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**AFRL-ML-TY-TR-2002-4519**



**In-Situ Anaerobic Dechlorination of Chlorinated  
Solvents at NAS Fallon, Nevada: Tracer-Test Study**

Victor S. Magar

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13. ABSTRACT (Maximum 200 words) This effort was conducted to determine the flow rate of the groundwater at NAS Fallon, Nevada, in support of research advancing in situ anaerobic dechlorination of chlorinated solvents. The study was conducted at an existing array of groundwater wells in an area contaminated by chlorinated solvents. Fresh water was used as the tracer due to the heavy loading of chlorides in the area. The tracer tests were inconclusive regarding groundwater transport in the treatment lanes.				
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February 3, 1998

Ms. Cathy Vogel  
USAF, AL/EQW-OL  
139 Barnes Drive, Suite 2  
Tyndall AFB, Florida 32403-5319

Dear Ms. Vogel:

**In Situ Anaerobic Dechlorination of Chlorinated Solvents at NAS Fallon, Nevada  
Tracer-Test Study  
ARO Delivery Order 1705**

This letter-report constitutes the final report for ARO Delivery Order 1705, for work conducted at the Naval Air Station (NAS) Fallon, Fallon, Nevada. Two studies were conducted under this delivery order. A final report of the first study was submitted to the Air Force on December 29, 1995, entitled "Determination of Groundwater Flow Direction at NAS Fallon." The second study, which is the subject of this letter report, involved the use of a groundwater tracer to establish groundwater flowrates at Site 1, NAS Fallon (Figure 1), in support of a dechlorination treatability study being conducted at this site. The data for the tracer studies were submitted via e-mail on December 2, 1997.

**Approach:** The site consists of five parallel, 25-ft long biotreatment lanes (Lanes A through E), separated by 20-ft-deep, high-density polyethylene (HDPE) barriers. The layout of the treatment lanes and corresponding injection, extraction, and groundwater monitoring wells is shown in Figure 2. Groundwater flow through the five lanes is hydraulically controlled using a single downgradient extraction well for all five lanes, and five injection wells located at the upstream end of each lane. The downgradient extraction well pump rate is approximately 200 gpd, and 10 gpd is injected into each of the groundwater injection wells.

Lane A is used as a control lane, and has four mono-level monitoring wells downgradient of the Lane A injection well. Lanes B, C, and D are fed alternative electron donors for chloroethene dechlorination; each lane has four bilevel monitoring wells located downgradient of their respective injection wells. All five lanes have upgradient monolevel monitoring wells, located 5 ft upgradient of the injection wells. Lanes B, C, and D have monolevel side wells (S wells), located on either side of the HDPE barriers that separate these lanes. The monolevel wells are screened from 9 to 10 ft below ground surface [bgs], and bilevel wells were screened at 9 to 10 ft and 11 to 12 ft bgs. All wells are 1-inch-diameter, stainless steel, direct-push wells. Lane E is being used by the EPA for a parallel study, and is not included in the results presented in this report.

Two tracer tests were conducted in series. In both tests, a freshwater tracer was injected at 10 gpd for a one- to two-week period into Lane C. High chloride concentrations (5,000 to 10,000 mg/L) at the site ruled out the use of chloride. Bromide concentrations are much lower than chloride concentrations; however, bromide was not used as a tracer because the high chloride levels could mask bromide detection in laboratory analyses. Freshwater was expected to result in reduced total dissolved solids (TDS) concentrations in Lane C, including chloride and other anions and cations.

The following wells were monitored during the tracer study. All nine Lane C monitoring wells were included, to examine the groundwater flowrate through Lane C. The upgradient Lane B and -D wells were monitored to examine potential groundwater crossover between lanes. The four side wells located adjacent to the Lane B/Lane C and Lane C/Lane D HDPE barriers were monitored to assess the potential for groundwater short-circuiting between the lanes, along the barriers. The Lane D S well (Well S-4) was unproductive and could not be sampled.

The first tracer test began July 16, 1997 and freshwater was injected into Lane C for 7 days, ending on July 23, 1997. For the second tracer test, freshwater was injected into Lane C between August 22 and September 29, 1997. The second, longer injection period was conducted because changes in the field parameters were not detected above background levels after the one-week injection test. Monitoring wells were sampled on July 15, 17, 20, 23, and 31; August 6, 13, and 27; September 3, 10, and 24; October 1, 8, 14, and 27; and November 27, 1997. Monitoring involved sample collection and measurement of field parameters (conductivity, temperature, pH, dissolved oxygen [DO], and oxidation-reduction potential [ORP]). Additional samples were sent overnight to the EPA (Kerr Research Laboratories, Ada, OK) during each sampling event. Samples included duplicate, unpreserved 100-mL samples collected in plastic bottles for analysis of anions (sulfate, total nitrates [nitrate + nitrite], and chloride), dissolved organic carbon, alkalinity, pH, and conductivity. The data from these analyses were maintained by the EPA and the Air Force. The data presented in this report include the field-collected parameters only.

**Results:** Results of the field parameters are plotted in Figures 3 through 22, as follows:

Figures 3 and 4: Conductivity vs. Time for the Lane C 10-ft and 12-ft-deep wells, respectively.

Figure 5: Conductivity vs. Time for the 10-ft-deep upgradient Lane B and D wells.

Figure 6: Conductivity vs. Time for the 10-ft-deep sidewall wells (S-1, S-2, and S-3).

Figures 7 and 8: pH vs. Time for the Lane C 10-ft and 12-ft deep wells, respectively.

Figure 9: pH vs. Time for the 10-ft-deep upgradient Lane B and D wells.

Figure 10: pH vs. Time for the 10-ft-deep sidewall wells (S-1, S-2, and S-3).

Figures 11 and 12: Temperature vs. Time for the Lane C 10-ft and 12-ft deep wells, respectively.

Figure 13: Temperature vs. Time for the 10-ft-deep upgradient Lane B and D wells.

Figure 14: Temperature vs. Time for the 10-ft-deep sidewall wells (S-1, S-2, and S-3).

Figures 15 and 16: DO vs. Time for the Lane C 10-ft and 12-ft deep wells, respectively.

Figure 17: DO vs. Time for the 10-ft-deep upgradient Lane B and D wells.

Figure 18: DO vs. Time for the 10-ft-deep sidewall wells (S-1, S-2, and S-3).

Figures 19 and 20: ORP vs. Time for the Lane C 10-ft and 12-ft deep wells, respectively.

Figure 21: ORP vs. Time for the 10-ft-deep upgradient Lane B and D wells.

Figure 22: ORP vs. Time for the 10-ft-deep sidewall wells (S-1, S-2, and S-3).

**Conductivity.** Conductivity in the Lane C 10-ft deep wells showed a slight decline, from an average of 21.2 to 13.8 mS, between days 0 and 43. After day 43, conductivity in all the wells was relatively stable, except for the 5-ft downgradient well, which showed the steepest decline in conductivity between days 0 and 43, and a rebound after day 71. The changes in conductivity could be based on sample variability; the variability in the Lane C samples was comparable to the variability in the upgradient Lane B and D wells and in the S wells; conductivity was relatively stable in the upgradient Lane B and D wells and in the S wells, with only a slight decline between days 0 and 40 and a rebound after day 40. Thus, the changes in conductivity could not be attributed to the injection of freshwater at the site.

Conductivity in the Lane C 12-ft-deep wells showed steep decline, beginning at 45-50 mS to approximately 25 mS over the 130-day test period. The steepest decline began after day 36, which coincides with the start of the second tracer test (day 37), and could have resulted from the tracer injection. This seems unlikely, however, because conductivity changed at the same rate and magnitude in all four deep wells (located 5, 10, 15, and 20 ft downgradient of the injection well). If the conductivity changed as a result of the freshwater injection, conductivity levels would have decreased in the most upgradient well (Well C-5-10) first, followed by changes in each downgradient well, and ending with the most downgradient well (Well C-20-10). Furthermore, the magnitude of the change in conductivity would be highest for the well closest to the injection source and would decrease due to dispersion, as the tracer traveled downgradient.

The effect of the freshwater tracer study on conductivity in the Lane B, C, and D wells, and in the S wells cannot be ascertained from this data, and remains inconclusive. The existing data do not indicate what other factors might have influenced conductivity in the groundwater.

**pH.** The pH levels ranged from 7.3 to 8.4 across the site. pH levels in the upper and lower wells were similar, showing no stratification in pH at the site. A low pH of approximately 5.5 was measured in the Lane B and D wells, but is assumed to be in error, because it is not supported by other pH measurements. A malfunctioning probe prevented pH monitoring on day 30. The overall conclusion is that the tracer test had an insignificant effect on pH.

**Temperature.** The average temperature was 20.8°C in the upper Lane C wells, and 21.1 in the lower Lane C wells. Thus, temperature was not significantly stratified in the aquifer between the upper and lower wells. Temperature changes could not be correlated with the tracer test, but temperatures are within a range that can support biological activity at the site.

**Dissolved Oxygen.** The figures showing DO over time suggest a significant DO drop at the site. However, the ORP results will attest that the site is under reduced conditions (ORP < 0.0 mV), where DO levels should be zero. Throughout the study period, DO was less than 1 mg/L. However, after the

first 60 days of the study, it was discovered that the DO probe was being calibrated at the saturated end of the DO spectrum, and not at zero-DO levels. On day 64, the DO probe was calibrated at the zero-DO level using a sodium sulfide standard. DO levels after day 64 were well below 0.5 mg/L, and often measured 0 mg/L, indicating anaerobic conditions at the site. The DO increase at the last data point (day 129) was due to a malfunctioning DO probe membrane.

**Oxidation-Reduction Potential (ORP).** ORP measurements suggest highly reducing conditions, indicative of intrinsic bioremediation at the site. The lowest levels ( $< -200$  mV) were measured in the upper Lane C wells, and in the Lane B, D, and S wells. Higher levels, between zero and  $-150$  mV, were measured in the deeper Lane C wells. The ORP stratification between the lower and upper wells is attributed to contaminant stratification at the site. Contaminants are introduced in the groundwater via dissolution from a light, nonaqueous-phase liquid (LNAPL) source. Slow groundwater movement minimizes vertical mixing, resulting in contaminant stratification. Consequently, most of the biological activity at the site appears to occur near the surface of the groundwater table. A moderate increase in the ORP is evident between days 0 and 64, in the shallow 10-ft wells. This may be attributed to the tracer addition at the site. However, the changes are too low to make any conclusions about the effect of the tracer study on ORP levels.

**Conclusions.** The tracer test results were inconclusive regarding groundwater transport in the treatment lanes at Site 1. Currently, the Air Force, Battelle, and the Environmental Protection Agency (EPA) are investigating the use of bromide as a tracer. The EPA has modified its instruments to be able to detect bromide above background chloride levels, and bromide has been added to the Lane C nutrient tank. In addition, inorganic samples that were sent to the EPA for analysis have been analyzed. The results of these analyses are being evaluated by the Air Force and the EPA with respect to the tracer test. Their groundwater model describing the treatment lanes will be used to simulate groundwater transport and the tracer results at the site. The EPA's results should be compared with the results presented in this report to assess the groundwater flowrates at the site.

The temperature at the site is within an expected range for groundwater, around  $20^{\circ}\text{C}$ . pH levels are somewhat higher than neutral, around pH 8.0, but are well within an acceptable range to support contaminant biodegradation at the site.

Problems with DO probe calibration made initial DO concentrations unusable. However, under optimal operating conditions of the DO meter, DO levels were measured at non-detectable to less than 0.25 mg/L, indicating that conditions at the site were anaerobic.

ORP levels support the DO results. ORP levels in the deep wells ranged from 0 to  $-150$  mV, and in the shallow wells were less than  $-200$  mV. Such low redox conditions in the shallow wells show that conditions at the site are anaerobic, most likely due to intrinsic contaminant biodegradation. The stratification in ORP levels between the upper and lower wells indicates that contaminants at the site are vertically stratified, with the highest concentrations occurring at the surface of the groundwater table, close to the LNAPL source. Contaminant data being generated by the EPA should be used to verify this conclusion.

Ms. Cathy Vogel  
February 3, 1998  
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Please contact me by phone at (617) 424-4604 or by e-mail at [magarv@battelle.org](mailto:magarv@battelle.org) if you have any further questions regarding this letter report.

Sincerely,

Victor S. Magar, Ph.D., P.E.  
Principal Research Scientist

VSM:bkm  
enclosures

cc: Erica Becvar (ARFL/MLQE, Tyndall AFB, FL)  
Art Fisher (NAS Fallon, Fallon, NV)  
Guy Sewell (EPA, Ada, OK)  
Kathy Daigle (Battelle)

Figure 1. NAS Fallon Site 1 Layout

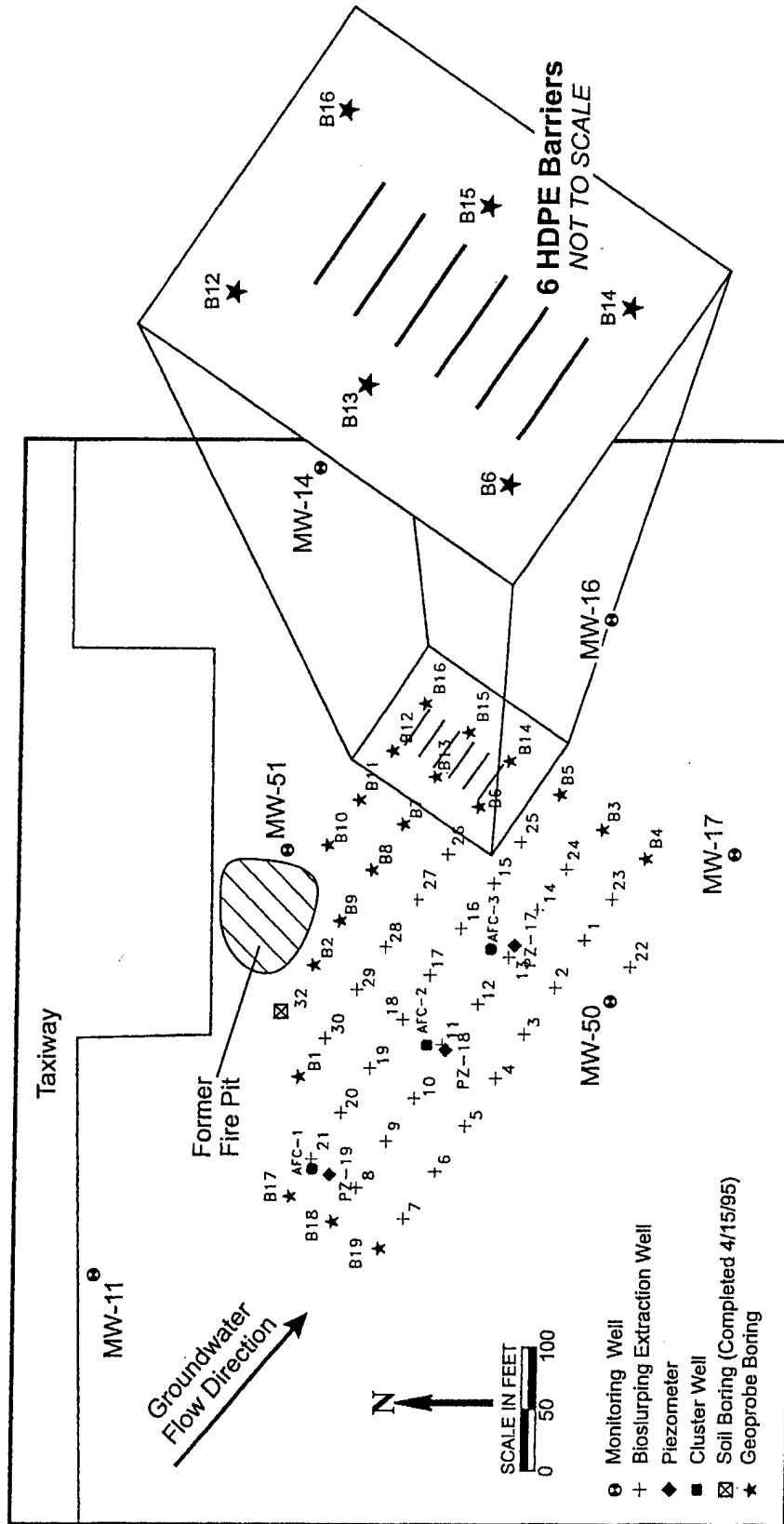




Figure 3. Conductivity vs. Time  
Well Series C, 10-ft Screen Depth

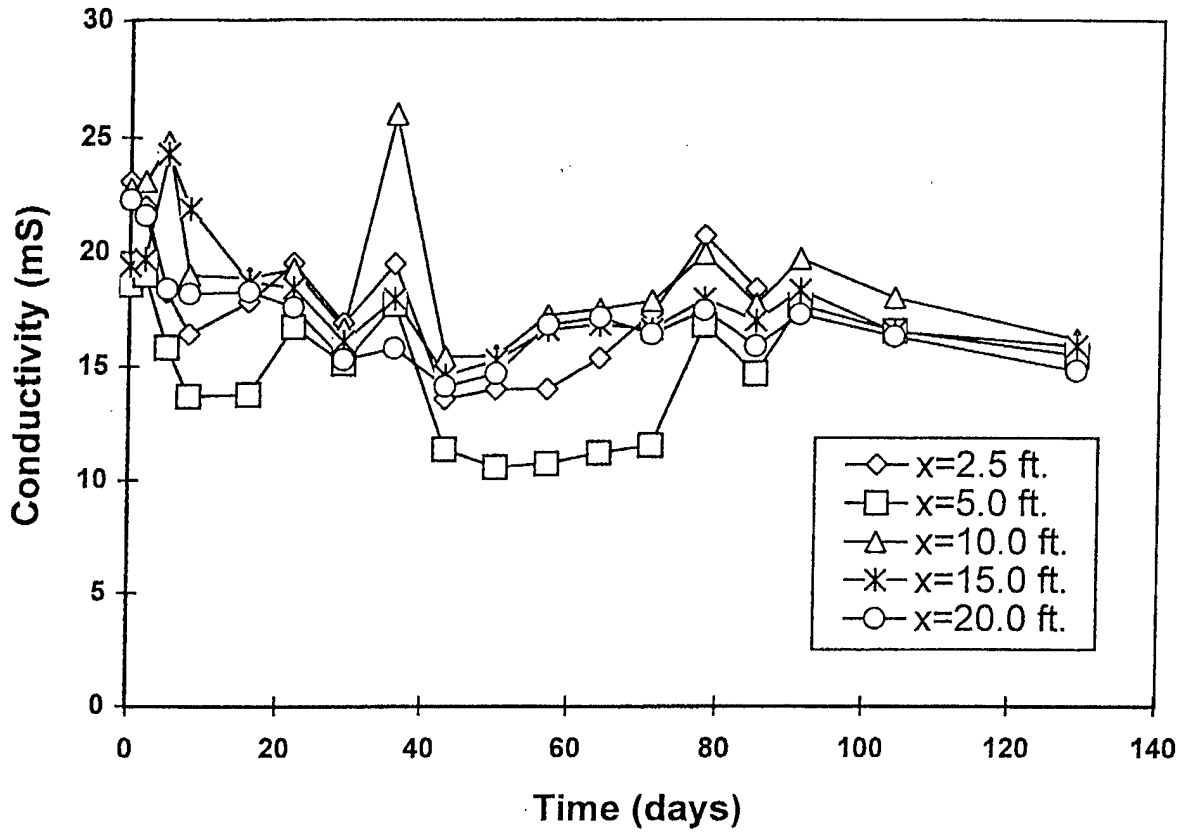


Figure 4. Conductivity vs. Time  
Well Series C, 12-ft Screen Depth

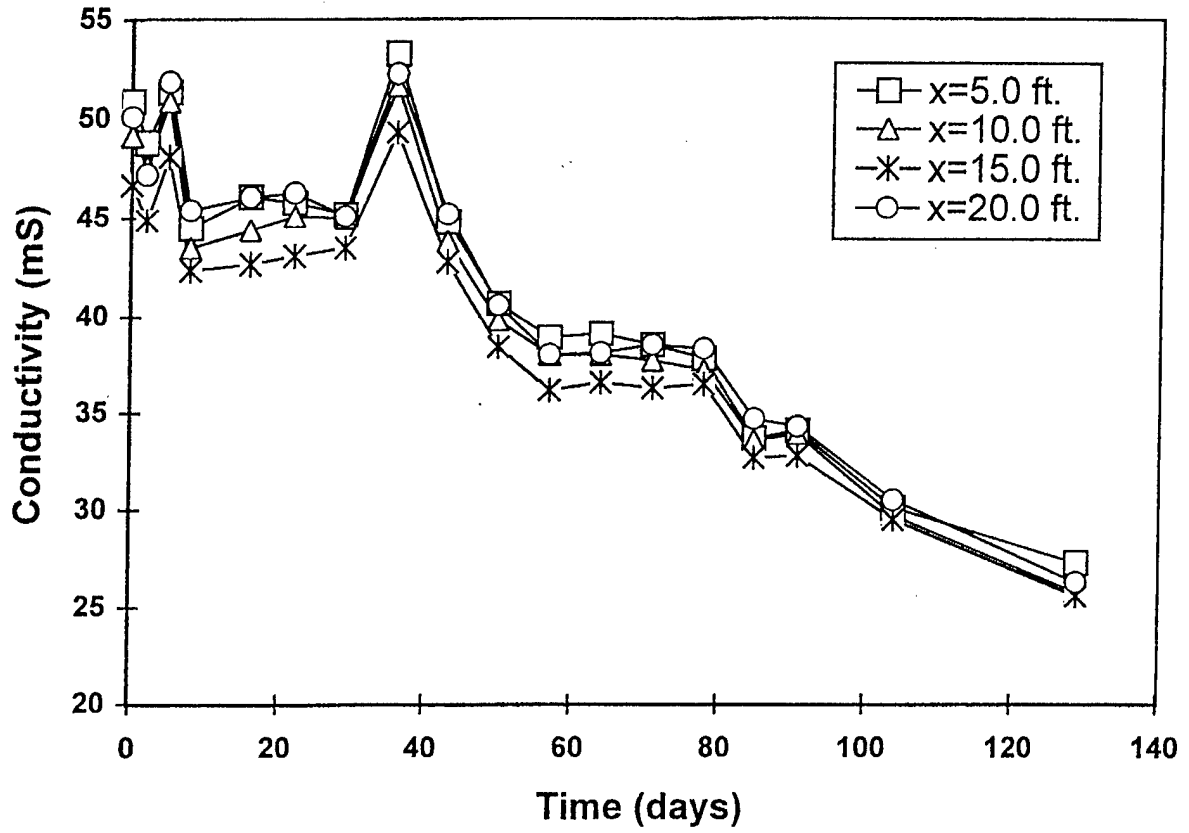


Figure 5. Conductivity vs. Time  
Upgradient B & D Wells, 10-ft Screen Depth

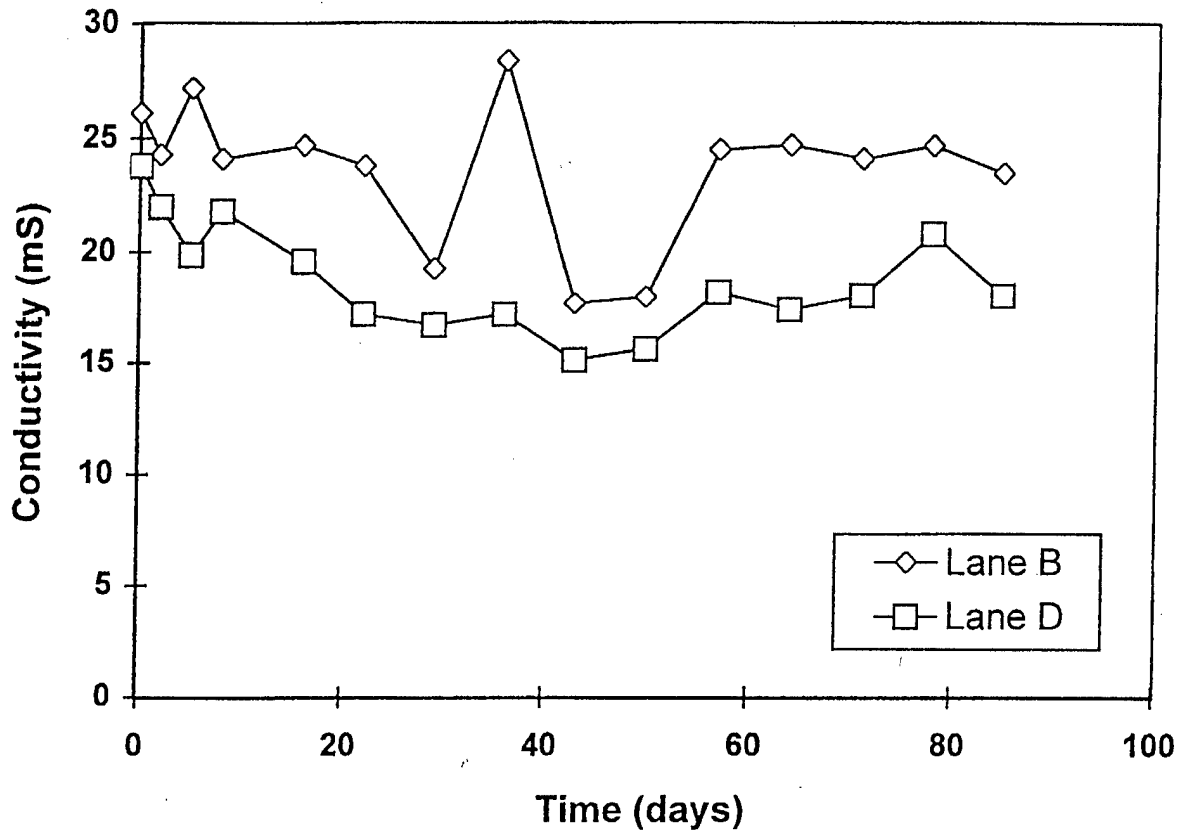


Figure 6. Conductivity vs. Time  
S-Wells, 10-ft Screen Depth

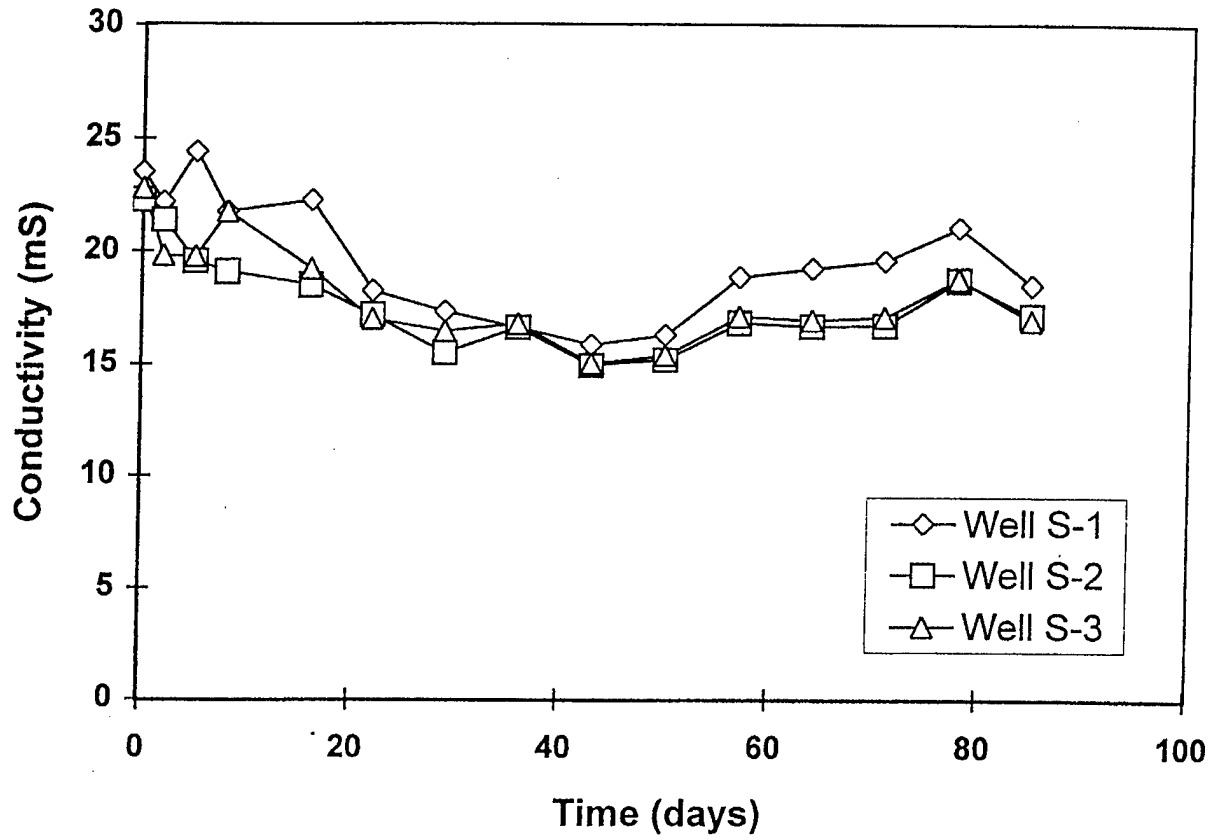


Figure 7. pH vs. Time  
Well Series C, 10-ft Screen Depth

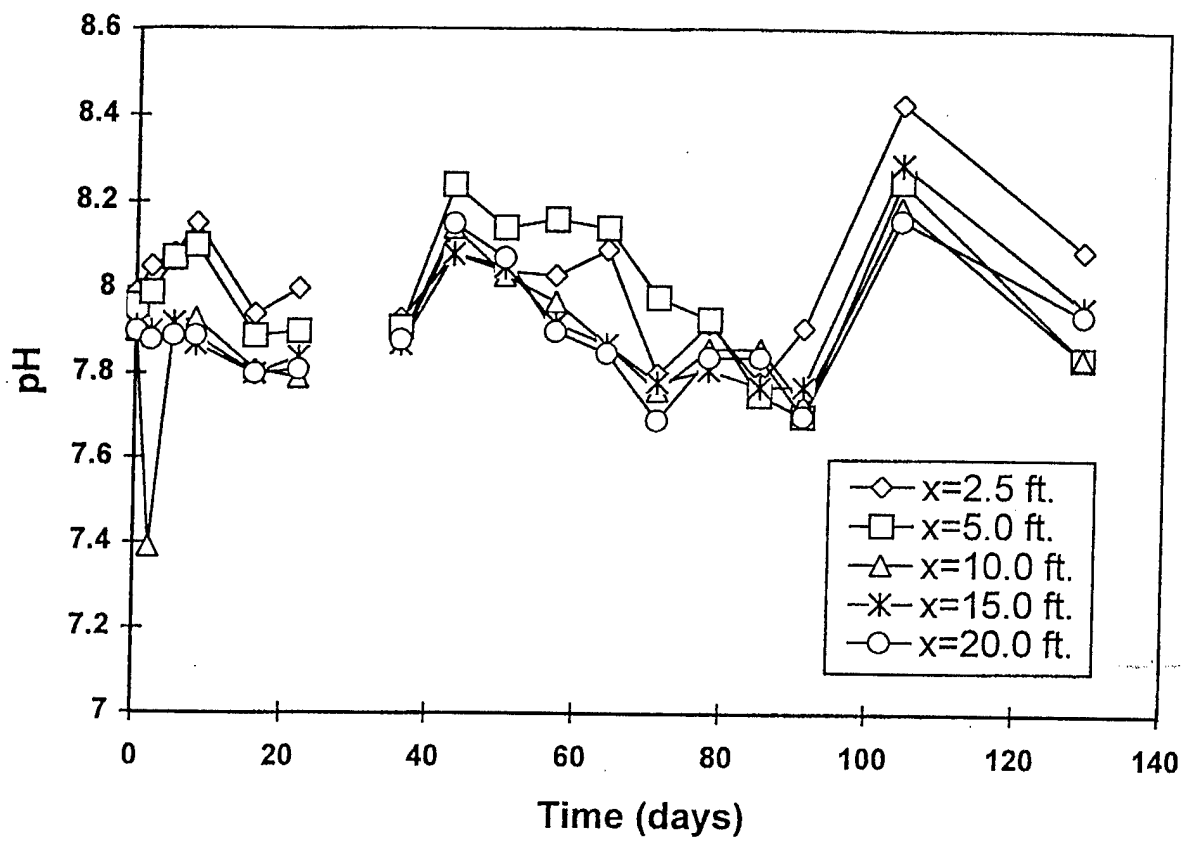


Figure 8. pH vs. Time  
Well Series C, 12-ft Screen Depth

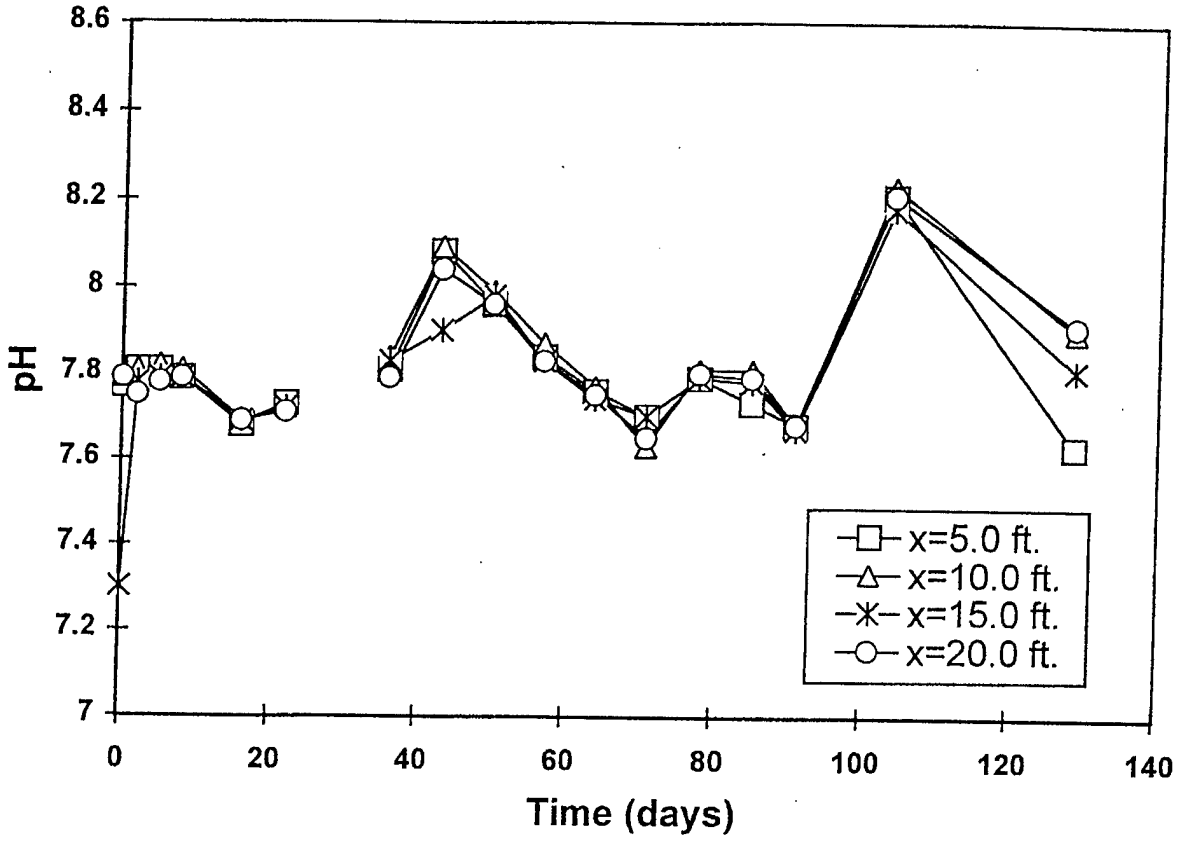


Figure 9. pH vs. Time  
Upgradient B & D Wells, 10-ft Screen Depth

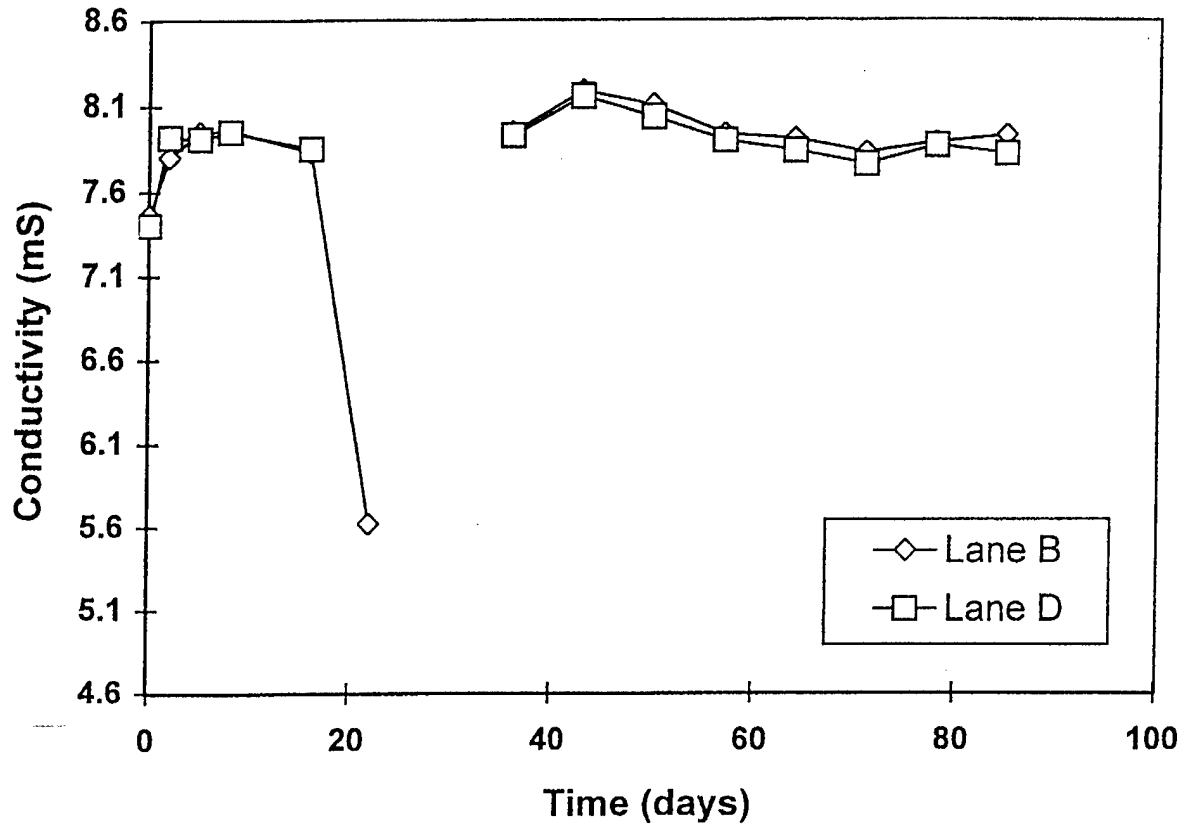


Figure 10. pH vs. Time  
S-Wells, 10-ft Screen Depth

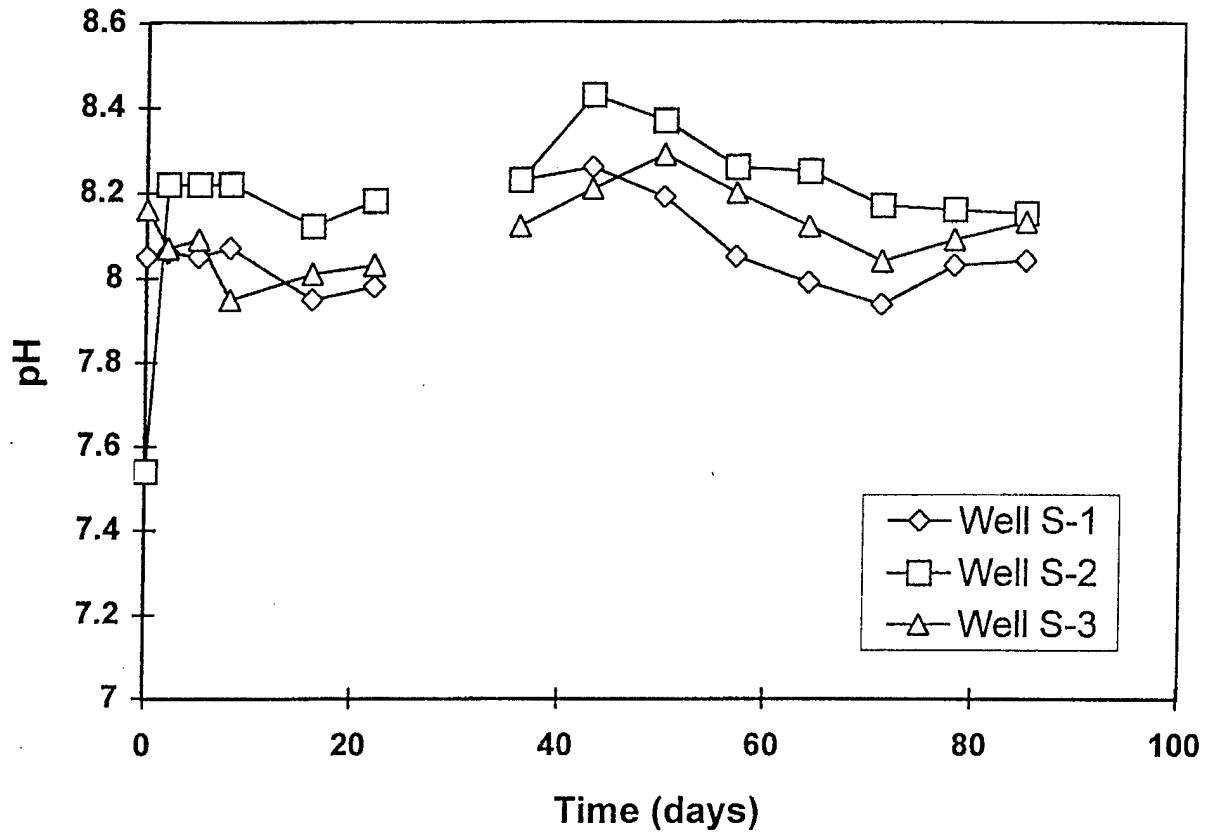


Figure 11. Temperature vs. Time  
Well Series C, 10-ft Screen Depth

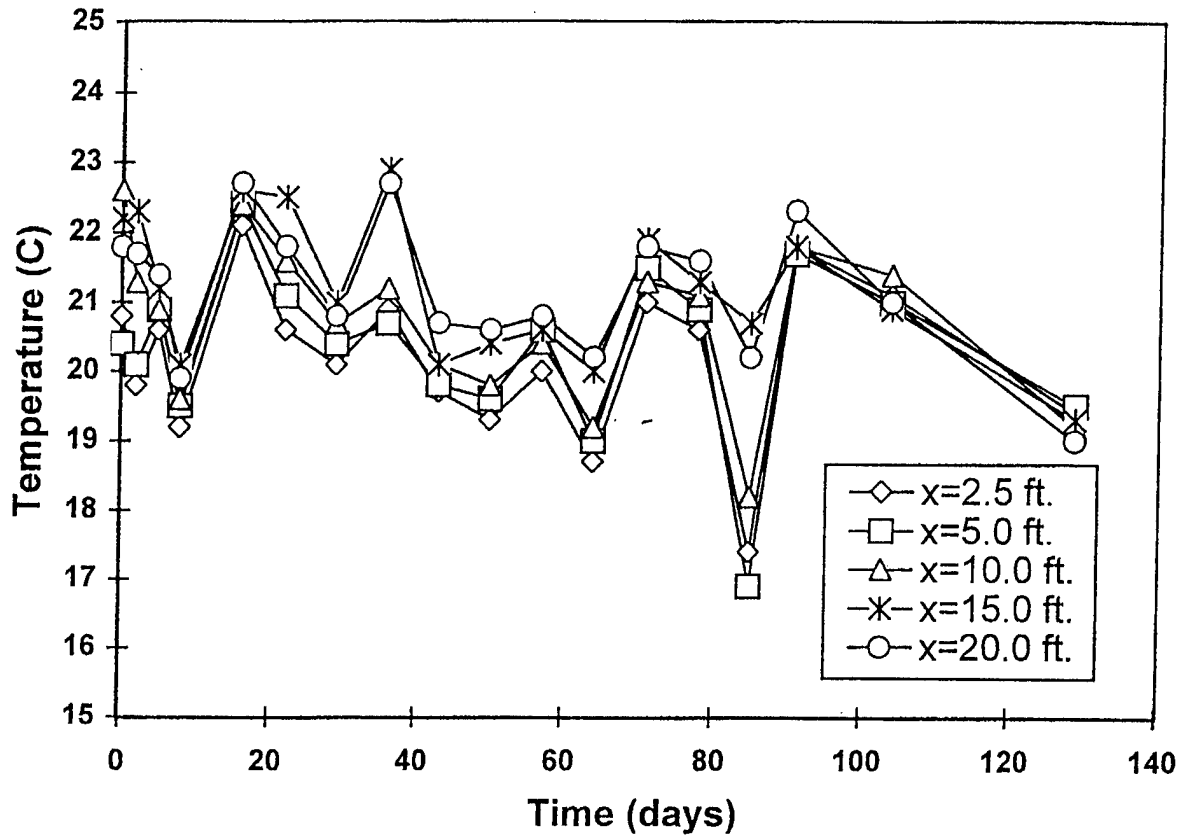


Figure 12. Temperature vs. Time  
Well Series C, 12-ft Screen Depth

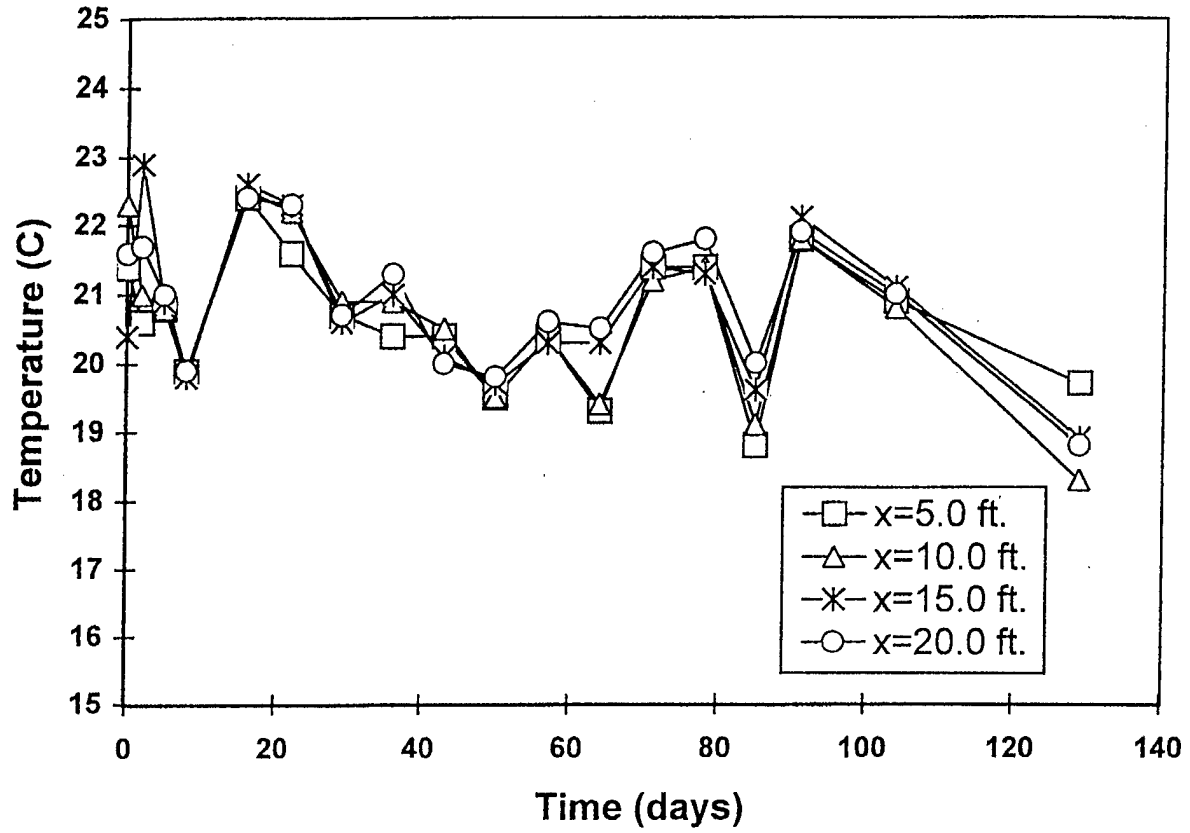


Figure 13. Temperature vs. Time  
Upgradient B & D Wells, 10-ft Screen Depth

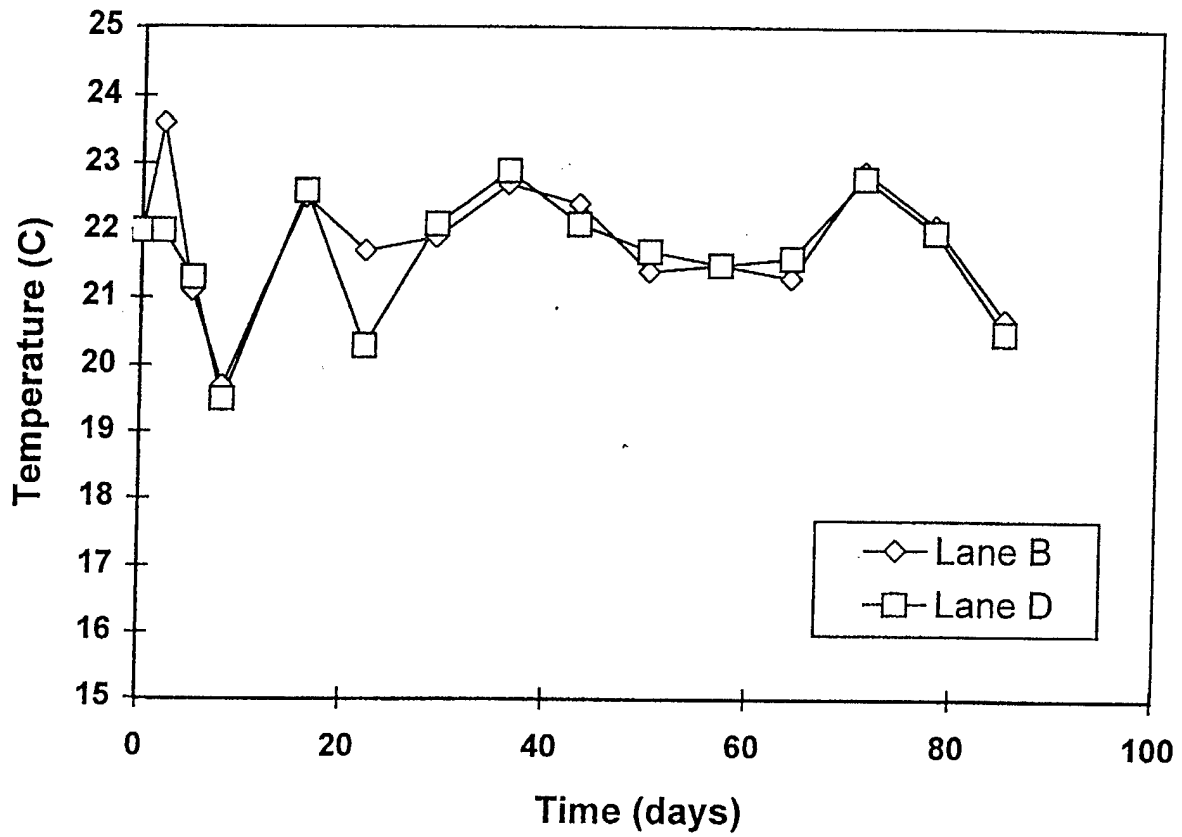


Figure 14. Temperature vs. Time  
S-Wells, 10-ft Screen Depth

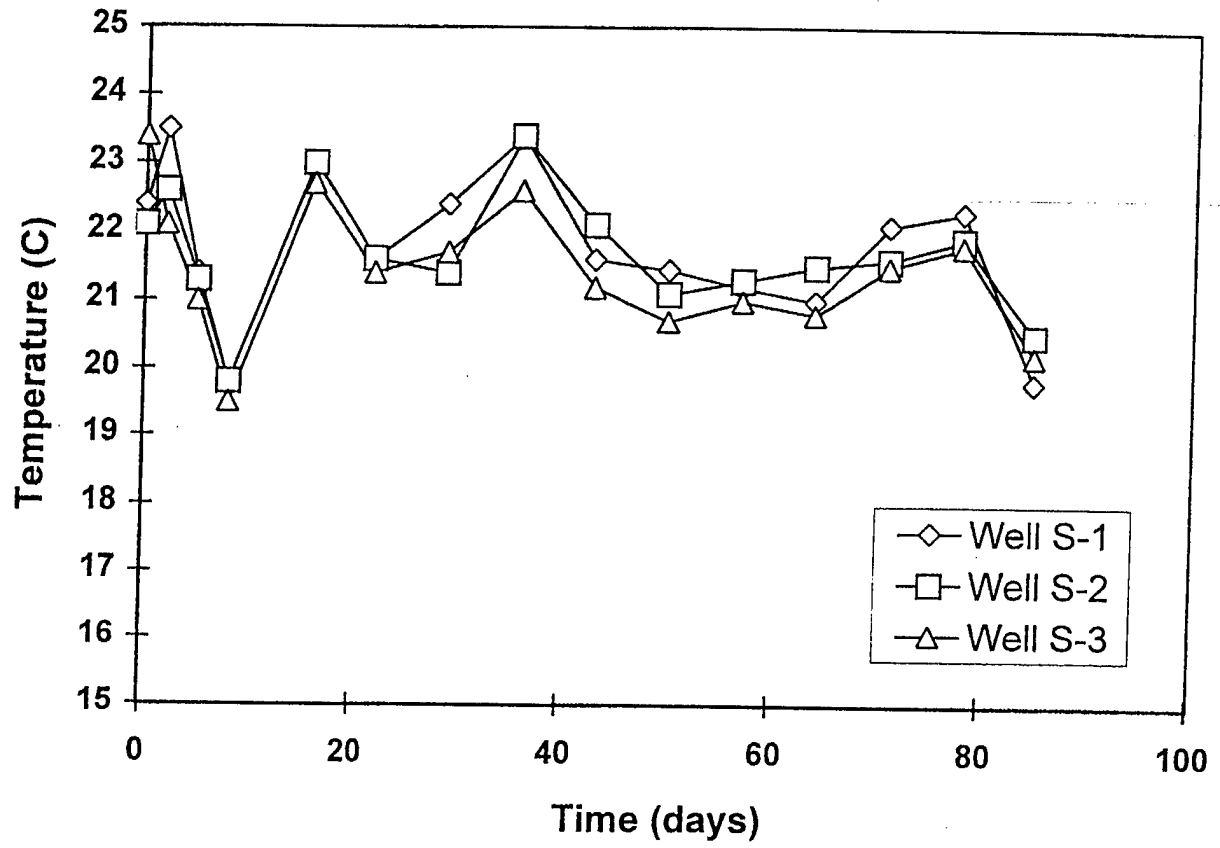


Figure 15. Dissolved Oxygen vs. Time  
Well Series C, 10-ft Screen Depth

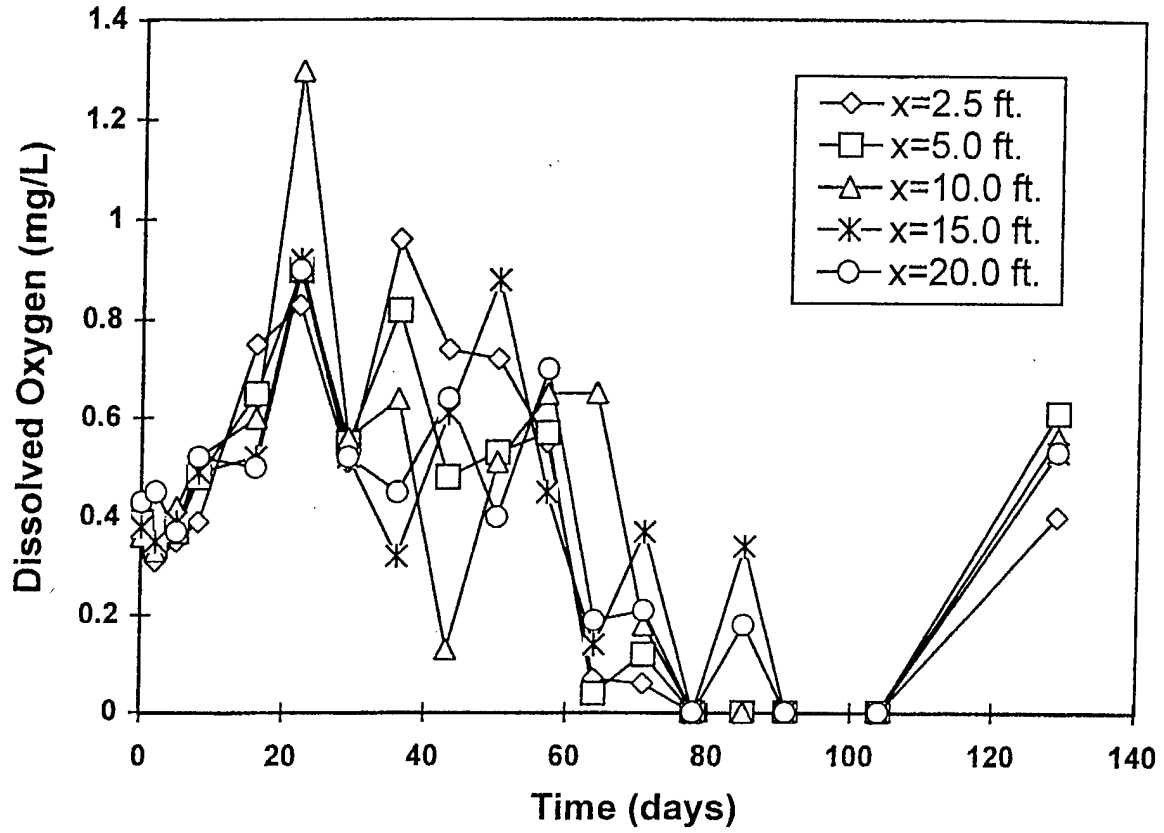




Figure 17. Dissolved Oxygen vs. Time  
Upgradient B & D Wells, 10-ft Screen Depth

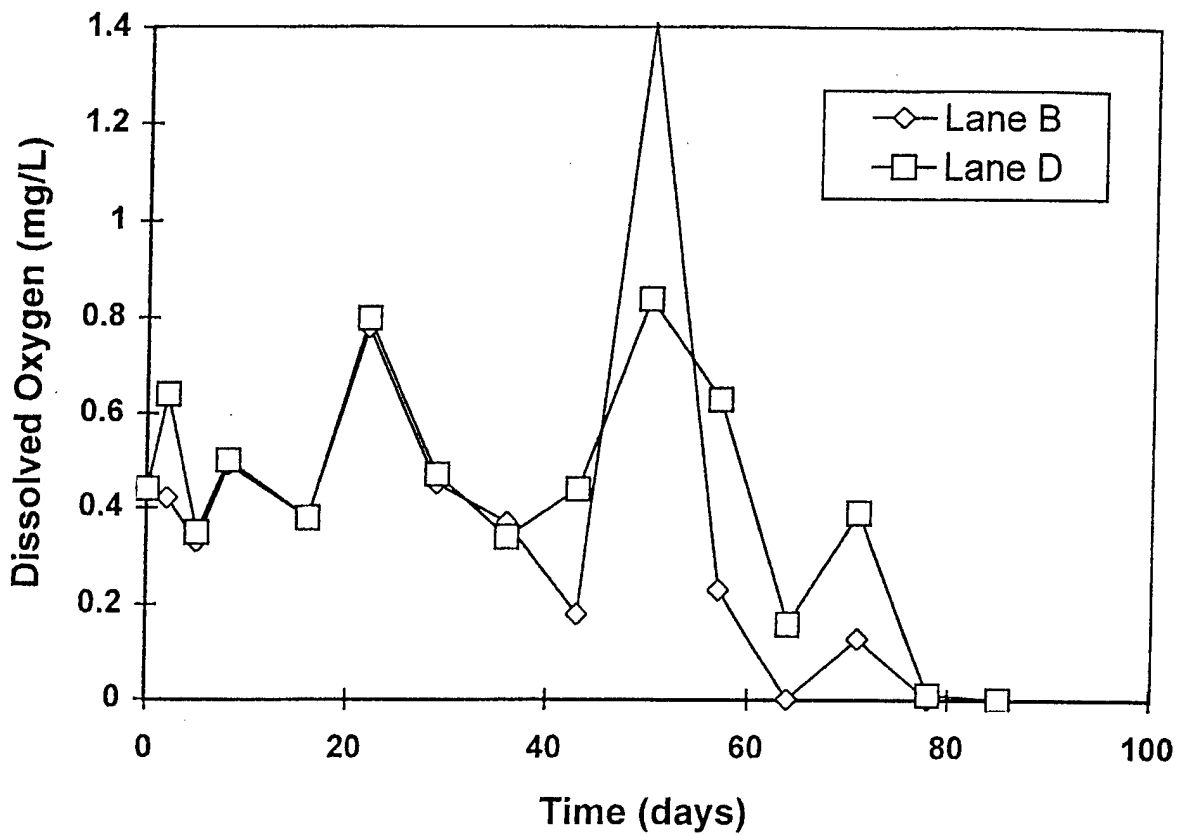


Figure 18. Dissolved Oxygen vs. Time  
S-Wells, 10-ft Screen Depth

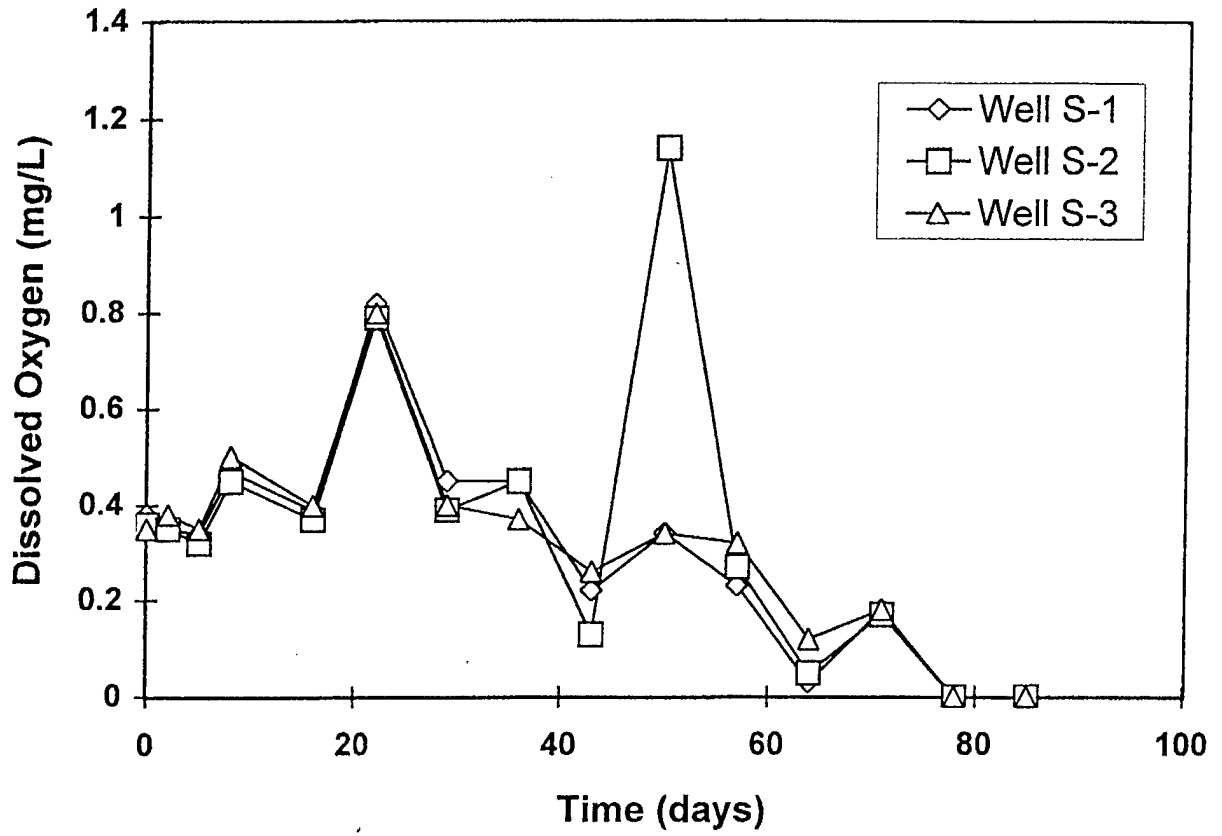


Figure 19. Oxidation Reduction Potential vs. Time  
Well Series C, 10-ft Screen Depth

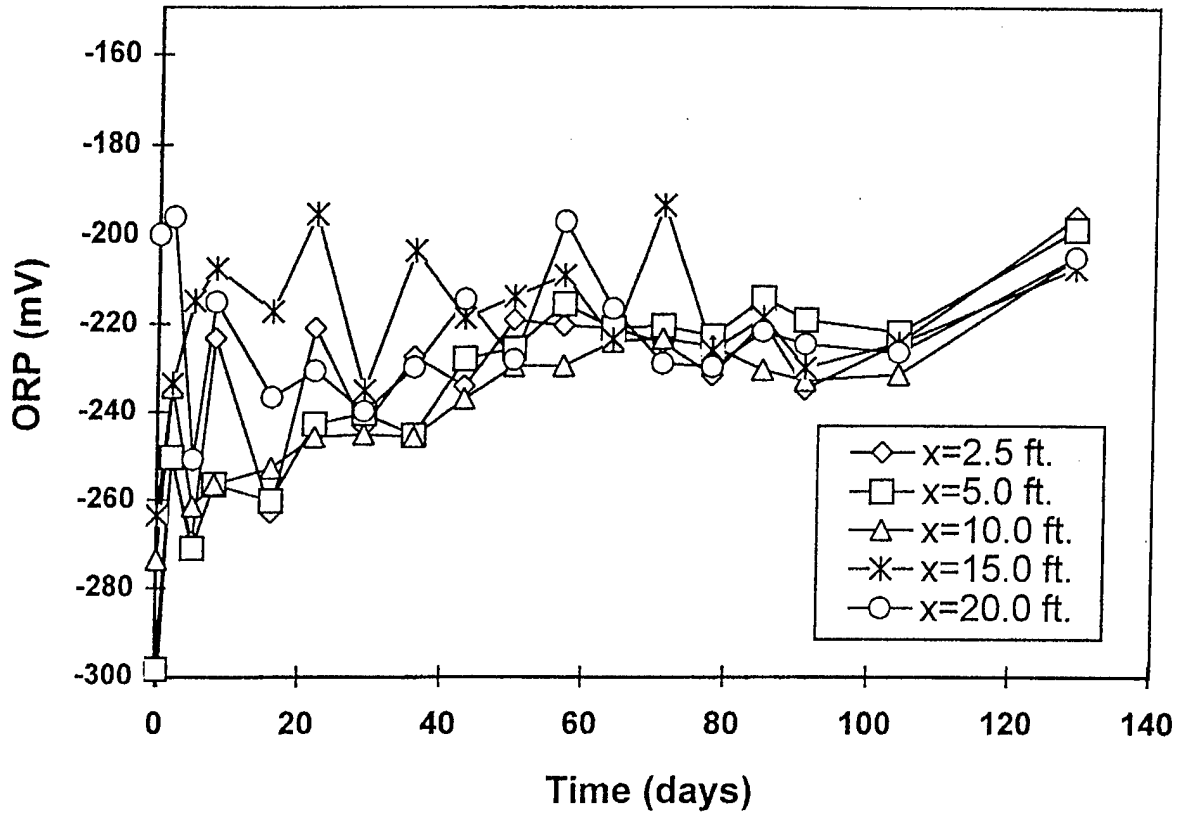


Figure 20. Oxidation Reduction Potential vs. Time  
Well Series C, 12-ft Screen Depth

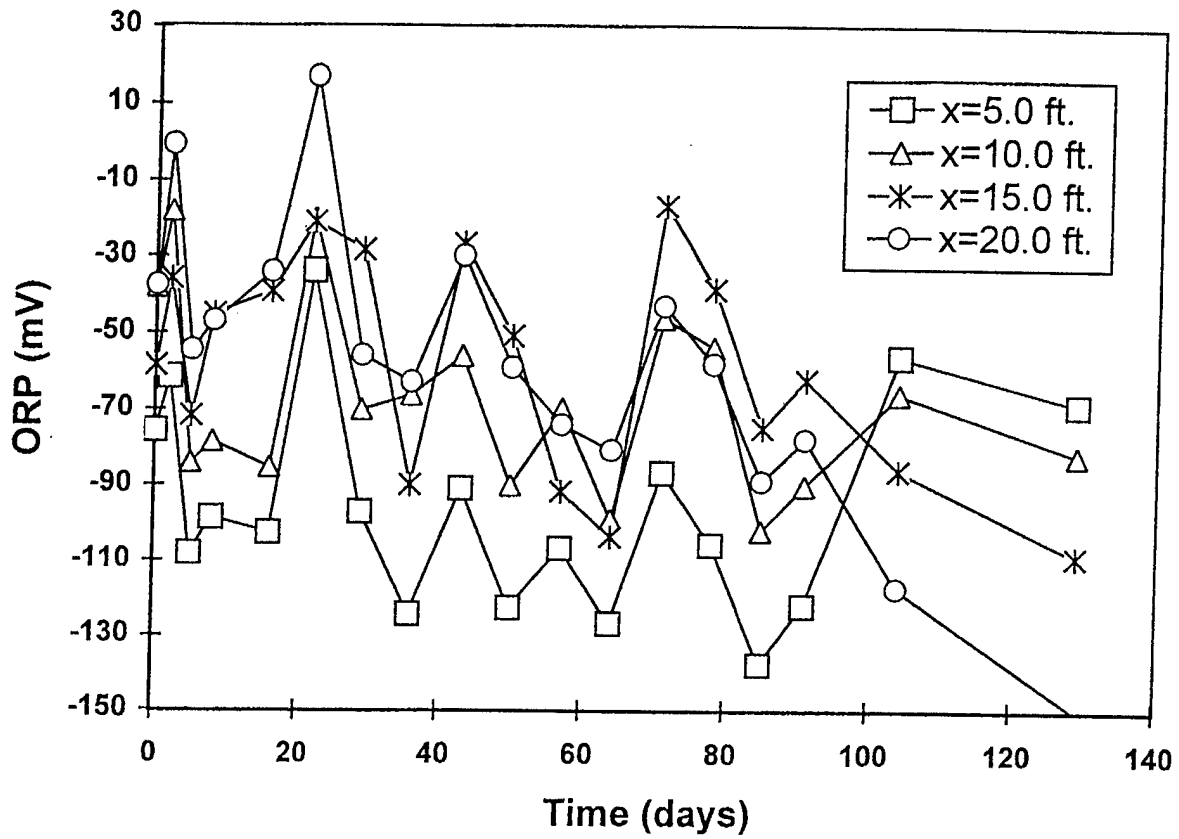


Figure 21. Oxidation Reduction Potential (ORP)  
Upgradient B & D Wells, 10-ft Screen Depth

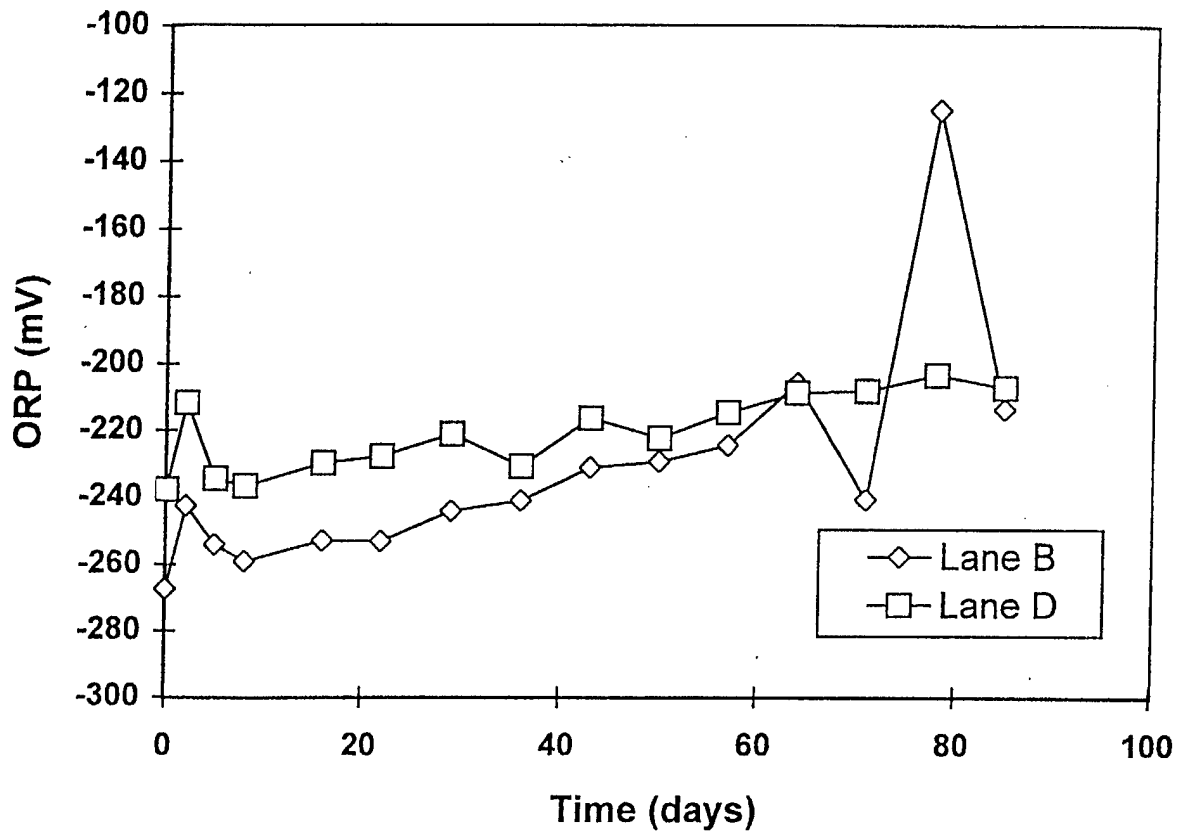


Figure 22. Redox vs. Time  
S-Wells, 10-ft Screen Depth

