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Recharge Monitoring in an Interplaya Setting

Bridget R. Scanlon, Robert C. Reedy, and Jinhuo Liang
Bureau of Economic Geology
The University of Texas at Austin

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Edited by

Angela L. Woods
Technical Editor

600 South Tyler • Suite 800 • Amarillo, TX 79101
(806) 376-5533 • Fax: (806) 376-5561
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AMARILLO NATIONAL RESOURCE CENTER FOR PLUTONIUM/
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A Report on

Recharge Monitoring in an Interplaya Setting

Bridget R. Scanlon, Robert C. Reedy, and Jinhuo Liang
Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas 78712

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1. EXECUTIVE SUMMARY

The objective of this investigation is to monitor infiltration in response to precipitation events in an interplaya setting. We evaluated data gathered from the interplaya recharge monitoring installation at the Pantex Plant (Pantex installation) from March through December 1998. We monitored thermocouple psychrometer (TCP) instruments to measure water potential and time-domain reflectometry (TDR) probes to measure water content and bulk soil conductivity. Heat-dissipation sensor (HDS) instruments were monitored to supplement the TCP data.

There was wetting in the late winter and spring followed by drying in the summer. The soils in the upper 0.5-m were initially wet in March through May and exhibited drying during the summer beginning in June. Water potential values in March through May over this depth interval were above -0.2 MPa. The soils from 0.8 to 1.4-m of depth exhibited water potential values from –1.0 to –1.3 MPa in March and progressively increased to values above –0.2 MPa by late June. As drying progressed during the summer, water potentials in the upper 0.8-m generally decreased to a range of about –4 to –7 MPa while values at the 1.1 and 1.4 m depths decreased to about –2.5 to –3 MPa.

Wetting occurred in the fall and early winter. Rapid infiltration occurred to depths ranging from 0.1 to 1.1 m at different locations after 33 mm of rain fell on October 1. A larger rainfall event of 118 mm on October 30 resulted in rapid infiltration to depths ranging from 0.8 to 1.4 m at different locations. Following the October events, water potential values at most locations in the upper 0.8 to 1.4 m remained above –0.4 MPa through December.

The borehole TCP instruments at the 1.5, 3.1, and 4.6-m depths indicated water potential values from –2.5 to –3.5 MPa in late summer. This was followed by continually increasing water potentials through December as values rose to –0.6 to –2 MPa and may reflect the continued infiltration of precipitation from the spring. The borehole TCP instruments from 6 to 22-m of depth indicated relatively stable water potential values increasing with depth from –2 to –1 MPa.

The TCP data from the Pantex installation are in reasonable agreement with the results of the water potential analyses of the borehole samples. Data from the Playa 5 installation exhibit similar response patterns to the Pantex installation, though Playa 5 exhibited overall wetter conditions and lower fluctuations than observed at the Pantex installation. Rapid response to the October 30th precipitation event was also observed at Playa 5, though to a greater depth of 2.9 m.

In August, water content over the top 0.5 m of soil measured with the TDR system increased systematically with depth from about 31 to 51% when over the 0.8 to 1.4-m depth interval the water content was more uniform from 43 to 46%. Water content had decreased gradually over the top 0.5 m to about 28 to 48% and over the 0.8 to 1.4-m depth interval to 42 to 44% by late October. Water contents immediately increased to about 43 to 50% over the entire range of depths to 1.4 m following the October 30th precipitation event and gradually decreased to values similar to those as before the event by late December. There was good correlation ($R^2 = 0.9$) between soil water content and bulk conductivity.

The rapid response of the TCP and TDR instruments following major precipitation events infers preferential flow. The rapid responses occurred to depths that ranged from 0.1 to 1.4-m of depth at different locations and times. The TDR instruments were more susceptible than the TCP instruments to preferential flow. Some of the TDR data were erratic due to the method of TDR waveform analysis. Further analysis of TDR analytical methods needs to be done before the data can be effectively used.

2. METHODS

A detailed description of methods can be found in Scanlon et al. (1997). The theory of operation and the manner in which the instruments were calibrated and installed can be found in a previous report (Scanlon et al. 1998). Briefly, the monitoring installation consists of single and duplicate instruments installed at various depths in either a shallow trench or in one of five boreholes. Instruments were installed in the trench at depths ranging from 0.1 to 1.4 m and in the boreholes at depths ranging from 0.2 to 22.4 m. Duplicate TCP and single TDR probes were installed in two locations in the trench. Duplicate HDS instruments were installed in shallow boreholes at 0.2, 0.3, and 0.5 m. Retrievable TCP instruments were installed in duplicate in two deep boreholes at approximately 1.5-m intervals from 1.5 to 6 m of depth and at approximately 3-m intervals to a depth of 22.4 m. Water potential is monitored with the TCP and HDS instruments while water content and soil bulk conductivity are monitored with the TDR probes.

Monitoring of the TCP instruments in the trench and at most of the borehole depths began on March 1, 1997. Monitoring of the TCP instruments installed in the boreholes at depths of 1.5 and 4.6 m began on August 26. Monitoring of the TDR probes began following installation of the TDR electronics and data logging system on August 27, 1997. The HDS instruments were also installed at that time. No data were obtained from the HDS instruments until October 29, 1997, because of an equipment malfunction that occurred two days following installation.

3. RESULTS AND DISCUSSION

Precipitation data were recorded at the Southeast rain gauge, located approximately 0.5 miles south of the monitoring station, and were provided by Pantex personnel (Figure 1). A total of 430 mm (16.9 in) of precipitation was reported for 1998, which was slightly lower than the long-term average of about 500 mm. The record indicated a rather wet late winter and spring, followed by a relatively dry summer, and finally an extremely wet October when 186 mm (7.3 in) of rain was recorded, accounting for about 43% of the total annual precipitation. Most of that rain fell during three events, with the October 30th event measuring 118 mm (4.6 in).

Time-series plots of selected TCP data from the trench and boreholes are also shown in Figure 1. There was variability between instruments installed at different locations in the trench. The east-end profile was consistently wetter and reflected infiltration to a greater depth than the west-end profile. The data displayed in Figure 1 were primarily taken from the instruments installed in the west-end of the trench. High water potential values (close to zero) indicate wet conditions and low water potential values (more negative) indicate drier conditions. The TCP data indicated that the top 0.5-m of soil was initially very wet, reflecting infiltration during the late winter and spring. Water potential values in March in the top 0.5-m of soil were near zero while values at 0.8 to 1.4-m of depth were drier (–1.0 to –1.3 MPa). Water potentials in the shallow subsurface (≤ 0.8 m) gradually decreased over the summer as the soils dried out. As drying progressed, water potentials in the upper 0.8-m decreased to –4 to –7 MPa. At greater depth (1.1 to 1.4 m), water potential continued to increase until late June to values above –0.2 MPa reflecting continued drainage from shallower depths. With drying, water potential values at the 1.1 to 1.4-m depths decreased to –2.5 to –3 MPa by late summer

Wetting occurred again in the fall and early winter. Infiltration occurred to depths ranging from 0.1 to 1.1 m at different locations after 33 mm of rain fell on October 1. A larger rainfall event of 118 mm on October 30 resulted in infiltration to depths ranging from 0.8 to 1.4 m at different locations. The affected instruments measured large increases in water potential immediately following both of those events. Water potential values at most locations in the upper 0.8 to 1.4 m increased to and remained above about –0.4 MPa through December. Some instruments located at the 1.1 and 1.4-m depths were not immediately affected by the October infiltration events and measured only gradual increases through December to water potential values of –0.8 to –1.8 MPa.

The borehole TCP instruments at the 1.5, 3.1, and 4.6-m depths indicated water potential values from –2.5 to –3.5 MPa in late summer. This was followed by a continual increase through December as values rose to –0.6 to –2 MPa. The increases may reflect the continued infiltration of precipitation from the spring. Below the 4.6-m depth, the borehole TCP instruments indicated relatively stable water potential values that gradually increased with depth from –2 to –1 MPa.

Comparison to the TCP data measured at the Playa 5 monitoring installation revealed similar instrument response patterns through the year. Conditions in the upper 1.1-m at Playa 5 through May were very similar, when near surface water potentials were near zero and ranged to about –1.0 MPa at the 1.1-m depth. With summer drying, the water potential values over most of the top 1.1 m decreased more rapidly and uniformly than at the Pantex installation, but remained slightly wetter with water potentials about –3.5 to –4.5 MPa. A rapid response of the TCP instruments following the October 30th precipitation event was also observed at Playa 5, though to a greater depth of 2.9 m. Water potentials ranged from about –1.0 MPa at the 12.2-m depth to –0.9 MPa at the 21.3-m depth at Playa 5, slightly higher than the –1.4 and –

1.0 MPa respectively observed at those depths at the Pantex installation.

Data from the HDS instruments were in reasonable agreement with the TCP data. There were few HDS data prior to the October 30th rain for comparison to the TCP data. Water potential values were beyond the calibrated range of the HDS instruments, which indicated values ranging from –1.9 to –3.4 MPa. By comparison, the TDP data at that time, which were more accurate, ranged from about –4.3 to –6.5 MPa. Most of the HDS instruments responded rapidly following the October 30th precipitation event when the affected HDS instruments indicated values ranging from –0.01 to –0.03 MPa. The affected TCP instruments installed at similar depths as the HDS instruments indicated lower values ranging from about –0.02 to –0.3 MPa.

The HDS instrument calibrations are accurate from -0.01 MPa to about –0.5 MPa. HDS instruments become increasingly insensitive to decreasing water potential below this range and the calibration predicts a value greater than the actual value. By comparison, data from TCP instruments are generally not considered reliable for water potential values greater than about -0.3 MPa. Thus, a direct comparison of data between the two instruments is often not applicable. However, general relative comparisons can be made and HDS data can indicate whether or not a TCP installed at the same depth might have failed.

Vertical profiles of water potential from both the trench and the boreholes combined with texture data from the borehole samples are shown in Figure 2. The plot compares the results of the laboratory analyses of water potential for samples obtained during drilling in February 1998 with the TCP data for selected dates during the summer and winter. The equilibrium line shown on the plot for reference represents equilibrium between water potential and gravitational potential. Points plotting to the right of the line indicate downward movement of water while those to the left indicate upward movement under steady flow conditions. The TCP data indicate generally higher water potential values than do the sample data, especially below about 15-m where the texture is coarser. The results are reasonable however, as coarser textured samples are more prone to drying during collection and analysis than are finer textured samples

Time-series plots of the TDR water content data are presented in Figure 3. The upper 0.5-m of soil had water contents that increased systematically with depth from about 31 to 51% in late August and that gradually decreased to about 28 to 48% by late October. Water content in the 0.8 to 1.4-m depth interval was more uniform from 44 to 46% in late August and decreased to 42 to 45% by late October. Water content increased rapidly at all depths to about 43 to 50% following the October 30th precipitation event. By late December, Water content returned to levels similar to as before the event. The erratic nature of some of the data in the plot is thought to be an artifact of the method used to analyze the TDR waveform and efforts are ongoing to rectify this problem. The calibration equation used to convert the waveform analysis results to water content values is that published by Topp (1980). The use of that function may result in over-estimating the actual water content because of the relatively high clay content of the soils at the monitoring station. It may therefore become necessary to develop a site-specific calibration function.

Figure 3 also shows time-series plots of the soil bulk conductivity monitored by the TDR probes and the relationship between soil bulk conductivity and water content. Similarly to the water content data, there was a systematic increase in conductivity to a depth of 0.5 m, below which the conductivity decreased somewhat and became more uniform with depth. The conductivity readings also rapidly increased in response to infiltration following the October 30th precipitation event and gradually decreased through December. The relationship between conductivity and water content had a significantly high correlation coefficient of 0.9.

Both the data from the instruments installed in the upper 1.4-m and field observations infer the presence of preferential flow. During the summer, desiccation cracks ranging up to 3 to 5 cm in width were observed to form in the surface soils surrounding the monitoring station. Desiccation cracks also formed along the perimeter of the trench excavation, more noticeably along the eastern end. Attempts were made during field visits to fill in the trench perimeter cracks but they persisted. The cracks in both the undisturbed soils and around the trench boundary are potential pathways for preferential flow following precipitation events having a significant runoff potential. The TDR instruments were installed directly into the walls of the trench while the TCP instruments were installed into horizontal holes drilled approximately 0.5 m into the trench wall. The TCP instruments were thus less susceptible than the TDR instruments to the influence of preferential flow along the trench perimeter.

4. CONCLUSIONS

Monitoring during 1998 showed that the top 1.4-m of soil was initially wet from March through June. Drying began in late May through June to sequential depths in the upper 1.4-m of soil and continued until October. The top 1.4-m of soil wetted to various depths at various times in October in response to large precipitation events and generally remained wet through December. Below the 1.4-m depth, TCP data indicated there might have been continued minor infiltration of the spring precipitation to the 4.6-m depth. Water potential values from the 6 to 20.5-m depths remained steady. Water potential data obtained with the TCP instruments are in general agreement with the data from the borehole sample analyses and with the supplemental HDS data. The data from the Playa 5 installation exhibited similar response patterns as those obtained from the Pantex installation, though the Playa 5 data indicated overall wetter conditions. Further analysis of the TDR analytical methods needs to be done before the water content and bulk conductivity data can be effectively used. There was good correlation between water content and bulk conductivity. Following larger precipitation events, many of the instruments installed in the trench responded rapidly to infiltration that extended to depths ranging from 0.1 to 1.4 m at different locations and times, inferring preferential flow. The TDR instruments were more susceptible than the TCP instruments to the influence of preferential flow.

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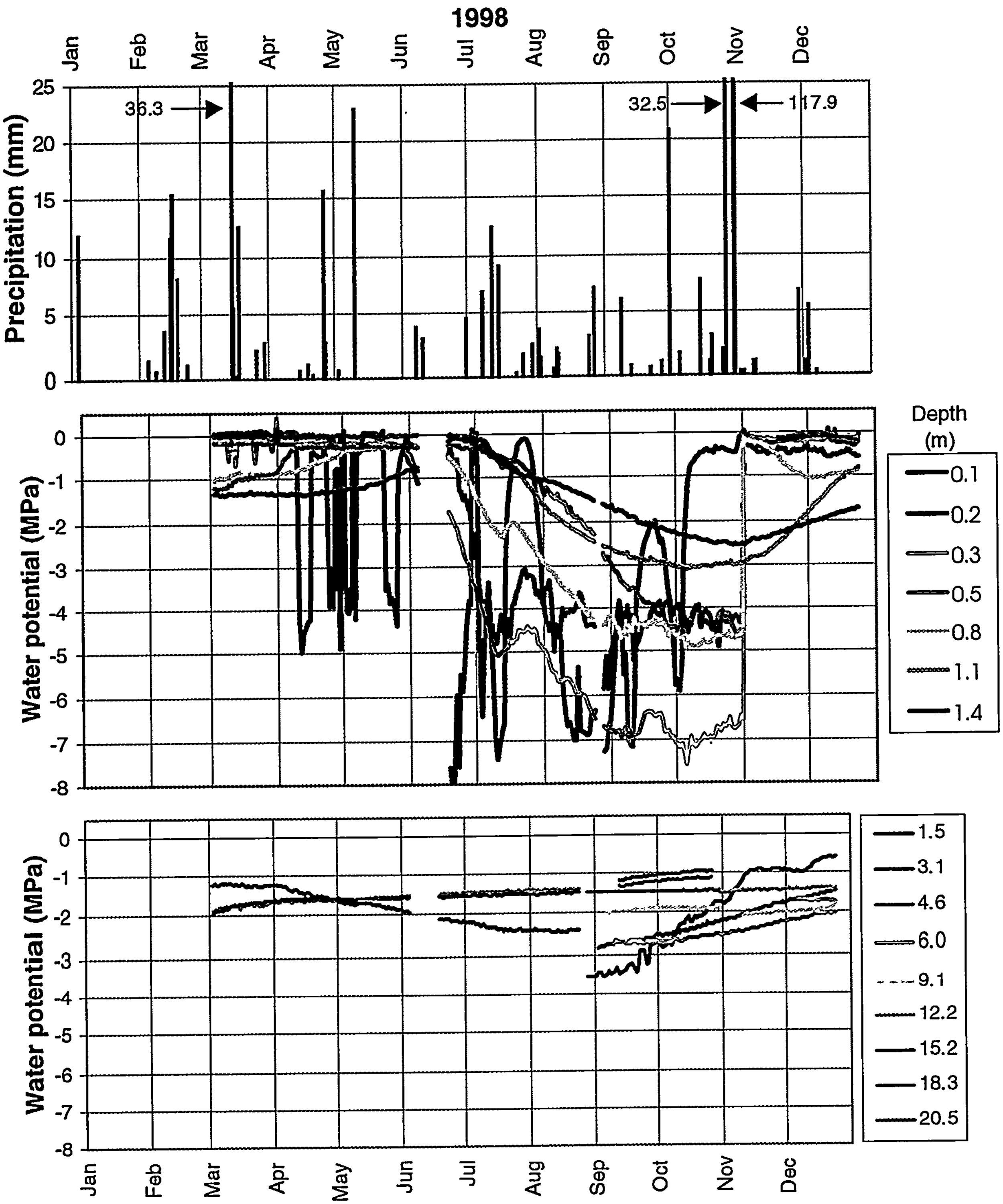

Figure 1: Precipitation and Time-Series Plots of TCP Water Potential Data for 1998

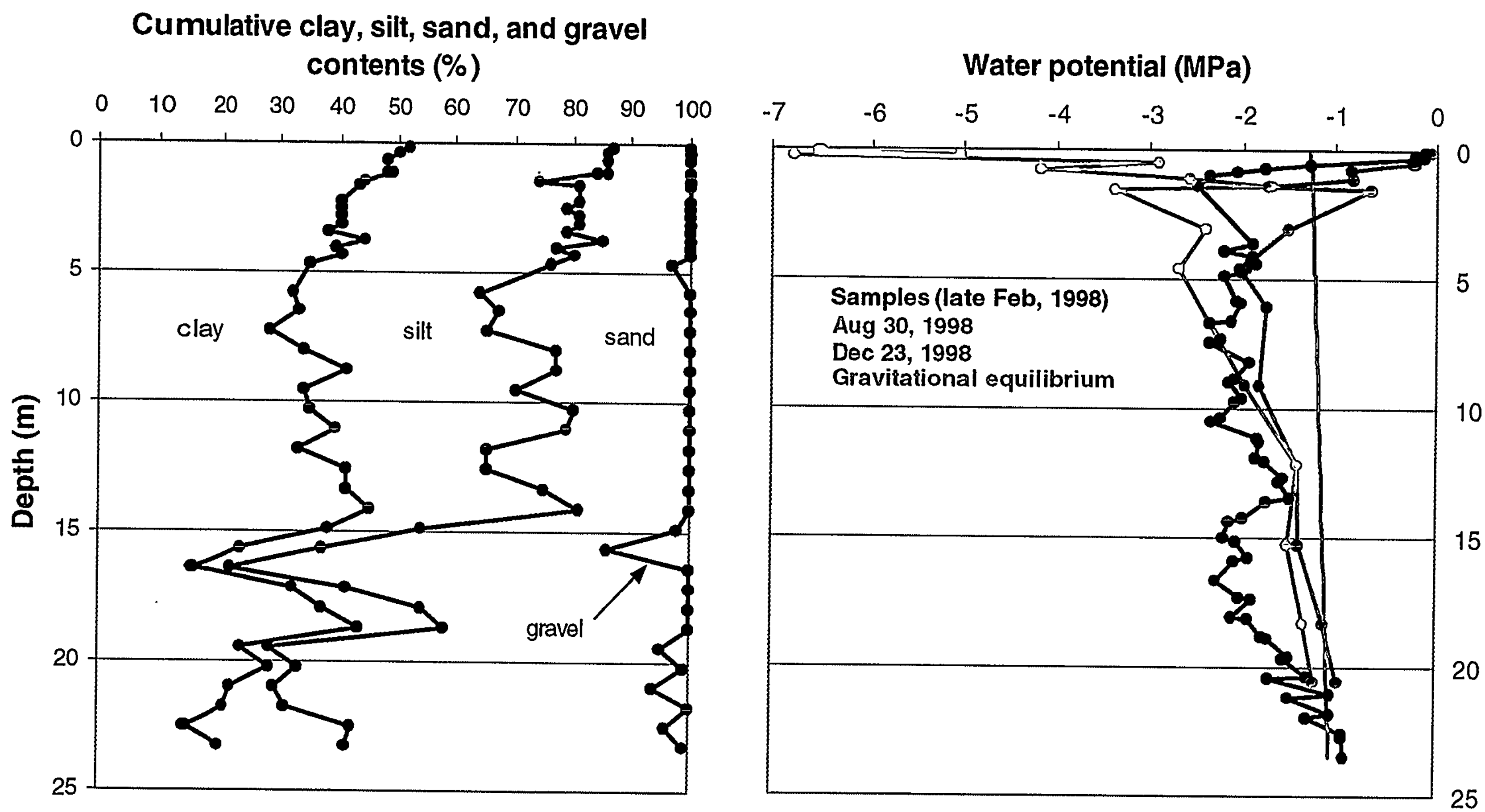

Figure 2: Texture Analyses of Borehole Samples and Water Potential Profiles for Selected Dates

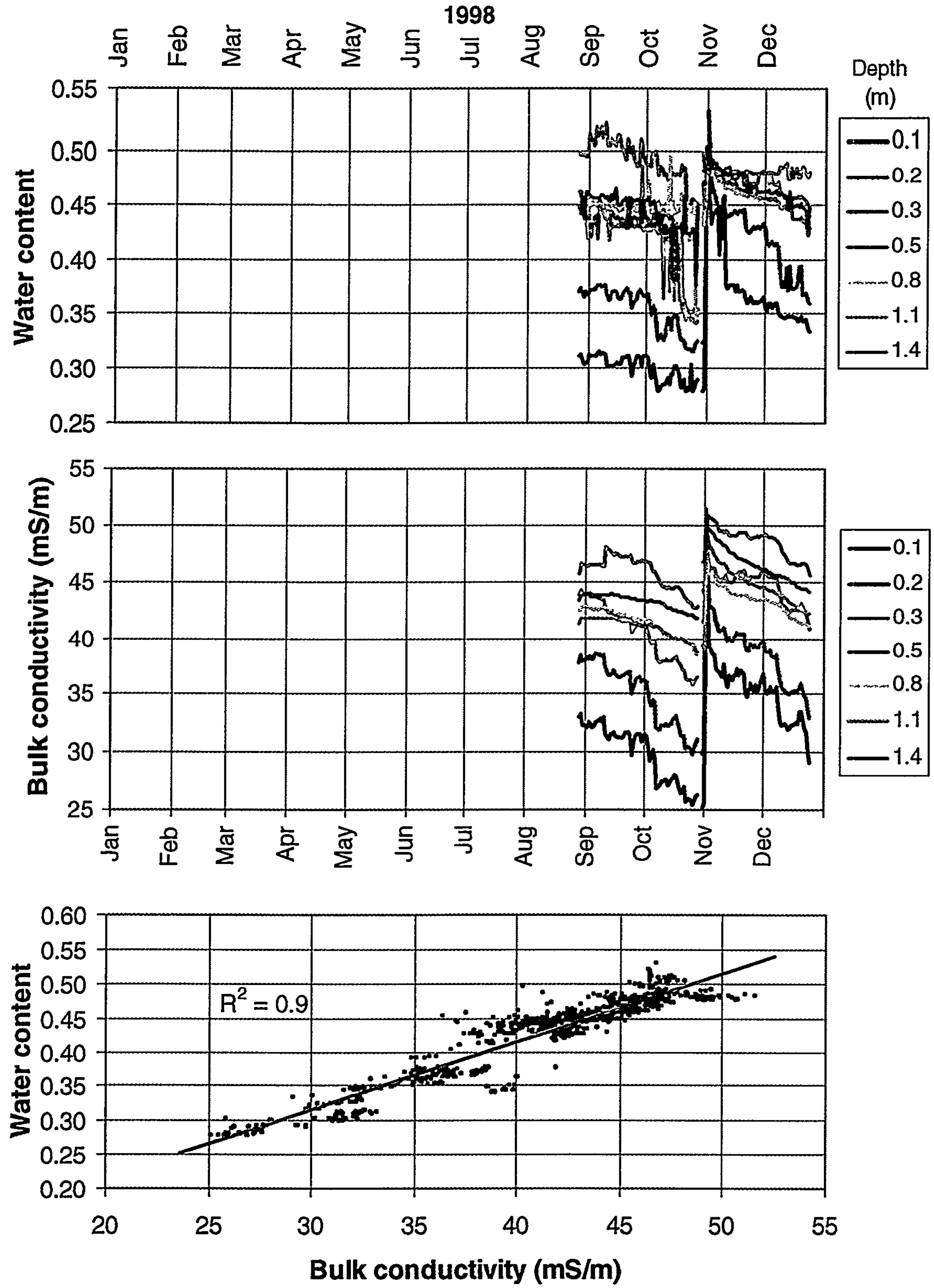

Figure 3: Time-Series Plots of Water Content and Soil Bulk Conductivity and the Correlation Between Water Content and Soil Bulk Conductivity