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# *Nevada Test Site*

## **2002 Waste Management Monitoring Report Area 3 and Area 5 Radioactive Waste Management Sites**

**June 2003**

*Prepared for:*  
**U.S. Department of Energy  
National Nuclear Security Administration  
Nevada Site Office**

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**2002 Waste Management Monitoring Report**

**Area 3 and Area 5 Radioactive Waste Management Sites**

**June 2003**

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

**Prepared for:**

**U.S. Department of Energy  
Nevada Site Office**

**Prepared by**

***Bechtel Nevada***

A small graphic element consisting of a series of black and white triangles, resembling a stylized mountain range or a sawtooth pattern, positioned directly beneath the company name.

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**LIST OF ACRONYMS**

ASER	Annual Site Environmental Report
BD	Bulk Density
BEIDMS	Bechtel Environmental Integrated Data Management System
BJY	Buster-Jangle Y
BN	Bechtel Nevada
CFR	Code of Federal Regulations
DCG	Derived Concentration Guide
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
E	Evaporation
EIC	Electret Ion Chamber
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
GCD	Greater Confinement Disposal
ICRP	International commission on Radiological Protection
LLW	Low-Level Waste
LLWMU	Low-Level Waste Management Unit
MDC	Minimum Detectable Concentration
MSL	Mean Sea Level
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NPCF	Neutron Probe Calibration Facility
NTS	Nevada Test Site
PA	Performance Assessment
PET	Potential Evapotranspiration
PPT	Precipitation
QAASP	Quality Assurance, Analysis, and Sampling Plan
REEC <sub>o</sub>	Reynolds Electrical and Engineering Co., Inc.
REM	Roentgen Equivalent Man
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
TDR	Time Domain Reflectometry
TLD	Thermoluminescent Dosimeter
TOC	Total Organic Carbon
TOX	Total Organic Halogen
TRU	Transuranic
TTR	Tonopah Test Range
VWC	Volumetric Water Content
WSS	Work Smart Standards



## EXECUTIVE SUMMARY

Environmental, subsidence, and meteorological 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, subsidence, and biota data. Although some of these media (radiation exposure, air, and groundwater) are reported in detail in other Bechtel Nevada (BN) 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. Groundwater monitoring data indicate that the groundwater in the uppermost aquifer beneath the Area 5 RWMS has not been affected by the facility. Meteorological data indicate that 2002 was a dry year: rainfall totaled 26 mm (1.0 in) at the Area 3 RWMS and 38 mm (1.5 in) at the Area 5 RWMS. Vadose zone monitoring data indicate that 2002 rainfall infiltrated less than 30 cm (1 ft) before being returned to the atmosphere by evaporation. Soil-gas tritium monitoring data indicate slow subsurface migration, and tritium concentrations in biota were lower than in previous years. Special investigations conducted in 2002 included: a comparison between waste cover water contents measured by neutron probe and coring; and a comparison of four methods for measuring radon concentrations in air. All 2002 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing within expectations of the model and parameter assumptions for the facility Performance Assessments (PAs).

## INTRODUCTION

This document summarizes the calendar year 2002 environmental monitoring data, as well as meteorology and subsidence monitoring data, collected for the Waste Management monitoring program for the Area 3 and Area 5 RWMSs. Refer to the RWMS Integrated Closure and Monitoring Plan (BN, 2001a) for details of the RWMS monitoring program. This report summarizes radiation exposure, air, groundwater, meteorology, vadose zone, subsidence, and biota data. These data are collected as required by BN and the 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). For a detailed description of these regulatory drivers, refer to BN (2001a). These WSS and 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 435.1 (Radioactive Waste Management).
- 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 and confirm compliance with NESHAP. Groundwater monitoring is conducted, as required by EPA regulations and DOE orders, to assess the water quality of the aquifer beneath the RWMS and 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 PAs, including no downward pathway, and evaluate the performance of the operational monolayer evapotranspiration (ET) 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. Subsidence monitoring is conducted to ensure that subsidence features are repaired to prevent the development of preferential pathways through the covers.

Details of the Quality Assurance, Analysis, and Sampling Plans (QAASPs) can be found in the Routine Radiological Environmental Monitoring Plan (RREMP) (BN, 1998a; 2003b). The RREMP was written through a Data Quality Objectives (DQO)-driven process to identify how and what technically-defensible environmental monitoring data are collected.

## **SITE DESCRIPTIONS**

### **Area 3 RWMS**

The Area 3 RWMS is located on Yucca Flat within the NTS. Yucca Flat is an elongated, sediment-filled basin that trends roughly north-south; the long axis extends approximately 27 km (17 mi), and the short axis approximately 16 km (10 mi). Yucca Flat is bound by Quartzite Ridge and Rainer Mesa on the north, the Halfpint Range on the east, the Massachusetts Mountains and Control Point Hills on the south, and Mine Mountain and the Eleana Range on the west. The Yucca Flat basin slopes from the north at an elevation of approximately 1,402 m (4,600 ft) above mean sea level (MSL) to the south toward Yucca playa, with the lowest part of the basin at an elevation of approximately 1,189 m (3,900 ft) above MSL. Yucca Flat was one of the several primary nuclear test areas and most of the length of the valley is marked with subsidence craters.

The thickness of the unsaturated zone at the Area 3 RWMS is estimated to be 488 m (1,600 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 (1,000 and 1,500 ft) below land surface.

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 42-year record (1961-2002) at a station located 4.5 km (2.8 mi) northwest of the RWMS is 162 mm (6.4 inches). Precipitation is highly variable, with scant precipitation being recorded in some years. Average annual potential evapotranspiration (PET) at the Area 3 RWMS, calculated using local meteorology data is approximately 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. It is bounded on the north by the Massachusetts Mountains 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. Ground-surface elevations range from 938 m (3,078 ft) above MSL at the playa to over 1,220 m (4,000 ft) above MSL in the nearby surrounding mountains.

The thickness of the unsaturated zone at the Area 5 RWMS is 235 m (770 ft) at the southeast corner of the RWMS (at Ue5PW-1), 256 m (840 ft) at the northeast corner of the RWMS (at Ue5PW-2), and 271 m (890 ft) to the northwest of the RWMS (at Ue5PW-3). Boreholes Ue5PW-1 and Ue5PW-2 penetrate only alluvium, while Ue5PW-3 encounters Tertiary tuff at a depth of approximately 189 m (620 ft).

Air temperatures can vary from -15°C (5°F) to 24°C (75°F) in winter and from 16°C (60°F) to 45°C (113°F) in summer. The climate of Frenchman Flat is arid. The average annual precipitation based on a 40-year record (1963-2002) at a station located 6.4 km (4 mi) south of the RWMS is 123 mm (4.9 in). Precipitation is highly variable, with scant precipitation being recorded in some years. Average annual PET at the Area 5 RWMS, calculated using local meteorology data, is approximately 13 times the annual average precipitation.

Areas 3 and 5 are similar, except for slight 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°C (4°F) cooler than at Area 5; and soils at Area 3 are generally finer-grained 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 zone are quite low. Below the near-surface region is a region where relatively steady upward movement of water is occurring. In this zone of slow upward water movement, stable isotope compositions of soil pore water confirm that evaporation is the dominant process (Tyler et al., 1996). This zone 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 zone, water potential measurements indicate the existence of a static zone, 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 zone, essentially no vertical liquid flow is currently occurring. Below this static zone, flow is steady and downward due to gravity. Stable isotope compositions of pore water from these depths indicate that infiltration into this zone occurred under cooler, past climatic conditions (Tyler et al., 1996). If water were to migrate below the currently static zone, movement to the groundwater would be extremely slow due to the low water content of the alluvium. Estimates of travel time to the groundwater (assuming zero upward flux), based on hydraulic characteristics of the alluvium and

assuming current conditions would still apply, are in excess of 500,000 years in Area 3 (Levitt and Yucel, 2002), and 50,000 years in Area 5 (Shott et al., 1998). Refer to Figure 2 for a diagram of the vadose zone hydrologic conceptual models at the Area 3 and Area 5 RWMSs.

Based on the results of extensive research, field studies, modeling efforts, and monitoring data, which are summarized in the Area 3 and Area 5 Performance Assessments (Shott et al., 1997; 1998), in Levitt et al. (1999), and in Levitt and Yucel (2002), groundwater recharge is not occurring under current climatic conditions at the RWMSs. Studies indicate that under bare-soil conditions such as those found at the operational waste cell covers, some drainage may eventually 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 one-dimensional modeling results (Levitt et al., 1999). In addition, monitoring data from a bare-soil weighing lysimeter located in Area 5 indicate that the soil water storage has increased slowly with time, although no free drainage has been measured through the bottom of the lysimeter.

## PROJECT DESCRIPTION

The Area 3 and Area 5 RWMSs, at the NTS, are designed and operated for disposal of low-level waste (LLW) from onsite, DOE offsite, and other approved offsite generators and mixed waste from onsite. 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 177 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. Craters U-3ax and U-3bl were combined to form the U-3ax/bl disposal unit, which is now covered with at least a 2.4 m-thick (8 ft-thick) vegetated native alluvium closure cover. For details of the final closure plan of U-3ax/bl disposal unit, refer to BN (2000). 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 Figure 1 for locations of the NTS and the RWMSs within the NTS, and refer to Figure 3 for locations of waste disposal cells at the Area 3 RWMS. 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 1960s. The LLWMU consists of 24 landfill cells (pits and trenches) and 13 Greater Confinement Disposal (GCD) boreholes. Some previous documents list 22 landfill cells, but BN (2001a) lists 23 cells by separating T04C and T04C-1. Pit 8 (P08U) was excavated in 2001, so there are currently 24 landfill cells.

Four of the GCD boreholes were used to bury classified transuranic (TRU) material 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 24 landfill cells, 3 pits and 14

trenches have been closed. The remaining five pits (P03U, P05U, P06U, P07U, and P08U) and two trenches (T07C and T08C) are open. Refer to Figure 4 for locations of pits and trenches at the Area 5 RWMS. 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). For further descriptions of pits, trenches, and GCD boreholes, refer to BN (2001a) and Cochran et al. (2001).

## ENVIRONMENTAL MONITORING DATA

### Data Summary

Area 3 RWMS monitoring locations are shown in Figure 3, and Area 5 RWMS monitoring locations are shown in Figures 4 and 5. Environmental monitoring data are in the process of being 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. Monitoring data currently being collected 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 americium concentrations
- Monthly plutonium concentrations
- Quarterly radon concentrations
- Annual radon flux measurements from waste covers

#### Groundwater monitoring data

- Quarterly water level measurements (manual)
- Continuous (hourly and daily averages) water level measurements (datalogger)

#### *Indicators of Contamination (semi-annual):*

- pH (field)
- specific conductance (field)
- total organic carbon (TOC)
- total organic halogen (TOX)
- tritium

*Routine Radiological Environmental Monitoring Plan (RREMP) data (biennial):*

- gross alpha
- gross beta
- gamma spectroscopy
- plutonium-238, and plutonium-239+240

*General Water Chemistry Parameters (semi-annual):*

- total Ca, Fe, Mg, Mn, K, Na, Si
- total SO<sub>4</sub>, Cl, F
- alkalinity

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 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
- Total precipitation

Vadose zone monitoring data*Annual soil gas-phase monitoring data:*

- Soil gas tritium concentrations measured at GCD-05U gas sampling ports (9 depths)

*Daily weighing lysimeter data:*

- Daily evaporation from the bare-soil weighing lysimeter
- Daily evapotranspiration from the vegetated weighing lysimeter

*Daily automated vadose zone monitoring system data:*

- Soil volumetric water content with depth in waste covers
- Soil volumetric water content beneath waste cells
- Soil matric potential with depth in waste covers
- Soil temperature with depth in waste covers
- Soil temperature beneath waste cells

*Neutron logging data:*

- Soil volumetric water content with depth at selected neutron access tubes

*Monthly subsidence monitoring data:*

- Locations and description of subsidence features on waste covers

Biota monitoring data

- Locations of sampled plants and plant water tritium concentrations

**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 for environmental monitoring data from the NTS.

**Radiation Exposure Data**

A comparison of 1998-2002 direct radiation exposure data using TLDs from the two RWMSs and background data from locations several kilometers away from the RWMSs (Well 5B and Buster-Jangle Y [BJY]) is presented in Figure 6. These data indicate that direct radiation exposure at the RWMSs was low. The two sites with the highest exposures (RWMS-S and U-3CO N in Area 3) are each located near a ground zero for past atmospheric nuclear tests. All sites had direct radiation exposures of less than 1.5 milliRoentgen (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) (International Commission on Radiological Protection [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. Note that the average annual dose equivalent from all radiation sources to the general public is approximately 1 mrem/day. These data are also presented in the annual ASER and NESHAP reports.

**Air Monitoring Data**Tritium

Atmospheric moisture is collected and analyzed for tritium at the Area 5 RWMS. Tritium is a highly mobile isotope of hydrogen that acts as a conservative tracer and is therefore an excellent

performance indicator of volatile radionuclide migration from waste cells. Tritium concentrations in air at the Area 5 RWMS are presented in Figure 7. Tritium concentrations in air from Schooner and Guard Station 510 are also included in Figure 7 for comparison. Schooner is located near the northwest corner of the NTS and the site of one “plowshare” test that resulted in elevated tritium concentrations in surface soils, and data from Guard Station 510, located at the southwest edge of the NTS, can be considered background. This figure indicates slightly elevated tritium concentrations in air at the Area 5 RWMS northeast station, but well below any concentrations of concern (the DOE Order 5400.5 [DOE, 1990] Derived Concentration Guide [DCG] level for the general public for tritium in air is  $1\text{E}5\text{ pCi/m}^3$ ). Note that the tritium concentrations at the Department of Defense (DoD) and Sugar Bunker stations were usually below the mean minimum detectable concentration (MDC) for tritium. The DoD and Sugar Bunker stations are located to the north and south of the Area 5 RWMS, respectively. There are no tritium monitoring stations at the Area 3 RWMS due to the lack of a tritium source. These data are also presented in detail in the annual ASER and NESHAP reports.

### Particulates

Air particulate samples are collected at the RWMSs and are analyzed for gross alpha radiation, gross beta radiation, gamma radiation, americium concentrations, and plutonium concentrations in air. Air particulate monitoring data indicate that radionuclide concentrations in air at the RWMSs in 2002 were not above other nearby stations. However, some radionuclide concentrations are usually higher at the Area 3 RWMS than at offsite monitoring stations. These elevated concentrations are not caused by waste management activities. They are caused by nearby contamination areas from atmospheric tests that immediately surround the Area 3 RWMS. This is evident in Figures 8 and 9, where plutonium concentrations in air are elevated at the Area 3 RWMS, compared with the mean MDC, but are generally lower than the concentrations at Bunker 9-300 (for Pu-239+240), which is surrounded by contamination areas from atmospheric tests. The DOE Order 5400.5 DCG level for Pu-238 and Pu-239+240 is  $0.04\text{ pCi/m}^3$ . These data are also presented in detail in the annual ASER and NESHAP reports.

### Radon

Radon flux measurements were conducted on the waste cell cover of Pit 1 (P01U) at the Area 5 RWMS from March 25 to April 2, 2002. Measurements were made using radon flux domes (Rad Elec, Inc.) at 27 locations in an array of  $3 \times 9$  spread over an area of approximately  $5,600\text{ m}^2$ . Pit 1 was selected for the flux analyses because Pit 1 has the highest radium inventory at the Area 5 RWMS. Two radon flux measurements were taken at the Area 5 RWMS lysimeter and pilot well #1 areas for comparison. Refer to Figure 10 for results of the 2002 flux measurements, and refer to Figure 11 for a comparison of results with measurements taken during previous years. These data indicate that radon flux is well below the performance objective (DOE Order 435.1), and regulatory limit (40 CFR 61, subpart Q), of  $20\text{ pCi/m}^2/\text{s}$ .

Radon concentrations in air were measured at 18 locations: six within the Area 3 RWMS, seven within the Area 5 RWMS, and five background sites (two near the Area 3 RWMS and three near the Area 5 RWMS). Measurements were made using the following detectors: electret ion chambers (EIC) using both TLD and EIC measured background gamma exposure, alpha track detectors manufactured by Radon Environmental Monitoring Company and alpha track detectors manufactured by Landauer, Incorporated. Detectors were exchanged quarterly. Results from all



locations over the past four years are shown in Figure 12. Overall, the radon concentration in air averaged about 1.0 pCi/L (standard deviation = 0.46, median = 0.96). The general pattern showed EIC measurements with TLD gamma correction tended to be higher (average and median = 1.3 pCi/L) and the Landauer alpha track detectors tended to be lower (average = 0.5, median = 0.4 pCi/L), with Radon Environmental Monitoring Company alpha track detectors and EIC measurements with EIC gamma corrections being intermediate (average = 0.6 and 0.7 pCi/L, respectively). While there appeared to be systematic differences between measurement methods, all measurements were very low. Because radon concentrations in air have been well-documented and compliance with the regulatory limit is demonstrated with radon flux measurements, future resources will be spent primarily on increasing radon flux measurements. Efforts will also be made to investigate the systematic differences between the radon in air measurement methods.

### **Groundwater Monitoring Data**

These data are presented in detail in the BN 2002 Data Report (BN, 2003a). All validated 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. Groundwater elevation measurements are taken quarterly using an electronic tape, and continuous measurements are taken using pressure transducers that are wired into dataloggers. Water level measurements by manual “tagging” and using pressure transducer data since 1999 are illustrated in Figure 13. Note how the groundwater elevation in these wells responds to atmospheric barometric pressure. Some apparent stretch has been observed when first deploying the transducers, resulting in an apparent rise in water level. Additionally, some ongoing apparent stretch is observed in the data. This may be due to transducer cables slowly straightening out from residual reel memory. All transducers are currently outfitted with a manufacturer-designed weight to eliminate this problem. All groundwater elevation tagging data collected since the wells were drilled in 1993 are shown in Figure 14. These 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 in) per year. Refer to Figure 5 for locations of the three Area 5 RWMS pilot wells.

### **Meteorology Monitoring Data**

Meteorology monitoring data collected in 2002 include: precipitation, air temperature, humidity, wind speed and direction, barometric pressure, incoming solar radiation load, net radiation, 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 were collected from one meteorology station near the Area 3 RWMS, and one meteorology station near the Area 5 RWMS.

Refer to Figures 3 and 4 for specific locations of the meteorology monitoring stations. The Area 3 RWMS meteorology station is located approximately 30 m (100 ft) northwest of the Area 3 RWMS. The Area 5 RWMS meteorology station is located southeast of the Area 5 RWMS, about 100 m (328 ft) from Ue5PW-1.

Selected figures are included that illustrate basic weather data at the Area 3 and Area 5 RWMSs: daily maximum/minimum air temperature, daily average relative humidity, daily average barometric pressure, and daily maximum and average wind speeds are shown in Figures 15 to 19.

#### Potential Evapotranspiration

The total calculated PET in 2002 for Areas 3 and 5 was 1,821 mm (72 in) and 1,818 mm (72 in), respectively. The PET was calculated using the radiation-based equation of Doorenbos and Pruitt (1977), which requires the following data inputs: solar radiation, air temperature, relative humidity, wind speed, and barometric pressure. This method provides results similar to the previously used Penman Equation (Jensen et al., 1990), but with reduced data input needs and lower maintenance costs. A comparison of daily PET calculated using these two PET calculation methods and using data from the Area 5 RWMS meteorology station are shown in Figure 20. Figure 20 demonstrates the similarity of these measurements, except for a period in July-August when the net radiometer dome was broken. Due to this similarity in results, and the difficulty in maintaining net radiometers in the arid environment of the NTS, the instrumentation required for the Penman Equation (net radiometer and soil heat flux plates) will be removed and PET will be calculated using the radiation-based equation in the future.

#### Precipitation Data

The year 2002 was the driest year on record at Area 3, and the second driest year (1989 was drier) on record at Area 5: rainfall totaled 26 mm (1.0 in) at the Area 3 RWMS (annual average at BJY station is 6.7 in) and 38 mm (1.5 in) at the Area 5 RWMS (annual average at Well 5B station is 6.4 in). It is notable that Area 3 received less rain than Area 5 in 2002, despite the higher elevation of Area 3. Figures 21 and 22 depict daily total precipitation. Figure 23 depicts historical precipitation recorded at BJY station (located about 3 km northwest of the Area 3 RWMS) and Well 5B station (located about 5.5 km south of the Area 5 RWMS).

#### Wind Roses

Wind roses from the Area 3 and Area 5 RWMS meteorology stations are presented in Figures 24 and 25, respectively. 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. The one-year wind roses presented here are very similar to the multiple-year wind roses presented in BN (2001b).

### **Vadose Zone Monitoring Data**

#### Vadose Zone Monitoring Strategy

Vadose zone monitoring is conducted at the Area 3 and Area 5 RWMSs to demonstrate compliance with DOE Orders 5400.1 and 435.1 to test PA assumptions regarding the hydrologic conceptual model including soil water contents, upward and downward flux rates, and volatile radionuclide releases; detect changing trends in performance; provide added assurance to PA conclusions regarding facility performance; evaluate the performance of the operational monolayer waste covers; and confirm the PA performance objective of protecting groundwater resources.

Vadose zone monitoring is conducted at the Area 3 and Area 5 RWMSs by measuring the water balance of the RWMSs and directly measuring tritium migration within the Area 5 RWMS. Water balance monitoring is accomplished by use of meteorology data to calculate PET, the driving force of upward flow; directly measuring actual evapotranspiration and bare-soil evaporation (Area 5 RWMS weighing lysimeter facility); and measuring soil water content and soil water potential in waste cell covers and floors (automated waste cover monitoring systems). The RWMS vadose zone monitoring strategy also employs sampling of soil gas for tritium at GCD-05U near the center of the Area 5 RWMS to evaluate the subsurface migration of tritium.

The current vadose zone monitoring program is designed based on a strong understanding of the vadose zone system from the results of extensive vadose zone characterization studies (BN, 1998b; Blout et al., 1995; Reynolds Electrical and Engineering Company, Inc. [REECo], 1993a, 1993b, 1994; Schmeltzer et al., 1996; Shott et al., 1998, 1997; Tyler et al., 1996), and modeling studies (Crowe et al., 1998; Levitt et al., 1999). In addition, the vadose zone monitoring program is designed in part, from the results of an Alternative Evaluation Study on vadose zone monitoring (BN, 1998c) using an organized team approach and in part from vadose zone monitoring field experience.

#### Gas-phase Tritium Monitoring Data

Gas-phase tritium monitoring is conducted via soil gas sampling at GCD-05U (see Figure 4 for location). This unit has a large tritium inventory (~2.2 million curies at time of disposal) and is instrumented with two strings of nine soil-gas sampling ports buried at depths ranging from 3 to 37 m (10 to 120 ft) below surface. Tritium sampling at GCD-05U provides a direct measure of tritium migration from waste packages with time due to degradation of waste containers and the natural transport processes of advection and diffusion.

Tritium in soil-gas was sampled from the nine GCD-05U sampling depths in September 2002. Results indicate that while soil-gas tritium concentrations generally continue to increase at depths between 15 and 37 m (50 and 120 ft), vertical migration is extremely slow. Note that the tritium concentration measured at a depth of 25.9 m (85 ft) has decreased slightly since 2001. It is not clear if this decrease is due to measurement error, or an actual reduction in tritium concentration at that depth due to radioactive decay. 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) and to validate the gaseous diffusion models in the PAs. Soil-gas tritium concentrations with depth and time are illustrated in Figures 26 and 27.

#### Area 5 Weighing Lysimeter Facility Data

The Area 5 weighing lysimeter facility consists of two precision weighing lysimeters located about 400 m (1,312 ft) southwest of the Area 5 RWMS. Each lysimeter consists of a steel box 2 m (6.6 ft) deep, filled with soil and having an area of 2 m x 4 m (6.6 ft x 13 ft). Each lysimeter is mounted on a sensitive scale, which is continuously monitored using an electronic loadcell. One lysimeter is vegetated with native plant species at the approximate density of the surrounding desert, and one lysimeter is kept bare (to simulate the bare operational waste covers at the Area 5 RWMS). The loadcells have been monitored continuously since March 1994 and provide an accurate dataset of

the surface water balance at the Area 5 RWMS. This monitoring time period also includes the wet El Nino year of 1998, when annual rainfall was twice the annual average. 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 evaporation (E), or ET, because no drainage has ever been measured through the bottoms 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 28 for the period of March 30, 1994, through December 31, 2002. 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 the vegetated lysimeter is considerably drier than the bare-soil lysimeter, despite the paucity of plants in the vegetated lysimeter (about 15 percent cover). No drainage has ever been measured from the permeable bottoms of either lysimeter to date. The increasing trend of soil water storage in the bare lysimeter may eventually lead to some drainage out the bottom of the lysimeter. Conservative modeling results also indicate that some slight drainage (1 percent of rainfall) will eventually leak from the bottom of the bare-soil lysimeter (Levitt et al., 1999). Cumulative PPT, ET, E, and the total soil water storage for 2002 are illustrated in Figure 29.

In March 2000, core samples were extracted from the weighing lysimeters in order to confirm the total soil water storage recorded using the electronic loadcells. Continuous core was collected to determine volumetric water content throughout the soil profile, which was integrated into total soil water storage in each lysimeter. To reflect this more accurate direct measurement, the historical lysimeter data were increased by about 7 cm (2.8 in) of total soil water storage to match the core data. Therefore, soil water storage from both weighing lysimeters is higher now than in documents published prior to 2000.

Monthly PPT, E, and ET totals are depicted in Figure 30. Note that E (bare lysimeter) is greater than ET (vegetated lysimeter) during every month. This is the result of a dry year, and the bare-soil lysimeter containing more water than the vegetated lysimeter. Therefore, there has been more water to evaporate from the bare-soil lysimeter than the vegetated lysimeter under the dry conditions of 2002.

#### Automated Waste Cover Monitoring System Data

In 1998, time domain reflectometry (TDR) probes were buried 1.2 m (4 ft) beneath the open pit floors of Pits 3 and 5 at the Area 5 RWMS. In 1999, TDR probes were installed in the operational cover of Pit 3 at two sites (north and south), at depths ranging from 10 to 180 cm (0.3 to 5.9 ft). In 2000, TDR probes were installed in the operational covers of Pits 4 and 5 at depths ranging from 20 to 180 cm (0.7 to 5.9 ft). In January 2002, the cables for TDR probes in the floor of Pit 3 were permanently cut for operational purposes.

An automated monitoring system was also installed in Area 5 adjacent to Ue5PW-1, at the Neutron Probe Calibration Facility (NPCF) in 1998. This TDR system has 36 TDR probes buried at depths of 30, 60, and 90 cm (1, 2, and 3 ft) and has performed well for over five years.

Soil water content, with time, is illustrated in Figures 31 through 35 for Pits 3, 4, and 5 waste cover TDR systems, and Pits 3 and 5 floor TDR systems. In Figures 31 to 34, note the depth of infiltration from precipitation never exceeded 90 cm (3 ft) before that water was returned to the atmosphere by evaporation. Slight increases in water contents are seen to greater depths, but these are likely the result of thermal effects rather than liquid wetting fronts.

In December 2000, TDR probes were installed in the waste cover of U-3ax/bl at four locations, with a stack of eight TDR probes per location. These probes are wired into two datalogger stations. Soil water content, with time for U-3ax/bl, is shown in Figures 36 and 37. These figures illustrate how the soil water content has generally decreased with time as the vegetation on the cover has grown.

#### Area 3 Drainage Lysimeter Facility Data

Construction of a drainage lysimeter facility, just to the northwest of U-3ax/bl waste disposal unit, at the Area 3 RWMS (refer to Figure 3), was initiated in November 2000, concurrently with the installation of TDR probes, application of 30 cm (1 ft) of soil, and revegetation at U-3ax/bl waste disposal unit (refer to BN, 2000). The lysimeter facility was constructed to fulfill data needs; including reducing uncertainty in the expected performance of monolayer-ET closure covers under various surface treatments and climatic change scenarios such as increased rainfall. The facility consists of eight lysimeters, each one instrumented with water content (TDR probes) and water potential and temperature sensors (heat dissipation probes) at eight depths per lysimeter. Each lysimeter was constructed such that drainage through each 2.4 m (8 ft)-thick cell can be directly measured using electronic tipping buckets. All sensors are wired into dataloggers for automated measurements. Figures 38 and 39 illustrate volumetric soil-water content with time for a bare and vegetated (native species) lysimeter, respectively. Starting in summer 2000, the vegetated lysimeter becomes significantly drier than the bare lysimeter and by late summer has relatively uniform water content throughout the soil profile. Figure 40 shows the calculated total water storage for all eight lysimeters using TDR data. Note the vegetated lysimeters (both seeded and invaders species cells) are significantly drier (lower soil water storage) than the bare cells. All vegetated lysimeters have similar soil water storage with the exception of the “G” lysimeter. This lysimeter has been observed to be less densely vegetated than the other cells with invader species.

The vegetated drainage lysimeters are slightly drier than the U-3ax/bl cover. This is due to the higher vegetation density on drainage lysimeter resulting from a higher germination success. A quantitative analysis of the vegetation density on the U-3ax/bl cover and the drainage lysimeters was conducted in spring 2002 (BN 2002a). The percent cover for U-3ax/bl and the seeded lysimeters were found to be 6 and 12 percent, respectively. The long-term goal for the vegetative cover is 12 percent cover based on the vegetation density of similar native environments. Therefore, the plant density on the seeded lysimeters is ideal, and the density on U-3ax/bl is low. For more information on the closure and monitoring of U-3ax/bl, refer to BN (2000).

Note that infiltration is seen to depths of 1.8 to 2 m (5 to 6 ft) at the U-3ax/bl west site (Figure 37), and in Drainage Lysimeter “E” (Figure 39) as a result of irrigation to ensure vegetation survival. Also note that moisture from those depths was quickly removed by ET within several months.

### Neutron Logging Data

Routine vadose zone water content monitoring by neutron logging was not conducted in the Area 3 or Area 5 RWMSs in 2002. With the exception of disposal unit U-3bh crater, future water content monitoring at Areas 3 and 5 will be conducted using only the automated TDR systems described above. U-3bh crater should continue to be neutron logged once every few years to monitor the deep wetting front resulting from excessive water application for dust control during early waste disposal operations. Refer to Levitt and Yucel (2002) for details on this wetting front. For a detailed history of the Neutron Logging Monitoring Program at Area 3 and Area 5 RWMSs, refer to BN (1997 and 2001b).

A special study was conducted in June 2002 to investigate the accuracy of waste cover water content data provided by neutron logging (and the neutron probe calibration). Four core samples were collected from four locations at the Area 5 RWMS with samples collected at 0.3, 0.6, 0.9, and 1.2 m (1, 2, 3, and 4 ft) depths. Concurrently, neutron probe measurements were taken at the same depths in adjacent neutron logging access tubes. The results of this study are presented in Table 1. Results of this comparison indicate that the average difference between neutron probe and core sample measurement methods was less than 1.7 percent volumetric water content (VWC) if a bulk density (BD) value of  $1.6 \text{ g/cm}^3$  was assumed. If actual measured BD values were used to calculate VWC, then the difference between measurement methods was slightly larger. However, it is possible that any BD values much higher than  $1.6 \text{ g/cm}^3$  were caused by compaction of the core sample. At three of the four locations, neutron probe measurements were approximately 3 percent VWC lower than core sample measurements of VWC, and at one location (tube 19) neutron probe measurements were approximately 2 percent VWC higher than core sample measurements of VWC. This may be caused by the presence of grout surrounding tube 19. It is important to note that measurements of VWC in waste covers using the neutron probe method have been terminated with the installation of the automated TDR systems at various locations (described above).

### Waste Cover Subsidence Monitoring

Subsidence monitoring is conducted to ensure that subsidence features are repaired to prevent the development of preferential pathways through the waste covers. Subsidence monitoring also helps to ensure that vadose zone monitoring data are representative of the entire RWMS. A formal program to monitor subsidence of waste covers was initiated in October 2000, including coordination with waste operations personnel to facilitate timely repair of subsidence features. The locations of subsidence features observed at the Area 5 RWMS in 2002 are shown in Table 2. These features were mostly in locations of recently covered waste and concentrated along the edges where compaction of the cover may be incomplete. In other locations within the Area 5 RWMS, only a few minor cracks and depressions required maintenance.

### **Biota Monitoring Data**

Vegetation monitoring within the disposal facilities was performed to help characterize and define trends in potential transport of radionuclides from deposited waste. Tritium is a dominant radionuclide observed due to its high mobility as tritiated water. Data from the air sampler adjacent to the northeast corner of the Area 5 RWMS consistently shows levels of tritium in air above background (see Figure 7). The primary mechanisms that transport tritium upward through waste covers and into the atmosphere include gaseous diffusion, gaseous advection, bioturbation, plant

uptake and transpiration, and soil evaporation. Sampling of plant water for tritium provides a direct measure of the plant uptake of tritium. Analysis of plant tissues for gamma emitting radionuclides, Sr-90, and alpha-emitting radionuclides provides information on uptake of those radionuclides.

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. For this reason, plants are generally sampled in late summer. Because of the dry conditions, measured plant water tritium concentrations may be a conservative representation of year-round concentrations.

Plant samples were collected from six locations within the Area 5 RWMS on July 22, 2002. A composite vegetation sample was also collected from the U-3ax/bl cover within the Area 3 RWMS on July 30, 2002. A control sample was taken outside of each of the Area 3 and Area 5 RWMS. Locations of vegetation samples are shown in Figure 41. Plant water was extracted from the samples by room temperature vacuum distillation and analyzed by liquid scintillation for tritium. Dried plant tissue was also submitted for analysis of gamma-emitting radionuclides, Sr-90, and Uranium. Results of detected radionuclides are listed in Table 3. Although direct comparison with previous studies is not possible due to differing sample locations, the range of tritium concentrations observed in vegetation sampled during 2002 was within that observed during the previous three years, but still much lower than that measured at the Area 5 RWMS in 1995 to 1996 (see BN 2001b, 2002b). It is important to note that tritium was also detected in water extracted from plants taken from control areas outside of each RWMS. In fact, the concentration in the control plant taken south of the Area 3 RWMS was about 77 percent higher than that observed in vegetation growing on the U-3ax/bl cover. Contributing factors to this were shrubs sampled from the U-3ax/bl cover were small ( $\sim 0.01 \text{ m}^3$ ) compared with the control shrub ( $\sim 4.75 \text{ m}^3$ ) and therefore had much shallower rooting depths. Also, both RWMSs overlap sites of historical testing that resulted in added radionuclides to soils throughout the immediate area prior to the existence of the RWMSs. Radionuclide levels observed in control vegetation is likely a measure of these earlier inputs. Uranium-233/234 was detected in all vegetation samples (controls not different from samples collected on the disposal areas), and Sr-90 and Cs-137 were detected in only one sample collected on the north end of Trench 6 at the Area 5 RWMS. Radionuclides in plants indicate that plants provide an upward pathway for radionuclide migration. Continued monitoring of this pathway will provide data on trends of radionuclides available for uptake over time.

## CONCLUSIONS

Environmental and operational 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 at the northwest corner of the Area 5 RWMS. 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 due to natural transport processes. Vadose zone monitoring data for 2002 indicate that infiltrating precipitation generally reached depths of less than 30 cm (1 ft) 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 nine years of their operation. Biota monitoring indicates that tritium continues to be detected in plant water and this upward pathway should continue to be monitored.



## FIGURES

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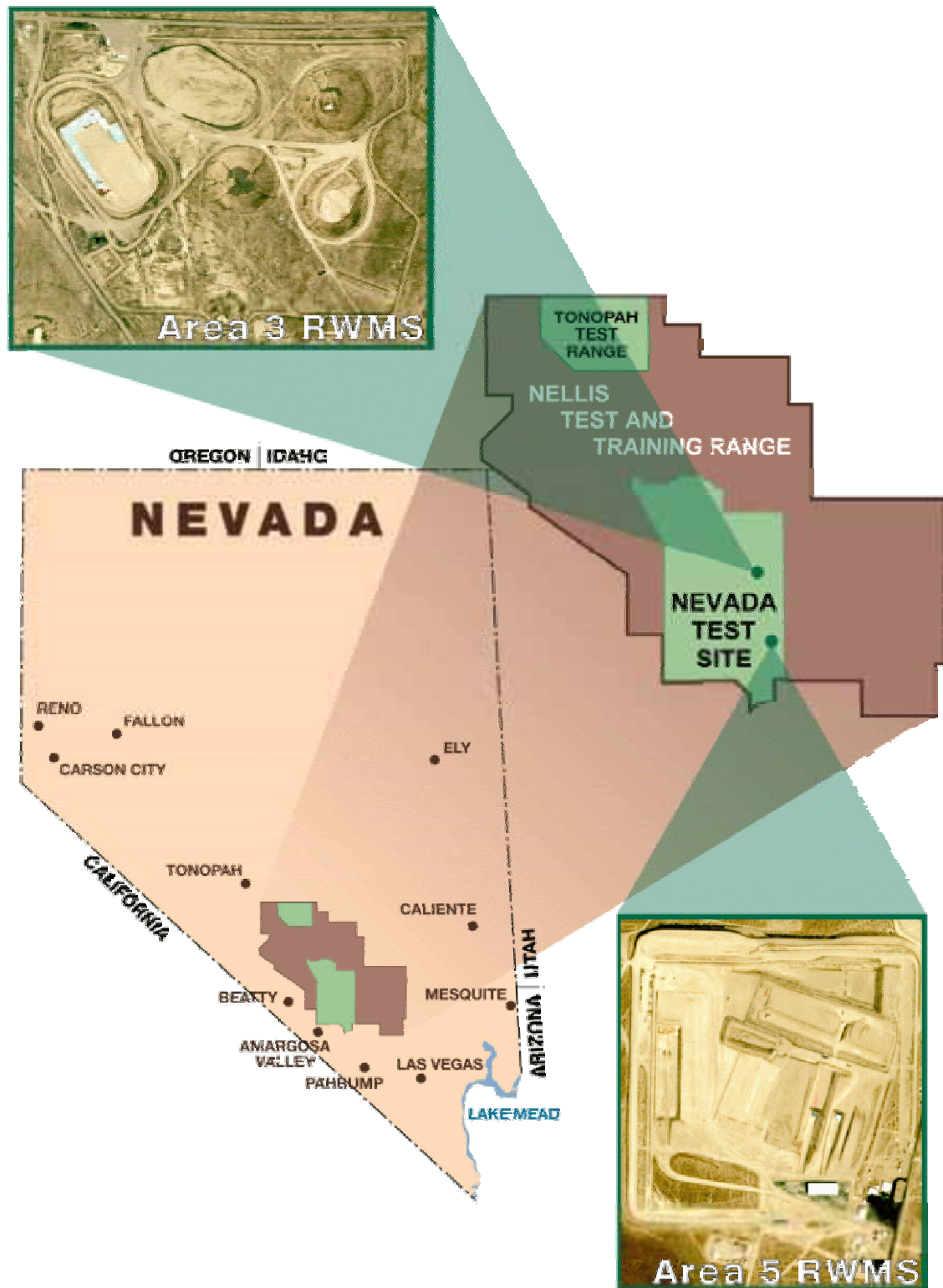


Figure 1. Location of the Area 3 and Area 5 RWMSs within the NTS and Nevada

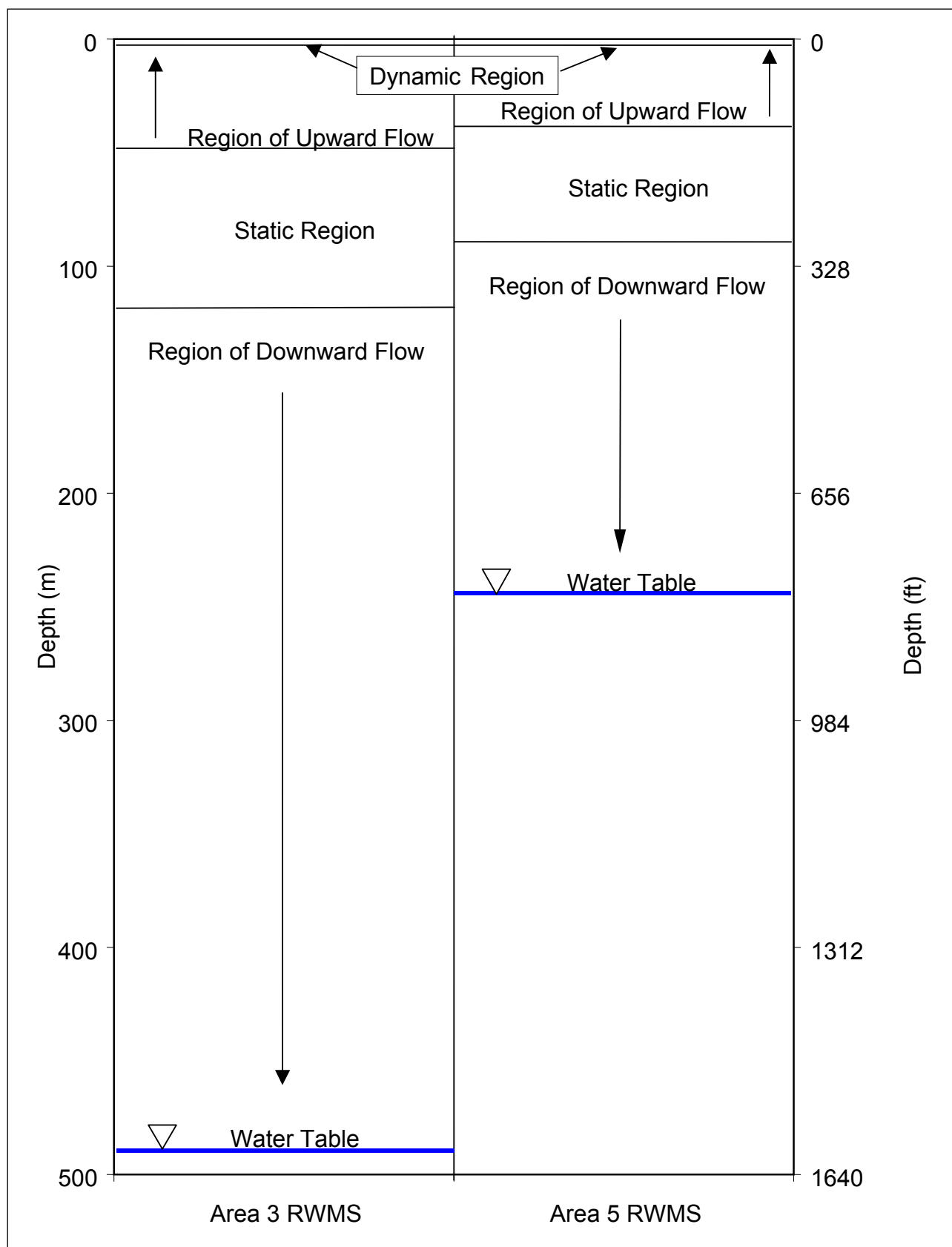
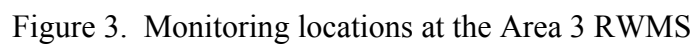


Figure 2. Vadose zone hydrologic conceptual model of the Area 3 and Area 5 RWMSs





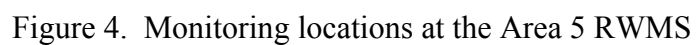




Figure 5. Location of the Area 5 RWMS pilot wells and weighing lysimeter facility

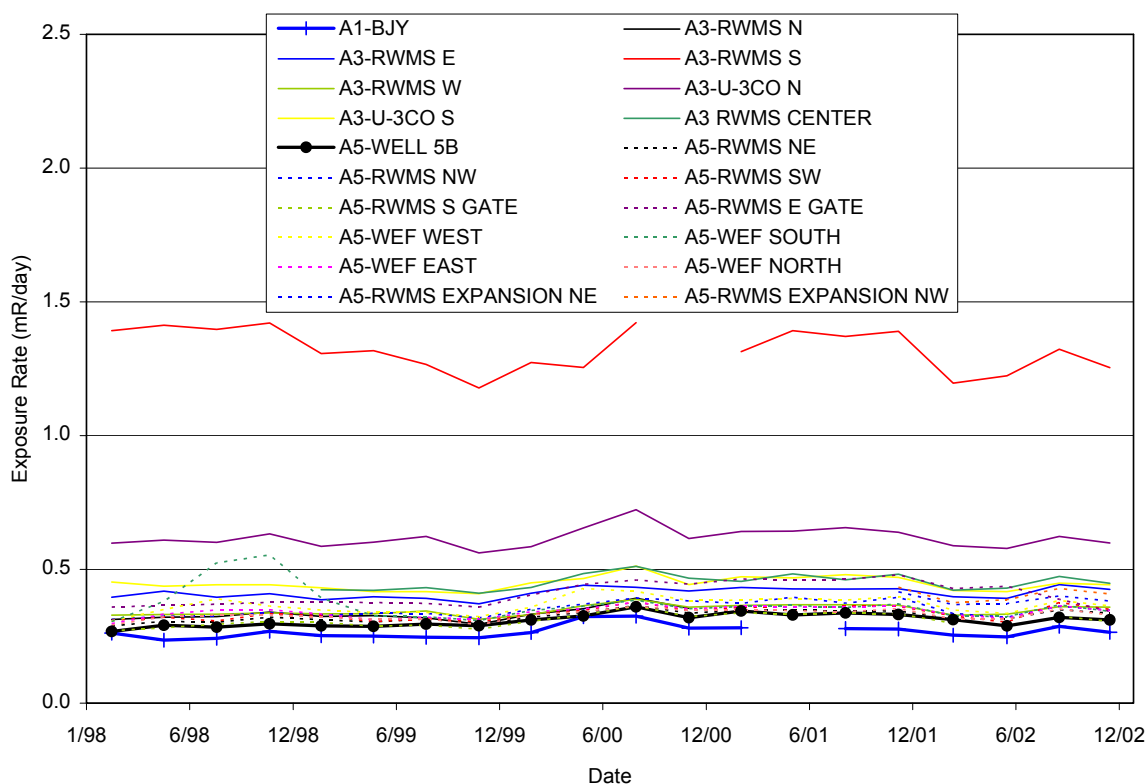


Figure 6. Exposure rate at the RWMSs, Well 5B, and BJY locations from 1998 through 2002

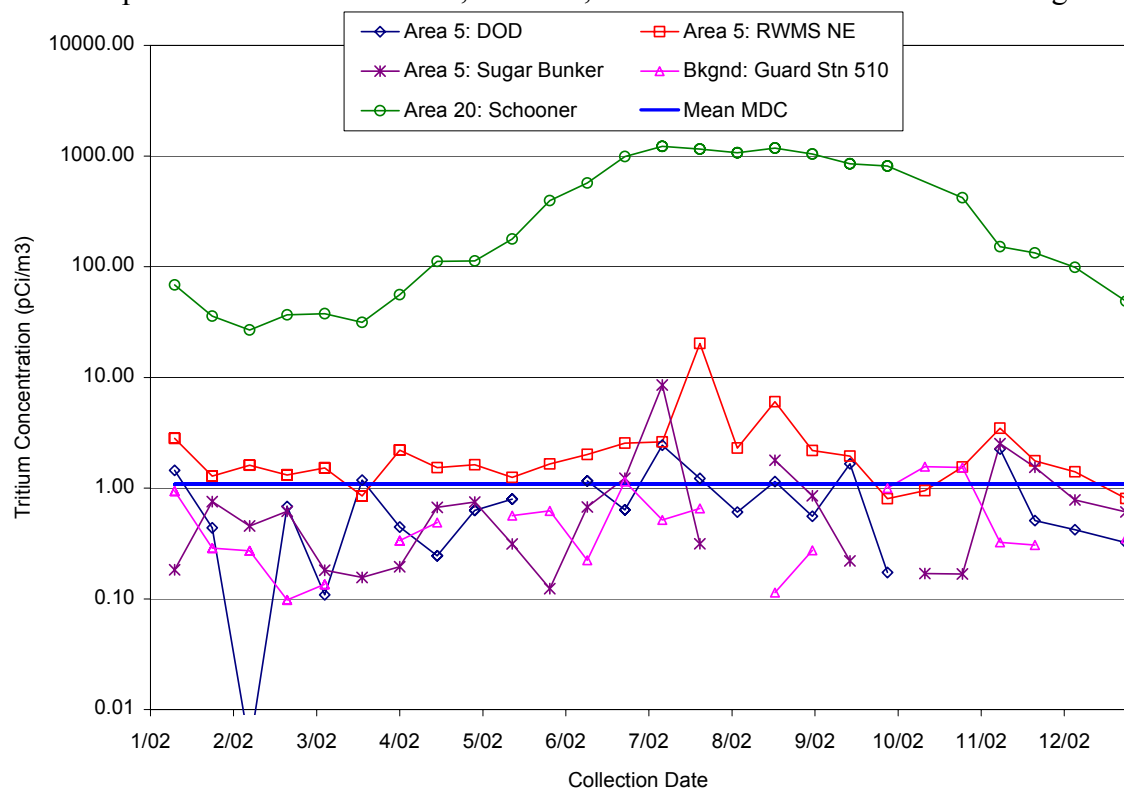


Figure 7. Tritium concentrations in air at the Area 5 RWMS, Schooner, and background locations in 2002



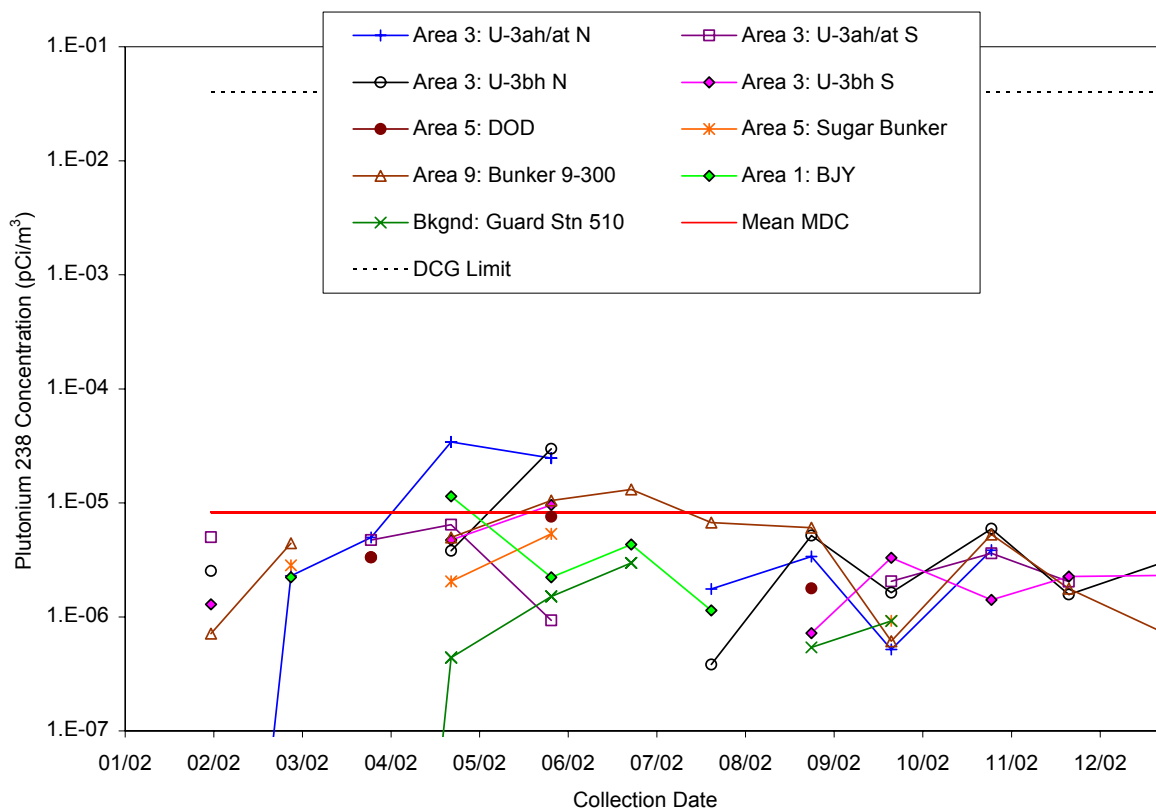


Figure 8. Plutonium 238 concentrations in air at the RWMSs and at various other locations

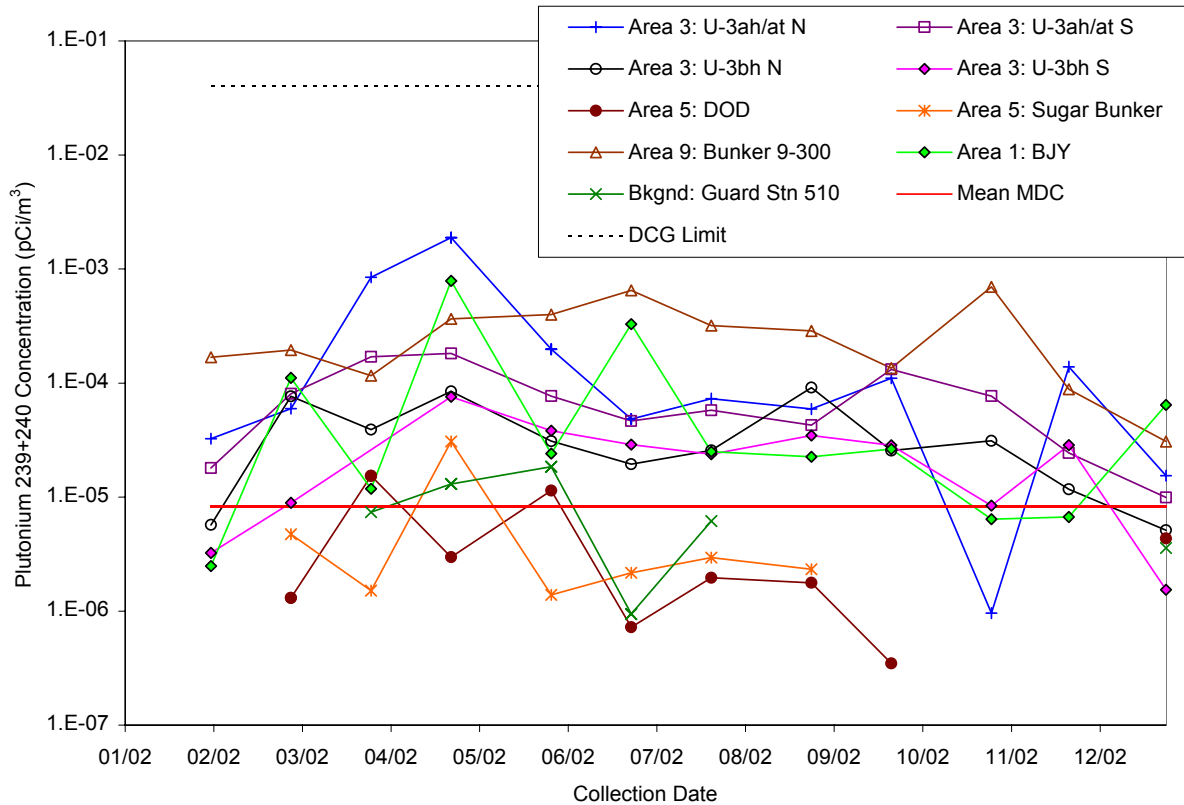


Figure 9. Plutonium 239+240 concentrations in air at the RWMSs and at various other locations

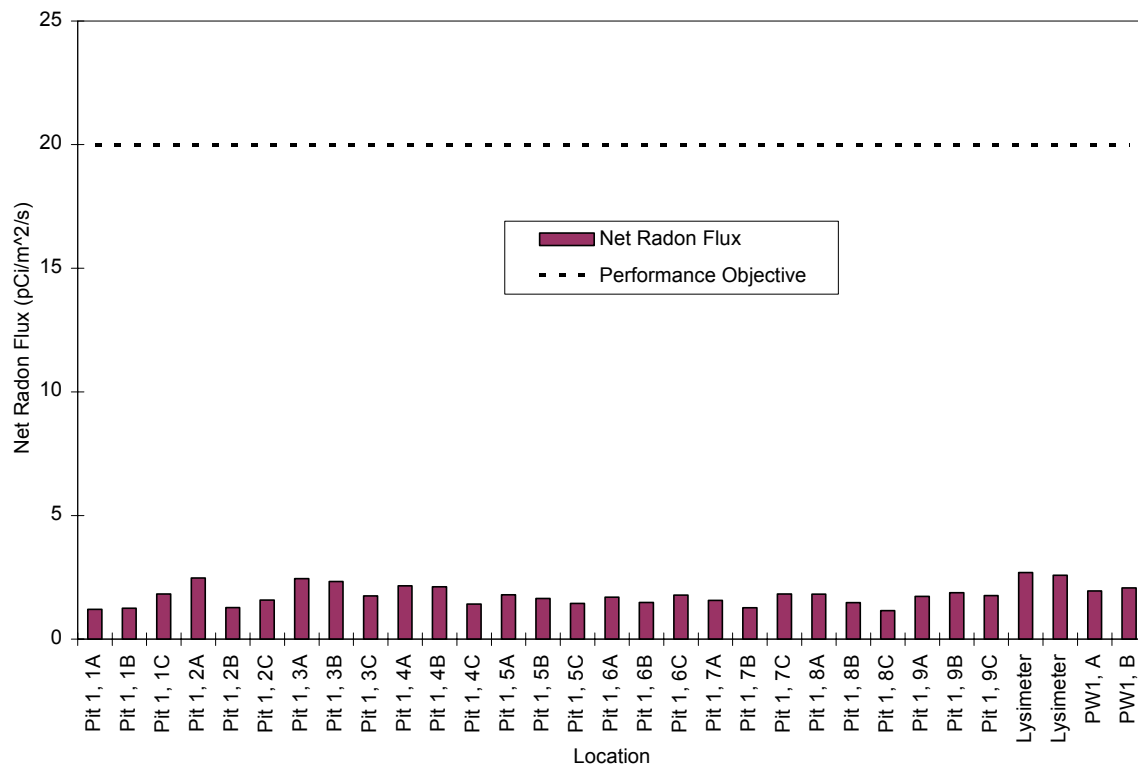


Figure 10. Radon flux measurements at Pit 1 and two other locations at the Area 5 RWMS from March 25 to April 2, 2002

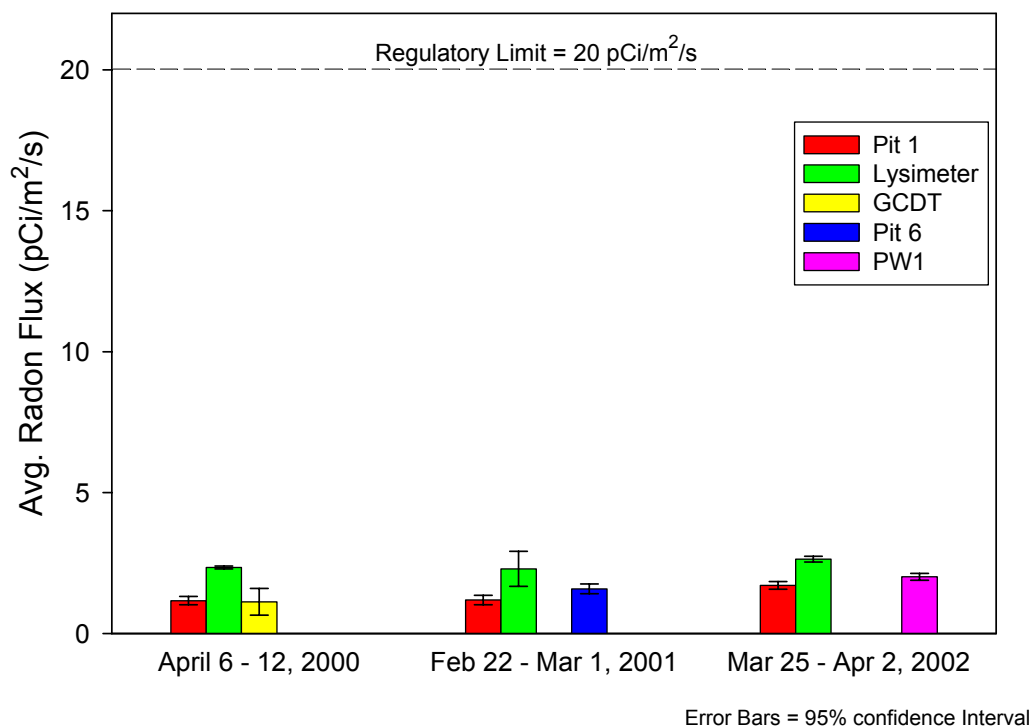


Figure 11. Radon flux measurements made at the Area 5 RWMS for 2000 to 2002

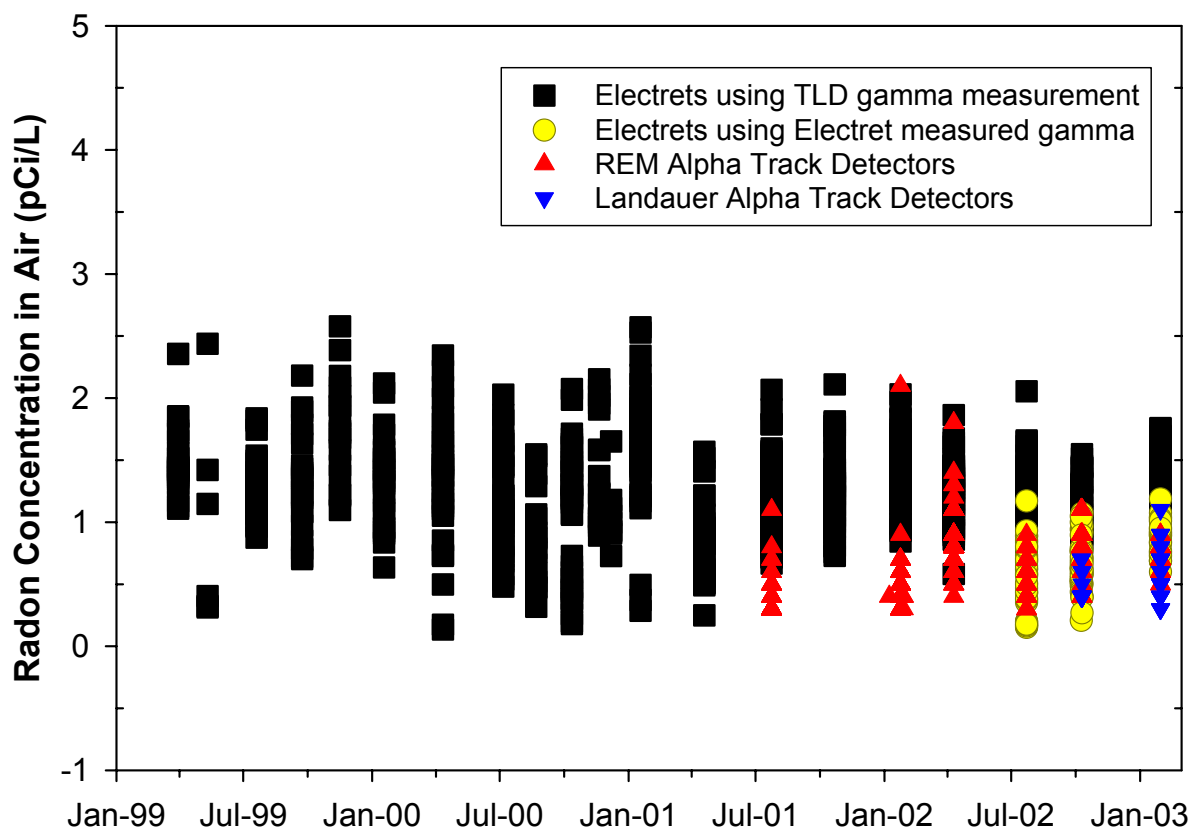


Figure 12. Comparison of radon concentrations measured using four methodologies

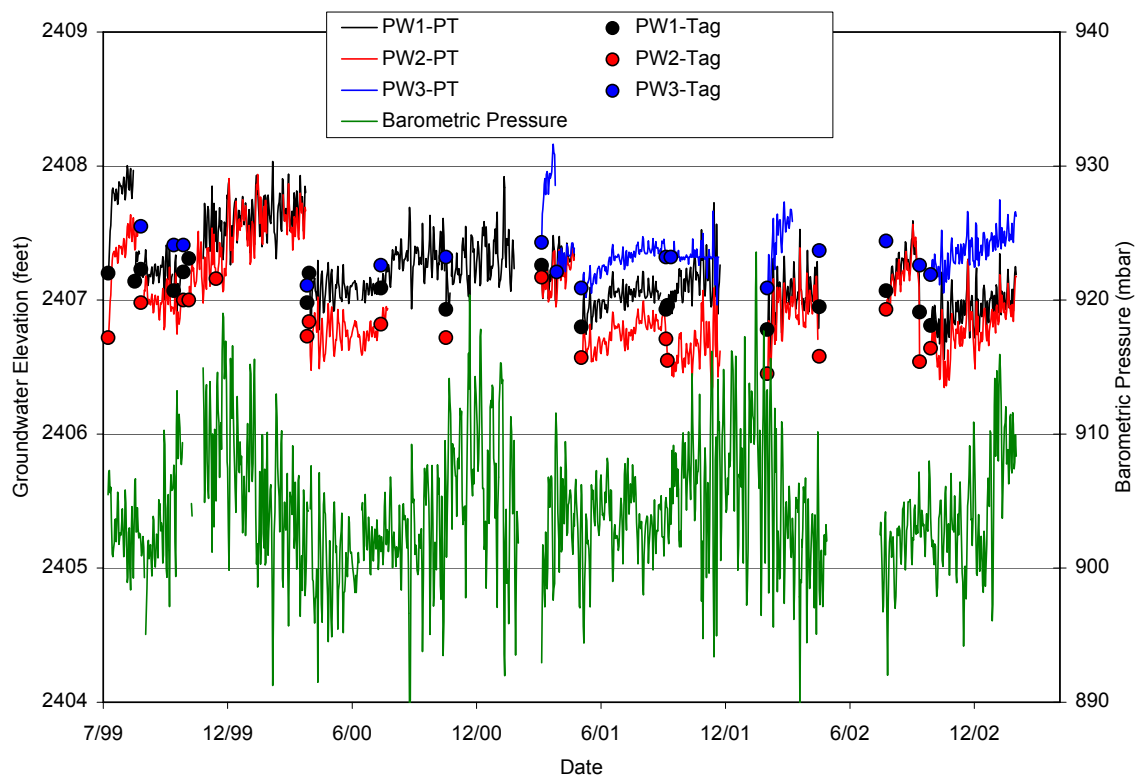


Figure 13. Groundwater elevation measurements recorded at the three Area 5 RWMS pilot wells using pressure transducers

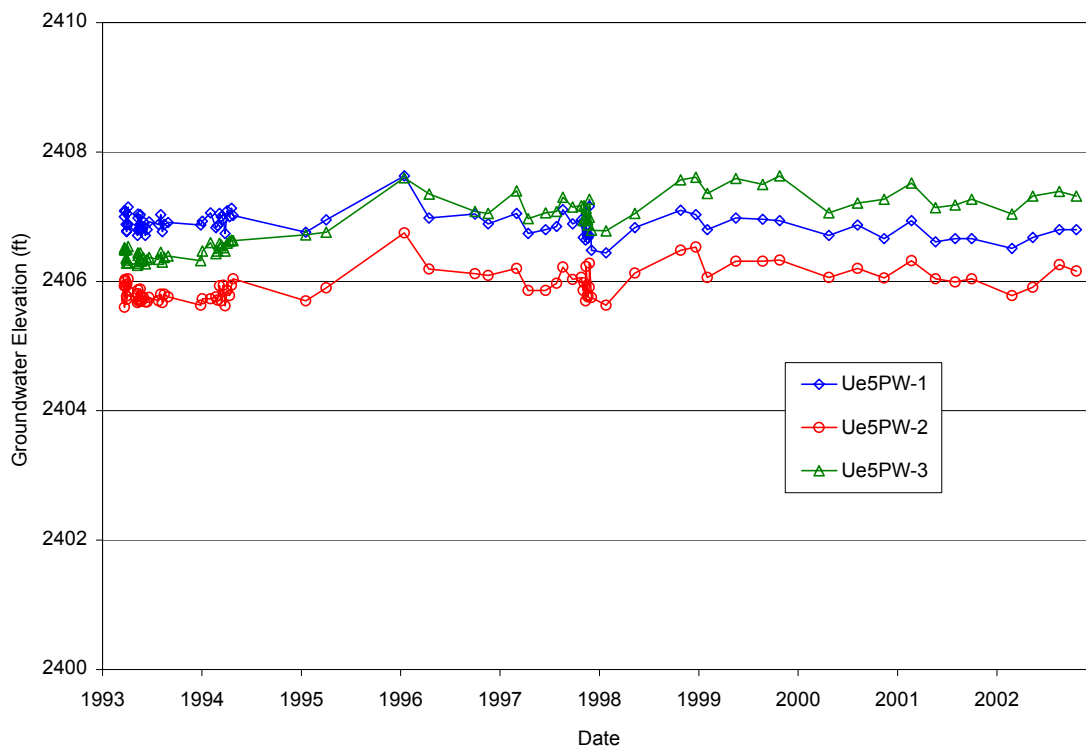


Figure 14. Groundwater elevation measurements made at the three Area 5 RWMS pilot wells by tagging

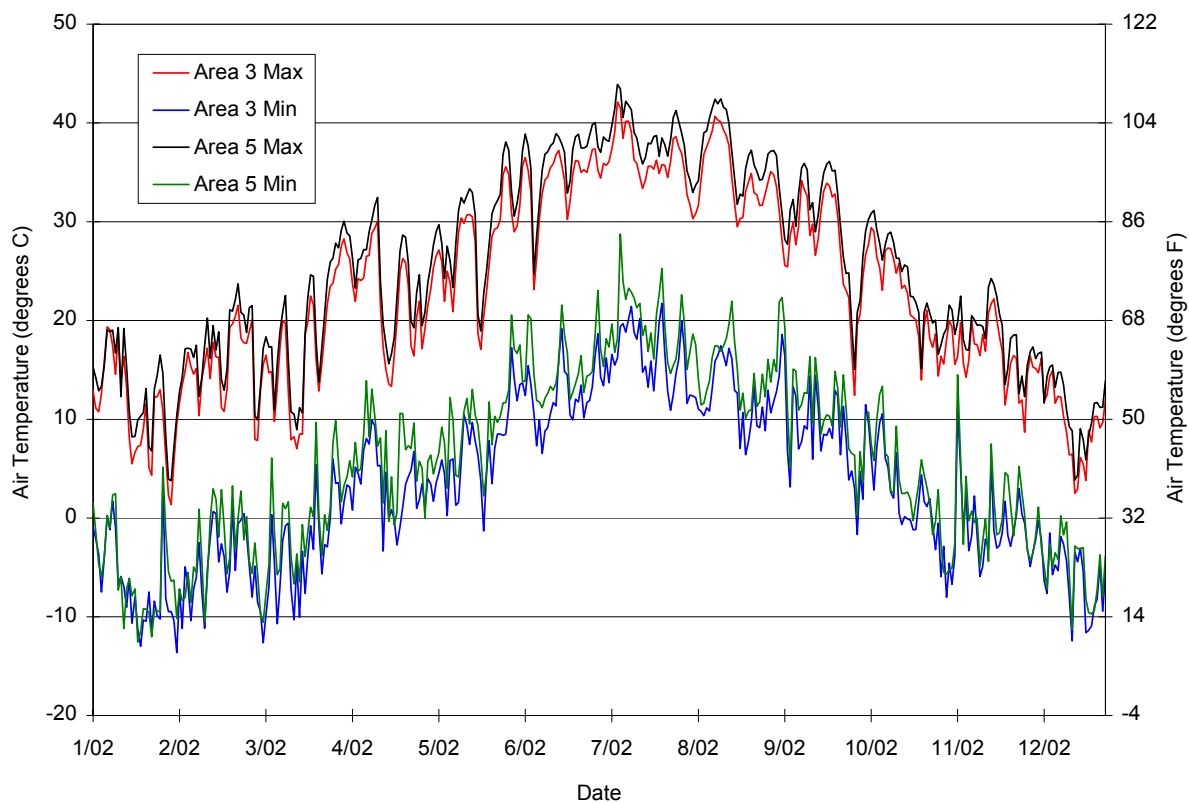


Figure 15. Daily air temperatures recorded at Area 3 and Area 5 RWMS meteorology stations

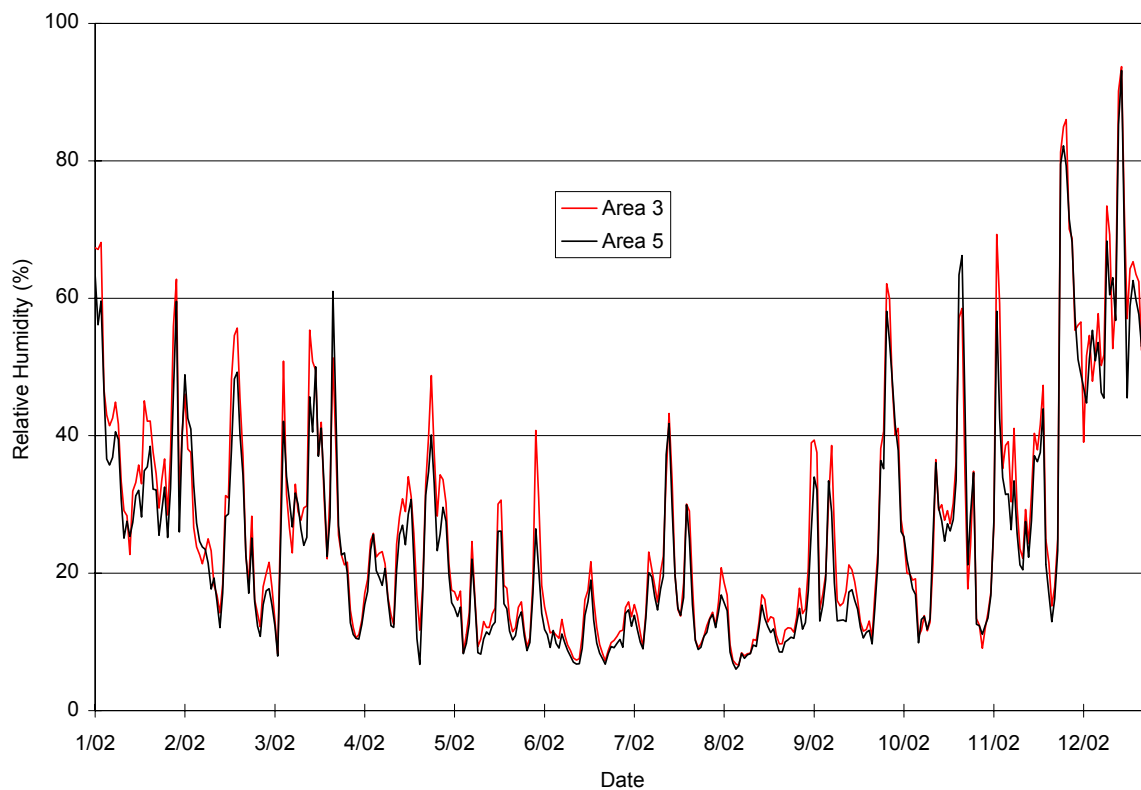


Figure 16. Daily average humidity recorded at Area 3 and Area 5 RWMS meteorology stations

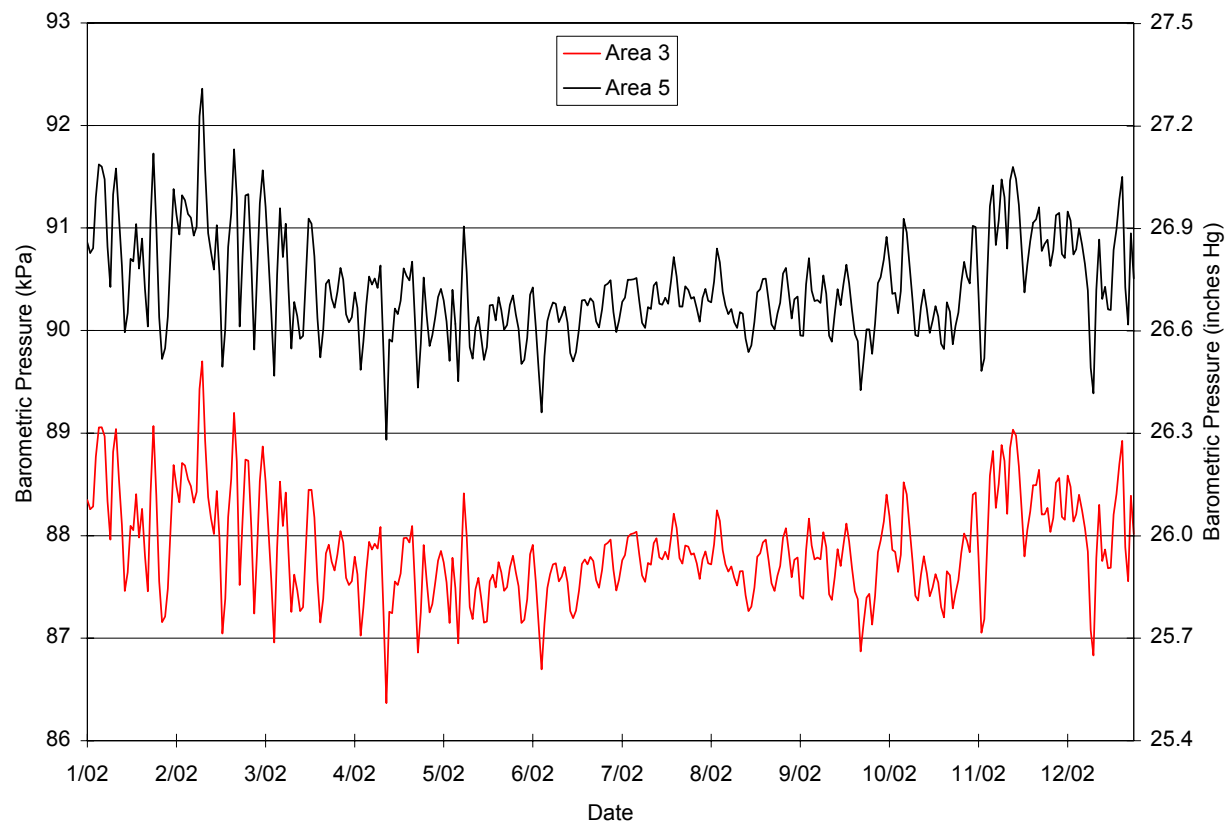


Figure 17. Daily average barometric pressure recorded at Area 3 and Area 5 RWMS meteorology stations

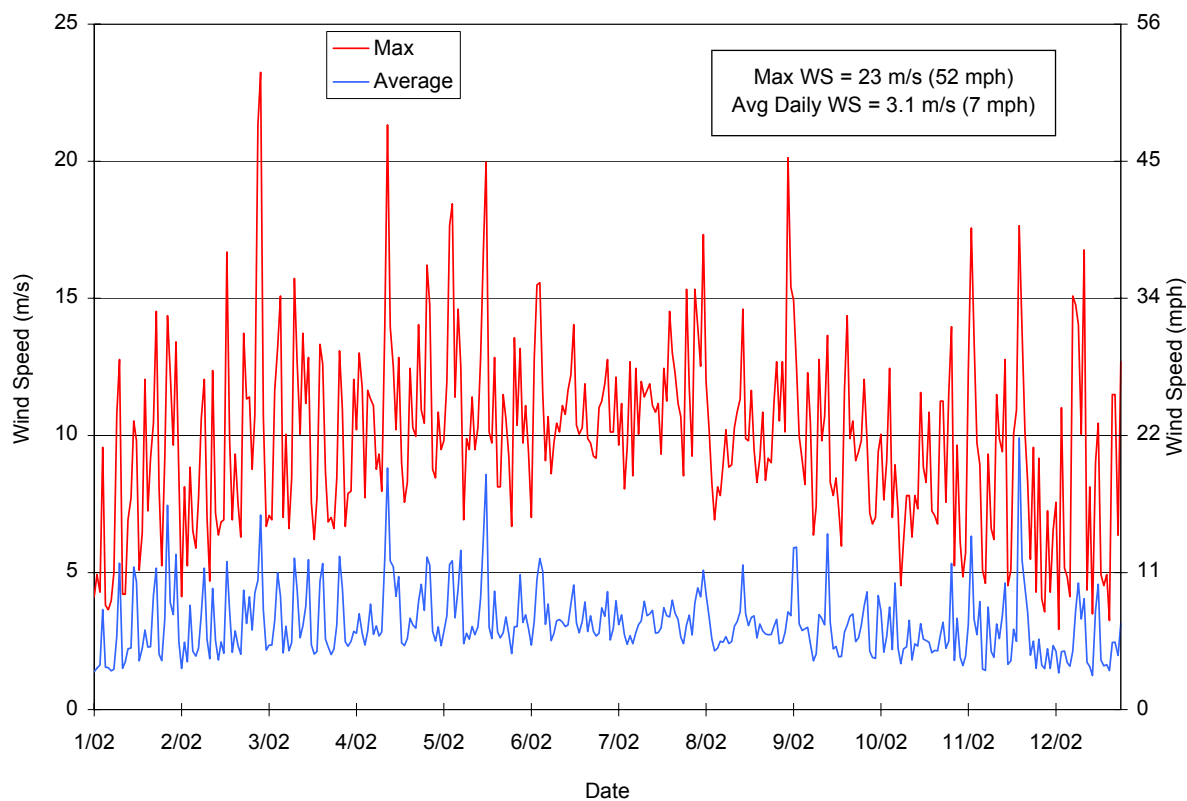


Figure 18. Daily wind speed recorded at Area 3 RWMS meteorology station at a height of 3 m

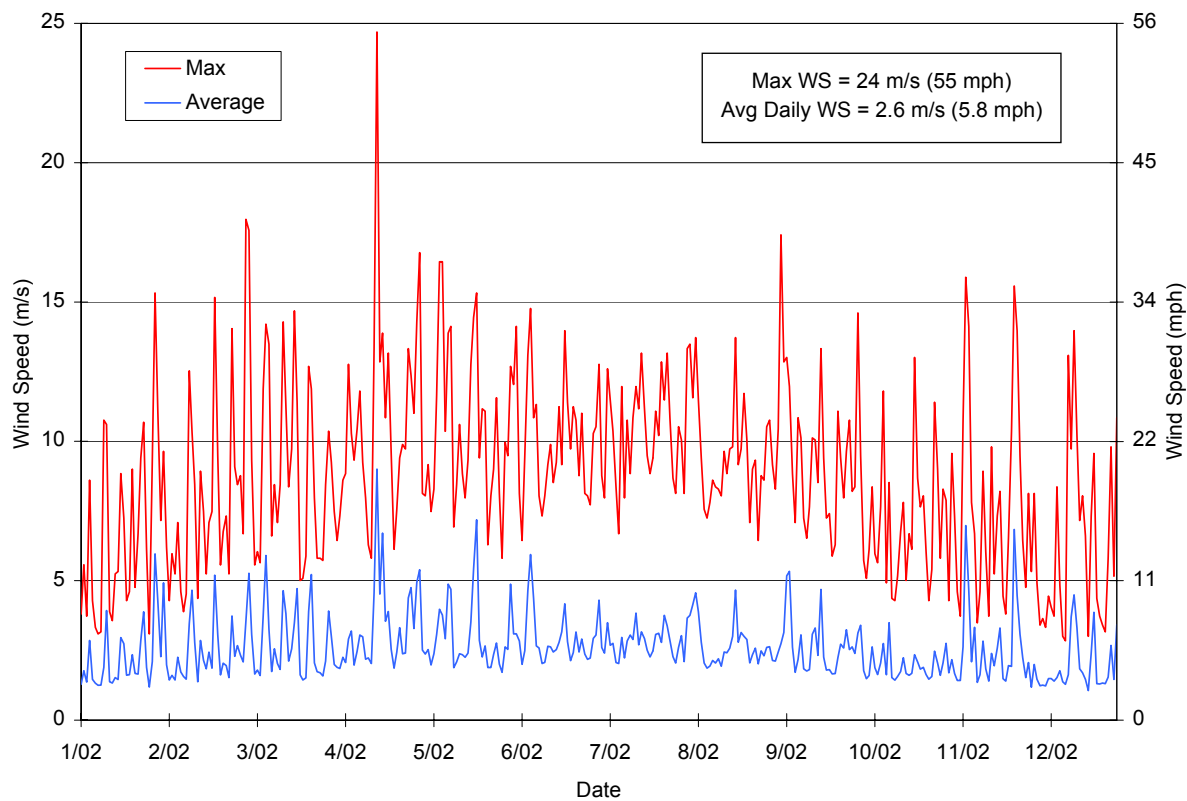


Figure 19. Daily wind speed recorded at Area 5 RWMS meteorology station at a height of 3 m

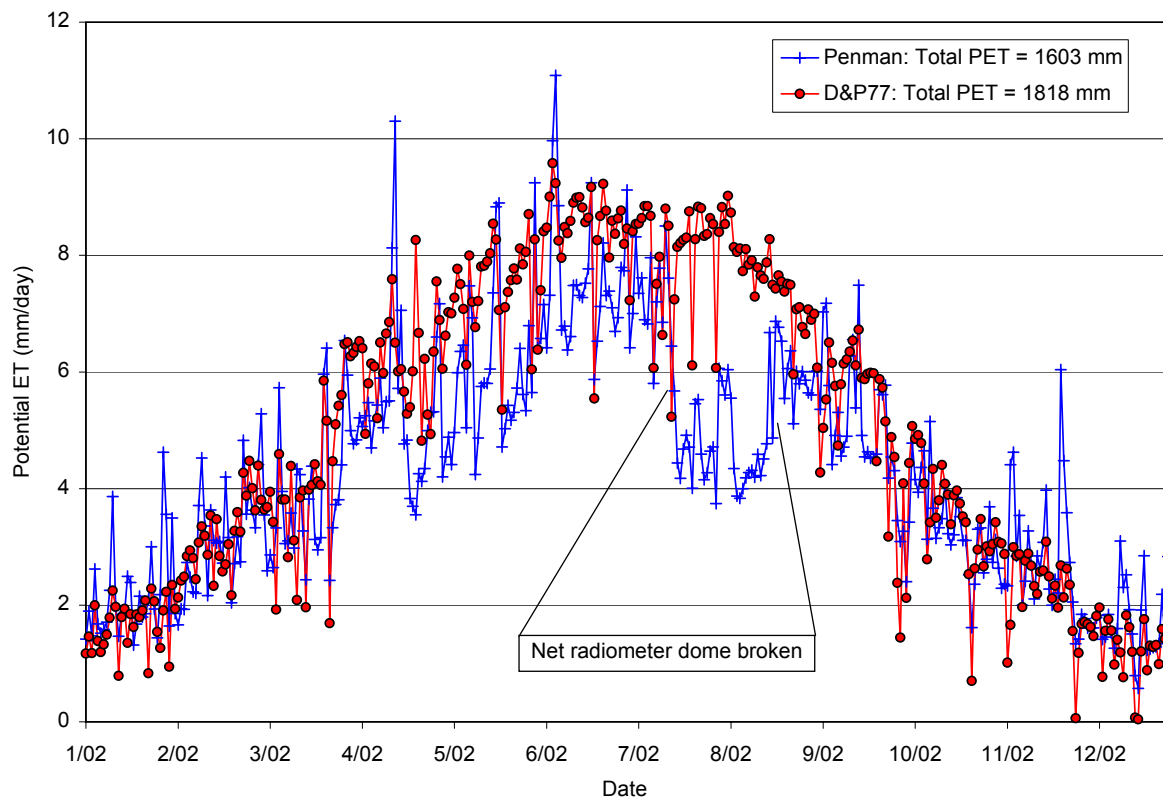


Figure 20. Daily PET for 2002 calculated using data from the Area5 RWMS meteorology station

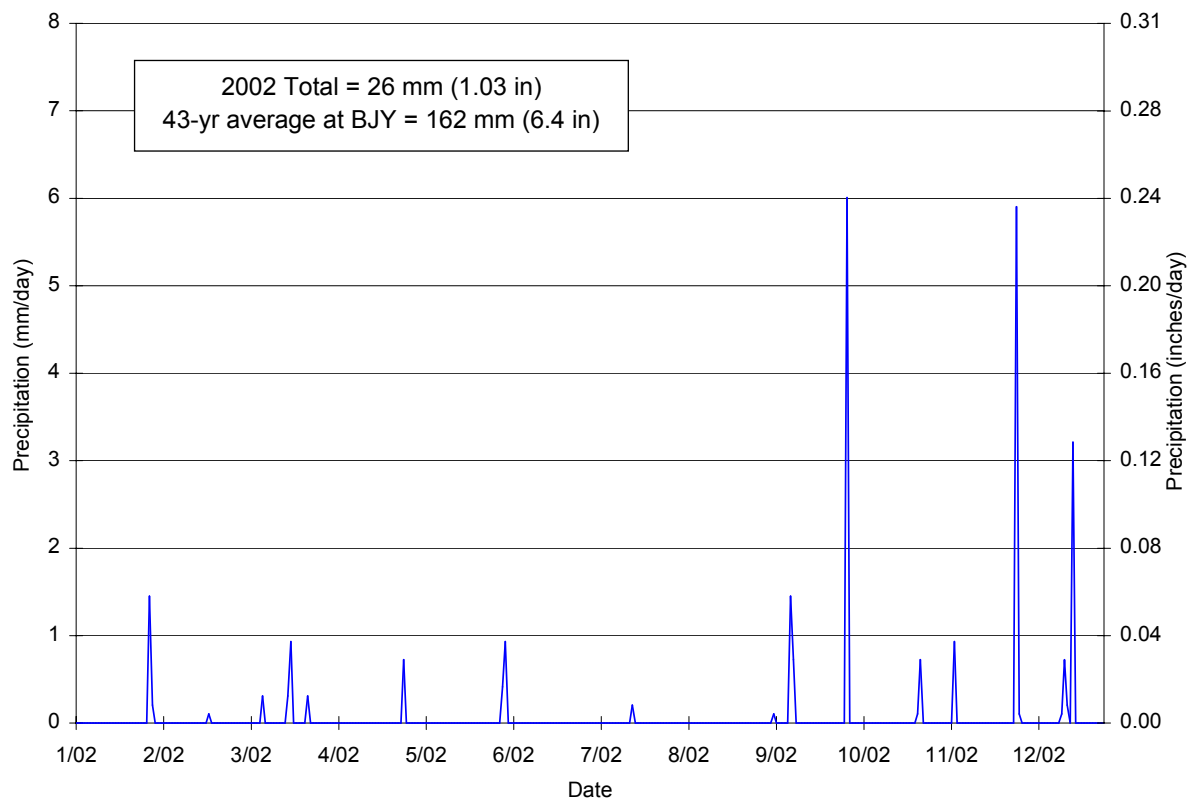


Figure 21. Daily precipitation recorded at Area 3 RWMS meteorology station



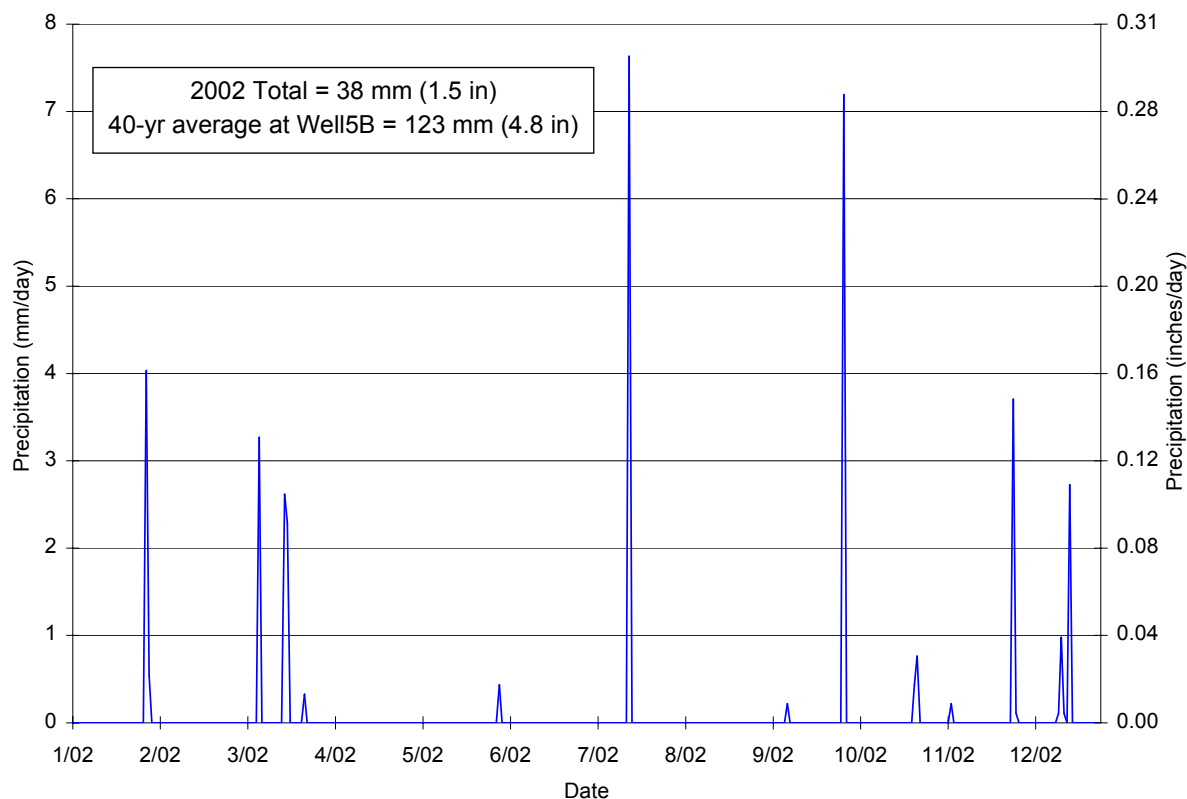


Figure 22. Daily precipitation recorded at Area 5 RWMS meteorology station

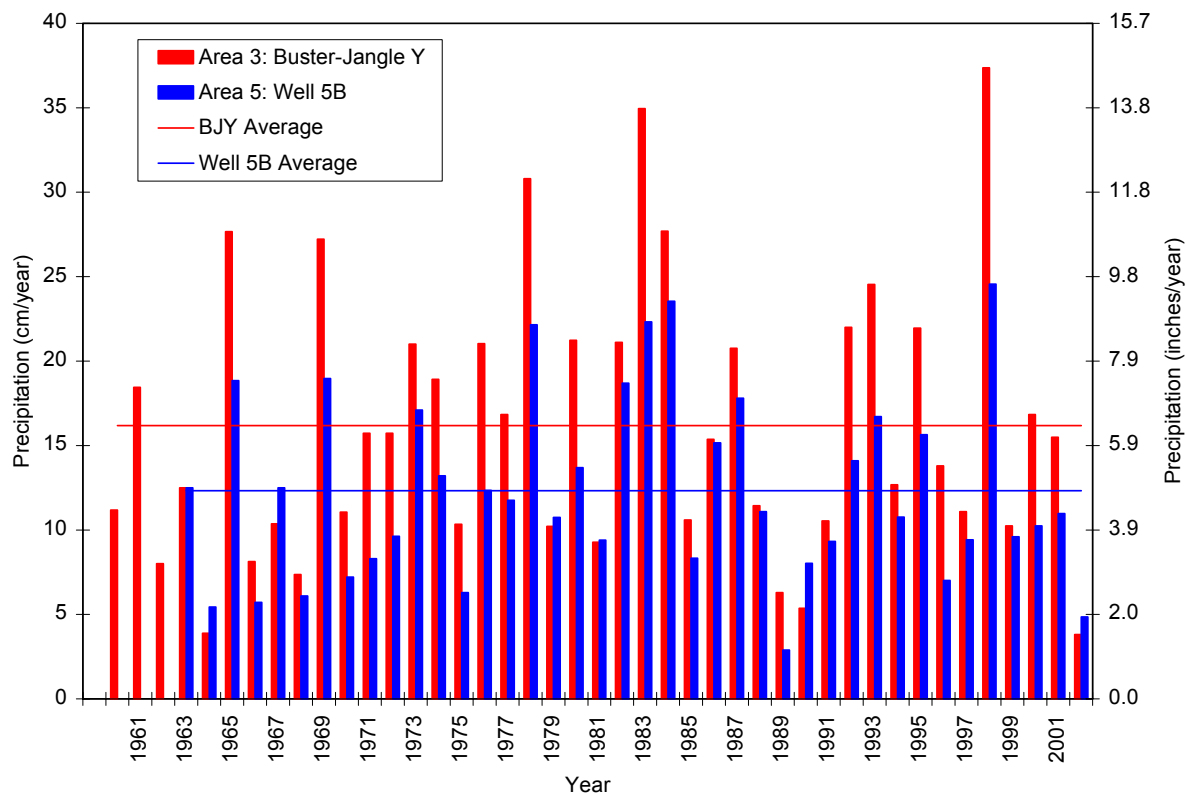


Figure 23. Historical precipitation record for Area 3 and Area 5

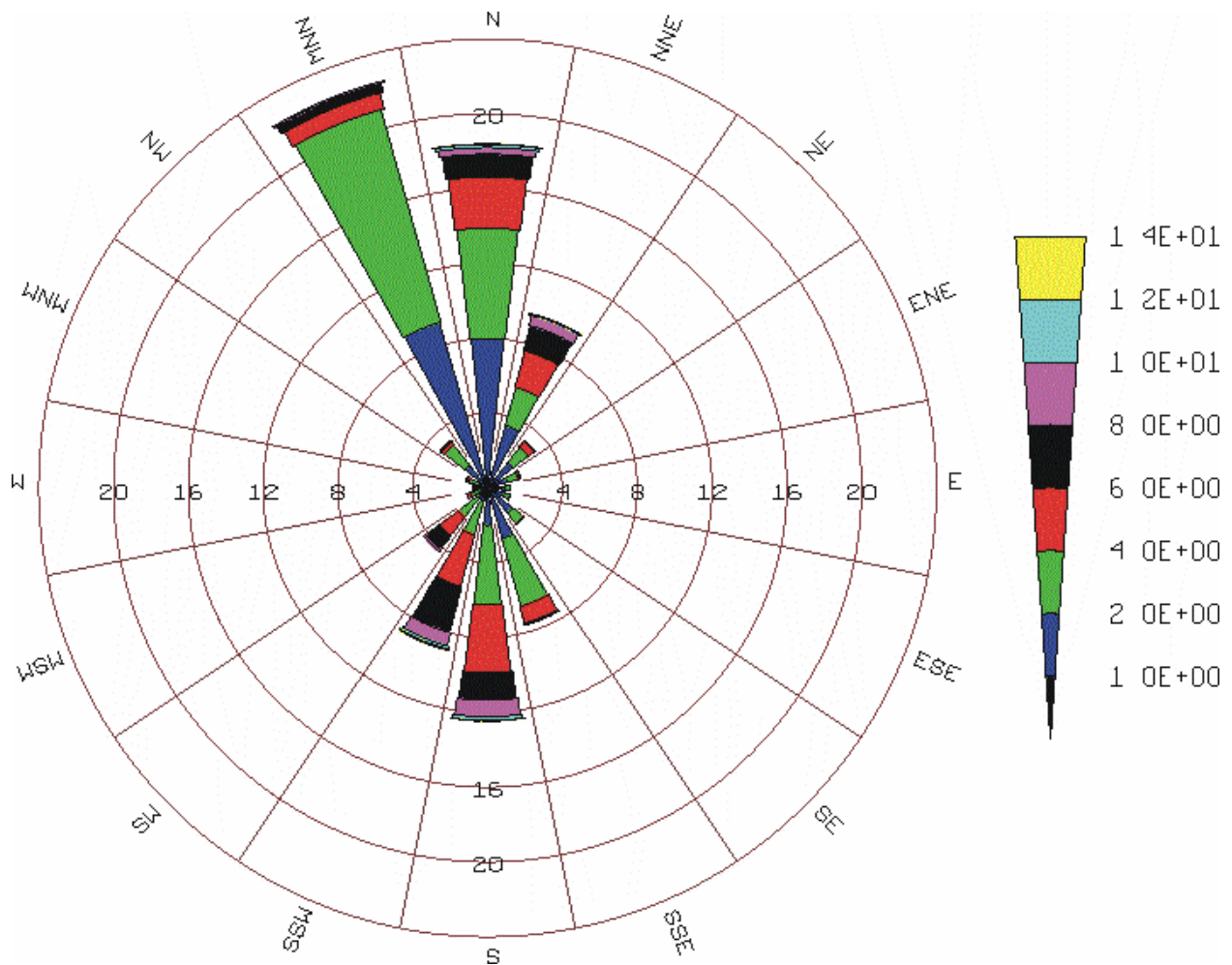


Figure 24. Wind rose diagram for 2002 data from the Area 3 RWMS meteorology station. Concentric labels indicate percent frequency, petal shading indicates wind speed in meters per second at a height of 3 m, and petal direction indicates direction of wind source

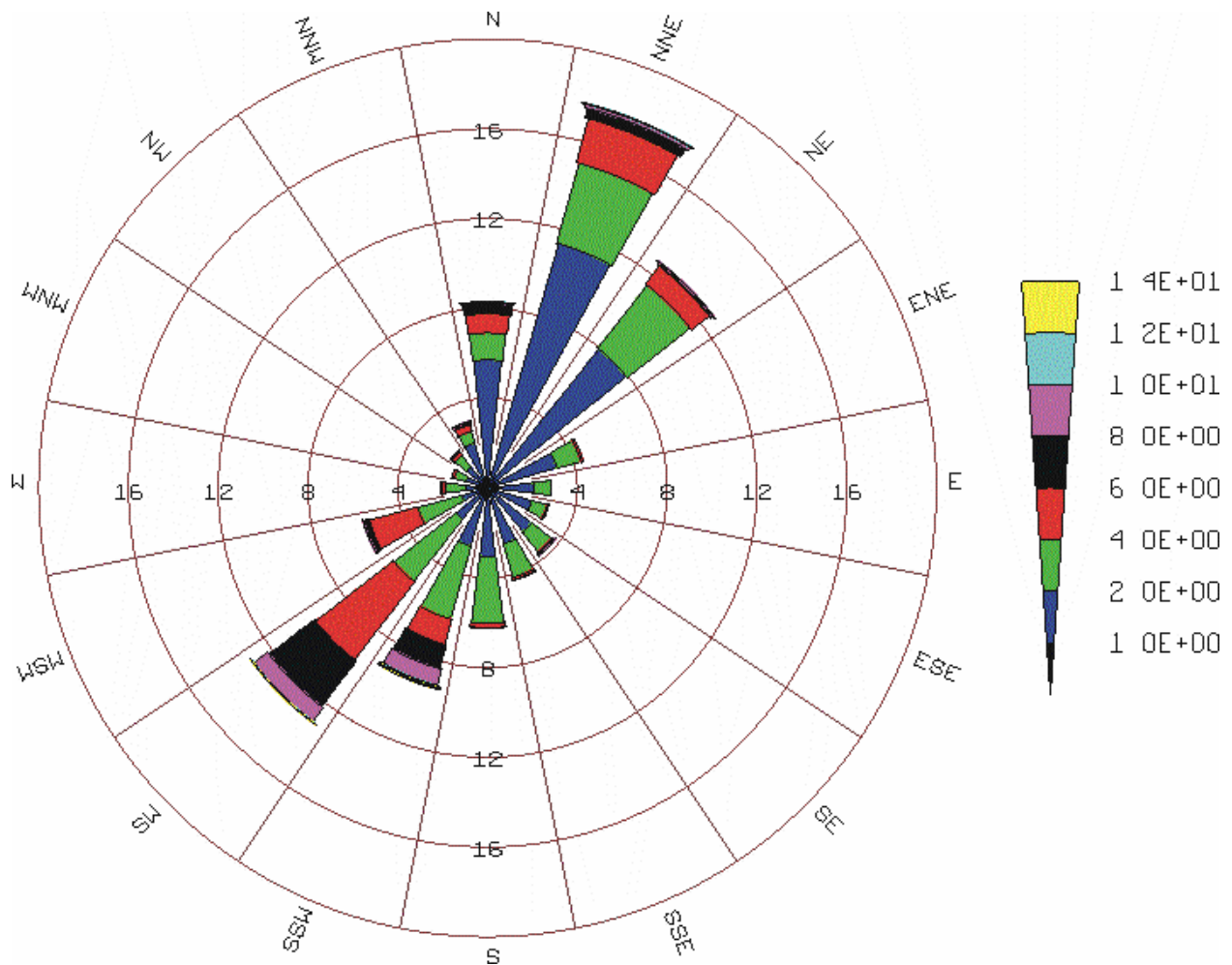


Figure 25. Wind rose diagram for 2002 data from the Area 5 RWMS meteorology station. Concentric labels indicate percent frequency, petal shading indicates wind speed in meters per second at a height of 3 m, and petal direction indicates direction of wind source

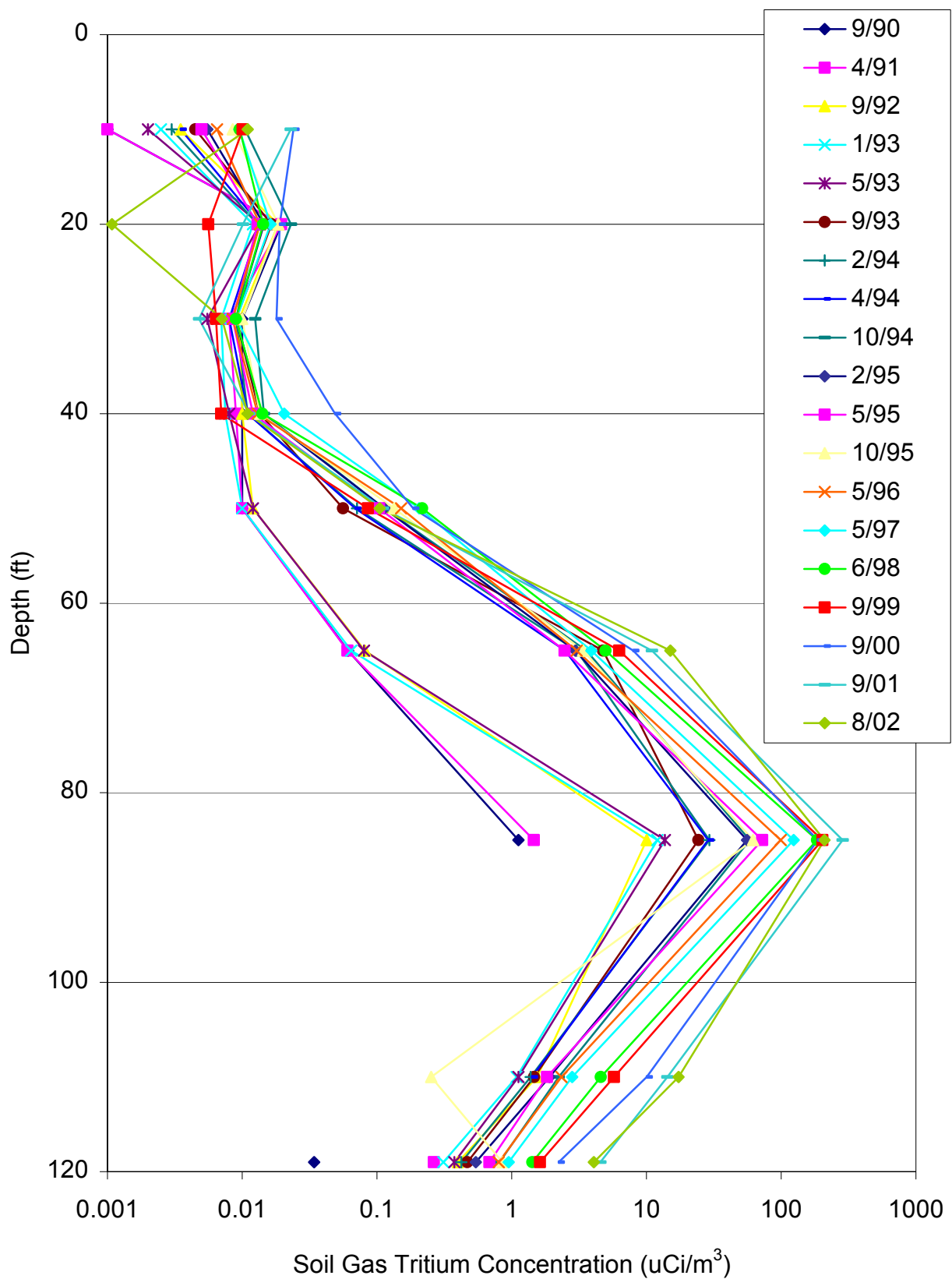


Figure 26. Soil-gas tritium concentrations with depth at GCD-05U

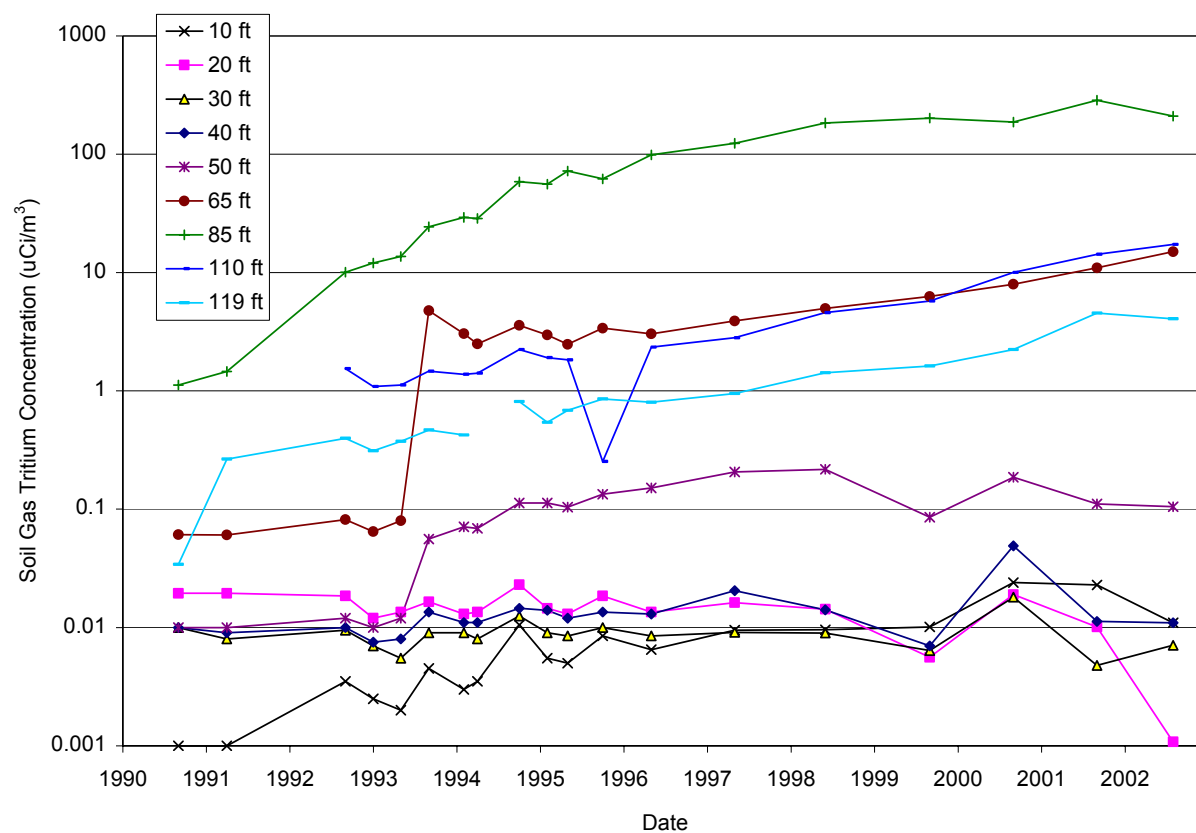


Figure 27. Soil-gas tritium concentrations with time at GCD-05U

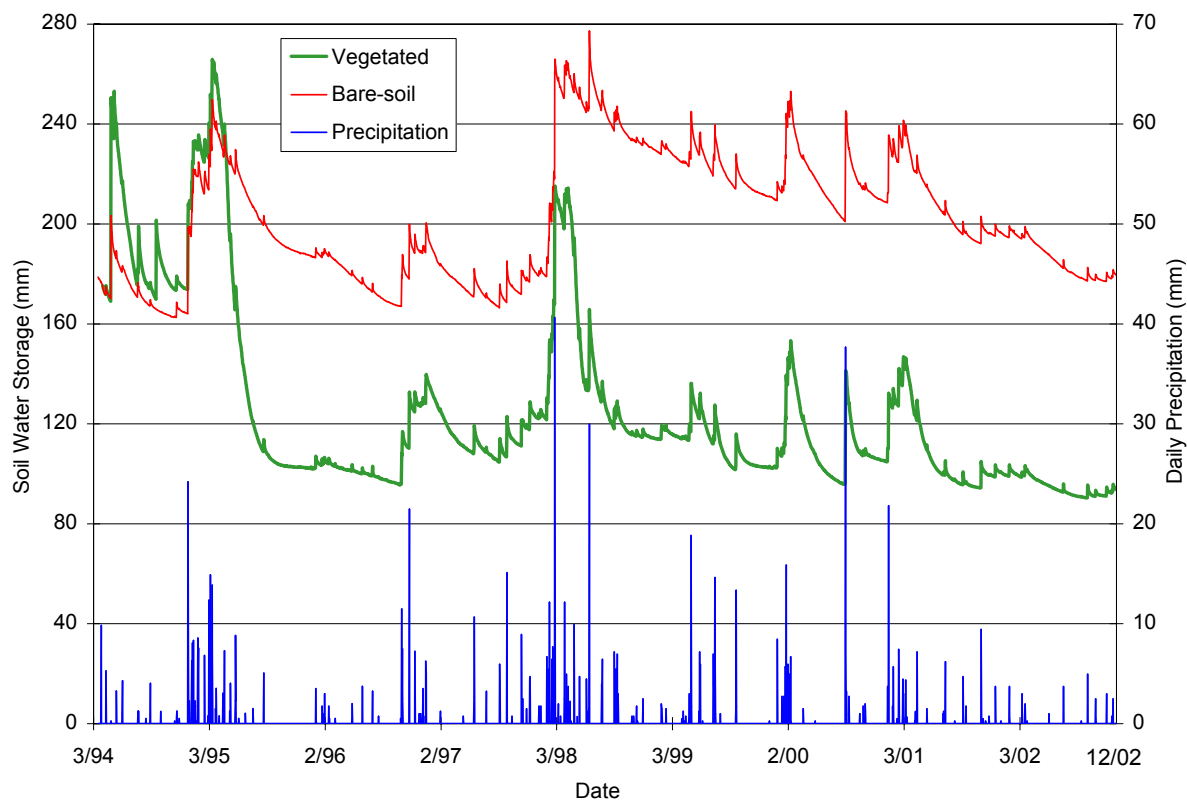


Figure 28. Weighing lysimeter and precipitation data from March 1994 to December 2002

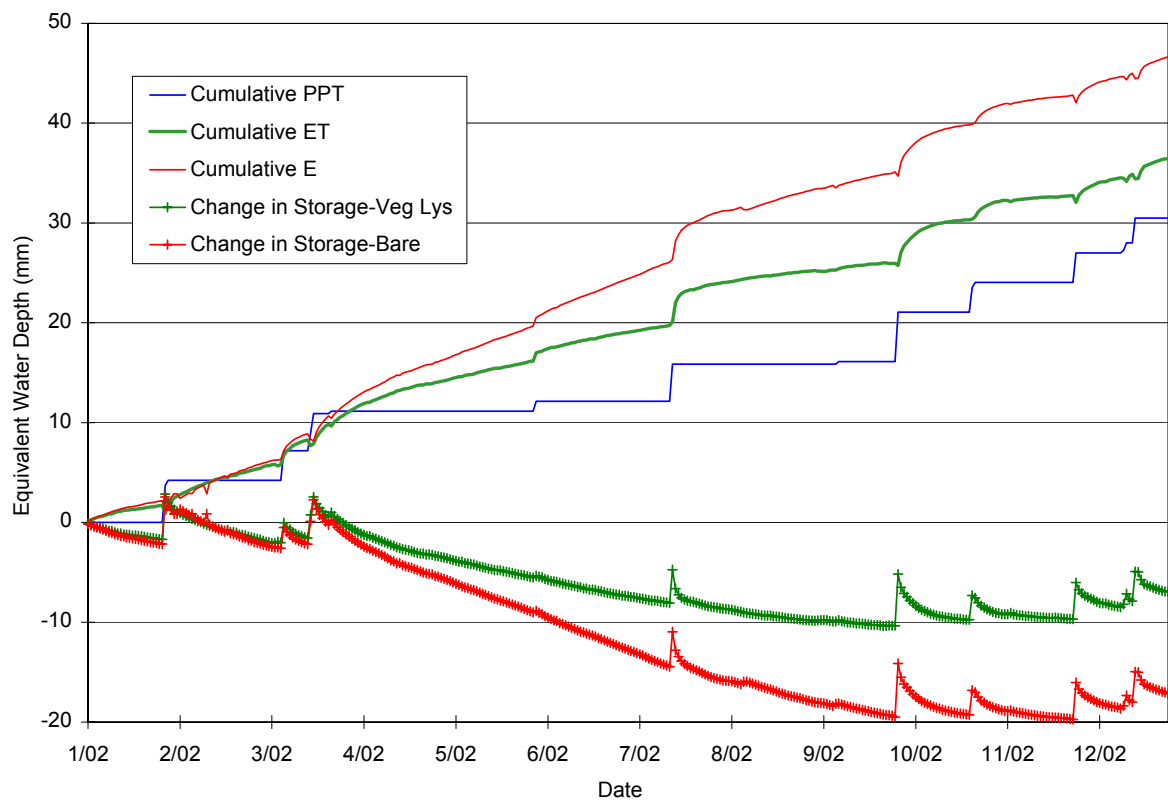


Figure 29. Cumulative PPT, ET, E, and change in storage for the weighing lysimeters in 2002

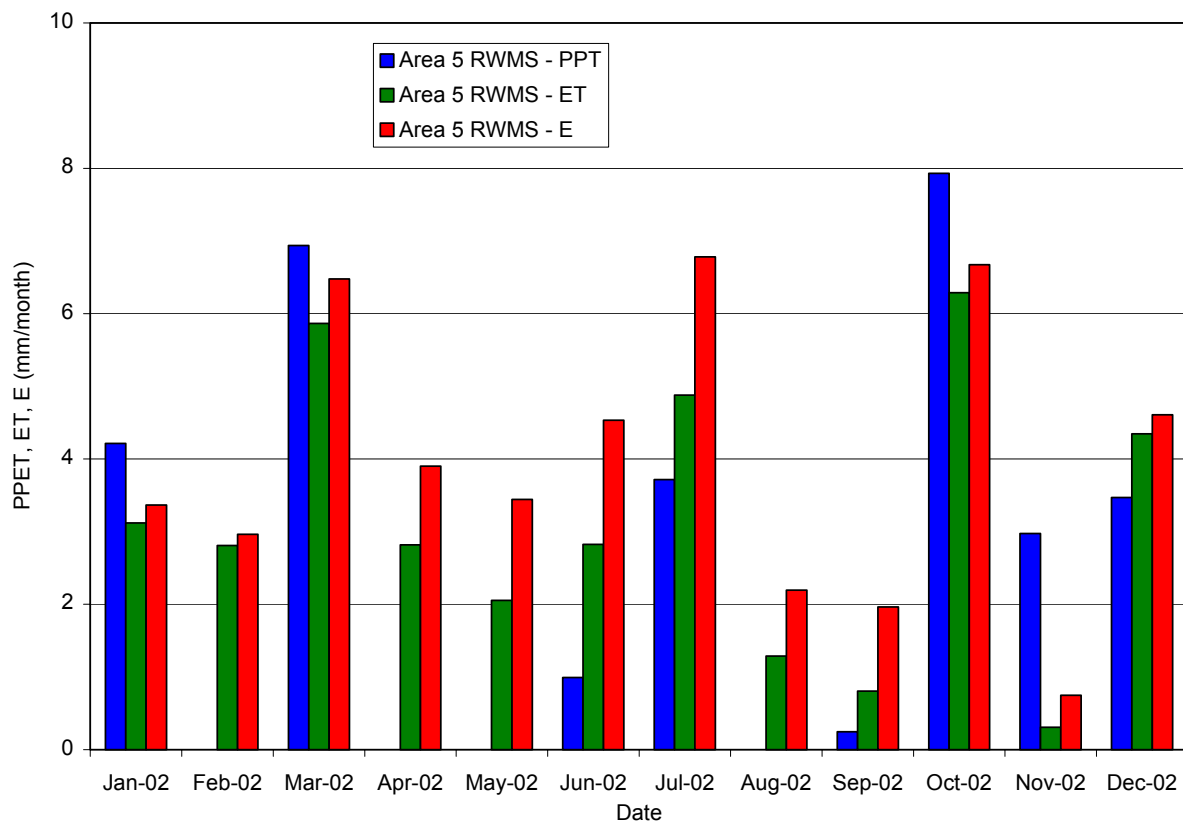


Figure 30. Monthly precipitation, evaporation, and ET recorded at the Area 5 RWMS in 2002

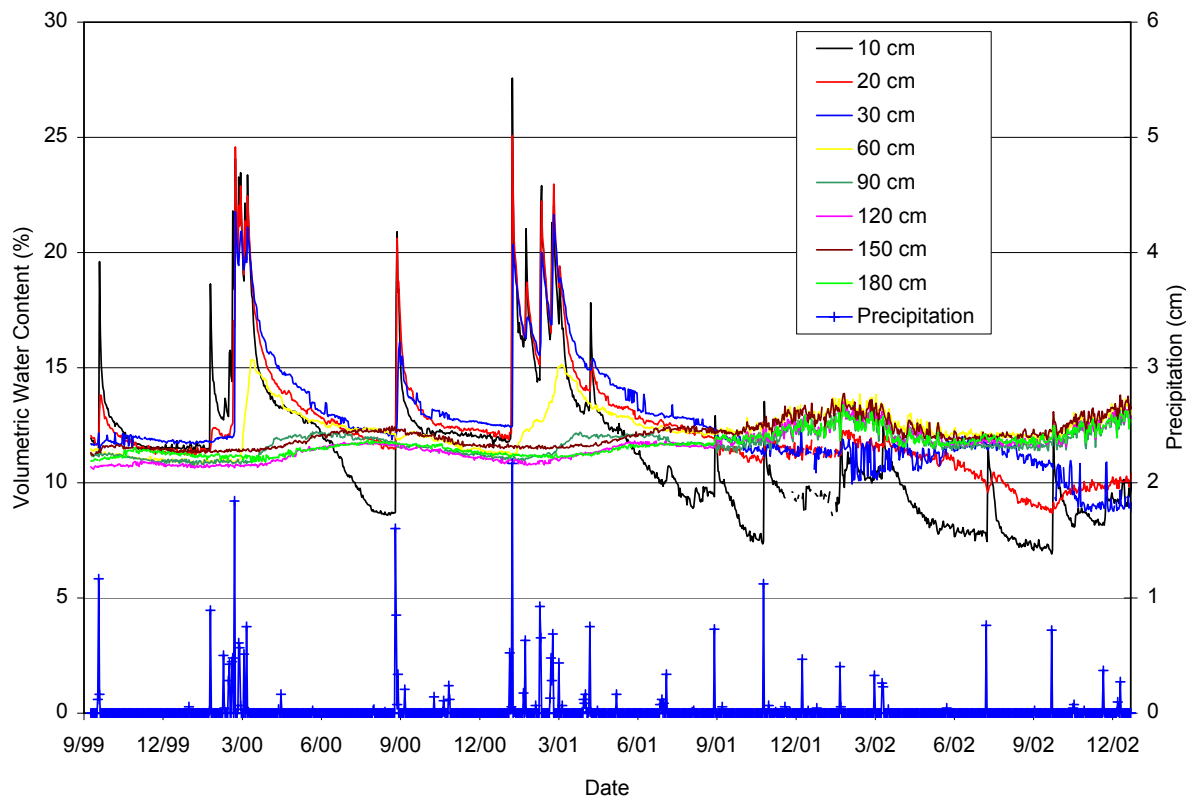


Figure 31. Soil water content in Pit 3 waste cover (north site) using an automated TDR system

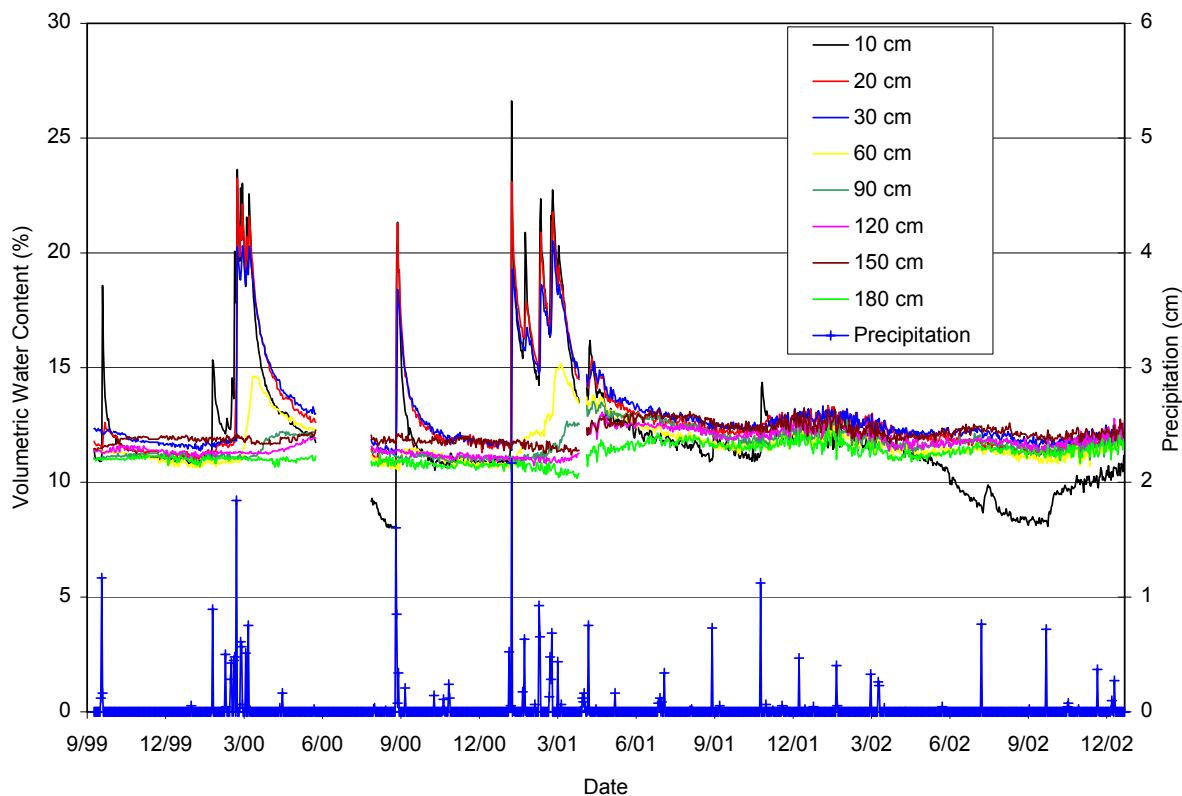


Figure 32. Soil water content in Pit 3 waste cover (south site) using an automated TDR system



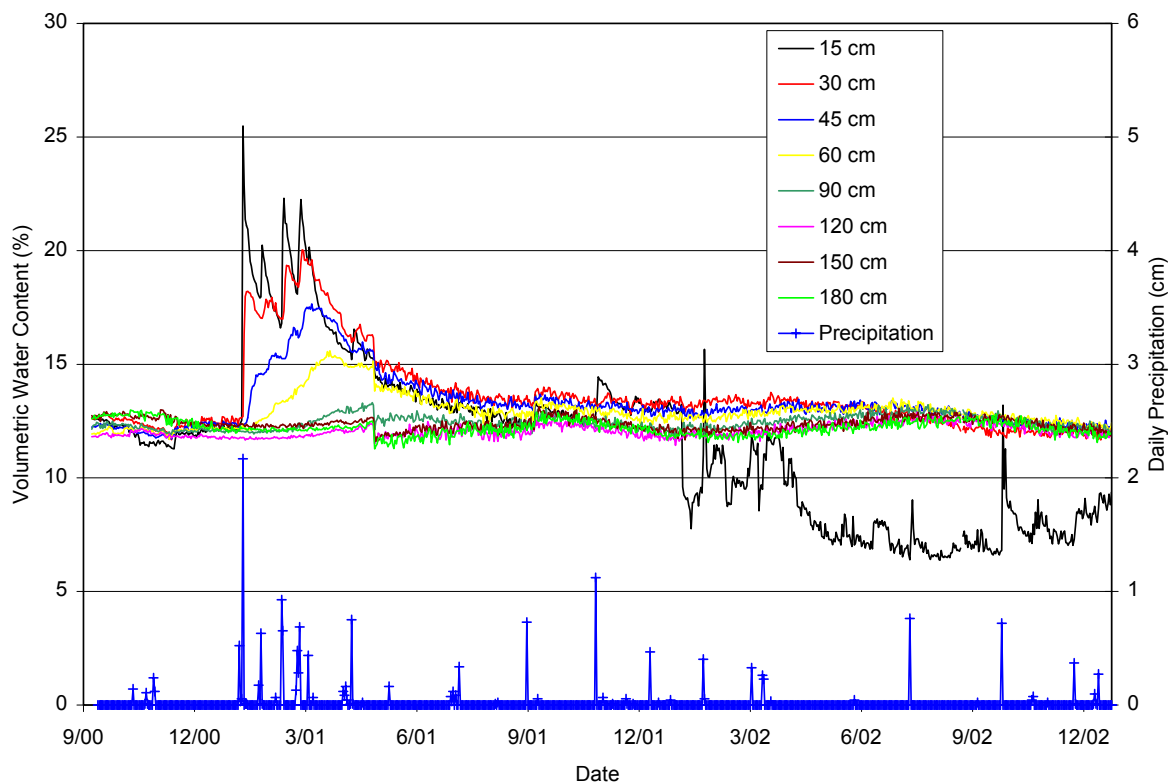


Figure 33. Soil water content in Pit 4 waste cover using an automated TDR system

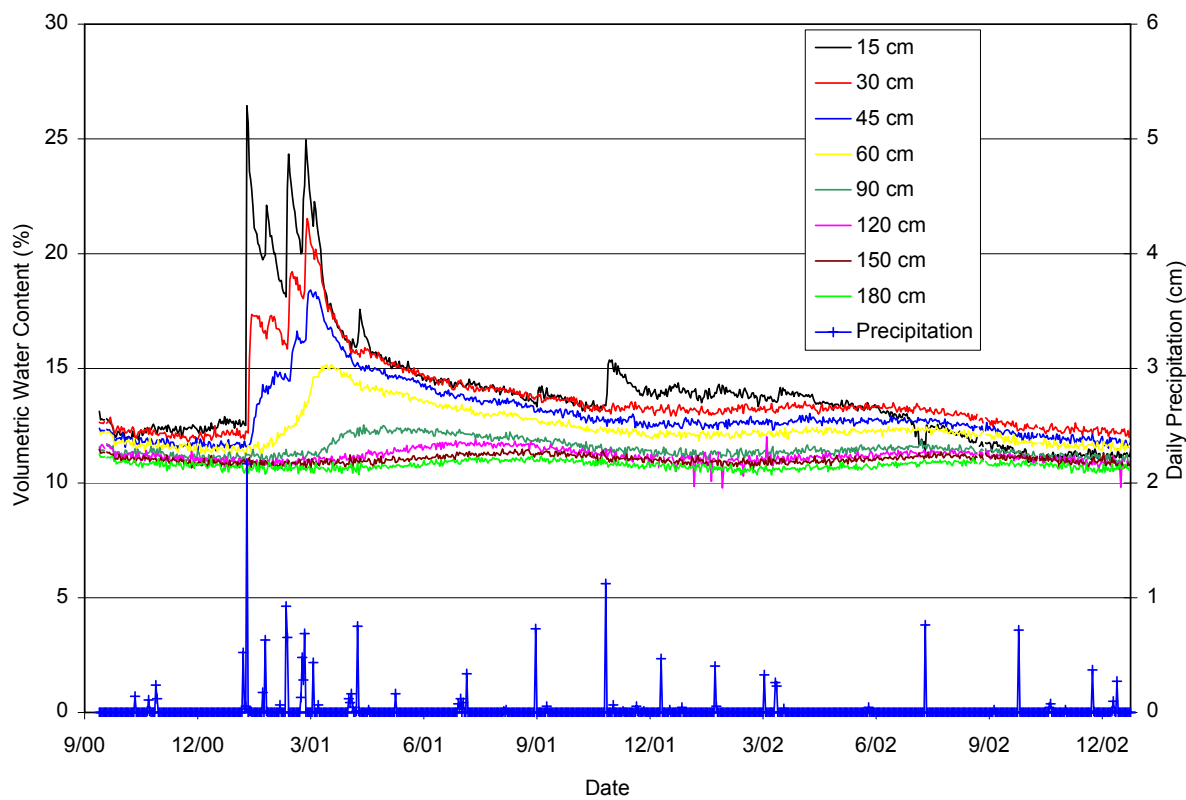


Figure 34. Soil water content in Pit 5 waste cover using an automated TDR system

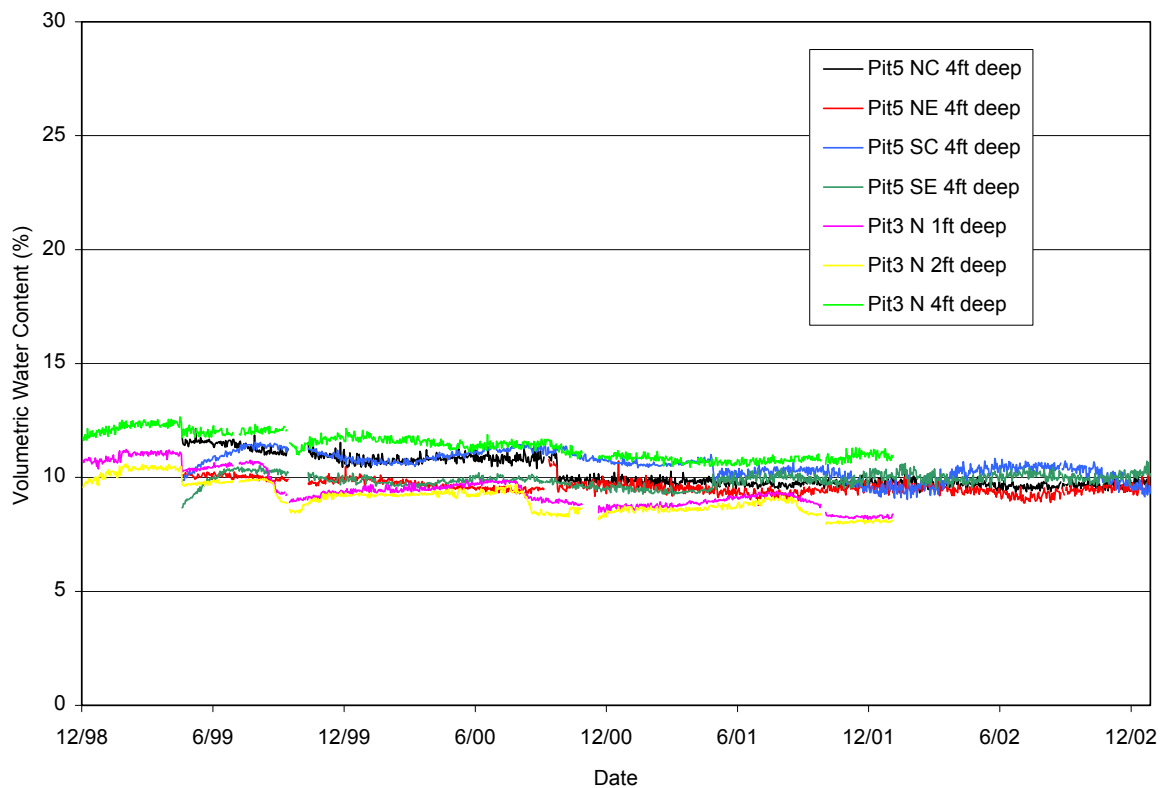


Figure 35. Soil water content in Pit 3 and Pit 5 floors using automated TDR systems

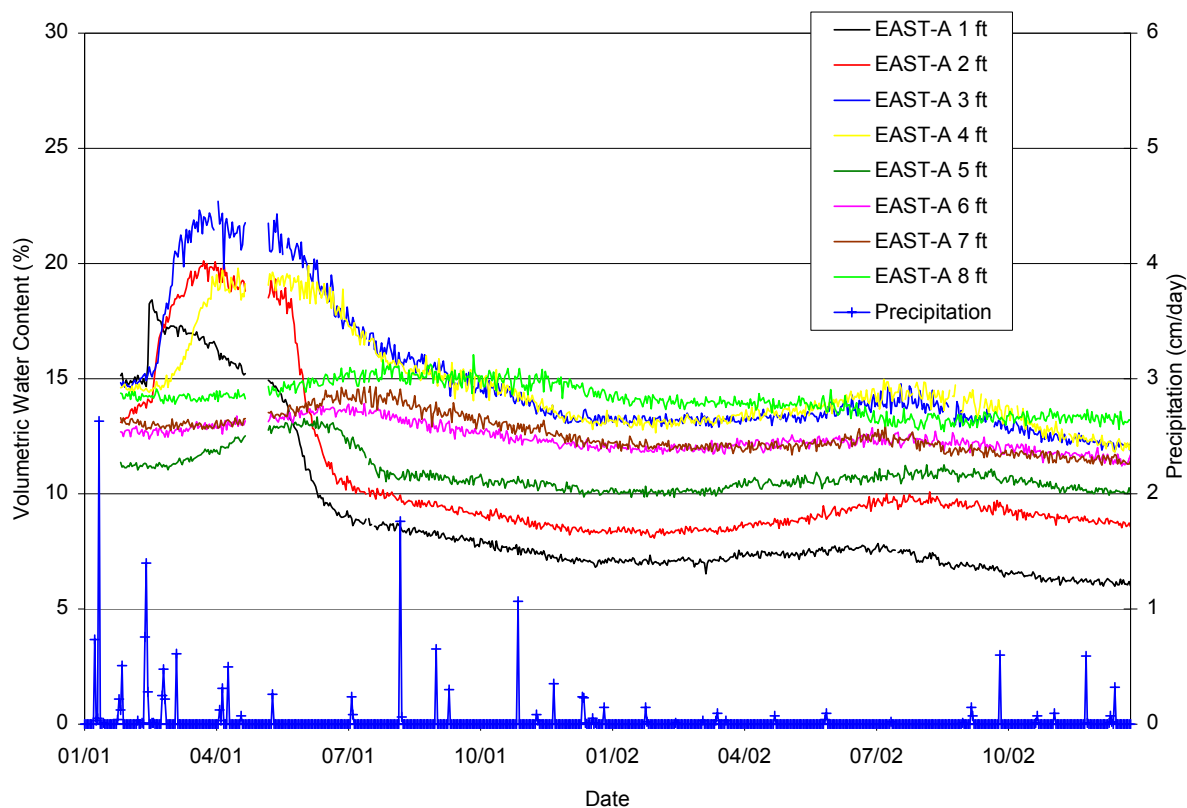


Figure 36. Soil water content in U-3ax/bl waste cover (east station) using a TDR system

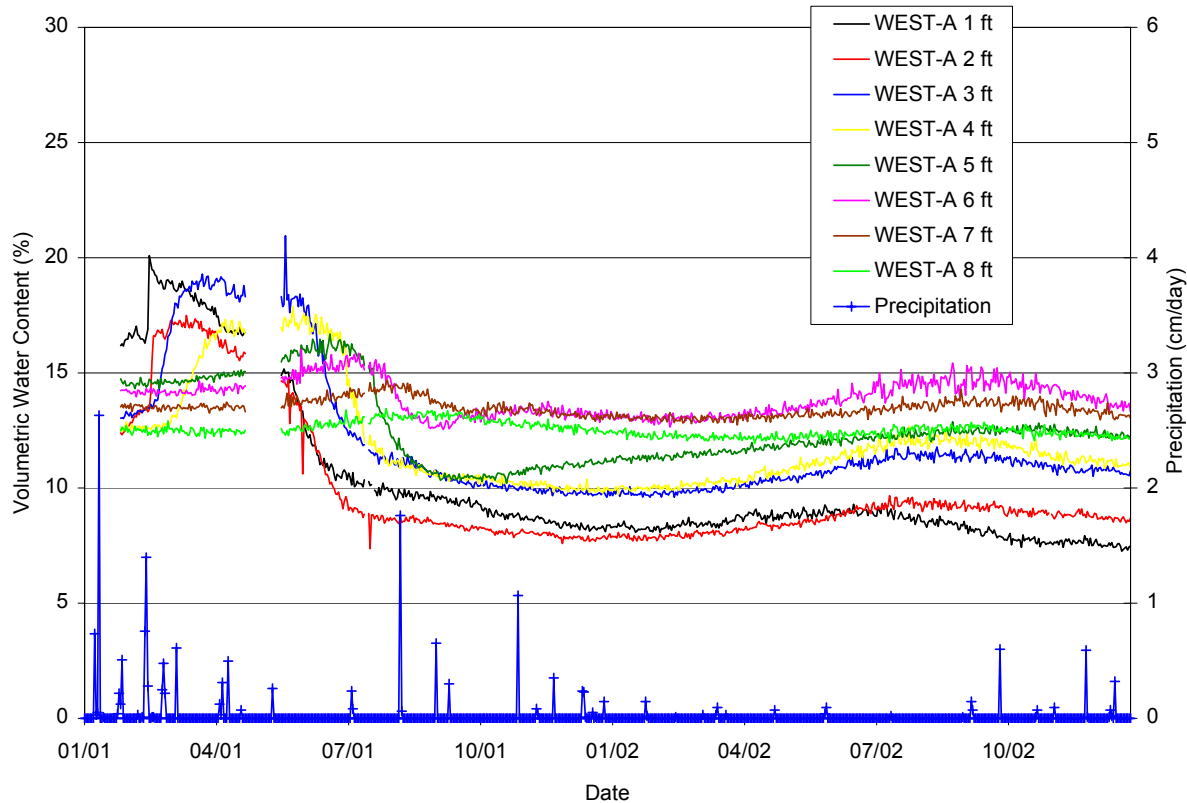


Figure 37. Soil water content in U-3ax/bl waste cover (west station) using a TDR system

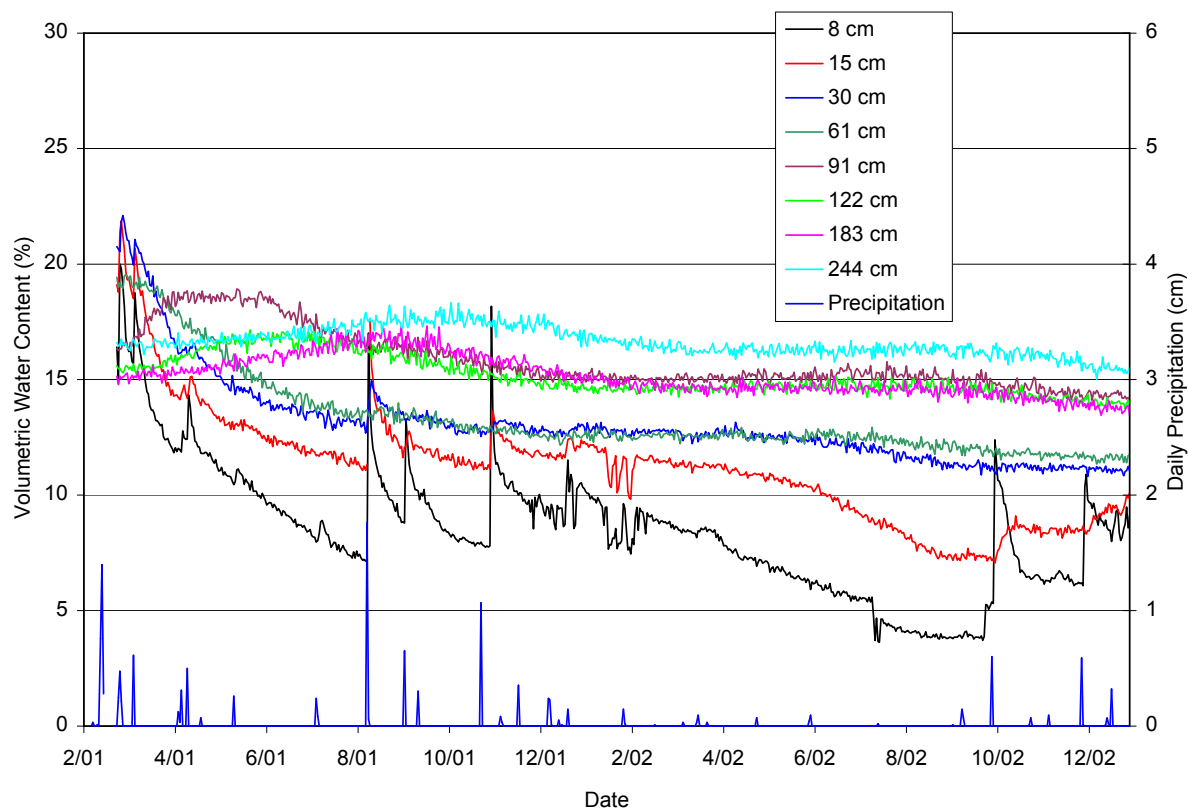


Figure 38. Soil water content in bare drainage lysimeter (A) using a TDR system

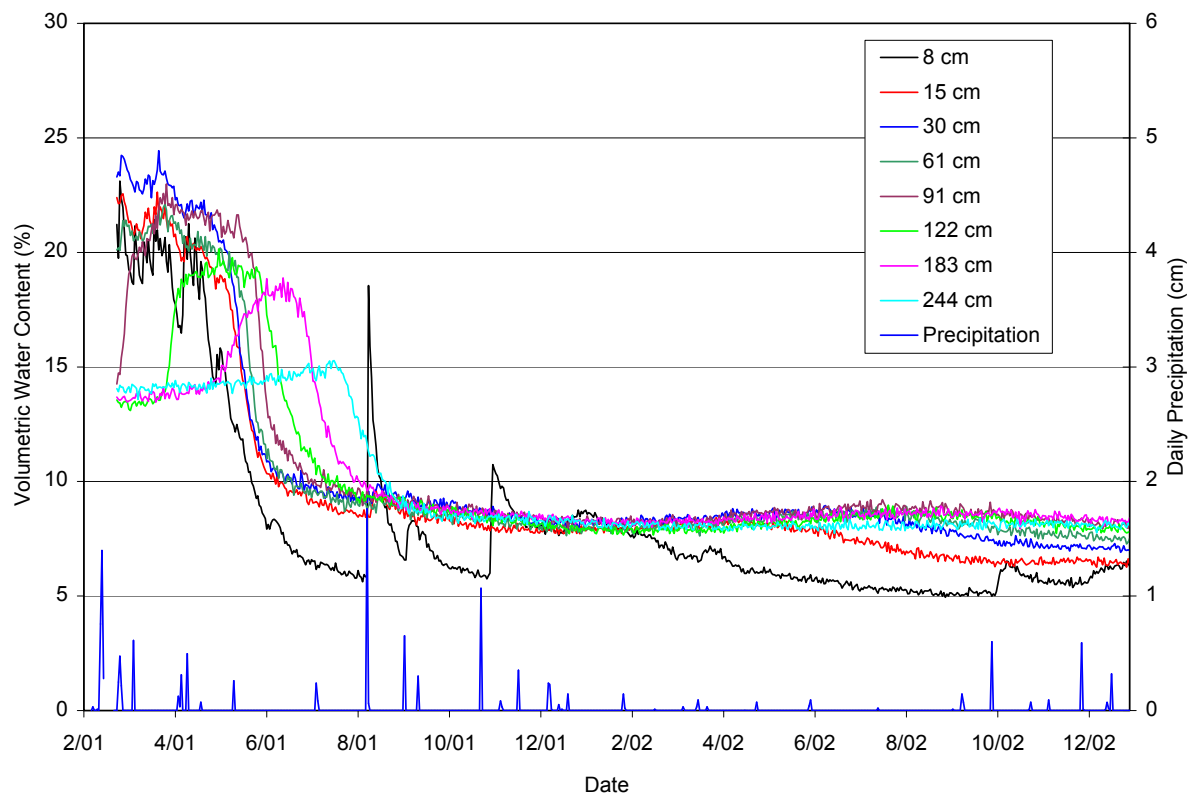


Figure 39. Soil water content in vegetated drainage lysimeter (E) using a TDR system

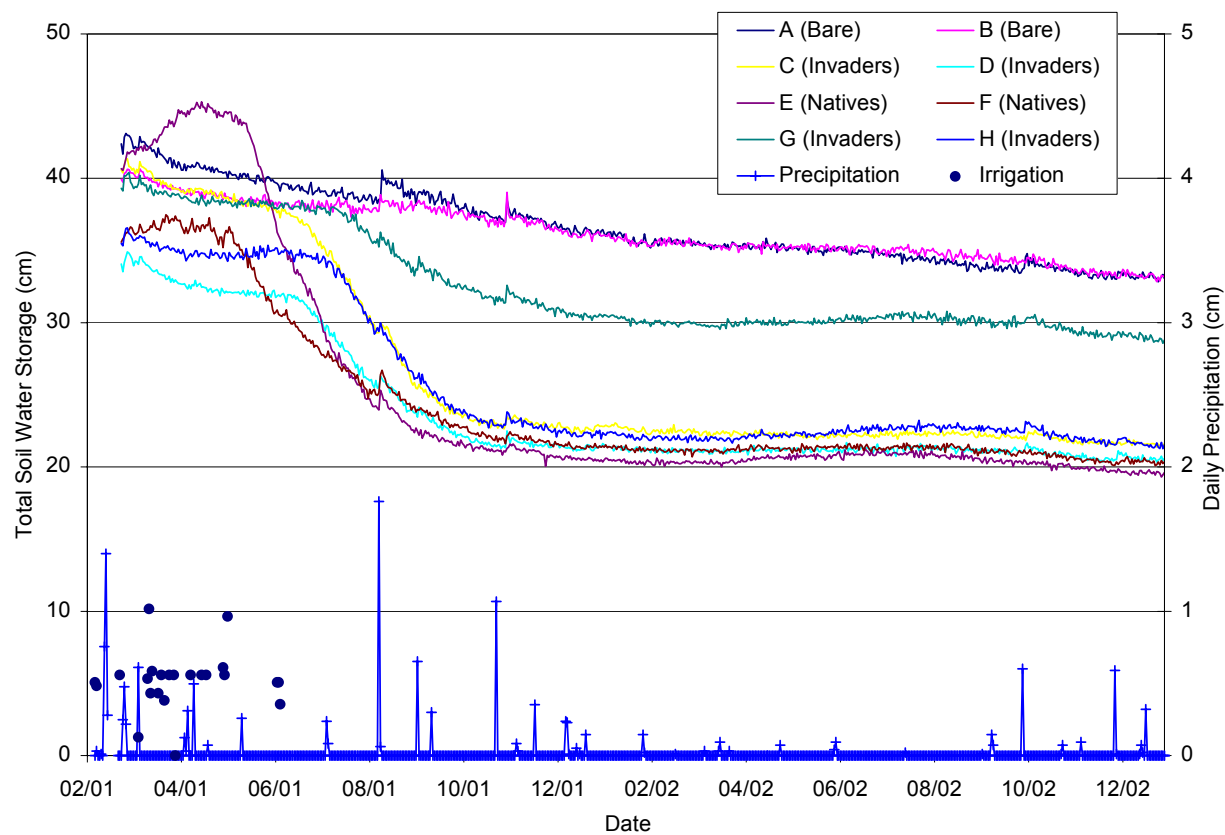


Figure 40. Soil water storage in drainage lysimeters

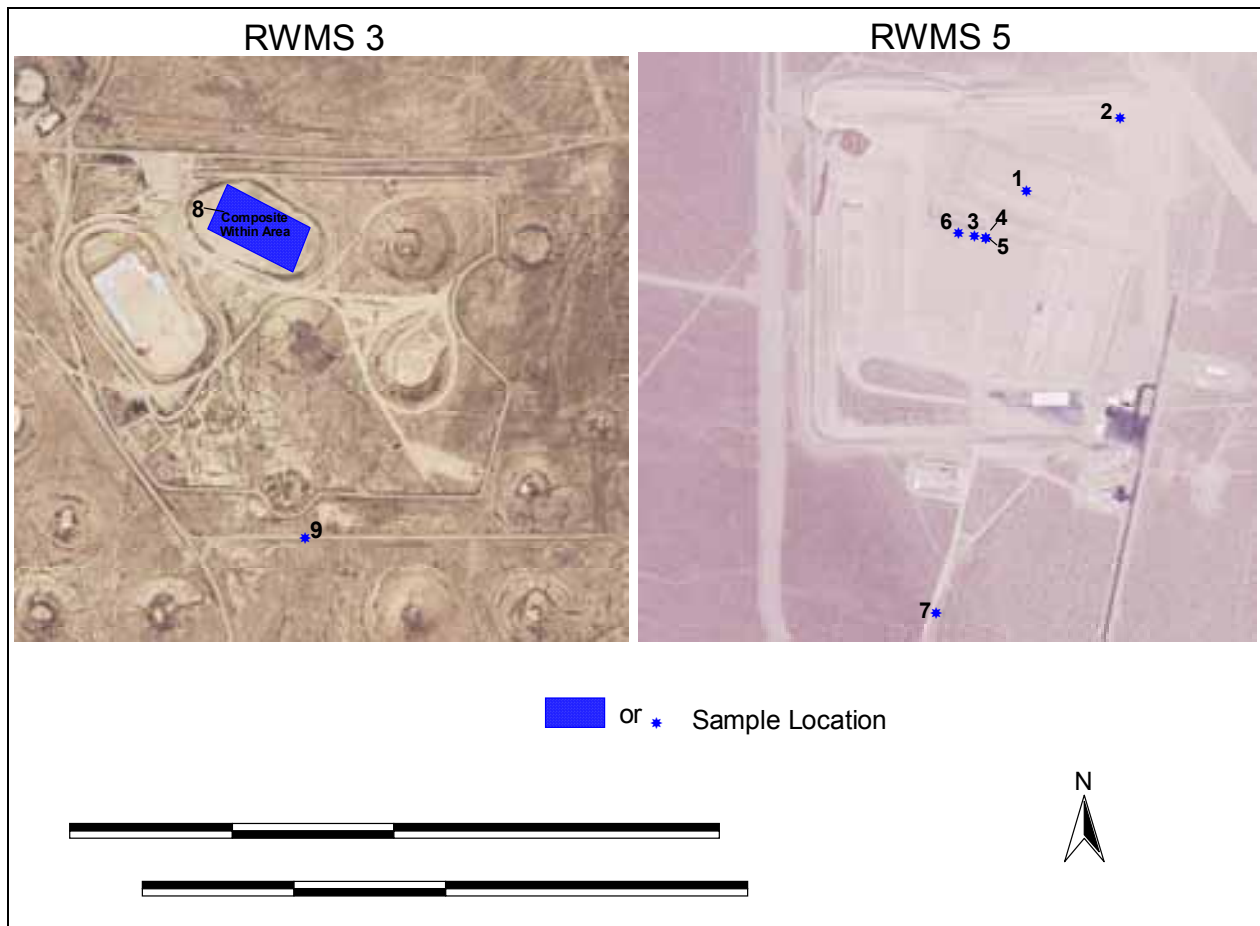


Figure 41. Locations of vegetation samples collected July 22, 2002 (Area 5 RWMS) and July 30, 2002 (Area 3 RWMS)

## TABLES

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Table 1. Comparison of water contents measured by coring and neutron probe in 2002

Location	Depth (ft)	Bulk Density (g/cm <sup>3</sup> )	Core Sample GWC (%)	Core Sample VWC (%) using actual BD	Core Sample VWC (%) using BD = 1.6	Neutron Probe VWC (%)	Core VWC minus NP VWC (using actual BD)	Core VWC minus NP VWC (using BD=1.6)
Pit 3 T2	1	1.89	5.53	10.45	8.85	3.89	6.56	4.96
Pit 3 T2	2	1.85	5.23	9.66	8.37	6.16	3.50	2.21
Pit 3 T2	3	1.59	6.85	10.91	10.96	7.64	3.27	3.32
Pit 3 T2	4	1.60	6.95	11.13	11.13	7.96	3.16	3.16
Pit 3 T22	1	1.60	5.22	8.36	8.36	3.90	4.45	4.45
Pit 3 T22	2	1.62	6.52	10.57	10.43	6.81	3.75	3.62
Pit 3 T22	3	1.60	6.02	9.63	9.63	6.91	2.73	2.73
Pit 3 T22	4	1.60	7.17	11.47	11.47	9.77	1.69	1.69
Pit 4 T19	1	1.63	5.67	9.22	9.08	10.48	-1.26	-1.40
Pit 4 T19	2	1.62	6.86	11.14	10.97	13.21	-2.07	-2.24
Pit 4 T19	3	1.67	6.76	11.26	10.81	13.11	-1.86	-2.30
Pit 4 T19	4	1.60	6.74	10.79	10.79	13.57	-2.78	-2.78
Pit 4 T8	1	1.60	5.84	9.35	9.35	5.79	3.56	3.56
Pit 4 T8	2	1.56	6.75	10.56	10.81	9.30	1.26	1.51
Pit 4 T8	3	1.60	7.20	11.52	11.52	9.15	2.37	2.37
Pit 4 T8	4	1.60	7.54	12.06	12.06	9.85	2.22	2.22
BD = Bulk Density						Average =	1.91	1.69
GWC = Gravimetric Water Content						Std Dev =	2.63	2.50
VWC = Volumetric Water Content								

Table 2. Locations and descriptions of subsidence features observed in 2002

Date	Area	Pit	Northing	Easting	Feature
01/07/2002	5	5	N/A	N/A	1 feature
01/30/2002	5	Classified	767417.67	709053.00	Pocket, 1' in diameter
01/30/2002	5	Classified	767387.90	709064.30	Pocket, 1' in diameter
12/17/2002	5	5	767422.54	709847.38	3' X 3' depression
12/17/2002	5	5	767244.44	709847.81	Large depression
12/17/2002	5	5	767507.13	709845.07	2' X 2' Hole
12/17/2002	5	5	767507.14	709610.89	3' X 3' Hole
12/17/2002	5	2	767507.15	709004.87	Crater

Table 3. Radionuclides detected during 2002 vegetation sampling at the RWMSs

Area	Location	Description	H-3 (pCi/L)	Sr-90 (pCi/g)	Cs-137 (pCi/g)	U-233/234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Area 5 RWMS	1	South Side of Classified Pit, Desert Saltbush or Allscale ( <i>Atriplex polycarpa</i> )	21,100,000 +/- <sup>a</sup> 5,280,000	<MDC <sup>b</sup>	<MDC	0.041 +/- 0.036	0.017 +/- 0.021 <sup>c</sup>	0.016 +/- 0.023 <sup>c</sup>
	2	North Side of Pit 3, Creosote Bush ( <i>Larrea tridentata</i> )	118,000 +/- 30,000	<MDC	<MDC	0.053 +/- 0.043	<MDC	0.043 +/- 0.039
	3	North End of Pit 2 on South-facing slope of GCD berm, Desert Saltbush or Allscale ( <i>Atriplex polycarpa</i> )	4,340,000 +/- 1,092,000	<MDC	<MDC	0.059 +/- 0.051	0.035 +/- 0.039 <sup>c</sup>	0.042 +/- 0.043 <sup>c</sup>
	4	North End of Trench 4 on East-facing slope of GCD berm, Desert Saltbush or Allscale ( <i>Atriplex polycarpa</i> )	716,000 +/- 181,600	<MDC	<MDC	0.062 +/- 0.047	0.019 +/- 0.027 <sup>c</sup>	0.021 +/- 0.028 <sup>c</sup>
	5	North End of Trench 4 on East-facing slope of GCD berm, Desert Saltbush or Allscale ( <i>Atriplex polycarpa</i> )	672,000 +/- 170,600	<MDC	<MDC	0.042 +/- 0.037	0.021 +/- 0.025 <sup>c</sup>	0.017 +/- 0.024 <sup>c</sup>
	6	North End of Trench 6 on South-facing slope of GCD berm, Desert Saltbush or Allscale ( <i>Atriplex polycarpa</i> )	721,000 +/- 183,200	0.354 +/- 0.159	0.550 +/- 0.414	0.081 +/- 0.058	0.017 +/- 0.024 <sup>c</sup>	0.034 +/- 0.037 <sup>c</sup>
	7	Control Site Approximately 600 m South of RWMS 5, Four-wing Saltbush ( <i>Atriplex canescens</i> )	1,290 +/- 594	<MDC	<MDC	0.065 +/- 0.047	<MDC	0.030 +/- 0.033 <sup>c</sup>
Area 3 RWMS	8	AX/BL, Composite from 30 Shadscale Saltbush ( <i>Atriplex Convertifolia</i> )	12,100 +/- 3,160	<MDC	<MDC	0.056 +/- 0.046	<MDC	<MDC
	9	South of RWMS 3, Along East CC Road, Desert Saltbush or Allscale ( <i>Atriplex polycarpa</i> )	21,400 +/- 13,400	<MDC	<MDC	0.095 +/- 0.062	0.047 +/- 0.041	0.042 +/- 0.042
<sup>a</sup> +/- 2 standard deviations <sup>b</sup> Less than minimum detectable concentration (MDC) <sup>c</sup> While the measured activity was higher than laboratory stated minimum detection limits, the stated concentration may be a false positive given the relatively large uncertainty values.								

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