TA49 11/1/2001

# ANNUAL MOISTURE-MONITORING REPORT
# FISCAL YEAR 2001
# TECHNICAL AREA 49
# MATERIAL DISPOSAL AREA AB

*MDA Focus Area*

*Environmental Restoration Project*

*Los Alamos National Laboratory*

**November 2001**

4040

# Appendix B

*Annual Moisture-Monitoring Report*
*Fiscal Year 2001*
*Technical Area 49, Material Disposal Area AB*

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## 1.0 INTRODUCTION

This report documents the results of moisture monitoring at Material Disposal Area (MDA) AB, Technical Area (TA) 49, at Los Alamos National Laboratory (the Laboratory) during the fourth quarter of Fiscal Year (FY) 2001. The moisture-monitoring system was installed during March 2000 to determine whether or not the evapotranspirative cover at MDA AB was maintaining or reducing subsurface moisture. It is anticipated that the cover material will behave similarly to native undisturbed areas and restore the semiarid conditions at the site. Monitoring was performed in accordance with ER-SOP-7.05, Rev. 1, "Subsurface Moisture Measurements Using a Neutron Probe."

The moisture-monitoring project utilizes three neutron access holes (49-10046, 49-10047, and 49-10048), eight boreholes (TH-1, TH-2, TH-3, TH-4, TH-5, 2A-O, 2A-Y, and 2B-Y), four time domain reflectometry (TDR) probes (TDR1, TDR2, TDR3, and TDR4), and a rain gauge to evaluate changes in moisture beneath the cover and the undisturbed areas near the cover (Figure 1). The eight boreholes are 4 in. in diameter, and the three access holes have a 2-in. aluminum casing that extends to the bottom of the hole. Adjacent to each of two access holes (49□10046 and 49-10048) are two TDR arrays; they consist of a shallow TDR probe positioned horizontally just beneath the surface soil (approximately 6 in.) and a deeper TDR probe positioned vertically beneath the cover materials at 6 ft (TDR1) and 10 ft (TDR3). A rain gauge is located at the surface of the cover near access hole 49-10046. Figure 1 gives locations of access holes, boreholes, TDR probes, the rain gauge, the cover, and the silt fence. Table 1 gives the depths of the TDR probes.

Moisture monitoring at MDA AB was completed for the first two months of the fourth quarter. The final month of monitoring was completed on September 28 after this report was written and will be reported in the first-quarter report for FY 2002. This report will include a discussion of moisture trends over time, a comparison of moisture results from the neutron probes and the TDR probes, and a discussion of the relationship between precipitation and moisture content.

## 2.0 MOISTURE-MONITORING EVENT

### 2.1 Neutron Logging

During the fourth quarter of FY 2001, neutron-logging events occurred at the end of July and August. Logging was performed with a dedicated CPN 503DR probe at all access holes and boreholes. The neutron counts from each of the 11 monitoring holes were recorded into a spreadsheet, and a corresponding volumetric moisture content was calculated for each. Plots of volumetric moisture content for each sampling period and all of the holes are shown in Appendix A.

### 2.2 TDR and Precipitation Measurements

TDR measurements and precipitation quantities were collected twice a day through August without interruption and were recorded to a Campbell Scientific datalogger. The Campbell Scientific datalogger was programmed to record a timestamp, temperature, TDR raw frequencies, and precipitation (in.). The program converts raw frequency to volumetric moisture content and then records the data (both raw and converted) to a *.dat file. Figures 2 and 3 display moisture measurements and precipitation from April 2000 through August 2001. The cumulative precipitation was calculated from the on-site rain gauge from August 2000 to April 30, 2001. On May 1, 2001, it became apparent that the rain gauge had become clogged with debris, so from May 1 to June 28, 2001, precipitation data were obtained from the

Laboratory TA-49 weather station. Data from the weather station will continue to be reported through the year to maintain consistency.

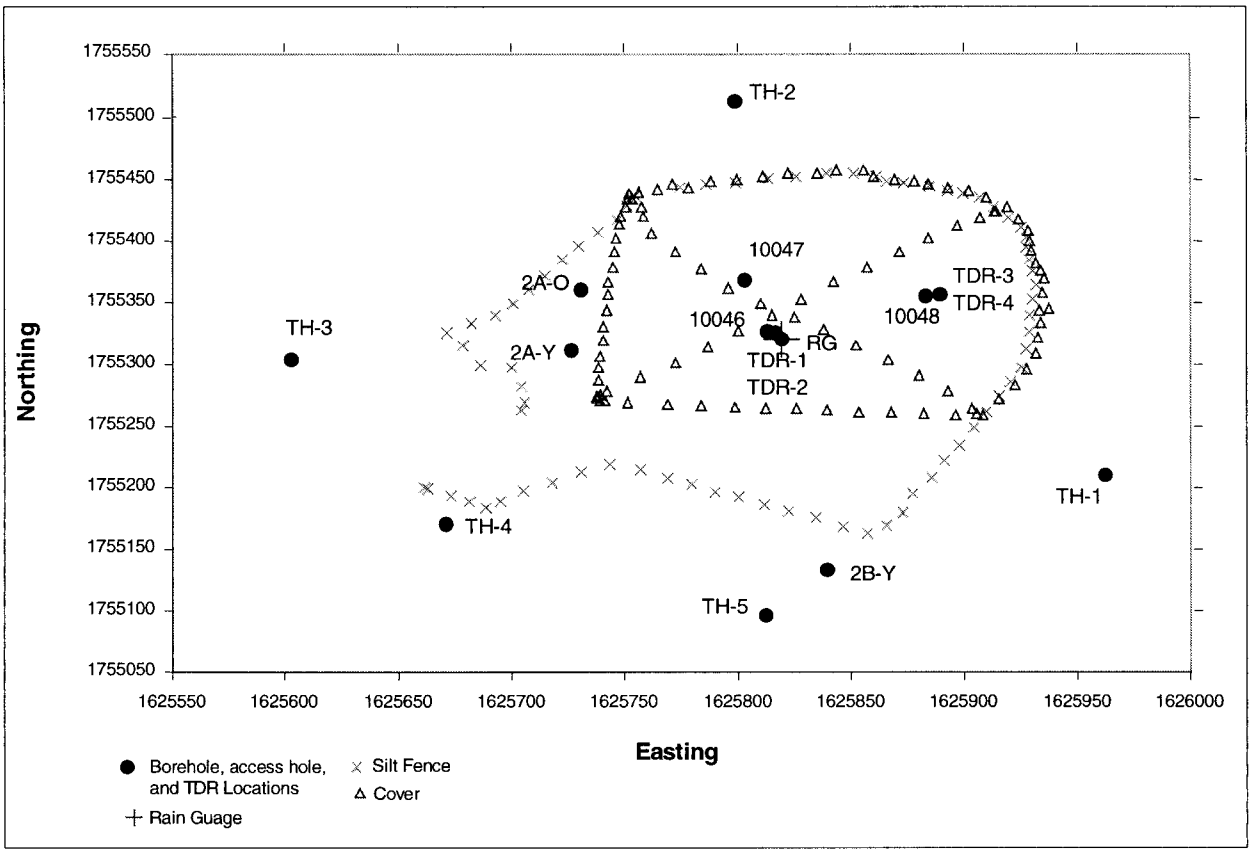


**Figure 1. Location of instrumentation, access holes, and boreholes on XY plane at TA-49**

**Table 1**
**TDR Array Descriptions**

| TDR Number | Array Type | Depth (ft) |
|---|---|---|
| TDR1 | Vertical, within soil overlaying Bandelier Tuff | 6 |
| TDR2 | Horizontal, at bottom of top-soil | 0.5 |
| TDR3 | Vertical, within El Cajete pumice formation | 10 |
| TDR4 | Horizontal, at bottom of top-soil | 0.5 |

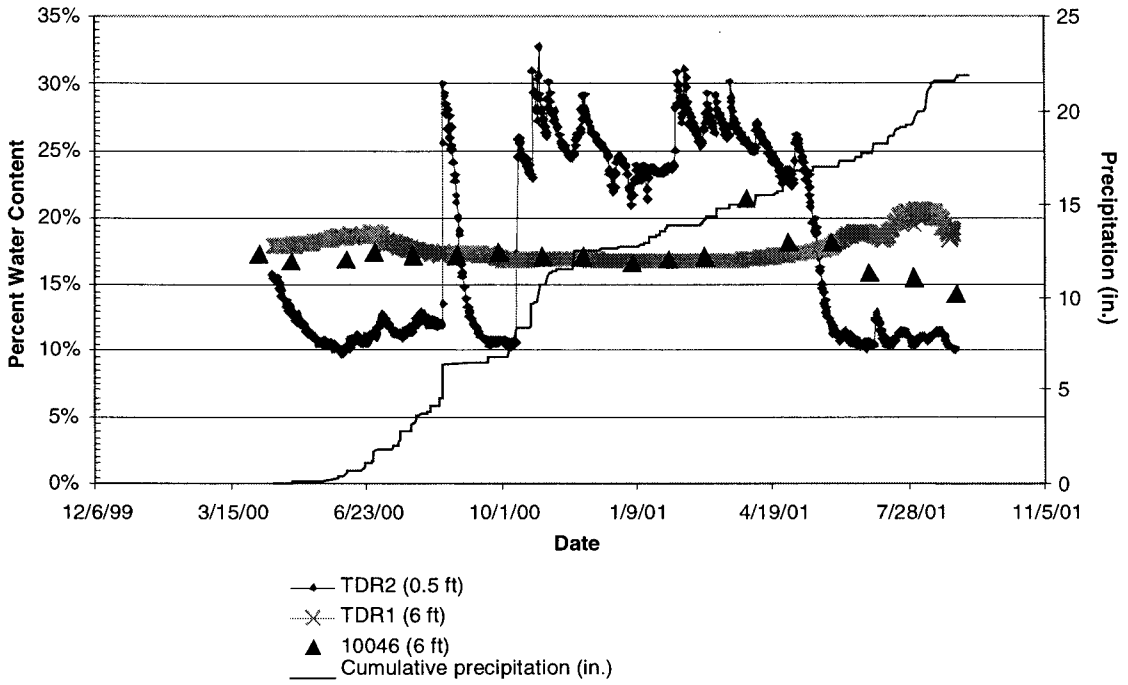


**Figure 2.** **TDR measurements compared with neutron measurements at access hole 49-10046, which is in close proximity and at the same corresponding depths as TDR1**

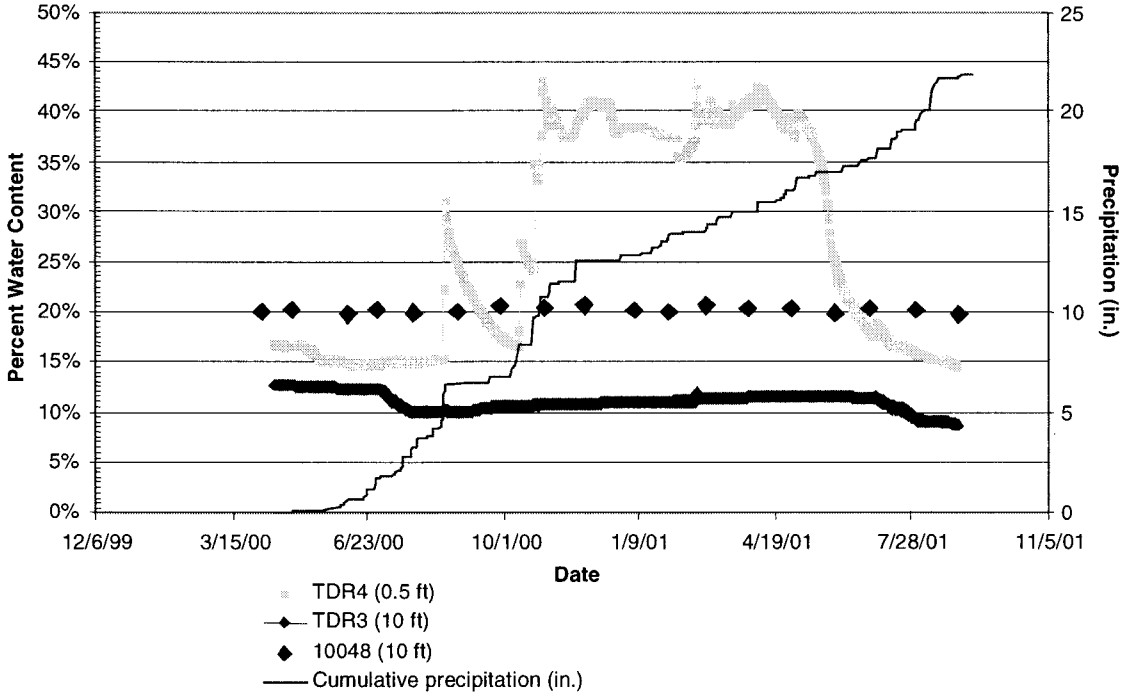


**Figure 3.** **TDR measurements compared with neutron measurements at access hole 49-10048, which is in close proximity and at the same corresponding depth as TDR3**

## 3.0 MOISTURE-MONITORING RESULTS AND DATA ANALYSIS

### 3.1 Introduction

During the last quarter, most neutron access holes and boreholes have shown a decrease in volumetric moisture content in the first 5 ft, an interval of unconsolidated materials and the soil tuff interface. Trend plots of time versus moisture content were created for specific depth intervals (Appendix B). These plots exhibit the impacts of snowmelt in the spring and monsoonal rains during July and early August in the near-surface depth (1 ft to 5 ft) for the boreholes and neutron access holes. They also show the apparent effects of evapotranspiration, which accounts for the reduction of near-surface soil moisture associated with infiltration from monsoonal rain showers during the fourth quarter.

### 3.2 Correlation between TDR Measurements and Precipitation Events

From August 1 to August 16, 2001, Los Alamos experienced summer monsoonal rainstorms with precipitation accumulations from 0.1 in. to 0.87 in. After August 16, little to no precipitation was observed at the site. The shallow TDR instruments measured small increases (1% to 2%) in moisture in response to the monsoonal rainstorms, but no steep moisture increases were measured. This is an indication that the vegetated cover is working as designed by taking up moisture through evapotranspiration and that no significant infiltration has occurred. The deep TDR probe at 6 ft displayed a minor increase in moisture content during the early part of August and then dropped 4% from August 17 through August 30. The TDR located at 6 ft has repeatedly shown a delayed response to infiltration events compared with the shallow TDR. TDR3 (located at 10 ft) detected a 0.5 % decrease in volumetric moisture content from August 1 through August 30.

### 3.3 TDR and Neutron Comparisons

The moisture-monitoring system is producing similar results from the TDR arrays and the neutron logging. Figures 2 and 3 display the deep TDR data associated with access holes 49-10046 and 49-10048; neutron probe data from the same depth are also shown. The TDR probes are quickly able to detect moisture increases in the subsurface, whereas the neutron probe captures the long-term effect of the same events. Over the last several months, the neutron probe data at access hole 49-10046 differs from the associated TDR results by approximately 5% (Figure 2). The neutron probe has been showing lower moisture contents; however, over the last quarter, both the neutron probe and TDR data show consistent downward trends. At access hole 49-10048, the TDR and neutron probe measurements differed approximately 13%, with the neutron probe reading lower than the TDR probe. Neither the TDR nor neutron probe measurements have shown much moisture change during the last quarter. The difference between the TDR and neutron probe measurements in 49-10048 is due to the placement of the TDR probe in the El Cajete pumice. The neutron probe is calibrated for materials with densities closer to crushed tuff; the El Cajete pumice has a much lower bulk density. Therefore, the difference is an artifact of the neutron probe calibration. The TDR probe is accurate for all densities of material found at the site and, thus, returns more realistic moisture content values for the El Cajete pumice. The correlation between the two moisture-monitoring methods will become more meaningful as further data are collected and further seasonal inputs occur.

### 3.4 Student T-test of Neutron Data

A student t-test analysis was performed to track trends in moisture over time for each of the boreholes and neutron access holes. The student t-test evaluates the significance of an apparent trend based on a selected confidence interval. For the purposes of this analysis, a 95% confidence interval was selected.

As of September 2001, 18 months of data events were available for statistical analysis. Table 2 presents the results of the student t-test analyses for each of the boreholes and neutron access holes. The trending analysis results show that moisture levels have increased only in the near-surface area (from 1 ft to 5 ft) for boreholes TH-2 and 2B-Y and for neutron access hole 49-10046. The only moisture-monitoring hole to show an increase in moisture at depths below 5 ft was borehole 2B-Y; an increasing moisture trend was detected from 6 ft to 20 ft. The 1-ft to 5-ft interval is most impacted by seasonal fluctuation in precipitation, and variations in this interval are expected. Because there are now 18 months of data available for the trending analysis and all seasons are now included in the data, seasonal fluctuations no longer bias the results as they did earlier.

**Table 2**
**Results of the Student T-Test Analysis, Based on a 95% Confidence Interval**

| Borehole/Neutron Access Hole Number | Moisture Trending Results |
|---|---|
| TH-1 | Analysis shows a decreasing moisture trend from 11 ft to 20 ft, 26 ft to 40 ft, 61 ft to 75 ft, and 106 ft to 110 ft |
| TH-2 | Analysis shows an increasing moisture trend from 1 ft to 5 ft and a decreasing moisture trend from 11 ft to 25 ft, 31 ft to 40 ft, 56 ft to 60 ft, 76 ft to 80 ft, and 86 ft to 90 ft |
| TH-3 | Analysis shows a decreasing moisture trend from 6 ft to 10 ft, 31 ft to 35 ft, 61 ft to 65 ft, and 91 ft to 95 ft |
| TH-4 | Analysis shows a decreasing moisture trend from 66 ft to 70 ft |
| TH-5 | Analysis shows a decreasing moisture trend from 6 ft to 20 ft, 31 ft to 35 ft, 56 ft to 60 ft, 71 ft to 75 ft, 81 ft to 85 ft, 91 ft to 95 ft, and 101 ft to 105 ft |
| 2B-Y | Analysis shows an increasing moisture trend from 1 ft to 20 ft |
| 2A-Y | Analysis shows a decreasing moisture trend from 6 ft to 10 ft |
| 2A-O | Analysis shows a decreasing moisture trend from 16 ft to 25 ft |
| 49-10046 | Analysis shows an increasing moisture trend from 3 ft to 4 ft and a decreasing moisture trend from 7 ft to 13 ft |
| 49-10047 | Analysis shows a decreasing moisture trend from 9 ft to 12 ft |
| 49-10048 | Analysis shows no moisture trends |

## 4.0 CONCLUSIONS

### Fourth Quarter

During the fourth quarter of FY 2001, moisture content remained constant or decreased slightly below the unconsolidated surface material across the site. This was expected because warmer summer days promote evaporation and plant transpiration, which limits infiltration below the rooting depth and near-surface environment. The shallow TDR probes showed small (1% to 2%) fluctuations in moisture during the monsoon rainstorms during early August. The deep TDR probes remained relatively stable during the fourth quarter. Because the TDR probe measurements are recorded every 12 hours, relatively short moisture content fluctuations only present in the near surface can be measured. TDR measurements at depth have confirmed that these impulses only penetrate the near surface. Both the neutron log and TDR probe data continue to indicate that the evapotranspirative cover at MDA AB is maintaining the local moisture content at levels comparable to nearby undisturbed areas.

### Annual

The neutron probe and TDR data indicate that subsurface moisture levels have been consistent with the site conceptual model. Eighteen months of neutron data were available to run a student t-test, which identifies statistically significant moisture trends. The results are thought to be more reliable because significant seasonal inputs during the 18 months of moisture monitoring have been incorporated. Of the TH-series boreholes, moisture content decreased over all depth intervals, with the exception of borehole TH-2, which showed increasing moisture content from 1 ft to 5 ft. Additionally, borehole 2B-Y and neutron access hole 49-10046 showed increasing moisture content trends from 1 ft to 5 ft. These trends are likely remaining artifacts of past seasonal moisture pulses, and as more data are collected through the drier months, these trends are expected to decrease in significance and eventually disappear. No significant trends were found in data from below the soil-tuff interface, indicating that infiltration is restricted to the top soil and unconsolidated cover materials. Data from neutron access holes located outside the cover area have indicated similar moisture content trends.

Since installation of the moisture-monitoring system during March 2000, the moisture content of the cover materials has remained relatively dry. Studies performed by Nyhan and Duffy. (1999, 70240) on crushed tuff covers reported that no seepage occurs until the average soil moisture content is greater than 38% by volume. All data indicate that the moisture content within the cover materials remained well below this 38% threshold. Moisture-monitoring results indicate the cover installed at MDA AB during 1998 is successful in maintaining soil moisture at levels that preclude infiltration from reaching potential subsurface contaminants.

## 5.0 RECOMMENDATIONS

MDA G at TA-54 is similar to MDA AB. Routine moisture monitoring has been performed at MDA G for more than 10 years. The results have indicated that very little, if any, detectable changes in moisture content occur below the near-surface environment and that any significant changes or trends are effectively captured by bimonthly monitoring. The moisture-monitoring results for the past 18 months at MDA AB have been consistent with those from MDA G. Measurements of the moisture content within the Bandelier Tuff at both mesa-top sites indicate that seasonal precipitation results in little, if any, deep infiltration. Therefore, it is recommended that moisture monitoring of all boreholes and neutron access holes be reduced from monthly to bimonthly. This will be sufficient to capture any potential long-term variability in moisture content below the near-surface environment. The current frequency of TDR measurements will continue to monitor the performance of the cover materials.

### References

Nyhan, J., and C. Duffy, September 14, 1999. "Spectral Analyses of Water Balance Parameters at the Protective Barrier Landfill Cover Demonstration to Develop a Technically Defensible Long-Term Monitoring Scheme for MDA-G," Los Alamos National Laboratory report LA-UR-099-6362, Los Alamos, New Mexico.

# Appendix A

*Neutron Moisture Measurements*

## APPENDIX A NEUTRON MOISTURE MEASUREMENTS

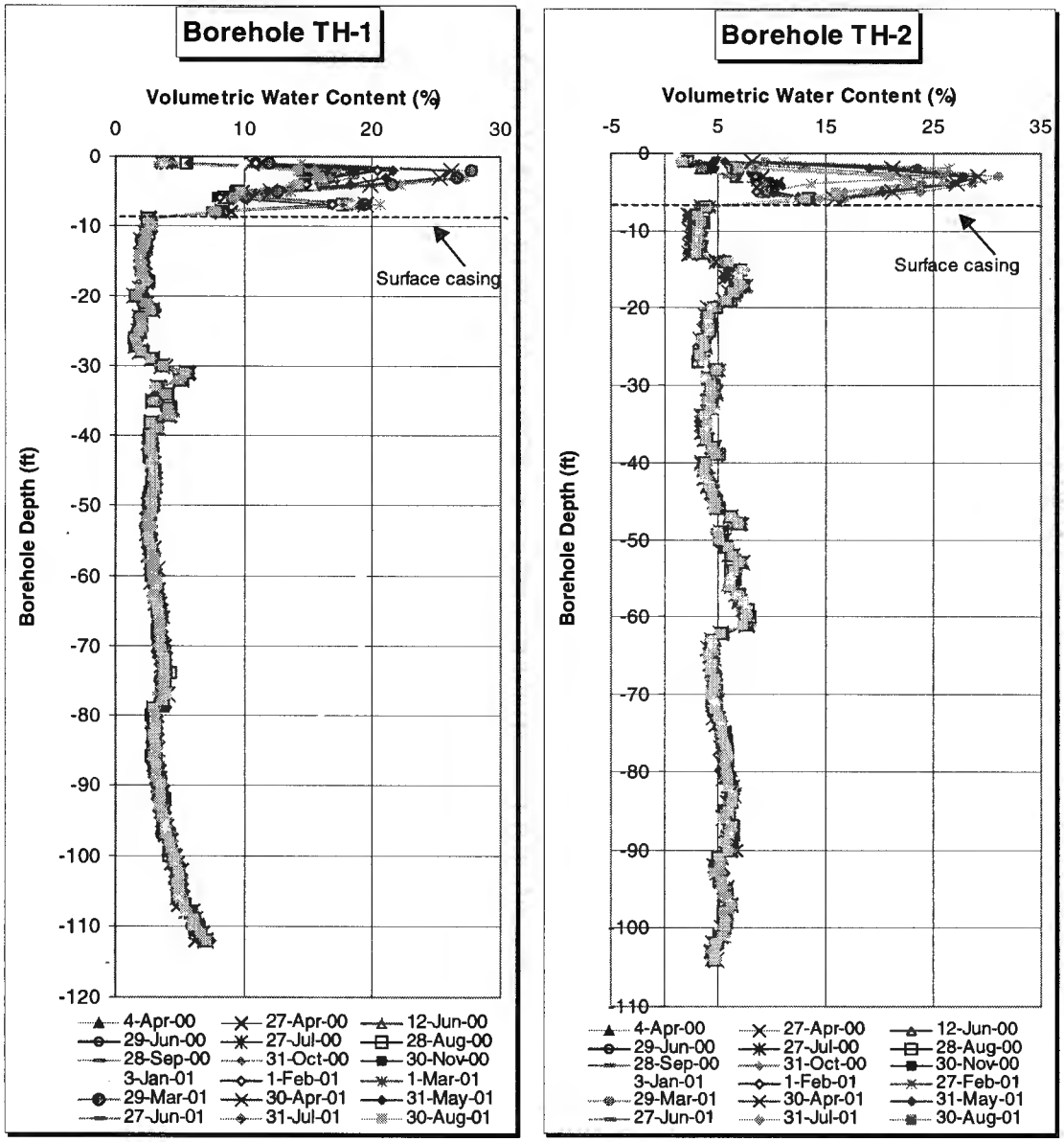


**Figure A-1. Neutron probe moisture measurements for boreholes TH-1 and TH-2**

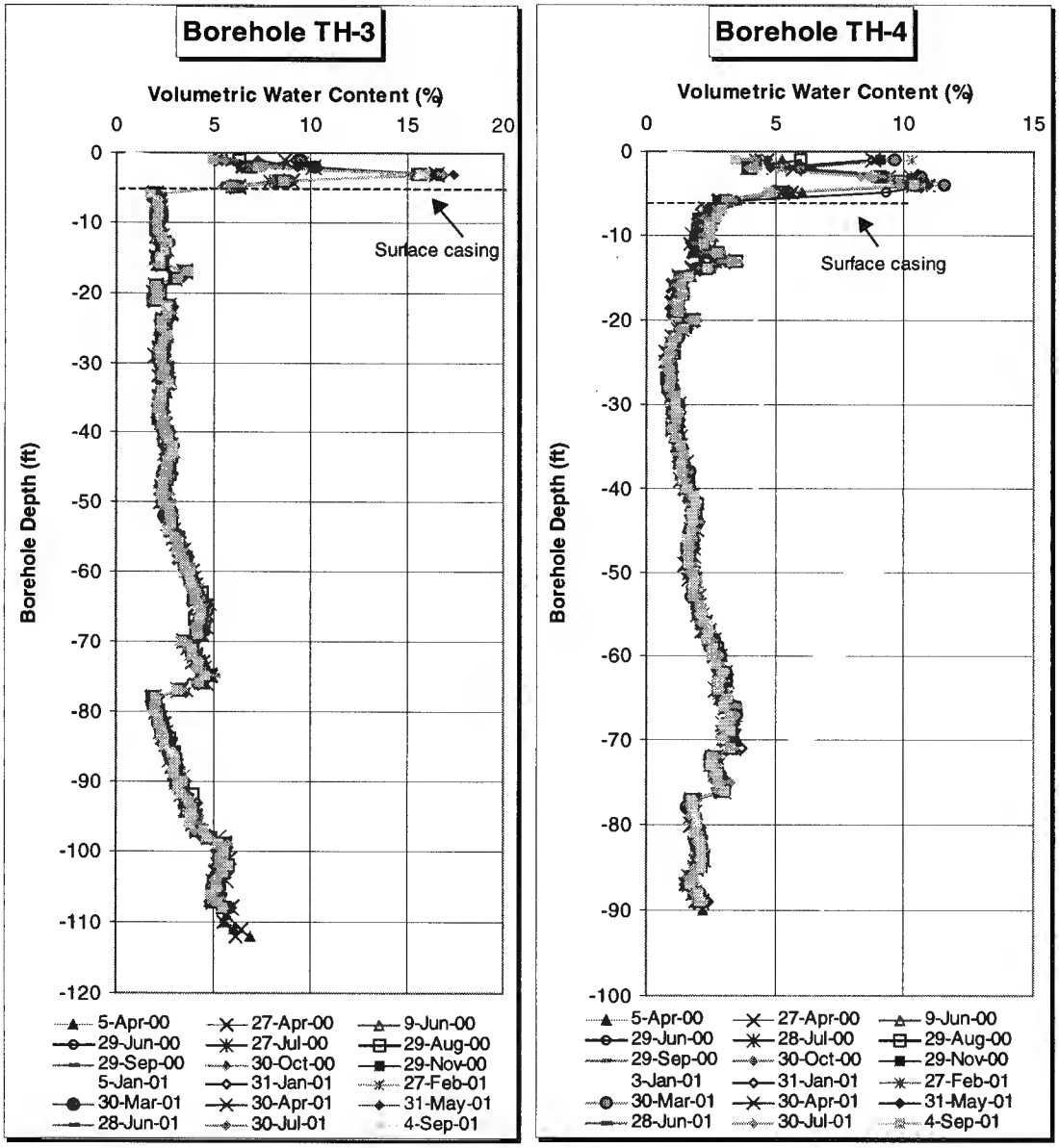


**Figure A-2. Neutron probe moisture measurements for boreholes TH-3 and TH-4**

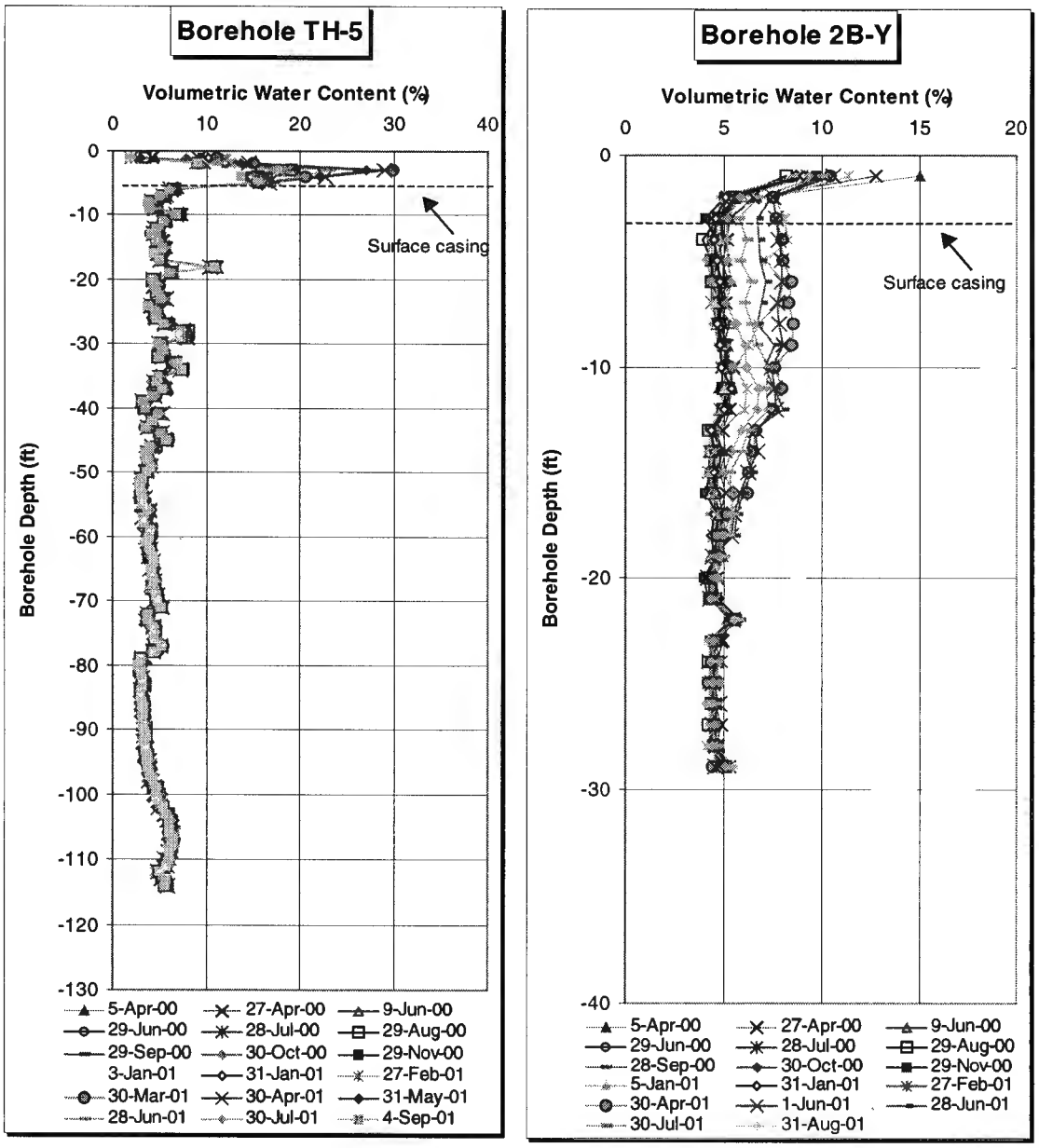


**Figure A-3. Neutron probe moisture measurements for boreholes TH-5 and 2B-Y**

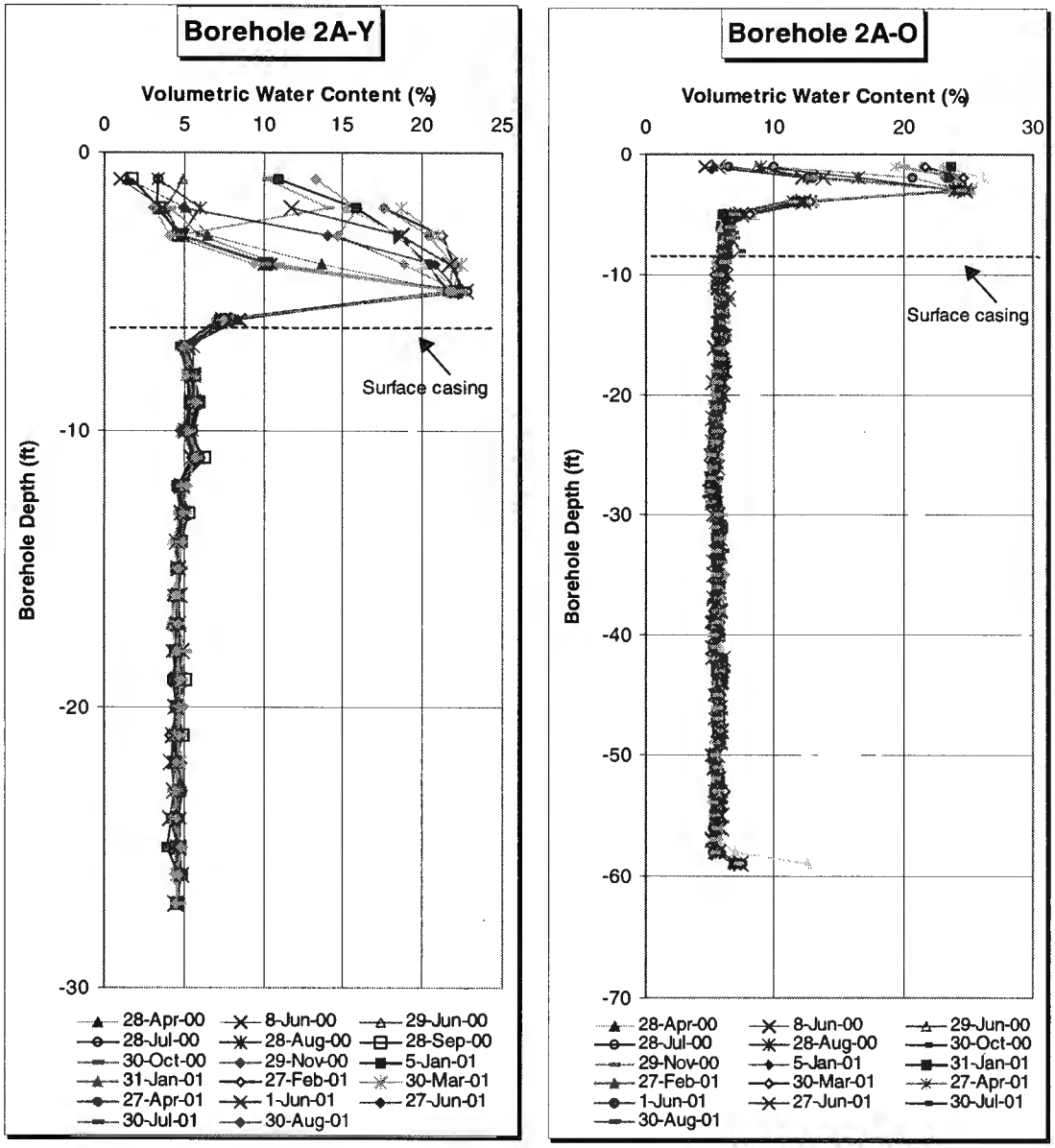


**Figure A-4. Neutron probe moisture measurements boreholes 2A-Y and 2A-O**

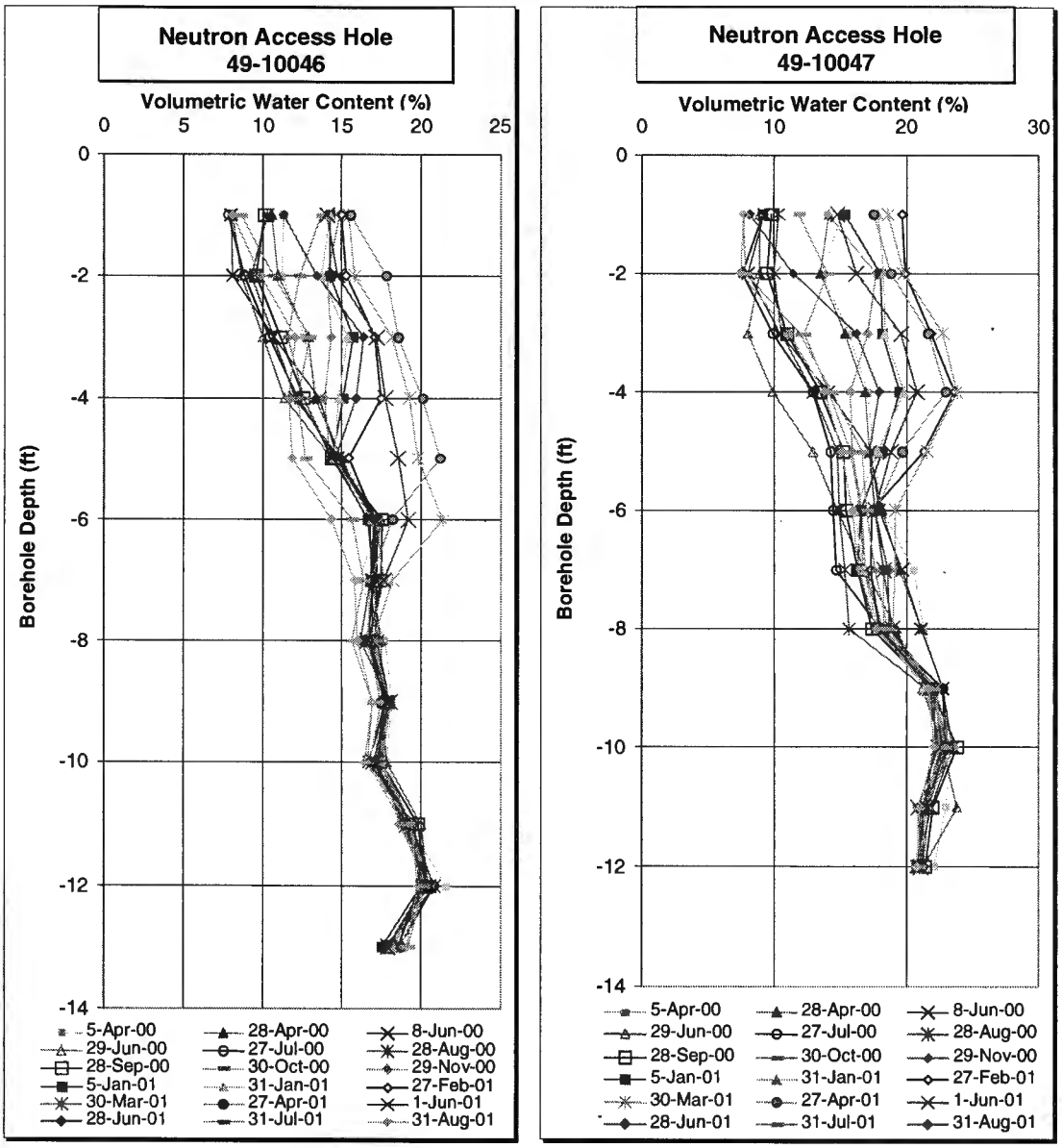


**Figure A-5. Neutron probe moisture measurements for neutron access holes 49-10046 and 49-10047**

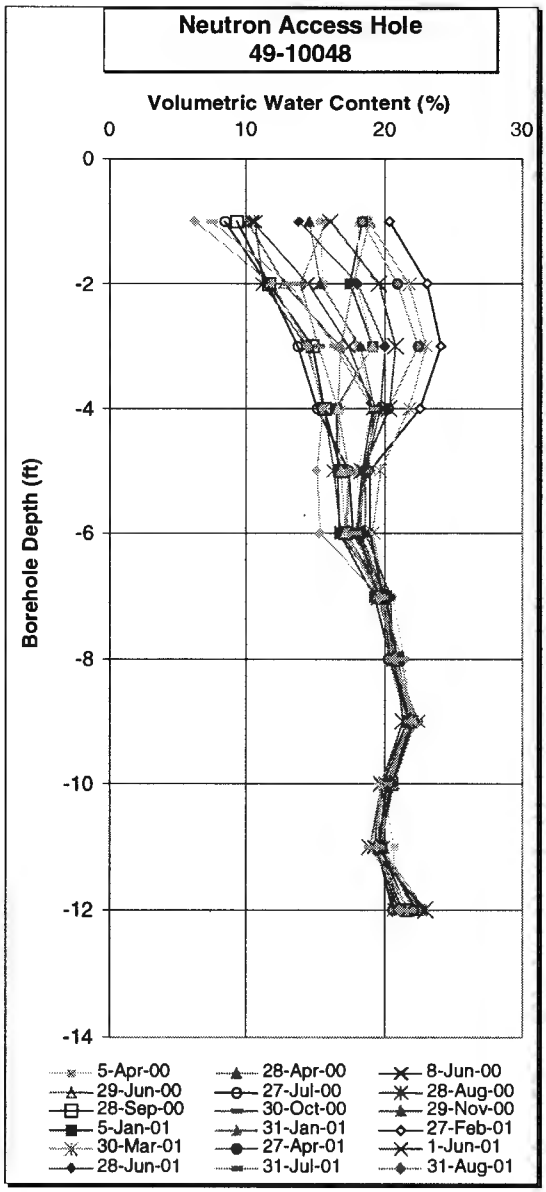


**Figure A-6. Neutron probe moisture measurements for neutron access hole 49-10048**

# Appendix B

*Time Versus Moisture Content Plots*

## APPENDIX B TIME VERSUS MOISTURE CONTENT PLOTS

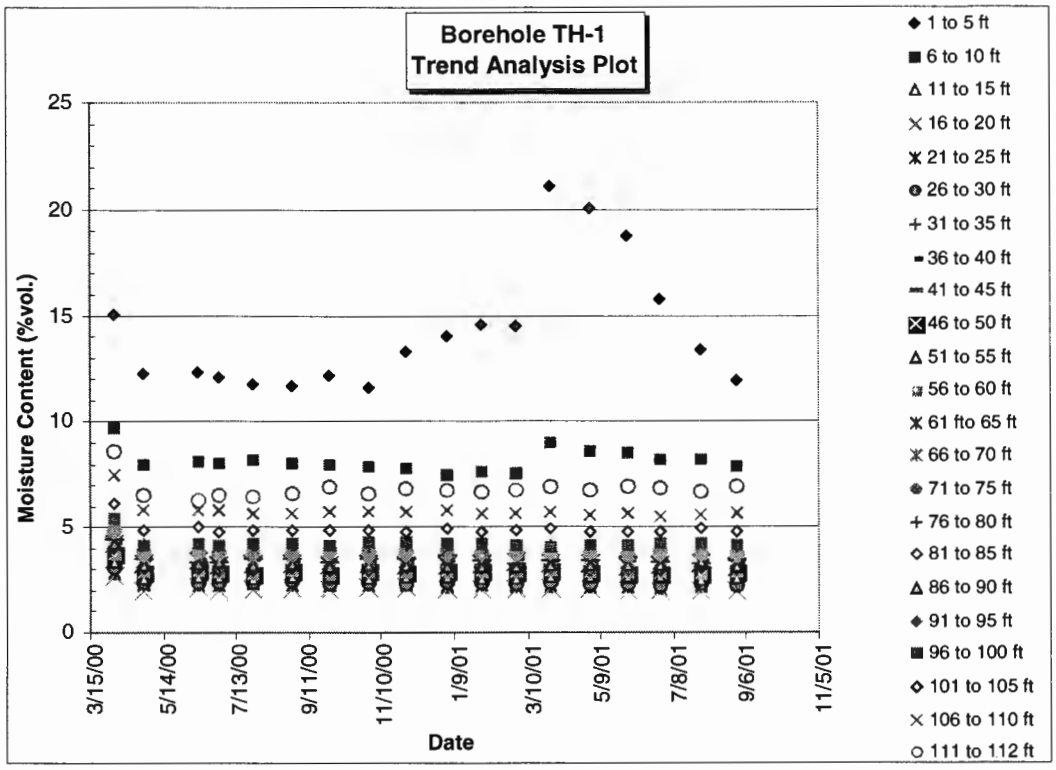


**Figure B-1. Trend plot of neutron moisture measurements, borehole TH-1**

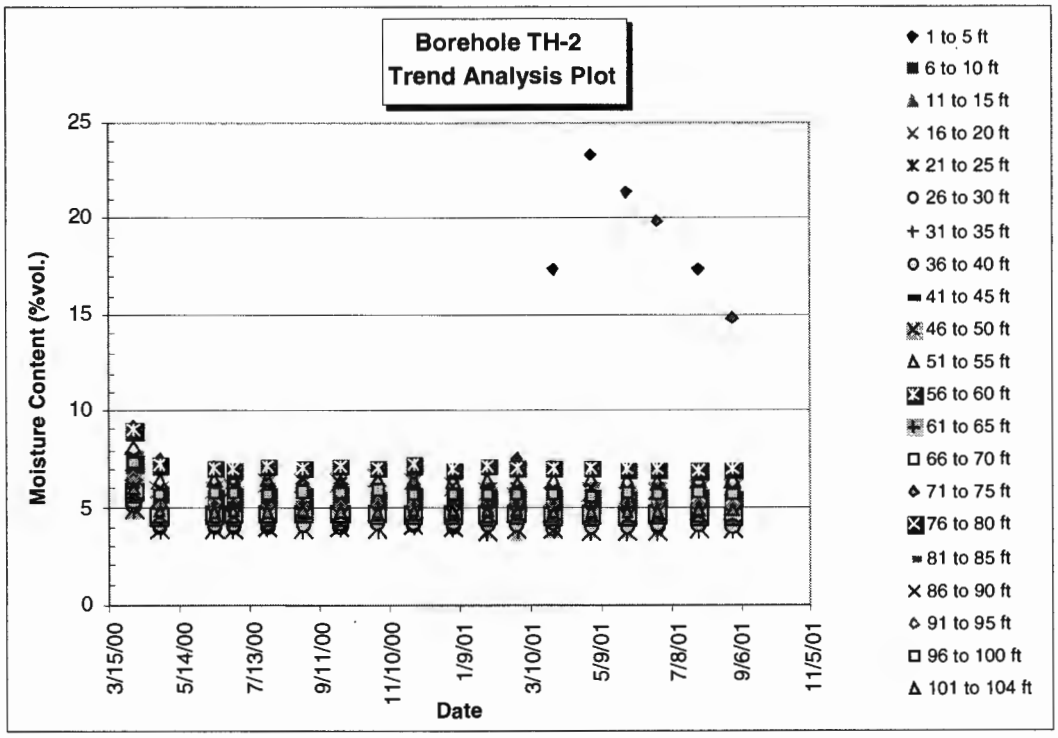


**Figure B-2. Trend plot of neutron moisture measurements, borehole TH-2**

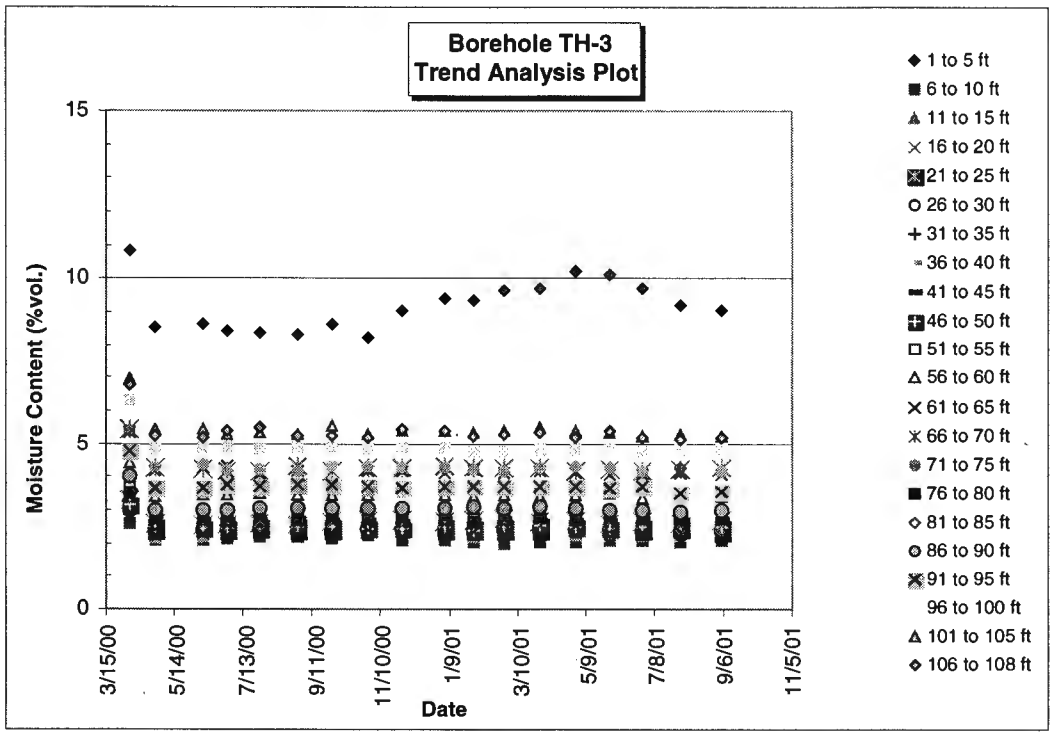


**Figure B-3. Trend plot of neutron moisture measurements, borehole TH-3**

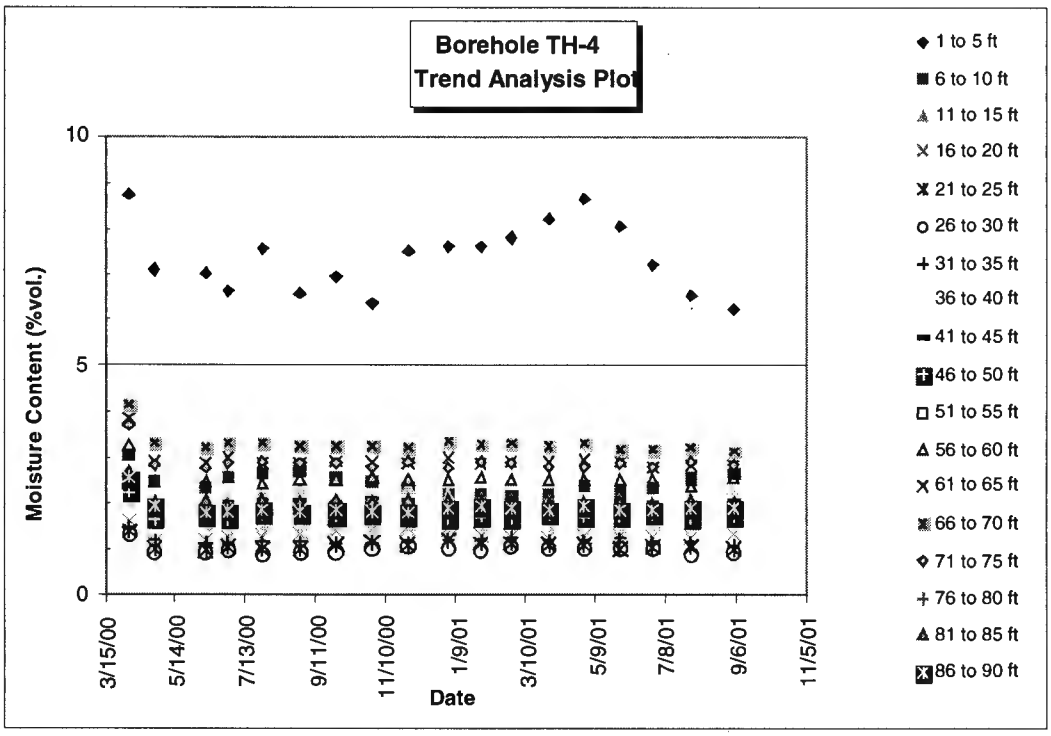


**Figure B-4. Trend plot of neutron moisture measurements, borehole TH-4**

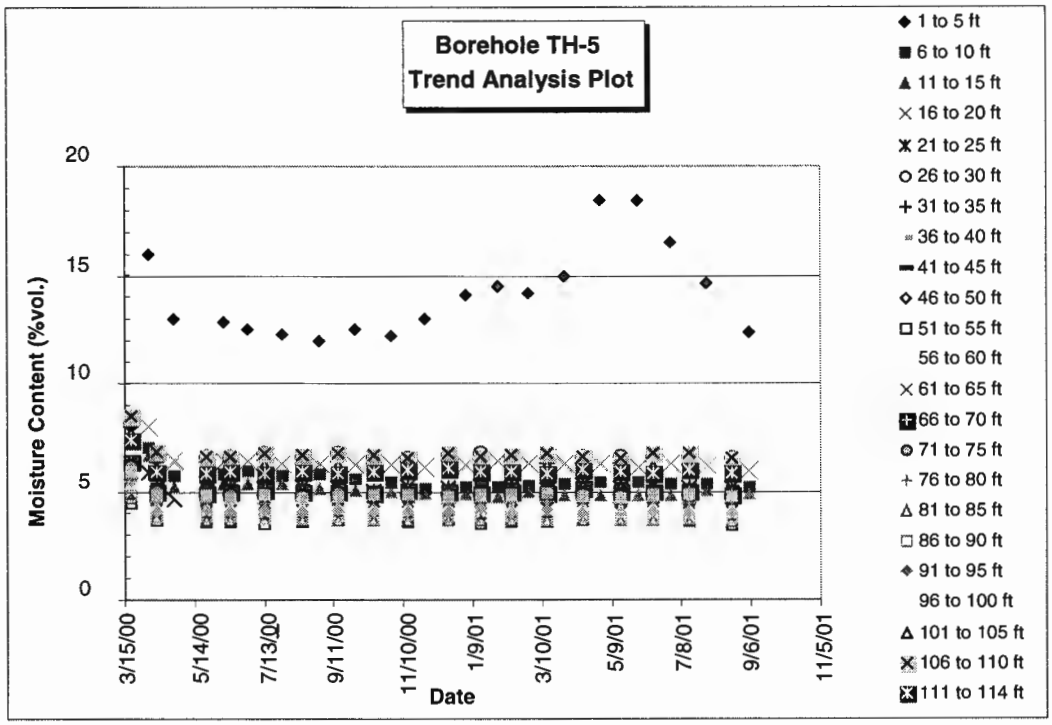


**Figure B-5. Trend plot of neutron moisture measurements, borehole TH-5**

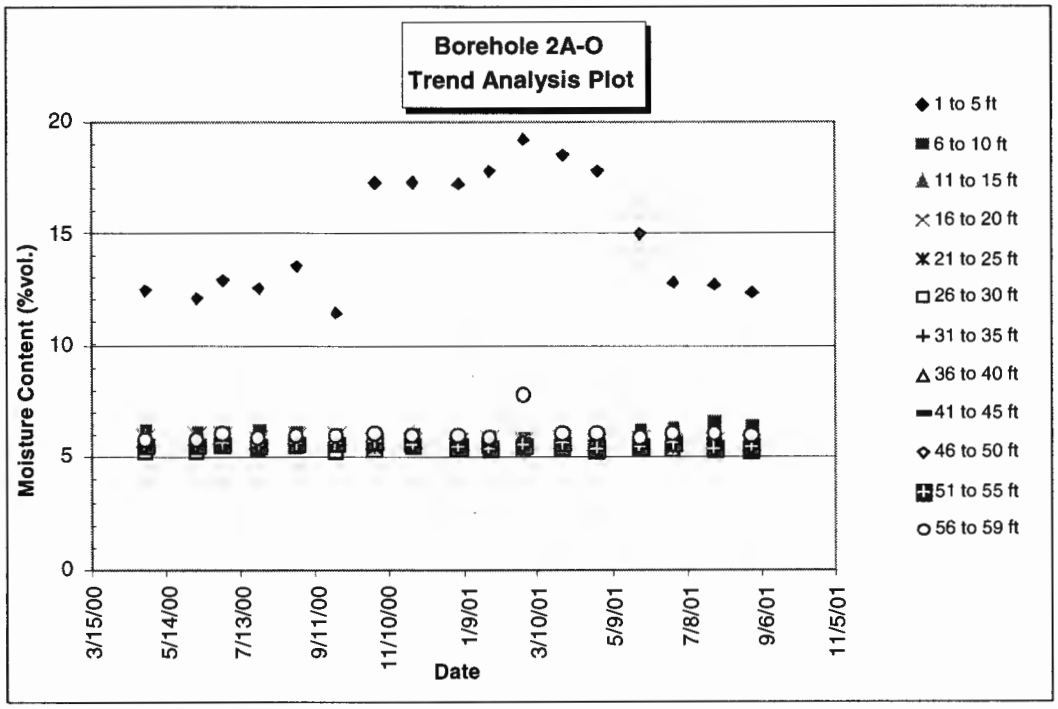


**Figure B-6. Trend plot of neutron moisture measurements, borehole 2A-O**

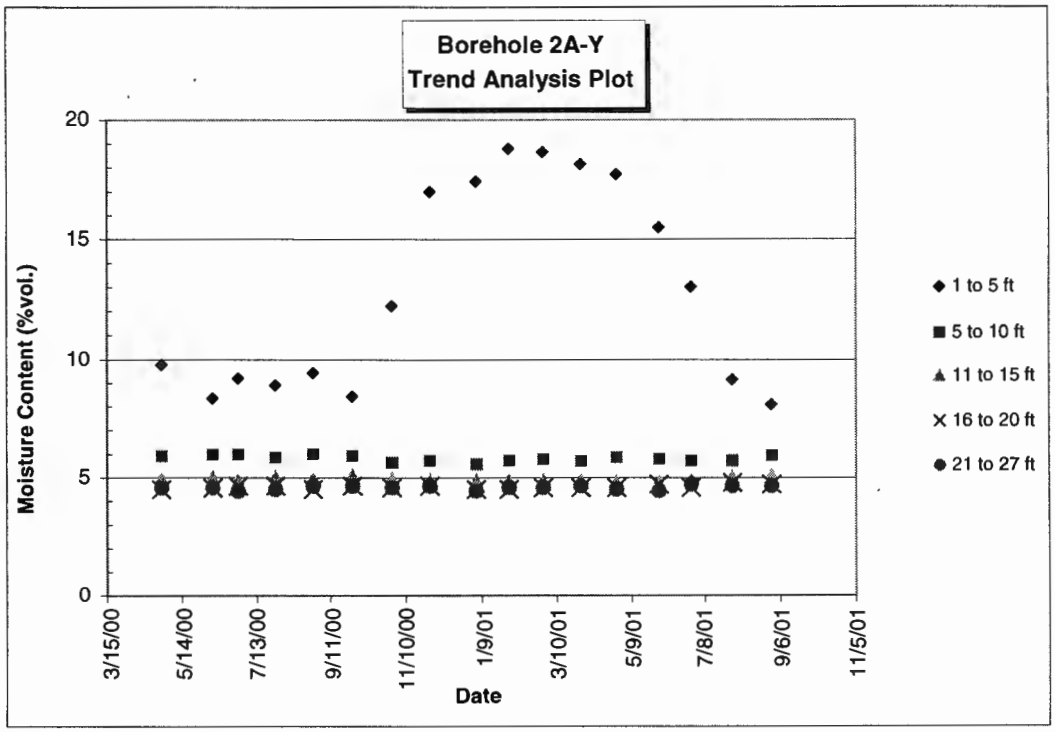


**Figure B-7. Trend plot of neutron moisture measurements, borehole 2A-Y**

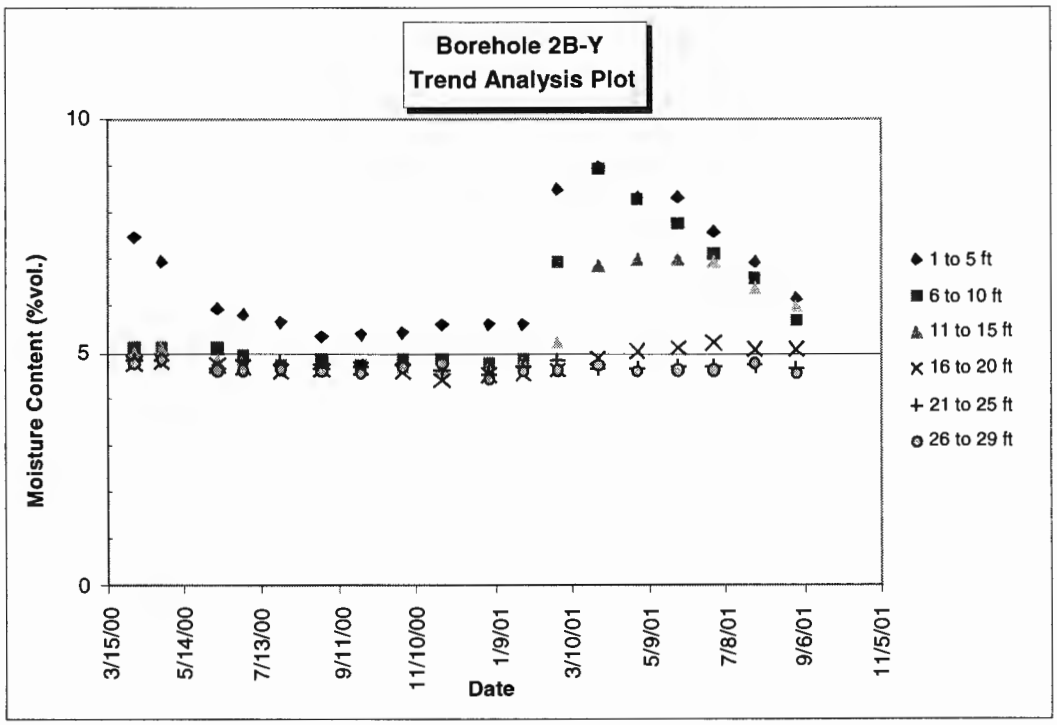


**Figure B-8. Trend plot of neutron moisture measurements, borehole 2B-Y**

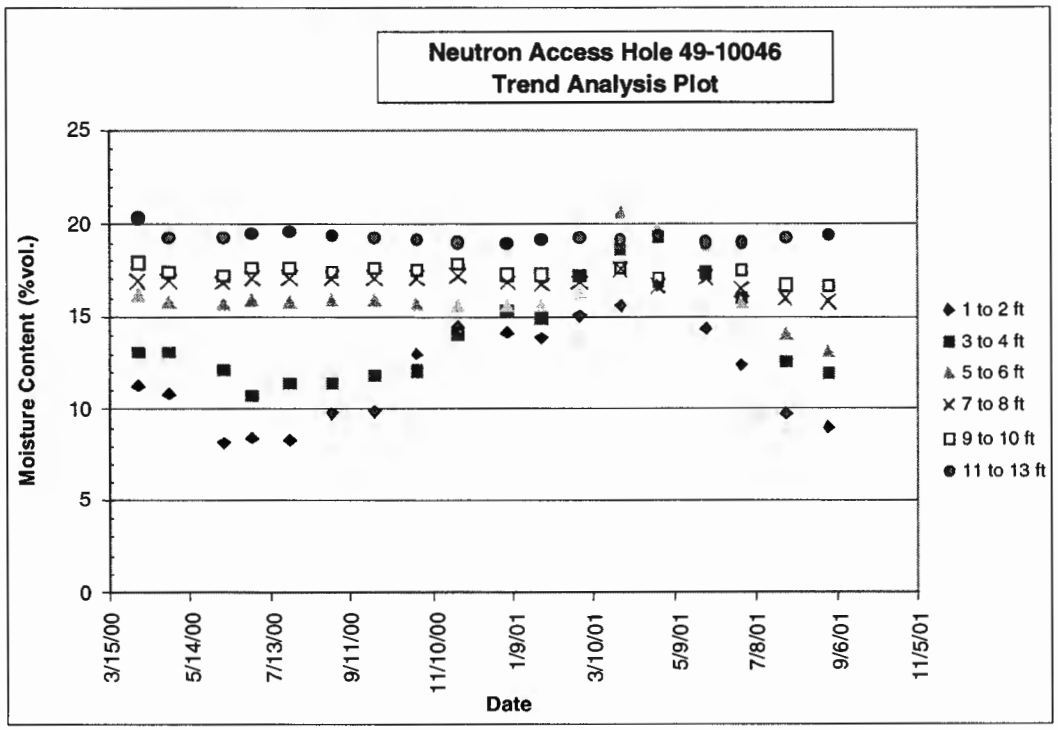


**Figure B-9. Trend plot of neutron moisture measurements, neutron access hole 49-10046**

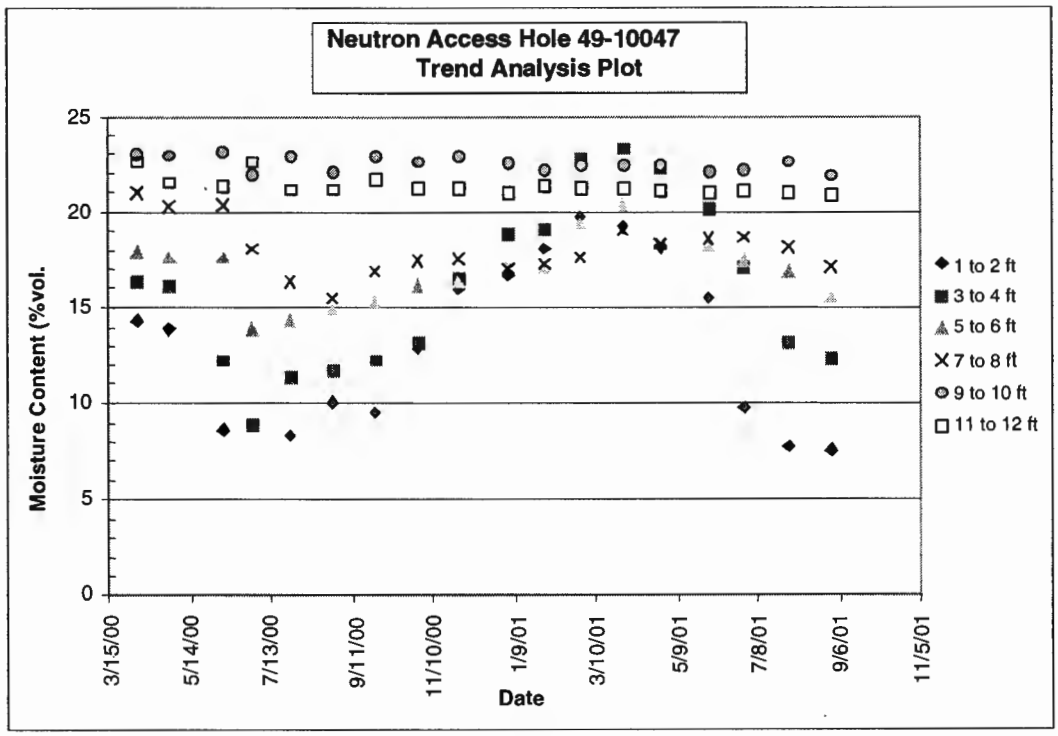


**Figure B-10. Trend plot of neutron moisture measurements, neutron access hole 49-10047**

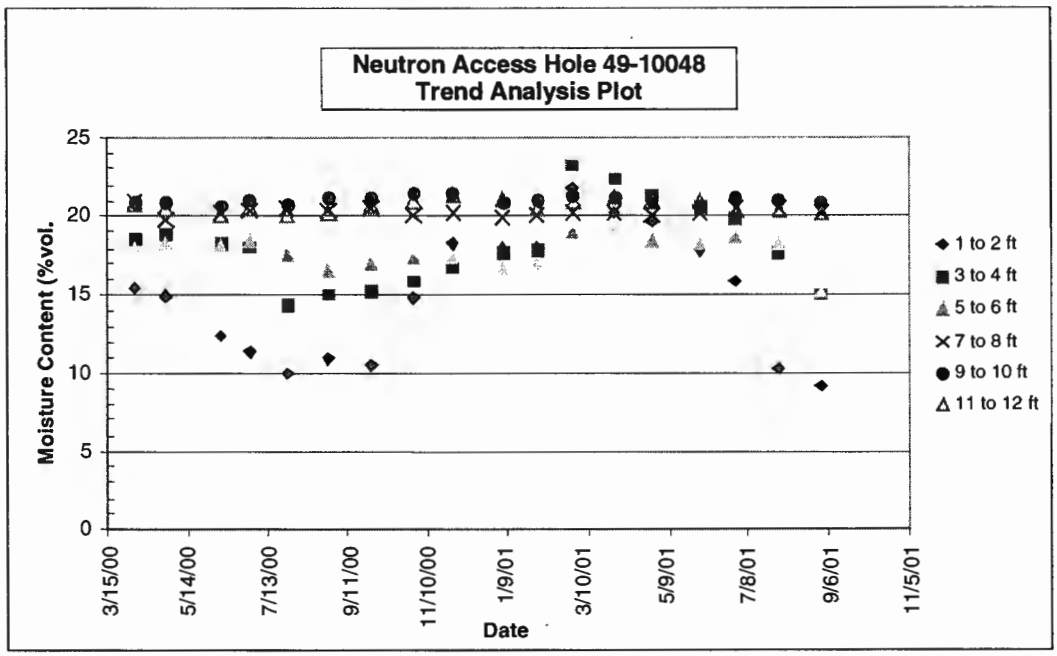


**Figure B-11. Trend plot of neutron moisture measurements, neutron access hole**