APPENDIX H
Report on Turbidity Analysis for Discharge at Liddell Spring

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March 30, 2009 Job#08023

Mr. Todd Sexauer
County Planning Department,
Government Sector.
701 Ocean St,
Santa Cruz, CA 95060

SUBJECT: Appendix H
Report on Turbidity Analysis
for discharge at Liddell Springs
Davenport, California

Dear Mr. Sexauer,

We have completed our analysis of turbidity in water exiting Liddell Spring, as requested. The purpose of our analysis was to estimate the volume of water entering the Santa Cruz City Water Department's diversion pipeline that is above the turbidity limits specified in the 1964 agreement between the City and the quarry operator. According to the 1964 agreement, the turbidity of this water is not to exceed 0.5 nephelometric turbidity units (NTU) under normal conditions and is not to exceed 2 NTU within 48 hours following a rainfall event. We have also estimated when the turbidity of the diverted springflow exceeded 25 NTU, which may require different approaches to be treated.
For the analysis, we estimated water volumes using data for the 2005, 2006, and 2007 Water Years (WYs). We also looked at the number and duration of turnouts over the time period for which the turnout data was provided (1991 to 2007).

We have preformed the following services during our investigation:

1.) Compilation of discharge, turbidity, precipitation, and turn-out data pertinent to Liddell Springs.

2.) Data analysis, interpretation, and estimation of water volumes over the 2005, 2006, and 2007 WYs diverted by the city that were out of compliance with the turbidity standards in the 1964 agreement between the city and the quarry.

3.) Preparation of this report.

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Hydrologic and Geologic Setting

Liddell Spring is located at the headwaters of the East Branch of Liddell Creek near the town of Davenport California. Liddell Springs is part of the Liddell Creek watershed, which has a topographic drain basin area of approximately 3.4 square miles (Balance Hydrologics, 2007). Liddell Spring is a discharge point for groundwater traveling through the local karst aquifer. Recent dye tracer studies preformed by P.E. LaMoreaux & Associates (PELA, 2004) indicate that recharge to this karst aquifer system occurs a wide area. Recharge sources to Liddell Spring include, but are not limited to, sinking reaches in Reggiardo, Laguna, and Whitesell creeks, and numerous sinkholes located in the marble outcrop. The large pit excavated by the quarry also acts as a recharge source.

Methodology

Data Sets

The data sets containing the turbidity, precipitation, and discharge data over the 2005, 2006, and 2007 WYs were provided by the Santa Cruz City Water Department. Turbidity measurements at Liddell Spring are provided by a HACH 1720c turbidimeter and a HACH Surface Scatter 6 (SS6) turbidimeter. These turbidimeters record turbidity values every fifteen minutes and the values are remotely downloaded approximately every hour. These two instruments are calibrated to read turbidity under low and high conditions, respectively. For the purpose of our analysis, we used the data from the 1720c instrument when the turbidity was 10 NTU or under, which was an adequate range for the first stage of our analysis. When the turbidity was higher than 10 NTU we used the data from the SS6 turbidimeter.

The discharge values provided by the City are for flow recorded by an in-pipe flow meter located in the City's diversion pipeline, just up-pipe from the turn-out valve that is used to shut off the diversion when turbidity values are too high. The discharge data is for instantaneous flow taken at fifteen minute intervals. The City's diversion pipeline downstream from the turn-out valve is cited by Balance Hydrologics to have a maximum capacity of 2.47 cubic feet per second (CFS) or 1,109 gallons per minute (GPM). Inspection of the discharge data suggests that the pipeline capacity is closer to 1,182 GPM. The reason for this apparent discrepancy is unknown. The discharge from the turnout pipe downstream from the flow meter can exceed the flow capacity of the diversion pipeline. Consequently, the measured flow in the pipeline when the source is turned out (flow going from Liddell Spring back into Liddell Creek) routinely exceeds the capacity of the diversion pipeline.

The precipitation data used in the analysis is from an event-logging, 5-inch, tipping-bucket rain gauge operated by Balance Hydrologics Inc. adjacent to Liddell Spring. This rain gauge was installed in October of 2000 and logs rainfall values every hour.

In addition to turbidity, precipitation, and discharge data, the City provided logs recording the date and time that flow to the diversion pipeline was turned in (water flowing from Liddell Spring to the City water treatment plant) or turned out (water from Liddell Spring being discharged back into Liddell Creek). This data was provided mostly in handwritten logs. We noted a number of errors in the data, usually consisting of double entry of turn-outs or turn-ins. We believe one of the factors causing the double entries is that the City Water Department operates the turn-out valve both manually (on-site) and remotely. We went through all the data manually to eliminate double entries.

In order to make a valid estimation of a yearly volume of water exceeding the 1964 agreement turbidity limit, we constructed a spreadsheet algorithm in excel. The turbidity limits specified in the 1964 agreement stated that the turbidity is to be under 0.5 NTU during non-rainfall conditions and be under 2 NTU in the 48 hours immediately following a rainfall event. For the purpose of our investigation, we have defined a rainfall event as any time the rainfall exceeds 0.1 inches in a 48-hour period.

These conditions were applied to the data in the excel spreadsheet. The spreadsheet algorithm identified times when the turbidity exceeded 0.5 NTU, and the times when turbidity exceeded 2 NTU within 48 hours of a rainfall event. These time periods were combined and discharge amounts during were calculated when the source was turned in. The total volume of water that was over 25 NTU and not turned out by the city was also estimated using data from the SS6 turbidimeter.

Some assumptions were made during our analysis. We rounded to the nearest fifteen minute interval for turn-out times that were in between the fifteen minute data set intervals. We also assumed that discharge measured every fifteen minutes was the average value over those fifteen minutes. This assumed average was then used to calculate an estimated volume of water during these fifteen minute time intervals.

Summary and Conclusions

The total volume of water over the turbidity limit specified in the 1964 agreement between the City and the quarry operator is summarized in Table 1. The volume of water over the turbidity limit increased significantly from the 2005 WY to the 2006 WY. The number of turn outs did not decrease from 2005 to 2006, but the average duration of these turn outs was lower in 2006. The volume of water over the turbidity limit decreased dramatically from the 2006 WY to the 2007 WY. The number and duration of turnouts decreased in 2007.

Table 1: Water Volumes Exceeding the 1964 Agreement Standards

Water Year	Total Volume of Diversion Exceeding 1964 Agreement Standards (gallons)	Total Volume of Diversion Exceeding 25 NTU (gallons)
2005	114,397,718	81,405
2006	161,263,185	2,856,585
2007	12,218,427	139,268

Table 2 shows the calculated water volumes corrected to the stated pipeline capacity of 1,109 GPM.

Table 2: Water Volumes Corrected for Stated Pipeline Capacity

Water Year	Total Volume of Diversion Exceeding 1964 Agreement Standards (gallons), from Table 1	Total Volume of Diversion Corrected to Stated Pipeline Capacity (gallons)
2005	114,397,718	112,953,188
2006	161,263,185	157,994,203
2007	12,218,427	11,840,184

Figure 1 shows the total number of turnouts per year for the data period. We see no trend in the number of turnouts per year in the data. However, the average duration of each turnout has declined markedly since 1998, resulting in a decreasing rate of turnout over the data period (Figure 2).

Please call me if you have any questions or require additional information.

Sincerely,

Jeffrey M. Nolan, CEG #2247
Principal Geologist

Aaron Powers, M.S.
Staff Geologist

Attachments: Figures 1-2

References

Chartrand, S., Hastings, B., Hecht, B., 2007, Annual Hydrologic record for Liddell Spring #1 Santa Cruz County, California: Data Report for Water Year 2006. Consulting report prepared for City of Santa Cruz Water Department by Balance Hydrologics, Berkeley California, 25 p.

Chartrand, S., Hastings, B., Hecht, B., 2008, Annual Hydrologic record for Liddell Spring #1 Santa Cruz County, California: Data Report for Water Year 2005. Consulting report prepared for City of Santa Cruz Water Department by Balance Hydrologics, Berkeley, California, .

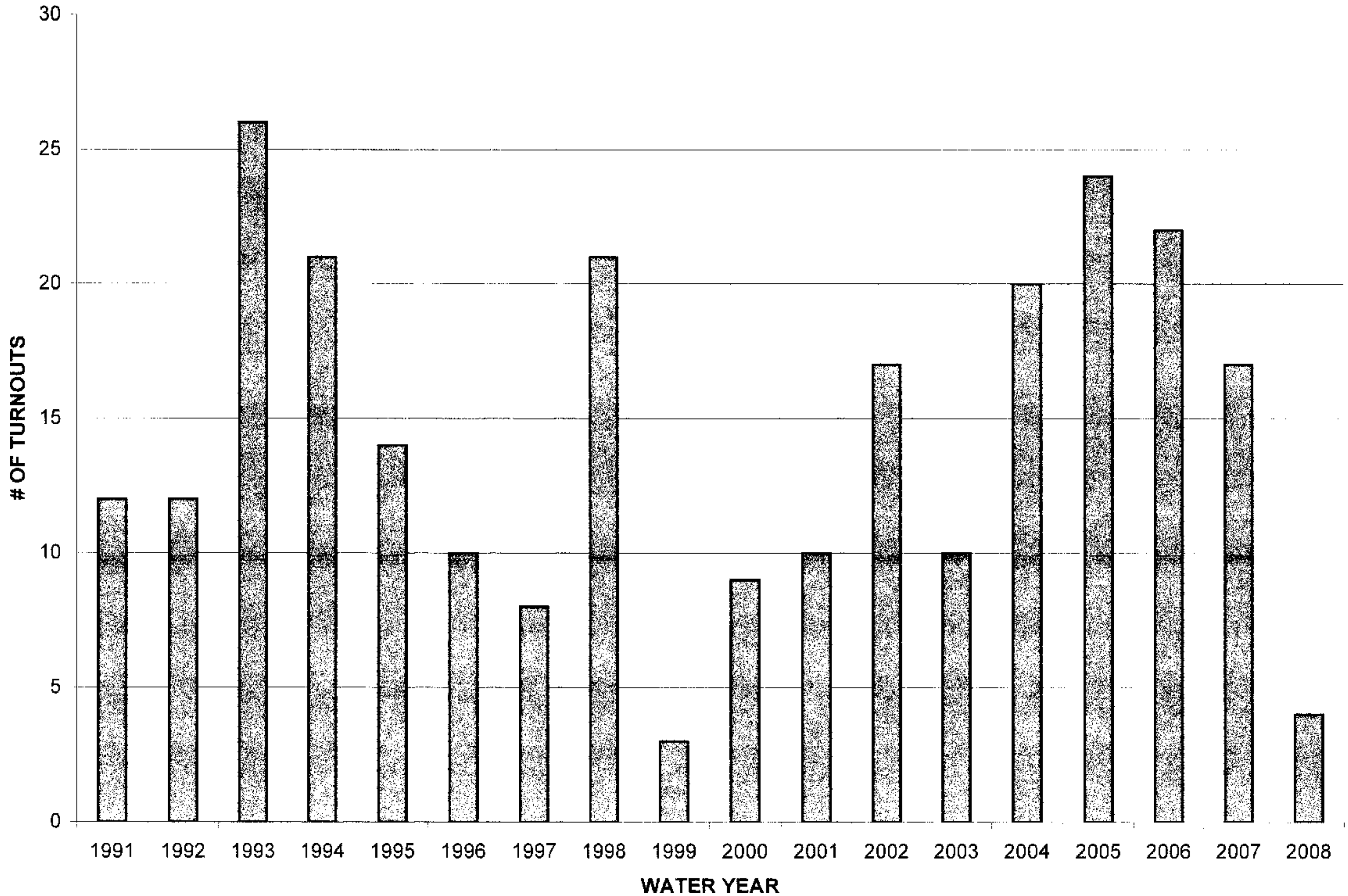

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Figure 1. **Turn-Outs vs Time**
Liddell Springs
CEMEX Limestone quarry
Davenport, California

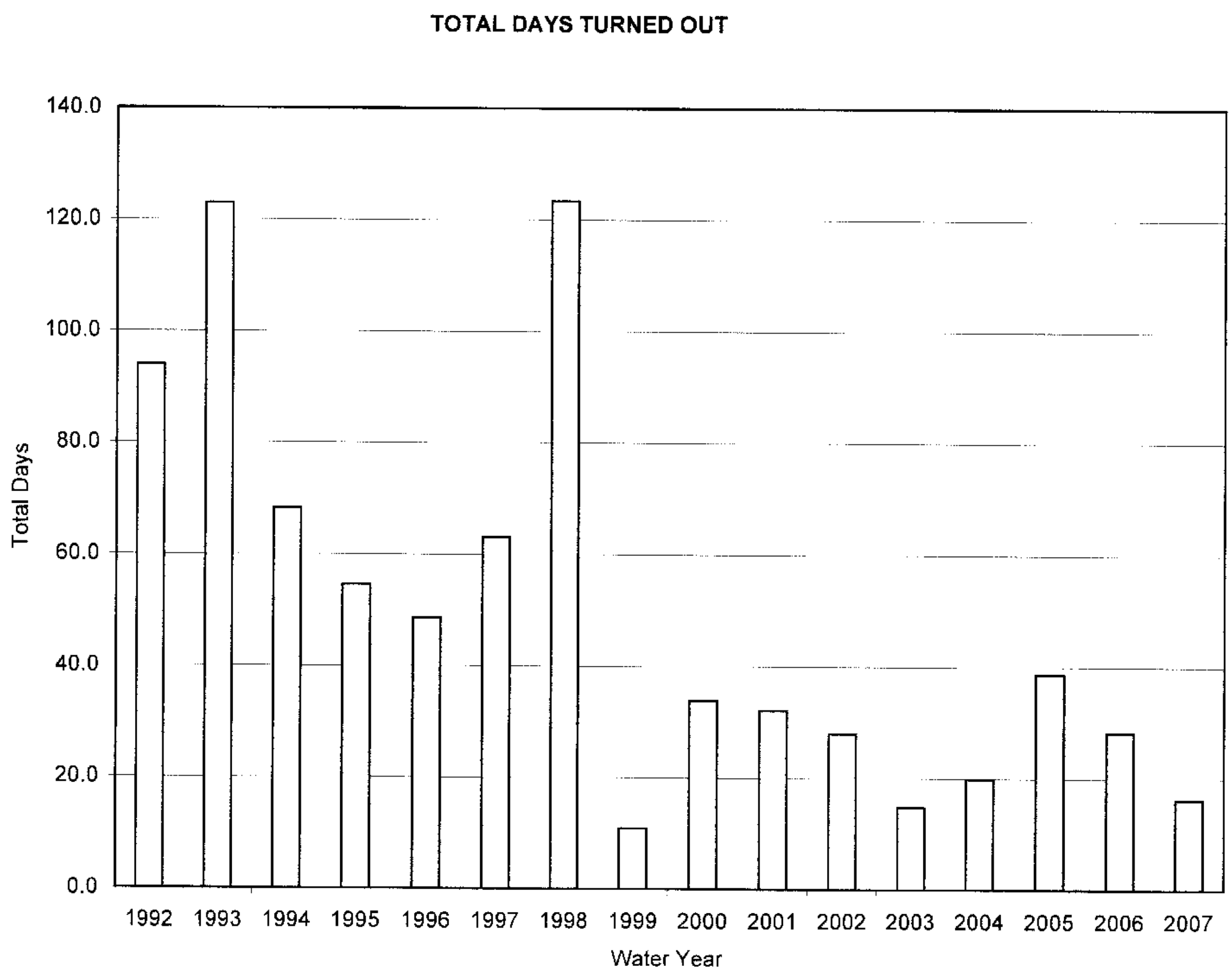

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Figure 2. **Days Turned out vs Time**
Liddell Springs
CEMEX Limestone quarry
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