (Figure 6). The Rio Grande water-bearing zone shows a different trend. It tends to be warmer than its surrounding confining beds. This is seen within the well field (Figure 4) as well as in wells F46 and B26 along the well field's southeast and northeast margins (Figures 5 & 6).

Figure 4. Within Well Field
CD 12,13 EF 22
Jan. 2005

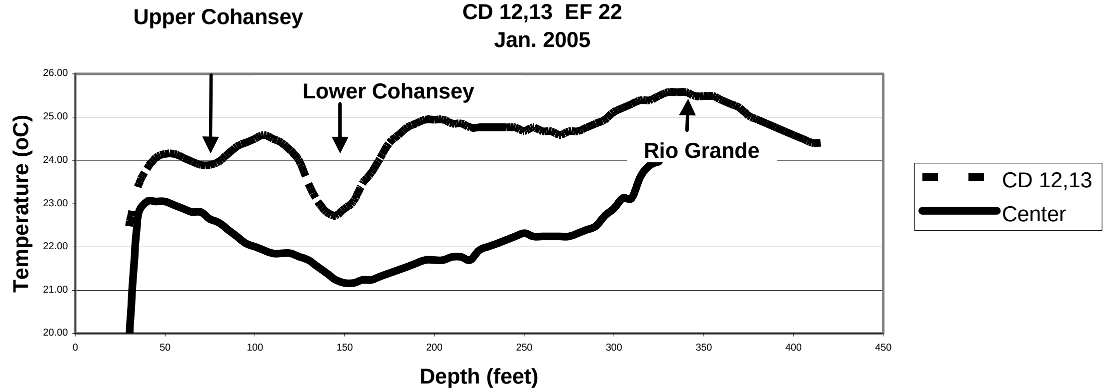


Figure 5. North & South Well Field Margins
B1 F46
Jan. 2005

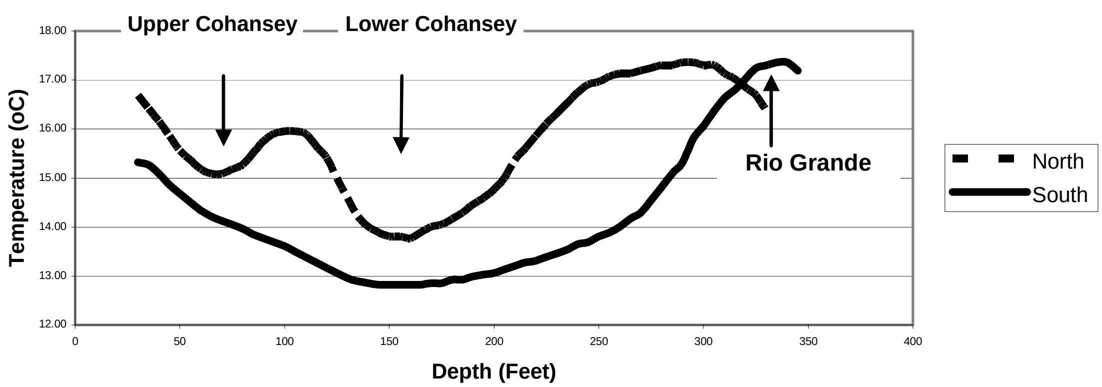
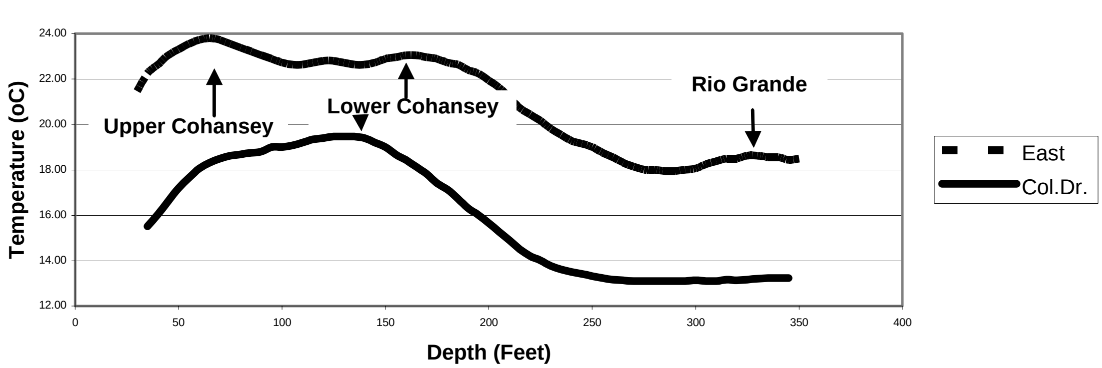


Figure 6. Downflow of Well Field
B26 College Drive
Jan. 2005



CONCLUSIONS: TEMPERATURE CHANGES IN THE LAST TEN YEARS

Temperature within the Stockton College geothermal well field has continued to rise since it began operation in 1994. The average temperature rose over 11 ^{o}C in the warmest parts of the field, over 7 ^{o}C in the last ten years. Groundwater temperature has increased at all depths within the well field but the magnitude of change varies from aquifer to confining bed. Natural groundwater flow, augmented by the operation of the college's wells, has cooled temperatures slightly within the well field in the Upper and Lower Cohansey aquifers while at the same time, advected heat from these aquifers downflow of the well field. The Rio Grande water-bearing zone on the other hand, has warmed slightly.

ACKNOWLEDGEMENTS

The authors would like to acknowledge RSC for the support through a Distinguihed Faculty Award and the help of student workers, Karl Milanus, Sandra Richards, Dale Leipe and Crystal Hoover.

REFERENCES

Epstein, C., (1994). Hydrogeology of the Stockton College Geothermal Well Field. *In* Monitoring and Analysis of the Geothermal Heat Pump Installation at Stockton College (NJ), edited by L. Stiles, 1994 Report to Atlantic Electric, EPRI, SNL, and SJTA. pp.6-1 to 6-24.

Epstein, C., (1995). Temperature Changes in the Geothermal Well Field. *In* Monitoring and Analysis of the Geothermal Heat Pump Installation at Stockton College (NJ). edited by L. Stiles, 1995 Report to Atlantic Electric, EPRI, SNL, and SJTA, pp. 3-1 to 3-10.

Epstein, C., (1998). *Impact of Groundwater Flow on the Stockton Geothermal Well Field. Underground Thermal Storage & Utilization,* Vol. I.

Epstein, C., W. Skinner, W., L. Stiles, H. Taylor, L. Sowers, & S. Pal, (1996). *Geothermal Heating on a Very Large Scale : the Stockton College Facility*. Well Water Journal, 9(3): 38-41.

L.S. Sowers, C. M. Epstein, K.P. York, B. VanGuilder, S. Jahangir, A. Steinberg, L. Stafford, J. Pierce with J. Brownhill, 1997. *Impact of a Large Scale Geothermal Project on its Surface and Subsurface Environment*. MEGASTOCK '97 Proceedings of the 7th International Conference on Thermal Energy Storage. Pp.85-90.