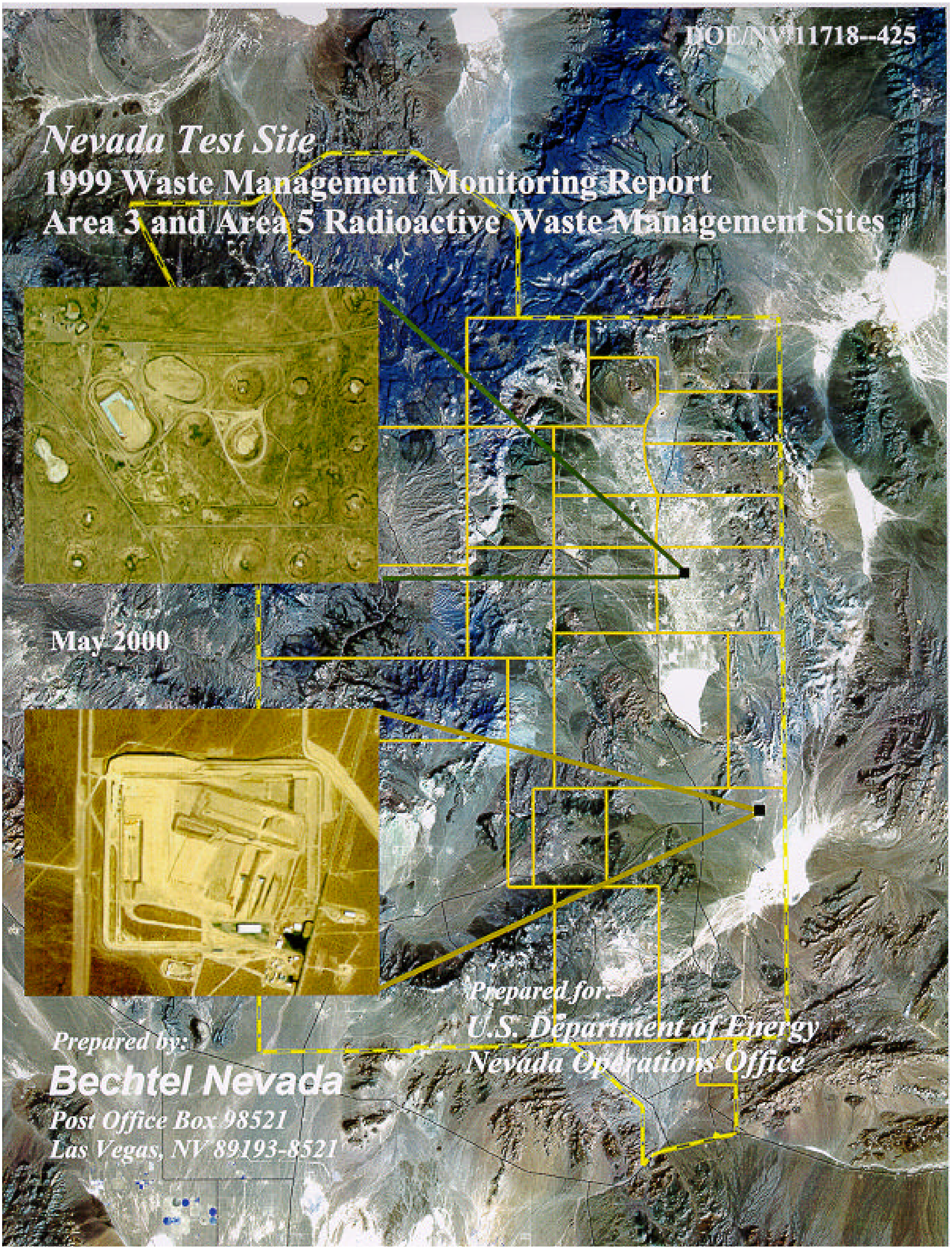
DOE/NV/11718--425

Nevada Test Site
1999 Waste Management Monitoring Report
Area 3 and Area 5 Radioactive Waste Management Sites



May 2000

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Nevada Operations Office

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1999 Waste Management Monitoring Report

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Work Performed Under
Contract No. DE-AC08-96NV11718

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LIST OF ACRONYMS

ASER	Annual Site Environmental Report
BEIDMS	Bechtel Environmental Integrated Data Management System
BJY	Buster-Jangle Y
BN	Bechtel Nevada
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy/Nevada Operations Office
DQO	Data Quality Objectives
E	Evaporation
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
GCD	Greater Confinement Disposal
LLW	Low-Level Waste
LLWMU	Low-Level Waste Management Unit
MDC	Minimum Detectable Concentration
MDL	Method Detection Limit
MSL	Mean Sea Level
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
PET	Potential Evapotranspiration
PPT	Precipitation
QAASP	Quality Assurance, Analysis, and Sampling Plan
REM	Roentgen Equivalent Man
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
TCP	Thermocouple Psychrometer
TDR	Time Domain Reflectometry
TLD	Thermoluminescent Dosimeter
TRU	Transuranic
TTR	Tonopah Test Range
W5B	Well 5B
WSS	Work Smart Standards

EXECUTIVE SUMMARY

Environmental monitoring data were collected at and around the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) at the Nevada Test Site (NTS) (refer to Figure 1). These monitoring data include radiation exposure, air, groundwater, meteorology, vadose zone, and biota data. Although some of these media (radiation exposure, air, and groundwater) are reported in detail in other Bechtel Nevada reports (Annual Site Environmental Report [ASER], the National Emissions Standard for Hazardous Air Pollutants [NESHAP] report, and the Annual Groundwater Monitoring Report), they are also summarized in this report to provide an overall evaluation of RWMS performance and environmental compliance. Direct radiation monitoring data indicate that exposure at and around the RWMSs is not above background levels. Air monitoring data indicate that tritium concentrations are slightly above background levels, whereas radon concentrations are not above background levels. Groundwater monitoring data indicate that the groundwater in the alluvial aquifer beneath the Area 5 RWMS has not been affected by the facility. Meteorology data indicate that 1999 was a dry year: rainfall totaled 3.9 inches at the Area 3 RWMS (61 percent of average) and 3.8 inches at the Area 5 RWMS (75 percent of average). Vadose zone monitoring data indicate that 1999 rainfall infiltrated less than one foot before being returned to the atmosphere by evaporation. Soil-gas tritium data indicate very slow migration, and tritium concentrations in biota were insignificant. All 1999 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing as expected at isolating buried waste.

INTRODUCTION

This document summarizes the 1999 environmental monitoring data collected for the Waste Management monitoring program for the Area 3 and Area 5 RWMSs. In previous years, this report was limited to reporting meteorology, water balance, and neutron logging data. Subsequent annual reports, starting with this 1999 data report, will include a summary of all environmental monitoring data including radiation exposure, air, groundwater, meteorology, vadose zone, and biota data. This document now includes data that were formerly reported in the annual Ecosystem Monitoring Report (radon and tritium monitoring data). Therefore, the Ecosystem report will no longer be produced.

These data are collected as required by Bechtel Nevada (BN) and U.S. Department of Energy (DOE) Contractual Work Smart Standards (WSS), which include various DOE orders and regulations from the Code of Federal Regulations (CFRs). These regulatory drivers exist to mitigate risk to the public and environment. They include:

- DOE Order 5400.1 (General Environmental Protection Program)
- DOE Order 5400.5 (Radiation Protection of the Public and the Environment)
- DOE Order 5820.2A (Radioactive Waste Management)
- 10 CFR 61 (Nuclear Regulatory Commission [NRC]: Licensing Requirements for Land Disposal of Radioactive Waste) which was in WSS from 1996 through 1999
- 40 CFR 61 (Environmental Protection Agency [EPA]: National Emissions Standards for Hazardous Air Pollutants)

- 40 CFR 264 (EPA: Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities)
- 40 CFR 265 (EPA: Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities)

Direct radiation monitoring is conducted to confirm that RWMS activities do not result in significant exposure above background levels. Air monitoring is conducted to confirm that RWMS activities do not result in significant radionuclide concentrations above background levels. Groundwater monitoring is conducted to assess the water quality of the aquifer beneath the RWMS and to confirm that RWMS activities are not affecting the aquifer. Vadose zone monitoring is conducted to assess the water balance of the RWMSs and confirm the assumptions made in the Performance Assessments, including no downward pathway, and evaluate the performance of the operational monolayer waste covers. Soil-gas monitoring for tritium is conducted to evaluate the upward and downward pathways, and biota monitoring for tritium is conducted to evaluate the upward pathway through the waste covers.

Details of the Quality Assurance, Analysis, and Sampling Plans (QAASPs) can be found in the Routine Radiological Environmental Monitoring Plan (RREMP) (BN, 1998). The RREMP was written through a Data Quality Objectives (DQO)-driven process to identify how and what technically-defensible environmental monitoring data are collected. A vadose zone monitoring QAASP is being developed and will be incorporated into the Waste Management Integrated Monitoring Plan and/or the RREMP during its next revision.

SITE DESCRIPTIONS

Area 3 RWMS

The Area 3 RWMS is located on Yucca Flat within the NTS (refer to Figures 2 and 3). Yucca Flat is a closed intermontane basin located in the northeastern portion of the NTS. It is bounded on the north by Quartzite Ridge, Rhyolite Hills, and the Halfpint Range; on the east by Slanted Butte, Piaute Ridge, and the Halfpint Range; on the south by the CP Ridge and Massachusetts Mountain; and on the west by the Timber Mountain Caldera, Mine Mountain, and the Eleana Range. The valley floor slopes gently toward a playa. Ground-surface elevations range from 1195 m (3920 ft) above mean sea level (MSL) at the playa to over 1524 m (5000 ft) above MSL in the nearby surrounding mountains.

The thickness of the unsaturated zone at the Area 3 RWMS is estimated to be approximately 488 m (1600 ft), and the water table is assumed to occur in Tertiary tuff, based on data from surrounding boreholes. The tuff-alluvium contact is estimated to occur at a depth of between 305 and 457 m (1000 and 1500 ft).

Air temperatures can vary from -18°C (0°F) to 24°C (75°F) in winter and from 16°C (60°F) to 41°C (105°F) in summer. The climate of Yucca Flat is arid. The average annual precipitation based on a 39-year record at a station located 4.5 km (2.8 mi) northwest of the RWMS is 165 mm/year (6.5 in/year). Precipitation is highly variable, with scant precipitation being recorded in some years. Average annual potential evapotranspiration at the Area 3 RWMS, calculated using the Penman equation (Jensen et al., 1990) and local meteorology data, is 1625 mm (64 in), or about ten times the annual average precipitation.

Area 5 RWMS

The Area 5 RWMS is located on northern Frenchman Flat at the juncture of three coalescing alluvial fan piedmonts (Snyder et al., 1995). Frenchman Flat is a closed intermontane basin located in the southeastern portion of the NTS (refer to Figures 4 and 5). It is bounded on the north by Massachusetts Mountain and the Halfpint Range, on the east by the Buried Hills, on the south by the Spotted Range, and on the west by the Wahmonie Volcanic Center. The valley floor slopes gently toward a central playa lakebed. Ground-surface elevations range from 938 m (3078 ft) above MSL at the playa to over 1220 m (4000 ft) above MSL in the nearby surrounding mountains.

The thickness of the unsaturated zone at the Area 5 RWMS is a minimum of approximately 235 m (770 ft) on the southeast side of the RWMS (at UE5PW-1) and 271 m (890 ft) on the northwest corner (at UE5PW-3). Every borehole under the RWMS penetrates only alluvium, except at UE5PW-3, where Tertiary tuff is encountered at a depth of approximately 189 m (620 ft).

Air temperatures can vary from -15^{o}C (5^{o}F) to 24^{o}C (75^{o}F) in winter and from 16^{o}C (60^{o}F) to 45^{o}C (113^{o}F) in summer. The climate of Frenchman Flat is arid. The average annual precipitation based on a 37-year record at a station located 6.4 km (4 miles) south of the RWMS is 126 mm/year (5.0 inches/year). Precipitation is highly variable, with scant precipitation being recorded in some years. Average annual potential evapotranspiration at the Area 5 RWMS, calculated using the Penman equation (Jensen et al., 1990) and local meteorology data, is 1620 mm (64 in) or about 13 times the annual average precipitation.

Areas 3 and 5 are quite similar, except for differences in air temperature, precipitation, and soil texture: Area 3 receives approximately 30 percent more rainfall than Area 5; the annual average temperature at Area 3 is about 2^{o}C (4^{o}F) cooler than at Area 5; and soil textures at Area 3 are slightly finer than at Area 5.

Hydrologic Conceptual Model of Area 3 and Area 5 RWMSs

Climate and vegetation strongly control the movement of water in the upper few meters of the alluvium. The magnitude and direction of both liquid and vapor fluxes vary seasonally and often daily. Except for periods following precipitation events, water contents in this near-surface region are quite low. Below this is a region where relatively steady upward movement of water is occurring. In this region of slow upward water movement, stable isotope compositions of soil pore water confirm that evaporation is the dominant process (Tyler et al., 1996). This region extends to depths from approximately 3 to 49 m (10 to 160 ft) in Area 3, and from approximately 3 to 40 m (10 to 131 ft) in Area 5. Below this region water potential measurements indicate the existence of a static region, which begins between approximately 49 to 119 m (160 to 390 ft) in Area 3, and between approximately 40 to 90 m (131 to 295 ft) in Area 5 (Shott et al., 1997, 1998). In this static region, essentially no vertical liquid flow is currently occurring. Below this static region, flow is steady and downward due to gravity. Stable isotope compositions of pore water from these depths indicate that infiltration into this region must have occurred under cooler, past climate conditions (Tyler et al., 1996). If contaminants were to migrate below the currently static region, movement to the groundwater would be extremely slow due to the low water content of the alluvium. Estimates of the unretarded (zero upward flux) travel time to the groundwater, based on hydraulic characteristics of the alluvium, are in excess of 500,000 years in Area 3 (Levitt et al., 1998), and 50,000 years in Area 5 (Shott et al., 1998).

Based on the results of extensive research, field studies, modeling data, and monitoring data which are summarized in the Area 3 and Area 5 Performance Assessments (Shott et al., 1997, 1998), and in Levitt et al. (1998, 1999), there is no aerially distributed groundwater recharge under current climatic conditions at the RWMSs. Recent studies do indicate that under bare-soil conditions such as those found at the operational waste cell covers, some drainage may occur through the waste covers into the waste zone. This drainage is estimated to be about 1 percent of the annual rainfall at Area 5, and 10 percent of annual rainfall at Area 3, based on conservative modeling results (Levitt et al., 1998, 1999). In addition, monitoring data from a bare-soil weighing lysimeter located in Area 5 indicate that soil water contents at depths of 1 to 2 m are slowly increasing. It is unclear if water contents are approaching equilibrium values or increasing until drainage occurs through the bottom of the lysimeter. Drainage through the waste covers should not be confused with groundwater recharge since the covers will ultimately become partially vegetated, eliminating the downward pathway. Deep drainage and potential groundwater recharge appear to be occurring in isolated valley locations at the NTS such as large drainage washes, where soil permeabilities are high and vegetation is sparse.

PROJECT DESCRIPTION

The Area 3 and Area 5 RWMSs at the NTS are designed and operated for disposal of low-level waste (LLW) from DOE and other approved offsite generators, and mixed waste from DOE Nevada Operations Office (DOE/NV). Waste disposal cells within the Area 3 RWMS are subsidence craters resulting from underground nuclear testing. The seven craters within the Area 3 RWMS, at the time of formation, ranged from 122 to 178 m (400 to 580 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth (Plannerer, 1996). Disposal in the U-3ax crater began in the late 1960s. Disposal began in U-3bl in 1984. Waste forms consisted primarily of contaminated soil and scrap metal, with some construction debris, equipment, and containerized waste. The U-3ax/bl disposal unit is currently covered with a minimum of 1.5 m (5 ft) of backfill that serves as an operational cover. For details on the final closure of U-3ax/bl disposal unit, refer to BN (1999a). Disposal in the combined unit U-3ah/at began in 1988. Disposal cell U-3ah/at is currently being used for disposal of bulk, low-level radioactive waste from the NTS and approved offsite generators. Crater U-3bh was originally used for disposal of contaminated soils from the Tonopah Test Range (TTR) in 1997. The U-3bh unit remains open for waste disposal from other approved generators. The remaining two craters are not in use. Refer to Figures 1 and 2 for locations of the NTS and the RWMSs within the NTS. For a detailed description of the facilities at the Area 3 RWMS refer to Shott et al. (1997).

Waste disposal at the Area 5 RWMS has occurred in a 37-hectare (92-acre) portion of the site, referred to as the LLW Management Unit (LLWMU), since the early 1960's. The LLWMU consists of 23 landfill cells (pits and trenches) and 13 Greater Confinement Disposal (GCD) boreholes. Four of the GCD boreholes were used to dispose transuranic (TRU) waste and are no longer active. Pit 3 (P03U) is the only active mixed waste disposal unit. All other active units contain low-level radioactive waste. Pit 6 (P06U) is used for disposal of thorium (at the bottom tier), and Pit 7 (P07U) is used for disposal of asbestiform LLW. Of the 23 landfill cells, 3 pits and 13 trenches have been closed. The remaining four pits (P03U, P05U, P06U, and P07U) and three trenches (T07C, T08C, and T09C) are open. Refer to Figure 6 for locations of pits and trenches. Pits and trenches range in depth from 4.6 to 15 m (15 to 48 ft). Disposal consists of placing waste in various sealed containers in the unlined pits and trenches. Soil backfill is pushed over the containers in a single lift approximately 2.4 m (8 ft) thick, as rows of containers reach approximately 1.2 m (4 ft) below original grade. For a detailed description of the facilities at the Area 5 RWMS refer to Shott et al. (1998).

ENVIRONMENTAL MONITORING DATA

Data Summary

These data are now archived in BN's environmental monitoring database: Bechtel Environmental Integrated Data Management System (BEIDMS). This report provides a general description and graphical representations of some of these data. Monthly and yearly summaries of meteorology data continue to be tabulated in this report (refer to Appendix A). These data include:

Radiation exposure data:
- Quarterly thermoluminescent dosimeter (TLD) measurements

Air monitoring data:
- Weekly alpha concentrations
- Weekly beta concentrations
- Bi-weekly tritium concentrations
- Monthly gamma concentrations
- Monthly plutonium concentrations
- Bi-monthly radon concentrations
- Annual radon flux measurements from waste covers

Groundwater monitoring data:
- Quarterly water level measurements

Indicators of Contamination (semi-annual):
- pH (field)
- specific conductance (field)
- total organic carbon
- total organic halogen
- tritium

Routine Radiological Environmental Monitoring Plan (RREMP) data (biennial):
- gross alpha
- gross beta
- gamma spectroscopy
- plutonium-238, and plutonium-239+240
- strontium-90
- radium-226, and radium-228

General Water Chemistry Parameters (semi-annual):
- total Ca, Fe, Mg, Mn, K, Na, SiO_2
- total SO_4, Cl, F
- alkalinity

Vadose zone monitoring data:
Annual soil gas-phase monitoring data:
- Tritium concentrations measured at four Area 5 RWMS perimeter holes
- Tritium concentrations measured at GCD-05U gas sampling string (9 depths)

Daily weighing lysimeter data:
- Daily evaporation from the bare-soil weighing lysimeter
- Daily evapotranspiration from the vegetated weighing lysimeter
- Average soil surface temperature of the bare-soil and vegetated lysimeters
- Maximum soil surface temperature of the bare-soil and vegetated lysimeters
- Minimum soil surface temperature of the bare-soil and vegetated lysimeters

Daily automated vadose zone monitoring system data:
- Soil volumetric water content with depth in waste covers
- Soil volumetric water content beneath waste cells
- Soil temperature with depth in waste covers
- Soil temperature beneath waste cells

Bi-monthly neutron logging data:
- Neutron counts with depth at selected neutron access tubes
- Soil volumetric water content with depth at selected neutron access tubes

Meteorology monitoring data:
Daily meteorology data:
- Average air temperature at heights of 3 m (10 ft) and 9.5 m (31 ft) above ground level
- Maximum air temperature at heights of 3 m and 9.5 m above ground level
- Minimum air temperature at heights of 3 m and 9.5 m above ground level
- Average relative humidity at heights of 3 m and 9.5 m above ground level
- Maximum relative humidity at heights of 3 m and 9.5 m above ground level
- Minimum relative humidity at heights of 3 m and 9.5 m above ground level
- Average wind speed at heights of 3 m and 9.5 m above ground level

- Maximum wind speed at heights of 3 m and 9.5 m above ground level
- Average barometric pressure
- Maximum barometric pressure
- Minimum barometric pressure
- Total solar radiation load
- Total precipitation

Hourly meteorology data:
- Average air temperature at heights of 3 m and 9.5 m above ground level
- Average relative humidity at heights of 3 m and 9.5 m above ground level
- Average wind speed at heights of 3 m and 9.5 m above ground level
- Average wind direction at heights of 3 m and 9.5 m above ground level
- Average barometric pressure
- Average solar radiation
- Average net radiation
- Average soil heat flux
- Total precipitation

Precipitation stations:
- Area 5 RWMS meteorology station
- Area 5 Lysimeter meteorology station (a.k.a. L1 station)
- Area 5 pilot well 2 station (UE5PW-2, a.k.a. PW2)
- Area 5 pilot well 3 station (UE5PW-3, a.k.a. PW3)
- Area 3 RWMS meteorology station
- Area 3 U-3bw meteorology station (a.k.a. BW station)

<u>Biota monitoring data:</u>
Data are not currently archived in BEIDMS

Bechtel Environmental Integrated Data Management System (BEIDMS)

BEIDMS is an Oracle® based relational database management system developed by Bechtel for the comprehensive management and processing of environmental data. This database management system has been licensed and tailored to support both small and large environmental projects at BN. BEIDMS will ensure consistency and promote advanced planning, while providing a central repository for all unclassified environmental data. BEIDMS is currently operational and on-line for all environmental monitoring data from the NTS.

Radiation Exposure Data

A comparison of 1998-1999 direct radiation exposure (TLD) data from the RWMSs and background data from locations several kilometers away from the RWMSs (Well 5B and Buster-Jangle Y [BJY]) are presented in Figure 7. These data indicate that direct radiation exposure at the RWMSs was low. The two sites with the highest exposures (RWMS-S and U-3CO S in

Area 3) are each located near a ground zero for atmospheric tests. All sites had direction radiation exposures of less than 1.5 mR/day, and all but two sites had exposure rates of less than 0.6 mR/day. The dose from one Roentgen can be approximated by one Roentgen Equivalent Man (REM) (ICRP, 1987). Therefore, this exposure rate corresponds to a dose of less than 0.6 mrem/day, which is well below any dose of concern. These data are presented in the annual ASER and NESHAP reports.

Air Monitoring Data

Air particulate samples are collected at the RWMSs and are analyzed for gross alpha radiation, gross beta radiation, gamma radiation, and plutonium concentrations in air. Atmospheric moisture is collected and analyzed for tritium which acts as a conservative tracer and is therefore an excellent performance indicator of radionuclide migration from waste cells. Tritium concentrations in air at the Area 5 RWMS and a background location (2-year average at Well 5B) are presented in Figure 8. Tritium concentrations in air from Schooner (2-year average) are also included in Figure 8 for perspective. These data indicate slightly elevated tritium concentrations in air at the Area 5 RWMS compared to Well 5B, but are well below any concentrations of concern. Note that most of the RWMS tritium concentrations, as well as the 2-year average tritium concentrations at Well 5B, were below the median Minimum Detectable Concentration (MDC) for tritium (refer to Figure 8). These data are presented in detail in the annual ASER and NESHAP reports.

Radon flux and air concentration data were previously reported in the "1999 Ecosystem Monitoring Report" (BN, 1999b). They are summarized in this report since the annual Ecosystem Monitoring Report will no longer be produced, and its data will be published in this annual Waste Management Monitoring Report.

Radon concentrations in air at the RWMSs in 1999 are shown in Figure 9. Although radon concentrations were more erratic at the Area 3 RWMS than the Area 5 RWMS, concentrations were not above background levels. Radon flux measurements were conducted at various locations on waste cell covers at the RWMSs from March 3-4, 1999, during a period with low atmospheric pressure. These data are illustrated in Figure 10 and indicate that radon flux was well below the performance objective flux of 20 pCi/m^2/s.

Groundwater Monitoring Data

These data are presented in detail in the annual groundwater monitoring data report (BN, 2000). All groundwater sampling data from the Area 5 RWMS pilot wells to date indicate that the groundwater in the uppermost aquifer is unaffected by RWMS activities. Tritium concentrations in the groundwater beneath the Area 5 RWMS have never exceeded the Method Detection Limit (MDL) for enriched tritium analysis (approximately 15 pCi/L). Groundwater chemistry data indicate that this groundwater is a sodium bicarbonate-type water. Groundwater elevation data indicate that the water table beneath the Area 5 RWMS is nearly flat, with groundwater flowing in a northeastern direction at a velocity of approximately 23 cm (9 inches) per year.

Vadose Zone Monitoring Data

Vadose Zone Monitoring Strategy

Vadose zone monitoring is conducted at the Area 3 and Area 5 RWMSs as part of the RWMS vadose zone monitoring strategy. This strategy is to quantify the water balance of the RWMSs and to directly measure tritium migration within and out of the Area 5 RWMS. Water balance monitoring is accomplished by use of: meteorology data to calculate potential evapotranspiration (PET), the driving force of upward flow; weighing lysimeters to directly measure actual evapotranspiration (ET) and bare-soil evaporation (E); automated vadose zone monitoring systems to measure soil water status in waste cell covers and floors; and neutron logging through access tubes to provide changes in soil water content over a large spatial area. These measurements collectively provide an excellent estimate of the overall water balance of the RWMSs. This strategy prevents relying on a single methodology for monitoring. All methodologies are linked through individual calibrations and cross-calibrations.

Vadose zone monitoring should provide data to confirm the assumptions made in the Performance Assessments, including no downward pathway, and evaluate the performance of the operational monolayer waste covers. Monitoring tritium in air and soil-gas will provide data to evaluate the upward pathway through the waste covers.

Meteorology Monitoring Data

Meteorology monitoring data for 1999 includes: precipitation, air temperature, humidity, wind speed and direction, barometric pressure, incoming solar radiation load, net radiation load, and surface soil heat flux. These are basic meteorological parameters required to quantify the exchange of water and heat between the soil and the atmosphere. These data are from one meteorology station near the Area 3 RWMS, and two meteorology stations near the Area 5 RWMS. In addition, data from additional stations are presented: rain data from the Area 3 crater station; wind speed and direction data from a temporary station located at the north edge of the Area 5 RWMS; as well as additional rain gauge stations located near pilot wells 2 and 3 (UE5PW-2 and UE5PW-3) in Area 5. These data are summarized in several Tables and Figures. Refer to Figures 3 and 5 for specific locations of the meteorology stations, and Table 1 for locations and elevations of these stations. Monthly and yearly data summaries are presented in Appendix A. These Tables are prepared so that they can be photocopied, stand-alone sheets for quick data reference.

The Area 3 RWMS meteorology station is located approximately 30 m (100 ft) to the northwest of the Area 3 RWMS. The Area 3 crater station is located about 335 m (1100 ft) to the southeast of the Area 3 RWMS boundary. The crater station is operated under the Site Characterization crater infiltration study. The Area 5 RWMS meteorology station is located to the southeast of the Area 5 RWMS, about 100 m (328 ft) from pilot well 1 (UE5PW-1). The Area 5 Lysimeter meteorology station is located at the weighing lysimeter facility about 400 m (1312 ft) to the southwest of the Area 5 RWMS. The temporary wind station is located on the high point of a large mound of soil fill, to the north of the operational RWMS. This station, as well as the Lysimeter meteorology station, are operated in addition to the Area 5 RWMS station, to characterize the complex wind patterns that affect the Area 5 RWMS.

Table 1. Locations and elevations of all data collection stations.

Station Description	Latitude	Longitude	Nevada Coordinate System North (ft)	Nevada Coordinate System East (ft)	Elevation
Area 3 Meteorology Station	37° 2' 49.80" N	116° 1' 42.00" W	836,800	686,600	1225 m (4020 ft)
U-3bw Crater Meteorology Station			834,780	689,979	1211 m (3972 ft)
Area 5 RWMS Meteorology Station	36° 51' 9.13" N	115° 56' 56.06" W	766,070	709,999	970.7 m (3184 ft)
Area 5 Lysimeter Meteorology Station	36° 51' 7.09" N	115° 57' 44.28" W	765,836	706,083	972.9 m (3191 ft)
UE5PW-2 Rain Gauge Station*	36° 51' 51.91" N	115° 56' 56.97" W	770,396	709,894	989.6 m (3246 ft)
UE5PW-3 Rain Gauge Station*	36° 52' 1.23" N	115° 58' 16.06" W	771,291	703,460	1005 m (3296 ft)
Area 5 Vegetated Weighing Lysimeter*	36° 51' 8.40" N	115° 57' 48.60" W	765,964	705,930	970.0 m (3182 ft)
Area 5 Bare-soil Weighing Lysimeter*	36° 51' 8.40" N	115° 57' 48.60" W	765,964	705,930	970.0 m (3182 ft)

Station Description	Data availability
Area 3 Meteorology Station	August 10, 1995 through December 31, 1999
U-3bw Crater Meteorology Station	October 7, 1998 through December 31, 1999
Area 5 RWMS Meteorology Station	November 18, 1993 through December 31, 1999
Area 5 Lysimeter Meteorology Station	January 4, 1994 through December 31, 1999
Area 5 Mt. Becker Wind Station	October 22, 1998 through December 31, 1999
UE5PW-2 Rain Gauge Station	February 10, 1994 through December 31, 1999
UE5PW-3 Rain Gauge Station	February 4, 1994 through December 31, 1999
Area 5 Vegetated Weighing Lysimeter	March 30, 1994 through December 31, 1999
Area 5 Bare-soil Weighing Lysimeter	March 30, 1994 through December 31, 1999

* indicates locations are approximate

Selected figures are included on pages 29 to 38 illustrating weather data at the Area 3 and Area 5 RWMSs: Figures 11 and 12 depict daily air temperature data; Figure 13 depicts daily average relative humidity data; Figure 14 depicts daily average barometric pressure data; Figures 15 and 16 depict daily wind speed data; Figure 17 depicts total solar radiation load in Area 3; and Figure 18 depicts total PET, calculated from Area 3 meteorology data. Total PET for 1999 was calculated to be 1632 mm (64 in) in Area 3, and 1612 mm (63 in) in Area 5 (Area 3 has higher wind speeds, and thus slightly higher PET). Figures 17 and 18 include data from Area 3 only, because the Area 5 data are very similar.

Precipitation Data

The year 1999 was dry: rainfall totaled 10.0 cm (3.9 in) at the Area 3 RWMS (61 percent of average) and 9.6 cm (3.8 in) at the Area 5 RWMS (75 percent of average). Notable 1999 rainfall events include storms that delivered 3.3 cm (1.3 in) in Area 3 and 2.1 cm (0.81 in) in Area 5 on April 29-30; and 1.5 cm (0.61 in) in Area 3 and 1.6 cm (1.4 in) in Area 5 during the period of July 8-15. Las Vegas received as much as 10.1 cm (4 in) during the storms of July 8-15. Figures 19 and 20 depict daily total precipitation. Figure 21 depicts historical precipitation recorded at BJY station (located about 3 km northwest of the Area 3 RWMS), and Well 5B (W5B) station (located about 5.5 km south of the Area 5 RWMS). Figure 22 depicts 1999 monthly precipitation totals recorded at the RWMSs and at W5B and BJY stations.

Wind Roses
In previous annual data reports, monthly wind roses were included. Since these data are now archived in BEIDMS, only annual and multi-year wind roses are included in this report. Wind roses from the three meteorology stations, as well as from the temporary wind station and the Area 3 crater station are depicted in Figures 23 through 30.

Wind rose diagrams illustrate wind direction (direction of wind source) and the occurrence of wind speed groupings in each direction, using hourly wind data, measured at a height of 3.0 m (10 ft) above the ground surface. Note that in general, low wind speeds tend to originate from the north, whereas high wind speeds tend to originate from the south. Note the similarity between one-year wind roses and four-year wind roses, indicating the highly predictable seasonal wind patterns. Note the strongly bi-modal character of winds in Area 3. Also note the difference between wind roses at the Area 5 RWMS and Lysimeter meteorology stations. These stations are located to the southeast (RWMS) and southwest (Lysimeter) of the RWMS facility. The RWMS station is strongly affected by the proximity of Scarp Canyon to the northeast of the facility. The lysimeter station located to the southwest of the RWMS facility appears to be less influenced by Scarp Canyon and receives less northeast wind flows than the RWMS meteorology station. The wind rose from the temporary station in the RWMS is similar to the RWMS station wind rose, indicating that most of the Area 5 RWMS wind patterns can be characterized by the RWMS wind rose, whereas only the southwestern edge of the RWMS is accurately characterized by the Area 5 Lysimeter station wind rose.

<u>Gas-phase Tritium Monitoring Data</u>
These data were previously reported in the "1999 Ecosystem Monitoring Report" (BN, 1999b). They are summarized in this report since the annual Ecosystem Monitoring Report will no longer be produced, and its data will be published in this annual Waste Management Monitoring Report.

Gas-phase tritium monitoring is conducted by soil gas sampling at the four perimeter holes immediately surrounding the Area 5 RWMS and, at GCD-05U, a Greater Confinement Disposal unit with a large tritium inventory (2.2 M Ci at time of disposal) located at the center of the RWMS, which is instrumented with a string of nine gas sampling ports buried at depths of 21 to 37 m (70 to 120 ft). Tritium sampling at the perimeter holes provides a measure of tritium migration from the Area 5 RWMS, and tritium sampling at GCD-05U provides a measure of tritium migration from waste packages with time due to degradation of waste containers and natural transport processes. Refer to Figure 5 for locations of perimeter holes and GCD-05U.

Perimeter Holes
Soil-gas tritium was sampled at the four perimeter holes surrounding the Area 5 RWMS in August 1999. Results were non-detect for all soil-gas tritium samples collected.

GCD-05U
Soil-gas tritium was sampled from the GCD-05U sampling string at nine depths in September 1999. Results indicate that while tritium soil-gas concentrations continue to increase at depths between 15 amd 37 m (50 and 120 ft), vertical migration is extremely slow. This ten-year data set could be used to calibrate a tritium vapor transport model to predict travel times to the ground

surface (and atmosphere). Tritium soil-gas concentrations with time in GCD-05U are illustrated in Figure 31.

<u>Weighing Lysimeter Data</u>

Two precision weighing lysimeters were installed about 400 m (1312 ft) southwest of the Area 5 RWMS. The lysimeters consist of soil tanks with a volume of 16 m^3 (565 ft^3) mounted on a sensitive scale. The top of the soil tank is flush with the ground surface, and access to the side of the soil tank is provided through an underground entry. One lysimeter was revegetated with native shrubs, whereas the other was kept bare to simulate a non-vegetated waste cover. Each of the weighing lysimeters is instrumented with time-domain reflectometry (TDR) probes to measure volumetric soil water content and thermocouple psychrometers (TCPs) to measure water potential and temperature at depths ranging from 10 to 170 cm (4 to 67 in). The TDR and TCP sensors are connected to automated datalogger systems that provide daily profiles of soil water content, soil water potential, and soil temperature. The sensitive scale (load cell) is also connected to a datalogger which provides extremely accurate measurements of evapotranspiration, bare-soil evaporation, and total soil water storage. For details of the weighing lysimeters, refer to Levitt et al. (1996).

Weighing lysimeter data represent a simplified water balance: change in soil water storage is equal to precipitation (PPT) minus E (or ET), because no drainage has been measured through the bottom of the lysimeters and because the one-inch high lip around the edge of the lysimeters prevents run-on or run-off.

Total soil water storage is illustrated in Figure 32 for the period of March 30, 1994, through December 31, 1999. Daily precipitation totals also are illustrated in this Figure. The soil water storage increases early in the data record for the vegetated lysimeter were due to irrigations to ensure that transplanted vegetation survived. Note the steep decrease in soil water storage in the vegetated lysimeter following high-rainfall periods. Note that while the vegetated lysimeter is considerably drier than the bare-soil lysimeter, total soil water storage never exceeded 210 mm (8.3 in) (integrated volumetric water content of 10.5 percent, or about one-third total saturation) in either lysimeter. No drainage has been measured from the permeable bottoms of the lysimeters to date. However, volumetric water contents in the bottom of the bare-soil lysimeter have increased from about 6 to 12 percent in the past 6 years. This increase in soil water content may eventually lead to some drainage out the bottom of the lysimeter, or it may be approaching an equilibrium residual volumetric water content of 10 to 12 percent that is seen in other data.

Monthly totals of E measured with the bare-soil weighing lysimeter and ET measured with the vegetated weighing lysimeter are illustrated with monthly PPT totals for Area 5 in Figure 33. In 1999, Area 5 total PPT was 96 mm (3.8 in), total E was 115 mm (4.5 in), and total ET was 108 mm (4.3 in). Evaporation was greater than ET in 1999 because the bare lysimeter was wetter than the vegetated lysimeter and therefore had more water available for E than was available for ET in the vegetated lysimeter.

Automated Vadose Zone Monitoring System Data

Installation of automated vadose zone monitoring systems was initiated in 1998 with water content sensors (TDR probes) and temperature sensors buried 121 cm (4 ft) beneath the open pit floors of Pit 3 and Pit 5 at the Area 5 RWMS. In 1999, TDR probes and temperature sensors were installed in the operational cover of Pit 3 at two sites, at depths ranging from 10 to 180 cm (4 to 71 in). Water potential sensors (heat dissipation probes [Reece, 1996]) will be installed at these locations in 2000. Sensors may also be installed in the operational cover of U-3ax/bl in 2000. In addition, an automated monitoring system was installed in Area 5 adjacent to UE5PW-1 as a Neutron Probe Calibration Facility, with 36 TDR probes buried at depths of 30, 60, and 90 cm (12, 24, and 36 in). These types of automated monitoring systems have performed well for over six years at the weighing lysimeter facility, and for at least 13 years at other sites (Dusek et al., 1987; Rockhold et al., 1995).

Soil water content with time is illustrated in Figures 34 through 36 for Pit 3 cover TDR systems, and Pits 3 and 5 floor TDR systems. Note the recent increase in water contents to a depth of 60 cm at Pit 3 cover due to the February and March rains in 2000. Soil water content with time is illustrated in Figure 37 for the Neutron Probe Calibration Facility. Note the residual water content of 10 to 12 percent that is commonly observed in these data, as well as in other data such as drill core data from the Area 5 RWMS. In Figures 34, 35, and 37, note the depth of infiltration from precipitation never exceeded 30 cm (12 in) in 1999 before that water was returned to the atmosphere by evaporation.

Neutron Logging Data

Vadose zone water content monitoring by neutron logging is also being conducted at the Area 3 and Area 5 RWMSs. At the Area 3 RWMS, deep vadose zone monitoring is conducted in cased boreholes angled under the U-3ah/at and U-3ax/bl disposal units, and in cased boreholes drilled directly into the floor of the U-3bh disposal unit. These boreholes are designated U-3at-D1, U-3at-D2, U-3bh-C1, U-3bh-C2, U-3bl-D1, U-3bl-D2, and U-3bl-U1 (refer to Table 2 and Figure 3). At the Area 5 RWMS, monitoring is conducted in access tubes penetrating the operational cover (approximately 2.4 m [8 ft]), the waste zone (6 to 9 m [20 to 30 ft]), and the vadose zone below the pit floor. Neutron access tubes for routine monitoring were selected based on data history, tube integrity, and to provide a representative area of wide spatial coverage. Area 5 RWMS access tubes provide data on the near-surface water balance, but Area 3 RWMS access tubes only provide data on changes in water contents at depth due to the presence of thick surface casings that cannot be logged. In 1999, some of these boreholes were neutron logged every other month. Various monitoring frequencies and sampling intervals have been attempted as part of an ongoing process of optimization of the neutron logging program. For example, since water contents at depths greater than about 2 m (6 ft) generally do not change, neutron logging frequency at the Area 3 RWMS may be reduced to once per year while sampling depth intervals will increase. For a detailed history of the Neutron Logging Monitoring Program at Area 3 and Area 5 RWMSs, refer to BN (1997).

Data from selected Area 5 neutron access tubes are presented in this report to describe wetting front movement. Refer to Figure 3 for locations of neutron access tubes at the Area 3 RWMS, and refer to Figures 5 and 6 for locations of Pits 1 through 5, and the four perimeter holes at the

Area 5 RWMS. Table 2 lists neutron logging access tube materials and geometries, and Table 3 lists exact locations and some elevations of neutron logging access tubes in Area 5.

Table 2. Neutron probe access tube materials and geometries.

Location	Material	Casing OD (inches)	Casing Thickness (inches)	Approximate Casing Depth (feet)	Surface Casing OD (inches)	Surface Casing Depth (feet)	Outer Surface Casing OD (inches)	Outer Surface Casing Depth (feet)
Area 5 - Cal Facility								
Tube #1 (North)	6" Thin Steel	6 5/8	3/8	4				
Tube #2	4" Aluminum	4	1/4	4				
Tube #3	6" Thick Steel	6 5/8	1/2	4				
Tube #4 (South)	4" Steel	4	1/4	4				
Area 5								
RWMS Perimeter Tubes								
NN1,NW1,NS1,NE1	6" Thin Steel	6 5/8	3/8	200				
Tube 50 (undist.)	4" Aluminum	4	1/4	50				
Pit 3 Tubes #1-24	4" Aluminum	4	1/4	50				
Pit 3 Tubes #1A-4A	4" Steel	4	1/4	40				
Pit 1 Tubes #1-6	4" Steel	4	1/4	40				
Pit 2 Tubes #1-8	4" Steel	4	1/4	40				
Pit 4 Tubes #1-9	4" Steel	4	1/4	40				
Pit 5 Tubes #1-6	4" Steel	4	1/4	40				
Pit 6 Tubes #1-6	4" Steel	4	1/4	12				
Area 3								
U-3at-D1 (60^o angle)	6" Thick Steel	6 5/8	1/2	600	10 3/4	183	12 3/4	10
U-3at-D2 (60^o angle)	6" Thick Steel	6 5/8	1/2	300	10 3/4	10		
U-3bh-C1 (vertical)	6" Thick Steel	6 5/8	1/2	210	8 5/8	30		
U-3bh-C2 (vertical)	6" Thick Steel	6 5/8	1/2	210	8 5/8	30		
U-3bl-D1 (45^o angle)	6" Thin Steel	6 5/8	3/8	228	7 5/8	10		
U-3bl-D2 (45^o angle)	6" Thick Steel	6 5/8	1/2	482	8 5/8	213	10 3/4	10
U-3bl-U1 (45^o angle)	6" Thin Steel	6 5/8	3/8	236	7 5/8	10		
U-3ah/at #1-10 (vert)	4" Steel	4	1/4	30				

OD = outer diameter

Soil water content profiles from access tubes U-3at-D1, U-3at-D2, U-3bh-C1, U-3bh-C2, U-3bl-U1, U-3bl-D1, and U-3bl-D2 from Area 3 for 1998-1999 are depicted in Figures 38-41. Soil water content profiles in these tubes remain stable with time. Water content data from cores obtained during borehole drilling are presented with these data. Note that water contents measured by neutron probe are higher than water contents from soil core data at U-3bl and U-3bh, but lower than U-3at soil core water contents. This inconsistency is puzzling because the casings at the U-3at, U-3bh, and U-3bl-D2 boreholes are all thick-walled (3/8-inch) steel casing. The casing at U-3at is suspected to differ in chemical composition from the casing from U-3bh and U-3bl-D2. Borehole U-3bh-C2 was not logged in 1999, and U-3bh-C1 was logged only once in 1999 because of the height of the casings, which extended too high for safe logging. These boreholes will be logged in 2000 using a man-lift if necessary.

The neutron probe measurements made in the deep casings at the Area 3 RWMS tend to be extremely consistent, indicating that these deep water content profiles are stable. There is no indication that wetting fronts are moving through these profiles. However, the use of water content measurements at such great depths is unnecessary if vadose zone monitoring systems are installed in the near-surface, such as the TDR systems currently in place in Area 5.

Table 3. Area 3 and Area 5 RWMS neutron probe access tube locations.

	Nevada Coordinates				Nevada Coordinates		
Access Tube	North	East	elevation (ft)	Access Tube	North (ft)	East (ft)	Elevation (ft)
PO3U-1	767966	709286		PO4U-13	767191.8	707679.7	3192.3
PO3U-2	767938	709286		PO4U-14	767193.6	707737.7	3191.8
PO3U-3	767911	709286		PO4U-15	767187.2	707800.4	3192.1
PO3U-4	767967	709258		PO4U-16	767049.7	707694.4	3190.3
PO3U-5	767938	709258		PO4U-17	767052.3	707727.3	3190.3
PO3U-6	767910	709258		PO4U-18	767051.8	707800.9	3192.3
PO3U-7	767966	709230		PO4U-19	766889.5	707702.2	3188.3
PO3U-8	767938	709230		PO4U-20	766889.0	707745.3	3188.7
PO3U-9	767883	709286		PO4U-21	766890.5	707794.3	3188.6
PO3U-10	767855	709287		PO4U-22	766748.0	707701.2	3186.8
PO3U-11	767827	709287		PO4U-23	766747.4	707744.3	3186.9
PO3U-12	767882	709258		PO4U-24	766746.5	707792.7	3186.9
PO3U-13	767854	709258		PO5U-1	767691.7	707500.9	3198.5
PO3U-14	767826	709258		PO5U-2	767690.1	707535.9	3198.1
PO3U-15	767910	709230		PO5U-3	767687.1	707570.4	3197.5
PO3U-16	767882	709230		PO5U-4	767568.5	707488.6	3197.5
PO3U-17	767854	709230		PO5U-5	767566.5	707531.4	3197.6
PO3U-18	767826	709230		PO5U-6	767566.0	707568.1	3197.4
PO3U-19	767798	709287		NN-1	768274.8	706467.1	3204.9
PO3U-20	767798	709259		NE-1	767229.1	709430.4	3196.6
PO3U-21	767798	709230		NS-1	765790.3	708094.1	3171.2
P03U-22	767770	709228		NW-1	766695.8	706971.1	3177.7
PO3U-23	767770	709259					
P03U-24	767770	709230		U-3at-D1	254647.4	209333.4	4011
Tube 50				U-3at-D2	254647.6	209327.4	4011
PO3U-1A	767906.0	709357.4	3212.6	U-3bh-C1	254689.7	209814.0	3950
PO3U-2A	767845.4	709359.8	3213.0	U-3bh-C2	254679.5	209823.0	3950
PO3U-3A	767752.9	709336.2	3210.0	U-3bl-D1	254869.0	209536.0	4013
PO3U-4A	767605.1	709340.2	3205.9	U-3bl-D2	248870.7	209527.8	4014
PO1U-1	767168.1	708549.1	3195.2	U-3bl-U1	254862.0	209527.0	4013
PO1U-2	767158.4	708569.0	3195.3				
PO1U-3	767100.2	708538.1	3193.8				
PO1U-4	767034.2	708446.1	3195.1				
PO1U-5	767035.2	708509.3	3193.5				
PO1U-6	767034.0	708539.7	3193.8				
PO2U-1	767245.7	708232.4	3198.6				
PO2U-2	767216.1	708255.0	3197.6				
PO2U-3	767202.8	708281.5	3196.9				
PO2U-4	767045.0	708160.5	3195.2				
PO2U-5	767022.5	708219.4	3194.8				
PO2U-6	766815.1	708079.1	3192.4				
PO2U-7	766804.1	708104.6	3193.2				
PO2U-8	766785.1	708139.3	3191.8				
PO4U-1	767696.3	707681.6	3198.5				
PO4U-2	767694.6	707730.1	3198.2				
PO4U-3	767693.6	707795.0	3198.2				
PO4U-4	767556.5	707694.1	3196.8				
PO4U-5	767556.0	707735.0	3196.7				
PO4U-6	767553.8	707794.9	3197.2				
PO4U-7	767424.3	707688.8	3195.2				
PO4U-8	767425.1	707730.5	3194.9				
PO4U-9	767425.5	707786.4	3194.9				
PO4U-10	767298.9	707706.1	3193.3				
PO4U-11	767299.3	707738.8	3193.4				
PO4U-12							

Soil water content data from selected access tubes in the Area 5 RWMS during 1998-1999 are presented in Figures 42 through 49. These figures include data from access tubes: Pit 1, tube 2; Pit 2, tubes 5 and 8; Pit 3, tubes 1, 2, 3, 4, 9, 10, 11, 19, 22, and 50; Pit 4, tubes 8, 14, and 19; and the four perimeter holes surrounding the Area 5 RWMS: NN-1 (north), NS-1 (south), NE-1 (east), and NW-1 (west). The locations of access tubes in pits at the Area 5 RWMS are shown in Figure 6. Water content profiles at the Area 5 RWMS are illustrated in Figures 42-45. Some of these boreholes were logged in the waste cover only, while the entire length of the Pit 3 boreholes were periodically logged. Note the high water content spike at a depth of about 38 feet at Pit 3. This spike is due to a layer of bentonite beneath the waste packages.

Water contents in the Area 5 RWMS waste covers generally increased to a depth of 1.5 m (5 ft) following large rainfalls in 1998 and have continued to dry out since then (refer to Figures 42-45). Although 1998 was the wettest year in a 37-year record, infiltration in a bare-soil waste cover was generally only seen to a depth of about 1.5 m (5 ft). Deeper infiltration to depths of 2.4 m (8 ft) was seen at isolated locations such as Pit 4, tube 19, although those profiles dried down to residual water content levels by the end of 1999. These neutron logging data, as well as the Pit 3 TDR data, confirm that a non-vegetated monolayer cover greater than 1.5 m (5 ft) in thickness effectively prevents significant infiltration into the waste zone, even following exceptionally wet years.

Water content profiles at Pit 3, tube 50 are also shown in Figure 45. This tube was installed just to the north of Pit 3, and was meant to serve as a measure of "undisturbed" water contents. In 1996, this tube was severely damaged by heavy equipment, and was repaired by excavation to a depth of about 3 m (10 ft) and replaced with new casing. The water content profiles measured at this borehole have two distinct responses depending on depth. The upper 3 m (10 ft) of soil possibly was heavily compacted after repair of the casing, compared to the undisturbed soil at depths greater than 3 m (10 ft). Or the upper section of new casing possibly is a different material than the old casing.

A time-series plot of water contents at depths of 1 and 3 m (3 and 10 ft) are illustrated in Figures 46 and 47. Figure 46 clearly shows water contents drying out following the 1998 precipitation. Figure 47 shows that by the end of 1999, water contents at 3 m (10 ft) were largely unaffected by the 1998 precipitation.

Water content profiles in the four perimeter holes are illustrated in Figures 48 and 49. Water contents remained unchanged below the top 1.5 m (5 ft) in profiles from the north, south, and east holes. The west perimeter hole is located within the west flood channel and has been subjected to repeated periods of infiltration, particularly after the storm of February 23-24, 1998, in which standing water was observed in the west flood channel. Infiltration in the west perimeter hole appeared to reach a depth of about 6 m (20 ft) by the end of 1999. However, it is not clear if the access tubes at the Area 5 RWMS, including the perimeter holes, act as preferential pathways for water flow (at the Area 3 RWMS, surface casings and cement support structures eliminate this problem). Future work should include drilling into the floor of the west flood channel and at other selected locations to confirm water contents measured by neutron logging, and determine if neutron access tubes are preferential pathways for infiltrating water.

In addition to 1998-1999 data, neutron logging has been conducted in various access tubes at Pit 3 since 1990. Although the neutron probe used for measurements made from 1990-1997 has never been calibrated to water content, an approximate cross-calibration has been developed for that neutron probe. Figure 50 illustrates water contents measured at Pit 3, tube 1 using this cross-calibration. Although the water contents shown in Figure 50 are estimated, they clearly show that wetting fronts reached maximum depths of approximately 2.3 m (7.5 ft) over a seven-year period. These data also confirm that a monolayer cover effectively prevents significant infiltration into the waste zone.

Neutron Probe Calibration

Neutron probe calibrations were conducted in April 1998 using two new neutron probes in four different casing types, and the correlation coefficients of the regression analyses were excellent ($R^2 = 0.99$). This calibration utilized state-of-the-art instrumentation and unique methodology. Neutron probe calibration is required because of drift in instrument response, necessity for instrument repair, or instrument replacement make the use of raw counts for documenting trends in water content problematic.

Biota Monitoring Data

Soil-gas sampling for tritium is conducted in conjunction with plant sampling for tritium. This type of direct measurement of a conservative tracer and radionuclide provides an excellent measure of the performance of the waste facility and its ability to isolate buried waste. Data from the air samplers surrounding the Area 5 RWMS occasionally indicate slightly elevated levels of tritium in air compared with background monitors. Tritium sampling of plants and soil gas will continue to provide information on the mechanisms by which tritium from waste migrates into the atmosphere.

Plant samples were collected from five locations within the Area 5 RWMS on July 7, 1999. Plant water was extracted from the samples by room temperature vacuum distillation and analyzed by liquid scintillation for tritium. Results from the Area 5 1999 plant sampling are presented in Table 4. Although direct comparison with previous studies is not possible due to differing locations, it is evident that the vegetation sampled in 1999 contain less tritium than the historic results reported in previous reports.

The amount of tritium released into the atmosphere by plant transpiration is affected by several factors including plant size, species, and available moisture. For example, plants under drought conditions may use water from deeper in the vadose zone and consequently have higher concentrations due to the proximity of the water to the waste zone. An estimate of tritium transport into the atmosphere can be calculated by assuming a transpiration rate and accounting for shrub size. An annual transpiration rate of 10.2 cm/yr (4 in/yr) has been assumed in previous studies. For ease of comparison with historic work, the same transpiration rate was assumed for the tritium transport estimates presented in Table 4. Transpiration values given in Table 4 are for the individual plants sampled only. Although results indicate that tritium concentrations in vegetation were considerably lower than previous studies, they are higher than concentrations found in vegetation at the background location (UE5PW-1). Slightly elevated tritium concentrations in air and vegetation at the Area 5 RWMS indicate that there is an upward pathway for tritium migration, and this pathway should continue to be monitored. Animals will only be monitored if warranted by increasing tritium trends in vegetation.

Table 4. 1999 Area 5 RWMS plant sampling for tritium.

Location	Plant Species (common name)	Plant Water Tritium Concentration (uCi/L)	Tritium Transpiration (uCi/yr)
East Fence	Creosote bush	3.00E-02	33.80
UE5PW-1	Creosote bush	2.63E-04	0.16
P03U Cover	Russian Thistle	5.16E-02	1.75
T01U Cover	Creosote bush	2.81E-02	10.20
GCD-05U	Salt bush	2.43E-01	10.90

CONCLUSIONS

Environmental monitoring data from the Area 3 and Area 5 RWMSs indicate that these facilities are performing as expected for long-term isolation of buried waste. Direct radiation exposure data indicate that exposure at and around the RWMSs is not above background levels. Air monitoring data indicate that tritium concentrations are slightly above background levels, whereas radon concentrations are not above background levels. Groundwater and vadose zone monitoring data indicate that the groundwater beneath the Area 5 RWMS is unaffected by waste disposal operations. Soil-gas monitoring at GCD-05U indicates that tritium is slowly migrating away from a large tritium inventory. All vadose zone monitoring data for 1999 indicate that infiltrating precipitation reached a depth of about one foot before returning to the atmosphere. Long-term vadose zone monitoring data from the weighing lysimeters indicate zero drainage through the bottoms of the lysimeters in the past six years of their operation. Long-term vadose zone monitoring data from neutron logging indicate stable water content profiles in the deep boreholes in Area 3, indicating little or no downward movement of water. In Area 5, long-term neutron logging data indicate that the bare-soil waste covers efficiently return water to the atmosphere, even following exceptionally wet years such as 1998. Biota monitoring in Area 5 indicate that although tritium concentrations were lower than in previous years, this upward pathway should continue to be monitored.

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FIGURES

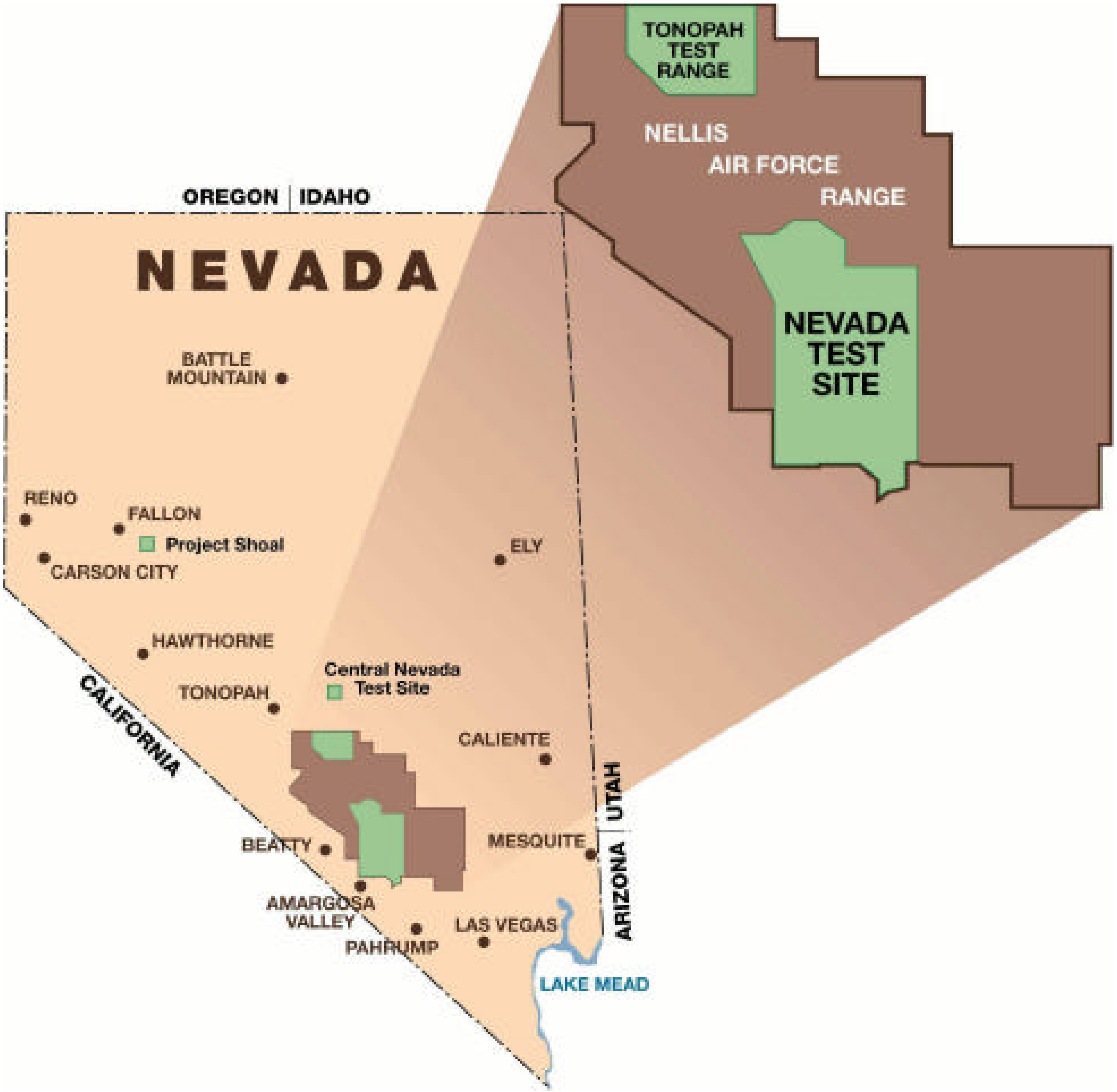
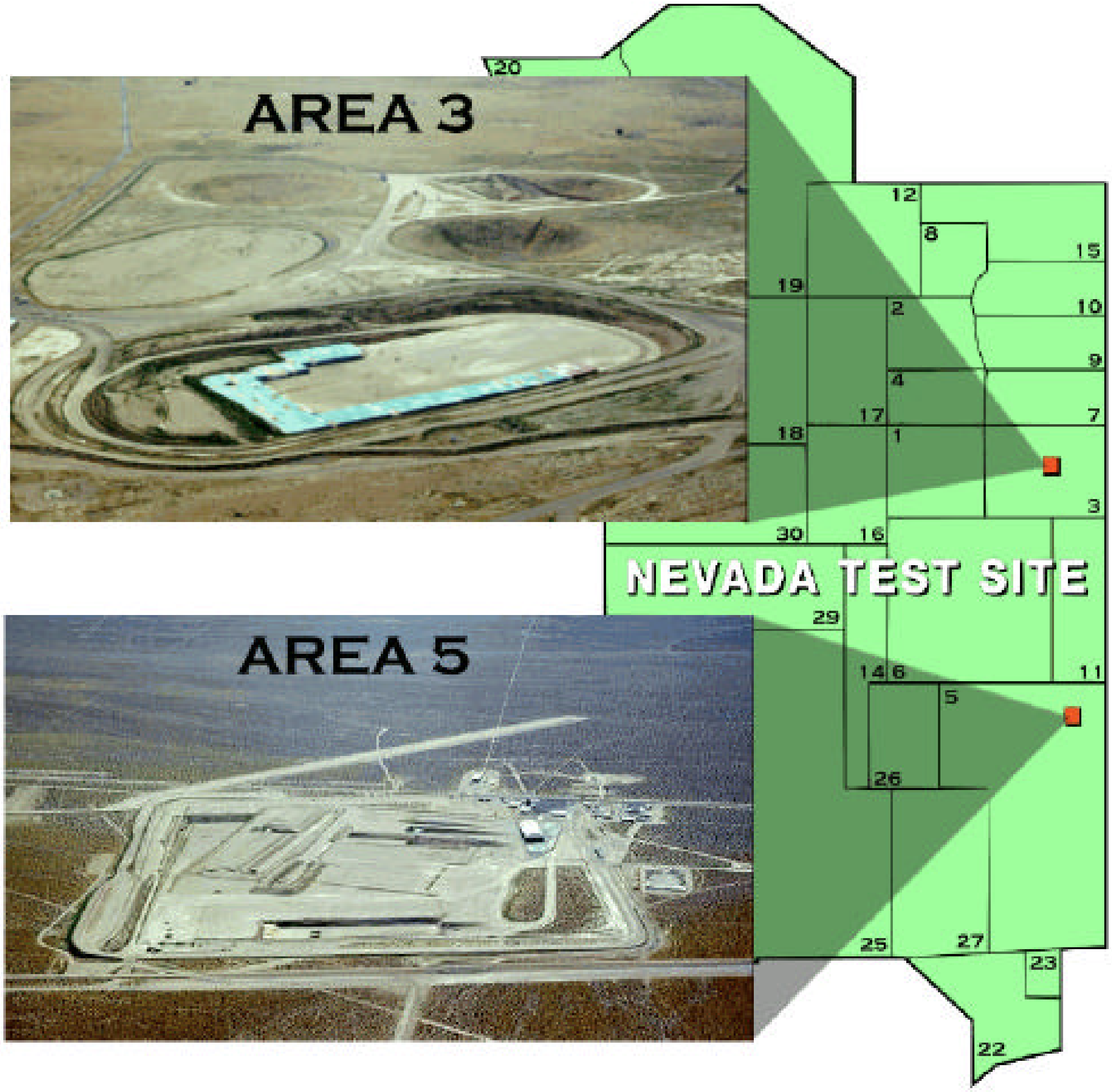


Figure 1. Location of the Nevada Test Site within Nevada.



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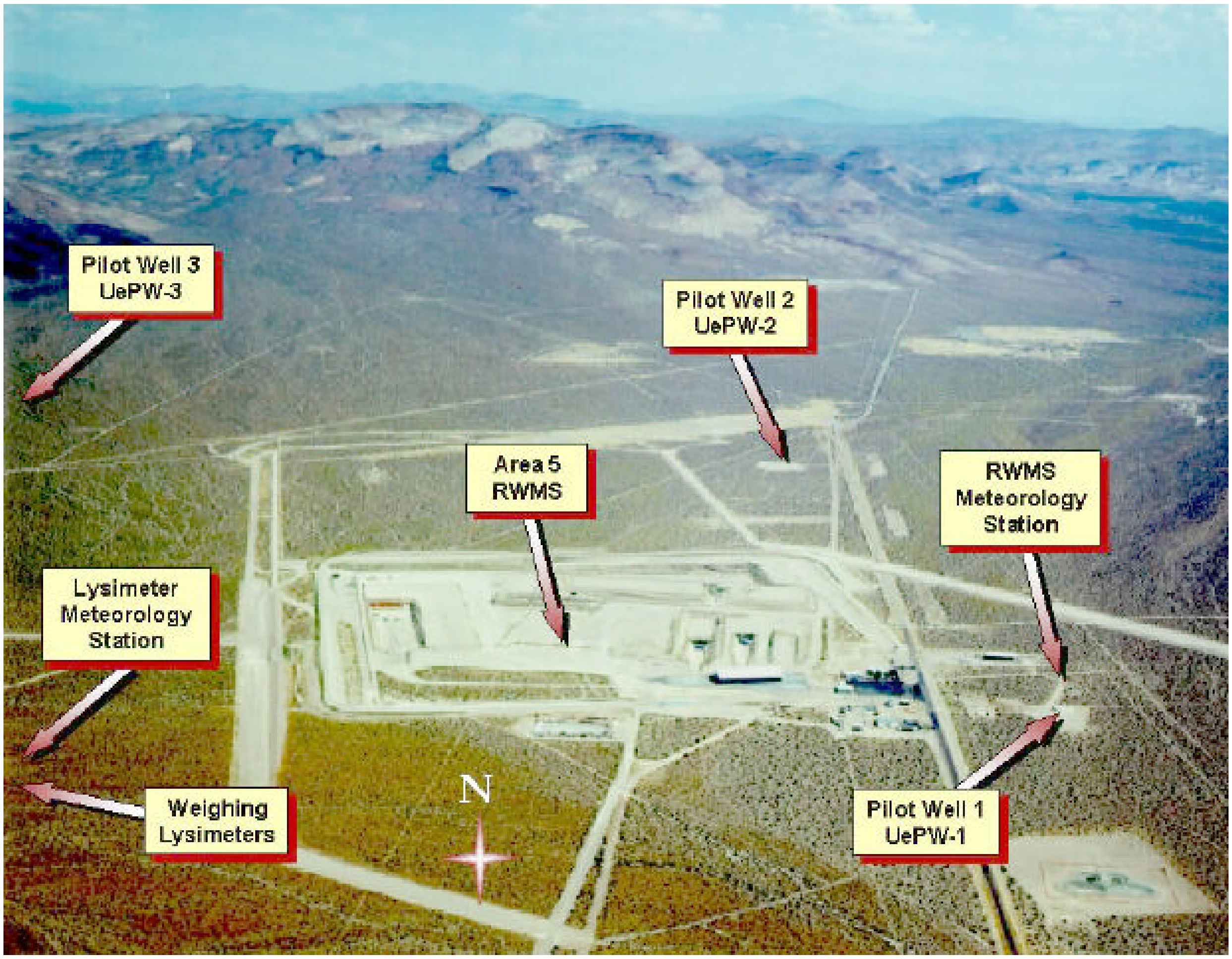
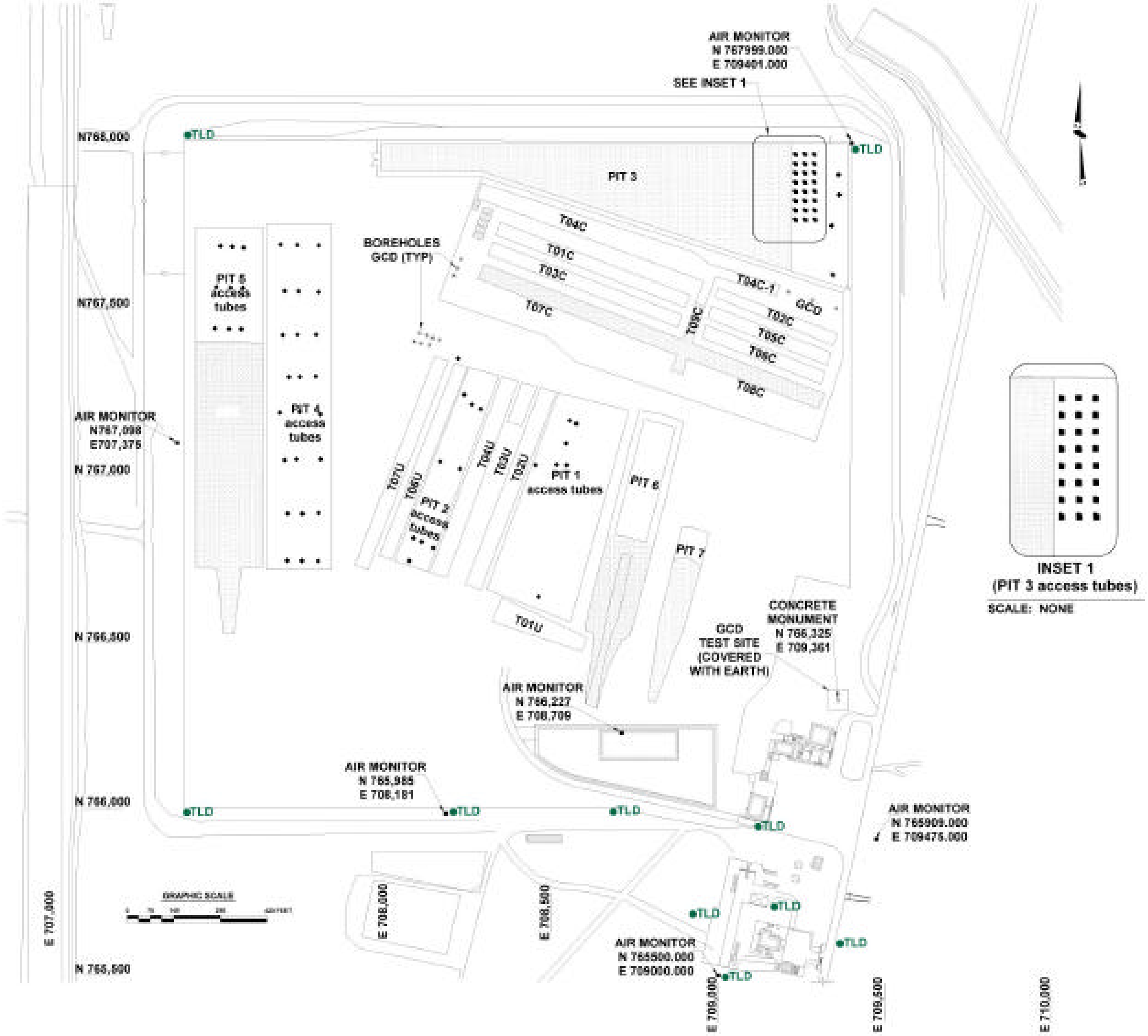


Figure 4. Large view of the Area 5 RWMS.

Figure 5. Detail of the Area 5 RWMS.



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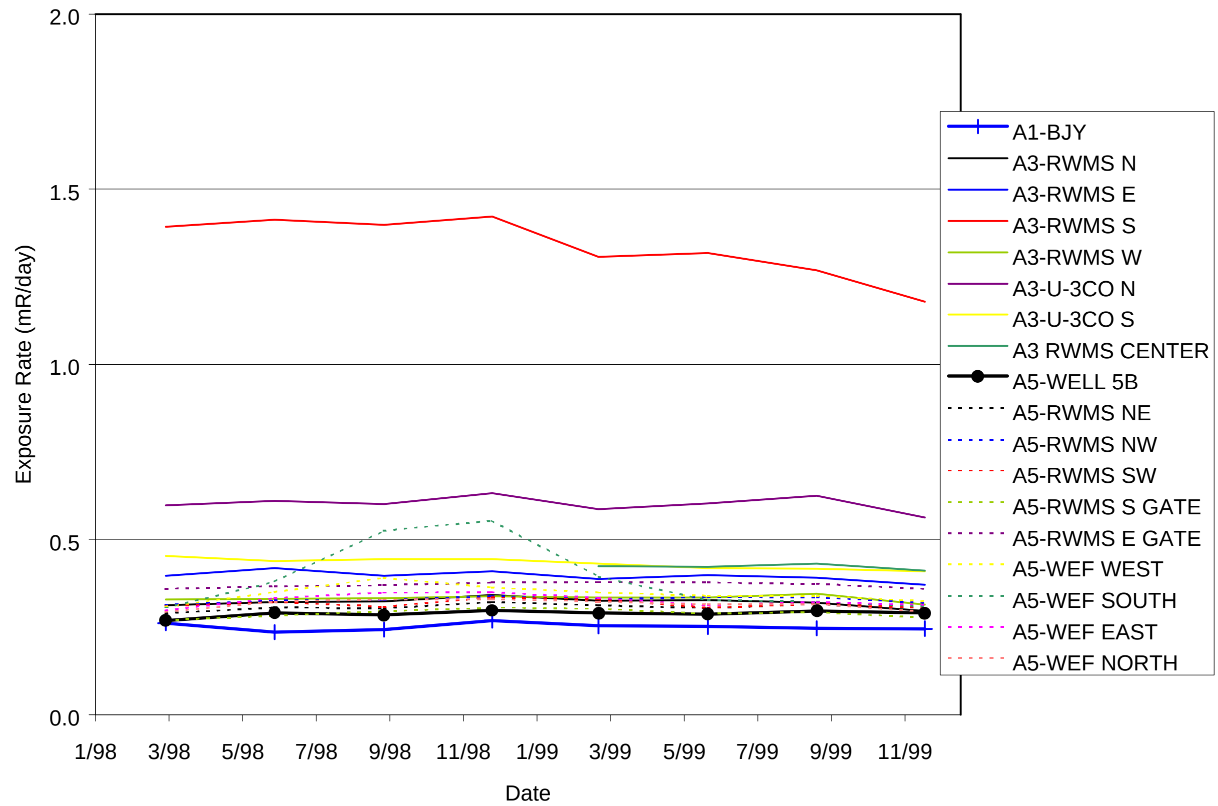

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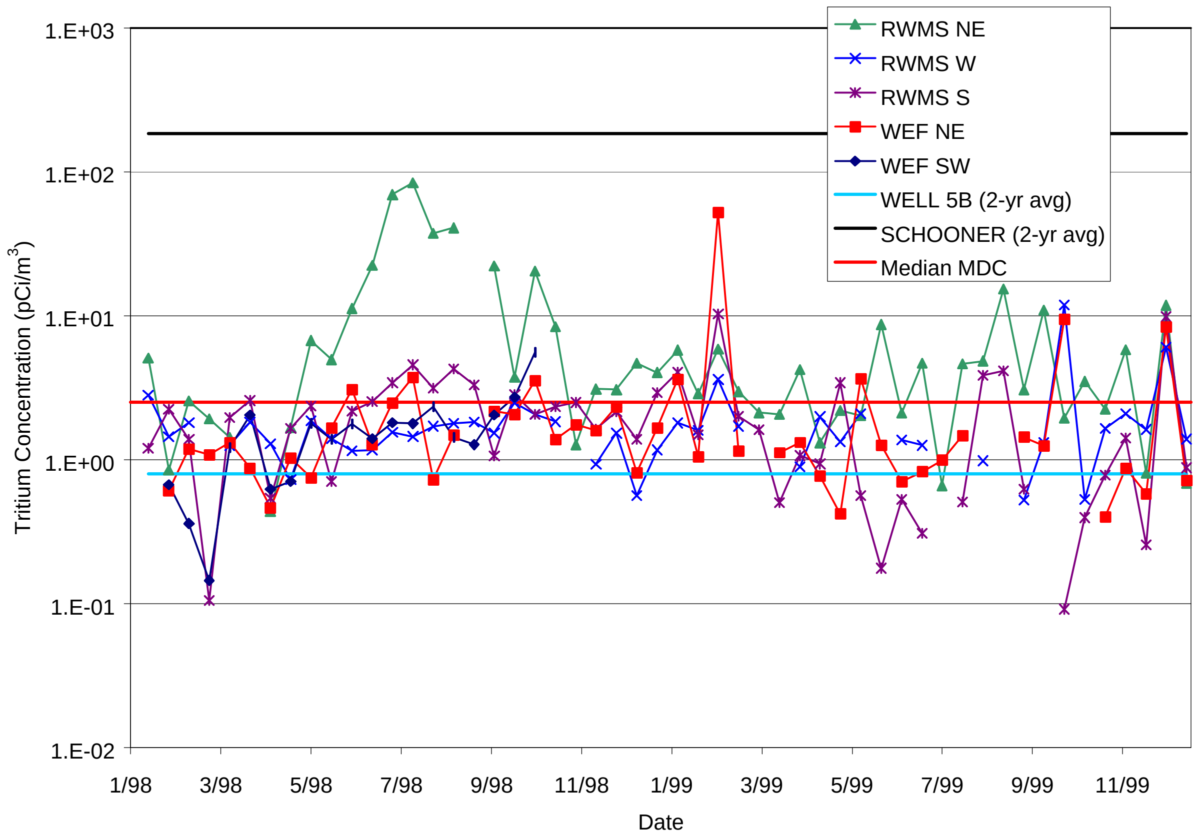

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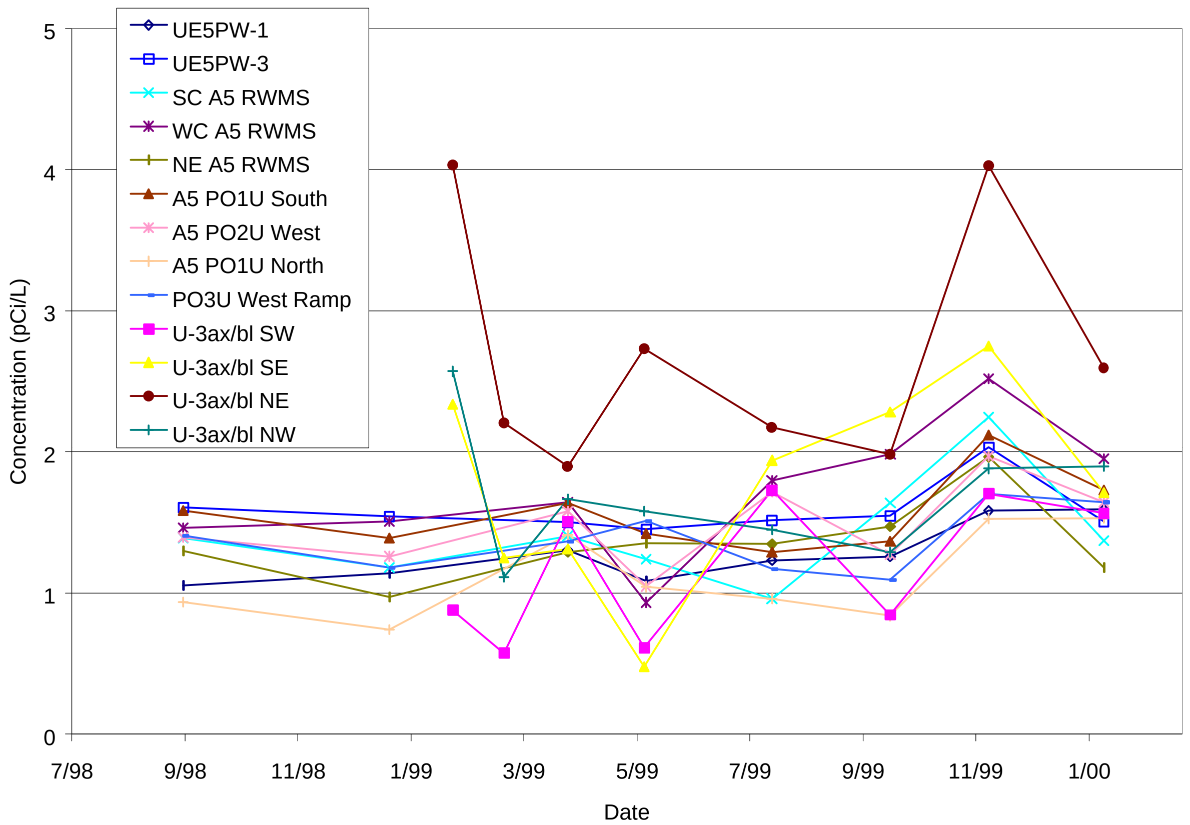
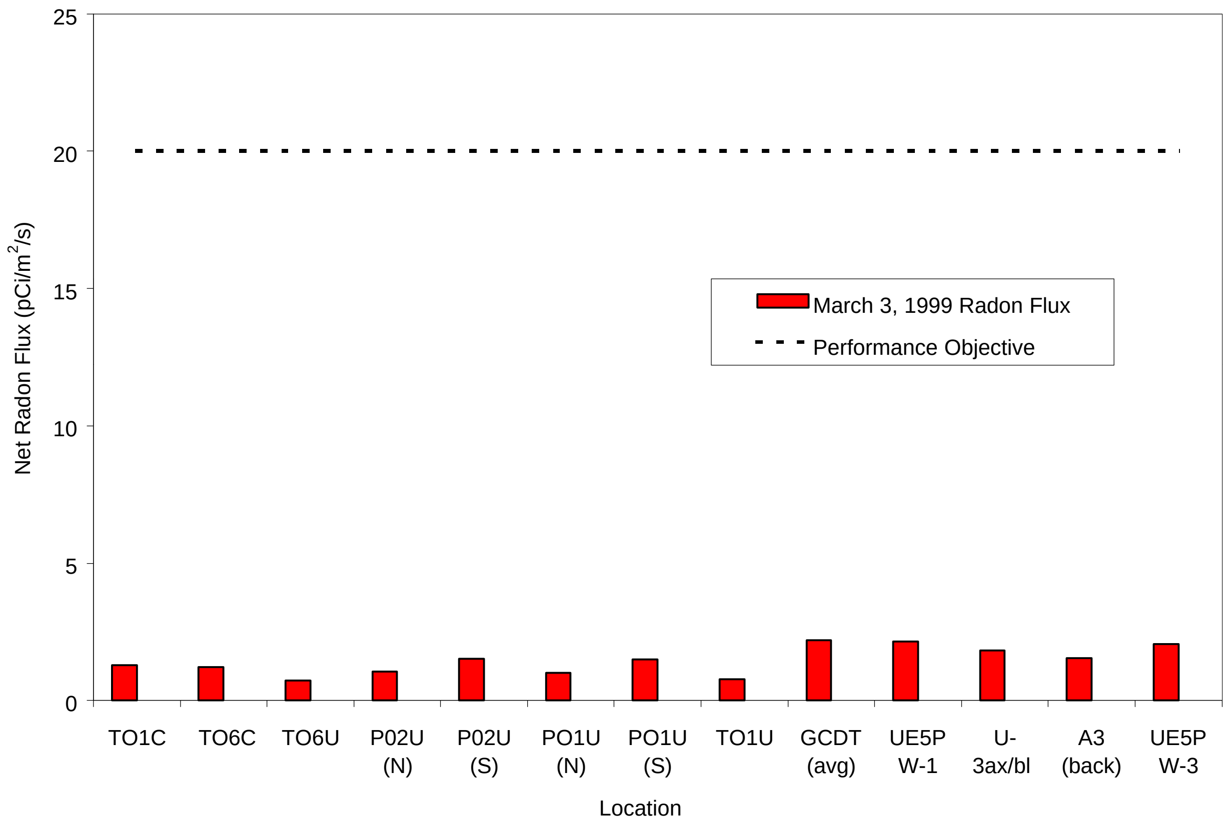


Figure 9. Radon concentrations in air at the RWMSs.



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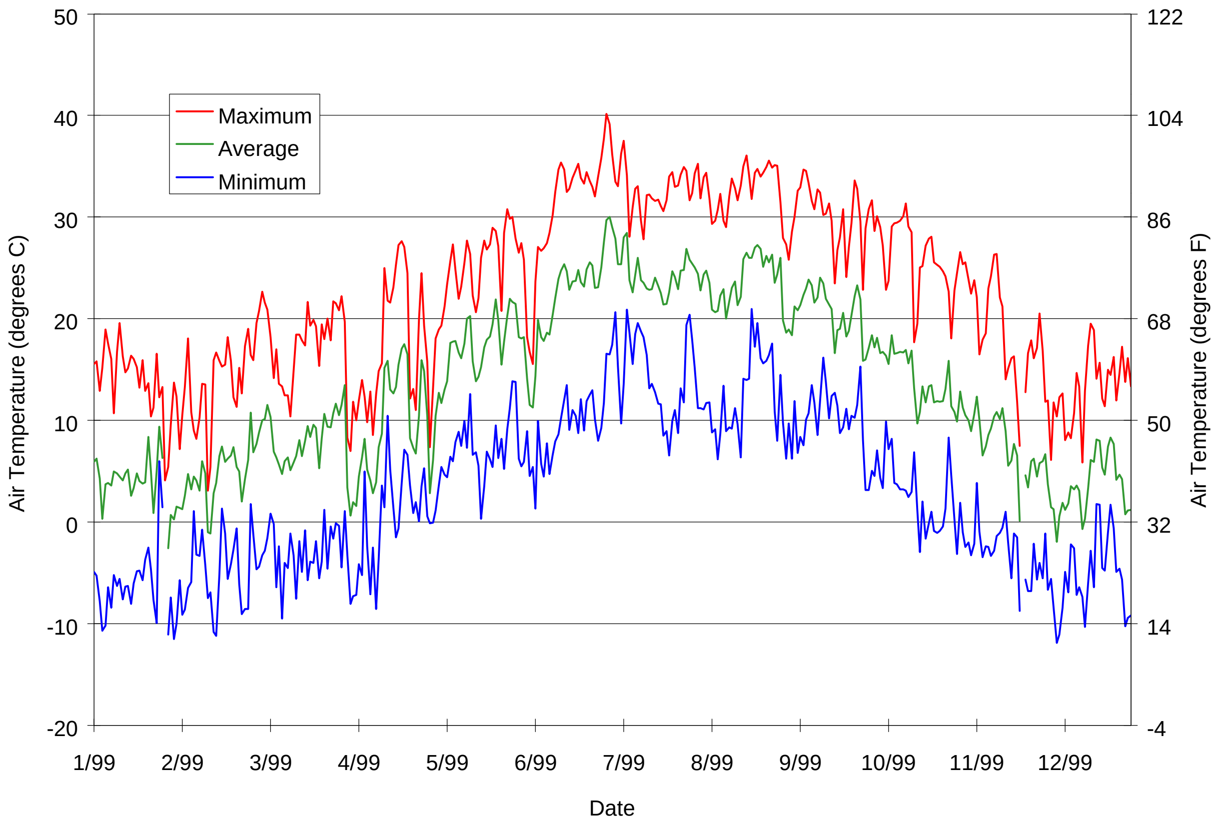


Figure 11. Daily air temperatures recorded at Area 3 RWMS meteorology station.

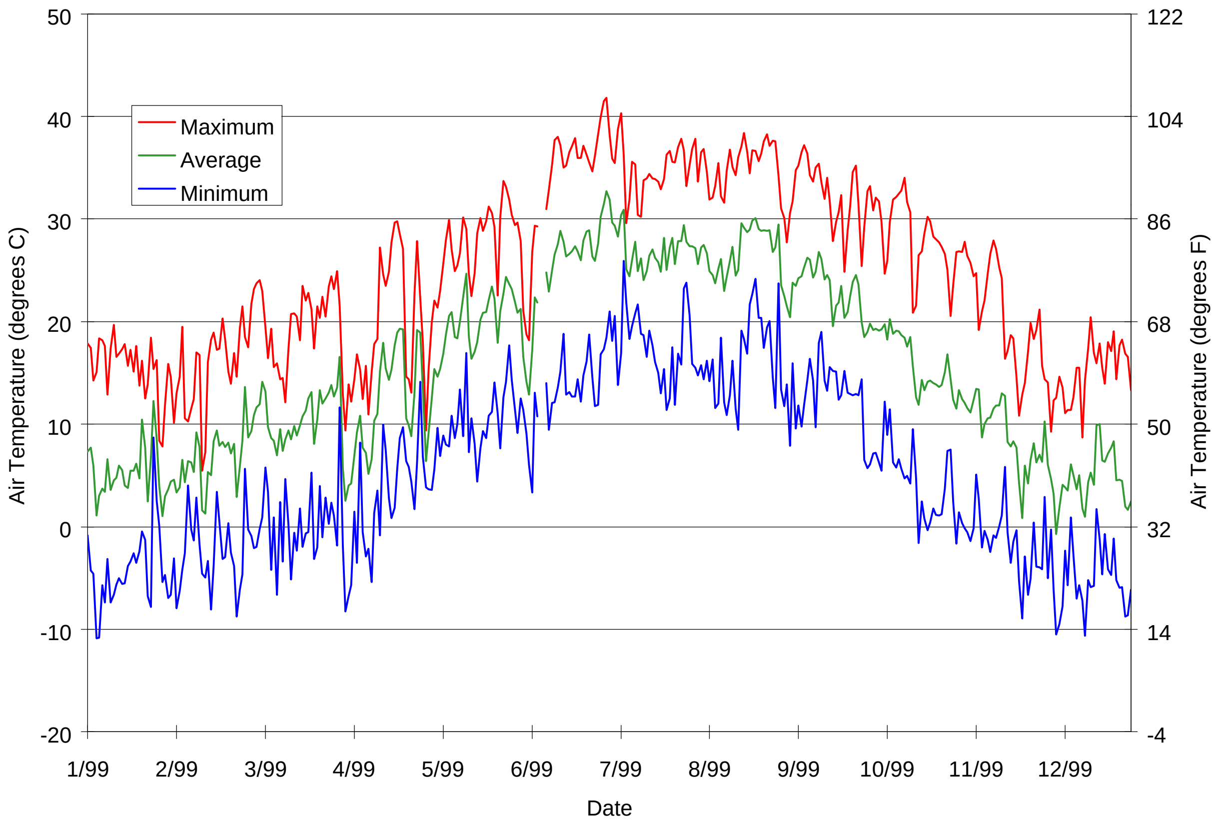


Figure 12. Daily air temperatures recorded at Area 5 RWMS meteorology station.

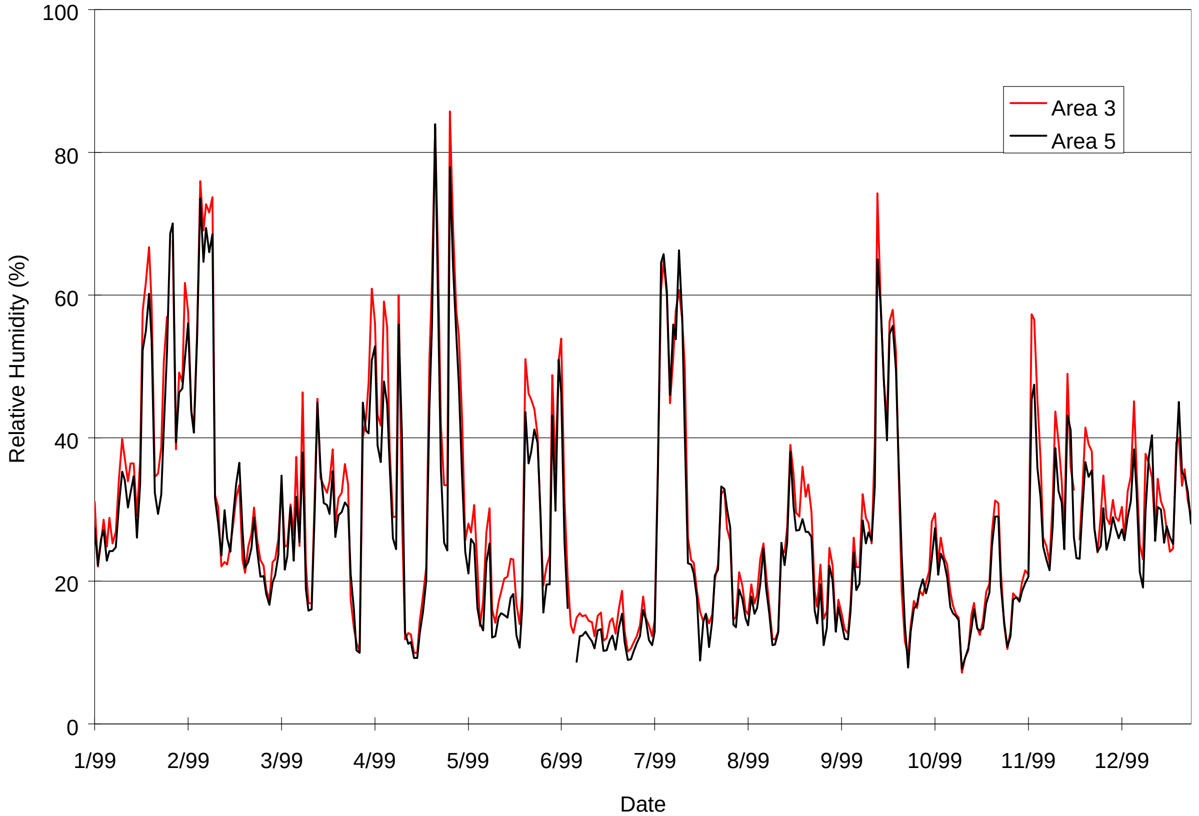


Figure 13. Daily average humidity recorded at Area 3 and Area 5 RWMS meteorology stations.

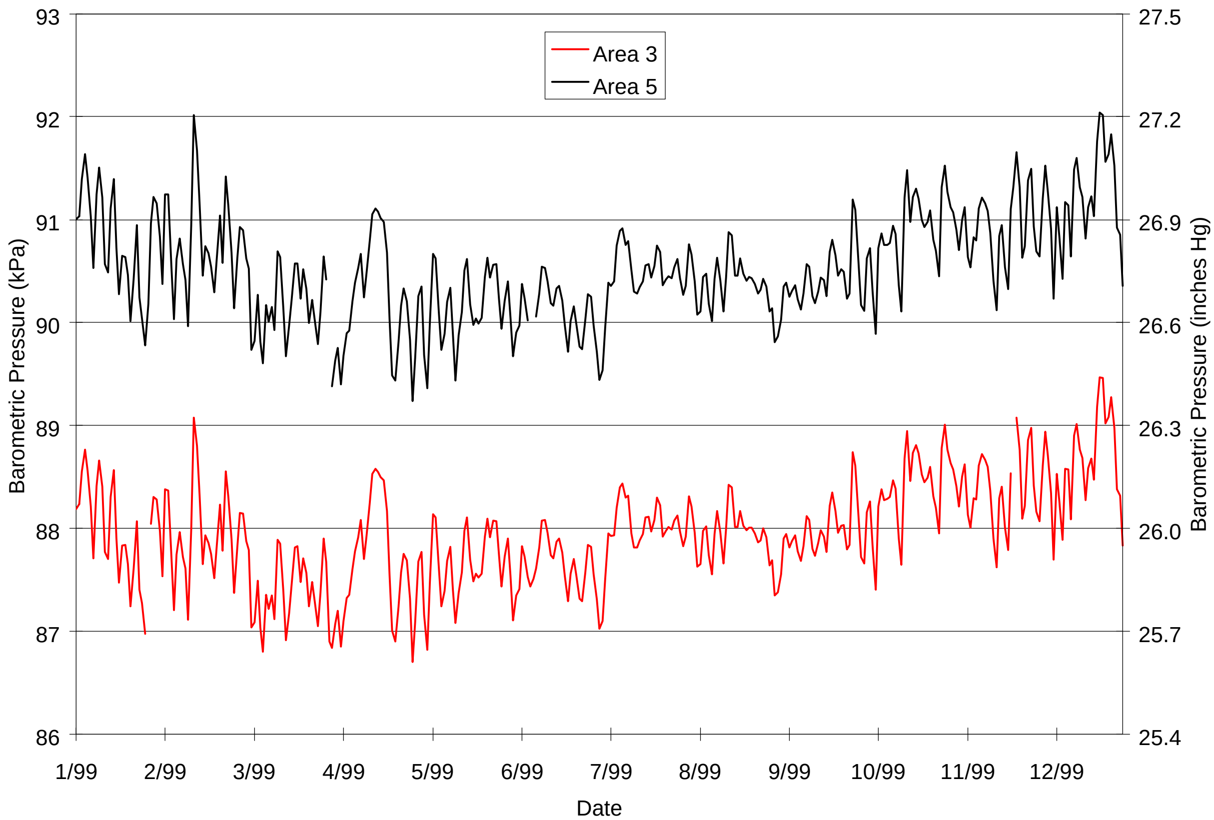


Figure 14. Daily average barometric pressure recorded at Area 3 and Area 5 RWMS meteorology stations.

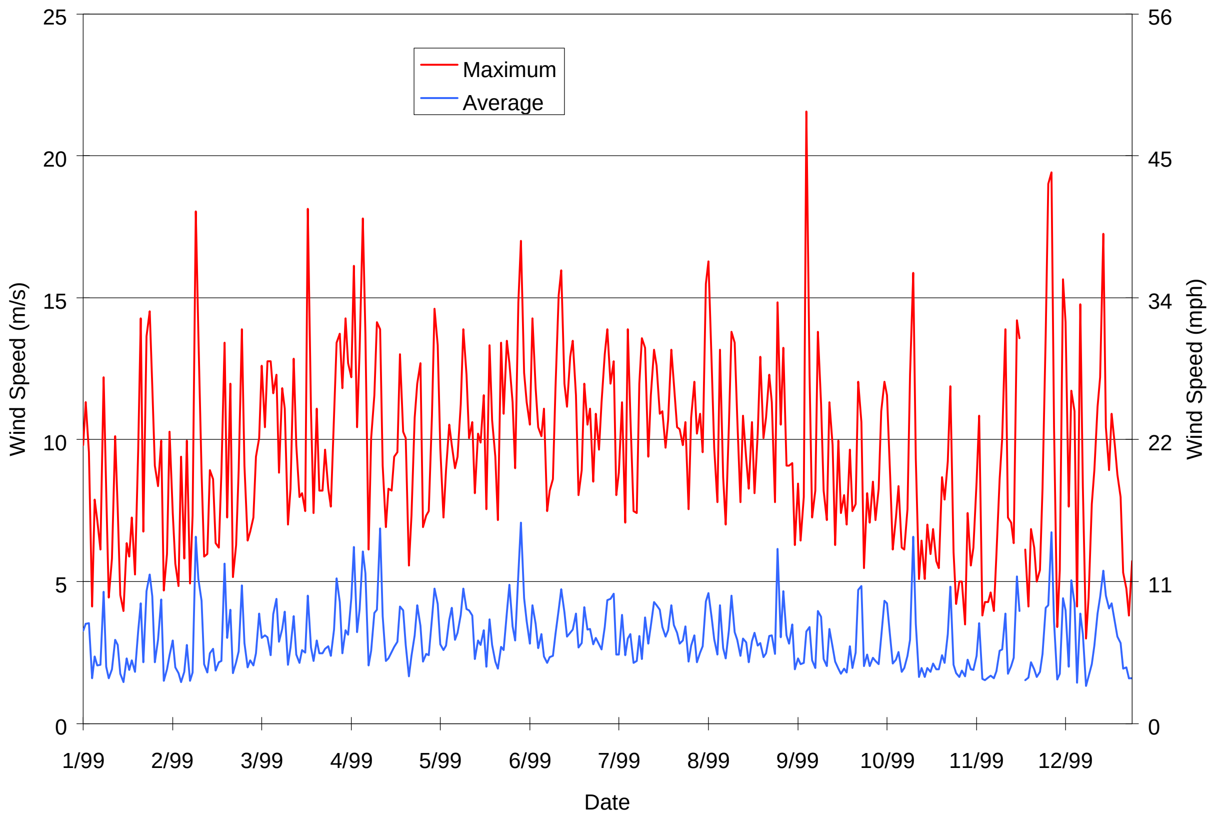


Figure 15. Daily wind speed recorded at Area 3 RWMS meteorology station at a height of 3 m.

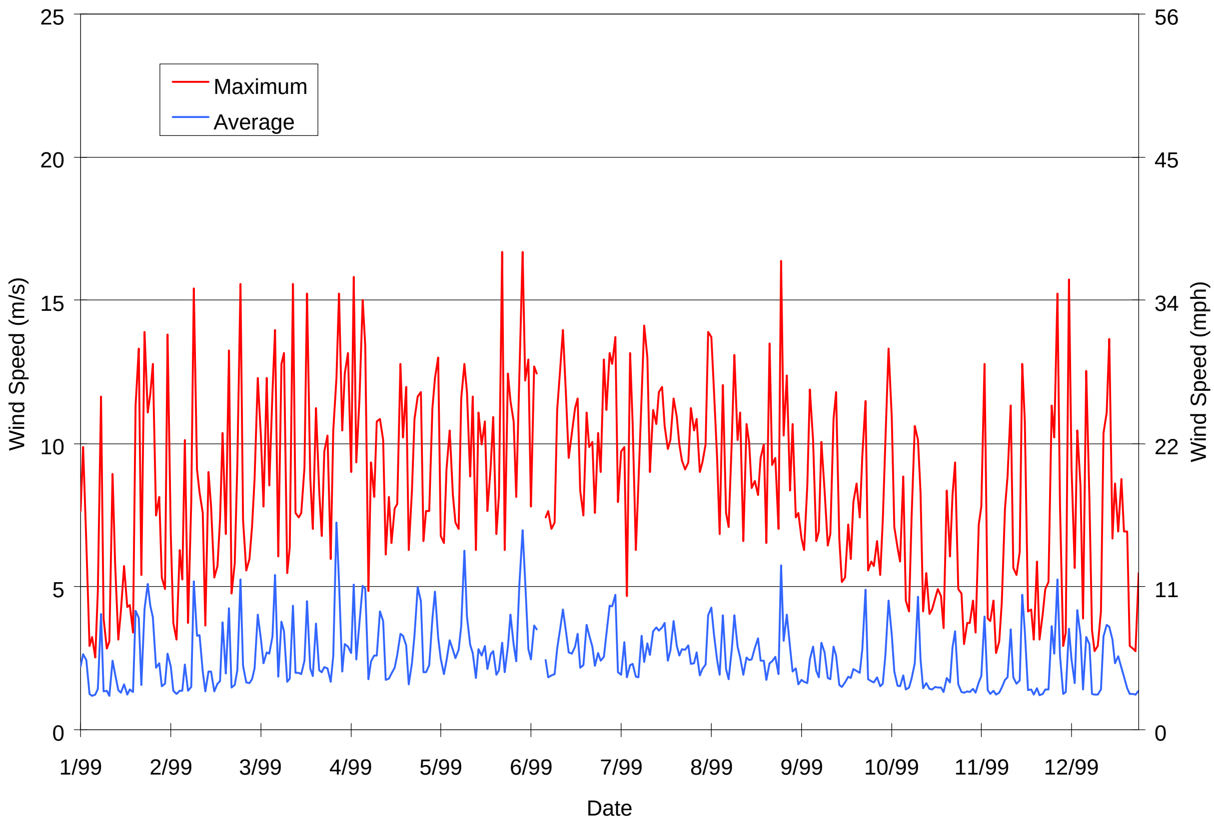
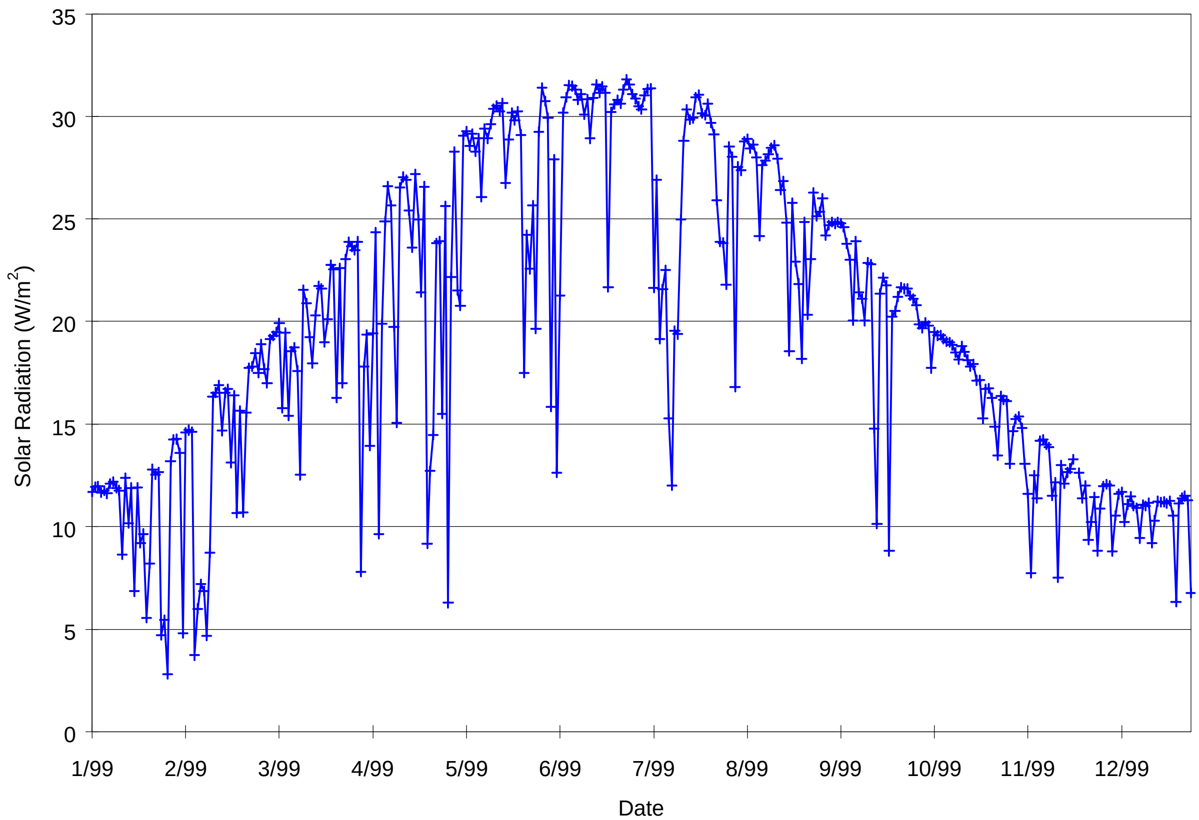


Figure 16. Daily wind speed recorded at Area 5 RWMS meteorology station at a height of 3 m.



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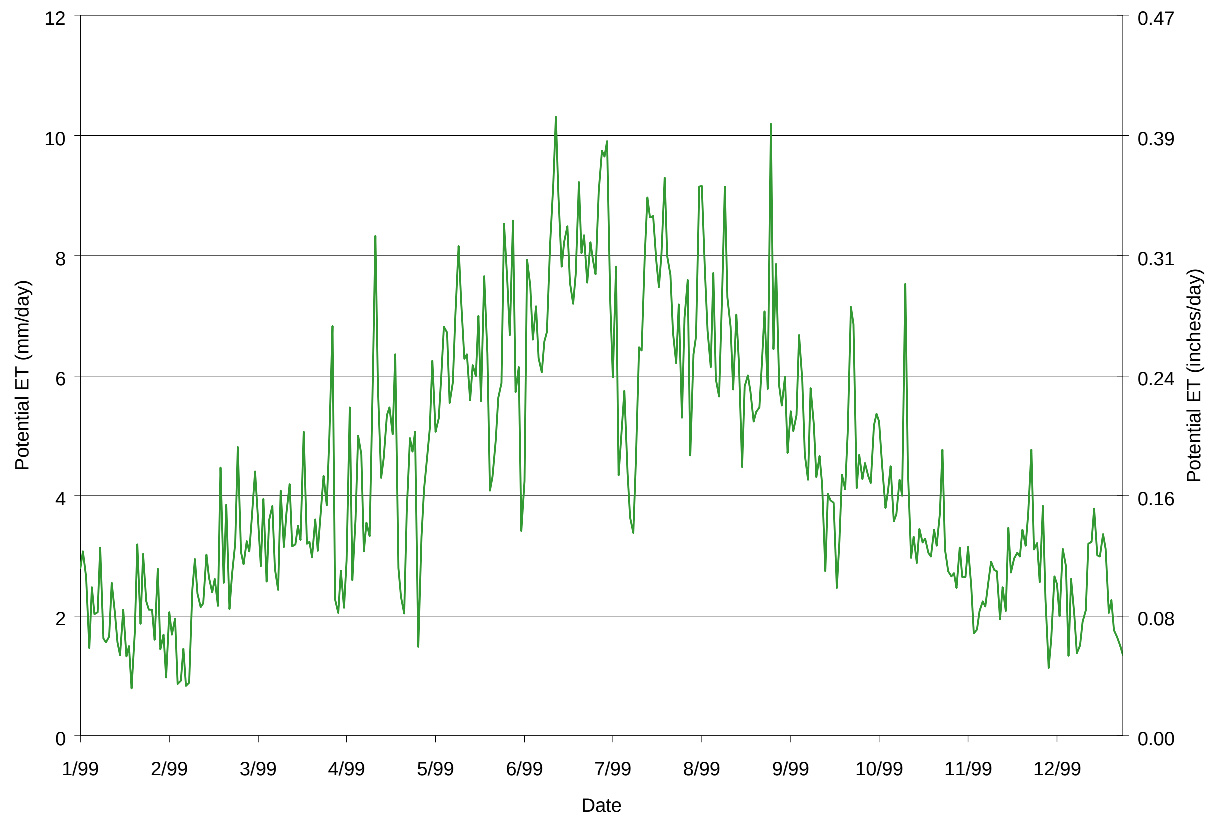


Figure 18. Daily PET calculated from Area 3 RWMS meteorology station data.

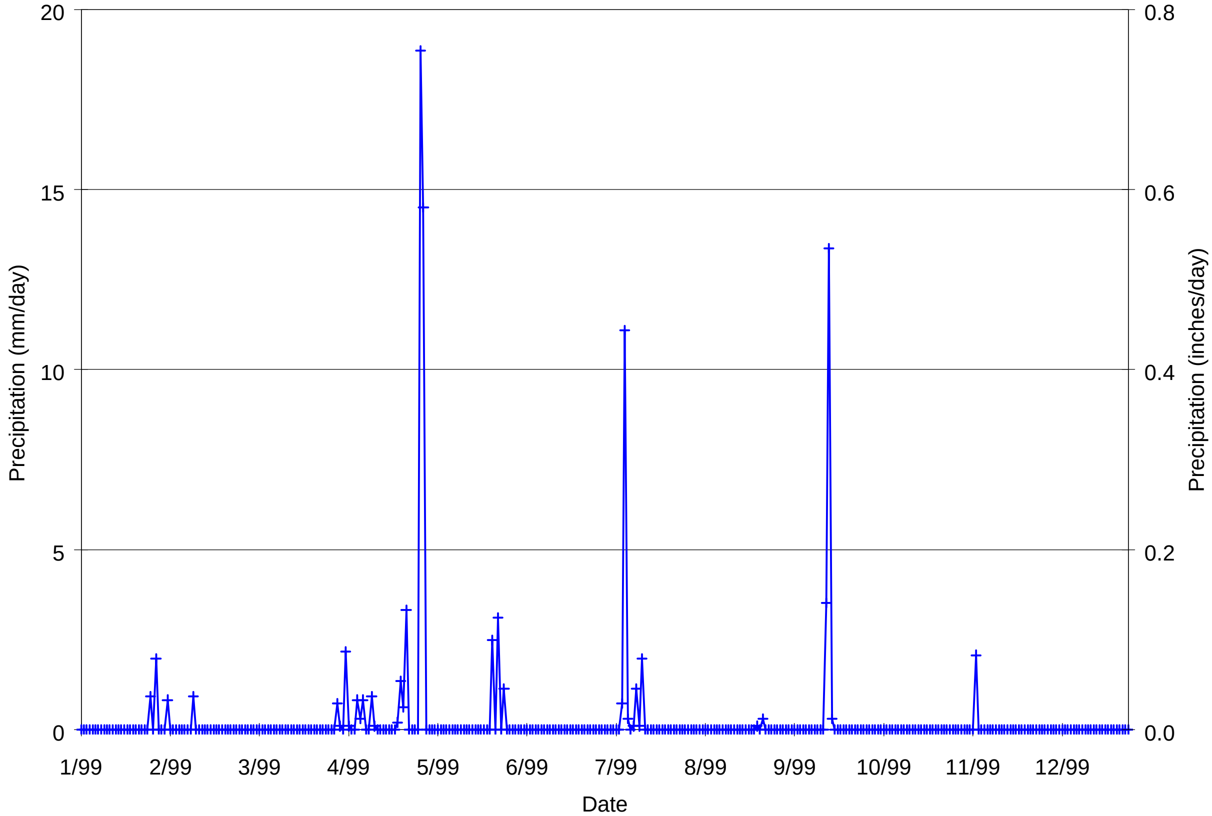


Figure 19. Daily precipitation recorded at Area 3 RWMS meteorology station.

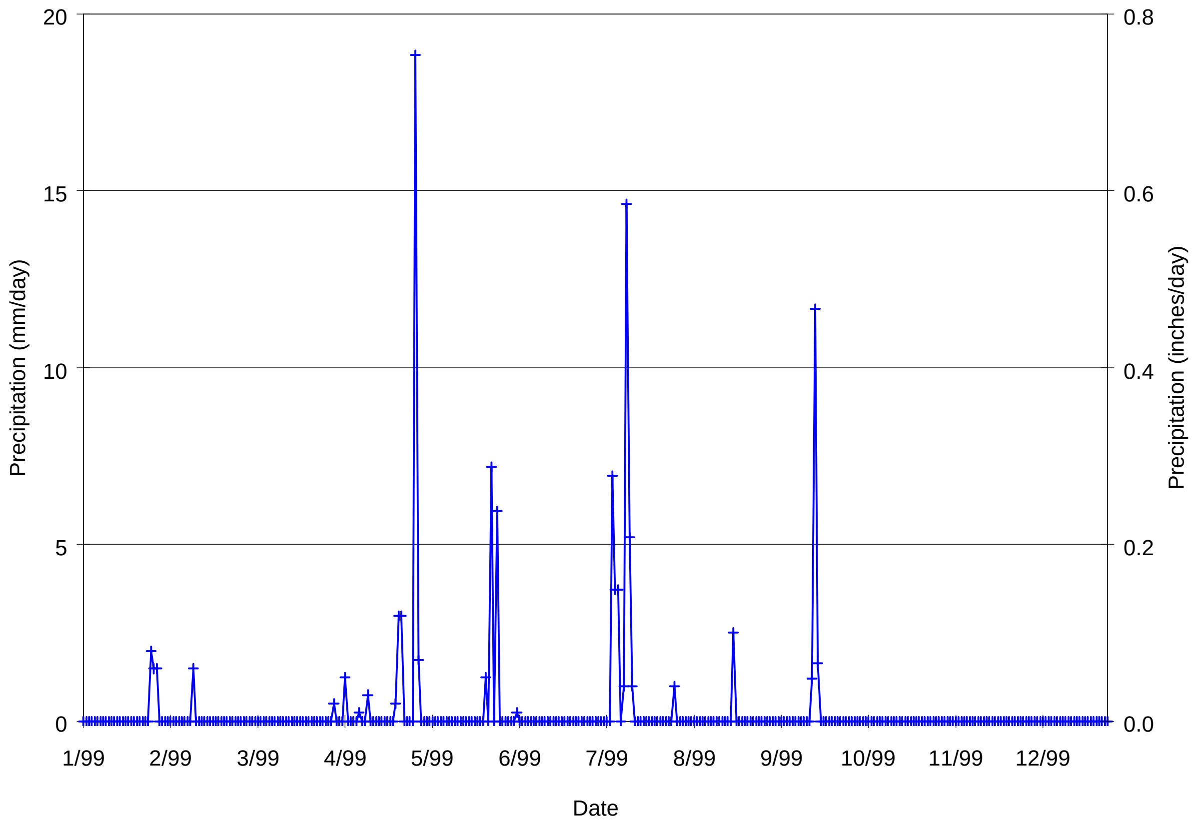
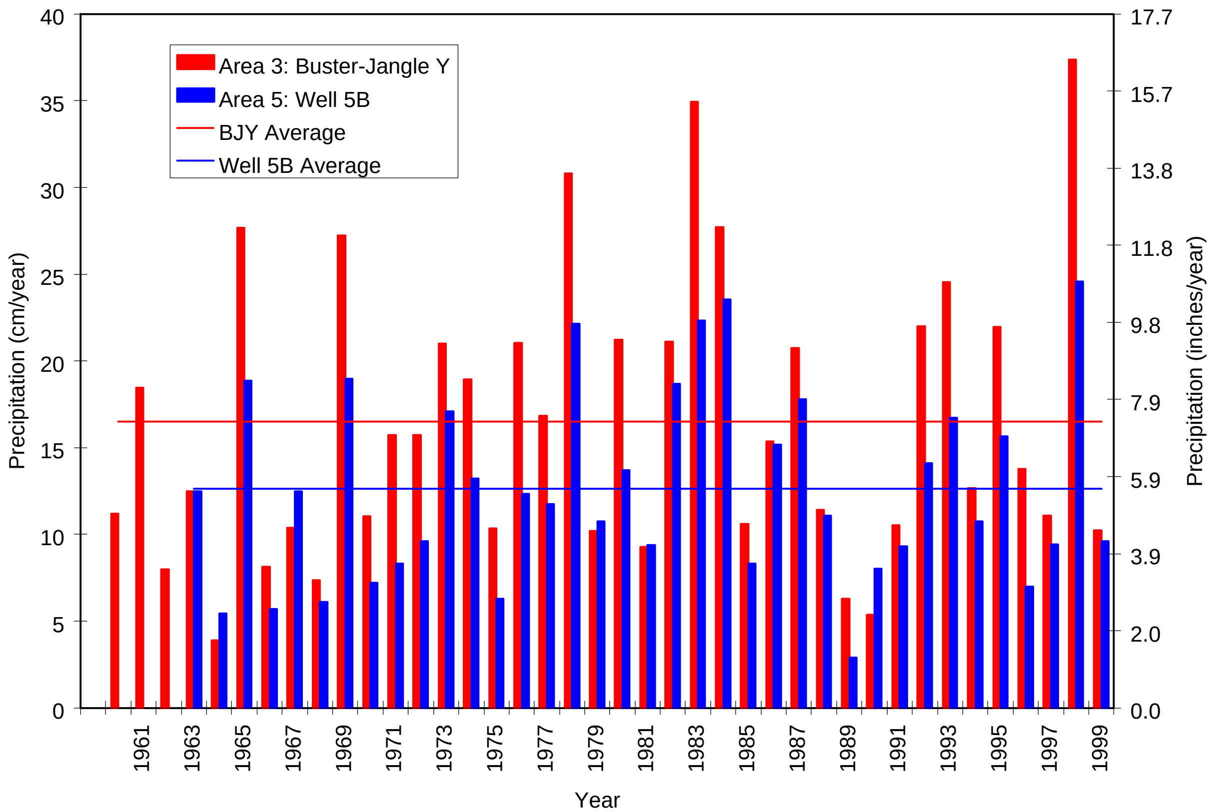


Figure 20. Daily precipitation recorded at Area 5 RWMS meteorology station.



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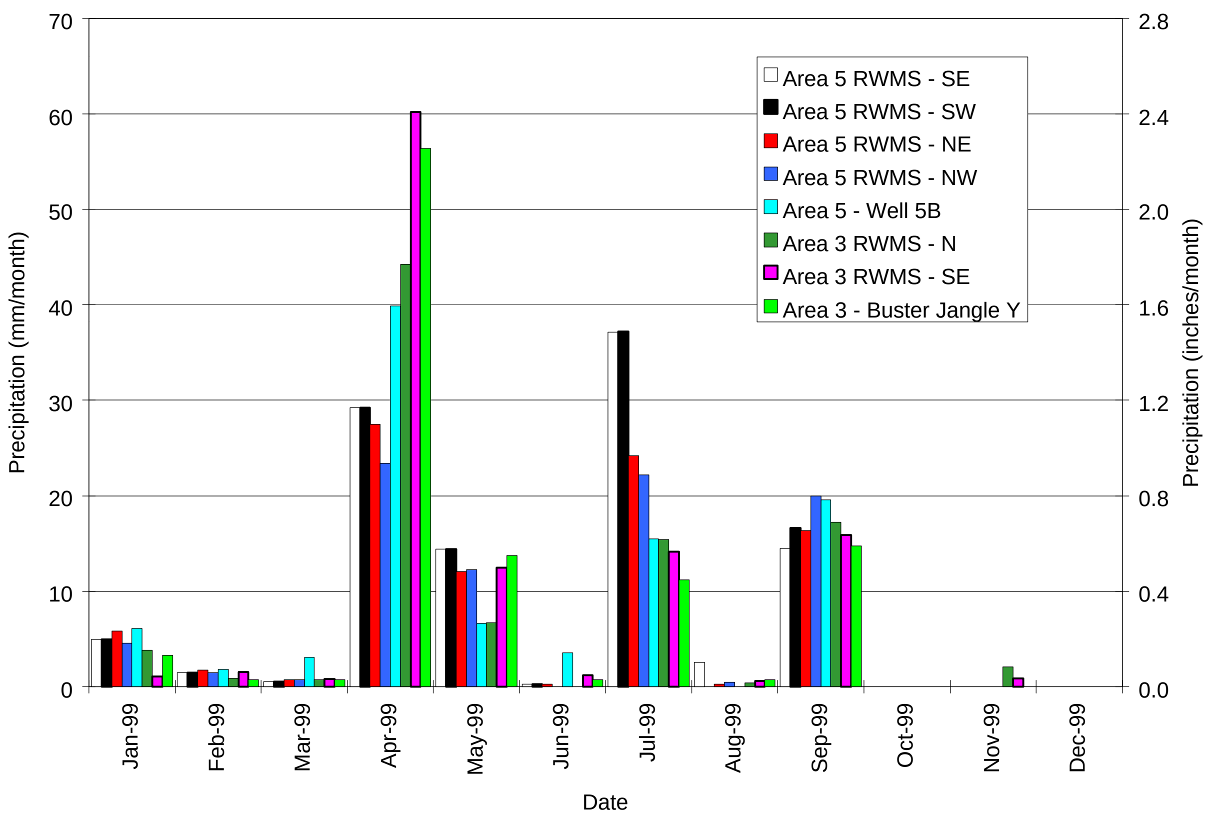

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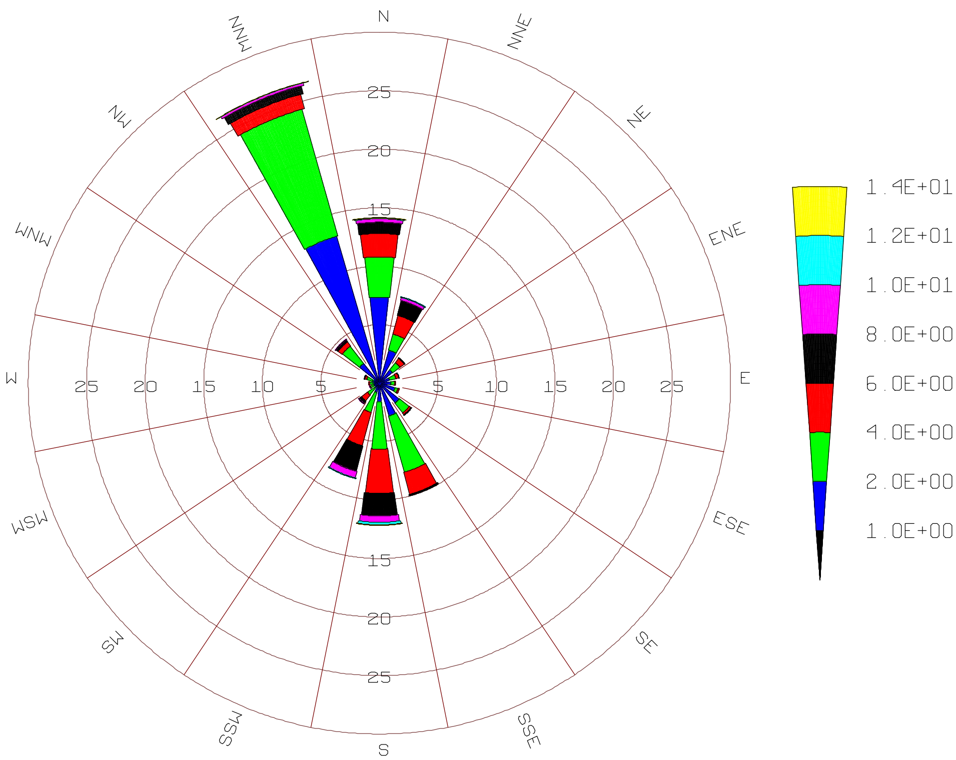


Figure 23. Wind rose diagram for 1999 data from the Area 3 meteorology station.

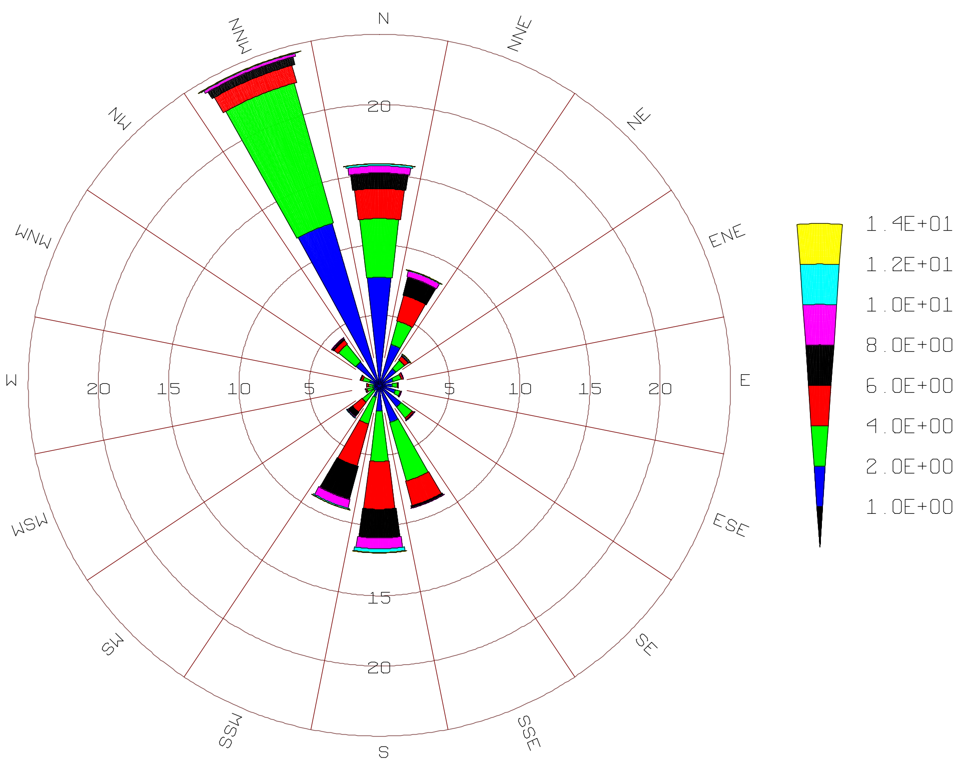


Figure 24. Wind rose diagram for 1996-1999 data from the Area 3 meteorology station.

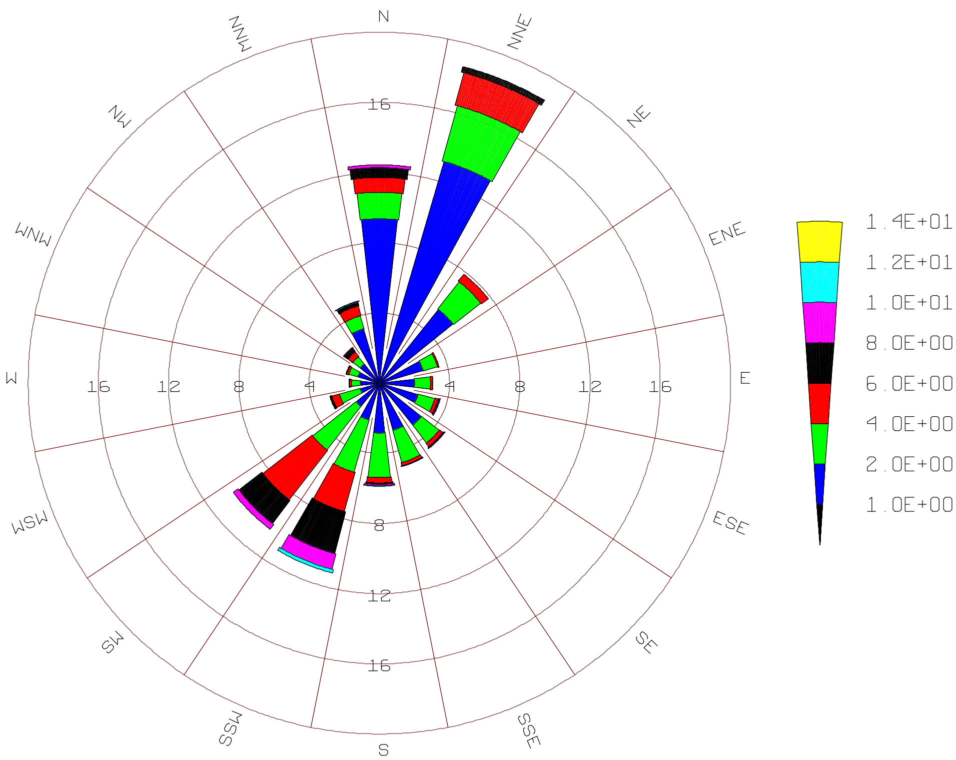


Figure 25. Wind rose diagram for 1999 data from the Area 5 RWMS meteorology station.

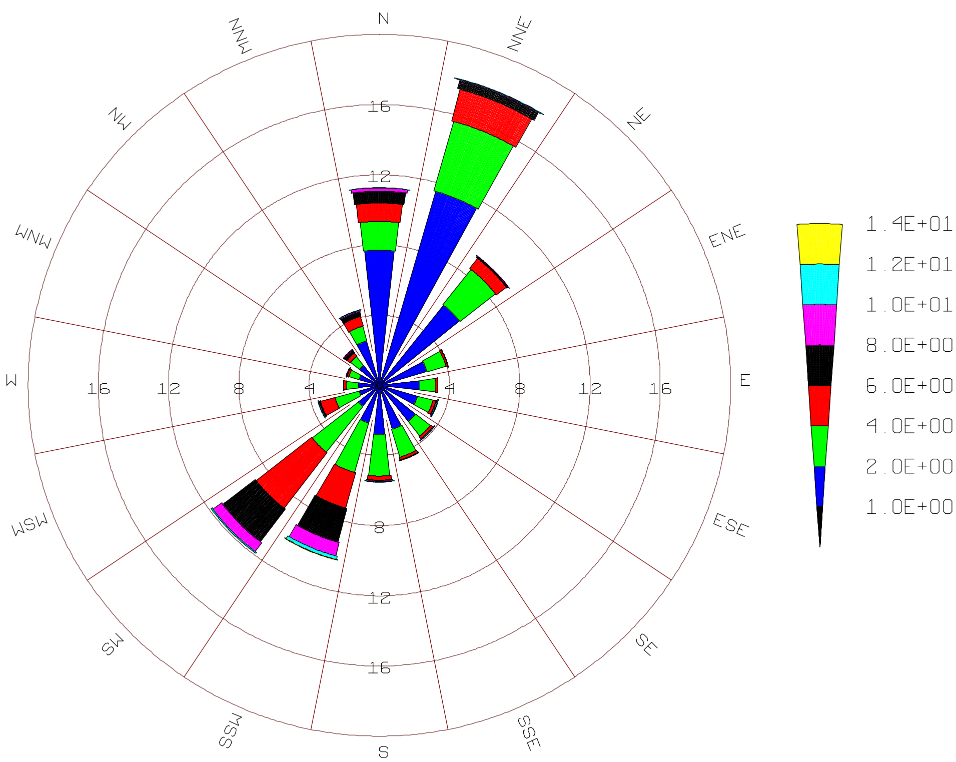


Figure 26. Wind rose diagram for 1996-1999 data from the Area 5 RWMS meteorology station.

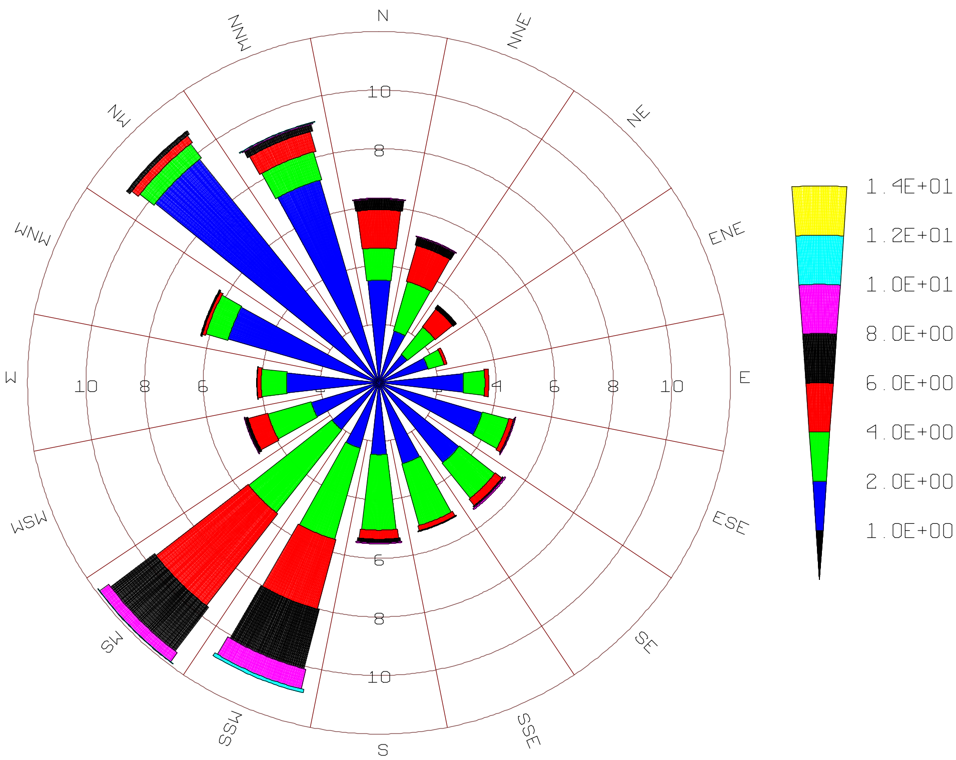


Figure 27. Wind rose diagram for 1999 data from the Area 5 Lysimeter meteorology station.

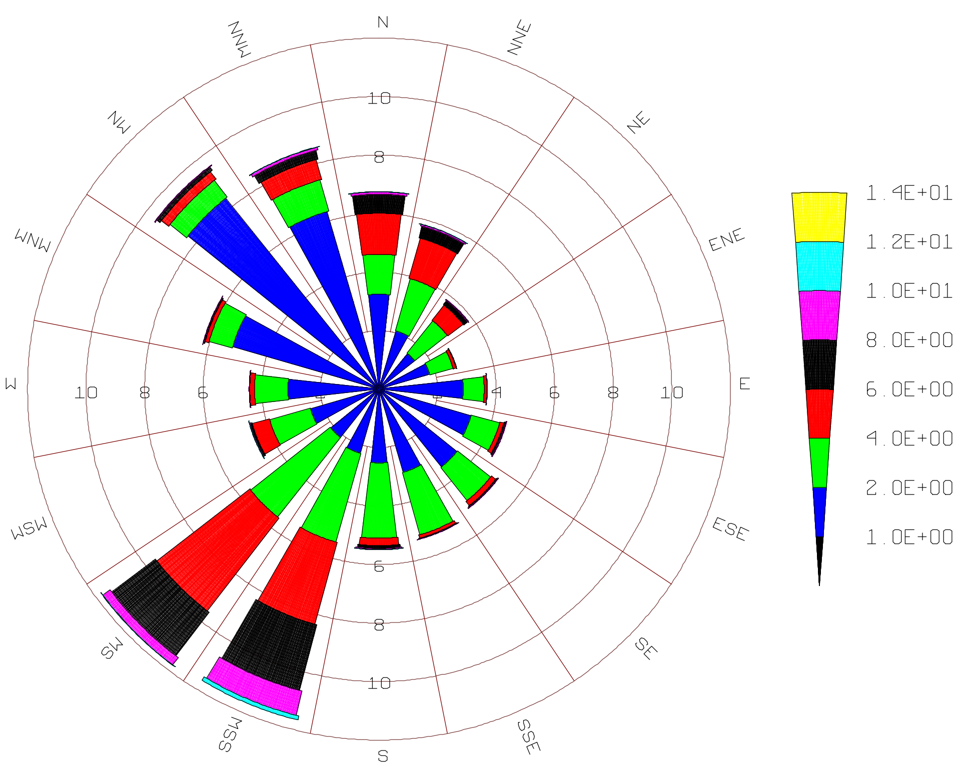


Figure 28. Wind rose diagram for 1996-1999 data from the Area 5 Lysimeter meteorology station.

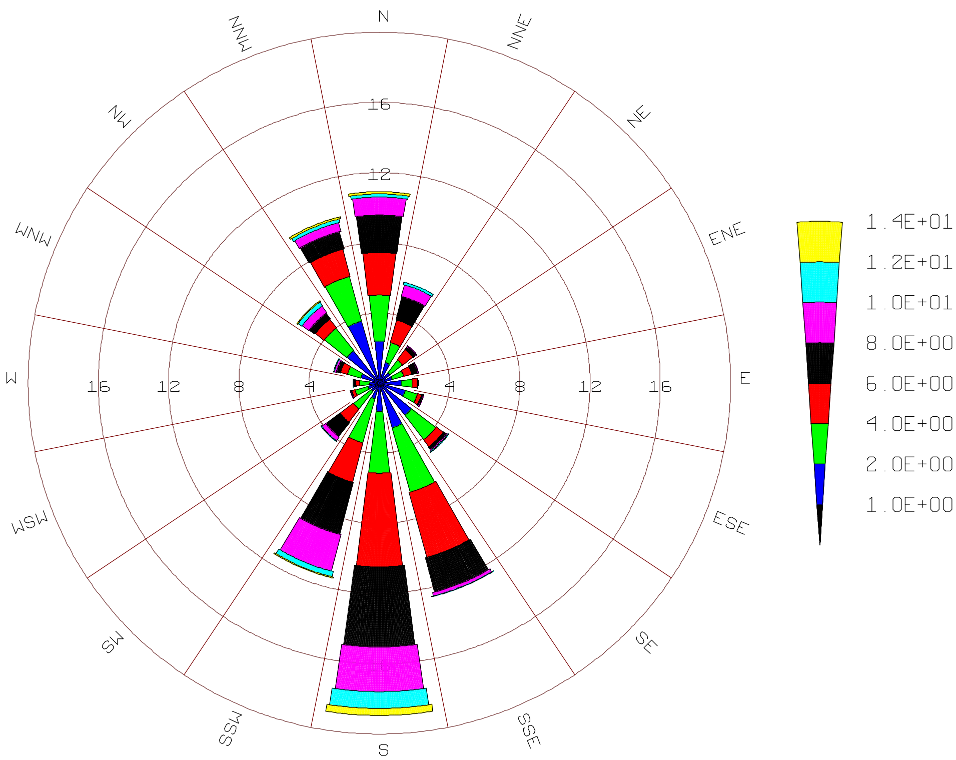
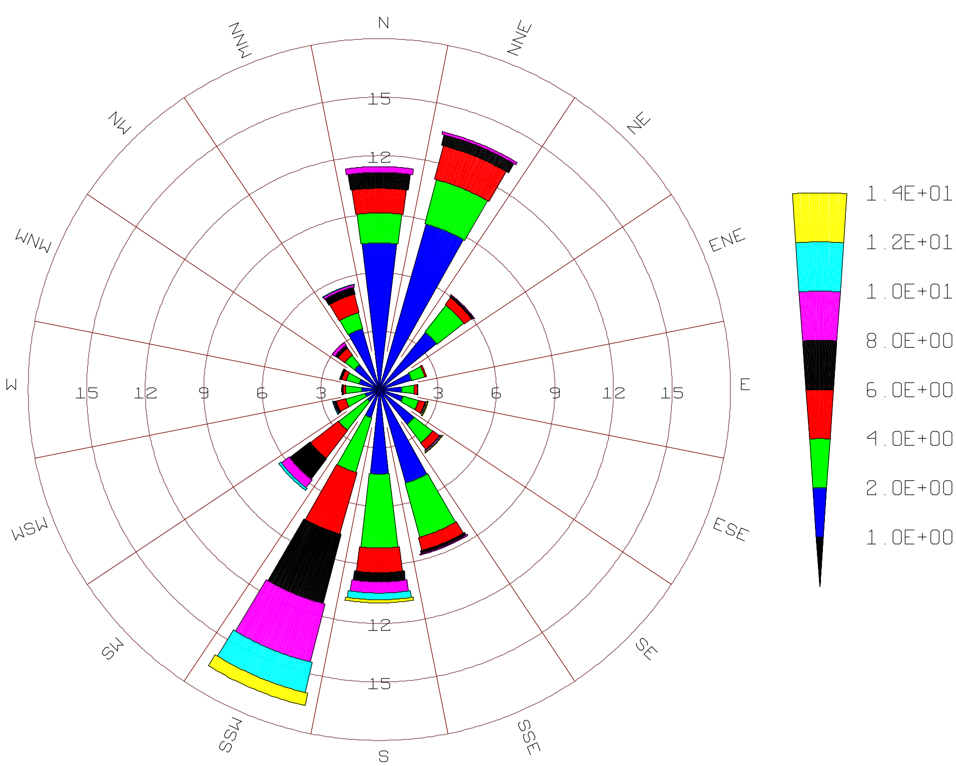


Figure 29. Wind rose diagram for 1999 data from the Area 3 Crater (U-3bw) meteorology station.



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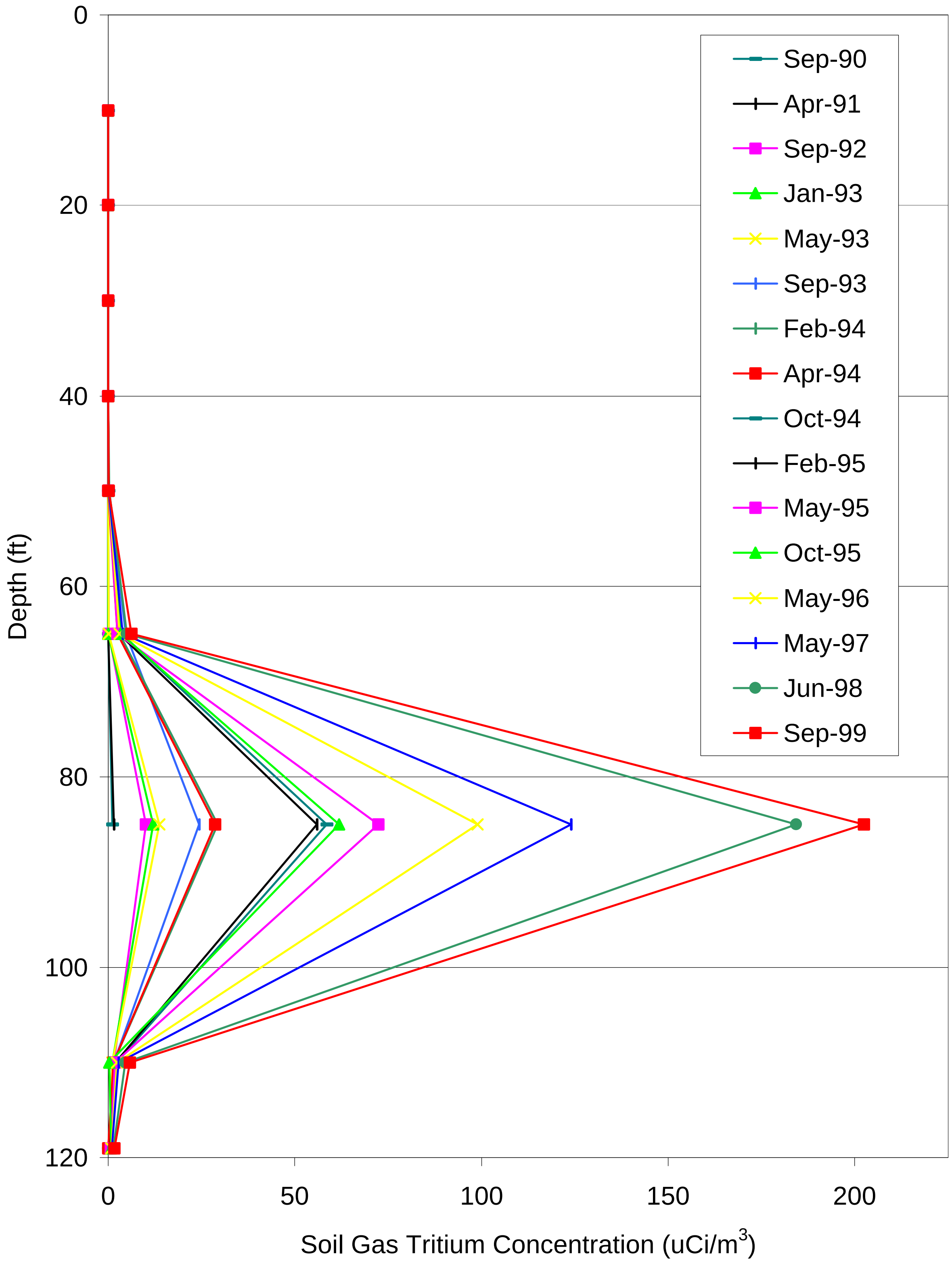
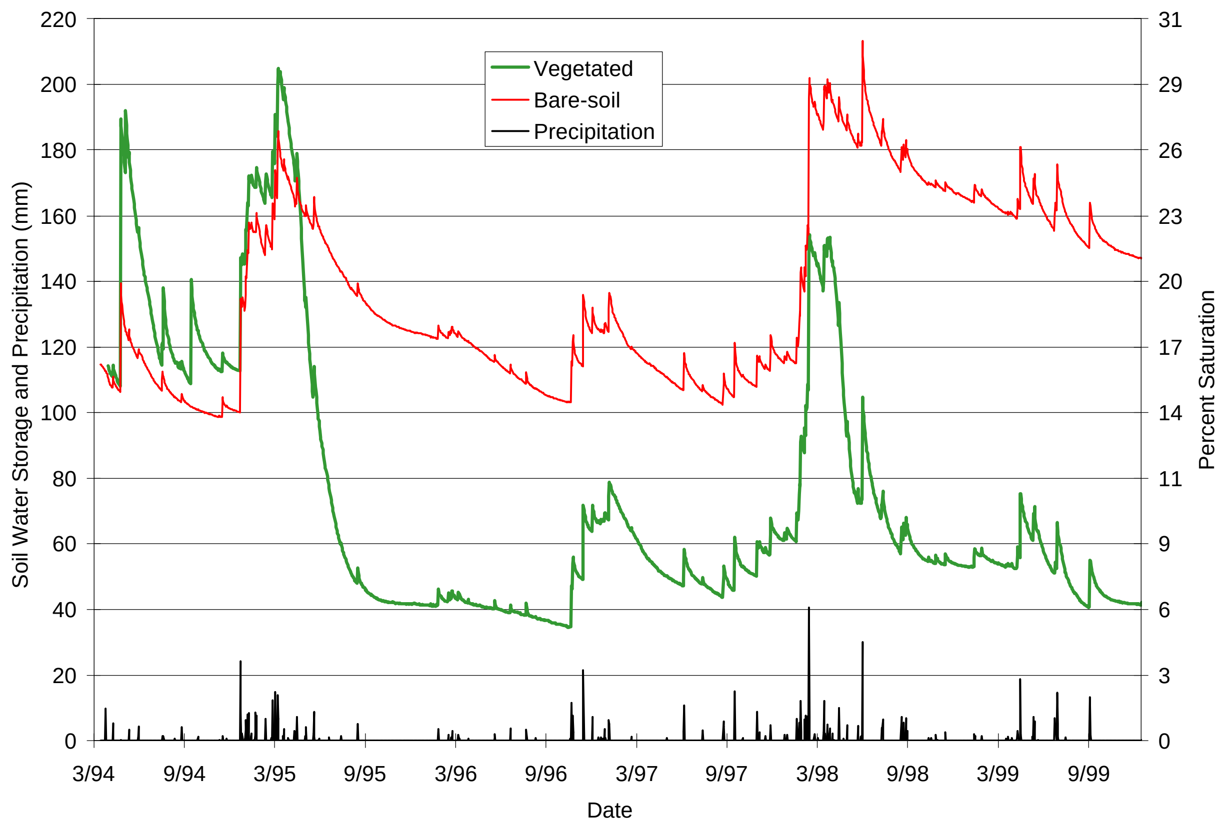


Figure 31. Tritium soil-gas concentrations with depth at GCD-05U.



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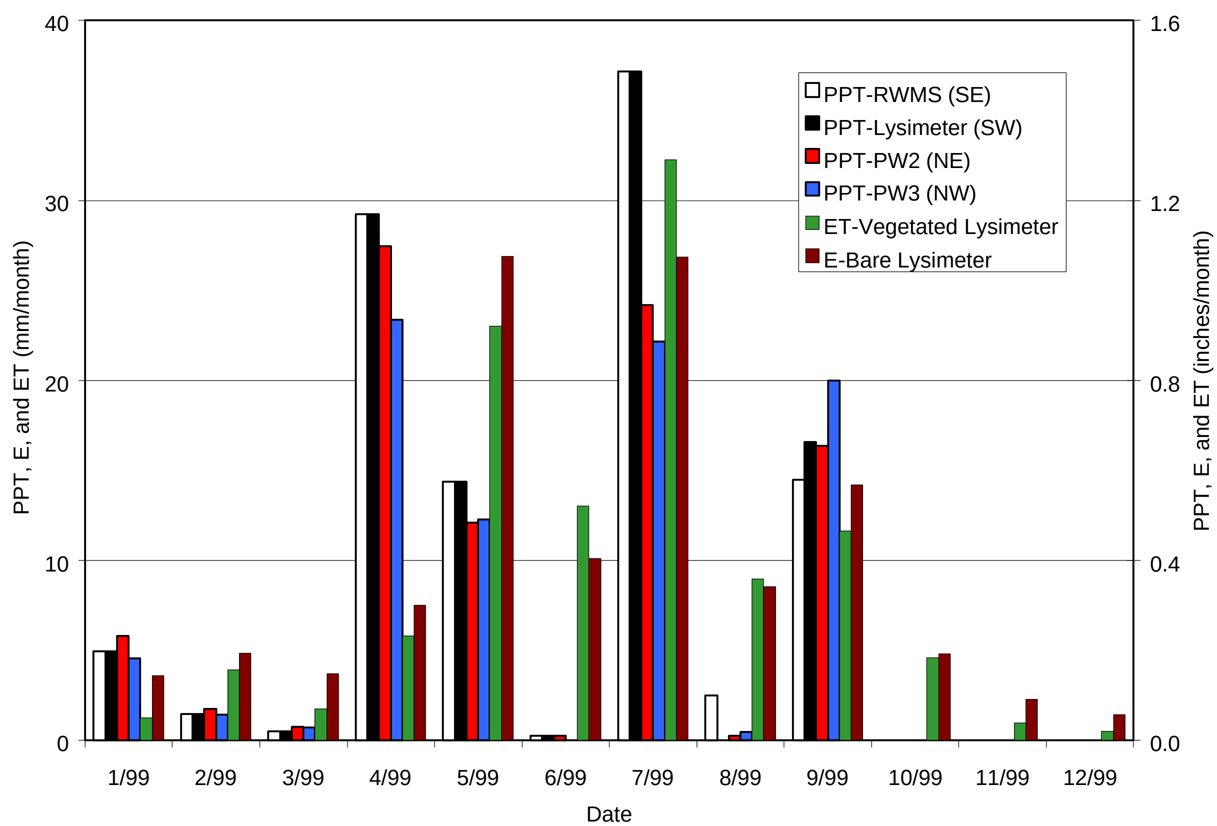


Figure 33. Monthly precipitation, evaporation, and ET recorded at the Area 5 RWMS.

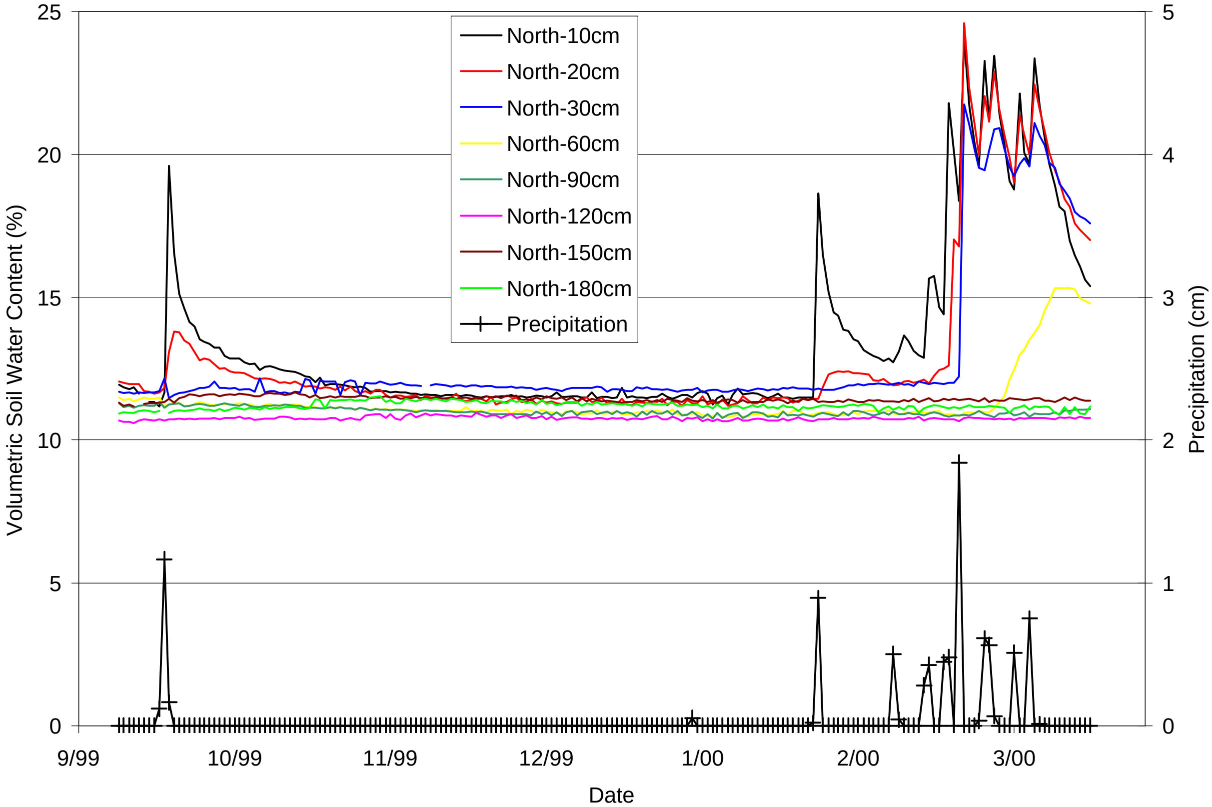


Figure 34. Soil water content in Pit 3 waste cover (N site) using an automated TDR system.

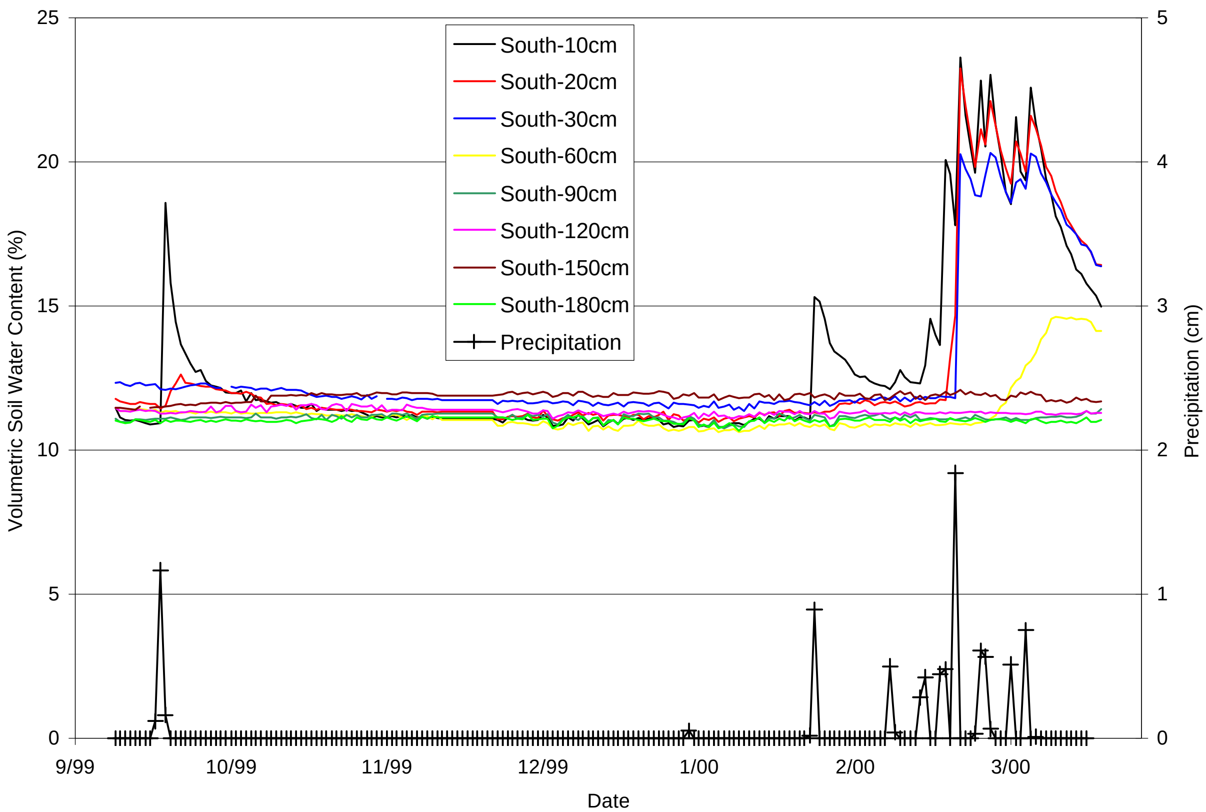


Figure 35. Soil water content in Pit 3 waste cover (S site) using an automated TDR system.

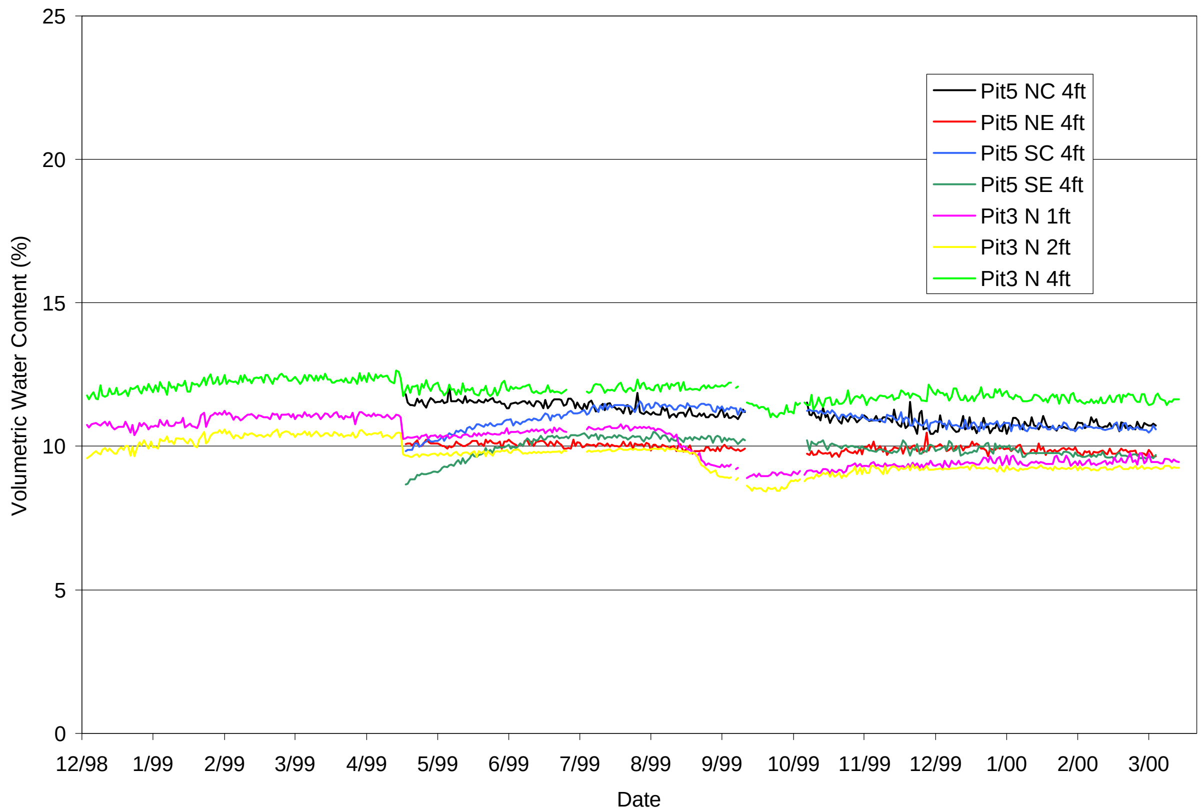


Figure 36. Soil water content in Pit 3 and Pit 5 floors using automated TDR systems.

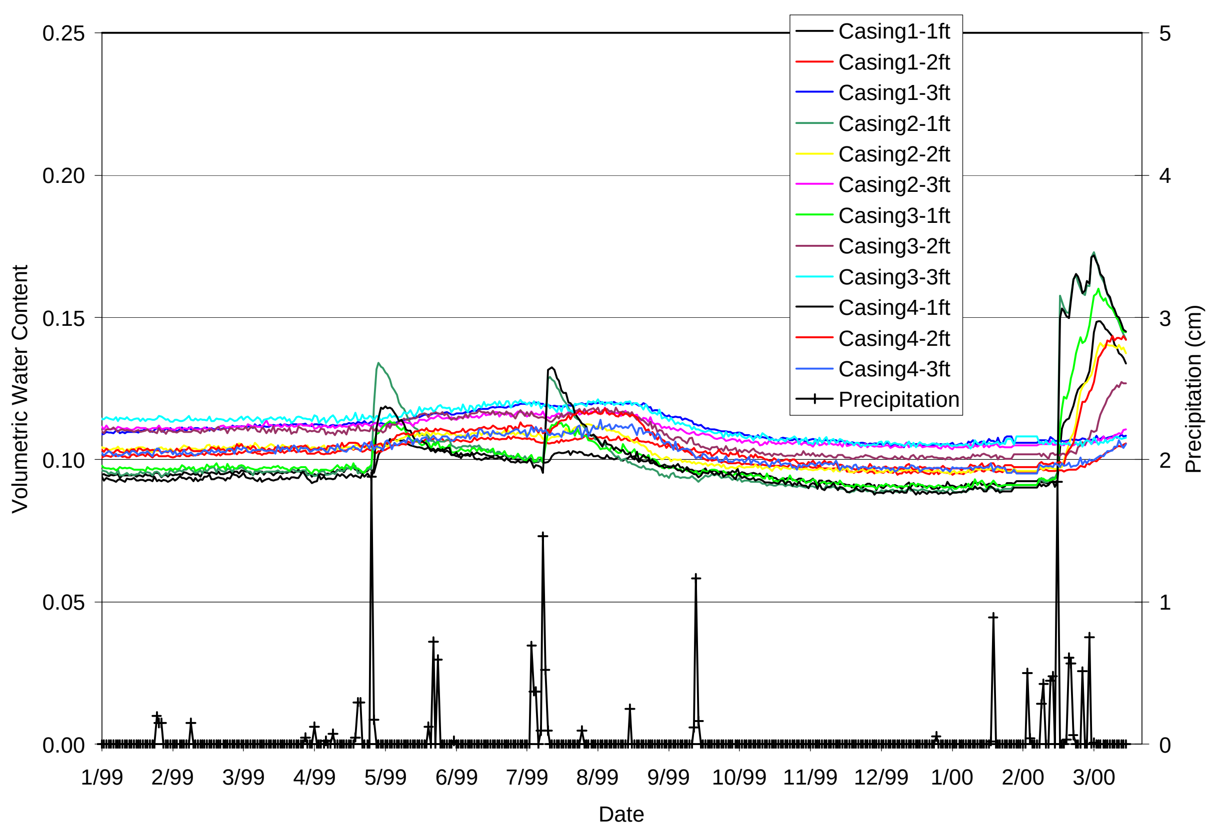


Figure 37. Soil water content at the neutron probe "cal pit" using an automated TDR system.

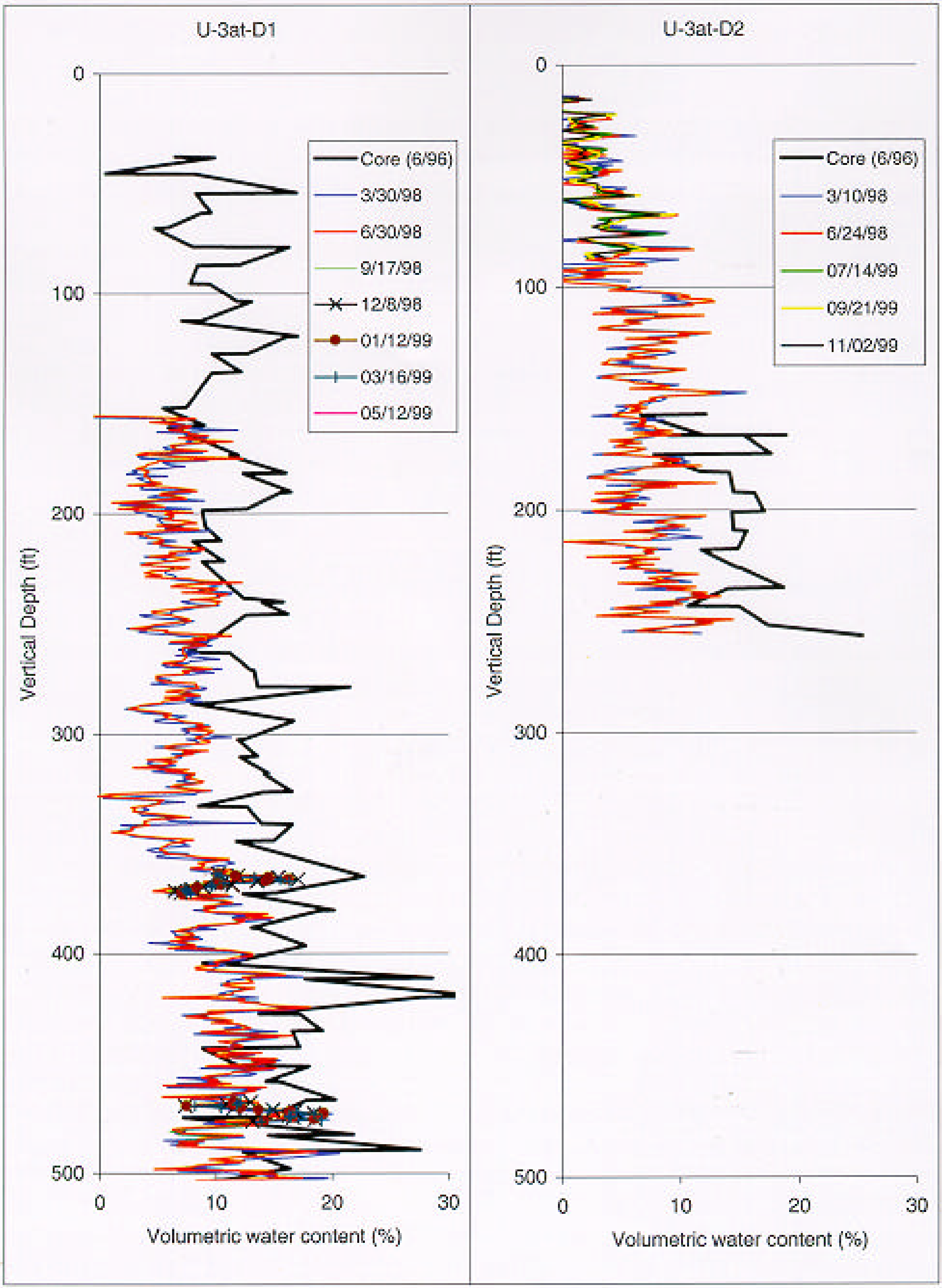


Figure 38. Water content profiles from U-3at-D1 and U-3at-D2.

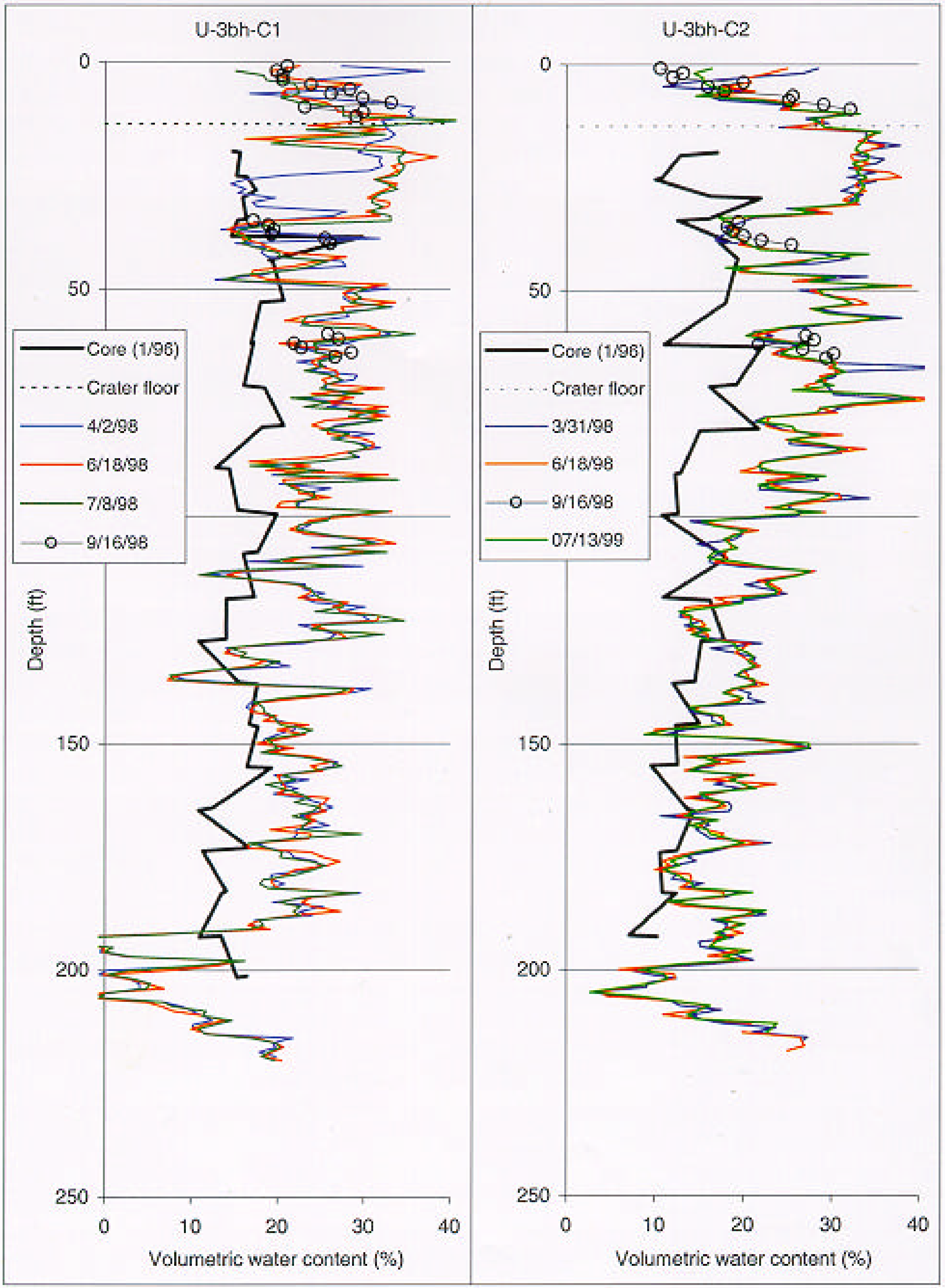
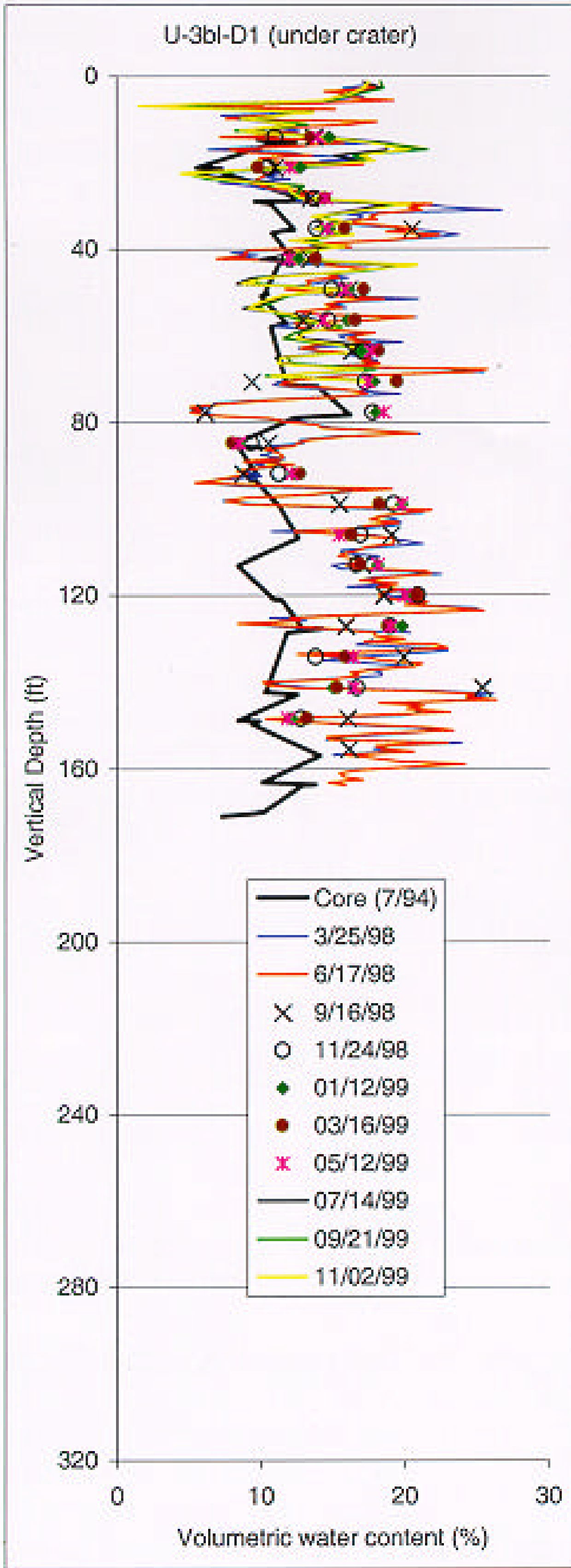


Figure 39. Water content profiles from U-3bh-C1 and U-3bh-C2.



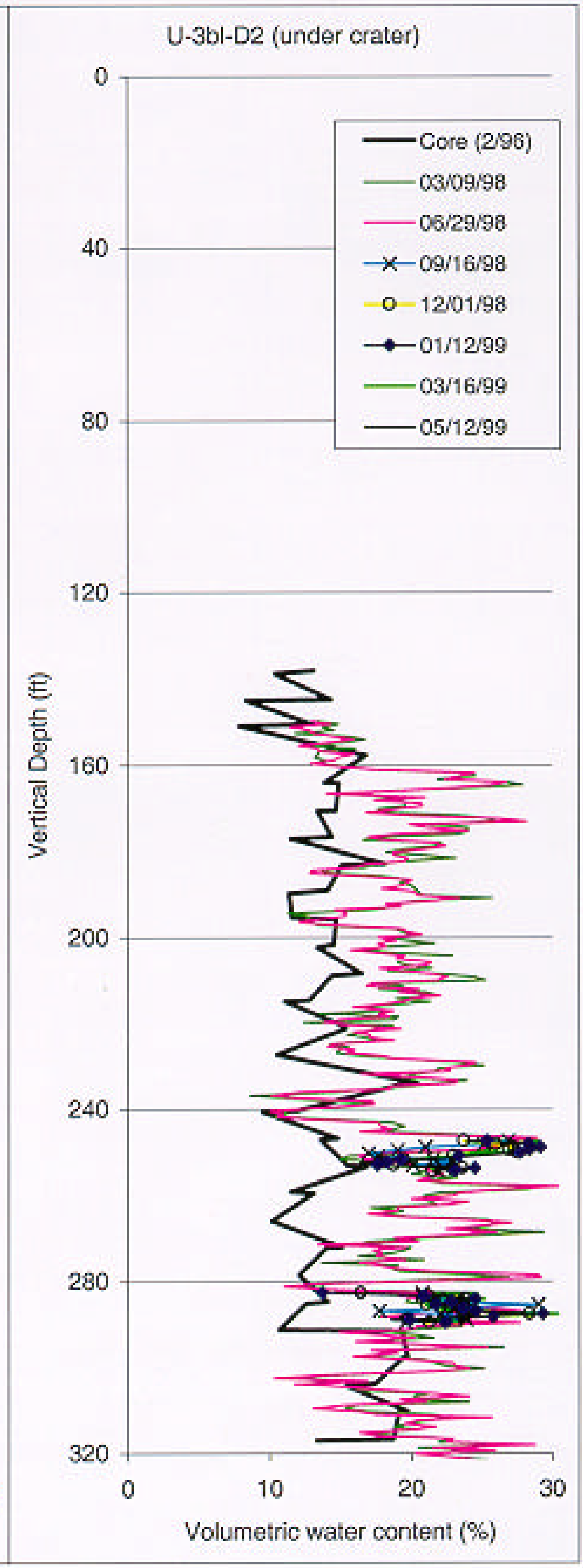


Figure 40. Water content profiles from U-3bl-D1 and U-3bl-D2.

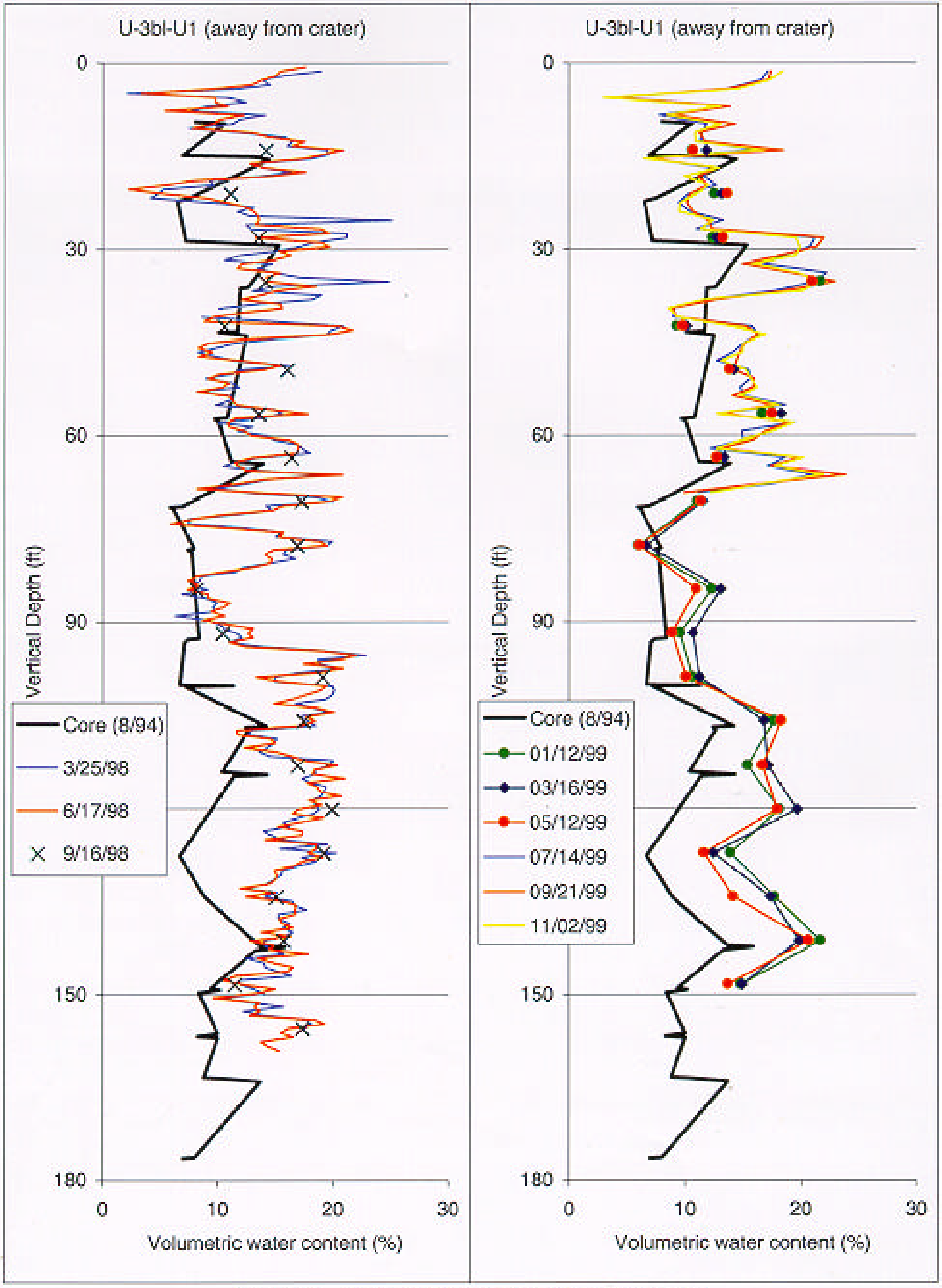


Figure 41. Water content profiles from U-3bl-U1.

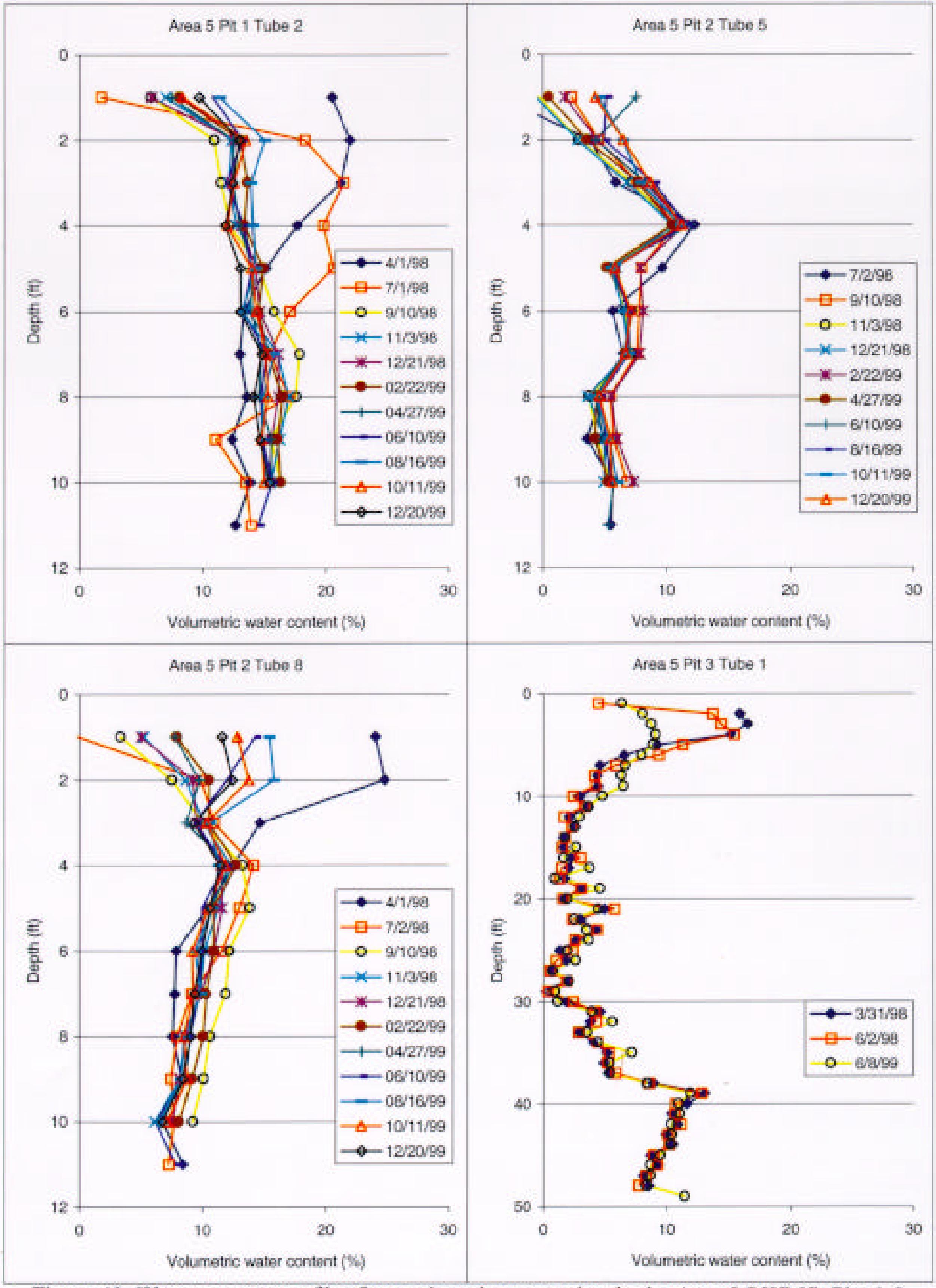


Figure 42. Water content profiles from selected access tubes in the Area 5 RWMS, Pits 1-3.

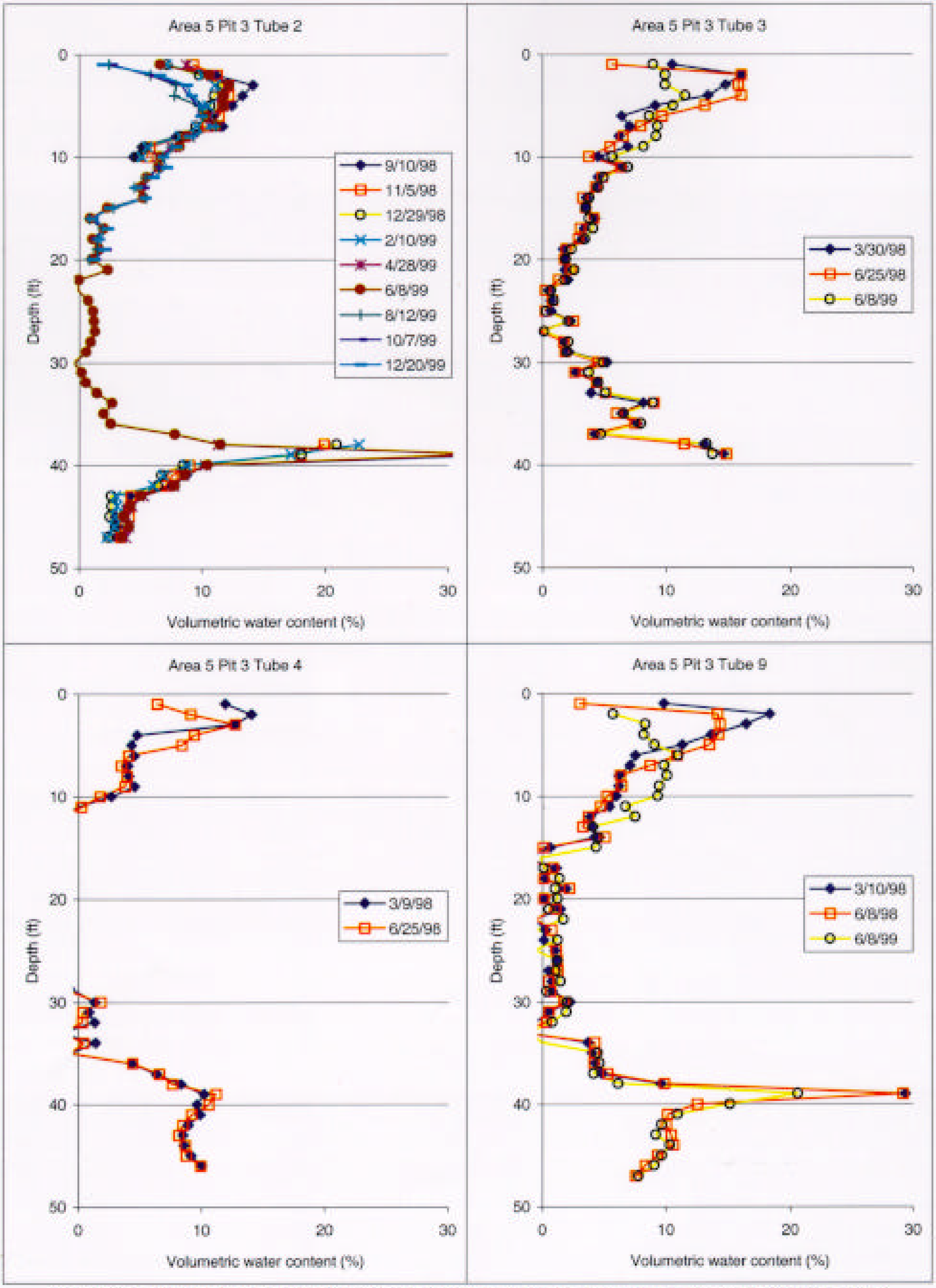


Figure 43. Water content profiles from selected access tubes in the Area 5 RWMS, Pit 3.

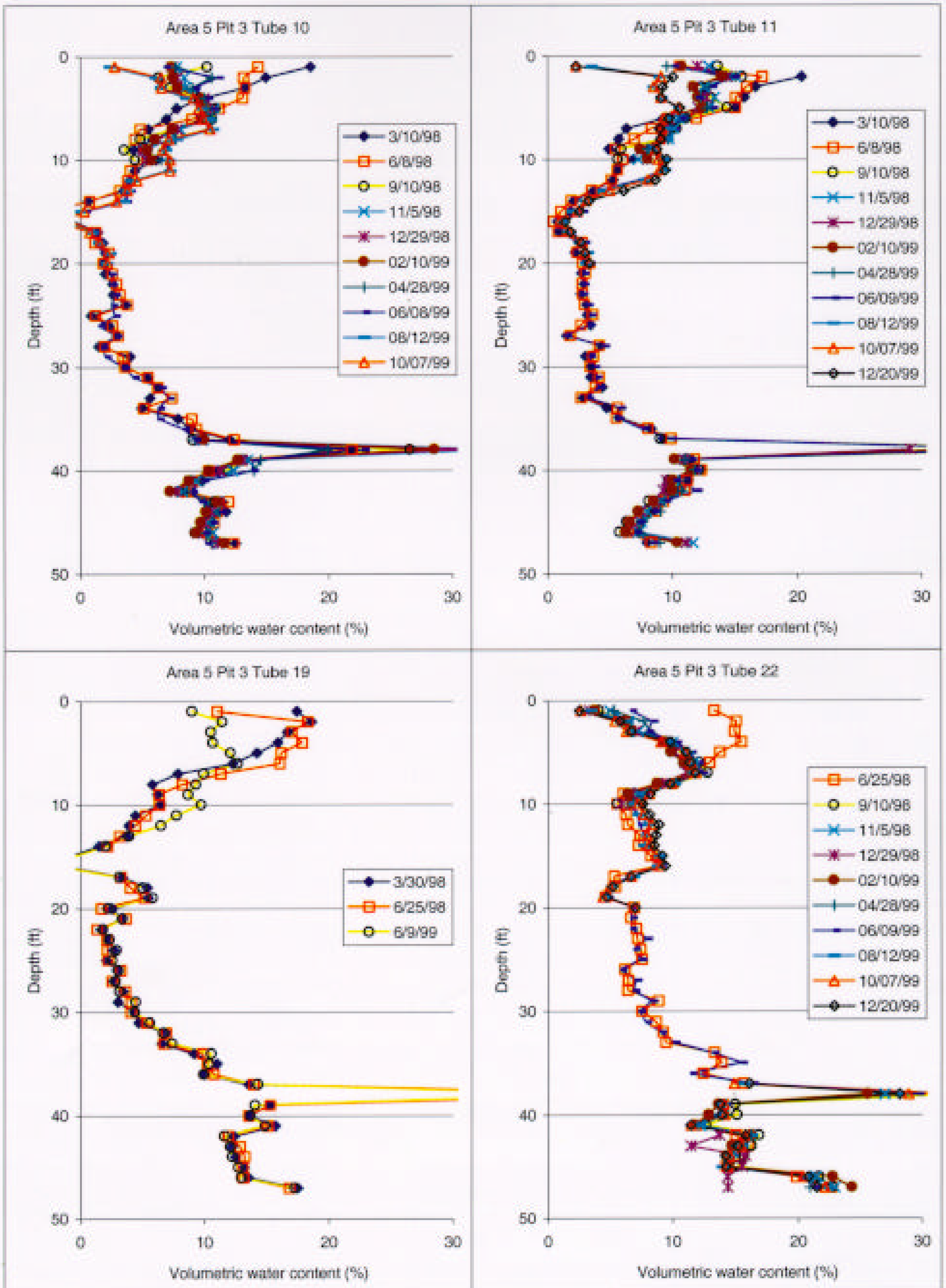


Figure 44. Water content profiles from selected access tubes in the Area 5 RWMS, Pit 3.

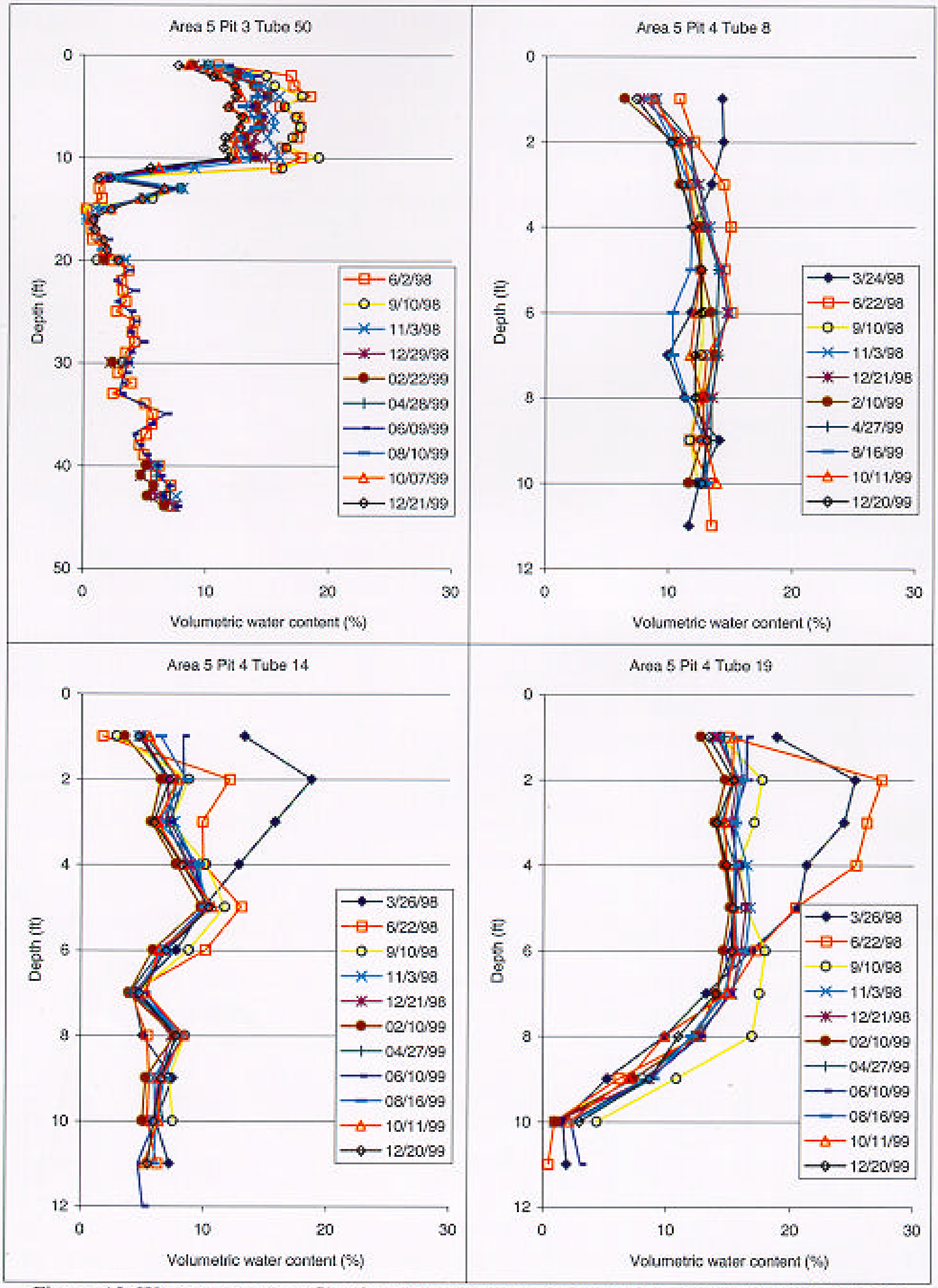


Figure 45. Water content profiles from selected access tubes in the Area 5 RWMS, Pits 3-4.

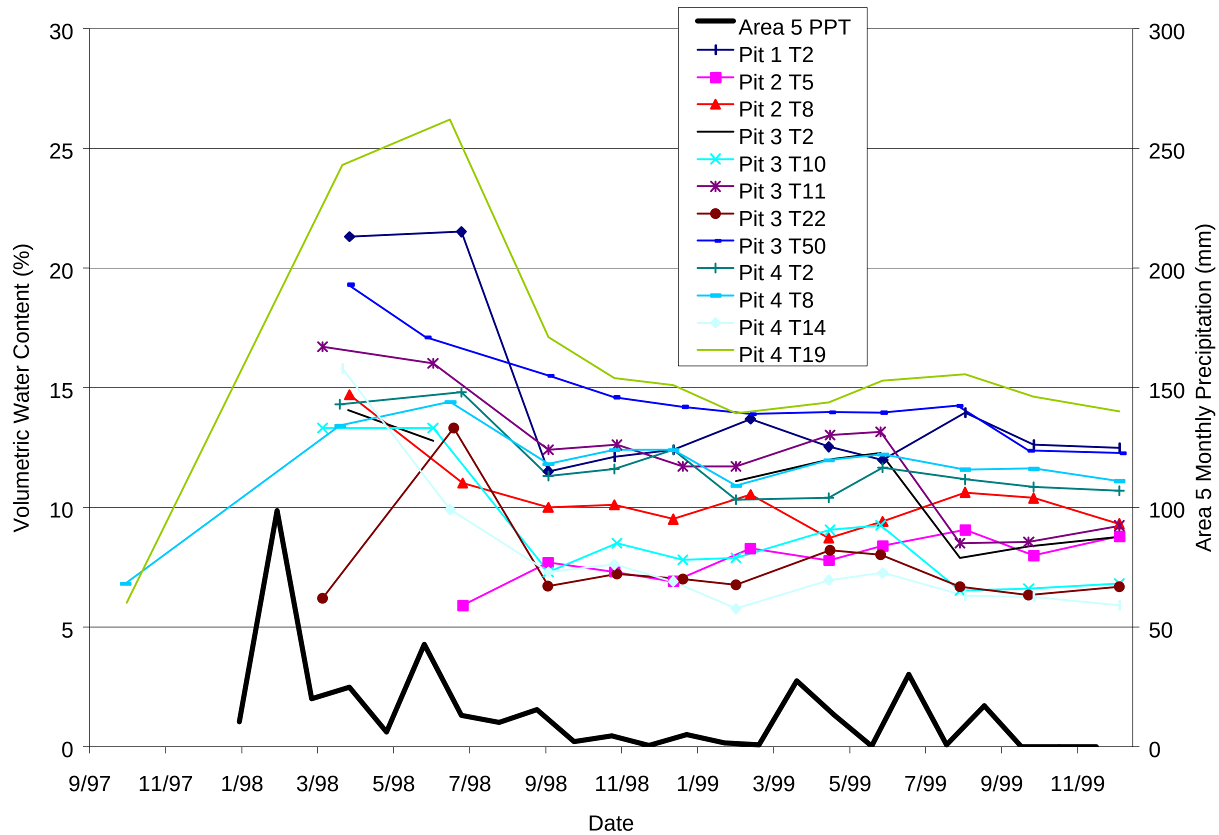


Figure 46. Water contents at 3 ft deep from selected access tubes at the Area 5 RWMS.

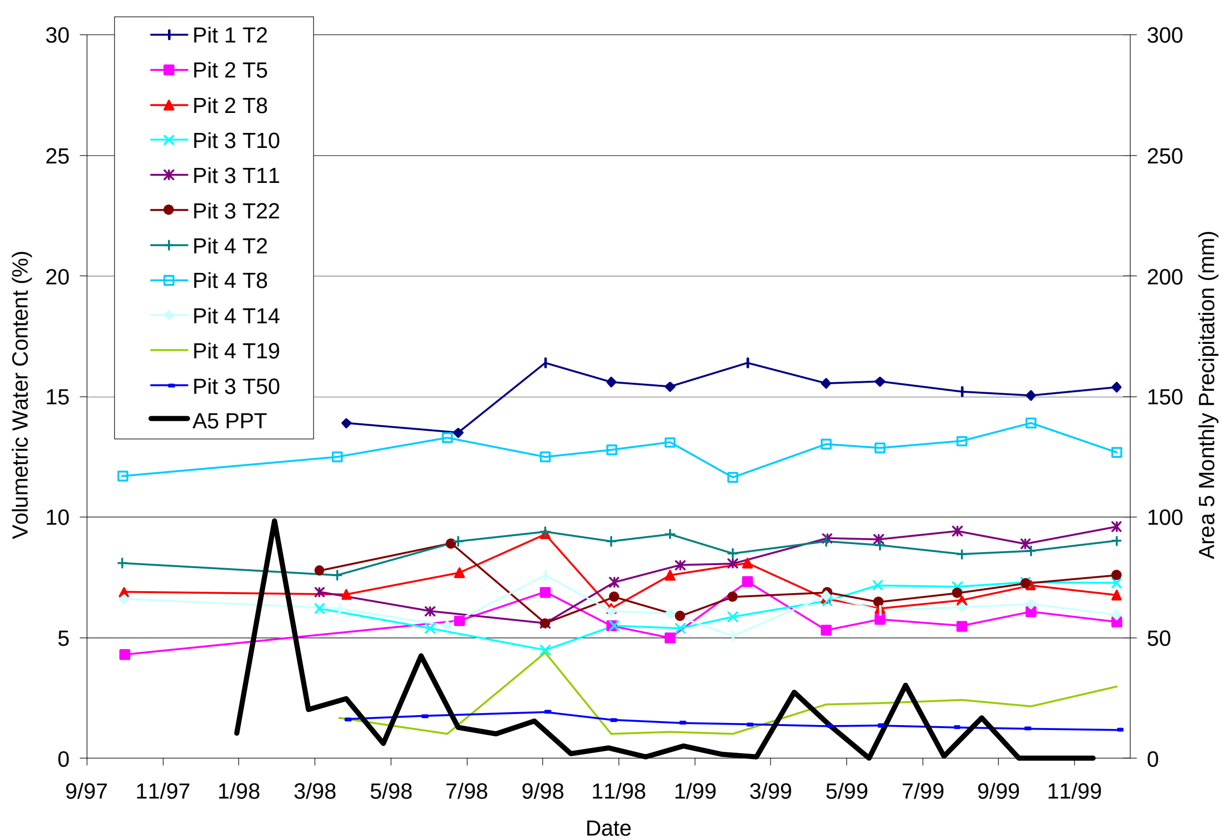


Figure 47. Water contents at 10 ft deep from selected access tubes at the Area 5 RWMS.

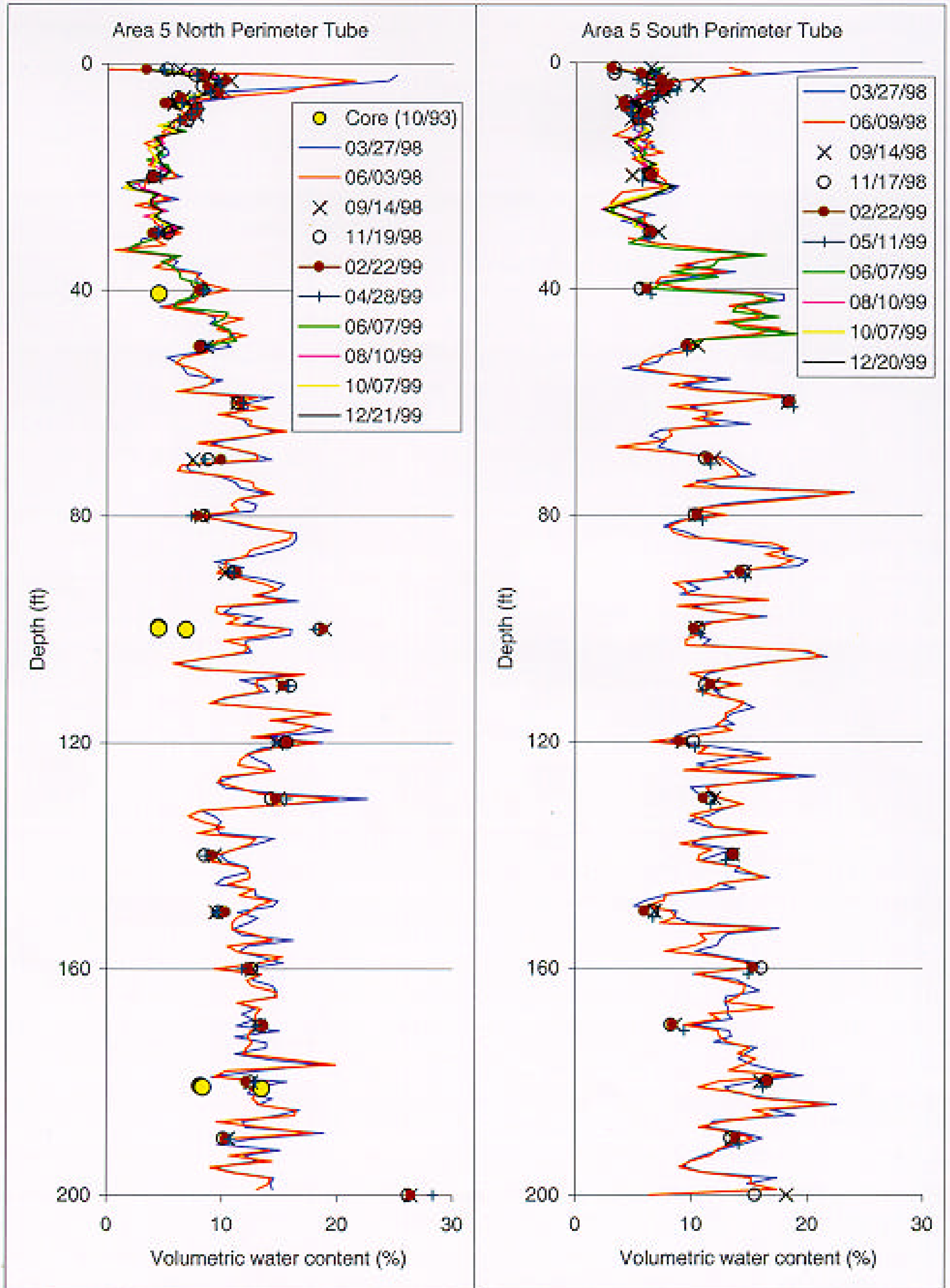


Figure 48. Water content profiles from North and South perimeter tubes at Area 5 RWMS.

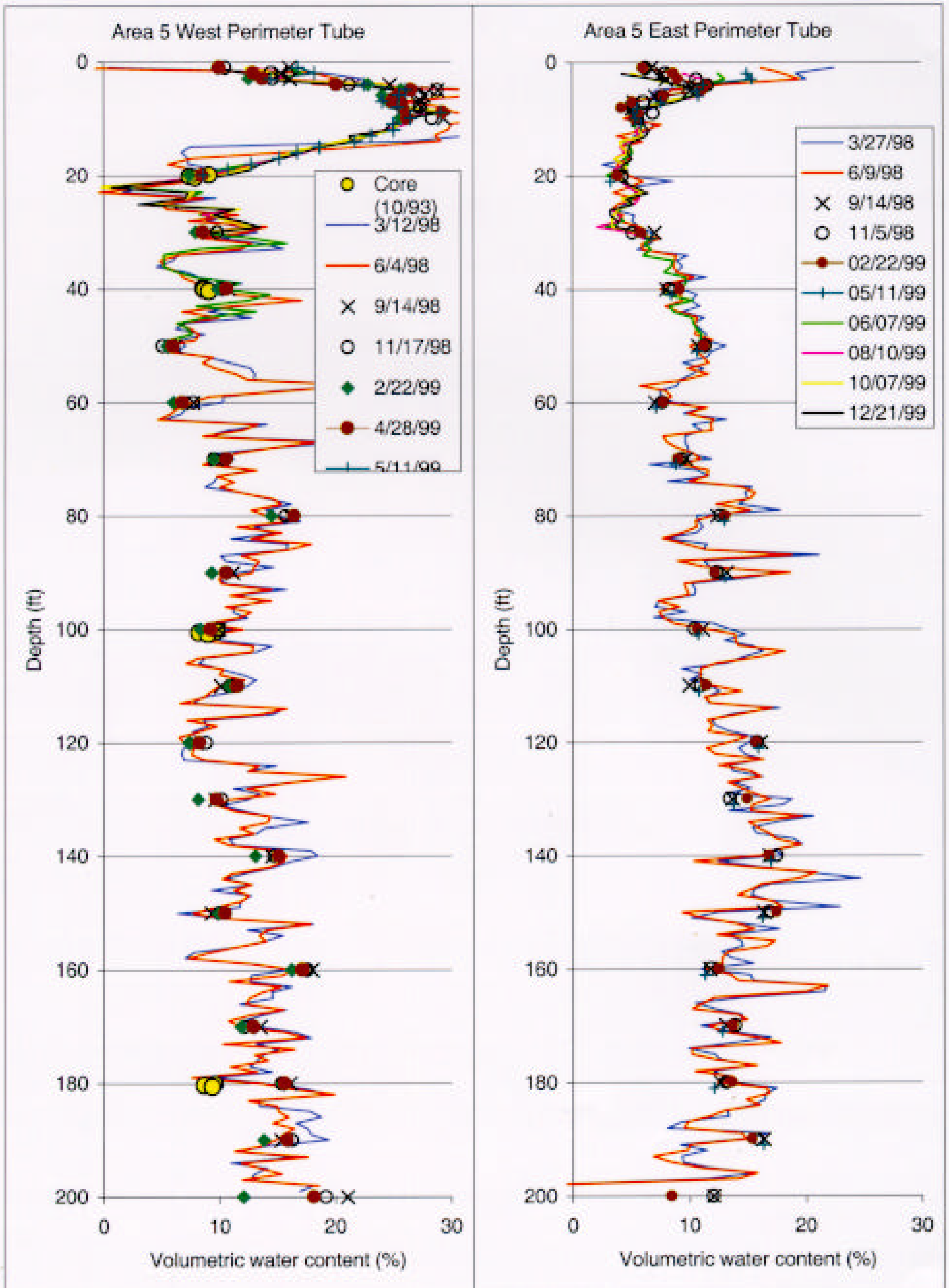


Figure 49. Water content profiles from West and East perimeter tubes at Area 5 RWMS.

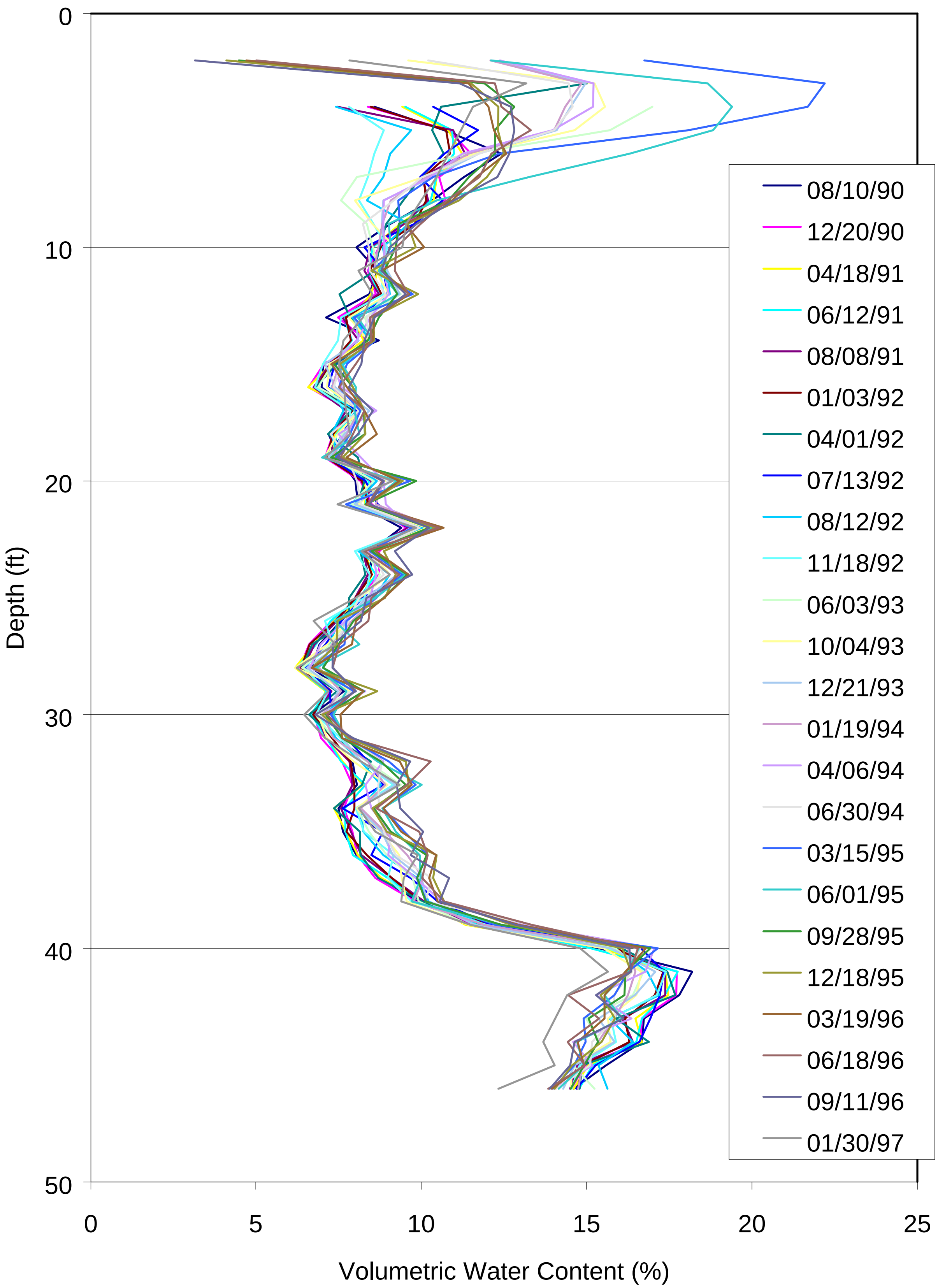


Figure 50. Water content profiles at Pit 3, tube 1, from 1990-1997.

Appendix A: Summary of Monthly and Yearly Meteorology Data

This appendix contains monthly summaries of meteorology data from each of the three meteorology stations for January 1 through December 31, 1999, and yearly summaries of all data.

Meteorology Data Summary
January 1 - December 31, 1999
Area 3 & 5 Radioactive Waste Management Sites, Nevada Test Site
by Bechtel Nevada for the U.S. Dept. of Energy, Nevada Operations Office

STATION: Area 3 RWMS (located NW of Area 3 RWMS)
MONTHLY DATA
LATITUDE: 37° 2' 49.80" N
LONGITUDE: 116° 1' 42.00" W
ELEVATION: 1225 m (4020 ft)
TIME ZONE: PACIFIC STANDARD

NEVADA COORDINATE SYSTEM
(Central)
N 836,800 ft
E 686,600 ft

Month	Tmax 9.5 m (deg C)	Tmax 3.0 m (deg C)	Tmin 9.5 m (deg C)	Tmin 3.0 m (deg C)	Tavg 9.5 m (deg C)	Tavg 3.0 m (deg C)	RHavg 9.5 m (%)	RHavg 3.0 m (%)	Wavg 9.5 m (m/s)	Wavg 3.0 m (m/s)	Wmax 9.5 m (m/s)	Wmax 3.0 m (m/s)	PPT (mm)	BP (kPa)	Srad (MJ/m^2)
Jan 99	19.9	19.6	-9.5	-11.5	5.2	3.8	39.0	40.8	3.5	2.7	16.8	14.5	3.7	88.0	324
Feb 99	20.5	20.8	-9.3	-11.2	5.9	4.9	36.5	37.2	3.5	2.8	21.1	18.0	0.9	88.0	386
Mar 99	22.3	22.7	-7.8	-9.5	9.2	8.4	28.1	28.4	3.8	3.0	21.1	18.1	0.7	87.4	605
Apr 99	27.0	27.6	-7.0	-8.5	9.7	9.2	40.7	41.1	4.3	3.5	20.8	17.8	44.2	87.6	620
May 99	30.2	30.8	1.9	0.4	17.7	17.2	27.0	28.2	4.0	3.3	17.3	14.6	6.7	87.7	856
Jun 99	39.4	40.1	3.7	1.4	22.5	21.7	18.6	19.4	4.2	3.4	20.7	17.0	0.0	87.6	871
Jul 98	38.6	39.2	9.7	6.6	25.2	24.7	30.7	30.8	3.9	3.3	17.6	13.9	15.4	88.0	812
Aug 99	35.4	36.1	8.9	6.2	24.7	23.9	22.2	22.3	3.8	3.1	18.4	16.3	0.4	88.0	792
Sep 99	34.2	34.7	4.8	3.1	21.4	20.5	28.2	29.1	3.4	2.7	22.4	21.6	17.2	87.9	640
Oct 99	31.4	31.7	-0.3	-3.2	15.9	14.4	17.8	18.8	3.2	2.6	17.5	15.9	0.0	88.3	556
Nov 99	26.5	26.6	-7.2	-8.7	9.6	8.0	30.3	31.7	2.8	2.2	17.2	14.2	2.1	88.4	356
Dec 99	19.7	19.5	-9.1	-11.9	4.7	3.6	30.7	31.5	4.0	3.3	21.9	19.4	0.0	88.6	331

Tmax = maximum air temperature
Tmin = minimum air temperature
Tavg = average air temperature
RHavg = average relative humidity
Wavg = average wind speed
Wmax = maximum wind speed
PPT = total precipitation
BP = average barometric pressure
Srad = total solar radiation load

Common units conversions	
Air temperature:	deg F = deg C x 9/5 + 32
Wind speed:	mph = m/s x 2.237
Precipitation:	inches = mm x 25.4
Barometric pressure:	in Hg = kPa x 0.2953
Barometric pressure:	mbar = kPa x 10
Solar radiation load:	langleys = MJ/m^2 x 23.9

Meteorology Data Summary
January 1 - December 31, 1999
Area 3 & 5 Radioactive Waste Management Sites, Nevada Test Site
by Bechtel Nevada for the U.S. Dept. of Energy, Nevada Operations Office

STATION: Area 5 RWMS (located SE of Area 5 RWMS)
MONTHLY DATA
LATITUDE: 36^o 51' 9.13" N
LONGITUDE: 115^o 56' 56.06" W
ELEVATION: 970.7 m (3184 ft)
TIME ZONE: PACIFIC STANDARD

NEVADA COORDINATE SYSTEM
(Central)
N 766,070 ft
E 709,999 ft

MONTH	Tmax 9.5 m (deg C)	Tmax 3.0 m (deg C)	Tmin 9.5 m (deg C)	Tmin 3.0 m (deg C)	Tavg 9.5 m (deg C)	Tavg 3.0 m (deg C)	RHavg 9.5 m (%)	RHavg 3.0 m (%)	Wavg 9.5 m (m/s)	Wavg 3.0 m (m/s)	Wmax 9.5 m (m/s)	Wmax 3.0 m (m/s)	PPT (mm)	BP (kPa)	Srad (MJ/m^2)
Jan 99	19.5	19.7	-10.1	-10.9	6.1	5.2	35.3	38.3	2.8	2.3	17.2	13.9	5.0	90.8	328
Feb 99	22.5	23.2	-7.2	-8.7	7.5	6.8	33.5	36.6	2.8	2.2	18.9	15.6	1.5	90.8	384
Mar 99	24.0	24.9	-5.0	-6.6	11.4	10.8	24.7	26.7	3.6	2.9	18.9	15.6	0.5	90.2	600
Apr 99	29.0	29.8	-6.5	-8.3	11.8	11.6	35.0	37.0	3.7	3.0	18.0	15.8	29.2	90.2	610
May 99	32.6	33.7	4.4	3.6	20.0	19.8	21.7	24.1	3.6	2.9	19.9	16.7	14.4	90.2	843
Jun 99	40.5	41.5	4.0	3.3	24.9	24.6	14.4	16.6	3.8	3.1	18.1	16.7	0.2	90.1	868
Jul 98	41.0	41.8	13.2	11.4	27.7	27.4	28.0	30.2	3.6	2.9	17.9	14.1	37.2	90.4	789
Aug 99	37.5	38.4	11.6	9.4	27.4	27.0	18.1	20.0	3.4	2.8	19.1	16.4	2.5	90.4	770
Sep 99	36.2	37.2	8.3	5.7	23.6	23.1	24.9	27.4	2.8	2.3	14.8	12.4	14.5	90.4	624
Oct 99	33.6	34.0	1.0	-1.6	17.5	16.3	14.9	17.8	2.4	2.0	15.4	13.3	0.0	90.8	541
Nov 99	28.1	27.9	-7.1	-8.9	10.6	9.4	25.4	28.4	2.2	1.8	17.0	12.8	0.0	90.9	364
Dec 99	20.3	20.4	-9.8	-10.6	5.7	4.8	26.9	29.8	3.0	2.4	19.7	15.7	0.0	91.2	325

Tmax = maximum air temperature
Tmin = minimum air temperature
Tavg = average air temperature
RHavg = average relative humidity
Wavg = average wind speed
Wmax = maximum wind speed
PPT = total precipitation
BP = average barometric pressure
Srad = total solar radiation load

Common units conversions	
Air temperature:	deg F = deg C x 9/5 + 32
Wind speed:	mph = m/s x 2.237
Precipitation:	inches = mm x 25.4
Barometric pressure:	in Hg = kPa x 0.2953
Barometric pressure:	mbar = kPa x 10
Solar radiation load:	langleys = MJ/m^2 x 23.9

Meteorology Data Summary
January 1 - December 31, 1999
Area 3 & 5 Radioactive Waste Management Sites, Nevada Test Site
by Bechtel Nevada for the U.S. Dept. of Energy, Nevada Operations Office

STATION: Area 5 LYSIMETER (located SW of Area 5 RWMS)
MONTHLY DATA
LATITUDE: 36^o 51' 7.09" N
LONGITUDE: 115^o 57' 44.28" W
ELEVATION: 972.9 m (3191 ft)
TIME ZONE: PACIFIC STANDARD

NEVADA COORDINATE SYSTEM
(Central)
N 765,836 ft
E 706,083 ft

	Tmax 9.5 m	Tmax 3.0 m (deg C)	Tmin 9.5 m (deg C)	Tmin 3.0 m (deg C)	Tavg 9.5 m (deg C)	Tavg 3.0 m (deg C)	RHavg 9.5 m (deg C)	RHavg 3.0 m (%)	Wavg 9.5 m (%)	Wavg 3.0 m (m/s)	Wmax 9.5 m (m/s)	Wmax 3.0 m (m/s)	Wmx3 (m/s)	PPT (mm)	BP (kPa)	Srad (MJ/m^2)
Jan 99	19.4	19.9	-10.6	-11.0	6.0	5.1	39.6	38.6	2.6	2.2	15.9	13.2	5.0	91.0	339	
Feb 99	22.5	23.2	-7.5	-8.8	7.5	6.8	37.7	37.0	2.7	2.2	18.3	15.7	1.5	91.0	398	
Mar 99	24.2	25.1	-5.4	-6.6	11.4	10.8	27.9	27.0	3.5	2.8	19.3	15.3	0.5	90.3	618	
Apr 99	29.2	29.7	-7.0	-8.4	11.9	11.8	39.2	37.1	3.7	3.0	17.2	14.5	29.2	90.2	631	
May 99	32.6	33.7	4.4	2.9	20.0	19.8	24.2	24.7	3.5	2.8	20.8	18.2	14.4	90.1	864	
Jun 99	40.7	41.7	3.8	3.2	25.0	24.5	14.9	17.1	3.7	3.0	18.8	15.1	0.2	90.0	878	
Jul 98	41.0	42.1	13.4	10.7	27.5	27.3	29.3	30.7	3.5	2.8	18.4	14.7	37.2	90.3	820	
Aug 99	37.5	38.8	11.4	8.9	27.4	27.0	18.7	20.1	3.3	2.7	18.8	14.4	0.0	90.3	793	
Sep 99	36.4	37.2	8.1	4.9	23.6	23.1	26.6	27.9	2.7	2.2	16.0	14.0	16.6	90.3	645	
Oct 99	33.3	33.7	0.9	-2.1	17.4	16.3	16.6	18.6	2.4	2.0	15.9	12.7	0.0	90.8	565	
Nov 99	27.6	28.1	-7.8	-9.7	10.4	9.2	28.8	28.9	2.0	1.7	14.9	12.5	0.0	90.9	382	
Dec 99	20.6	21.0	-9.3	-10.6	5.7	4.8	30.8	30.3	2.8	2.3	19.6	15.2	0.0	91.1	341	

Tmax = maximum air temperature
Tmin = minimum air temperature
Tavg = average air temperature
RHavg = average relative humidity
Wavg = average wind speed
Wmax = maximum wind speed
PPT = total precipitation
BP = average barometric pressure
Srad = total solar radiation load

Common units conversions	
Air temperature:	deg F = deg C x 9/5 + 32
Wind speed:	mph = m/s x 2.237
Precipitation:	inches = mm x 25.4
Barometric pressure:	in Hg = kPa x 0.2953
Barometric pressure:	mbar = kPa x 10
Solar radiation load:	langleys = MJ/m^2 x 23.9

Meteorology Data Summary
Area 3 & 5 Radioactive Waste Management Sites, Nevada Test Site
by Bechtel Nevada for the U.S. Dept. of Energy, Nevada Operations Office

STATION: Area 3 RWMS (located NW of Area 3 RWMS)
YEARLY DATA
LATITUDE: 37° 2' 49.80" N
LONGITUDE: 116° 1' 42.00" W
ELEVATION: 1225 m (4020 ft)
TIME ZONE: PACIFIC STANDARD

NEVADA COORDINATE SYSTEM
(Central)
N 836,800 ft
E 686,600 ft

DATE	Tmax 9.5 m (deg C)	Tmax 3.0 m (deg C)	Tmin 9.5 m (deg C)	Tmin 3.0 m (deg C)	Tavg 9.5 m (deg C)	Tavg 3.0 m (deg C)	RHavg 9.5 m (%)	RHavg 3.0 m (%)	Wavg 9.5 m (m/s)	Wavg 3.0 m (m/s)	Wmax 9.5 m (m/s)	Wmax 3.0 m (m/s)	PPT (mm)	BP (kPa)	Srad (MJ/m^2)
1996	39.4	40.0	-12.4	-13.7	15.2	14.6	30.9	35.2			21.4	17.9	112.4	87.5	7369
1997	39.1	39.9	-10.6	-12.2	14.5	13.8	33.5	34.7			25.4	23.2	123.9	87.7	6960
1998	41.3	41.4	-13.5	-17.4	12.8	12.0	42.6	45.5			31.9	21.8	374.1	87.6	6860
1999	39.4	40.1	-9.5	-11.9	14.3	13.4	29.2	29.9	3.7	3.0	22.4	21.6	91.5	88.0	7148

STATION: Area 5 RWMS (located SE of Area 5 RWMS)
YEARLY DATA
LATITUDE: 36° 51' 9.13" N
LONGITUDE: 115° 56' 56.06" W
ELEVATION: 970.7 m (3184 ft)
TIME ZONE: PACIFIC STANDARD

NEVADA COORDINATE SYSTEM
(Central)
N 766,070 ft
E 709,999 ft

DATE	Tmax 9.5 m (deg C)	Tmax 3.0 m (deg C)	Tmin 9.5 m (deg C)	Tmin 3.0 m (deg C)	Tavg 9.5 m (deg C)	Tavg 3.0 m (deg C)	RHavg 9.5 m (%)	RHavg 3.0 m (%)	Wavg 9.5 m (m/s)	Wavg 3.0 m (m/s)	Wmax 9.5 m (m/s)	Wmax 3.0 m (m/s)	PPT (mm)	BP (kPa)	Srad (MJ/m^2)
1994	42.6	43.0	-11.7	-13.2	17.4	17.0					20.1	16.7	95.5	90.4	
1995	41.6	43.0	-11.1	-11.4	16.3	15.8	36.2	39.4			20.7	19.3	136.8	90.4	6975
1996	41.4	42.8	-10.8	-12.9	17.0	16.6	30.8	33.2			18.6	16.6	76.8	90.4	7065
1997	41.5	42.7	-10.1	-11.8	16.5	16.1	34.0	35.8			20.4	15.7	82.7	90.5	7090
1998	43.0	43.8	-13.8	-15.0	15.0	14.6	39.4	38.4			25.2	22.2	244.2	90.5	6816
1999	41.0	41.8	-10.1	-10.9	16.2	15.6	25.3	27.7	3.2	2.5	19.9	16.7	105.0	90.5	7045

STATION: Area 5 LYSIMETER (located SW of Area 5 RWMS)
YEARLY DATA
LATITUDE: 36° 51' 7.09" N
LONGITUDE: 115° 57' 44.28" W
ELEVATION: 972.9 m (3191 ft)
TIME ZONE: PACIFIC STANDARD

NEVADA COORDINATE SYSTEM
(Central)
N 765,836 ft
E 706,083 ft

DATE	Tmax 9.5 m (deg C)	Tmax 3.0 m (deg C)	Tmin 9.5 m (deg C)	Tmin 3.0 m (deg C)	Tavg 9.5 m (deg C)	Tavg 3.0 m (deg C)	RHavg 9.5 m (%)	RHavg 3.0 m (%)	Wavg 9.5 m (m/s)	Wavg 3.0 m (m/s)	Wmax 9.5 m (m/s)	Wmax 3.0 m (m/s)	PPT (mm)	BP (kPa)	Srad (MJ/m^2)
1994	42.2	43.1	-12.5	-13.7	17.5	16.8					21.2	18.5	87.5	90.3	
1995	41.6	42.6	-11.3	-11.9	16.4	15.7		38.0			21.4	17.2	151.8	90.3	6945
1996	41.6	42.4	-11.1	-12.8	17.2	16.5	28.1	31.3			18.9	16.5	75.8	90.3	7011
1997	41.1	42.0	-10.3	-11.2	16.7	16.3	31.3	33.8			19.0	15.7	82.9	90.5	7183
1998	43.5	44.7	-15.1	-16.3	14.9	14.7	41.8	40.4			25.6	20.1	239.1	90.5	6900
1999	41.0	42.1	-10.6	-11.0	16.2	15.5	27.9	28.2	3.0	2.5	20.8	18.2	104.6	90.5	7274

Tmax = maximum air temperature
Tmin = minimum air temperature
Tavg = average air temperature
RHavg = average relative humidity

Wavg = average wind speed
Wmax = maximum wind speed
PPT = total precipitation
BP = average barometric pressure
Srad = total solar radiation load

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