



## Agenda Memorandum

Agenda Item – {{section.number}}.A.

City Council Meeting  
November 20, 2023



### Strategic Priority 1: Preparedness and Resilience

Build a system of intentional support for residents, businesses and the environment that mitigates risks and proactively seeks out ways to ensure the community not only endures, but thrives.

**Subject:** Air Quality Monitoring at Rocky Flats and an Update on the Greenway Trail

**Prepared By:** Trea Nance, Senior Water Quality Analyst  
Joe Reale, Open Space Superintendent

### Recommended City Council Action:

This report is for information only and requires no action by City Council.

### Summary Statement:

- On September 11, 2023, City Council requested additional information on air quality monitoring at Rocky Flats and the Rocky Mountain Greenway Trail (RMG).
- Multiple studies have been performed over the years at and in the communities surrounding the Rocky Flats Site (RFS).
- Results from monitoring have been consistently low-level and below the limiting air quality standards.
- Local government members of the Rocky Flats Stewardship Committee, along with the Colorado Department of Public Health and Environment (CDPHE), the Environmental Protection Agency (EPA), and the Department of Energy (DOE), met on November 14, 2022. During this meeting the DOE clarified that it is not prepared to perform, nor provide funding for, additional air monitoring on or around RFS.
- An ad-hoc committee of interested local governments including Arvada, Broomfield, Boulder County, Jefferson County, and Westminster was formed following the November 14, 2022 meeting and is in the process of gathering more information on studies that have already been performed.

- Any future endeavors for additional air monitoring would require leadership and funding from interested local governments.

## **Background Information:**

Extensive air quality monitoring has been performed at the RFS during operation, during decommissioning and cleanup, and after fires that have occurred on the RFS post-cleanup.

### *Recent Air Quality Topics and Requests*

In response to the Marshall Fire in December 2021, there was increased interest in air quality monitoring at RFS. Letters to the DOE were sent by the City and County of Broomfield, the City of Arvada, and Boulder County requesting air quality monitors be deployed in the vicinity of RFS.

In response to these letters, the DOE hosted an air quality meeting on November 14, 2022 with local government members of the Rocky Flats Stewardship Committee along with the CDPHE and the EPA. During the meeting, the DOE referred to the studies summarized in the next section and clarified that air emissions at RFS do not present health or environmental concerns. The DOE representatives advised meeting participants that the DOE is not required to perform air monitoring, nor would it provide funding to other parties to do so. The DOE representatives stated that doing so would undermine the finality of the Record of Decision and protectiveness of the Remedy, or clean-up.

The local government representatives discussed with DOE the history and goals of potential air quality monitoring and concluded that the objectives of any potential future monitoring need to be made clear and the locations of the air monitoring sites need to be determined. Following that meeting, an ad-hoc committee of interested local governments including Arvada, Broomfield, Boulder County, Jefferson County, and Westminster was formed. The committee met on May 5, 2023 and concluded it needed to gather additional information, and is considering steps toward a community-led effort for additional air monitoring. The documents summarized in the next section were sent to the meeting attendees for reference.

Implementing air quality monitoring in the future would be a significant undertaking requiring leadership by the interested local governments. Funding requirements could be significant due to equipment expenses and the costs of laboratory analyses. Additionally, it would be advisable to hire a consultant with expertise in air quality monitoring and to have personnel available for the deployment and maintenance of air quality monitoring equipment.

### *Historic Data and Investigations*

According to the Corrective Action Decision/Record of Decision (CAD/ROD), air quality monitoring during production and cleanup activities at RFS remained compliant with regulatory requirements. The highest values observed at the time of decommissioning and cleanup, when the most disturbance to contaminated soil and surfaces occurred, reached a maximum of 3 percent of the limiting standard, which is ten-millirem per year. While soil contamination remains at the site, air emissions are expected to continue to be significantly lower than during site operation and decommissioning. Air modeling referenced in the CAD/ROD showed that, even if the historically high plutonium-contaminated areas were to be impacted directly by a wildland fire, radioactive air emissions would still be significantly lower than the EPA's ten-millirem benchmark for an airborne exposure pathway.

There are many documents in the Comprehensive Environmental Response, Compensation, and

Liability Act (CERCLA) record for the RFS documenting wildland fires that occurred on the site post-cleanup. These studies and their results are summarized in the table below. The full studies are attached to this document.

Study Date	Study Type	Size	Location	Results	Above Limiting Standards? <sup>[i]</sup>	Additional Information
1990 - 2005	Community air monitoring	N/A	Westminster, Arvada, Broomfield, Northglenn	All low-level.	No	Attachment A
April 6, 2000	Controlled burn + wind tunnel	50 acres	Refuge (south)	Extremely low-level radioactivity detected directly downwind.	No	Attachments B and C
July 10, 2000	Post-wildfire + wind tunnel	10 acres	Refuge (east)	Large fraction of soil particle sizes too large for resuspension / emissions.	No	Attachment D
December 1, 2000	Hypothetical firefighter in smoke plume	N/A	Directly downwind in plume	The firefighter would receive a maximum dose of one mrem. <sup>[ii]</sup>	No	Attachment E
April 2, 2006	Air samplers active during fire	850 acres	Refuge (north)	All results below detection limit.	No	Attachment F

<sup>[i]</sup>The limiting standard set by EPA is ten-millirem per year. For perspective, the average annual dose for an American, a measure of actual exposure, is 360 to 400 millirem per year.

<sup>[ii]</sup> The study also provided recommendations for when a firefighter should not be in proximity to a fire based on potential radiation dose.

### *Rocky Mountain Greenway Trail*

In 2016, Jefferson County contacted the City to join in a partnership with Boulder County, the City and County of Broomfield, and the cities of Boulder and Arvada for a Federal Lands Access Program (FLAP) grant that would fund more than 83 percent of the costs of the RMG connections to the Rocky Flats. The RMG is a proposed regional trail across the northern Denver metropolitan area connecting the Rocky Mountain Arsenal National Wildlife Refuge (NWR) in Commerce City to the Rocky Flats NWR, which directly abuts Westminster's western boundary at Indiana Street. The City of Westminster has partnered with the Federal Highway Administration to construct the portion of the trail located in Westminster.

Much of the RFG utilizes existing regional trails, passing through two parts of Westminster. The Little Dry Creek Trail section of the RFG will cross through south Westminster. The trail also passes through Westminster north of 86th Parkway and east of Indiana Street, across Standley Lake Regional Park and Westminster Hills Open Space. The trail follows the east side of Standley Lake along the base of the Standley Lake Dam. The Greenway Trail uses the Big Dry Creek Trail along the east and north side of Standley Lake to Simms Street. West of Simms Street, the trail runs south of the Standley Lake Regional Park Nature Center and crosses 100th Avenue onto the Westminster Hills Open Space. The trail continues in a northwesterly alignment to about 108th Avenue and Indiana Street. Subsequent phases will cross Indiana Street, extend the trail onto the Rocky Flats NWR and eventually to Boulder and perhaps Rocky Mountain National Park. See Attachment H for map.

On July 11, 2016, City Council adopted Resolution No. 24 to conditionally support Jefferson County Open Space's (JCOS) request to pursue a FLAP grant and to provide up to \$220,000 in matching funds for the construction of a pedestrian overpass crossing Indiana Street and a pedestrian

underpass at State Highway 128. The support for this project application and the construction of connections was contingent on the development and findings of a soil analysis plan (SAP). The findings of the SAP reflected radionuclide activity levels consistent with the standards used by the EPA and Colorado Department of Public Health and Environment (CDPHE) to demonstrate that the Rocky Flats NWR is safe for public use. The mean activity values of surface soil radionuclide samples from both the State Highway 128 underpass location and the Indiana Street bridge and overpass location were, without exception, lower than the historic values for the relevant exposure units, namely points of human contact with contaminated media. The levels are consistent with the conservative benchmarks established. The SAP Report findings were presented to City Council on February 1, 2021, and the complete report can be found in Attachment G.

On February 22, 2021, City Council adopted Resolution No. 2 Approving an Intergovernmental Agreement for Funding of the RMG Crossings, to be paid from the General Capital Improvement or Parks, Open Space and Trails Fund. This agreement included additional requirements for air quality monitoring during the trail construction.

The JCOS and the United States Fish and Wildlife Service (USFWS) have been working since that time on design and construction of the Indiana Street overpass and the Highway 128 underpass. The 100 percent engineering drawings and draft construction package are complete, and bids closed November 1, 2023. All ground disturbance work, installation of bridges, underpasses, and trail construction will occur at the same time to limit the number of disturbance windows and mobilizations. This work is proposed to occur in September of 2024 but may be earlier based on contractor timelines and anticipated to open in early 2025.

The City's Strategic Priorities of Preparedness and Resilience and Robust Infrastructure are met by providing a history of air quality monitoring at the RFS and providing updates on current air quality initiatives and the RMG trail progress. The RMG project supports the Strategic Priority of Quality of Life by helping to ensure access to the City's open spaces and trails.

Respectfully submitted,

A handwritten signature in black ink that reads "Mark A. Freitag". The signature is written in a cursive, flowing style.

Mark A. Freitag  
City Manager

**Attachments:**

Attachment A – Effects of Prescribed Grass Fire on Wind Erosion Rates from Surface Soil at Rocky Flats, Colorado

Attachment B – Modeling Wind Erosion Impacts Following a Grassland Fire

Attachment C – Effect of Wildfires on Soil Erodibility by Wind

Attachment D – Assessment of April 2006 Grass Fire at the Rocky Flats Site: Modeling of Grass Fire Emissions and Discussion of Air Sampling as it Relates to a Grass Fire



Attachment E – Radiation Dose Assessment for Firefighters During a Grass Fire

Attachment F – ComRad Program Closeout Report

Attachment G – Rocky Mountain Greenway Trail Crossings Soil Sampling Results Report

Attachment H – USFWS Rocky Mountain Greenway Trail Map

## **Effects of Prescribed Grass Fire on Wind Erosion Rates from Surface Soil at Rocky Flats, Colorado**

Patrick Haines and Susan Templeman  
URS/Radian, 8181 East Tufts Ave., Denver, Co 80237  
patrick.haines@rfets.gov

Martha Hyder  
Wind River Environmental Group LLC, 3785 S. Poplar Street, Denver, CO 80237  
martha.hyder@rfets.gov

Chatten Cowherd, Jr. and Mary Ann Grelinger  
Midwest Research Institute, 425 Volker Boulevard, Kansas City, MO 64110  
ccowherd@mriresearch.org

### **ABSTRACT**

Removal of plants and plant litter by fire significantly increases the erosion potential of the underlying soil for some period of time. By using a portable wind tunnel to simulate high winds across test plots within a prescribed burn area, the effects of fire on soil erosion potential may be quantified as a function of wind speed and elapsed time following the fire.

A portable wind tunnel was used to generate high winds and collect soil particles eroded from a 50-acre study area that underwent a controlled burn in April 2000. Wind tunnel studies of the burned area and neighboring control areas were performed following the test burn, and again at intervals of 25 and 73 days following the fire. Soil erosion rates at incremented wind speeds were determined using optical particle counters and gravimetric analysis of dust samples. Shallow soil samples were collected from areas around the wind tunnel study plots for analysis in a soil dustiness test chamber.

The study was directed at answering the following questions:

- What increase in soil erosion potential may be expected as a result of grassland fire?
- What is the recovery rate of soil protective elements (vegetation and litter) for an area denuded by fire, as indicated by soil erosion potential?
- What algorithms may be employed to estimate increases in fugitive dust emissions resulting from post-fire increases in soil erosion potential?
- How may such algorithms be employed in common atmospheric dispersion models?

### **INTRODUCTION**

The U.S. Department of Energy's Rocky Flats Environmental Technology Site (Site) has several areas of actinide-contaminated soil as a result of spills and releases during the Site's nuclear weapons production era. Most such areas are well vegetated, which has stabilized potential wind-driven resuspension of actinide-contaminated soil particles. The Site is currently undergoing cleanup and closure, and as plans are being made for post-closure use, the increase in actinide emissions that might result following removal of vegetation by fire has become an issue of great interest. The Site has experienced three small lightning-caused grass fires in the past 10 years, so fires represent reasonably foreseeable occurrences.

In Spring 2000, the Site conducted a test burn to evaluate a proposed program of prescribed burning for weed control and prairie restoration. The test burn, which covered approximately 50 acres in the Site's buffer zone (the large, undeveloped area surrounding the Site's industrial area), presented an opportunity to gather data on post-fire resuspension rates and subsequent recovery for use in estimating emissions and impacts from wildfires at the Site. A portable wind tunnel was used to generate high winds and collect soil particles eroded from soil surfaces following the test burn, and again at intervals of 25 and 73 days following the test burn. Wind tunnel tests were performed by Midwest Research Institute (MRI) on representative portions of the test-burn area and also on an adjacent, unburned grassy area within the Rocky Flats site.

Because removal of standing plants and plant litter by fire significantly increases the erosion potential of the underlying soil for some period of time, one goal of the study was to evaluate the length of time it takes for a burned surface to regain protection against wind erosion comparable to pre-burn conditions. The objectives of the study also included determining how dust resuspension increases from one wind speed plateau to the next and how resuspension rates decay in time at a given wind speed. The wind tunnel tests determined wind erosion emission rates that will be used in the future to model short-term and annual particulate matter and actinide emissions from potential fires at the Site. The methods and results of the study are described below.

## TEST EQUIPMENT AND PROCEDURES

The prescribed burn was conducted on April 6, 2000 and wind tunnel testing was initiated the day after the burn. Wind tunnel tests were performed by MRI using a portable reference wind tunnel, described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites*.<sup>1</sup> Two TSI DustTRAK monitors were used to provide real-time concentrations of PM<sub>10</sub> (particles less than or equal to 10 micrometers [ $\mu\text{m}$ ] in aerodynamic diameter) in the tunnel effluent. Laboratory dustiness tests were run on bulk surface soil samples from burned areas to characterize the soil texture and to investigate the effects of soil moisture on erosion potential.

### Wind Tunnel Trials

Field tests of the prescribed burn area at Rocky Flats were performed over one-week periods beginning April 7, May 2, and June 19, 2000. During each test, the wind tunnel was moved three times over the test area, to collect additional particulate on the back-up filter in the effluent sampling train and to improve the detection and precision of the PM<sub>10</sub> erosion potential estimates.

The primary test device used in the evaluation was MRI's portable reference wind tunnel, shown in Figure 1. Although the portable wind tunnel does not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnel simulates the smaller scales of atmospheric turbulence. It is the smaller scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to the particle entrainment mechanisms. The wind tunnel method relies on a straightforward mass balance technique for calculation of particulate emission rates. Previous wind erosion studies using the MRI reference wind tunnel have led to the U.S. Environmental Protection Agency (EPA) recommended emission factors for industrial wind erosion presented in *Compilation of Air Pollutant Emission Factors (AP-42)*.<sup>2</sup>

For each run, the open-floored test section was placed directly over the surface to be tested. Air was drawn through the tunnel at controlled velocities, increasing at 2 meter per second [ $\text{m/s}$ ] (5 mile per hour [ $\text{mph}$ ]) increments, to a maximum velocity of about 40 mph at the tunnel centerline. This corresponded to a wind speed between 97 and 145 mph at a 10 meter (m) height; the equivalent 10-m speed varied with the roughness height of the surfaces tested in each trial.

Typically, each time the wind speed was increased, a PM<sub>10</sub> concentration spike was observed. Furthermore, upon each successive increase, the peak value of the spike increased and the rate of decay decreased. The PM<sub>10</sub> concentration values for each wind speed plateau were observable in the “real-time” concentration histories, recorded by the DustTRAK monitors (described below). For higher wind speed plateaus, the duration of sampling was increased to allow additional time for the spike to decay. An example of the concentration spikes that occurred during wind tunnel testing on the burned area can be seen in Figure 2.

A pitot tube was used to measure the centerline wind speed in the open-floored test section. The volumetric flow rate through the wind tunnel was determined from a published relationship between the maximum centerline velocity in a circular duct and the average velocity, as a function of Reynolds’ number.<sup>3</sup> Because the ratio of the centerline wind speed in the sampling extension to the centerline wind speed in the working section was nearly independent of flow rate, the ratio could be used to determine isokinetic sampling conditions for any flow rate in the tunnel.

The surface roughness heights for the test runs were determined by fitting vertical profiles of wind speed in the test section of the wind tunnel to a logarithmic function. An average roughness height was calculated for each test series, for purposes of calculating friction velocities and 10-m equivalent wind speeds. The friction velocity, which is a measure of wind shear at the erodible surface, characterizes the capacity of the wind to cause surface particle movement.

The exit air stream from the test section was passed through a circular duct fitted with a sampling probe near the downstream end. The particulate sampling train, which was operated at 68 cubic meters per hour (m<sup>3</sup>/hr) (40 actual cubic feet per minute [acfm]), consisted of the tapered sampling probe, cyclone pre-collector, quartz backup filter, and high-volume motor. The sampling probe was pointed into the air stream, and isokinetic sampling was achieved by fitting the sampling probe with a nozzle of appropriate size. Sampled total airborne particulate (TP) emissions were separated into two particle size fractions by the cyclone: particles larger than PM<sub>10</sub> were collected inside the cyclone, and PM<sub>10</sub> was collected on the backup filter below the cyclone.

A high-volume ambient air sampler was operated at 68 m<sup>3</sup>/hr (40 acfm) near the inlet of the wind tunnel to provide for measurement and subtraction of the contribution of the ambient background particulate level. The filter was vertically oriented, parallel to the tunnel inlet face.

At the completion of each test series, the sampling train was disassembled and taken to the field instrument van, where the collected samples of dust emissions (cyclone catch and backup filter) were carefully placed in protective containers. Dust samples from the field tests were returned to an environmentally controlled laboratory for gravimetric analysis. Quartz filters were conditioned at constant temperature (23 degrees Celsius [°C] ±1°C) and relative humidity (45% ± 5%) for 24 hours prior to weighing (the same conditioning procedure used prior to tare weighing). The particulate catch from the cyclone pre-collector was weighed in a tared poly bag.

## **DustTRAK Monitoring**

Continuous monitoring of particulate concentration in the sampling extension provides for a greater level of detail in tracking the dynamics of the wind erosion process. For this study, two portable DustTRAK Aerosol Monitors (TSI, Inc., St. Paul, Minnesota) were used to continuously sample the air between the cyclone and the backup filter to track the PM<sub>10</sub> concentrations in the tunnel effluent.

The DustTRAK monitor is a portable, battery-operated instrument that gives real-time measurements and has a built-in data logger. The operating principle of the DustTRAK is based on 90°

light scattering. Light scattering (deflection) by local variations in refractive index is caused by the presence of particles whose size is comparable to the wavelength of the incident light. The theoretical detection efficiency peaks at about 0.2-0.3  $\mu\text{m}$  and gradually decreases for larger particle sizes. A pump draws aerosol into the optics chamber where either solid or liquid particles are detected using a laser diode light source and a solid-state photodetector. The instrument can store measurements at programmable intervals for later trending and reporting.

The DustTRAK  $\text{PM}_{10}$  monitor was calibrated against the actual  $\text{PM}_{10}$  mass collected on the backup filter of the wind tunnel effluent sampling train during a given test run. This calibration required an integration of the real-time DustTRAK  $\text{PM}_{10}$  concentration profile (versus time) and calculation of the average DustTRAK  $\text{PM}_{10}$  concentration. The average DustTRAK  $\text{PM}_{10}$  concentration was then compared to the average  $\text{PM}_{10}$  concentration calculated from the  $\text{PM}_{10}$  mass collected on the backup filter below the cyclone.

Use of the DustTRAK monitor provided a more comprehensive analysis of surface erodibility than wind tunnel sampling alone, especially appropriate to study surfaces that do not have a well defined wind erosion threshold velocity. There are multiple contributors to wind generated particulate emissions on the burned vegetative surfaces at the Site: 1) bulk soil, 2) settled surface dust trapped by vegetation, and 3) the vegetation itself. The particle releases from these reservoirs are all driven by different mechanisms, each with a different wind speed dependence.

The approach taken in this study was to expose each test surface to a well-defined time history of increasing wind speeds, while simultaneously monitoring the  $\text{PM}_{10}$  concentration in the tunnel effluent. Each time the wind speed was increased, a concentration spike was observed. Time integration of these spikes generated erosion mass increments of  $\text{PM}_{10}$  that when added together yielded cumulative erosion potential as a function of wind speed.

## **Dustiness Testing**

In April and May 2000, six subareas in the controlled burn area were sampled for surface soil. The soil samples were collected to a depth of approximately 1 to 1.5 centimeters (cm) using a whiskbroom and dustpan. The areas were judged to be representative of the wind tunnel test areas.

Dustiness testing was performed on samples of surface soil to characterize the potential for release of airborne  $\text{PM}_{10}$  when the soil is disturbed. Dustiness tests were also run under varying soil moisture levels to provide information on the mitigating effect of soil moisture in reducing  $\text{PM}_{10}$  emissions. The moisture levels selected for dustiness testing were 0%, 2%, 4%, 6%, and 8%.

The MRI Dustiness Test Chamber is a laboratory device used to determine the tendency of finely divided bulk materials (e.g., soils, powders) to release fine particles. Within the chamber, the particles generated from controlled pouring of material are captured on an overhead filter with a sampling rate of 5 liters per minute. The net weight of particulate matter caught on the filter (final filter weight minus tare weight) is divided by the mass of material poured to calculate the mass emission rate in units of milligrams of dust per kilogram of material poured. This quantity is defined as the dustiness index of the test material.

## TEST ANALYSIS

Because wind erosion is an avalanching process, it is reasonable to assume that the loss rate from a surface is proportional to the amount of erodible material remaining:

$$\frac{dM}{dt} = -kM \quad (1)$$

where

$M$  = quantity of erodible material on the surface at any time, grams per square meter ( $\text{g/m}^2$ )

$k$  = proportionality constant, inverse seconds ( $\text{s}^{-1}$ )

$t$  = cumulative erosion time, seconds (s)

Integration of Equation 1 yields:

$$M = M_0 e^{-kt} \quad (2)$$

where

$M_0$  = erosion potential, i.e, quantity of erodible material present on the surface before the onset of erosion,  $\text{g/m}^2$

The loss of erodible material ( $\text{g/m}^2$ ) from the exposed surface area during a test is calculated:

$$L = \frac{CQt}{A} \quad (3)$$

where

$C$  = average particulate concentration in tunnel exit stream (after subtraction of background concentration),  $\text{g/m}^3$

$Q$  = tunnel flow rate, cubic meters per second ( $\text{m}^3/\text{s}$ )

$A$  = exposed test surface area (0.918 square meters [ $\text{m}^2$ ] for the reference wind tunnel)

Alternatively, the erosion potential can be directly calculated from the cyclone and filter net mass (after correction for background).

For a specific surface, the wind erosion potential is dependent on the wind speed and on the frequency of disturbance of the erodible surface. Each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action that results in the exposure of fresh surface material. For this study, a disturbance occurred when the soil surface was exposed by the prescribed burn.

Whenever a surface is tested at sequentially increasing wind speeds, the measured losses from the lower speeds are added to the losses at the next higher speed and so on. This reflects the hypothesis that, if the lower speeds had not been tested beforehand, correspondingly greater losses would have occurred at the higher speeds.

In summary, the calculated test results for each test surface included:

- Roughness height: from extrapolated subthreshold velocity profile;

- Friction velocity: from measured centerline wind speed and roughness height;
- Equivalent wind speed at reference 10-m height: from measured centerline wind speed and roughness height; and
- Erosion potential (for “limited reservoir” surfaces) for a maximum wind speed: equivalent to the cumulative particle mass loss.

In addition to the wind tunnel results, 6-second concentrations were graphed and integrated over wind tunnel run time to calculate the hypothetical mass that would have been collected by each DustTRAK monitor. As discussed previously, the integrated mass (erosion potential) for each wind speed plateau included integrated masses from each previous plateau. Finally, the average PM<sub>10</sub> mass for the entire DustTRAK sampling period was compared to the actual PM<sub>10</sub> mass collected on the PM<sub>10</sub> backup filter.

## TEST RESULTS

The results of the wind tunnel tests and erosion potential calculations are presented in Table 1. As expected, the average PM<sub>10</sub> concentration in the wind tunnel effluent for the April test series was much higher for the burned areas than for the adjacent unburned areas. At the beginning of the first test series, one day after the burn, the average PM<sub>10</sub> erosion potential was approximately nine times higher than found for unburned grassland adjacent to the burn area.

The PM<sub>10</sub> erosion potentials, normalized to a 10-m wind speed of 95 mph, are shown graphically in Figure 3. Normalization was performed because the growth of vegetation between the prescribed burn and the later tests, on both burned and unburned plots, resulted in different surface roughness heights and consequent 10-m wind speed equivalents for the maximum wind tunnel centerline speeds. This effect is also shown in the progression of roughness heights and friction velocities between the earlier and later tests that can be seen from Table 1.

From Figure 3, the PM<sub>10</sub> erosion potential of the burned area appears to decay in time with the regrowth of vegetation. Observations made at the time of each test series also indicated that the ground was somewhat moist in May but was fairly dry for both the April and June test series on the burned area. The dustiness tests that were performed with soil from the burned area showed that moisture is very effective in limiting PM<sub>10</sub> erosion potential. As moisture was increased from 2% to 8%, for example, in the laboratory testing, the dustiness (potential for release of airborne PM<sub>10</sub>) was seen to decrease by over an order of magnitude.

The PM<sub>10</sub> erosion potential for the unburned grassland remained consistently low, in the range of 0.05 g/m<sup>2</sup> or less, as seen from April and June tests shown in Table 1. The PM<sub>10</sub> erosion potential for the unburned areas also decreased between April and June as the vegetation grew.

Table 1 also shows erosion potential for total particulates. The results show a somewhat different pattern than found for PM<sub>10</sub> and indicate that erosion potential increased with time, on both the burned and unburned areas. These results are somewhat misleading, because the results cannot be normalized in the same manner as the PM<sub>10</sub> since DustTRAK data are not available for the larger particles, nor would they be reliable. However, the indicated trend may also result from changes in vegetation with time. As the vegetation grew, it would have presented a larger surface area to catch and hold deposited dust. Other researchers have found that larger particles may be more easily dislodged from vegetation surfaces than smaller particles, such as PM<sub>10</sub>, which may be better protected by boundary layer effects on the leaves themselves.<sup>4,5</sup> As a result, the growing vegetation may constitute an effective reservoir of erodible particles, particularly in the larger size fractions that contribute to total airborne particulate.



The logging mode of the DustTRAK provided 6-second average concentration values for each of the test runs. After subtracting out a minimum value assumed to be background, these values were used to find an average concentration value from the beginning of the test run to the end of the run time for each 10-m wind speed. The average concentration along with the tunnel volumetric flow rate, the length of time from the beginning of the test until the end of the specified wind speed plateau, and the exposed test surface area were used to determine the (cumulative) erosion potential for that wind speed.

It should be noted that the actual average PM<sub>10</sub> concentration in the tunnel effluent was several times higher than the average PM<sub>10</sub> concentration indicated by the DustTRAK. This reflects the fact that while the coarse mode of the PM<sub>10</sub> (particles larger than 2.5 µm) constitutes much of the PM<sub>10</sub> sample mass, it does not scatter light very effectively. Calibration of DustTRAK results to backup filter mass corrected for this bias.

Figure 4 shows average erosion potential values versus wind speed (mph) at a 10-m height. The same pitot tube pressure differentials for the predetermined tunnel centerline wind speeds were used for the three test periods, yet the roughness height of the surface changed over the three-month period, corresponding to increases in 10-m wind speeds, in relation to centerline values.

It is clear from Figure 4 that the erosion potential distributions (versus 10-m wind speed) decay with time after the prescribed burn. The May curve lies below the June curve because of the damp soil conditions encountered during the May testing.

## **DISPERSION MODELING APPROACH**

Wind tunnel test results are being used to model the movement of airborne particulate matter and actinides in the Site environment. A Site-specific wind erosion equation was developed from previous wind tunnel studies performed at the Site by MRI in 1993.<sup>6</sup> In that approach, particulate emissions from undisturbed, vegetated surfaces at the Site were calculated as a function of the 1-hour average wind speed measured at a 10 m height, and the presence or absence of snow cover. Actinide emissions were calculated based on concentrations in the underlying soil.

Emissions were then modeled using a Site-specific implementation of EPA's Industrial Source Complex Short Term model (ISCST3) (the model uses a 1-hour time step). Comparison of model predictions to measured ambient air plutonium and americium concentrations at various locations around the Site indicated that the approach overpredicts actinide concentrations by up to an order of magnitude close to source areas and by a factor of 3 to 6 at the downwind fenceline (located 2,500 to 3,000 m east of source areas)<sup>7</sup>. Much of this overprediction is presumed to be caused by the inability of the present model to account for limitations in the available reservoir of erodible particles. Rather than depleting the supply of particles that can be eroded in an hour at a given wind speed, the model assumes that each subsequent hour at a similar wind speed could erode a similar mass of material.

Refinements are being made to the modeling approach to take this limitation into account. The modeling approach is also being revised to account for removal of vegetation by a fire and to incorporate the subsequent, temporary increases in erosion potentials that were the subject of the study reported here. The refined approach is outlined below for a 1-year modeling scenario, using historical meteorological data measured at the Site.

- Track 15-Minute Wind Speed and Precipitation

The 15-minute mean wind speeds are representative of maximum sustained winds (wind data from the Site are recorded as 15-minute averages). The 15-minute wind speed and precipitation data will be used to calculate wind erosion rates.

- Develop 15-Minute Emission Rates as a Function of Wind Speed Using Wind Tunnel Data From Undisturbed Areas

Dispersion models for open dust sources require emission rates in units of mass per unit area per unit time (i.e.,  $\text{g/m}^2/\text{s}$ ). In contrast, particulate emissions from wind erosion are expressed in terms of mass per unit area ( $\text{g/m}^2$ ) for the maximum sustained wind speed (minimum of 2 minutes) between surface disturbances. To account for these differences, the refined approach will assume that the erosion potential for a given wind speed will be exhausted within a 15-minute time step and the total particulate and actinide emissions will be averaged over the time step. It will be assumed that additional erosion for subsequent wind speeds at or below the initial wind speed will be insignificant until the erosion potential is replenished by surface disturbance; subsequent higher wind speeds will be allowed to erode an additional increment of material based on wind tunnel erosion potential data for undisturbed, vegetated surfaces.

- Eliminate Periods During and Immediately After Precipitation Events and When Snow Cover is Present

High winds that occur in the same 4-hour period as light precipitation or within 24 hours of significant precipitation are unlikely to cause significant wind erosion. Emission rates for these periods will be reduced to zero for calculation purposes. Similarly, periods with snow cover (based on measured albedo data) will also be reduced to zero.

- Project Hourly Particle Deposition and Erosion Potential Replenishment

A small replenishment of erosion potential will occur on an ongoing basis because of particle deposition, freeze/thaw events, etc. Hourly estimates of particle and actinide deposition will be made based on measured meteorological data and historical  $\text{PM}_{10}$ , total suspended particulate, and ambient actinide concentration data for the Rocky Flats area. A small additional increment will be added for ongoing, small-scale soil disturbances such as freeze/thaw cycles, rainsplash, and animal activity.

- Calculate Hourly Emission Rates, Taking into Account Erosion Losses from Previous Wind Events

The erosion potential will be reduced with each high wind event. If the erosion potential at 35 mph (10-m height) is  $x \text{ g/m}^2$ , then that erosion potential will no longer be available for future winds of 35 mph or less until the erosion potential is restored by deposition or other means. Only winds above ~35 mph will produce future soil erosion. In addition, if a 50-mph wind event follows a 25-mph wind event, the curve will produce  $y \text{ g/m}^2$  erosion potential, but the previous wind erosion potential must be subtracted to give only  $(y - x) \text{ g/m}^2$  for the 50-mph wind event.

Hourly emission rates will be calculated for each source area by treating this situation using a mass balance, “bookkeeping” approach. Beginning with an assumed initial erosion potential at the beginning of the modeling period, increases and decreases in erosion potential will be calculated for each 15-minute period based on losses due to emissions and inputs due to deposition, etc. Emissions will be constrained for each 15-minute time step so that they do not exceed the net remaining erosion potential for the applicable wind speed. The calculated 15-minute emissions will be used to develop hour-by-hour emission rates for input to ISCST3.

To model resuspension following a fire, multipliers will be developed and applied to the above-estimated emissions. The multipliers will vary based on the elapsed time following the fire and based on soil moisture conditions, as follows.

- Generate Erosion Potential Decay Curves for Each Tested Wind Speed, Soil Condition, and Time Period Following a Grass Fire

Erosion potentials for three different elapsed times following the test burn are given in  $\text{g/m}^2$  for each tested wind speed in Figure 4. May is assumed to represent “damp soil” erosion potential, while the April and June tests are assumed to represent dry conditions. Erosion potentials at intermediate wind speeds can be interpolated from the curves.

- Use Damp/Dry Soil Curves as Appropriate for each 15-Minute Period

High winds that occur within 24 to 48 hours of significant precipitation should be associated with a damp soil curve for calculation of erosion potential and emissions.

- Model 1-yr Periods (Assume Full Revegetation and Restoration of Original, Reduced Erosion Potential Within 1 Year)

Decay curves will be assumed to decline to a level represented by the unburned area tests after one year. Restoration of the full vegetation protection against wind erosion will not be complete until a new layer of thatch is laid down and covers the soil between grass clumps.

## CONCLUSIONS

The results of the wind erosion tests on the Rocky Flats prescribed burn area showed that low  $\text{PM}_{10}$  emissions occurred below 40 mph (equivalent wind speed at a height of 10 m above ground). Above 40 mph,  $\text{PM}_{10}$  emissions increased with increasing wind speed. After burning, the land was observed to retain many of the characteristics that limit wind erosion—including soil crusts, rocks/pebbles that protected the surface soil, and grass clumps. Grass clumps, even when burnt, are very protective of soil erosion, but usually were not spaced closely enough on Rocky Flats land for good protection of all of the exposed area.

$\text{PM}_{10}$  emissions were observed to increase as wind speed increased, and erosion potentials were calculated for various wind speed plateaus during each of the three months of testing. Erosion potentials from the prescribed burn area were always somewhat greater than for unburned areas, even for the June tests—approximately 2½ months after the burn. This was clearly due to the wind protection afforded by dead grass thatch that had formerly covered the unburned areas, but was not present after the prescribed burn.

Even though the burned areas had revegetated to a large extent by the June test period, bare soil that constituted an emission source was still visible between the revegetating plants. Moreover, the vegetative restoration of the prescribed burn areas included mostly tall, thin plants that did not completely protect the soil from wind erosion through late June, when the latest wind tunnel tests were conducted. During May tests, soil moisture was observed to be effective in reducing soil erosion rates from high winds at moderate temperatures. However, when rainfall wets the soil surface and temperatures are warm, the surface dries quickly in the relatively low humidity environment of Rocky Flats, so this mitigating effect is transient.

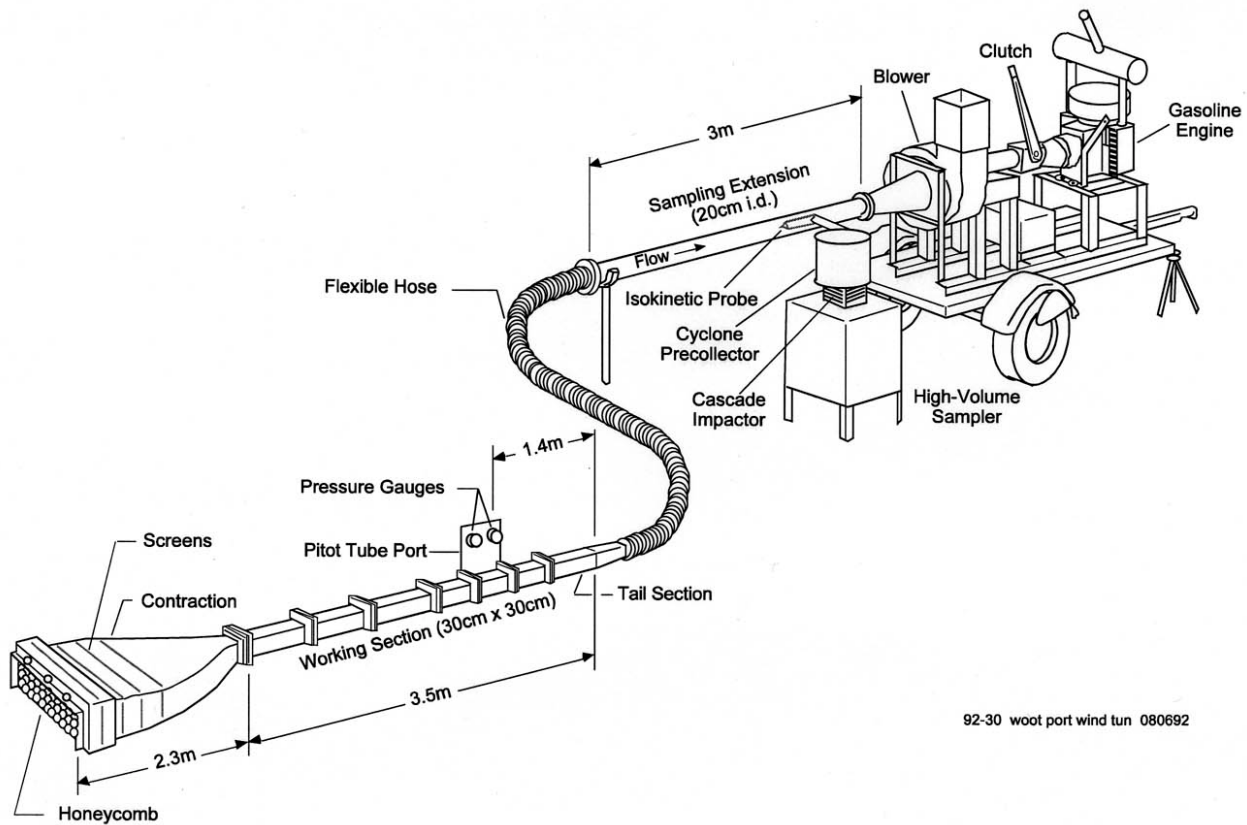
A new approach to ambient impact modeling of a grass fire is being developed for wind erosion sources to reflect a limited reservoir erosion potential (emission rate) in units of  $\text{g/m}^2$ . This approach tracks historical 15-minute mean wind speeds. The times and extent of wind erosion are dominated by the occurrence of the highest wind speeds. Wind tunnel data provide the relationship between particulate emission rates and maximum sustained winds. The modeling approach takes into account losses of erosion potential from previous high wind events, the mitigating effects of vegetation, and the role of background dust deposition.

The new approach will account for the absence of emissions during precipitation events and when snow cover is present. Increases and decreases in erosion potential will be calculated for each 15-minute period based on losses due to resuspension and input due to deposition and other natural processes (e.g., freeze/thaw). A mass balance accounting will be performed so that emissions will not exceed the net remaining erosion potential for a given source area for the applicable wind speed. Calculated 15-minute emissions will be used to develop hour-by-hour emission rates for input to ISCST3. To model resuspension following a fire, multipliers based on the elapsed time following the fire and on soil moisture conditions will be applied to the above-estimated emissions.

## REFERENCES

- 1) U.S. Environmental Protection Agency. *National Technical Guidance Series Air Pathway Analysis Procedure for Superfund Applications*. Vol. II: *Estimates of Baseline Air Emissions at Superfund Sites*. Research Triangle Park, NC, 1989; EPA-450/1-89-002a.
- 2) U.S. Environmental Protection Agency. *Compilation of Air Pollutant Emissions Factors*, AP-42. Fifth Edition, Supplements A-F, Volume I: *Stationary Point and Area Sources*. Research Triangle Park, NC, 2000.
- 3) Owen, E.; Pankhurst, R.C. *The Measurement of Air Flow*; Pergamon Press; London, 1969.
- 4) Garland, J.A. *Resuspension of Particulate Matter From Grass Experimental Programme 1979-1980*. UKAEA Atomic Energy Research Establishment, Environmental and Medical Sciences Division, Harwell, England, 1982; AERE-R-10106.
- 5) Langer, G. *Resuspension of Soil Particles from Rocky Flats Containing Plutonium Particles*. EG&G Rocky Flats, Inc., Golden, CO, 1991.
- 6) Midwest Research Institute. *OU3 Wind Tunnel Study*, Vol. I: *Test Report*. Prepared for EG&G Rocky Flats, Inc., Golden, CO, 1994.
- 7) Radian International. *Air Transport and Deposition of Actinides at the Rocky Flats Environmental Technology Site, FY00 Report*. Prepared for Kaiser-Hill Company, L.L.C., Golden, CO, 2000.

**Figure 1. MRI portable wind tunnel.**



**Figure 2. DustTRAK graph for run CB-8B.**

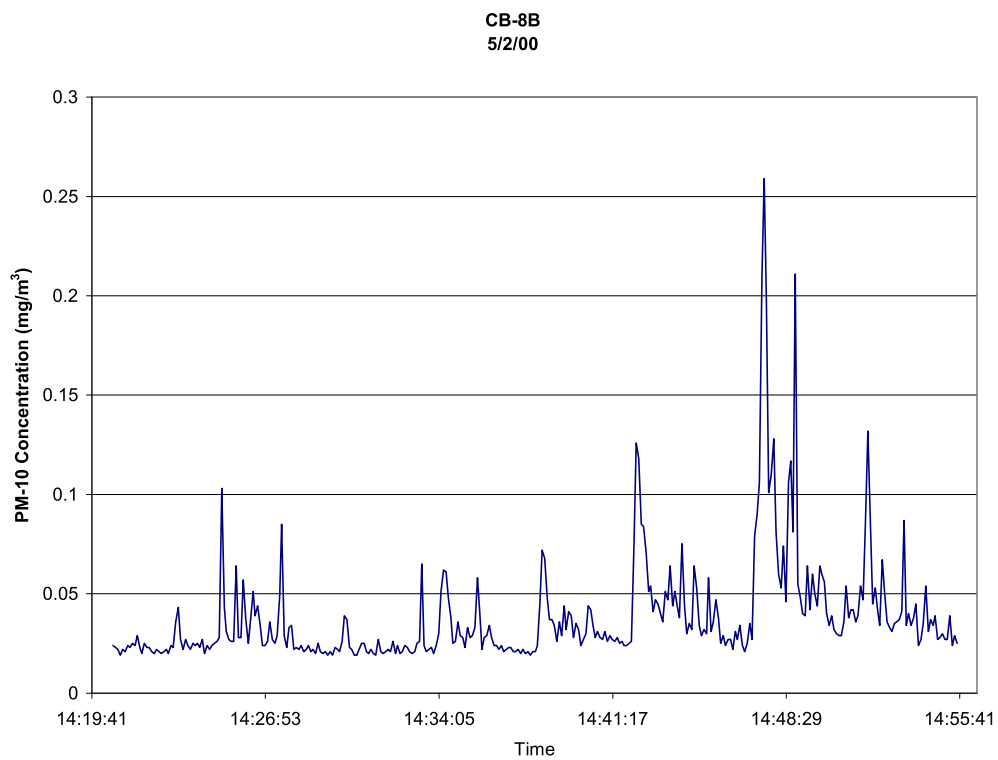


Figure 3. Erosion potential history for each test series.

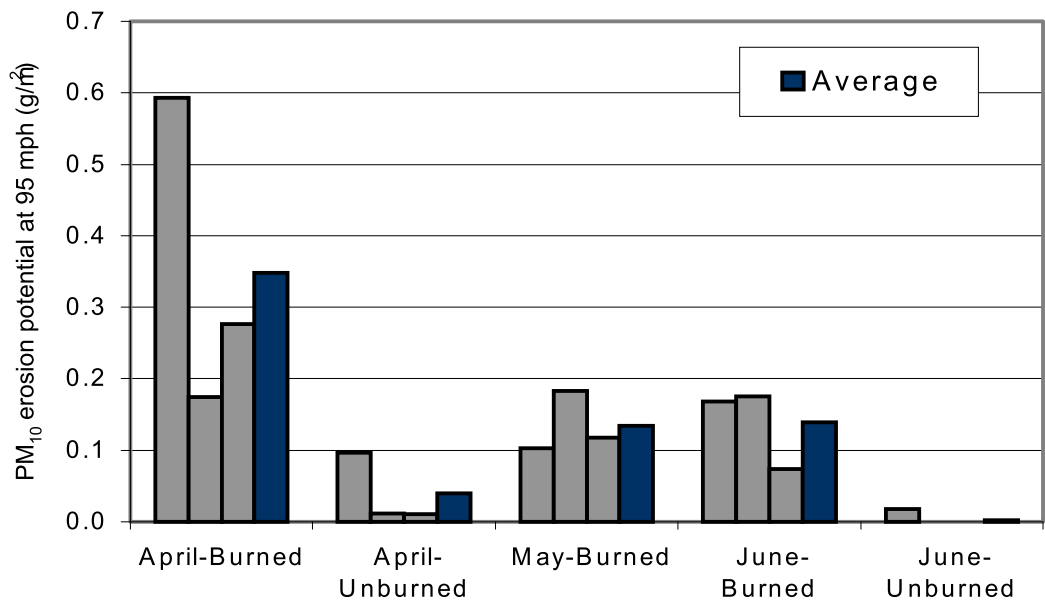
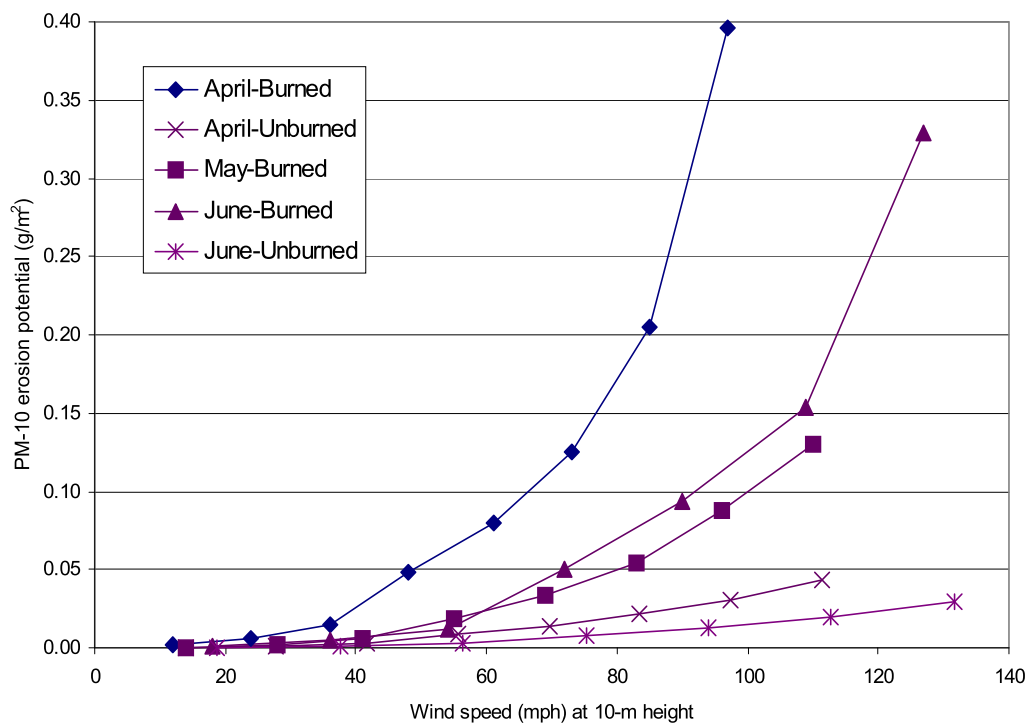


Figure 4. Erosion potential at 10-m wind speeds as determined from DustTRAK data.



**Table 1. Wind tunnel erosion potentials.**

Date of test series	Surface condition	Average roughness height (cm)	Maximum wind speed (mph) at tunnel CL <sup>a</sup>	Equivalent maximum wind speed (mph) at 10-m height <sup>b</sup>	Corresponding friction velocity <sup>b</sup> (cm/s)	Erosion potential <sup>c</sup> (g/m <sup>2</sup> )		
						TP	PM <sub>10</sub>	PM <sub>10</sub> normalized to 95 mph at 10-m height
4/7/00	Burned	0.85	40.3	97.6	244.7	1.33	0.65	0.59
4/8/00	Burned	0.66	40.3	97.6	244.7	0.61	0.19	0.17
4/8/00	Burned	0.89	40.3	97.6	244.7	0.62	0.30	0.28
4/9/00	Unburned	1.65	39.7	110.1	301.0	0.31	0.14	0.10
4/10/00	Unburned	1.76	40.3	111.9	305.8	0.13	0.02	0.01
4/11/00	Unburned	0.92	40.3	111.9	305.8	0.18	0.02	0.01
5/2/00	Burned	1.10	37.0	100.5	271.4	1.07	0.12	0.10
5/2/00	Burned	1.31	40.3	109.6	295.8	2.50	0.26	0.18
5/3/00	Burned	1.57	37.2	101.2	273.3	0.76	0.14	0.12
6/21/00	Burned	3.00	38.6	138.3	425.9	11.09	0.67	0.17
6/21/00	Burned	3.12	29.2	104.7	322.4	1.67	0.23	0.18
6/22/00	Burned	2.91	35.8	128.4	395.3	3.65	0.23	0.07
6/22/00	Unburned	3.17	39.3	145.2	452.5	0.16	0.05	0.02
6/23/00	Unburned	3.16	34.8	128.6	400.6	0.45	<0.02	<0.02
6/23/00	Unburned	3.32	37.5	138.8	432.4	0.83	<0.02	<0.02

Notes:

cm = centimeter

mph = miles per hour

CL = centerline

m = meters

cm/s = centimeters per second

g/m<sup>2</sup> = grams per square meter

TP = total particulate

<sup>a</sup> Average maximum wind speed at tunnel centerline for all three tests.

<sup>b</sup> Average roughness height over three runs used to calculate equivalent 10-m wind speed and friction velocity.

<sup>c</sup> Calculated using net mass.



## **KEYWORDS**

Wind tunnel

PM<sub>10</sub>

Fire

Controlled burn, prescribed burn

Fugitive dust

# **Modeling Wind Erosion Impacts Following a Grassland Fire**

**Paper #43420**

**Martha W. Hyder**

Wind River Environmental Group LLC  
3785 S. Poplar Street, Denver, CO 80237

**Patrick M. Haines**

URS Group  
8181 East Tufts Ave., Denver, Co 80237

## **ABSTRACT**

A portable wind tunnel was used to generate high winds and collect soil particles eroded from a 50-acre study area that underwent a controlled burn in April 2000. Wind tunnel studies of the burned area and neighboring control areas were performed following the test burn, and again at intervals of 25 and 73 days following the fire. Soil erosion rates were determined at incremented wind speeds using optical particle counters and gravimetric analysis of dust samples. The effects of fire on soil erosion potential were quantified as a function of wind speed and elapsed time following the fire.

A new approach to modeling wind erosion following a grass fire was developed to reflect a limited reservoir erosion potential (emission rate). Wind tunnel data provided the relationship between particulate matter emission rates and maximum sustained winds. The modeling approach took into account losses of erosion potential from previous high wind events, the mitigating effects of vegetation, and the role of background dust deposition.

The approach accounted for the absence of emissions during precipitation events and when snow cover is present. Increases and decreases in erosion potential were calculated for each 15-minute period based on losses due to resuspension and input due to deposition and other natural processes (e.g., freeze/thaw). A mass balance accounting was performed so that emissions could not exceed the net remaining erosion potential for a given source area for the applicable wind speed. Calculated 15-minute emissions were used to develop hour-by-hour emission rates for input to ISCST3. To model wind erosion following a fire, multipliers based on the elapsed time following the fire were applied to the estimated unburned grassland emissions.

## **INTRODUCTION**

The U.S. Department of Energy's Rocky Flats Environmental Technology Site (Site) has several areas of actinide-contaminated soil as a result of spills and releases during the Site's nuclear weapons production era. Most such areas are well vegetated, which has stabilized potential wind-driven resuspension of actinide-contaminated soil particles. The Site is currently undergoing cleanup and closure, and as plans are being made for post-closure use, the increase in actinide emissions that might result following removal of vegetation by fire has become an issue

of great interest. The Site has experienced three small lightning-caused grass fires in the past 10 years, so fires represent reasonably likely occurrences.

In Spring 2000, the Site conducted a test burn to evaluate a proposed program of prescribed burning for weed control and prairie restoration. The test burn, which covered approximately 50 acres in the Site's Buffer Zone (the large, undeveloped area surrounding the Site's industrial area), presented an opportunity to gather data on post-fire wind erosion emissions for use in estimating emissions and impacts from wildfires at the Site. A portable wind tunnel was used to generate high winds and collect soil particles eroded from soil surfaces following the test burn. The purpose was to measure resuspension of soil and ash immediately following a fire and at intervals after a fire to determine how wind erosion emission rates varied from those measured over unburned, undisturbed areas of the Site. The post-fire sequence of wind tunnel tests was designed to investigate the time period over which wind erosion emission rates would recover to pre-fire conditions.

The wind tunnel tests determined wind erosion emission rates that were used to model annual particulate matter, plutonium (Pu), and americium (Am) emissions following a hypothetical fire at the Site. The methods and results of the study are described below.

## **WIND TUNNEL TEST EQUIPMENT AND PROCEDURES**

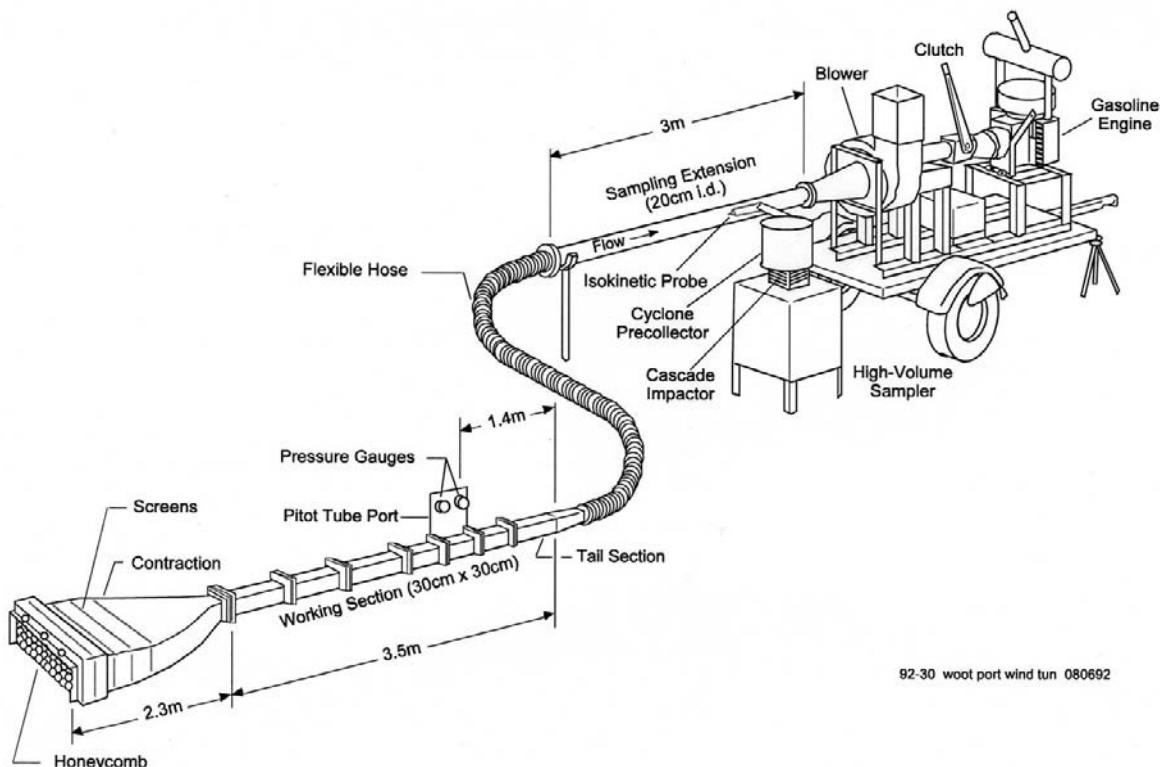
The prescribed burn was conducted on April 6, 2000 and wind tunnel testing was initiated the day after the burn. Wind tunnel tests were conducted over the burned area and paired tests were conducted in an adjacent, unburned area. Additional tests were conducted over the burned area in early May and late June. The June series also gathered additional data on resuspension from an adjacent, unburned plot for comparison. The wind tunnel studies at the Site in 2000 have been described in detail in a series of reports and papers.<sup>1, 2, 3</sup>

Wind tunnel tests were performed by Midwest Research Institute (MRI) using a portable reference wind tunnel, described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites*.<sup>4</sup> The portable wind tunnel is shown in Figure 1.

Although the portable wind tunnel does not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnel simulates the smaller scales of atmospheric turbulence. It is the smaller-scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to particle entrainment (wind erosion). The wind tunnel method relies on a straightforward mass balance technique to calculate particulate matter emission rates. Previous wind erosion studies using the MRI reference wind tunnel have led to the U.S. Environmental Protection Agency (EPA)-recommended emission factors for industrial wind erosion presented in *Compilation of Air Pollutant Emission Factors (AP-42)*.<sup>5</sup>

For each wind tunnel run, the open-floored test section of the tunnel was placed directly over the surface to be tested. Air was drawn through the tunnel at controlled velocities, increasing at

**Figure 1: MRI Portable Wind Tunnel**



2 meter per second (m/s) (5 mile per hour [mph]) increments, to a maximum velocity of about 40 mph at the tunnel centerline. This corresponded to a wind speed between 97 and 145 mph at a 10-meter (m) height; the equivalent 10-m wind speed varied with the roughness of the surfaces tested in each trial.

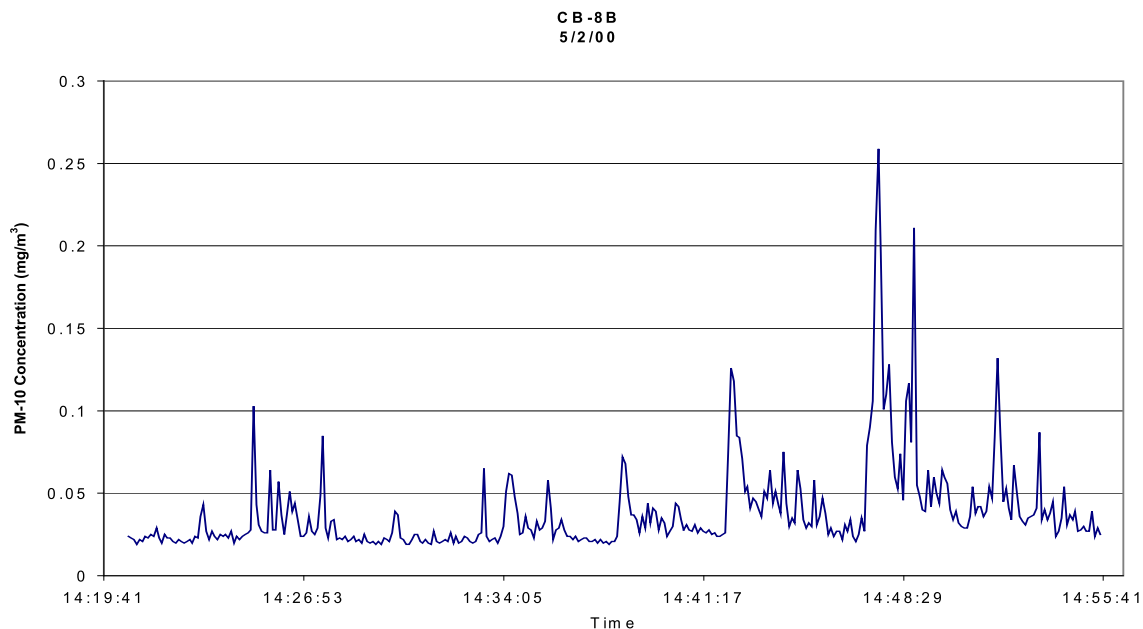
The exit air stream from the wind tunnel test section was passed through a particulate matter sampling train, consisting of a tapered sampling probe, a cyclone pre-collector, a quartz backup filter, and a high-volume motor. Sampled total airborne particulate emissions were separated into two particle size fractions by the cyclone—particles larger than approximately 10 micrometers [ $\mu\text{m}$ ] aerodynamic equivalent diameter ( $\text{PM}_{10}$ ) were collected inside the cyclone, and  $\text{PM}_{10}$  was collected on the backup filter. A high-volume ambient air sampler was operated near the inlet of the wind tunnel to provide for measurement and subtraction of ambient background particulate matter.

At the completion of each test series, the sampling train was disassembled and the collected samples (cyclone catch and backup filter) were placed in protective containers. Dust samples from the field tests were returned to an environmentally controlled laboratory for gravimetric analysis.

Continuous monitoring of PM<sub>10</sub> concentrations in the sampling extension provided additional details regarding the dynamics of the wind erosion process. For this study, a portable DustTRAK Aerosol Monitor (TSI, Inc., St. Paul, Minnesota) was used to continuously sample the air between the cyclone and the backup filter to track the PM<sub>10</sub> concentrations in the tunnel effluent. The operating principle of the DustTRAK is based on light scattering (deflection), caused by the presence of particles whose sizes are comparable to the wavelength of the incident light. A pump draws aerosol into the optics chamber where particles are detected.

Typically, each time the wind speed was increased, a PM<sub>10</sub> concentration spike was observed on the DustTRAK monitor. Upon each successive increase in wind speed, the peak value of the spike increased and the rate of decay decreased. An example of the concentration spikes that occurred during wind tunnel testing on the burned area can be seen in Figure 2.

**Figure 2: Example PM<sub>10</sub> Concentration History From Wind Tunnel**



The logging mode of the DustTRAK provided 6-second average concentration values for each of the test runs. After subtracting out a minimum value assumed to be background, these values were used to find an average concentration value from the beginning of the test run to the end of the run time for each 10-m wind speed. The average concentration, along with the tunnel volumetric flow rate, the length of time from the beginning of the test until the end of the specified wind speed plateau, and the exposed test surface area were used to determine the (cumulative) **erosion potential** for that wind speed. Erosion potential is the quantity of erodible material present on the surface before the onset of erosion, measured in grams per square meter of surface area, g/m<sup>2</sup>.

## WIND TUNNEL TEST RESULTS

As expected, the average  $PM_{10}$  concentration in the wind tunnel effluent for the April test series was much higher for the burned areas than for adjacent, unburned areas. At the beginning of the first test series, one day after the burn, the average  $PM_{10}$  erosion potential in the burned area was approximately nine times higher than that found for unburned grassland.

$PM_{10}$  erosion potentials, normalized to a 10-m wind speed of 95 mph, are shown graphically in Figure 3. Normalization was performed because the growth of vegetation between the prescribed burn and later tests resulted in different surface roughness heights and 10-m wind speed equivalents for the maximum wind tunnel centerline speeds. From Figure 3, the  $PM_{10}$  erosion potential of the burned area appears to decay in time with the regrowth of vegetation.

**Figure 3: Normalized Wind Tunnel Results**

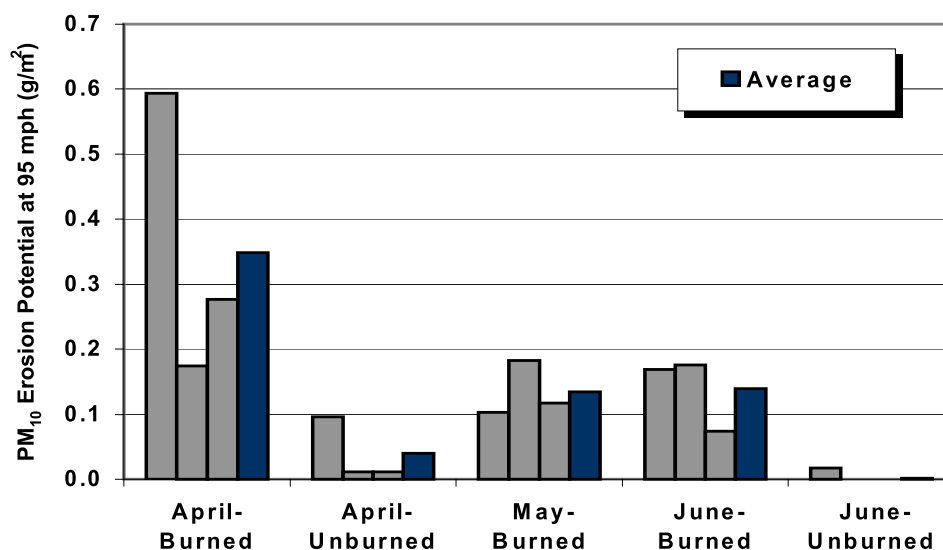
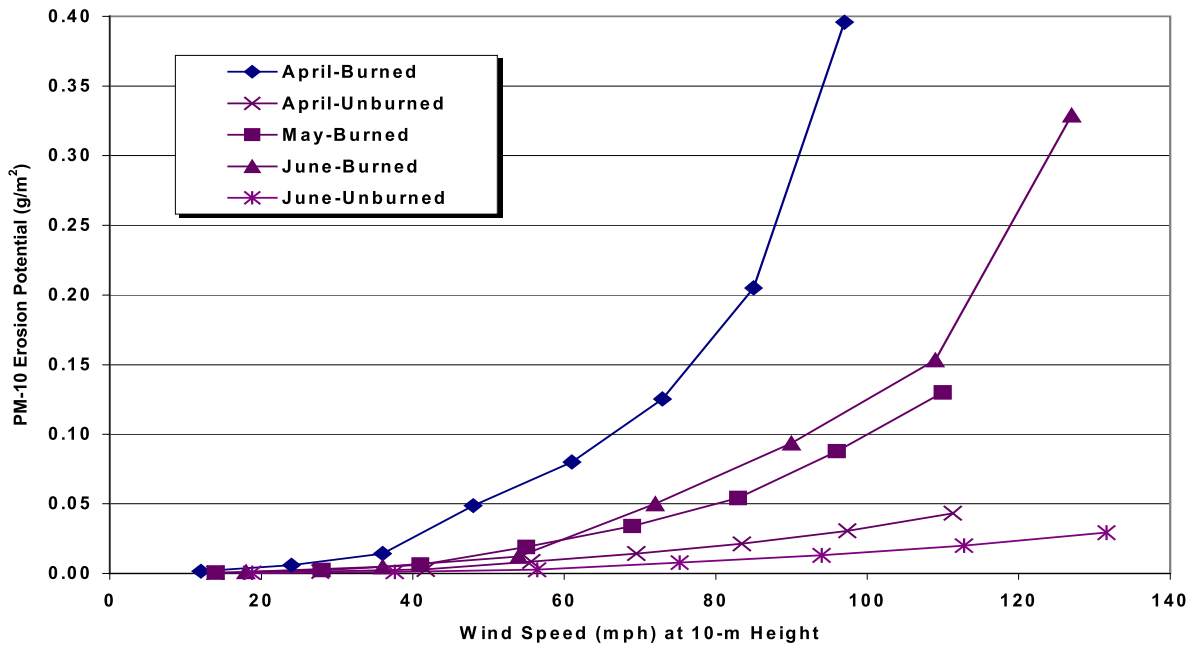


Figure 4 shows average erosion potential values versus wind speed at a 10-m height. It is clear from Figure 4 that the erosion potential distributions decay with time after the prescribed burn. The May curve lies below the June curve because of damp soil conditions encountered during the May testing. During May tests, soil moisture was observed to be effective in reducing soil erosion rates from high winds at moderate temperatures. However, when rainfall wets the soil surface and temperatures are warm, the surface dries quickly in the relatively low humidity environment of Rocky Flats, so this mitigating effect is transient.

The wind erosion tests on the Rocky Flats prescribed burn area showed that  $PM_{10}$  emissions increased with increasing wind speed, particularly above a 10-m equivalent wind speed of 40 mph. Erosion potentials calculated for various wind speed plateaus during each of the three months of testing were always somewhat greater for the prescribed burn area than for unburned

**Figure 4: PM<sub>10</sub> Erosion Potentials at Various Wind Speeds**



areas, even for the June tests—approximately 2½ months after the burn. This was due to the wind protection afforded by dead grass thatch that had formerly covered the unburned areas, but was not present after the prescribed burn, where bare soil that constituted an emission source was still visible between the revegetating plants.

## DERIVED WIND EROSION EMISSION EQUATION

The data shown in Figure 4 were converted to total suspended particulate matter (TSP) erosion potentials by assuming that the average ratio of PM<sub>10</sub> to TSP-size particles in the particulate matter collected by the wind tunnel was 0.39, based on the average PM<sub>10</sub>/TSP ratio observed in ambient particulate matter collected around the perimeter of the Site. After conversion to TSP, a power function was fitted to the resulting combined April and June unburned area data ( $R^2 = 0.88$ ). The resulting erosion potential equation, as a function of 10-m wind speed (m/s) is:

$$EP = 3.933 \times 10^{-6} (U^{2.516}) \quad (1)$$

where:

EP is the TSP erosion potential per 15-minute period ( $g/m^2$ ); and  
 U is the 10-m wind speed (m/s).

## APPLICATION OF THE WIND EROSION EMISSION EQUATION

The emission estimating technique described above has been used to evaluate the movement of airborne particulate matter and associated actinides in the Site environment.<sup>6</sup> Wind erosion



emissions were calculated and then modeled in a 1-year simulation using a Site-specific implementation of EPA's Industrial Source Complex Short Term model (ISCST3). The process used to calculate and model wind erosion emissions at the Site is described below.

Meteorological data collected at the Site in 1996 were processed into 15-minute averages (1996 data have been used previously for dispersion modeling baseline studies). Equation 1 was applied to each 15-minute average, 10-m wind speed, assuming that the erosion potential for a given wind speed will be exhausted within a 15-minute time step. A sequential file of **potential** emissions of particulate matter from undisturbed areas of the Site ( $\text{g/m}^2/15\text{-minutes}$ ) was generated for the year.

However, wind erosion emissions are not a function of wind speed alone. Instead, emissions are also dependent on mechanisms such as periodic disturbances that act to renew the erosion potential of the surface. If erosion potential is not renewed following an erosive event, additional emissions will not occur. Consequently, **actual** wind erosion emissions will be a function of potential emissions, coupled with the amount of erodible particulate matter present on Site surfaces during any given time period. If potential emissions exceed the amount of erodible material, actual emissions will be limited to the mass of particles that constitute the erodible material "reservoir".

How frequently and to what extent is Site erosion potential renewed by disturbances? In most of the Site Buffer Zone, large-scale disturbances (i.e., excavations, traffic) are rare and isolated. Small-scale disturbances, in contrast, occur frequently due to freeze/thaw action, burrowing animals, movement of large animals such as deer over the surface, splashing caused by raindrops, disturbance of surface crusts by vegetation growth, and turbulence caused by dust devils and thunderstorm convective activity. These frequent small disturbances renew erosion potential to some extent, but no measurements of this phenomenon are available for the Site.

Erosion potential is also renewed by deposition of airborne particulate matter. Particulate matter in the air over the Site is constantly being deposited on Site soil and vegetation surfaces. Deposition rates vary with wind speed and other conditions. As with small-scale generation of erosion potential, the dynamic nature of deposition has not been measured at the Site.

In the absence of specific data regarding the rate and dynamics of deposition and erosion potential generation by small-scale disturbances, the emission estimating procedure assumed that both phenomena occur at a relatively constant rate over the year. This allowed the amount of erodible material to be tracked over time as the erodible material reservoir was renewed by deposition and small-scale disturbances and depleted by resuspension. The simulation was initialized by setting the particulate matter erosion potential to the average erosion potential measured during the wind tunnel trials for the unburned areas. For each 15-minute period of the year-long data set, the mass of particles in the erodible material reservoir was compared with the potential particulate matter emissions defined by Equation 1. Actual particulate matter emissions were calculated as the lesser of the potential emissions or the amount of material available for resuspension at the appropriate wind speed. "Leftover", unresuspended material was carried forward to the next 15-minute period, so that during periods of low wind speeds, the "available

material” reservoir was built up and during windy periods it was depleted. A computer code was written to track these dynamics.

## Effects of Precipitation and Snow Cover

It was assumed that no wind erosion emissions would occur while there was snow cover. The presence or absence of snow cover was determined from solar reflectance (albedo) data; the information was applied in the emission tracking program so that no emissions were calculated for periods when snow cover was present. Deposition and small-scale erosion potential generation were assumed to continue during snow cover periods.

The effect of precipitation was also considered. Tests performed on soil samples from the wind tunnel test areas showed that moisture is very effective in limiting PM<sub>10</sub> erosion potential. Consequently, no wind erosion emissions were expected to occur from soil surfaces during precipitation events and for a short period thereafter as the soil was drying. The extent of the period following a precipitation event during which wind erosion emissions were eliminated was based on the amount of precipitation and on soil temperature, both of which were obtained from Site 1996 meteorological data records (higher soil temperatures were assumed to speed the restitution of erosion potential by increasing moisture evaporation rate). This information was used by the tracking program to determine whether emissions would occur for a given 15-minute period. As with snow cover, deposition and small-scale generation of erosion potential were assumed to continue during periods of no emissions due to precipitation effects.

## Renewal of Erosion Potential

The renewal of erosion potential through deposition of particulate matter was estimated using monitoring data. TSP concentrations are monitored at various locations around the Site perimeter. Monthly average TSP concentrations from four of the locations were averaged for each month in 1996. Particulate matter deposition was calculated by multiplying the average monthly concentration of TSP (in g/m<sup>3</sup>) by a deposition velocity (in m/15-minute time step) to yield deposition estimates (in g/m<sup>2</sup>/15-minute period) for each month. Deposition velocities were calculated using an algorithm contained in the *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models*<sup>7</sup> and 1996 meteorological data for the Site.

The rate of ongoing erosion potential renewal through small-scale disturbances was estimated indirectly. In 2001, a calculation was performed to determine the net loss of plutonium (Pu-239/240) and americium (Am-241) from the Site each year through the air pathway, based on previous simulation modeling.<sup>8</sup> By excluding regional background concentrations, these net loss calculations should represent the off-Site movement of **Site-generated** actinide emissions through the air pathway.

The net loss estimates were used to calculate the rate at which erosion potential is renewed by small-scale disturbances. Basically, an assumption was made that an ongoing actinide loss from the Site through the air pathway can only be sustained by the corresponding generation of new, erodible actinide-containing material in at least equal amounts. The total annual net loss of Pu-239/240 and Am-241 from the Site was partitioned among various actinide-contaminated soil

areas based on their size and soil activity levels. A loss rate in picocuries per square meter per year ( $\text{pCi}/\text{m}^2/\text{yr}$ ) was calculated for each contaminated soil area. The estimated actinide loss rate was used to calculate a rate of generation of particulate matter erosion potential by factoring out the soil activity concentration levels ( $\text{pCi}/\text{m}^2/\text{yr}$  divided by picocuries per gram [ $\text{pCi}/\text{g}$ ] = grams per square meter per year [ $\text{g}/\text{m}^2/\text{yr}$ ]). These values were converted to particulate matter generation per 15-minute time step, assuming that erosion potential renewal is constant throughout the year.

## Calculation of Actinide Emissions

To model actinide emissions, estimated particulate matter emissions for each 15-minute period (in  $\text{g}/\text{m}^2/15\text{-minute period}$ ) were combined with information regarding the activity concentration of the available particulate matter (in  $\text{pCi}/\text{g}$ ) to yield estimated actinide emissions (in  $\text{pCi}/\text{m}^2/15\text{-minute period}$ ). This required tracking additional information for each contaminated soil **source area**.

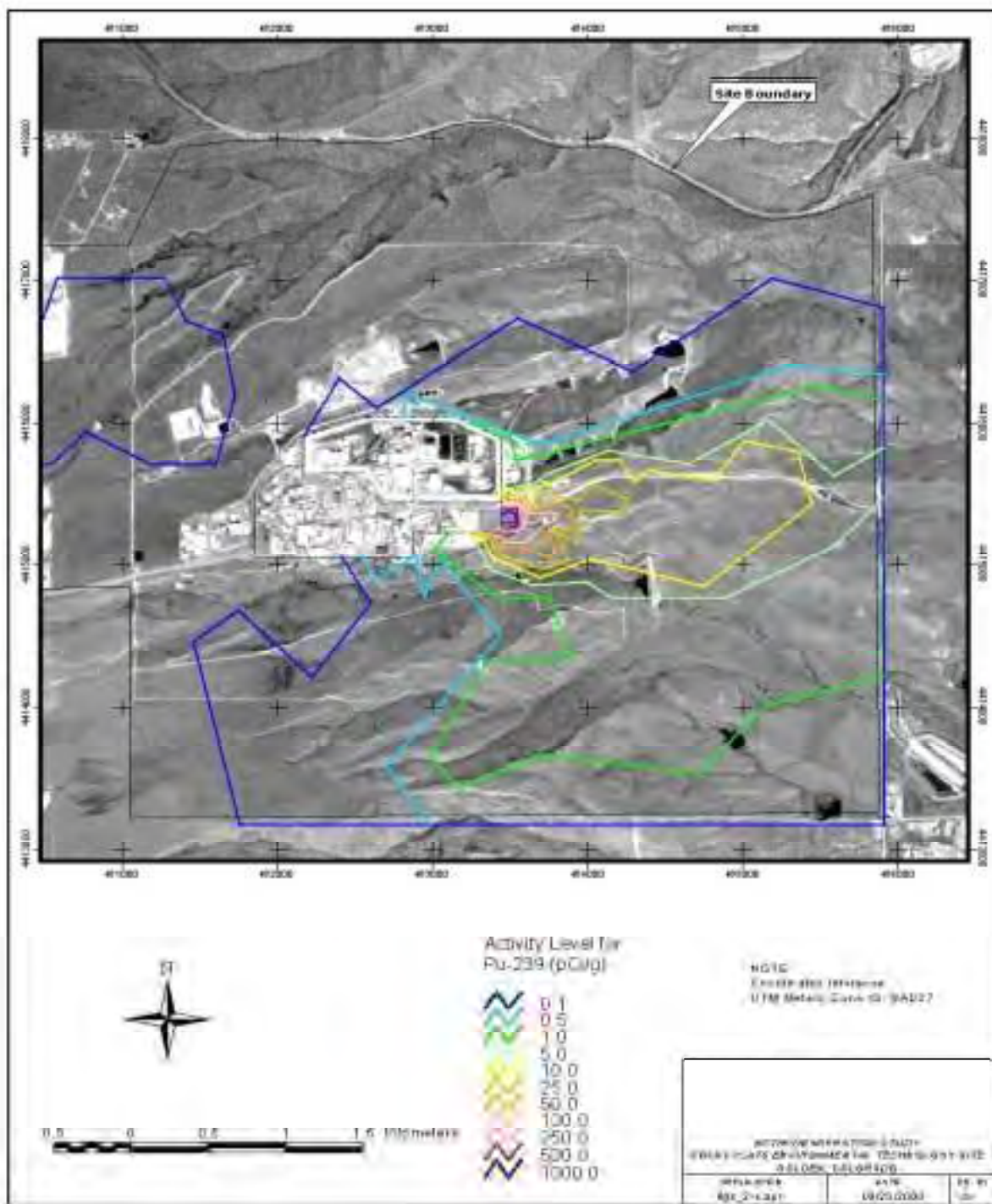
While particulate matter emissions were assumed to be uniform across undisturbed areas of the Site, actinide emissions vary by source area. These contaminated soil source areas can be represented by isopleths showing the distribution of actinides in surface soils at the Site. Figure 5 shows the distribution of Pu-239/240 in Site surface soils; Am-241 is similarly distributed but in lesser concentrations.

The renewal of erosion potential by small-scale disturbances will generate erodible material that will reflect the actinide concentration levels in the underlying surface soil. The renewal of erodible material by deposition, in contrast, will generate erodible material that will reflect the actinide concentration levels in the air over the Site. To calculate the rate of activity deposition, average airborne Pu-239/240 and Am-241 concentrations were estimated over each of the contaminated soil source areas. Data from ambient radioparticulate samplers at the Site were used to produce annual average air concentration isopleths over the Site for Pu-239/240 and Am-241. The air concentration patterns were mapped to the contaminated soil source areas. As with particulate matter, deposition of actinides was estimated by multiplying an average air concentration (in picocuries per cubic meter [ $\text{pCi}/\text{m}^3$ ]) by a deposition velocity (in  $\text{m}/15\text{-minutes}$ ) to calculate deposition of Pu-239/240 and Am-241 (in  $\text{pCi}/\text{m}^2/15\text{-minute period}$ ). Deposition velocities were calculated as for particulate matter using 1996 meteorological data for the Site and Site-specific information on actinide distribution in various size fractions of airborne dust. Rates of erosion potential renewal by actinide deposition were tracked separately for each contaminated soil source area.

The ongoing generation of actinide erosion potential through small-scale disturbances was described previously. As with deposition, the period-by-period renewal of erosion potential through this mechanism was tracked separately for each contaminated soil source area. For each actinide and source area, the available activity was initialized by multiplying the initial particulate matter erosion potential by the  $\text{pCi}/\text{g}$  activity concentration in the soil.

For each 15-minute time period, the increase in available erodible activity was calculated due to deposition and small-scale disturbances for each actinide and source area (in picocuries per

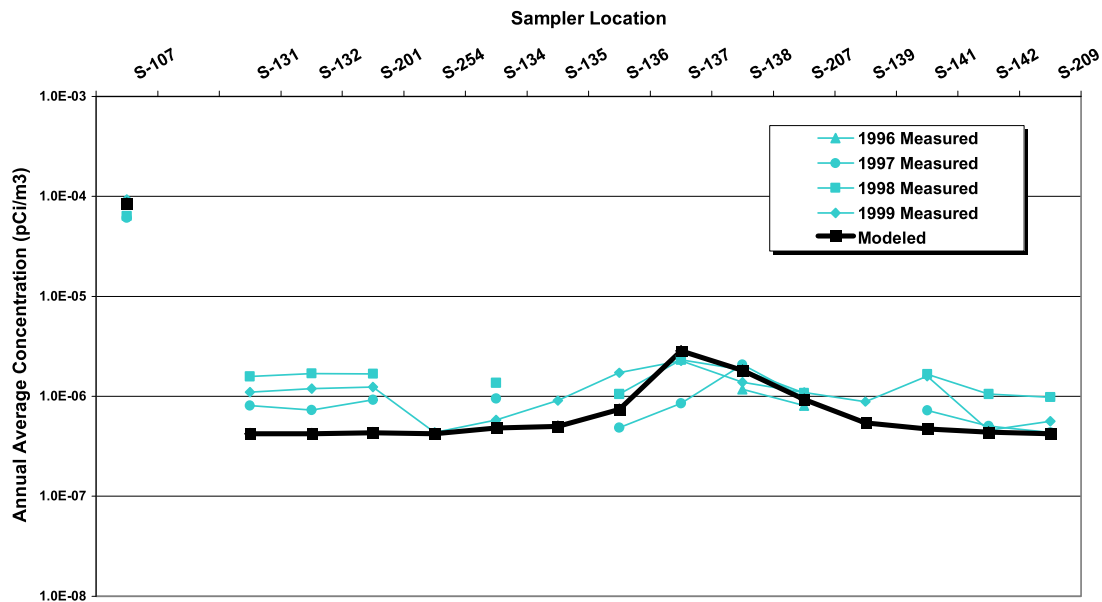
Figure 5: Contaminated Surface Soil Source Areas (Pu-239/240)



square meter [ $\text{pCi}/\text{m}^2$ ]) and added to the erodible activity remaining from the previous time step. The activity concentration of the available erodible material was calculated by dividing the total  $\text{pCi}/\text{m}^2$  for each actinide and source area by the total available particulate matter (in  $\text{g}/\text{m}^2$ ) for each time step. The resulting  $\text{pCi}/\text{g}$  value determined for each actinide and source area was then multiplied by the calculated particulate matter emissions for each time step to determine actinide emissions. A computer code was written to track these dynamics and to produce a variable emission rate file for each contaminated soil source area for input to ISCST3.

Wind erosion emissions of Pu-239/240 and Am-241 from undisturbed areas of the Site were modeled with ISCST3 and compared to measured ambient air plutonium and americium concentrations at various locations around the Site. Wind erosion emissions were treated as ground-level area sources with the spatial extent of each source based on the surface soil distribution of Pu-239/240 and Am-241 (see Figure 5). The annual average concentrations of Pu-239/240 and Am-241 predicted by the model, when added to regional background concentrations, provide a good fit to measured data at all sampler locations. Results for Pu-239/240 are shown in Figure 6; modeled impacts of Am-241 showed similar patterns.

**Figure 6: Pu-239/240 Modeling Results**



## DISPERSION MODELING APPROACH FOR POST-FIRE EMISSIONS

To model wind erosion following a fire, a series of multipliers was developed and applied to the emissions estimated for undisturbed areas of the Site. Immediately following a fire, wind erosion potential would increase relative to pre-fire conditions due to removal of the protective vegetative cover. The erosion potential would decrease gradually with time to pre-fire (baseline) conditions. The rate of recovery will depend on the time of year that the fire occurs, the fire intensity, and the amount and frequency of rainfall occurring after the fire.

Though vegetation density may return to its pre-burned state in a matter of weeks under optimal conditions, it may take up to a full year or more for vegetation to recover under dry conditions. Full restoration of protection from wind erosion probably requires a layer of thatch, composed of dead grasses and vegetation pushed over and matted down by rain, wind, and snow during the fall and winter months. Thatch covers the bare soil between plants, reducing both direct resuspension from the soil surface and the transfer of soil particles to plant surfaces by rainsplash.

Wildfires resulting from presumed lightning strikes were modeled under two discrete sets of assumptions, representing a spring fire with a relatively rapid recovery period and a fall fire, with a slower recovery to baseline wind erosion conditions. The hypothetical fires were assumed to burn approximately 100 acres in the area of the Site with the highest surface soil actinide concentrations. Pre-fire emissions were modeled from the area of the hypothetical fires to provide a base case against which to compare the post-fire model results.

## **Emission Estimation**

For the base case, emissions of Pu-239/240, Am-241, and particulate matter were estimated as previously described. For the post-fire scenarios, the erosion potential was assumed to be greater for the unprotected (unvegetated) soil than for normal, undisturbed grassland and the rates of deposition and erosion potential generation due to small-scale disturbances were also assumed to increase. The wind tunnel studies of the test burn area were used to characterize the increase in erosion potential that would follow a fire.

The April and June 2000 wind tunnel data from the unburned area formed the basis of the emission estimates for unburned grassland described above. The average erosion potential for these unburned areas was approximately  $0.03 \text{ g/m}^2$ . This value was used as the baseline erosion potential for the hypothetical fire scenarios.

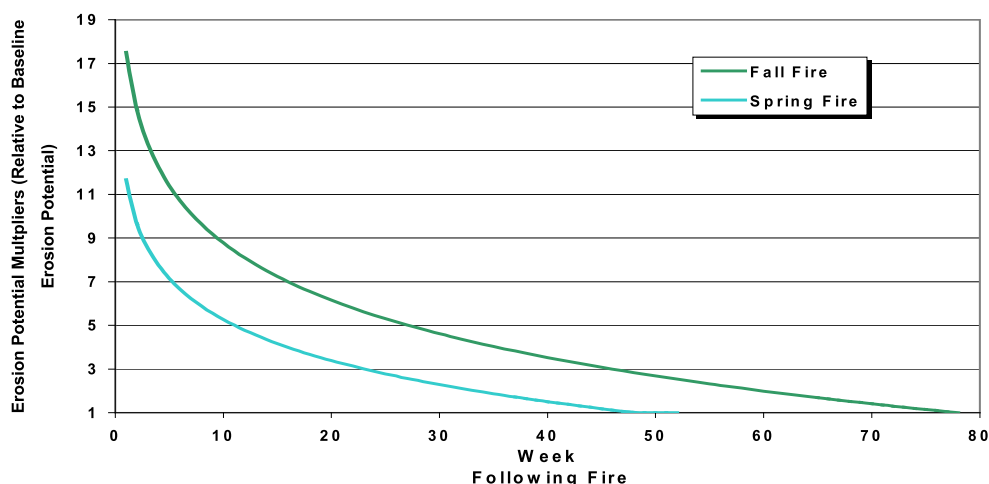
Potential emissions for the post-fire cases were calculated by defining weekly multipliers that were applied to the wind erosion equation (Equation 1). The weekly multipliers were developed from the wind tunnel data shown in Figure 3 as follows:

- Two post-fire scenarios were defined—one based on a spring fire and a 12-month recovery to baseline erosion potential, the second based on a fall fire and an 18-month recovery period (through a second winter to ensure a layer of thatch).
- The April and June burned area average  $\text{PM}_{10}$  erosion potentials (see Figure 3) were used to define an erosion potential characteristic of each period (May results were excluded because the ground was much wetter during that period than during either April or June test periods). The April data were used to define erosion potential for the first week following the hypothetical spring fire. The June data defined erosion potential during the 11<sup>th</sup> week following a spring fire. The baseline erosion potential rate ( $0.03 \text{ g/m}^2$ ) was assumed to represent the 52<sup>nd</sup> week following a spring fire.

- Power and logarithmic curves were plotted using these three data points. The logarithmic curve fit the data better for the period of interest ( $R^2 = 0.997$ ) and defined a slower (and therefore more conservative) decrease in erosion potential over time. The resulting equation was used to fill in erosion potentials for the other weeks.
- Weekly erosion potentials were converted to weekly multipliers by dividing each erosion potential by the baseline erosion potential of  $0.03 \text{ g/m}^2$ . The weekly multipliers were applied to the chronic wind erosion equation for undisturbed conditions (Equation 1) to generate potential TSP emissions for each 15-minute period in the 1996 meteorological data set. These values defined potential emissions for the spring fire case (the spring fire was assumed to occur on April 1, so the highest multiplier was applied to the first week in April, with subsequent multipliers “wrapping” back to the January through March period to complete a year-long data set for modeling).
- For the fall fire, a logarithmic curve was fitted to two points to define multipliers for a longer, slower recovery than was assumed for the spring fire. The average April burned area  $\text{PM}_{10}$  erosion potential was multiplied by 1.5 and this value was set as the erosion potential for the first week following the fall fire. The baseline erosion potential ( $0.03 \text{ g/m}^2$ ) was set equal to the erosion potential in week 78. The resulting curve was used to fill in erosion potentials for the intervening weeks, which were converted to weekly multipliers by dividing each by the baseline erosion potential.
- The fall fire was assumed to occur September 1. The weekly multipliers were applied to Equation 1 to generate potential TSP emissions for each 15-minute period in the 1996 meteorological data set. As with the spring fire, the multipliers were “wrapped” around to the January through August period to complete a year-long data set for modeling.

The 15-minute potential emissions were adjusted using the albedo and precipitation flags developed for the base case. These factors accounted for periods when no emissions would occur because of snow cover or rain. The changes in erosion potential following the hypothetical spring and fall fires are illustrated in Figure 7.

**Figure 7: Changes in Erosion Potential Following Hypothetical Spring and Fall Fires**





## Other Post-Fire Inputs

As previously explained, the available erodible material is renewed throughout the year through deposition of particulate matter and through small-scale disturbances of the soil. A fire would be expected to increase particulate matter emissions, which, in turn, could result in increased deposition of particulate matter back onto the burned area.

Immediately above the burned area, the particulate matter in the air would be a mixture of particulate matter derived from the area of the hypothetical fire and particulate matter originating from elsewhere. A model developed by Argonne National Laboratory deals with a similar situation in which the total “mass loading” in the air over an area of soil contamination is partitioned between “clean” particulate matter originating outside the contaminated area and contaminated soil blown off the area of contamination. The Residual Radioactivity model (RESRAD) accounts for this partitioning through an area factor that varies with the size of the contaminated area and the annual average wind speed. The area factor formulation was developed through repeated dispersion model simulations and curve fitting.<sup>9</sup>

The RESRAD Version 5.82 area factor formulation was used to determine the fraction of the particulate matter in the air over the hypothetical fire location that would originate from the burned area and the fraction that would originate from elsewhere. The fractions were approximately 15% from the burned area and 85% from elsewhere.

For the post-fire scenarios, the expected increase in the particulate matter in the air over the burned area was calculated by scaling up the fraction originating from the burned area itself by the multipliers shown in Figure 7 (i.e., it was assumed that particulate matter concentration would increase linearly with the potential emissions) and adding that to the fraction originating from elsewhere. The average airborne concentrations of Pu-239/240 and Am-241 were also increased for the post-fire simulations by assuming that particulate matter originating from the burned areas would carry actinide activity at the same concentrations as the surface soil of those areas. Particulate matter originating from outside the burned area was assumed to carry the same actinide concentrations used for the pre-fire base cases.

Fire may also change the size distribution of particles that are resuspended from the burned area. Annual average particulate matter and actinide deposition velocities were recalculated using size fraction data characteristic of disaggregated Rocky Flats soil.<sup>10</sup> Compared to the deposition velocities used for baseline modeling, the post-fire deposition velocity for particulate matter originating from the burned area was decreased to 65% of the original value, while the post-fire deposition velocity for airborne activity originating from the burned area was decreased to 33% of the original value. Monthly particulate matter and actinide deposition velocities were calculated for the post-fire simulations as weighted averages based on the percentage of total post-fire airborne particulate matter or actinide assumed to originate from the burned area vs. from the surrounding unburned areas.

No information is available on the possible effect of a fire on the rate at which erosion potential is renewed through freeze/thaw, burrowing animal activity, the activities of larger animals such as deer, rainsplash, etc. For the post-fire simulations, it was assumed that the rate would initially

double for mass. The multiplier was then assumed to decrease from 2 to 1 over a 12-month period for the spring fire and over an 18-month period for the fall fire. Monthly multipliers were calculated assuming a logarithmic decrease. Revised activity generation was calculated for Pu-239/240 and Am-241 by multiplying the revised particulate matter generation rate by the surface soil activity level for each contaminated soil source area and actinide.

The initial erodible particulate matter was set to the predicted January erosion potential from the logarithmic curve projections described previously for each scenario. As with the baseline modeling, the initial erodible particulate matter value was multiplied by the surface soil actinide activity level for each contaminated soil source area to define initial activity levels.

## RESULTS

For the post-fire scenarios, Pu-239/240, Am-241, and particulate matter concentrations resulting from wind erosion of an area recovering from a wildfire were estimated and compared to wind erosion impacts from the same area in an undisturbed state using ISCST3. Results are summarized in Table 1. Wind erosion following a fire was predicted to cause a 5- to 13-fold increase in annual actinide concentrations when compared to unburned conditions. Particulate matter concentrations were predicted to increase by smaller amounts. The increases in particulate matter and actinide concentrations would vary with the location of the fire and with the time of the year that the fire occurred. A fall fire would cause greater concentration increases than a spring fire because vegetation would recover more slowly over the winter months than during the spring and summer.

**Table 1. Post-Fire Modeling Results**

Pollutant	Maximum Estimated Annual Concentration	
	On Site	Off Site
<b>Base Case</b>		
Particulate matter (TSP) ( $\mu\text{g}/\text{m}^3$ )	2.45	0.064
Pu-239/240 ( $\text{pCi}/\text{m}^3$ )	$1.2 \times 10^{-4}$	$6.6 \times 10^{-7}$
Am-241 ( $\text{pCi}/\text{m}^3$ )	$4.8 \times 10^{-5}$	$2.1 \times 10^{-7}$
<b>Spring Fire Recovery</b>		
Particulate matter (TSP) ( $\mu\text{g}/\text{m}^3$ )	7.35	0.144
Pu-239/240 ( $\text{pCi}/\text{m}^3$ )	$9.2 \times 10^{-4}$	$3.6 \times 10^{-6}$
Am-241 ( $\text{pCi}/\text{m}^3$ )	$3.7 \times 10^{-4}$	$1.1 \times 10^{-6}$
<b>Fall Fire Recovery</b>		
Particulate matter (TSP) ( $\mu\text{g}/\text{m}^3$ )	10.85	0.219
Pu-239/240 ( $\text{pCi}/\text{m}^3$ )	$1.5 \times 10^{-3}$	$6.1 \times 10^{-6}$
Am-241 ( $\text{pCi}/\text{m}^3$ )	$5.8 \times 10^{-4}$	$2.0 \times 10^{-6}$

Notes:

$\mu\text{g}/\text{m}^3$  = micrograms per cubic meter

Am = americium

$\text{pCi}/\text{m}^3$  = picocuries per cubic meter

Pu = plutonium

TSP = total suspended particulate matter

## CONCLUSIONS

The analyses indicated that emissions from a burned surface would be significantly limited by the rate at which erodible material is renewed. This observation parallels previous erosion studies that have shown that emissions decrease from a surface over time unless the surface is disturbed. The erodible material is exhausted and no additional emissions occur until the erodible material can be resupplied.

This effect is important in limiting emissions following a fire. For example, the simulations indicated that fall post-fire particulate matter emissions, assuming unlimited erodible material, would have been double what was predicted by these simulations. Similarly, spring post-fire particulate matter emissions would have increased by 1.5 times the predicted amount. These emission increases would generally have translated into comparable increases in particulate matter and actinide concentrations.

The post-fire simulations revealed additional interactions that may influence airborne actinide concentrations. Dilution of contaminated surface soil with deposited “clean” particulate matter appears important in limiting actinide emissions. Changes in particle size distribution following a fire would affect not only deposition and concentration patterns but would also alter the amount of particulate matter and actinide available for erosion. Increased emissions from the burned areas may increase particulate matter concentrations over them, creating a feedback loop that enhances particulate matter emissions but decreases actinide emissions through dilution. For a spring fire at the Site, emissions would be limited because the summer period, during which the erosion potential would be highest, experiences lower wind speeds than fall and winter, by which time substantial vegetative recovery would be expected. These types of interactions indicate that airborne actinide concentrations following a fire event cannot be accurately predicted by taking into account the potential increase in erosion potential alone.

## REFERENCES

1. Midwest Research Institute. *Effect of Controlled Burning on Soil Erodibility by Wind, Final Test Report*. Kansas City, MO, 2001. MRI Project No. 110056.
2. Midwest Research Institute. *Effect of Wildfires on Soil Erodibility by Wind, Final Test Report*. Kansas City, MO, 2001. MRI Project No. 110056.1.004
3. Haines, P. M.; Templeman, S. M.; Hyder, M. W.; Cowherd, C.; Grelinger, M.A. “Effects of Prescribed Grass Fire on Wind Erosion Rates from Surface Soil at Rocky Flats, Colorado.” U.S. Environmental Protection Agency International Emission Inventory Conference, Denver, CO, May 2001.
4. U.S. Environmental Protection Agency. *National Technical Guidance Series Air Pathway Analysis Procedure for Superfund Applications*. Vol. II: *Estimates of Baseline Air Emissions at Superfund Sites*. Research Triangle Park, NC, 1989; EPA-450/1-89-002a.
5. U.S. Environmental Protection Agency. *Compilation of Air Pollutant Emissions Factors*, AP-42. Fifth Edition, Supplements A-F, Volume I: *Stationary Point and Area Sources*. Research Triangle Park, NC, 2000.

6. URS Group, 2001. *Air Transport and Deposition of Actinides for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site: FY01 Report*. Prepared for Kaiser-Hill Company, L.L.C.: Golden, CO, 2001.
7. U.S. Environmental Protection Agency. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume I and II*. Office of Air Quality Planning and Standards: Research Triangle Park, NC, 1995; EPA-454/B-95-003a.
8. Radian International. *Air Transport and Deposition of Actinides at the Rocky Flats Environmental Technology Site, FY00 Report*. Prepared for Kaiser-Hill Company, L.L.C.: Golden, CO, 2000.
9. Chang, Y. S.; Yu, C.; Wang, S. K. *Evaluation of the Area Factor Used in the RESRAD Code for the Estimation of Airborne Contaminant Concentrations of Finite Area Sources*. Report ANL/EAD/TM82. Argonne National Laboratory: Argonne, IL, 1998.
10. Ranville, M.; Harnish, R. A.; Winkler, S.; Honeyman, B. D. *Soil Aggregation and Its Influence on <sup>239,240</sup>Pu Particle-Size Distributions of Soils Collected from Rocky Flats, Colorado*. Department of Chemistry and Geochemistry, Division of Environmental Science and Engineering, Colorado School of Mines: Golden, CO, July 2000.

## KEY WORDS

Actinide

Wind tunnel

PM<sub>10</sub>

Fire

Controlled burn, prescribed burn

Fugitive dust

Wind erosion, resuspension



# Effect of Wildfires on Soil Erodibility by Wind

## Final Test Report

For

Radian International  
Rocky Flats Environmental Technology Site

**Midwest  
Research  
Institute**

425 Volker Boulevard  
Kansas City, Missouri  
64110-2299  
(816) 753-7600



MRI Project No. 110056.1.004

May 16, 2001

ADMIN RECCRD

DOCUMENT CLASSIFICATION  
REVIEW WAIVER PER  
CLASSIFICATION OFFICE

SW-A-004356

*solutions through science and technology*

Y51



**Effect of Wildfires on  
Soil Erodibility by Wind**

**Final Test Report**

**For Radian International  
Rocky Flats Environmental Technology Site  
10808 Highway 93, Unit B  
Building T130C  
Golden, CO 80403**

**Attn: Patrick Haines**

**MRI Project No. 110056.1.004**

**May 16, 2001**

## Preface

---

This report was prepared by Midwest Research Institute (MRI) for Radian International under Purchase Order No. 803991. In this report, MRI presents the methodology and results of the wind erodibility testing of an area burned by a wildfire at the Rocky Flats Environmental Technology Site, located northwest of Denver, Colorado.

The work was conducted in MRI's Applied Engineering Division. Dr. Chatten Cowherd, who served as the project leader for MRI, coordinated the preparation of this report. Other MRI technical staff who contributed to the program were Mary Ann Grelinger (data acquisition) and Courtney Kies (data reduction).

MIDWEST RESEARCH INSTITUTE



Chatten Cowherd, Ph.D.  
Program Manager

Approved:



Paul C. Constant, P.E.  
Acting Director  
Applied Engineering Division

May 16, 2001

# Contents

---

Preface .....	ii
Figures .....	iv
Tables .....	iv
Section 1. Introduction .....	1
Section 2. Test Methods .....	3
2.1 Wind Tunnel Sampling Equipment .....	3
2.2 Wind Tunnel Sampling Procedure .....	6
2.3 Interpretation of Wind Tunnel Results .....	8
2.4 DustTRAK Monitoring .....	9
2.5 Surface Soil Sampling .....	11
2.6 Isotopic Analysis of PM-10 Filters and Soil Samples .....	12
Section 3. Results of Field Tests .....	13
3.1 Tunnel Comparison Tests on Unpaved Road .....	13
3.2 Wildfire Tests .....	14
Section 4. Results of Laboratory Tests .....	22
4.1 Isotopic Analyses of Soil Samples .....	22
4.2 Isotopic Analysis of PM-10 Filter Samples .....	23
4.3 Soil Deposition .....	25
Section 5. Conclusions .....	26
Section 6. References .....	27

## Appendices

Appendix A—Results of Gravimetric Analysis
Appendix B—Results of Soil Isotopic Analysis
Appendix C—Results of Filter and Cyclone Catch Isotopic Analysis
Appendix D—CB-22 Example Calculation



## Figures

---

Figure 1. MRI Portable Wind Tunnel .....	4
Figure 2. Erosion Potentials at Test Run Maximum Wind Speed for Comparative Wind Tunnel Tests on Unpaved Road .....	17
Figure 3. Erosion Potential for 50 mph Wind Speed at 10-m Height for Comparative Wind Tunnel Tests on Unpaved Road .....	17
Figure 4. Erosion Potential History .....	20
Figure 5. Erosion Potential at 10-m Wind Speeds as Determined by Emission Sampler Weighted DustTRAK Data .....	21

## Tables

---

Table 1. Test Site Parameters for Wind Tunnel Tests (8/22/00) .....	15
Table 2. Comparative Wind Tunnel Test Results: Average Concentrations .....	15
Table 3. Comparative Wind Tunnel Results: Erosion Potentials .....	15
Table 4. Test Site Parameters for Wildfire Tests .....	16
Table 5. Average Concentrations for Wildlife Area .....	19
Table 6. Erosion Potentials for Wildfire Area .....	19
Table 7. DustTRAK Average PM-10 Erosion Potentials vs. 10-m Wind Speed .....	20
Table 8. Pu239 Activity by Soil Particle Size for Wildfire Surface Soil Samples .....	22
Table 9a. Wind Tunnel Test Data for Isotopic Analysis of PM-10 Samples .....	24
Table 9b. Wind Tunnel Test Data for Isotopic Analysis of TSP Samples .....	24
Table 10. Summary of PM-10 and TSP Pu239 Unit Activity and Concentrations .....	25

## Section 1. Introduction

---

The purpose of this study was to determine the impact of a wildfire on the potential for wind-generated particulate emissions from radioactive soils and vegetation at the Rocky Flats Environmental Technology Site northwest of Denver. On the evening of July 10, 2000, a lightning strike in the Rocky Flats buffer zone ignited a wildfire. The fire was controlled after burning 8.4 acres of grassland. The exposed soil surrounding the clumps of burned vegetation was known to contain actinide particles that could be resuspended by wind erosion.

Wind tunnel testing was initiated on August 22, 2000. The MRI reduced-scale wind tunnel was used in performing the tests on the wildfire area, in case contamination from the radioactive elements found in the area required disposal of the wind tunnel at the conclusion of testing. Typically, wind tunnel tests are performed using MRI's primary test device, a larger portable wind tunnel that has served as a reference test device to develop EPA-approved emission factors for wind erosion.

Both the larger and smaller wind tunnels have the same design and incorporate (a) time-integrating air samplers for PM-10 collection, and (b) two TSI DustTRAK monitors to provide real-time concentrations of PM-10 and PM-2.5 in the tunnel effluent. However, the reduced-scale wind tunnel has an open-floored test section that has approximately two-fifths the test area of the larger reference wind tunnel test section. Based on this size difference, initial tests were performed by operating both wind tunnels on an unpaved roadway surface with uniformly textured surface aggregate, so the performance of the two wind tunnels could be compared.

After comparative testing of the two tunnels on the unpaved gravel roadway, the reduced-scale wind tunnel was moved to the wildfire burned area where wind erosion testing was conducted. In addition to the wind tunnel tests that were performed, surface soil samples were collected from the wildfire burned area. Both the soil samples and the filters used in the wind tunnel testing were analyzed for isotopic activity.

The August 2000 test series on the wildfire area was preceded by three test series on a prescribed burn area in the Rocky Flats buffer zone. The prescribed burn tests are reported in a companion report, "Effect of Controlled Burning on Soil Erodibility by Wind." The prescribed burn tests were performed with the larger MRI portable wind tunnel.

The objective of the August tests on the wildfire area was to determine the actual actinide release through wind erosion of burned grassland. The wildfire area provided a scenario to verify the overall conclusions associated with the first series of tests of the prescribed burn area. Moreover, it offered the opportunity to characterize wind erosion emission potential as actinide release potential for different wind speeds.

This report describes (a) the types of equipment and the procedures that were used in the field testing at Rocky Flats and in the laboratory analysis of collected samples at MRI and Rocky Flats, and (b) the field and laboratory test results along with an analysis and interpretation of the results. The report is organized as follows:

- Section 2 describes the equipment and procedures used for field sampling of the wildfire-burned area and for laboratory tests of surface soil samples and PM-10 filters from the wind tunnel testing.
- Section 3 presents the wind tunnel test results along with an analysis and interpretation of the results. The comparative tests of the two different-scale wind tunnels are also described in this section.
- Section 4 presents the laboratory test results together with an analysis and interpretation of the results.
- Section 5 concludes the report with a summary of the test results and the conclusions that can be drawn from the results.
- Section 6 lists the literature references.

## Section 2.

### Test Methods

---

Field tests were performed to observe the effect of wind speed on the particulate emissions generated from wildfire-burned grassland area at Rocky Flats. The impact of the wildfire on surface soil exposure to wind generated emissions was evaluated using MRI's reduced-scale wind tunnel along with two TSI DustTRAK monitors.

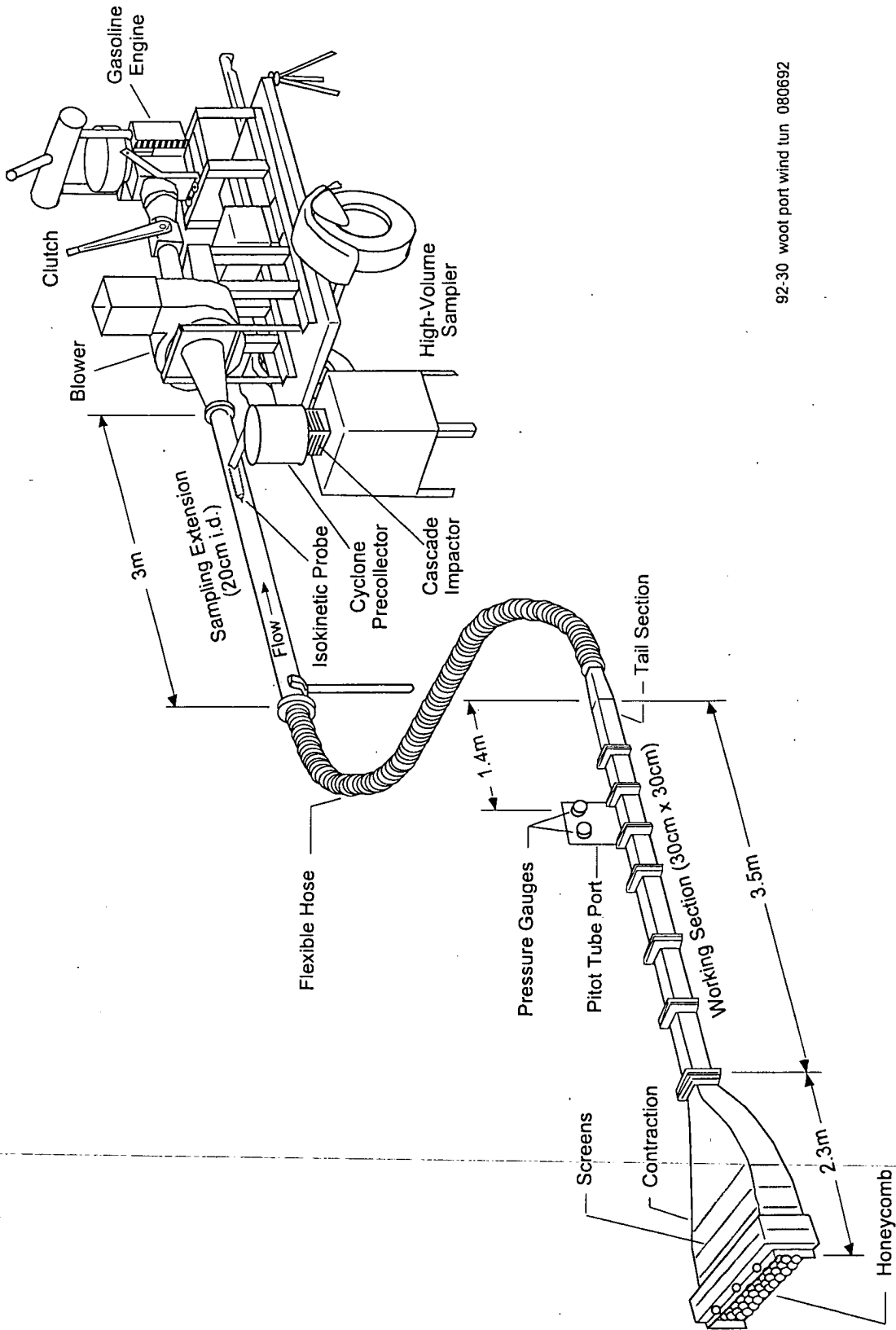
Additional field tests were performed on an unpaved roadway surface with uniformly textured surface aggregate (i.e., raked gravel). These tests were performed using the two different-scale wind tunnels to characterize the performance of the reduced-scale wind tunnel in comparison to the larger-scale reference wind tunnel employed during the prescribed burn tests of April-June 2000.

#### 2.1 Wind Tunnel Sampling Equipment

The MRI portable pull-through wind tunnel, as described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites* (USEPA, 1989), was used in performing the field study of wind-generated emissions from a prescribed burn area in April through June of 2000. This MRI reference wind tunnel (Figure 1) features all of the required design and operating characteristics, including the equipment for extracting isokinetic samples of wind generated particulate matter for measurement of mass emissions and particle size distribution. It is powered by a gasoline engine with direct mechanical linkage to the primary blower, which pulls the airflow through the tunnel.

The MRI reference wind tunnel is identical in design to that developed by Gillette (1978) but is nearly twice as large. It consists of a two-dimensional 5:1 contraction section, an open-floored working section with a 30-cm by 30-cm cross-section, and a roughly conical diffuser. The test area of this tunnel (30 cm by 3.1 m) provides for its use on rougher surfaces. The tunnel centerline airflow is adjustable up to an approximate maximum speed of 19 m/s (40 mph), as measured by a pitot tube at the downstream end of the test section. The equivalent wind speed at a reference height of 10 m above the ground is approximately two to three times the speed at the tunnel centerline, depending of the roughness height of the surface-being-tested.

The MRI reduced-scale wind tunnel is similarly designed but has a smaller working section (15-cm x 2.44-m open floor) and flow cross-section (15-cm by 15-cm). The ratio of the working areas of the two tunnels is 0.40. An industrial blower powers the reduced-scale tunnel and is driven by an electric motor with a speed control. A gasoline powered electric generator supplies power to the blower motor.



92-30 woot port wind tun 080692

Figure 1. MRI Portable Reference Wind Tunnel

In operating both the reduced-scale and reference wind tunnel, the open-floored test section is placed directly over the surface to be tested. Air is drawn through the tunnel at controlled velocities. The exit air stream from the test section passes through a circular duct fitted with a sampling probe near the downstream end. Air is drawn through the probe by a high-volume sampling train that separates total airborne particulate (TP) emissions into two particle size fractions: particles larger than 10  $\mu\text{m}$  in aerodynamic diameter that are collected inside a cyclone, and particles smaller than 10  $\mu\text{m}$  in aerodynamic diameter (PM-10) that are collected on a backup filter under the cyclone.

A high-volume ambient air sampler is operated near the inlet of the wind tunnel to provide for measurement and subtraction of the contribution of the ambient background particulate level. By sampling under light ambient wind conditions, background interferences from upwind erosion sources can be minimized.

The wind tunnel method relies on a straightforward mass balance technique for calculation of emission rate and no assumptions about plume configuration are required. This technique provides for precise study of the wind erosion process on specific test surfaces for a wide range of wind speeds. Previous wind erosion studies using the MRI reference wind tunnel have led to the EPA recommended emission factors presented in *Compilation of Air Pollutant Emission Factors (AP-42)*, published by U.S. EPA (1995).

Although the reference wind tunnel and the reduced-scale tunnel do not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnels simulates the smaller scales of atmospheric turbulence. It is the smaller scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to the particle entrainment mechanisms.

The wind speed profiles near the test surface (tunnel floor) and the walls of the tunnel have been shown to follow a logarithmic distribution (Gillette, 1978):

$$u(z) = \frac{u^*}{0.4} \ln \frac{z}{z_0} \quad (1)$$

where:  $u$  = wind speed, cm/s  
 $u^*$  = friction velocity, cm/s  
 $z$  = height above test surface, cm  
 $z_0$  = roughness height, cm

The friction velocity, which is a measure of wind shear at the erodible surface, characterizes the capacity of the wind to cause surface particle movement. As indicated from Equation 1, the wind velocity at any fixed height above the surface (but below the centerline of the wind tunnel) is proportional to the friction velocity. The "micro-scale" roughness height of each test surface is determined by extrapolation of the logarithmic wind speed profile near the surface to where  $u = 0$  cm/s.

An emissions sampling module (referred to in Figure 1 as the sampling extension) provides for representative extraction and aerodynamic sizing of particulate emissions generated by wind erosion. The sampling module is located between the tunnel outlet hose and the fan inlet. The particulate sampling train, which is operated at 68 m<sup>3</sup>/h (40 acfm), consists of a tapered probe, cyclone precollector, glass fiber backup filter, and high-volume motor. The sampling intake is pointed into the air stream, and the sampling velocity is adjusted to the approaching air speed by fitting the intake with a nozzle of appropriate size.

When operated at 68 m<sup>3</sup>/h (40 cfm), the cyclone has a nominal cutpoint of 10 µm aerodynamic diameter, based on laboratory calibration (Baxter et al., 1986). Thus the particulate fraction that penetrates the cyclone constitutes PM-10.

A pitot tube is used to measure the centerline (CL) wind speed in the sampling extension, upstream of the point where the sampling probe is installed. The volumetric flow rate through the wind tunnel is determined from a published relationship (Ower and Pankhurst, 1969) between the centerline (maximum) velocity in a circular duct and the average velocity, as a function of Reynolds' number. Because the ratio of the centerline wind speed in the sampling extension to the centerline wind speed in the working section is nearly independent of flow rate, the ratio can be used to determine isokinetic sampling conditions for any flow rate in the tunnel.

A portable high-volume air sampler with an open-faced glass fiber filter is operated on top of the tunnel inlet section to measure background levels of total suspended particulate matter (TSP). The aerodynamic cutoff diameter of TSP is usually assigned a value of 30 µm. The filter is vertically oriented, parallel to the tunnel inlet face. Based on historical data from Rocky Flats (Haines, 2001), 38.95% of the mass collected on the upwind, background filter is PM-10. The total mass collected represents total suspended particulate matter (TSP). The sampler is operated at 68 m<sup>3</sup>/h (40 cfm).

## 2.2 Wind Tunnel Sampling Procedure

Prior to each test series, the working section of the tunnel is placed directly on the selected test surface. To prevent air infiltration under the sides of the open-floored section, the rubberized skirts, attached to the bottom edges of the tunnel sides, are stretched out on the surface adjacent to the test surface. Rubber inner tubes filled with sand are laid along the skirts to assure a tight seal.

With the tunnel in place, the airflow is gradually increased to the threshold for the onset of wind erosion. If a wind erosion threshold exists, the threshold velocity is determined by visual observation of migration of coarse particles. A wind speed profile is measured at a sub-threshold velocity to determine the surface roughness height. In the

absence of a clearly evident threshold velocity, the wind speed profile is measured at a tunnel centerline wind speed of approximately 9 m/s (20 mph).

The measured micro-scale roughness height allows for conversion of the tunnel centerline wind speed to the equivalent friction velocity and to the equivalent wind speed at a standard 10-m height, using the logarithmic wind speed profile. If the terrain roughness (rolling hills, vegetation, etc.) is much larger than the microscale roughness of the test plot, a separate area-wide roughness height reflecting the larger terrain features is used to convert the tunnel centerline wind speed to the equivalent wind speed at a standard 10-m height.

For test surfaces that are found to have a well-defined threshold velocity, sampling is initiated just after the tunnel centerline wind speed reaches the first prescribed super-threshold level corresponding to the desired friction velocity or wind speed corrected to a height of 10 m. Alternatively, for other test surfaces without a well-defined threshold velocity, sampling is initiated as air begins to flow through the wind tunnel. After the prescribed sampling period, the flow is shut off and the particulate samples (cyclone catch and glass fiber backup filter) are removed.

At the end of each test, the sampling train is disassembled and taken to the field instrument van, and the collected samples of dust emissions are carefully placed in protective containers. For transfer of samples to a laboratory setting, high-volume filters are placed in individual protective envelopes or in specially designed carrier cases. Dust is transferred from the cyclone precollector by brushing it into a tared clear, resealable plastic pouch. Alternatively, the cyclone catch can be sieved using a standard 325 sieve (45  $\mu$ m pore size). The sieved cyclone catch, when recombined with the PM-10 mass from the backup filter, comprises total suspended particulate matter (TSP), which can be represented approximately as PM-30.

Dust samples from the field tests are returned to an environmentally controlled laboratory for gravimetric analysis. Glass fiber filters are conditioned at constant temperature (23°C  $\pm$  1°C) and relative humidity (45%  $\pm$  5%) for 24 h prior to weighing (the same conditioning procedure as used before tare weighing). The particulate catch from the cyclone precollector is weighed in the tared pouch.

The raw test data that are recorded include the following:

- Site code and description
- Test date, run number, and type of test
- Sample IDs (filters, cyclone catches, surface soils)
- Start time and sampling duration
- Threshold wind speed at tunnel centerline
- Subthreshold wind speed profile from which microscale roughness height is determined
- Operating wind speeds at tunnel centerline and at centerline of sampling tube



- Sampling module flow rate
- Ambient meteorology (wind speed and direction; temperature; barometric pressure)

## 2.3 Interpretation of Wind Tunnel Results

Because wind erosion is an avalanching process, it is reasonable to assume that the loss rate from the surface is proportional to the amount of erodible material remaining:

$$\frac{dM}{dt} = -kM \quad (2)$$

where:  $M$  = quantity of erodible material present on the surface at any time,  $g/m^2$   
 $k$  = proportionality constant,  $s^{-1}$   
 $t$  = cumulative erosion time,  $s$

Integration of Equation 2 yields:

$$M = M_o e^{-kt} \quad (3)$$

where  $M_o$  = erosion potential, i.e., quantity of erodible material present on the surface before the onset of erosion,  $g/m^2$

The loss of erodible material ( $g/m^2$ ) from the exposed surface area during a test is calculated as follows:

$$L = \frac{CQt}{A} \quad (4)$$

where:  $C$  = average particulate concentration in tunnel exit stream (after subtraction of background concentration),  $g/m^3$   
 $Q$  = tunnel flow rate,  $m^3/s$   
 $A$  = exposed test surface area ( $0.918 m^2$  for the reference wind tunnel  
 $0.3716 m^2$  for the reduced-scale wind tunnel)

Alternatively, the erosion potential can be directly calculated from the filter-net mass (blank-corrected and with background subtracted).

Whenever a surface is tested at sequentially increasing wind speeds, the measured losses from the lower speeds are added to the losses at the next higher speed and so on. This reflects the hypothesis that, if the lower speeds had not been tested beforehand, correspondingly greater losses would have occurred at the higher speeds.

Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action that results in the exposure of fresh surface material. On a soil surface, this would occur whenever soil is either added to or removed from the old surface, or whenever surface material is turned over to a depth exceeding the size of the largest pieces of aggregate present in the soil.

In summary, the calculated test results for each test surface and maximum wind speed include:

- Roughness height (microscale): from extrapolated subthreshold velocity profile
- Friction velocity: from measured centerline wind speed and roughness height, using Equation 1
- Equivalent wind speed at reference 10-m height: from measured centerline wind speed and roughness height, using Equation 1
- Erosion potential (for "limited reservoir" surfaces): equivalent to the cumulative particle mass loss at a particular wind speed

## 2.4 DustTRAK Monitoring

Continuous monitoring of particulate concentration in the emissions sampling module provides for a much greater level of detail in tracking the dynamics of the wind erosion process. In the case of the subject study, two portable DustTRAK Aerosol Monitors (TSI, Inc., St. Paul, Minnesota) continuously sampled air between the cyclone and the backup filter for the purpose of tracking the PM-10 and PM-2.5 concentrations in the tunnel effluent.

The DustTRAK monitor is a portable, battery-operated instrument that gives real-time measurements and has a built-in data logger. It weighs 3.3 lbs and uses four C cells. The instrument, as originally configured, samples PM-10, but can be fitted with a Dorr-Oliver nylon cyclone for industrial hygiene sampling ( $\sim 3.5 \mu\text{m}$  cutpoint), or impactors for PM-2.5 and PM-1 sampling.

The operating principle of the DustTRAK is based on  $90^\circ$  light scattering. The theoretical detection efficiency based on Mie light scattering theory peaks at about  $0.2\text{--}0.3 \mu\text{m}$  and gradually decreases for larger particle sizes. A pump draws aerosol into the optics chamber where either solid or liquid particles are detected. A laser diode light source, along with a solid-state photodetector, ensures greater stability and longevity. The specially designed sheath air system is used to isolate the aerosol in the chamber, keeping the optics clean and reducing maintenance. The instrument design gives measurements of particle concentrations from  $0.001$  to  $200 \text{ mg/m}^3$ . (Note that the instrument comes precalibrated to indicate mass concentration in  $\text{mg/m}^3$  using Arizona road dust as the calibration reference).

The DustTRAK has two basic modes of operation: a survey mode and a logging mode. The survey mode displays real-time aerosol concentration measurements in  $\text{mg}/\text{m}^3$ . The logging mode functions similar to the survey mode with the added feature that the measurements are stored at programmable intervals for trending and reporting using the TrakPro Data Analysis Software.

Once data have been logged by the monitor (30,000 data points can be recorded using 3 logging modes), the DustTRAK software can retrieve the information for a more comprehensive analysis, including maxima, minima, and averages for the entire sampling period or any user-selected interval. The PC software also has a graphing capability that allows the comparison of PM-10 and PM-2.5 concentrations, assuming two monitors are available (one with a PM-2.5 impactor inlet) and simultaneous sampling occurs.

The DustTRAK PM-10 monitor is calibrated against the actual PM-10 mass collected on the back-up filter of the wind tunnel effluent sampling train during a given test run. This calibration entails an integration of the real-time DustTRAK PM-10 concentration profile (versus time) and calculation of the average DustTRAK PM-10 concentration for comparison to the average PM-10 concentration calculated from the net PM-10 mass collected on the back-up filter below the cyclone.

Use of the DustTRAK monitors provides for a more comprehensive analysis of surface erodibility, especially appropriate to the study of surfaces that do not have a well-defined wind erosion threshold velocity. On the burned vegetative surfaces at Rocky Flats, there are multiple contributors to wind generated particulate emissions: (a) the bulk soil with the usual protection afforded by consolidation, (b) settled surface dust that is trapped by the vegetation and resides on the soil surface, (c) settled dust that is trapped on the surface of the vegetation, and (d) the vegetation itself. The particle releases from these reservoirs are all driven by different mechanisms, each with a different wind speed dependence.

Thus, the approach taken in this study was (a) to expose each test surface of burned grassland to a well defined time history of increasing wind speeds, and (b) to monitor continuously the PM-10 and PM-2.5 concentrations in the tunnel effluent. Specifically, the tunnel centerline wind speed was increased in increments of 2 m/s (5 mph) up to the capacity of the wind tunnel as follows:

Wind speed at tunnel-CL (mph)	Start time (min:sec)	Duration (min:sec)
5	0:00	2:00
10	2:00	2:00
15	4:00	2:00
20	6:00	4:00
25	10:00	4:00
30	14:00	4:00
35	18:00	4:00
40	22:00	4:00

Typically, each time the wind speed was increased, a PM-10 concentration spike was observed. Furthermore, upon each successive increase, the peak value of the spike increased and the rate of decay decreased. For centerline wind speeds at or above 20 mph, the duration of sampling was increased to a minimum of 4 min to allow additional time for the spike to decay. Time integration generates erosion mass increments that when added together yield cumulative erosion potentials for PM-10 and PM-2.5 as a function of wind speed.

## 2.5 Surface Soil Sampling

During the August testing, four subareas within the wildfire area near the wind tunnel test plot were selected for surface soil sampling. The areas were representative of the surfaces where MRI wind tunnel tests were performed. The surface soil samples were typical of the source material emitted from the wildfire-burned area through the wind erosion process.

Within each sampling area, approximately eight incremental samples were collected and then hand sieved into three size fractions: coarse, midsize and fine. The purpose of the size segregation of the surface soil sample was to determine whether higher isotopic activity was present in the fine soil fraction. A higher surface area to mass ratio for particles in the fine soil fraction could imply that radioactive contamination is preferentially attached to the fine soil particles.

Each incremental soil sample was hand sieved, using a nest of two sieves and a bottom pan. The coarse soil particles were collected on the top sieve, a standard sieve #30 with 600-micron openings. The mid-size soil fraction passed through sieve #30 but was captured on a standard sieve #200 with 75-micron openings. Finally, the fine (silt) fraction passed the standard sieve #200 and was captured in the bottom pan. Before the incremental surface soil samples were sieved, the larger pebbles and larger pieces of organic material (dead and burnt grass, occasionally deer droppings) were manually retrieved and discarded.

The sieving was accomplished by manually rotating and tapping the covered nest of sieves at the sampling location. Forty rotations were performed for each dry surface sample, and the sieves were tapped by hand after each ten rotations, for a total of 4 taps. After hand sieving, each size fraction was transferred to a labeled sample bottle. This method is very similar to the hand-sieving procedure found in AP-42, EPA's *Compilation of Air Pollutant Emission Factors*.

A method was developed to collect approximately equal amounts of three 125-mL samples from each soil sample, one for each of three size fractions. First, all the sieved silt from the pan was transferred to the 125-mL bottle designated for the fine soil fraction. Second, an equal volume of the mid-size soil fraction was transferred to the mid-size

bottle. Third, an equal volume of the coarse soil fraction was transferred to the coarse soil bottle, after removal of most of the thatch that had accumulated on the top sieve (#30). In summary, six to eight surface soil samples, each of approximately 200 to 300 g, were required from each of the four wildfire areas to obtain 125-mL volumes for the three sieve fractions.

## **2.6 Isotopic Analysis of PM-10 Filters and Soil Samples**

The procedures for isotopic analysis of PM-10 on filters and in soil samples are discussed in the Sampling and Analysis Plan.

## Section 3.

### Results of Field Tests

---

The field tests were conducted on August 22-25, 2000. Wind tunnel tests were performed (a) on an unpaved road (raked gravel surface) using both the MRI reference wind tunnel and the reduced-scale wind tunnel, and (b) on the wildfire area using the reduced-scale wind tunnel.

#### 3.1 Tunnel Comparison Tests on Unpaved Road

On August 22, 2000, wind tunnel tests were performed on an unpaved roadway in the Rocky Flats area, so that the performance of the reference wind tunnel and the reduced-scale wind tunnel could be compared. The test roadway had a uniformly textured surface material (i.e., raked aggregate). A total of five wind tunnel tests were performed, three using the reduced-scale wind tunnel and two with the reference wind tunnel. The first two tests, Runs CB-16A and CB-16B incorporated the same cyclone back-up filter to provide more sample mass for gravimetric measurement.

The wind tunnel tests were performed at incrementally increasing tunnel centerline wind speeds. The wind speed increments were 2 m/s (5 mph) at the centerline, up to the capacity of the wind tunnel. The "peak" PM-10 and PM-2.5 concentration values (6-sec averages) for each wind speed plateau was observable in the "real-time" concentration histories, recorded by the DustTRAK monitors.

The test site parameters are presented in Table 1. The reduced-scale wind tunnel was used for Runs CB-16 and CB-19, and the larger reference tunnel was employed on Runs CB-17 and CB-18. The surface roughness height of the gravel surface was found using the reference wind tunnel velocity profiles from Runs CB-17 and CB-18.

The comparison tests on the unpaved road surface indicate that the reference wind tunnel and the reduced-scale wind tunnel measured similar values for PM-10 concentration and TP erosion potential, neither of which are affected by nonisokinetic sampling. The PM-10 erosion potentials and the TP concentrations differed between the two tunnels, due to anisokinetic sampling that occurred when the sampling extension for the high-flow reference wind tunnel was adapted to the reduced-scale wind tunnel. This resulted in a superisokinetic condition because of the reduced flow rate in the sampling extension. The superisokinetic sampling condition oversamples PM-10 mass and underestimates the TP concentration. The procedure for adjusting for this sampling situation begins with determining the isokinetic flow ratio (IFR), which is defined as the ratio of sampling intake velocity to approach flow velocity. Then the TP concentration is multiplied by the IFR and the PM-10 mass collected is divided by the IFR.

Table 2 presents the average concentration values observed during the wind tunnel tests. The IFR corresponding to the maximum 10-m wind speed is also provided. In Table 2, the TP concentration in the reduced-scale wind tunnel effluent has been adjusted for anisokinetic sampling as previously described. The average concentrations produced during all four tests are approximately equivalent, i.e., within the range of variation normally encountered in wind tunnel tests of subareas of the same surface type. Thus, no correction is needed for concentration results from the reduced-scale wind tunnel.

Table 3 presents the erosion potential values for the gravel road surface, with the reduced-scale wind tunnel values adjusted for anisokinetic sampling. The values are again roughly equivalent between the two wind tunnels, showing that a correction for the erosion potential values provided by the smaller wind tunnel is not necessary. Since the calculated erosion potentials apply to different 10-m wind speeds attained during testing, the values were adjusted to a 50-mph wind speed to provide for a better comparison. As an illustration of the effects of adjusting for anisokinetic sampling, the adjustment lowered the average loss ratio for the reduced-scale wind tunnel tests from 0.175 to 0.041, which is close to the average value of 0.053 for the tests performed with the reference wind tunnel.

### 3.2 Wildfire Tests

Field tests of the wildfire area were performed from August 23-25, 2000, using the reduced-scale MRI wind tunnel. During each test, the wind tunnel was moved six times to separate test plots within the wildfire area, to increase the particulate sample masses and improve the detection of actinide activity and the PM-10 erosion potential.

The wind tunnel tests were performed at incrementally increasing tunnel centerline wind speeds. The wind speed increments were 2 m/s (5 mph) at the centerline, up to the capacity of the wind tunnel as done in the unpaved road tests. The "peak" PM-10 and PM-2.5 concentration values (6-sec averages) for each wind speed plateau were observable in the "real-time" concentration histories, recorded by the DustTRAK monitors.

The test site parameters for each of the wind tunnel test runs in the wildfire area are provided in Table 4. The surface roughness height was determined for only one test due to the difficulty in positioning the pitot-tube at specified distances from the ground surface. The surface roughness height was determined from the wind speed profile for Run CB-23F. The vertical profile of wind speed in the test section of the wind tunnel was fitted to a logarithmic function to determine a surface roughness height that is considered representative for the wildfire-burned area.

Table 1. Test Site Parameters for Comparative Wind Tunnel Tests (8/22/00)

Run no.	Surface characteristics	Wind tunnel	Start time	Duration (min)	Wind speed(mph)/ direction	Temperature (°F)	Barometric Pressure (in. Hg)	Relative humidity (%)	Surface roughness height (cm)
CB-16A	Unpaved Road	Reduced-scale	10:40	19	7 NE	86	24.50	30	NA
CB-16B	Unpaved Road	Reduced-scale	11:50	19	7 NE	86	24.50	30	NA
CB-17	Unpaved Road	Reference	14:05	30	5.4 SSE	82	24.50	28	0.02
CB-18	Unpaved Road	Reference	15:06	25	2.8	83	24.50	26	0.04
CB-19	Unpaved Road	Reduced-scale	16:09	17	8.1 NNE	81	24.50	31	NA

NA= no data available

Table 2. Comparative Wind Tunnel Test Results: Average Concentrations

Run no.	Duration (min)	Average effluent PM-10 conc. (mg/m <sup>3</sup> )	Background PM-10 conc. <sup>b</sup> (mg/m <sup>3</sup> )	Net <sup>a</sup> effluent PM-10 conc. (mg/m <sup>3</sup> )	Maximum wind speed IFR	Net <sup>a</sup> effluent TP Conc. <sup>c</sup> (mg/m <sup>3</sup> )	Average DustTRAK PM-10 conc. (mg/m <sup>3</sup> )	Ratio of effluent/ DustTRAK PM-10 conc.	Average DustTRAK PM-2.5 conc. (mg/m <sup>3</sup> )	Ratio of DustTRAK PM-2.5 conc./ PM-10 conc.
CB-16	38	7.03	0.019	7.01	4.89	165.80	0.513	13.71	0.349	0.68
CB-17	30	6.00	0.019	5.98	0.95	109.82	0.779	7.70	0.467	0.60
CB-18	25	7.57	0.019	7.55	1.07	146.30	0.997	7.59	0.478	0.48
CB-19	17	3.04	0.019	3.02	4.98	74.50	0.366	8.29	0.166	0.45

<sup>a</sup> Net = Average effluent concentration - Background concentration

<sup>b</sup> Historical Rocky Flats PM-10/TSP ratio of 0.3895 used.

<sup>c</sup> Reduced scale wind tunnel values adjusted for anisokinetic sampling.

Table 3. Comparative Wind Tunnel Test Results: Erosion Potentials

Run no.	Roughness height <sup>a</sup> (cm)	Tunnel centerline (CL) height (cm)	Maximum wind speed (mph) at tunnel CL	Equivalent maximum wind speed (mph) at 10-m height	Corresponding friction velocity (cm/s)	Erosion potential/loss <sup>b</sup> (g/m <sup>2</sup> )			Erosion potential/loss at a 50 mph wind speed at 10-m height (g/m <sup>2</sup> )	
						TP <sup>c</sup>	PM-10 <sup>c</sup> (PM-10/TP)	Loss ratio	TP <sup>c</sup>	PM-10 <sup>c</sup> Loss ratio (PM-10/TP)
CB-16	0.03	7.65	29.6	55.6	95.4	133.5	5.6	0.042	120.1	5.0
CB-17	0.02	15.2	37.4	62.6	107.4	276.6	15.1	0.054	221.1	12.0
CB-18	0.04	15.2	36.7	61.4	105.5	307.1	15.8	0.052	249.9	12.9
CB-19	0.03	7.65	25.4	47.8	82.1	52.6	2.1	0.040	55.0	2.2

<sup>a</sup> Roughness height not calculated for smaller wind tunnel runs, average of two larger runs used.

<sup>b</sup> Erosion potential calculated using net mass and alternative calculation.

<sup>c</sup> Reduced scale wind tunnel values adjusted for anisokinetic sampling.

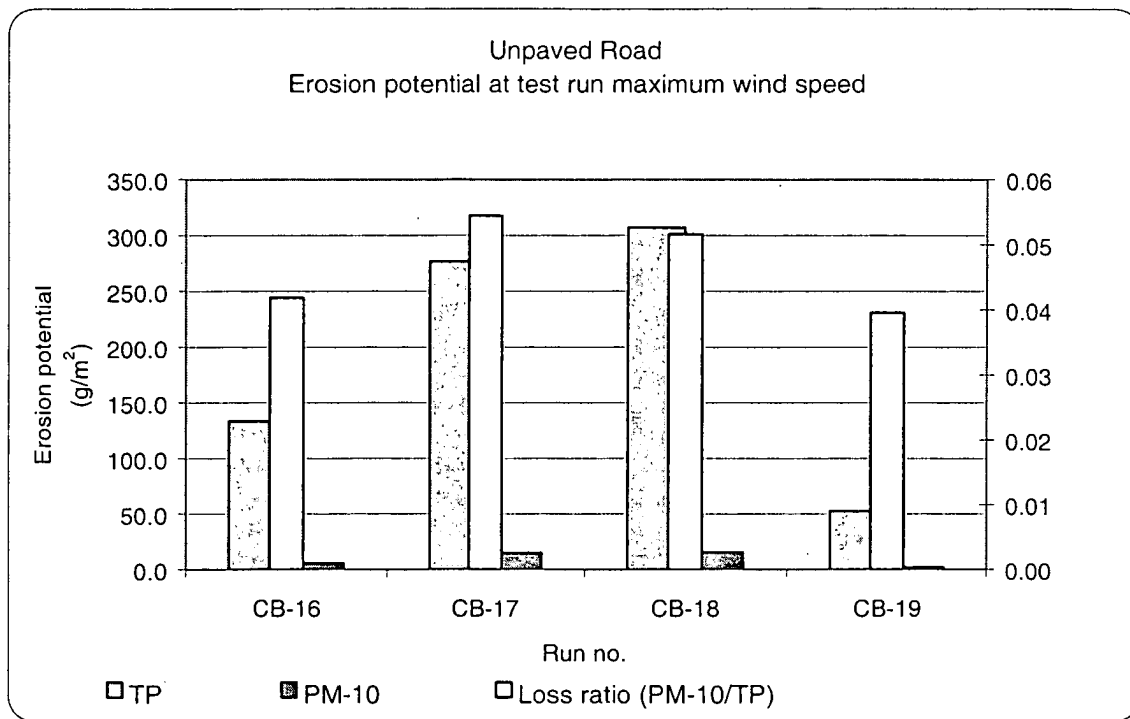


**Table 4. Test Site Parameters for Wildfire Tests**

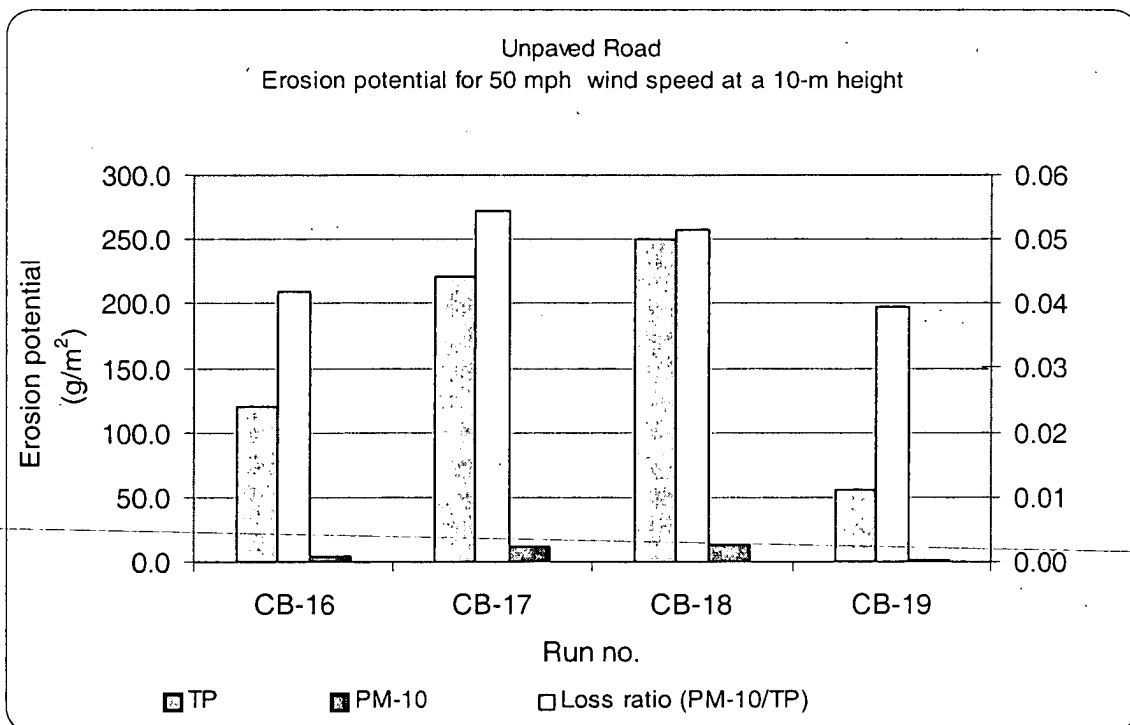
Date	Surface characteristics	Run no.	Start time	Duration (min)	Wind speed (mph)/ direction	Temperature (°F)	Barometric pressure (in. Hg)	Relative humidity (%)
8/23/00	Wildfire Area	CB-20A	11:33	21	8.5	79	24.75	43
		CB-20B	12:04	22	7.2 S	85	NA	35
		CB-20C	12:34	22	4.1 SSE	85	NA	32
		CB-20D	13:13	20	6.5 SE	85	24.70	33
		CB-20E	13:42	24	7.5 SE	86	NA	29
		CB-20F	14:28	21	8.0 ESE	85	NA	31
8/24/00	Wildfire Area	CB-21A	8:22	22	NA	NA	24.70	NA
		CB-21B	8:51	21	1.9 SE	76	NA	33
		CB-21C	9:20	22	3.5 E	76	NA	NA
		CB-21D	9:53	22	NA	NA	NA	NA
		CB-21E	10:22	27	NA	NA	NA	NA
		CB-21F	10:55	30	3.2 SE/E	82	24.80	33
8/24/00	Wildfire Area	CB-22A	12:57	20	4.6 SSE	82	24.80	28
		CB-22B	13:23	21	6	84	NA	29
		CB-22C	13:59	21	6.4 S	82	NA	28
		CB-22D	14:25	22	4.5 S	83	24.70	31
		CB-22E	14:52	21	3.1 SW	NA	NA	NA
		CB-22F	15:19	21	3.6 S/SSW	90	NA	25
8/25/00	Wildfire Area	CB-23A	8:06	21	3.4 N	75	NA	47
		CB-23B	8:34	21	1.7	76	24.70	37
		CB-23C	8:59	31	1	78	NA	38
		CB-23D	9:30	22	4.3 E	83	NA	35
		CB-23E	9:57	21	4.6 E	84	NA	28
		CB-23F	10:24	21	5.8 E	82	24.70	29

NA= no data available.

21



**Figure 2. Erosion Potentials at Test Run Maximum Wind Speed for Comparative Wind Tunnel Tests on Unpaved Road**



**Figure 3. Erosion Potentials for 50 Mph Wind Speed at 10-M Height for Comparative Wind Tunnel Tests on Unpaved Road**

The average concentrations for the wind tunnel tests of the wildfire area are presented in Table 5. The same procedure used for the unpaved road comparison tests to adjust the TP concentration and PM-10 mass was also incorporated in the wildfire area calculations. Since the mass collected on the background filter constitutes TSP, the background air concentrations of PM-10 were determined using the average PM-10/TSP ratio of 0.39 from historical air quality data at Rocky Flats. The relatively high background concentration found on Run CB-23 required adjustment based on the highest proportion of inlet outlet concentration of 0.06. The high background concentration determined from the filter mass was probably due to the recirculation of the effluent from the wind tunnel.

At the time, it was not known if sufficient mass could be generated from an undisturbed wildfire surface, so for Runs CB-20 and CB-21, the surface was raked to insure release of adequate soil emissions for characterization of actinide activity in the PM-10 fraction. After preliminary analysis of sample masses collected in Runs CB-20 and CB-21, Runs CB-22 and CB-23 were conducted on an undisturbed wildfire surface. These last two tests best represent the soil erosion process for the wildfire burned area.

Table 5 shows that the average PM-10 concentration in the tunnel effluent, as determined from the filter mass loading, was several times higher than the average PM-10 concentration indicated by the DustTRAK. This reflects the fact that while the coarse mode of the PM-10 (particles larger than 2.5  $\mu\text{m}$  but smaller than 10  $\mu\text{m}$ ) constitutes much of the PM-10 sample mass, it does not scatter light very effectively. This behavior also tends to inflate the PM-2.5/PM-10 ratio given in the last column of Table 5.

Table 6 presents calculated values of PM-10 and TSP erosion potential for each test run. The PM-10 erosion potentials are shown graphically in Figure 4. Consistent with the unpaved road tests, the reduced-scale wind tunnel generated an inflated proportion of PM-10 to TSP eroded from the surface, due to anisokinicity and oversampling of PM-10 mass. Adjusting the PM-10 mass by the IFR produced more reasonable values for the erosion potential and PM-10/TSP loss ratio.

The 6-sec DustTRAK average PM-10 concentration values for each of the test runs were used to find an average time-integrated concentration value from the beginning of the test run to the end of the incremental test period (for each 10-m wind speed plateau). The average concentration, together with the tunnel volumetric flow rate, the length of time from the beginning of the test until the end of the incremental test period, and the exposed test surface area were used to determine the PM-10 erosion potential for each 10-m wind speed. Because the surface tested in Runs CB-20 and CB-21 was artificially disturbed by raking before testing, the incremental erosion potentials were calculated only for the undisturbed surfaces that were tested in Runs CB-22 and CB-23. The average PM-10 erosion potential values for Runs CB-22 and 23 are given in Table 7.

Table 5. Average Concentrations for Wildfire Area

Date	Run No.	Duration (min)	Average effluent TSP conc. <sup>e</sup> (mg/m <sup>3</sup> )	Background d TSP conc. (mg/m <sup>3</sup> )	Net TSP conc. <sup>b</sup> (mg/m <sup>3</sup> )	Average effluent PM-10 conc. (mg/m <sup>3</sup> )	Background PM-10 conc. <sup>a</sup> (mg/m <sup>3</sup> )	Net PM-10 conc. <sup>b</sup> (mg/m <sup>3</sup> )	Average DustTRAK PM-10 conc. <sup>c</sup> (mg/m <sup>3</sup> )	Ratio of effluent PM-10/ DustTRAK PM-10 conc.	Average DustTRA K PM-2.5 conc. <sup>c</sup> (mg/m <sup>3</sup> )	Ratio of DustTRAK PM-2.5 conc./ PM-10 conc.
8/23/00	CB-20	130	10.541	0.677	9.864	1.595	0.264	1.332	0.172	9.26	0.063	0.36
8/24/00	CB-21	144	7.198	0.052	7.146	2.847	0.020	2.827	0.047	60.15	0.016	0.34
8/24/00	CB-22	126	1.980	0.052	1.928	0.508	0.020	0.488	0.060	8.43	0.026	0.43
8/25/00	CB-23	137	0.572	0.239	0.333	0.239	0.093	0.146	0.032	7.58	0.015	0.47
	CB-23 <sup>d</sup>	137	0.572	0.034	0.538	0.239	0.013	0.226	0.032	7.58	0.015	0.47

<sup>a</sup> Background PM-10 mass determined by using Rocky Flats PM-10/TSP ratio of 38.95%.

<sup>b</sup> Net = Average effluent concentration - Background concentration.

<sup>c</sup> DustTRAK averages determined by finding mean concentration over all six tests.

<sup>d</sup> CB-23 background concentration adjusted to be 6% of effluent concentration (largest ratio of other three tests).

<sup>e</sup> TSP concentration adjusted for anisokinetic sampling.

NOTE: all emission sampler values corrected for average blank filter weights.

Table 6. Erosion Potentials for Wildfire Area

Date	Run No.	Average roughness height <sup>a</sup> (cm)	Maximum wind speed (mph) tunnel CL	Equivalent maximum wind speed (mph) at 10-m height <sup>b</sup>	Corresponding friction velocity <sup>c</sup> (cm/s)	Maximum wind speed IFR	Erosion potential/loss (g/m <sup>2</sup> )
8/23/00	CB-20	1.21	23.9	87.2	232.2	5.37	TSP <sup>e</sup> 5.78 PM-10 <sup>e</sup> 0.15 Loss ratio (PM-10/TSP) 0.03
8/24/00	CB-21	1.21	27.5	100.3	267.0	4.66	7.43 2.94 0.40
8/24/00	CB-22	1.21	26.5	96.6	257.1	4.93	1.52 0.36 0.24
8/25/00	CB-23	1.21	26.5	96.5	256.9	4.58	-0.54 -0.19 0.36
	CB-23 <sup>d</sup>	1.21	26.5	96.5	256.9	4.58	0.43 0.18 0.43

<sup>a</sup> Roughness height determined from CB-23F used for all tests.

<sup>b</sup> Average maximum wind speed at tunnel centerline (CL) for all six tests.

<sup>c</sup> Calculated using net mass, ratio of sampling tube area to nozzle area, and exposed test surface area.

<sup>d</sup> CB-23 background concentration adjusted to be 6% of effluent concentration.

<sup>e</sup> Erosion potentials adjusted of anisokinetic sampling.

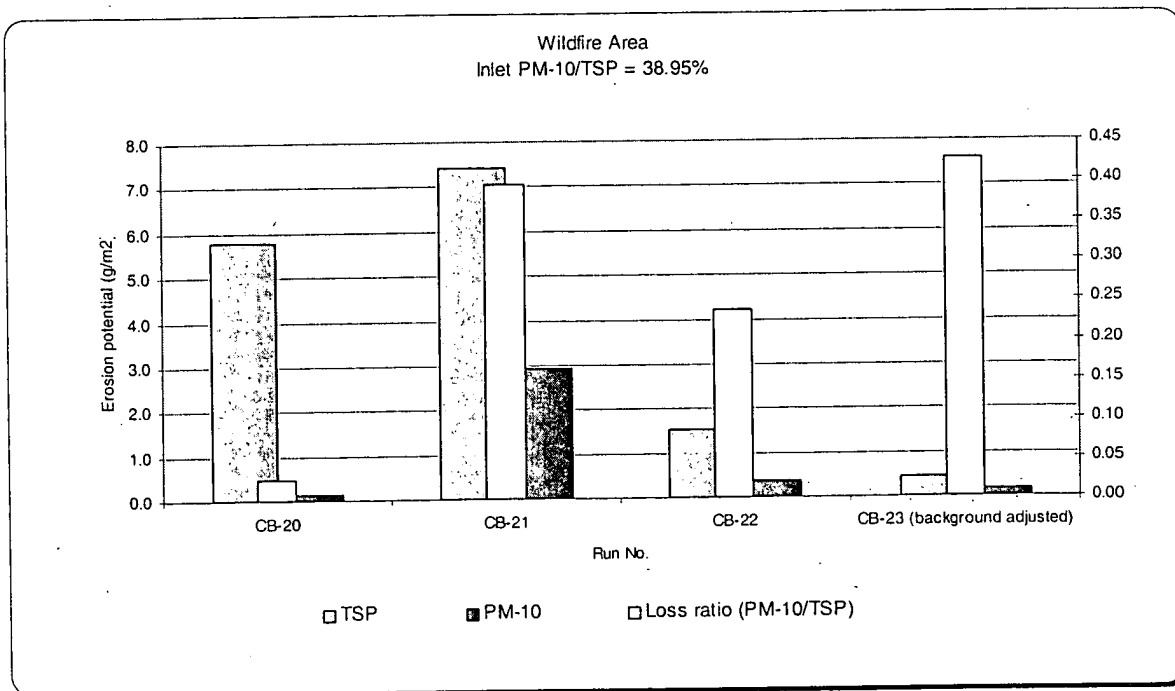
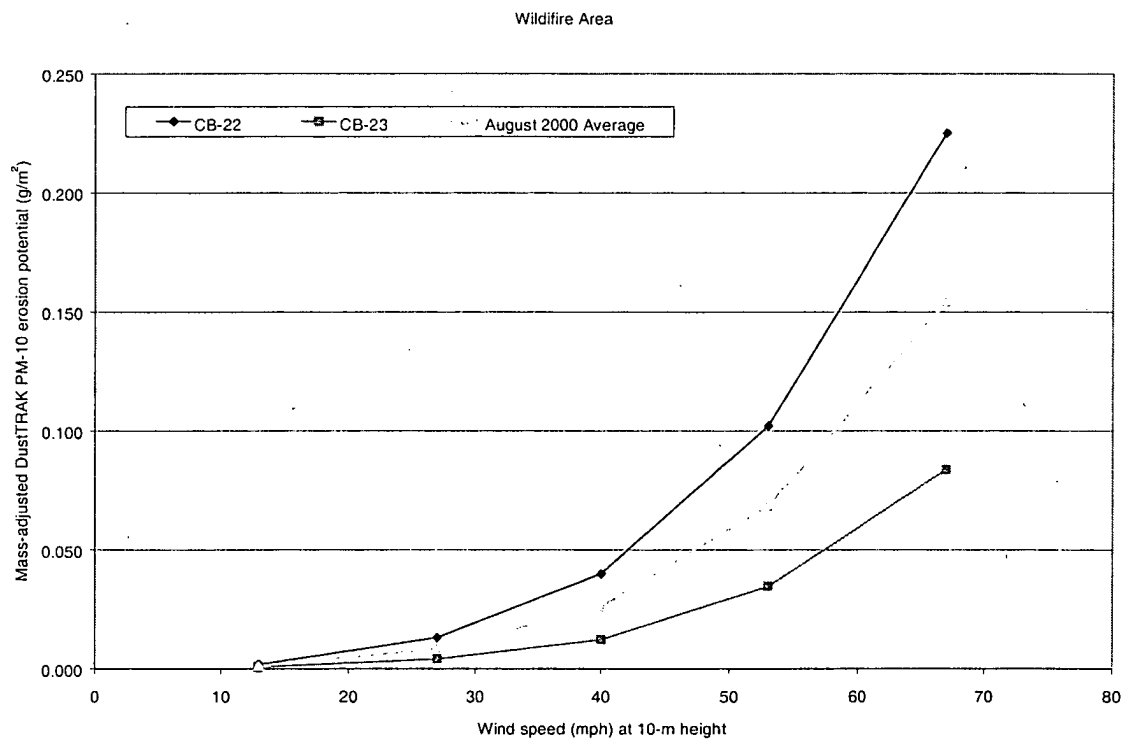


Figure 4. Erosion Potential History

Table 7. DustTRAK Average PM-10 Erosion Potentials vs. 10-m Wind Speed

Wind speed (mph) at 10-m height	DustTRAK (g/m <sup>2</sup> )			Mass-weighted based on emission sampler DustTRAK PM-10 conc. ratio (g/m <sup>2</sup> )		
	CB-22	CB-23	Undisturbed areas average	CB-22	CB-23	Undisturbed areas average
13	0.0002	0.0001	0.0002	0.002	0.001	0.001
27	0.0016	0.0005	0.0011	0.013	0.004	0.009
40	0.0050	0.0015	0.0034	0.040	0.012	0.026
53	0.0128	0.0043	0.0089	0.102	0.035	0.068
67	0.0281	0.0104	0.0215	0.225	0.084	0.154

Figure 5 shows the average PM-10 erosion potential versus 10-m wind speed (mph) as determined from DustTRAK data. Because the optically read DustTRAK PM-10 concentrations were consistently lower than PM-10 concentrations from mass-based samplers, mass weighting was performed by finding the average concentration during the period of testing for both the DustTRAK and the emission sampler. The ratio of these two concentrations allowed for conversion of the DustTRAK erosion potentials to the actual erosion potentials shown in Figure 5.



**Figure 5. Erosion Potential at 10-m Wind Speeds as Determined by Emission Sampler Weighted DustTRAK Data**

## Section 4.

### Results of Laboratory Tests

#### 4.1 Isotopic Analyses of Soil Samples

Isotopic analyses of the 12 soil samples (4 wildfire plots x 3 size fractions) were also performed. As shown in Table 8, the four coarse soil fractions contained the minimum isotopic activity levels for Pu239, with an average 1.27 pCi/g. This may have resulted from a higher proportion of organic material (small pieces of thatch) in this largest size fraction. The two finer size fractions exhibited approximately equal activity rates of 2.09 pCi/g for the mid-size fraction, and 1.77 pCi/g for the silt (fine) fraction.

A 125-mL volume of each of the three sieve fractions of surface soil (> 600 microns; 75-600 microns; < 75 microns) was obtained from four wildfire plots for isotopic analysis. As shown in Table 8, over 90 percent of the surface soil in the wildfire area was in the coarse (average 50 percent) and mid-size (42 percent) ranges, with only 8 percent of the surface soil in the silt size range (e.g., less than 75 micron diameter). Thus, the 125-mL sample volumes were easiest to obtain for the two largest size fractions, but sieving of multiple samples was required to obtain a 125-mL sample of the silt fraction.

**Table 8. Pu239 Activity by Soil Particle Size for Wildfire Surface Soil Samples**

Sample ID	Location	Size fraction	Pu239 (pCi/g)	Mass fraction of loose soil <sup>1</sup>	Average Pu239 (pCi/g)	Average mass fraction of loose soil	Average portion of Pu239 total activity
003.001	1	Coarse	1.03	49.7%	1.27	49.7%	37.6%
006.001	2	Coarse	0.85	53.2%			
009.001	3	Coarse	1.78	46.5%			
012.001	4	Coarse	1.43	49.4%			
002.001	1	Mid	2.23	42.0%	2.09	42.0%	53.7%
005.001	2	Mid	1.54	39.6%			
008.001	3	Mid	2.20	43.3%			
011.001	4	Mid	2.40	43.0%			
001.001	1	Fine	2.09	8.2%	1.77	8.2%	8.8%
004.001	2	Fine	0.94	7.2%			
007.001	3	Fine	2.37	10.1%			
010.001	4	Fine	1.66	7.4%			

<sup>1</sup> For locations 2-4, mass of each size fraction was determined for one soil sample of the several composited. For location 1, the averages of location 2-4 size ratios were used; no size ratio measurements were performed.

## 4.2 Isotopic Analysis of PM-10 Filter Samples

The fine soil fraction ( $< 75 \mu\text{m}$ ) is the source of all PM-10 emissions from wind erosion. Thus, the Pu239 activity level associated with the fine soil fraction (1.77 pCi/g) can be compared to the activity level of the particulate mass of PM-10 captured on the filter. The comparison is presented in Table 9a, and shows an average activity level of 1.19 pCi/g for PM-10 mass captured on the 8-in x 10-in backup filter. The PM-10 activity level is higher (1.19 and 1.85 pCi/g) for the two artificially disturbed test areas (runs CB-20 and CB-21), than for the undisturbed soil (1.08 and 0.66 pCi/g).

This reduced Pu239 activity on the undisturbed soil may indicate that the uppermost thin layer of surface soil is less contaminated with Pu239 than the surface soil profile extending to a depth of 1 to 2 cm below the surface. This might be attributed to surface deposition of uncontaminated particles from ambient air. Certainly, an area with standing vegetation, such as the unburned grassland at Rocky Flats, will tend to trap airborne fine particles that are deposited on the vegetation and on the soil surface. Precipitation will tend to transfer the particles collected on the vegetation to the soil below. Thus, a less contaminated crust of fine particles (assuming rainfall does not wash away most deposited particles) will be formed on the soil surface and will protect against wind erosion emissions. Any emissions that do occur will contain lower concentrations of Pu239 than found in disturbed surfaces with exposed lower soil profiles.

Ambient background concentrations were measured during the four wildfire tests of wind erosion. Because runs CB-21 and CB-22 were performed on the same day, only one background sample was required. Background Pu239 activity levels for PM-10 and TSP are shown in Tables 9a and 9b. Clearly, the Pu239 activity in background PM-10 is very low in comparison with PM-10 generated from the surface soil at the wildfire area. As stated above, a thin surface layer of soil deposited from ambient air will contain little Pu239, and, if crusted, can serve to protect the underlying contaminated soil from wind erosion of Pu239-contaminated particles lying below the surface.

The net PM-10 and TSP concentrations along with the respective Pu239 concentrations are presented in Table 10.



Table 9a. Wind Tunnel Test Data for Isotopic Analysis of PM-10 Samples

Run	Emission sampling duration (min)	Background sampling duration (min)	Tunnel effluent mass <sup>a</sup> (mg)	Tunnel inlet mass <sup>a,b</sup> (mg)	Tunnel effluent conc. (mg/m <sup>3</sup> )	Tunnel inlet conc. (mg/m <sup>3</sup> )	Tunnel effluent activity (dpm)	Tunnel inlet activity (dpm)	Tunnel effluent activity (pCi/g)	Tunnel inlet activity (pCi/g)	Tunnel effluent Pu239 conc. (pCi/m <sup>3</sup> )	Tunnel inlet Pu239 conc. (pCi/m <sup>3</sup> )
CB-20	130	138	234.87	41.20	1.595	0.264	0.621	0.463	1.19	1.97	0.00190	0.0005191
CB-21	144	289	464.37	6.69	2.847	0.020	1.910	0.004	1.85	0.10	0.00527	0.0000021
CB-22	126	289	72.57	6.69	0.508	0.020	0.174	0.004	1.08	0.10	0.00055	0.0000021
CB-23	137	133	37.07	14.05	0.239	0.093	0.054	0.061	0.66	0.76	0.00016	0.0000710
CB-23 <sup>c</sup>	137	133	37.07	2.01	0.239	0.013	0.054	0.009 <sup>d</sup>	0.66	0.76	0.00016	0.0000102

NOTE: Background = Tunnel inlet.

<sup>a</sup> PM-10 net mass on filter is corrected for average of seven filter blank weights (-1.4 mg).

<sup>b</sup> Tunnel inlet PM-10 mass = 38.95% TSP mass collected on filter.

<sup>c</sup> CB-23 background adjusted.

<sup>d</sup> Activity level adjusted based on actual activity level per mass.

Table 9b. Wind Tunnel Test Data for Isotopic Analysis of TSP Samples

Run	Emission sampling duration (min)	Background sampling duration (min)	Tunnel effluent PM-10 mass <sup>a</sup> (mg)	Tunnel effluent >PM-10 mass <sup>c</sup> (mg)	Tunnel inlet TSP mass <sup>a</sup> (mg)	Tunnel inlet TSP conc. <sup>c</sup> (mg/m <sup>3</sup> )	Tunnel effluent PM-10 activity (dpm)	Tunnel inlet TSP activity (pCi/g)	Tunnel effluent >PM-10 activity (pCi/g)	Tunnel inlet TSP activity (pCi/g)	Tunnel effluent TSP conc. (pCi/m <sup>3</sup> )	Tunnel inlet TSP conc. (pCi/m <sup>3</sup> )
CB-20	130	138	234.87	1317.26	1552.13	105.77	0.677	0.621	2.140	1.675	0.0210	0.001333
CB-21	144	289	464.37	709.72	1774.09	17.17	0.052	1.910	1.930	1.870	0.0137	0.000005
CB-22	126	289	72.57	210.07	282.59	17.17	0.052	0.174	1.200	1.124	0.0023	0.000005
CB-23	137	133	37.07	51.75	88.83	36.07	0.239	0.054	2.430	1.070	0.0010	0.000182
CB-23 <sup>b</sup>	137	133	37.07	51.75	88.83	5.17	0.034	0.054	2.430	1.070	0.0010	0.000026

<sup>a</sup> Net mass on filter is corrected for average of seven filter blank weights (-1.4 mg).

<sup>b</sup> CB-23 background adjusted.

<sup>c</sup> Adjusted for anisokinetic sampling.

29

**Table 10. Summary of PM-10 and TSP Pu239 Unit Activity and Concentrations**

Run	Net PM-10 emission conc. (mg/m <sup>3</sup> )	Pu239 concentration in eroded PM-10 (pCi/m <sup>3</sup> )	Net TSP emission conc. (mg/m <sup>3</sup> )	Pu239 concentration in eroded TSP (pCi/m <sup>3</sup> )
CB-20	1.332	0.00138	9.864	0.0197
CB-21	2.827	0.00527	7.146	0.0137
CB-22	0.488	0.00055	1.928	0.0023
CB-23	0.146	0.00009	0.333	0.0008
CB-23 <sup>a</sup>	0.215	0.00014	0.538	0.0009

<sup>a</sup> CB-23 background adjusted.

### 4.3 Soil Deposition

After stabilization of the Pu239 source area, relatively clean ambient air particles will be deposited to the ground through both dry and wet deposition. Some of these particles will initially be intercepted by vegetation and then either washed off to the ground or resuspended by the wind. If the ground is covered with grasses, vegetative thatch, or other non-erodible elements, little resuspension of ground based particles will occur. This was demonstrated in the two sets of wind erosion tests on unburned areas at Rocky Flats in April and June 2000. Consequently, particle deposition will likely exceed particle resuspension for well-vegetated areas.

In semi-arid regions such as Rocky Flats, little water runoff of soil occurs, so that soil continues to accumulate in vegetated areas. The particle deposition rate is a measure of particles deposited from the air to a unit area of ground per year. The deposition rate is obtained by multiplying the particle mass concentration at a height of approximately 1 m by the deposition velocity (default value of 1000 m/day). This deposition rate reflects both wet and dry particle deposition to the ground.

A reasonable approximation of the ambient air PM-10 concentration at Rocky Flats is 20  $\mu\text{g}/\text{m}^3$ . Based on many studies of PM-10, a considerable fraction of these particles is organic in nature. Carbon particles will not contribute to long-term soil buildup as they are released to the air and to vegetative uptake. For calculation purposes, a conservatively low 10  $\mu\text{g}/\text{m}^3$  PM concentration is assumed to produce an annual deposition rate of 3.65  $\text{kg}/\text{m}^2/\text{yr}$ . Assuming half of this amount is washed off by rainfall, the annual soil buildup rate is 1.8  $\text{kg}/\text{m}^2/\text{yr}$ , or 0.08  $\text{cm}/\text{yr}$ .

This soil buildup will consist of relatively clean particles. As shown in Table 9a, the Pu239 activity rates in background air were found to be very low—ranging from 0.0001 to 0.0020 pCi/g. The highest value of 0.0020 pCi/g occurred during variable winds that may have transported eroded particles from the outlet of the tunnel blower to the background sampler.

## Section 5.

### Conclusions

---

The comparison tests between the reference wind tunnel and the reduced-scale wind tunnel on the unpaved road surface showed that the two tunnels produce erosion test results that are equivalent, i.e., within the range of variation normally found between test areas of the same type. Although the reduced-scale wind tunnel samples under anisokinetic conditions, the correction using the IFR was found to be the only adjustment needed to provide a good comparison between tests performed using the reference wind tunnel and the reduced-scale wind tunnel.

Only 8 percent of the surface soil at the wildfire areas is in the particle size range that can be suspended as dust emissions (i.e., silt particles with diameters less than 75  $\mu\text{m}$ ). A significant fraction of Rocky Flats soil particles in the wildfire area were found to be protective of wind erosion emissions because of their size. Nearly 50 percent of the soil particles in the wildfire area are greater than 600  $\mu\text{m}$ . The burned vegetative stubble provided additional protection against wind erosion.

In addition, the coarsest soil size range above 600  $\mu\text{m}$  in diameter was found to have the lowest Pu239 activity (1.27 pCi/g). The highest Pu239 activity (2.09 pCi/g) was observed in the mid-size range (75-600  $\mu\text{m}$  diameter). The silt soil fraction (< 75  $\mu\text{m}$  diameter) had a Pu239 activity level of 1.77 pCi/g, which is also representative to the composite soil activity level. The observation was counter to the hypothesis that the finest soil particles on the surface were most contaminated with Pu239.

When the soil was disturbed to a depth of 1 to 2 cm, wind tunnel tests of the wildfire area showed both higher erodibility and higher Pu239 activity rate than for the undisturbed wildfire soil. This indicates that the surface soil is less contaminated than the soil immediately beneath the surface. This may be attributed to dry and wet soil deposition of "cleaner" ambient air particles that accumulate on the soil surface over time. The deposition rate would result in a relatively clean (but thin) soil surface layer that, if crusted, would inhibit wind erosion of subsurface contaminated soil.

## Section 6.

### References

---

Baxter, T. E., D. D. Lane, C. Cowherd, Jr., F. Pendleton. "Calibration of a Cyclone for Monitoring Inhalable Particulate". *Jour. Environ. Engineering*, 112(3), pp. 468-478. 1986.

Cowherd, C., Jr., G. E. Muleski, P.J. Englehart, D.A. Gillette. *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites*. EPA/600/8-85/002. USEPA, Washington, DC. 1985.

Cowherd, Chatten, Jr. *Background Document for AP-42 Section 11.2.7 on Industrial Wind Erosion*. EPA Contract No. 68-02-4395, Midwest Research Institute. July 1988.

Cowherd, C. Jr., M.A. Grelinger, P.J. Englehart, R.F. Kent, K.F. Wong. Apparatus and Methodology for Predicting the Dustiness of Materials. *Am Ind. Hyg. Assoc. Jour.* (50), pp. 123-130. 1989.

Gillette, Dale. "Tests with a Portable Wind Tunnel for Determining Wind Erosion Threshold Velocities." *Atmos. Environ.* 12:2309. 1978.

Haines, P. Personal Communication. 2001.

Huntzicker, J.J., R.L. Johnson, J.J. Shah, R.A. Cary. "Analysis of Organic and Elemental Carbon in Ambient Aerosol by a Thermal-Optical Method," in *Particulate Carbon: Atmospheric Life Cycle*, pp 79-88. G.T. Wolff, R.L. Klimisch, Eds., Plenum Press, New York, NY. 1982.

Ower, E., R.C. Pankhurst. *The Measurement of Air Flow*. Pergamon Press, London. 1969.

U.S. Environmental Protection Agency. *National Technical Guidance Series Air Pathway Analysis Procedure for Superfund Applications*. Vol. II: *Estimates of Baseline Air Emissions at Superfund Sites*. EPA-450/1-89-002a. 1989.

U.S. Environmental Protection Agency. "Compilation of Air Pollutant Emissions Factors", AP-42. Fifth Edition, Supplements A-F, Volume I: *Stationary Point and Area Sources*. Research Triangle Park, NC. 2000.

Watson, J.G., J. Chow. "Particle and Gas Measurement on Filters," in *Sampling of Environmental Materials for Trace Analysis* (edited by B. Markert), pp. 83-115. VCH Publisher, Weinheim, New York, Tokyo. 1994.

**Appendix A**

---

**Results of Gravimetric Analysis**

**Table A-1. Cyclone Back-up Filter Weights (mg)**

Date	Run no.	Filter no.	Tare weight	Final weight	Blank correction	Blank corrected net weight	Cyclone catch (g)	Filter/ Cyclone
8/22/00	CB-16	0012079	3590.30	3893.10	-0.10	302.70	1.3979	0.2165
8/22/00	CB-17	0012080	3633.65	3837.60	-0.10	203.85	3.5295	0.0578
8/22/00	CB-18	0012081	3673.35	3887.85	-0.10	214.40	3.9298	0.0546
8/22/00	CB-19	0012082	3638.00	3696.55	-0.10	58.45	0.2765	0.2114
8/23/00	CB-20	31	2759.5	2993.0	-1.37	234.87	0.2453	0.9575
8/24/00	CB-21	34	2754.1	3217.1	-1.37	464.37	0.1523	3.0491
8/24/00	CB-22	43	2779.8	2851.0	-1.37	72.57	0.0426	1.7036
8/25/00	CB-23	46	2808.8	2844.5	-1.37	37.07	0.0113	3.2807

**Table A-2. Upwind/ Background Filter Weights (mg)**

Date	Run no.	Filter no.	Tare weight	Final weight	Blank Correction	Blank corrected net weight	Duration (min)	Flow rate (cfm)
8/22/00	CB-16,17,18,19	0012078	3678.60	3686.35	-0.10	7.65	136	40
8/23/00	CB-20	33	2763.8	2868.2	-1.37	105.77	138	40
8/24/00	CB-21, 22	39	2740.7	2756.5	-1.37	17.17	289	40
8/25/00	CB-23	45	2725.8	2760.5	-1.37	36.07	133	40

**Table A-3. Blank Filter weights (mg)**

Date	Run no.	Filter no.	Tare weight	Final weight	Net weight
8/22/00	CB-16,17,18,19	0012083	3625.40	3625.15	-0.25
8/22/00	CB-16,17,18,19	0012084	3609.65	3609.70	0.05
8/23/00	CB-20	32	2783.7	2783.7	0.00
8/24/00	CB-21	35	2766.4	2767.5	1.10
8/24/00	CB-22	44	2738.0	2735.2	-2.80
8/25/00	CB-23	47	2766.2	2764.0	-2.20
8/23/00	CB-20	36	2804.2	2803.8	-0.40
8/24/00	CB-22	42	2716.6	2713.7	-2.90
8/25/00	CB-23	48	2770.7	2768.3	-2.40

Unpaved road average blank filter net weight = -0.10 mg.

Wildfire area average blank filter net weight = -1.37 mg.

34

**Appendix B**

---

**Results of Soil Isotopic Analysis**

Table B-1. Soil Data

Sample ID	Location	Number of samples composited <sup>b</sup>	Final sample volume (ml)	Size fraction, $\phi$ m cut size	Mass fractions of loose soil <sup>a</sup>	Mass of bottled soil sample <sup>c</sup> (g)
001.001	1	8	125	<75	8.2%	132.0
002.001	1	8	125	75-600	42.0%	107.0
003.001	1	8	125	>600	49.7%	78.0
004.001	2	7	125	<75	7.2%	120.0
005.001	2	7	125	75-600	39.6%	100.0
006.001	2	7	125	>600	53.2%	43.0
007.001	3	6	125	<75	10.1%	147.0
008.001	3	6	125	75-600	43.3%	108.0
009.001	3	6	125	>600	46.5%	51.0
010.001	4	8	125	<75	7.4%	138.0
011.001	4	8	125	75-600	43.0%	104.0
012.001	4	8	125	>600	49.4%	52.0

<sup>a</sup> For locations 2-4, mass of each size fraction was determined for one soil sample of the several composited. For location 1, the average of location 2-4 size ratios was used (no size ratio measurements performed for that batch).

<sup>b</sup> Soil was collected to 1.5 cm depth and then sieved using a #30 and #200 standard sieve, followed by a pan. Sieve volume limited sample size.

<sup>c</sup> Mass of soil sample in bottle, less bottle tare. Sample compression occurred during bottling.



Table B-2. Analytical Data

Sample ID	Location	Pu239/240 activity (pCi/g)	Total error (pCi/g)	MDA (pCi/g)
001.001	1	2.09	0.683	0.130
002.001	1	2.23	0.718	0.131
003.001	1	1.03	0.421	0.135
004.001	2	0.94	0.393	0.183
005.001	2	1.54	0.553	0.190
006.001	2	0.85	0.365	0.074
007.001	3	2.37	0.752	0.130
008.001	3	2.20	0.703	0.148
009.001	3	1.78	0.612	0.157
010.001	4	1.66	0.595	0.143
011.001	4	2.40	0.779	0.141
012.001	4	1.43	0.514	0.128

Table B-3. Isotopic Summary

Sample ID	Location	Pu239/240 (pCi/g)	Am241 (pCi/g)	Pu239/Am241 Ratio	U234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	U234/U238 Ratio
001.001	1	2.09	0.88	2.4	1.62	0.25	1.28	1.3
002.001	1	2.23	0.35	6.4	0.99	0.39	1.49	0.7
003.001	1	1.03	0.23	4.5	0.85	0.23	0.84	1.0
004.001	2	0.94	0.20	4.6	1.64	0.41	1.65	1.0
005.001	2	1.54	0.45	3.4	1.03	0.16	0.76	1.3
006.001	2	0.85	0.47	1.8	0.71	0.09	0.73	1.0
007.001	3	2.37	0.70	3.4	1.02	0.15	1.24	0.8
008.001	3	2.20	0.55	4.0	0.69	0.27	1.18	0.6
009.001	3	1.78	0.25	7.2	0.64	0.15	0.51	1.3
010.001	4	1.66	0.47	3.5	0.96	0.17	1.25	0.8
011.001	4	2.40	0.38	6.3	1.42	0.10	1.31	1.1
012.001	4	1.43	0.36	4.0	0.86	0.16	0.63	1.4

38

## Appendix C

---

### Results of Filter and Cyclone Catch Isotopic Analysis

**Table C-1. Filter Data**

Sample ID	Location	Run no.	Filter no.
001.001	CB-20-1	CB-20	31
002.001	CB-20,21-BKG	CB-20 background	33
003.001	CB-21-1	CB-21	34
004.001	CB-22-1	CB-22	43
005.001	CB-22,23-BKG	CB-21,22 background	39
006.001	CB-23-1	CB-23	46
007.001	CB-24,25-BKG	CB-23 background	45

**Table C-2. Filter Analysis Data**

Sample ID	Pu239/240 activity (dpm)	Total error (dpm)	MDA (dpm)
001.001	0.621	0.177	0.048
002.001	0.463	0.157	0.053
003.001	1.910	0.462	0.050
004.001	0.174	0.046	0.049
005.001	0.004	0.025	0.047
006.001	0.054	0.041	0.046
007.001	0.061	0.051	0.049

**Table C-3. Filter Isotopic Summary**

Sample ID	Pu239/240 (dpm)	Pu238 (dpm)	Am241 (dpm)	U233/234 (dpm)	U235 (dpm)	U238 (dpm)
001.001	0.621	0.021	0.165	0.301	0.021	0.372
002.001	0.463	0.041	0.070	0.562	0.041	0.587
003.001	1.910	0.010	0.402	0.705	-0.012	0.782
004.001	0.174	-0.003	0.045	0.148	0.015	0.093
005.001	0.004	-0.004	-0.010	-0.015	0.003	0.141
006.001	0.054	-0.004	0.010	0.162	0.033	0.182
007.001	0.061	-0.007	0.010	0.037	0.000	0.126

**Table C-4. Cyclone Catch Data**

Sample ID	Location	Run no.
008.001	CB-20-A1	CB-20
009.001	CB-21-A1	CB-21
010.001	CB-22-A1	CB-22
011.001	CB-23-A1	CB-23

**Table C-5. Cyclone Catch Analysis**

Sample ID	Pu239/240 activity (pCi/g)	Total error (pCi/g)	MDA (pCi/g)
008.001	2.140	0.526	0.021
009.001	1.930	0.534	0.101
010.001	1.200	0.518	0.116
011.001	2.430	1.500	0.549

**Table C-6. Cyclone Catch Isotopic Summary**

Sample ID	Pu239/240 (dpm)	Am241 (dpm)	U233/234 (dpm)	U235 (dpm)	U238 (dpm)
008.001	2.140	0.370	1.370	0.038	1.250
009.001	1.930	0.525	2.040	0.124	2.080
010.001	1.200	0.566	3.460	0.090	3.770
011.001	2.430	3.170	11.600	0.566	9.280

Appendix D  
**CB-22 Example Calculation**

## Part I: Calculation of tunnel effluent concentrations

- Duration of testing:

CB-22A	=	20 min	CB-22D	=	22 min
CB-22B	=	21 min	CB-22E	=	21 min
CB-22C	=	21 min	CB-22F	=	21 min

**Total for CB-22 = 126 min**

- Blank-corrected effluent filter net weight:

Tare weight = 2779.8 mg

Final weight = 2851.0 mg

Blank correction = -1.37 mg

Filter net weight = 72.57 mg

\*Net weight constitutes PM-10 mass collected by effluent sampler

- Effluent sampler flow rate = 40 cfm = 1.13267 m<sup>3</sup>/min

### Average effluent PM-10 concentration:

$$\frac{72.57 \text{ mg}}{1.13267 \text{ m}^3/\text{min} \times 126 \text{ min}} = 0.508 \text{ mg/m}^3$$

- Blank-corrected inlet filter net weight:

Tare weight = 2740.7 mg

Final weight = 2756.5 mg

Blank correction = -1.37 mg

Filter net weight = 17.17 mg

\*Net weight constitutes TSP mass collected by inlet sampler

\*Based on historical data, 38.95% of TSP mass assumed to be PM-10 mass collected from ambient air

PM-10 mass collected = 6.688 mg

- Duration of inlet sampling = 289 min

- Inlet sampler flow rate = 40 cfm = 1.13267 m<sup>3</sup>/min

### Inlet PM-10 concentration:

$$\frac{6.688 \text{ mg}}{1.13267 \text{ m}^3/\text{min} \times 289 \text{ min}} = 0.020 \text{ mg/m}^3$$

### Net PM-10 concentration (attributable to emissions from test area):

$$0.508 \text{ mg/m}^3 - 0.020 \text{ mg/m}^3 = 0.488 \text{ mg/m}^3$$

43

- Cyclone catch (sieved to remove particles with diameters greater than 45  $\mu\text{m}$  [#325 screen]):

Bag tare weight = 3.6340 g

Bag final weight = 3.6766 g

Bag net weight = 0.0426 g = 42.6 mg

\*Sample collected in bag represents suspended particles greater than 10  $\mu\text{m}$  aerodynamic diameter and less than 45  $\mu\text{m}$  physical diameter, i.e., approximately TSP - PM-10

The mass of the sieved cyclone catch must be adjusted for non-isokinetic flow conditions. The adjustment is based on the isokinetic flow ratio (IFR) which is defined as the intake air velocity of the sampling nozzle divided by the approach air velocity at the centerline of the effluent tube (sampling extension). PM-10 has negligible inertial characteristics and requires no correction for non-isokinetic sampling.

- Isokinetic flow ratio (IFR) at maximum wind speed (which contributes most of the sieved cyclone catch) = 4.93
- Adjusted cyclone catch:  
IFR adjusted mass (TSP - PM-10) = 42.6 x 4.93 = 210.02 mg

**Average effluent TSP concentration:**

$$\frac{72.57 \text{ mg} + 210.02 \text{ mg}}{1.13267 \text{ m}^3/\text{min} \times 126 \text{ min}} = 1.980 \text{ mg/m}^3$$

**Inlet TSP concentration:**

$$\frac{17.17 \text{ mg}}{1.13267 \text{ m}^3/\text{min} \times 289 \text{ min}} = 0.052 \text{ mg/m}^3$$

**Net TSP concentration (attributable to emissions from test area):**

$$1.980 \text{ mg/m}^3 - 0.052 \text{ mg/m}^3 = 1.928 \text{ mg/m}^3$$



## Part II: Calculation of erosion potentials

- Average maximum  $\Delta p$  for pitot tube at centerline (CL) of working section during test runs:  
CB-22A = 0.33 in. H<sub>2</sub>O  
CB-22B = 0.36 in. H<sub>2</sub>O  
CB-22C = 0.27 in. H<sub>2</sub>O  
CB-22D = 0.25 in. H<sub>2</sub>O  
CB-22E = 0.25 in. H<sub>2</sub>O  
CB-22F = 0.23 in. H<sub>2</sub>O  
CB-22 = 0.28 in. H<sub>2</sub>O (average)
- Factor for conversion of  $\Delta p$  to wind speed (mph):  
Average barometric pressure = 24.8 in. Hg  
Ambient temperature = 84°F

$$K' = 10.83 \times \left( \frac{(84^\circ\text{F} + 459.3)}{24.8 \text{ in. Hg}} \right)^{1/2} = 50.69$$

### Maximum wind speed (mph) at tunnel CL:

$$50.69 \times (0.28 \text{ in. H}_2\text{O})^{1/2} = 26.8 \text{ mph}$$

- Tunnel CL height = 7.62 cm
- Surface roughness height for test surface = 1.21 cm
- \* Estimated from velocity profile during run CB-23F

### Equivalent maximum wind speed (mph) at 10-m height:

$$\frac{26.8 \text{ mph} \times \ln \frac{1000 \text{ cm}}{1.21 \text{ cm}}}{\ln \frac{7.62 \text{ cm}}{1.21 \text{ cm}}} = 97.5 \text{ mph}$$

### Corresponding friction velocity:

$$\frac{26.8 \text{ mph} \times 0.4}{\ln \frac{7.62 \text{ cm}}{1.21 \text{ cm}}} = 5.83 \text{ mph} = 259.6 \text{ cm/s}$$

**Net PM-10 mass collected:**

$$\frac{72.57 \text{ mg}}{4.93} - \left( 6.688 \text{ mg} \times \frac{126 \text{ min}}{289 \text{ min}} \right) = 11.80 \text{ mg} = 0.0118 \text{ g}$$

\*Inlet mass time-weighted to effluent sampler run time

\*PM-10 mass oversampled, adjust for IFR

- Ratio of effluent tube area to intake nozzle area:

$$\begin{aligned} \text{Effluent tube i.d.} &= 7.874 \text{ in} & \text{Effluent tube area} &= 48.69 \text{ in}^2 \\ \text{Intake nozzle i.d.} &= 0.88 \text{ in} & \text{Intake nozzle area} &= 0.608 \text{ in}^2 \\ \text{Area ratio} &= 80.08 \end{aligned}$$

- Exposed test surface area dimensions = 8 ft x 6 in
- Area of ground surface sampled = 4 ft<sup>2</sup> = 0.3716 m<sup>2</sup>

**PM-10 erosion potential/loss:**

$$\frac{0.0118 \text{ g} \times (80.08 \times 85\%)}{6 \times 0.3716 \text{ m}^2} = 0.36 \text{ g/m}^2$$

\*Six test areas sampled during CB-22

\*85% of the centerline wind speed is the average wind speed across the area of the effluent tube (sampling extension)

**TSP erosion potential/loss:**

$$\frac{(0.0118 \text{ g} + 0.0426 \text{ g}) \times (80.08 \times 85\%)}{6 \times 0.3716 \text{ m}^2} = 1.52 \text{ g/m}^2$$

\*Six test areas sampled during CB-22

\*85% of the centerline wind speed is the average wind speed across the area of the effluent tube (sampling extension)

### Part III: Calculation of tunnel effluent Pu239 activity levels and concentrations

The first calculation method relies on the amount of air sampled ( $\text{m}^3$ ) and the total activity (pCi) to find the activity level per volume of air ( $\text{pCi}/\text{m}^3$ ). This concentration is found for both the effluent and inlet samples, and the net effluent Pu239 concentration is determined by subtracting the inlet concentration from the effluent concentration.

- Duration of effluent sampling = 126 min
- Duration of inlet sampling = 289 min
- Volume of air sampled by effluent sampler:  
 $40 \text{ cfm} \times 126 \text{ min} = 5040 \text{ ft}^3 = 142.7 \text{ m}^3$
- Volume of air sampled by inlet sampler:  
 $40 \text{ cfm} \times 289 \text{ min} = 11560 \text{ ft}^3 = 327.3 \text{ m}^3$
- Tunnel effluent filter Pu239 activity (PM-10) = 0.174 dpm
- Tunnel inlet filter Pu239 activity (TSP) = 0.004 dpm
- Tunnel inlet PM-10 Pu239 activity (assuming that Pu239 activity is not dependent on particle size in the TSP size range):

$$0.004 \text{ dpm} \times 0.3895 = 0.00156 \text{ dpm}$$

- Conversion factor: 1 pCi = 2.2 disintegrations per min (dpm)

#### Tunnel effluent Pu239 concentration (PM-10):

$$\frac{0.174 \text{ dpm} \times 0.45 \text{ pCi/dpm}}{142.7 \text{ m}^3} = 0.00055 \text{ pCi}/\text{m}^3$$

#### Tunnel inlet Pu239 concentration (PM-10):

$$\frac{0.00156 \text{ dpm} \times 0.45 \text{ pCi/dpm}}{327.3 \text{ m}^3} = 0.00000214 \text{ pCi}/\text{m}^3$$

#### Pu239 concentration attributed to PM-10 eroded from soil:

$$0.00055 \text{ pCi}/\text{m}^3 - 0.00000214 \text{ pCi}/\text{m}^3 = 0.0005479 \text{ pCi}/\text{m}^3$$

As shown above the tunnel inlet air contributes only 0.2% of the Pu239 activity found in the effluent air.

The fraction of TSP above PM-10 must be adjusted for non-isokinetic flow conditions. PM-10 as negligible inertial characteristics and requires no correction for non-isokinetic sampling.

- Tunnel effluent mass (TSP - PM-10) = 42.6 mg
- Isokinetic flow ratio (IFR) at maximum wind speed = 4.93  
\* TSP mass sampled under non-isokinetic conditions, must be adjusted by IFR ratio

$$\text{IFR adjusted mass (TSP - PM-10)} = 42.6 \times 4.93 = 210.02 \text{ mg}$$

- Volume of air sampled by effluent sampler:  
 $40 \text{ cfm} \times 126 \text{ min} = 5040 \text{ ft}^3 = 142.7 \text{ m}^3$
- Volume of air sampled by inlet sampler:  
 $40 \text{ cfm} \times 289 \text{ min} = 11560 \text{ ft}^3 = 327.3 \text{ m}^3$
- Tunnel effluent Pu239 activity (TSP - PM-10) = 1.200 pCi/g = 0.0012 pCi/mg
- Tunnel inlet Pu239 activity (TSP) = 0.004 dpm

**Tunnel effluent concentration (TSP - PM-10):**

$$\frac{210.02 \text{ mg}}{142.7 \text{ m}^3} = 1.47 \text{ mg/m}^3$$

**Tunnel effluent Pu239 concentration (TSP - PM-10):**

$$0.0012 \text{ pCi/mg} \times 1.47 \text{ mg/m}^3 = 0.0018 \text{ pCi/m}^3$$

- Tunnel effluent Pu239 concentration(PM-10) = 0.00055 pCi/m<sup>3</sup> from previous calculation

**Tunnel effluent Pu239 concentration (TSP = PM-10 + [TSP - PM-10]):**

$$0.0018 \text{ pCi/m}^3 + 0.00055 \text{ pCi/m}^3 = 0.0023 \text{ pCi/m}^3$$

**Tunnel inlet Pu239 concentration (TSP):**

$$\frac{0.004 \text{ dpm/filter} \times 0.45 \text{ pCi/dpm}}{327.3 \text{ m}^3/\text{filter}} = 0.0000055 \text{ pCi/m}^3$$

**Pu239 concentration attributed to TSP eroded from soil:**

$$0.0023 \text{ pCi/m}^3 - 0.0000055 \text{ pCi/m}^3 = 0.002309 \text{ pCi/m}^3$$

## Alternative Calculation

The alternative calculation method relies on the net particulate concentration ( $\text{mg}/\text{m}^3$ ) and the net Pu239 activity level ( $\text{pCi}/\text{mg}$ ) to find the Pu239 concentration ( $\text{pCi}/\text{m}^3$ ). The net mass ( $\text{mg}$ ) and the net Pu239 specific activity ( $\text{pCi}$ ) are used to find the concentrations and activity levels.

- Duration of testing = 126 min
- Blank-corrected tunnel effluent mass (PM-10) = 72.57 mg = 0.07257 g
- Duration of inlet sampling = 289 min
- Blank-corrected tunnel inlet mass (TSP) = 17.17 mg
- Blank-corrected tunnel inlet mass (PM-10) = 6.688 mg
- Time-weighted blank-corrected tunnel inlet mass (PM-10 background mass for test time only):

$$6.688 \text{ mg} \times \frac{126 \text{ min}}{289 \text{ min}} = 2.916 \text{ mg} = 0.0029 \text{ g}$$

### Net tunnel effluent mass (PM-10):

$$72.57 \text{ mg} - 2.916 \text{ mg} = 69.66 \text{ mg} = 0.06966 \text{ g}$$

- Volume of air sampled by effluent sampler:  
 $40 \text{ cfm} \times 126 \text{ min} = 5040 \text{ ft}^3 = 142.7 \text{ m}^3$

### Net effluent concentration (PM-10):

$$\frac{69.66 \text{ mg}}{142.7 \text{ m}^3} = 0.488 \text{ mg}/\text{m}^3 = 0.000488 \text{ g}/\text{m}^3$$

- Tunnel effluent Pu239 activity = 0.174 dpm
- Tunnel inlet Pu239 activity = 0.004 dpm

### Tunnel effluent Pu239 activity (PM-10):

$$\frac{0.174 \text{ dpm} \times 0.45 \text{ pCi}/\text{dpm}}{0.07257 \text{ g}} = 1.08 \text{ pCi}/\text{g}$$

$$1.08 \text{ pCi}/\text{g} \times 0.07257 \text{ g} = 0.078 \text{ pCi}$$

### Tunnel inlet Pu239 activity (PM-10):

$$\frac{0.004 \text{ dpm}/\text{filter} \times 0.45 \text{ pCi}/\text{dpm}}{0.01717 \text{ g}} = 0.10 \text{ pCi}/\text{g}$$

$$0.10 \text{ pCi/g} \times 0.002916 \text{ g} = 0.000306 \text{ pCi}$$

**Net Pu239 activity (PM-10):**

$$0.078 \text{ pCi} - 0.000306 \text{ pCi} = 0.0780 \text{ pCi}$$

$$\frac{0.0780 \text{ pCi}}{0.06966 \text{ g}} = 1.12 \text{ pCi/g}$$

**Pu239 concentration attributed to PM-10 eroded from soil:**

$$1.12 \text{ pCi/g} \times 0.000488 \text{ g/m}^3 = 0.00055 \text{ pCi/m}^3$$

- Tunnel effluent mass (TSP - PM-10) = 42.6 mg
- Isokinetic flow ratio (IFR) at maximum wind speed = 4.93
- \* TSP mass sampled under non-isokinetic conditions, must be adjusted by IFR ratio

$$\text{IFR adjusted mass (TSP - PM-10)} = 42.6 \times 4.93 = 210.02 \text{ mg}$$

- Tunnel effluent mass (TSP):  
210.02 mg + 72.57 mg = 282.59 mg
- Blank-corrected tunnel inlet mass (TSP) = 17.17 mg = 0.01717 g
- Time-weighted blank-corrected tunnel inlet mass (TSP):

$$17.17 \text{ mg} \times \frac{126 \text{ min}}{289 \text{ min}} = 7.49 \text{ mg} = 0.00749 \text{ g}$$

**Net tunnel effluent mass (TSP):**

$$282.59 \text{ mg} - 7.49 \text{ mg} = 275.10 \text{ mg} = 0.27510 \text{ g}$$

- Volume of air sampled by effluent sampler:  
40 cfm x 126 min = 5040 ft<sup>3</sup> = 142.7 m<sup>3</sup>

**Net TSP concentration:**

$$\frac{275.10 \text{ mg}}{142.7 \text{ m}^3} = 1.928 \text{ mg/m}^3 = 0.001928 \text{ g/m}^3$$

- Tunnel effluent Pu239 activity (PM-10) = 0.078 pCi from previous calculation
- Tunnel effluent Pu239 activity (TSP - PM-10) = 1.200 pCi/g

**Tunnel effluent Pu239 activity (TSP):**

$$(1.200 \text{ pCi/g} \times 0.21002 \text{ g}) + 0.078 \text{ pCi} = 0.330 \text{ pCi}$$

- Tunnel inlet Pu239 activity (TSP) = 0.004 dpm/ filter

**Tunnel inlet Pu239 activity (TSP):**

$$\frac{0.004 \text{ dpm/filter} \times 0.45 \text{ pCi/dpm}}{0.01717 \text{ g/filter}} = 0.10 \text{ pCi/g}$$

$$0.10 \text{ pCi/g} \times 0.00749 \text{ g} = 0.000785 \text{ pCi}$$

**Net Pu239 activity (TSP):**

$$0.320 \text{ pCi} - 0.000785 \text{ pCi} = 0.330 \text{ pCi}$$

$$\frac{0.330 \text{ pCi}}{0.27510 \text{ g}} = 1.198 \text{ pCi/g}$$

**Pu239 concentration attributed to TSP eroded from soil:**

$$1.198 \text{ pCi/g} \times 0.001928 \text{ g/m}^3 = 0.002309 \text{ pCi/m}^3$$

**Assessment of April 2006 Grass Fire at the Rocky Flats Site:  
Modeling of Grass Fire Emissions and  
Discussion of Air Sampling as it Relates to a Grass Fire**

On April 2, 2006, a grass fire ignited in the northeastern quadrant of the RFS (Rocky Flats Site). A "small wildland fire" was reported at 1:46 P.M. at the end of the power line on the south side of Rock Creek at Highway 128 (next to the Colorado Department of Public Health and Environment air sampler location within the RFS boundary); firefighting teams were called in immediately and the fire was reported as controlled at approximately 8:06 P.M., having burned over a thousand acres, including a portion of the Open Space between Indiana Street and Great Western Reservoir. Winds were generally out of the northwest at speeds from 6 to 25 miles per hour with gusts reported as high as 39 miles per hour. The map attached as Figure 1 shows the extent of the burned area within the RFS boundary, and Figure 2 includes photographs taken 1 day and 24 days after the fire. Damage to property was confined to power poles, fence posts and some water monitoring equipment located in a drainage to the east of Pond B-5 on RFS itself. The cause of the fire was described in the Cherryvale Fire Report as "arc from faulty contact, broken conductor" on the power line. Regarding radiological contamination, the area on which the fire occurred is known to be only very moderately contaminated with plutonium and americium, the concentration levels in the soil being mostly at background with some small areas of contamination nearer the old industrial area approaching several picocuries per gram (pCi/g) in the surface soil. The entire northeastern Buffer Zone was covered with accumulated litter from many years of vegetative growth that had been protected from fire by policies developed following intense participatory public discussions.

A great deal of interest in this fire can be anticipated based around the question of the hazard associated with the possible release of airborne radioactive contaminants in the smoke from the fire. The discussion that follows provides general answers to that question.

Air Quality Modeling of a Hypothetical Grass Fire at RFS

In the summer of FY 2000, Rocky Flats environmental protection staff developed an assessment of probable exposure consequences of a grass fire to firefighters who might be called to the Site. The reason for this assessment was the recognition that a fire would inevitably occur, as had been demonstrated that summer by a small fire ignited by a lightning strike in the eastern Buffer Zone. That fire was confined to about 10 acres due to the close proximity and easy access of observers and firefighting personnel on the site. Local fire teams had been called to assist in extinguishing that fire and some interest was expressed by these firemen regarding the potential radiological hazards they might have encountered.

The modeling assessment, performed for both typical and worst case meteorological conditions, estimated the concentrations to which a firefighter might be exposed should the firefighter remain in the downwind smoke plume continuously for periods of from 1 to 5 hours, and assessed the potential inhalation dose from such an exposure. The results of the modeling assessment are reported in a "White Paper on the Radiation Dose Assessment for Firefighters During a Grass Fire" (Attachment 1).

The white paper provides strong evidence that the radiological hazards of a grass fire at RFS are negligible, based on both U.S. Department of Energy (DOE) guidelines and U.S. Environmental



Protection Agency (EPA) regulations. DOE requirements provide that no member of the public is to receive a potential dose in excess of 100 millirem (mrem) per year. EPA regulations limit emissions of airborne contaminants to a level below which any member of the public would be exposed to concentrations that could result in a potential dose of 10 mrem per year via the airborne pathway.

The modeling assessment asked two fundamental questions: what air concentrations would result at breathing height in the downwind smoke plume for a fire that occurred in an area with a 1 pCi/g uniform soil contaminant concentration; and what would be the limiting uniform soil contaminant concentrations that would result in no more than a 1 mrem dose to the firefighter who remained in the plume continuously for the varying time periods of the study? The answer to the first of these questions suggested that the average concentration of plutonium and americium in air would be 0.0004 pCi/m<sup>3</sup> per pCi/g under the worst probable conditions of meteorology and exposure time. This level would result in a potential inhalation dose of 0.00066 mrem, considerably less than the 10 mrem limit to which a member of the public could be exposed for an entire year without exceedance of the EPA's airborne radionuclide dose standards. The estimates were adjusted considering the increased breathing rate of the firefighters compared to the breathing rates used to derive the EPA standard. Modeling to a dose limit of one mrem, one tenth of the EPA standard, resulted in the conclusion that this arbitrary 1 mrem dose limit would not be exceeded for a fire burning in a uniformly contaminated area of less than 115 pCi/g plutonium and less than 102 pCi/g depleted uranium (Depleted uranium is the limiting case for uranium isotope mixtures; the limiting natural uranium concentration is higher, as is the limiting concentration of enriched uranium). Americium contribution to dose is included with the plutonium.

Using these results, the probable emissions from the grass fire of April 2006 can be evaluated. Following the cleanup of the contaminated soils at RFS where some soil concentrations initially exceeded 50 pCi/g of plutonium, there are assuredly no significant contaminated surface soil areas exceeding this concentration. In the area of the burn, where project cleanup was not required, the soil concentrations are known to be very low with the average concentration over the area being less than 1 pCi/g, with much of the area showing considerably less, approaching or achieving insignificant background levels. This information, and the results of the modeling study, lead to the conclusion that no significant air concentrations resulted from radionuclide emissions during the April 2006 fire. The model results can be extended to show that maximum air concentrations would not have exceeded about 0.0004 pCi/m<sup>3</sup>, as noted above, and concentrations further downwind would have rapidly diminished due to normal dispersion of the smoke. Firefighters with higher breathing rates than the population used to establish the ambient-based standard, would have received doses considerably less than one mrem, one-tenth of the Radionuclide NESHAP (National Emission Standards for Hazardous Air Pollutants) standard upon which the concentration limits of these analyses were based.

#### Radioactive Air Sampling of Grass Fires at RFS

Routine air monitoring has been continued at RFS even though no facility exists at the Site that houses operations that would trigger a requirement for such monitoring under EPA's Radionuclide NESHAP for DOE facilities (see 40 CFR 61, subpart H). The three monitors that remain are being used to evaluate the air quality that exists following remediation of surface contamination and the consequent natural revegetation and weathering of the surface following that remediation. During development of the final 2005 Integrated Monitoring Plan, fire

scenarios were not considered as a serious driver for monitoring. The reasons for this are several-fold. First, in a grass fire, the location and magnitude of the fire, and direction of localized smoke travel are not predictable over the short-term periods of interest. Generally, the monitoring of such fires requires the use of portable equipment and dedicated staff who can move the equipment to keep it in the plume. Second, as indicated in the modeling already discussed, there is no potential for such fires to yield a significant contribution to the radionuclide emissions of the site. Finally, at the concentrations that are estimated, the high-volume air samplers that are deployed would not be able to collect enough sample to provide a measurable estimate of the radionuclide concentrations in the plume.

Regarding this last point: prior to Site closure, the radionuclide air monitoring program at RFS was designed to quantitatively detect radionuclide air concentrations at levels equivalent to those that would yield a hypothetical dose at the receptor locations (monitoring locations) of about 1 percent of the Rad-NESHAP standard *using a 30-day sampling period*. (Evaluation for compliance against the standard is based on annual exposure to the averaged air concentration.) The site chose to continue this monitoring strategy following the completion of accelerated remedial actions. One percent of the Rad-NESHAP standard, stated as an air concentration, is about  $2 \times 10^{-5}$  pCi/g of Plutonium-239. The laboratory protocols can yield approximately this detection limit for air samples that are collected for a continuous month, about 720 hours of sampling. Shorter periods of sampling at this air concentration will not normally yield sufficient material on the filter and impaction substrates to allow a quantitative estimate of the average air concentration. At the modeled maximum air concentrations estimated for this grass fire ( $0.0004 \text{ pCi/m}^3$ , as discussed above) the air sampler would have to be immersed in that average plume concentration for more than 30 hours. Realistically, fixed samplers would likely not be immersed in the maximized grass-fire smoke plume for more than 15 minutes to half an hour at RFS. Also, as previously noted, the April 2006 fire was reported as controlled in just over 6 hours, so immersion in the plume for over 30 hours would not have been possible.

In summary, a grass fire at RFS is not expected to yield detectable air concentrations in the present fixed network of samplers, nor is the network intended for that purpose.

#### Sampling During the April 2006 Grass Fire

In the April 2006 fire, only one of the three samplers appears to have been immersed in the smoke plume. Sampler S-136 is located near Indiana Street approximately a quarter mile south of Highway 128. On the date of the fire, telemetry data from this sampler indicate that it ceased operation approximately 6 minutes after the fire had been reported. (The fire was reported at approximately 1:46 P.M., the sampler stopped operating at 1:53 P.M.) Examination of the filter substrate did not indicate any discoloration that might suggest the smoke plume had been sampled. The other two samplers, S132 (located on Highway 93, upwind of the fire), and S-138 (located approximately 1 mile south of S-136 on Indiana) showed no discoloration even though both operated continuously throughout the fire. Sampler S-138 may have been immersed incidentally in the plume but at its distant proximity from the nearest approach of the fire, the smoke would have experienced considerable dispersion and consequent reduction in concentration compared to the smoke immediately in front of the fire.

The samples from the three samplers were submitted for expedited laboratory analysis even though they were likely not impacted by the fire. Both fine samples (for particles less than about

10 micrometers aerodynamic diameter) and coarse samples (particles between about 10 and 25 micrometer aerodynamic diameter) were submitted from each location. Through laboratory technician error the fine samples were accidentally discarded during initial processing (Attachment 2); the coarse samples were processed and analyzed. None of the coarse samples showed detectable concentrations of either plutonium or americium. Uranium was detected at concentrations typically seen at these sampler locations but the concentrations were not sufficiently high to yield a reliable quantitative result. Table 1 shows the results of these measurements and compares the reported results to concentrations reported since October 2005 when the three-station air monitoring network began operation.

*Table 1. Coarse particle concentrations reported for the three air monitoring locations during the April 2006 grass fire. Samplers had been running for the previous month prior to the fire and samples were submitted for laboratory analysis immediately following the fire event. These calculated concentrations are compared to those observed in the same samplers for the reported periods to-date following physical completion at RFS.*

Sampling Location, Size	Parameter	Total Concentration (pCi/m <sup>3</sup> )	Comment	Highest Reported -- October 2005 thru Dec 2005 (pCi/m <sup>3</sup> )
S-132 Coarse	Americium 241	3.145E-07	Non-detect	1.237E-06
	Plutonium 239/40	2.752E-07	Non-detect	1.434E-06
	Uranium-234	3.616E-05		1.609E-04
	Uranium-235	-4.324E-07	Non-detect	9.468E-06
	Uranium-238	3.656E-05		1.237E-04
S-136 Coarse	Americium 241	0.000E+00	Non-detect	2.358E-06
	Plutonium 239/40	-5.611E-07	Non-detect	2.358E-06
	Uranium-234	2.485E-05		4.167E-05
	Uranium-235	2.805E-07	Non-detect	5.940E-06
	Uranium-238	1.523E-05		4.520E-05
S-138 Coarse	Americium 241	1.559E-07	Non-detect	4.962E-07
	Plutonium 239/40	2.729E-06	Non-detect	1.682E-06
	Uranium-234	2.534E-05		2.928E-05
	Uranium-235	9.355E-07	Non-detect	6.451E-06
	Uranium-238	2.339E-05		3.235E-05

Note: Negative concentrations are an artifact of sampling-medium blank correction

#### Discussion of Fine Particle Concentrations versus Coarse Concentrations Reported

The modeling performed for the grass fires provides additional insight into the probable relationship between what would have been observed in the fine fraction of the air sample compared to what was observed in the coarse fraction. In the modeling assessment, estimates of partitioning between fine-fraction concentrations of smoke mass and coarse-fraction concentrations were calculated. These calculations were based on Bureau of Land Management sponsored studies of grass fires of the same type as occur at RFS (see reference to Leenhouts 1998 in Attachment 1). Those calculations suggested that as much as 75 percent of the smoke mass from a grass fire will be found in the fine fraction, with the rest going to the coarse fraction.

At RFS, the mechanism for contamination of vegetative matter has been studied in some detail. Since plutonium and americium are not expected to be absorbed into the plant matter (see Kaiser-Hill, April 2002, *Actinide Migration Evaluation Pathway Analysis Summary*, with appendices), contamination of plant matter by these isotopes is understood to occur via the mechanisms of wind-blown deposition and rain splash. Comparisons of contamination on plants with that on the underlying soil have shown that the concentrations observed in plant material are roughly 18 percent, on the average, of the concentrations observed in the soil in the vicinity of the plants. In other words, if the soil is contaminated to a level of 1 pCi/g, the plant material would be expected to yield a concentration of 0.18 pCi/g or so.

There is no evidence in airborne measurements of plutonium at RFS that there is a preferential partitioning of the material into the fine fraction. To the contrary, the routine air data show about 40 percent of the contamination resides in the fine fraction and about 60 percent resides in the coarse fraction. Mass distribution studies of plutonium in resuspended soil particles show a similar result. The explanation is that the very small plutonium and americium particles released into the environment attached very quickly to larger soil particles. The resulting distribution of airborne plutonium is determined by the size distribution of the agglomerated soil particles rather than by the distribution of the plutonium itself.

The consequence of these observations for the April 2 grass fire is that the expected distribution of radioactivity in the air samples would not be expected to differ markedly from the underlying distribution of the radioactivity in the mass itself. The rain-splashed particles adhere to the plant material and would be emitted into the smoke with the soil particles as the plant material burns. The smoldering plant material that continues to emit after the passage of the flame front would likely have much less contamination associated with it since the rain-splash contaminated leaves and sheath will have been burned away in the initial fire.

#### Probable Post-Fire Air Emissions

Another potential concern from a fire on a contaminated soil surface might be the residual effects of wind-blown erosion following the fire. The amount of increased erosion and its duration is determined in part by the condition of the soil following the fire, and by the rate at which vegetative matter recovers and grows over the burned soils. From the prescribed test burn in 2000, and from the later lightning-initiated fire that same summer, RFS personnel have gathered several bits of pertinent information. As would be predicted by consideration of the amount of combustible material, the grass fires observed at RFS have not lingered for a long period of time over any one area of the soil. The result, shown in Figure 3, is that the temperature of the soil does not become so hot as to damage the root systems of typical vegetation nor is the organic matter in the soil destroyed as might be typical of a more intense fire such as that associated with a burning forest.

Evidence verifying this concept has been found following both the CY2000 fires (and others on the site) and following the subject fire of this assessment—the plant cover over the burned surface has been observed to recover very quickly and grow in a manner that could be described as “vigorous”. The net result from an air quality perspective is that the soil does not remain unusually erodible for longer than a few weeks to a few months, depending on time of year when the fire occurs. A full discussion of these effects can be found in RAC, October 1999, *Final Report: Task 3: Input and Assumptions, Radionuclide Soil Action Level Oversight Panel*; and



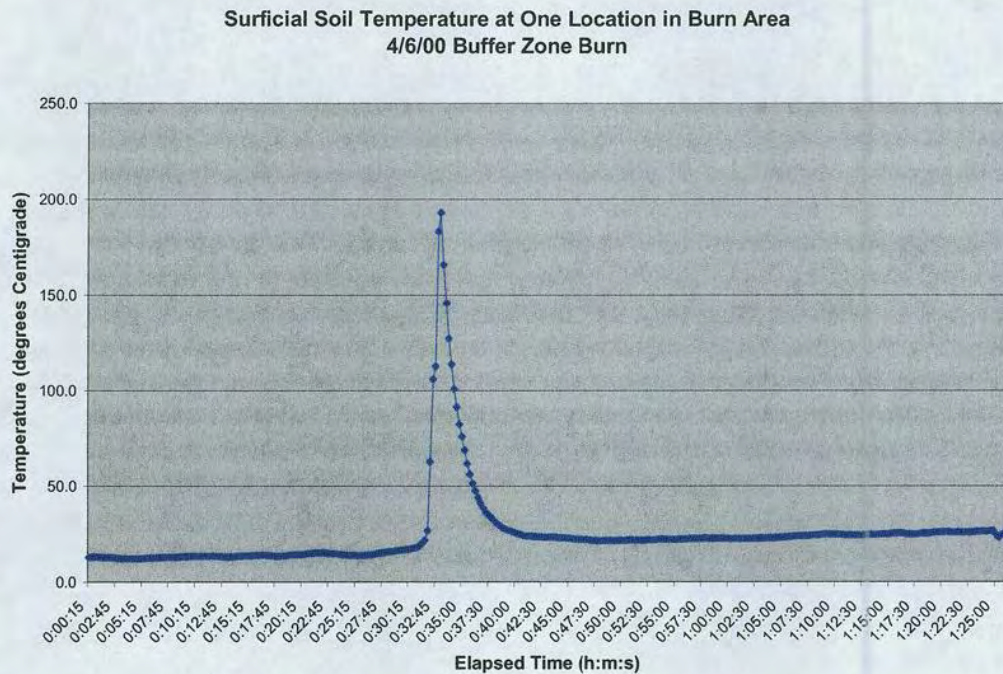


Figure 3. Soil temperature profile as a grass fire passed over a buried recording temperature sensor. Derived from data recorded during the prescribed test burn in Spring of CY 2000.

#### Air Monitoring Recommendation

In consideration of the information presented above, no viable reason for air monitoring of grass fires at RFS can be justified. While such monitoring would possibly satisfy an “academic” curiosity regarding what is contained in the samples, the data and investigations already performed suggest the minor residual contamination at RFS does not have sufficient potential to produce air concentrations of plutonium and associated americium of concern, based on existing regulatory guidance.



# April 2, 2006 Wildfire at Rocky Flats

Figure 1

- April 2, 2006 Wildfire Area
- Lakes & ponds
- Streams & ditches
- Boundary Fence
- Roads
- Contours (20 ft. intervals)

DATA SOURCE BASE FEATURES:  
 The map was created using data provided by the U.S. Army Corps of Engineers, 1996. The data was digitized from the 1996 map and other sources. The map was created using the U.S. Army Corps of Engineers, 1996. The data was digitized from the 1996 map and other sources. The map was created using the U.S. Army Corps of Engineers, 1996. The data was digitized from the 1996 map and other sources.



State Plane Coordinate Projection  
 Colorado Central Zone  
 Datum: NAD27

U.S. Department of Energy  
 Rocky Flats Environmental Technology Site  
 Prepared by:  
 Professional Environmental Group, L.L.C.

MAP ID: 06-0027

April 4, 2006

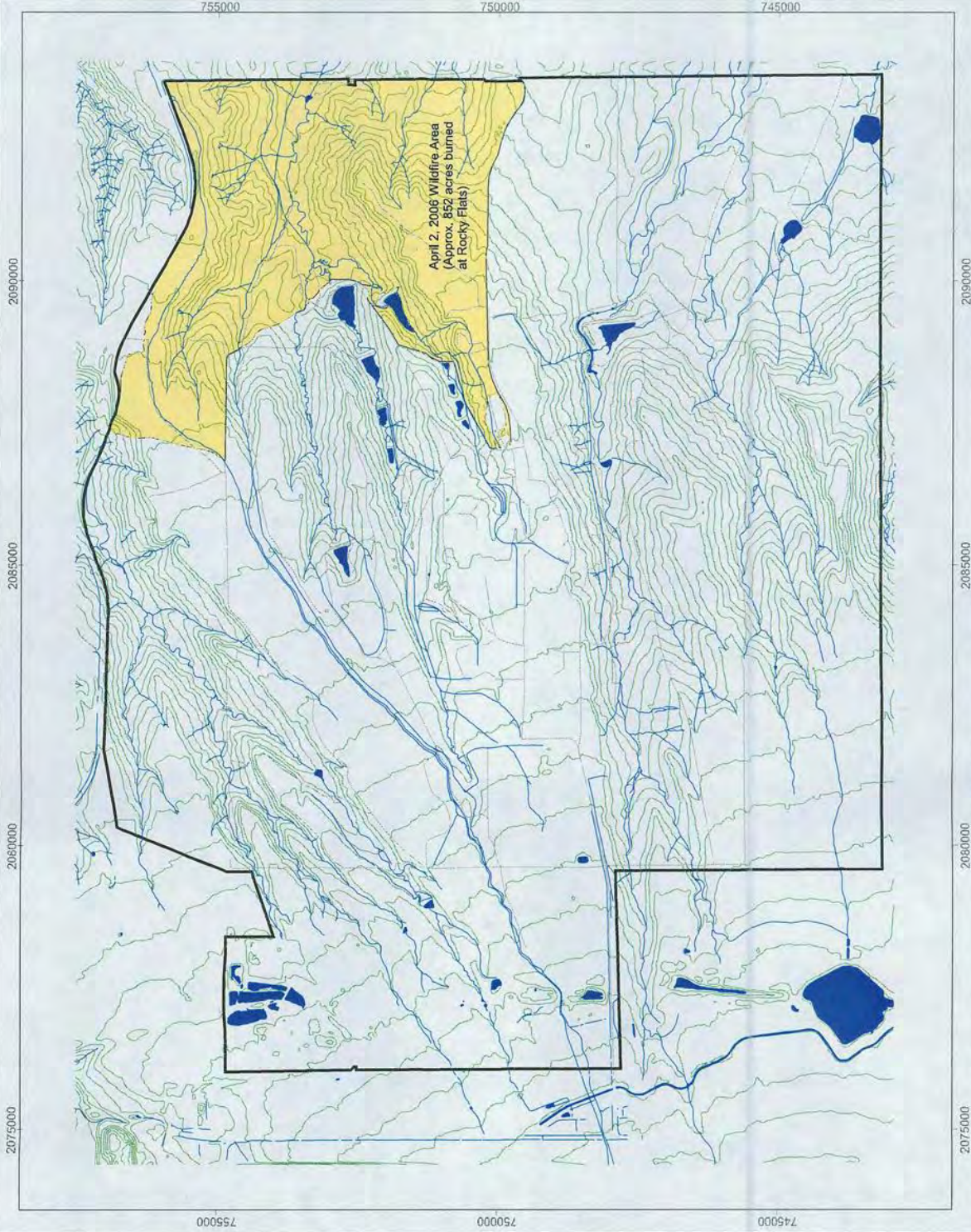




Figure 2. Photos from burned area after 1 day (April 3) and 24 days (April 26).



April 3, 2006 - Walnut Creek looking NE from A-4 dam.



April 26, 2006 - Walnut Creek looking NE from A-4 dam.



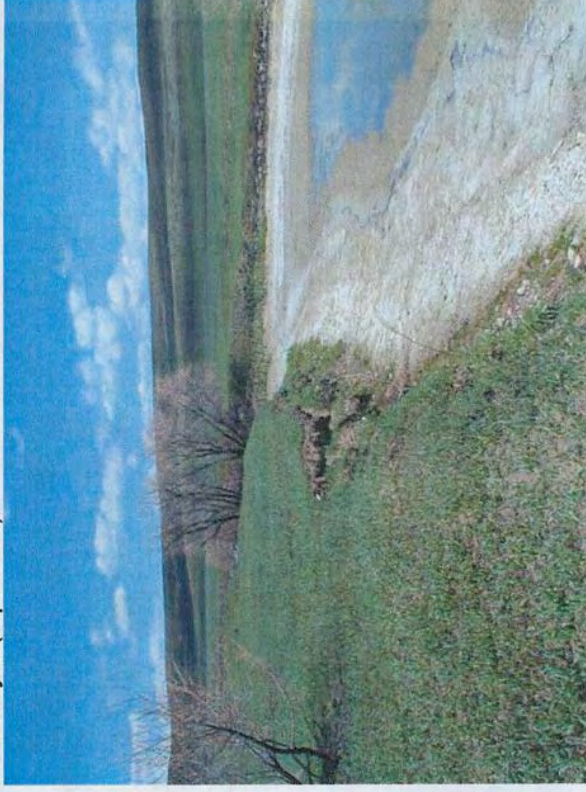
April 3, 2006 - Walnut Creek looking SE from A-4 dam.



April 26, 2006 - Walnut Creek looking SE from A-4 dam.



Figure 2. Photos from burned area after 1 day (April 3) and 24 days (April 26).



April, 3, 2006 –View NW from near surface water station GS03. April, 26, 2006 –View NW from near surface water station GS03.



## **RADIATION DOSE ASSESSMENT FOR FIREFIGHTERS DURING A GRASS FIRE**

### **Introduction**

A radiation dose assessment was performed for firefighters at the Rocky Flats Environmental Technology Site (RFETS) trying to extinguish a grass fire. This dose assessment is being performed to assure that firefighters would not exceed any radiation dose limits. This radiation dose assessment will be used to delineate areas at RFETS where firefighters would be advised to not follow a grass fire based on increased radiation dose potential.

Radiation dose could be received by the firefighter through the inhalation of resuspended radioactive material. This resuspended radioactive material augments naturally occurring radioactive material in the air. For the purposes of this study, the radiation dose to firefighters located adjacent to a grass fire will be assessed so that the maximum radiation dose to the firefighter is estimated. Conservative assumptions were made in the dose assessment to assure that radiation dose to the firefighter was overestimated in the calculations.

It is recommended that the "Soil Contamination Area" (SCA) radiological posting limits be used as the demarcation where firefighters should not follow a grass fire based on potential radiation dose. SCA posting limits for Pu-239/Am-241, enriched uranium and depleted uranium in surface soils have been set at 115 pCi Pu-239/gram soil, 188 pCi Total Enriched U/gram soil and 102 pCi Total Depleted U/gram soil, respectively, based on soil action levels prescribed presently in the Rocky Flats Cleanup Agreement (RFCA). By following this recommendation, a firefighter should not receive more than 1 mrem of radiation dose while extinguishing a grass fire at RFETS (See Table 1, "Allowable Soil Concentration Based on Radiation Dose to Firefighters From Grass Fires.").

The radiation dose assessment was performed by: 1) defining the locations where individuals could receive radiation dose, 2) calculating the amount of radioactive material in air at this location during grass fires and 3) computing the radiation dose with its associated acceptable soil concentration. Each of these steps is discussed below.

### **Location of Individuals**

In order to assess the radiation dose to a firefighter, the location of the firefighter must first be defined. The maximum radiation dose would be received by a firefighter directly adjacent to the grass fire and downwind since these individuals would be exposed to the highest air concentrations of radioactive material. For conservatism, it is assumed that a firefighter is located immediately downwind of the burning grass for the duration of the grass-burning episode. It is also assumed that this firefighter is not wearing any type of

respiratory protection. It should be noted that normal fire fighting methods do not place the firefighters in the path of the fire or the direct smoke plume from the fire.

#### Air Concentrations at Firefighter Location

Radioactive material present in the environment is resuspended and transported downwind during a grass burning episode. By knowing the amount of radioactive material in the grass, the concentration of radioactive material in air can be calculated using resuspension factors applicable to a fire. The firefighter can subsequently inhale some fraction of this radioactive material in the air.

This dose assessment is based on a computer model of emissions from a series of hypothetical fire and atmospheric conditions (See Attachment A – "Hypothetical Wildfire Air Modeling Analysis."). For this radiation dose assessment, the concentration of radioactive material in air is maximized. By modeling, the firefighter immediately downwind of the fire is exposed for several different time-periods and for several different wind conditions in this assessment. To capture a range of air concentrations, a grass fire duration of 1, 2 and 5 hours is assessed for average and worst-case conditions.

#### Radiation Dose

To calculate radiation dose, the concentration of radioactive material in the air is initially multiplied by the firefighters breathing rate and the duration of the grass fire. This product will be the estimated amount of radioactive material inhaled. This amount inhaled is then multiplied by a dose conversion factor to calculate radiation dose. The radiation dose to the firefighters from plutonium, americium and uranium are outlined in Table 2, "Radiation Dose from Plutonium & Americium to Firefighters Due to Inhalation of Particulates During a Grass Fire," Table 4, "Radiation Dose from Enriched Uranium to Firefighters Due to Inhalation of Particulates During a Grass Fire," and Table 5, "Radiation Dose from Depleted Uranium to Firefighters Due to Inhalation of Particulates During a Grass Fire."

The firefighters at the boundary of the burn site will inhale at a rate of  $3.2 \text{ m}^3/\text{hr}$ . The firefighters inhalation rate is indicative of a short term, heavy activity inhalation rate. This inhalation rate was taken from EPA's "Exposure Factors Handbook," dated August 1997 (EPA/600/P-95/002).

The radiation Dose Conversion Factor (DCF) is used to convert the amount of radioactive material taken into the body into a radiation dose. The inhalation DCF used to calculate radiation dose for Am-241, Pu-239, U-234, U-235 and U-238 were taken from EPA's Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," dated September, 1988 (EPA-520/1-88-020). The inhalation DCF used to calculate

radiation dose was the highest DCF available and corresponded to the Committed Effective Dose Equivalent.

It was assumed that the Am-241/Pu-241 activity ratio is 18%. This is consistent with the median Am-241/Pu-241 activity ratio seen in surface soils east of RFETS (Health Physics, Vol. 70, No. 4, April 1996). For assessing uranium isotope ratios, typical values for depleted and enriched uranium were taken from the "Health Physics and Radiological Health Handbook." Uranium isotope ratios are outlined in Table 3, "Uranium Isotope Characterization."

The acceptable soil concentration was then calculated by dividing a radiation dose limit by the radiation dose calculated for a unit concentration of activity. This will give the soil concentration that would give the firefighter the designated radiation dose limit for the given burn conditions (See Table 1).

### Recommendations

The results of this assessment indicate that the maximum dose will be less than 1 mrem to any individual downwind of a fire if the fire is not in an area exceeding the SCA radiological posting limit. It is therefore recommended that the SCA radiological posting limit be used as the demarcation where firefighters should not follow a grass fire. SCA posting limits for Pu-239/Am-241, enriched uranium and depleted uranium in surface soils are at 115 pCi Pu-239/gram soil, 188 pCi Total U/gram soil and 102 pCi Total U/gram soil, respectively. By following this proposal, a firefighter should not receive more than 1 mrem of radiation dose.

### Attachments

Attachment A – Hypothetical Wildfire Air Modeling Analysis

### Tables

Table 1 - Allowable Soil Concentration Based on Radiation Dose to Firefighters from Grass Fires

Table 2 - Radiation Dose from Plutonium & Americium to Firefighters Due to Inhalation of Particulates during a Grass Fire

Table 3 - Uranium Isotope Characterization

Table 4 - Radiation Dose from Enriched Uranium to Firefighters Due to Inhalation of Particulates during a Grass Fire

Table 5 - Radiation Dose from Depleted Uranium to Firefighters Due to Inhalation of Particulates during a Grass Fire

## **ATTACHMENT A**

### **Hypothetical Wildfire Air Modeling Analysis**

#### **Introduction**

A wildfire may release radionuclides to the environment if radionuclides are present on or in the vegetation, or on soil attached to the vegetation surfaces. Airborne radionuclides may then be inhaled by fire fighters, resulting in a radiation dose to the individual.

Studies at the Rocky Flats Environmental Technology Site (RFETS or Site) and elsewhere have shown that plants do not readily uptake actinides such as plutonium (Pu) and americium (Am) from soil (Arthur and Alldredge, 1982). However, radionuclide-contaminated soil may be resuspended by wind or rain splash and become attached to vegetation surfaces. Measurements conducted at RFETS show that both standing vegetation and litter may trap radionuclide-contaminated soils, with litter showing a higher radionuclide content than the standing vegetation (Langer, 1986).

To look at radiation dose from a hypothetical wildfire, a dispersion model was used to calculate downwind concentrations of particulate matter. Assuming that airborne soil particles released from the burning plants have the same radionuclide concentrations as the surrounding contaminated surface soils allowed an estimate of airborne radionuclides that might be released during a wildfire. The dispersion modeling and subsequent radiation exposure calculations are described below.

#### **Fire Scenario Modeling**

A series of hypothetical wildfires was modeled, based on fire durations of 1, 2, or 5 hours and a variety of wind speed/stability combinations. The 54 wind speed/stability combinations that were used for this study were taken from the U.S. Environmental Protection Agency's (EPA's) SCREEN dispersion model (EPA, 1995a) and represent the probable range of wind speed and stability that are likely to occur in nature. For each wind speed and fire duration, the U.S. Forest Service's fire behavior model BEHAVE was used to predict the area and length-to-width ratio of the burned area.

Particulate emissions (and therefore actinide emissions) from the hypothetical fires were maximized by assuming that the fire would begin in late September, when fuel loading would be at a maximum. Subsequent dispersion was assumed to occur under each of the 54 wind speed/stability combinations. Dispersion from the fire was modeled for the 1-hour case for each of the 54 meteorological combinations. Worst-case impacts were found to occur under light winds (1 meter per second [m/s]) and stable conditions (nighttime stability, F). The 2- and 5-hour fires were modeled for the worst case conditions and also under annual average wind speed and stability conditions (4 m/s and

neutral [D] stability). These meteorological conditions were assumed to persist for the full 2 or 5 hours for the longer duration fires.

Dispersion from each fire was simulated using a model developed by the EPA, the Industrial Source Complex Short-Term model (ISCST3). Each hypothetical wildfire was represented by a rectangular area with dimensions based on the total acreage and the length-to-width ratios predicted by BEHAVE. The fire was input as a ground-based area source with an initial vertical dimension based on the expected height to which a smoke plume would rise (described below). The "regulatory default" options were used, along with rural dispersion coefficients. The model essentially assumed that the entire fire area would be burning simultaneously, which would not be the case in a real fire.

Winds were assumed to blow from west to east during each fire. Receptors (points at which the model will calculate a concentration) were established in a rectangular grid pattern over the eastern half of the fire and for some distance beyond the burned area to the north, south, and east. Receptor spacing was 100 m in the north-south direction and 50 m east-west. Because each fire was represented as a ground-based source, the receptors near the eastern edge of the fire will show the maximum concentrations that would be produced anywhere by a hypothetical fire. All receptors were assumed to be located 2 m above the ground (breathing level).

#### Fire Scenario Particulate Emissions

Particulate emissions from fires have been estimated by a number of researchers. Emission factors for a grass fire similar to the hypothetical wildfires generally range from approximately 3 grams (g) of particulate matter per kilogram (kg) of grass burned to around 18 g/kg. For this study, emission factors were taken from Leenhouts (1998). These factors have been used in a recent update to the Bureau of Land Management's (BLM's) *Simple Approach Smoke Estimation Model* (SASEM) (Sestak and Riebau, 1988) and are specific to western perennial grassland fires. The particulate emissions calculated represent emissions of particles smaller than 10 micrometers aerodynamic diameter (PM<sub>10</sub>).

Equations given in the SASEM documentation (Sestak and Riebau, 1988) were used to estimate heat release and plume rise from each of the hypothetical fires. The SASEM approach assumes that a fire line will produce multiple small plumes, with horizontal dimensions governed by the depth of the fire line, rather than a single, massive plume. The expected plume rise for each individual plume is then largely a function of how hot the fire is (heat release) and the wind speed (higher winds inhibit plume rise).

The plume rise was calculated for a 1-hour fire for each of the 54 wind speed/stability combinations. Based on equations in the ISCST User's Guide (EPA, 1995b), these plume rise figures were used to estimate the initial vertical dimension of the fire plume for each meteorological condition. Once the worst-case dispersion conditions were identified by modeling each 1-hour fire with ISCST3, plume rise and initial vertical

dimension were also calculated for the 2- and 5-hours fires for the worst-case and average conditions.

#### Fire Scenario Radionuclide Emissions

Measurements have been taken on Site of the amount of soil attached to vegetation and litter. An autumn maximum figure plus one standard deviation of 134 milligrams of soil per gram of plant mass (mg/g) was used for this study (Arthur and Alldredge, 1982). The attached soil was assumed to be radiologically contaminated at a level of 1 picocurie per gram of soil ( 1 pCi/g). In addition, a small amount of radioactivity was assumed to be present within the plant material itself, based on transfer coefficients from Baes, et al. (1984).

#### Fire Scenario Results

The maximum and average 1-hour, 2-hour, and 5-hour particulate and radionuclide concentrations predicted by the modeling are shown in Table 1.

**Table 1. Hypothetical Wildfire Air Modeling Results**

<b>Fire Duration and Scenario</b>	<b>Maximum Particulate Concentration (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>Maximum Pu- 239/240 Concentration (<math>\text{pCi}/\text{m}^3</math>)</b>	<b>Maximum Am- 241 Concentration (<math>\text{pCi}/\text{m}^3</math>)</b>	<b>Maximum Uranium Concentration (<math>\text{pCi}/\text{m}^3</math>)</b>
1 hour Worst-case meteorology	2,989	$4.02 \times 10^{-4}$	$4.17 \times 10^{-4}$	$4.26 \times 10^{-4}$
1 hour Average meteorology	728	$9.79 \times 10^{-5}$	$1.02 \times 10^{-4}$	$1.04 \times 10^{-4}$
2 hour Worst-case meteorology	2,962	$3.98 \times 10^{-4}$	$4.13 \times 10^{-4}$	$4.22 \times 10^{-4}$
2 hour Average meteorology	722	$9.70 \times 10^{-5}$	$1.01 \times 10^{-4}$	$1.03 \times 10^{-4}$
5 hour Worst-case meteorology	2,883	$3.88 \times 10^{-4}$	$4.02 \times 10^{-4}$	$4.11 \times 10^{-4}$
5 hour Average meteorology	695	$9.34 \times 10^{-5}$	$9.69 \times 10^{-5}$	$9.90 \times 10^{-5}$

**Notes:**

$\mu\text{g}/\text{m}^3$  = micrograms per cubic meter

$\text{pCi}/\text{m}^3$  = picocuries per cubic meter

Pu-239/240 = plutonium 239/240

Am-241 = americium 241

U = uranium species

All radionuclide concentrations based on soil contamination at 1 picocurie per gram  
( $\text{pCi}/\text{g}$ )

## References Cited

- Arthur, W.J. and A.W. Alldredge, 1982. "Importance of Plutonium Contamination on Vegetation Surfaces at Rocky Flats, Colorado." *Environ. Experi. Botany* 22(1):33-38.
- Baes, C.F., R.D. Sharp, A.L. Sjöreen, and R.W. Shor, 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture*. Oak Ridge National Laboratory, Oak Ridge, TN.
- EPA, 1995a. *Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised*. EPA-450/R-92-019. U.S. Environmental Protection Agency, Research Triangle Park, NC.
- EPA, 1995b. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume I – User Instructions*. EPA-454/B-95-003a. U.S. Environmental Protection Agency, Research Triangle Park, NC.
- Langer, G., 1986. *Dust Transport—Wind Blown and Mechanical Resuspension*. Rockwell International, Golden, CO.
- Leenhouts, B., 1998. *Assessment of Biomass Burning in the Coterminous United States, Conservation Ecology* (Online), 2(1):1, available from <http://www.Consecol.org/vol12/iss1/art1>.
- Sestak, M. L. and A.R. Riebau, 1988. *Simple Approach Smoke Estimation Model*. Technical Note 382. U.S. Department of the Interior, Bureau of Land Management, Cheyenne, WY.



**TABLE 1**  
**ALLOWABLE SOIL CONCENTRATION BASED ON RADIATION DOSE TO FIREFIGHTERS**  
**FROM GRASS FIRES**

**ALLOWABLE PLUTONIUM SOIL CONCENTRATION**

Burn Conditions	Radiation Dose (mrem)/(pCi Pu-239/gram soil)	Allowable Pu-239 Soil Concentration at Radiation Dose = 0.1 mrem (pCi Pu-239/gram soil)	Allowable Pu-239 Soil Concentration at Radiation Dose = 1 mrem (pCi Pu-239/gram soil)	Allowable Pu-239 Soil Concentration at Radiation Dose = 10 mrem (pCi Pu-239/gram soil)
Worst Case, Duration = 1 hour	6.59E-04	152	1518	15180
Average Case, Duration = 1 hour	1.61E-04	623	6229	62288
Worst Case, Duration = 2 hour	1.30E-03	77	767	7666
Average Case, Duration = 2 hour	3.18E-04	314	3144	31436
Worst Case, Duration = 5 hour	3.18E-03	31	315	3146
Average Case, Duration = 5 hour	7.65E-04	131	1307	13067

**ALLOWABLE ENRICHED URANIUM SOIL CONCENTRATION**

Burn Conditions	Radiation Dose (mrem)/(pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 0.1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 10 mrem (pCi Total U/gram soil)
Worst Case, Duration = 1 hour	1.77E-04	565	5653	56528
Average Case, Duration = 1 hour	4.32E-05	2315	23155	231549
Worst Case, Duration = 2 hour	3.50E-04	285	2853	28532
Average Case, Duration = 2 hour	8.55E-05	1169	11690	116898
Worst Case, Duration = 5 hour	8.53E-04	117	1172	11718
Average Case, Duration = 5 hour	2.06E-04	486	4865	48649

**ALLOWABLE DEPLETED URANIUM SOIL CONCENTRATION**

Burn Conditions	Radiation Dose (mrem)/(pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 0.1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 10 mrem (pCi Total U/gram soil)
Worst Case, Duration = 1 hour	1.63E-04	615	6153	61531
Average Case, Duration = 1 hour	3.97E-05	2520	25204	252039
Worst Case, Duration = 2 hour	3.22E-04	311	3106	31057
Average Case, Duration = 2 hour	7.86E-05	1272	12724	127243
Worst Case, Duration = 5 hour	7.84E-04	128	1276	12755
Average Case, Duration = 5 hour	1.89E-04	530	5295	52954

**TABLE 2**  
**RADIATION DOSE FROM PLUTONIUM & AMERICIUM TO FIREFIGHTERS**  
**DUE TO INHALATION OF PARTICULATES DURING A GRASS FIRE**

**EXPOSURE PARAMETERS**

Exposure Factors Description	Units	Parameter Value
Inhalation Rate (Burn Worker)	m <sup>3</sup> /hr	3.2
Exposure Frequency - Short	hr/day	1
Exposure Frequency - Medium	hr/day	2
Exposure Frequency - Long	hr/day	5
Exposure Duration	days	1
Am-241/Pu-239 activity ratio	unitless	0.18

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 1 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	4.17E-04	2.40E-04	4.44E+05	1.07E-04
Pu-239/240	4.02E-04	1.29E-03	4.29E+05	5.52E-04
TOTAL				6.59E-04

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 1 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	1.02E-04	5.88E-05	4.44E+05	2.61E-05
Pu-239/240	9.79E-05	3.13E-04	4.29E+05	1.34E-04
TOTAL				1.61E-04

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 2 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	4.13E-04	4.78E-04	4.44E+05	2.11E-04
Pu-239/240	3.98E-04	2.55E-03	4.29E+05	1.09E-03
TOTAL				1.30E-03

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 2 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	1.01E-04	1.18E-04	4.44E+05	5.17E-05
Pu-239/240	9.70E-05	8.21E-04	4.29E+05	2.88E-04
TOTAL				3.18E-04

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 5 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	4.02E-04	1.16E-03	4.44E+05	5.14E-04
Pu-239/240	3.68E-04	8.21E-03	4.29E+05	2.88E-03
TOTAL				3.18E-03

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 5 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	9.69E-05	2.79E-04	4.44E+05	1.24E-04
Pu-239/240	9.34E-05	1.49E-03	4.29E+05	6.41E-04
TOTAL				7.65E-04

**TABLE 3**  
**URANIUM ISOTOPE CHARACTERIZATION**

RADIONUCLIDES	URANIUM MASS FRACTION (gram)		
	NATURAL URANIUM (1)	ENRICHED URANIUM (1)	DEPLETED URANIUM (1)
Uranium-234	0.000057	0.0003	0.000005
Uranium-235	0.007204	0.0296	0.0025
Uranium-238	0.992739	0.9701	0.9975

(1) - Typical values taken from "The Health Physics and Radiological Health Handbook." Values may vary.

RADIONUCLIDES (Ci/gram of isotope)	URANIUM SPECIFIC ACTIVITY (2)
Uranium-234	6.24E-03
Uranium-235	2.16E-06
Uranium-238	3.35E-07

(2) - Taken from "The Health Physics and Radiological Health Handbook."

RADIONUCLIDES	URANIUM ACTIVITY (Ci/gram)		
	NATURAL URANIUM	ENRICHED URANIUM	DEPLETED URANIUM
Uranium-234	3.56E-07	1.87E-06	3.12E-08
Uranium-235	1.56E-08	6.39E-08	5.40E-09
Uranium-238	3.33E-07	3.25E-07	3.34E-07
TOTAL	7.04E-07	2.26E-06	3.71E-07
URANIUM PERCENT			
Uranium-234	50.5	82.8	8.4
Uranium-235	2.2	2.8	1.5
Uranium-238	47.3	14.4	90.1

**TABLE 4**  
**RADIATION DOSE FROM ENRICHED URANIUM TO FIREFIGHTERS**  
**DUE TO INHALATION OF PARTICULATES DURING A GRASS FIRE**

**EXPOSURE PARAMETERS**

Exposure Factors Description	Units	Parameter Value
Inhalation Rate (Burn Worker)	m <sup>3</sup> /hr	3.2
Exposure Frequency - Short	hr/day	1
Exposure Frequency - Medium	hr/day	2
Exposure Frequency - Long	hr/day	5
Exposure Duration	days	1

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 1 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.26E-04	1.36E-03	1.32E+05	0.83	1.49E-04
U-235	4.26E-04	1.36E-03	1.23E+05	0.03	5.03E-06
U-238	4.26E-04	1.36E-03	1.18E+05	0.14	2.25E-05
<b>TOTAL</b>					<b>1.77E-04</b>

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 1 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.04E-04	3.33E-04	1.32E+05	0.83	3.65E-05
U-235	1.04E-04	3.33E-04	1.23E+05	0.03	1.23E-06
U-238	1.04E-04	3.33E-04	1.18E+05	0.14	5.60E-06
<b>TOTAL</b>					<b>4.32E-05</b>

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 2 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.22E-04	2.70E-03	1.32E+05	0.83	2.96E-04
U-235	4.22E-04	2.70E-03	1.23E+05	0.03	9.97E-06
U-238	4.22E-04	2.70E-03	1.18E+05	0.14	4.46E-05
<b>TOTAL</b>					<b>3.50E-04</b>

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 2 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.03E-04	6.59E-04	1.32E+05	0.83	7.22E-05
U-235	1.03E-04	6.59E-04	1.23E+05	0.03	2.43E-06
U-238	1.03E-04	6.59E-04	1.18E+05	0.14	1.09E-05
<b>TOTAL</b>					<b>8.55E-05</b>

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 5 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.11E-04	6.58E-03	1.32E+05	0.83	7.20E-04
U-235	4.11E-04	6.58E-03	1.23E+05	0.03	2.43E-05
U-238	4.11E-04	6.58E-03	1.18E+05	0.14	1.09E-04
<b>TOTAL</b>					<b>8.53E-04</b>

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 5 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	9.80E-05	1.58E-03	1.32E+05	0.83	1.74E-04
U-235	9.80E-05	1.58E-03	1.23E+05	0.03	5.64E-06
U-238	9.80E-05	1.58E-03	1.18E+05	0.14	2.82E-05
<b>TOTAL</b>					<b>2.06E-04</b>

**TABLE 5**  
**RADIATION DOSE FROM DEPLETED URANIUM TO FIREFIGHTERS**  
**DUE TO INHALATION OF PARTICULATES DURING A GRASS FIRE**

**EXPOSURE PARAMETERS**

Exposure Factors Description	Units	Parameter Value
Inhalation Rate (Burn Worker)	m <sup>3</sup> /hr	3.2
Exposure Frequency - Short	hr/day	1
Exposure Frequency - Medium	hr/day	2
Exposure Frequency - Long	hr/day	5
Exposure Duration	days	1

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 1 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.26E-04	1.36E-03	1.32E+05	0.08	1.44E-05
U-235	4.26E-04	1.36E-03	1.23E+05	0.02	3.35E-06
U-238	4.26E-04	1.36E-03	1.18E+05	0.90	1.45E-04
<b>TOTAL</b>					<b>1.63E-04</b>

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 1 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.04E-04	3.33E-04	1.32E+05	0.08	3.51E-06
U-235	1.04E-04	3.33E-04	1.23E+05	0.02	8.19E-07
U-238	1.04E-04	3.33E-04	1.18E+05	0.90	3.53E-05
<b>TOTAL</b>					<b>3.97E-05</b>

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 2 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.22E-04	2.70E-03	1.32E+05	0.08	2.85E-05
U-235	4.22E-04	2.70E-03	1.23E+05	0.02	6.84E-06
U-238	4.22E-04	2.70E-03	1.18E+05	0.90	2.87E-04
<b>TOTAL</b>					<b>3.22E-04</b>

**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 2 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.03E-04	6.59E-04	1.32E+05	0.08	8.96E-06
U-235	1.03E-04	6.59E-04	1.23E+05	0.02	1.62E-06
U-238	1.03E-04	6.59E-04	1.18E+05	0.90	7.00E-05
<b>TOTAL</b>					<b>7.88E-05</b>

**RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 5 HOUR**

Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.11E-04	6.58E-03	1.32E+05	0.08	8.94E-05
U-235	4.11E-04	6.58E-03	1.23E+05	0.02	1.62E-05
U-238	4.11E-04	6.58E-03	1.18E+05	0.90	6.98E-04
<b>TOTAL</b>					<b>7.84E-04</b>


**RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 5 HOUR**


Radionuclide	Air Concentration (pCi/m <sup>3</sup> )	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	9.90E-05	1.59E-03	1.32E+05	0.08	1.67E-05
U-235	9.90E-05	1.59E-03	1.23E+05	0.02	3.90E-06
U-238	9.90E-05	1.59E-03	1.18E+05	0.90	1.88E-04
<b>TOTAL</b>					<b>1.89E-04</b>

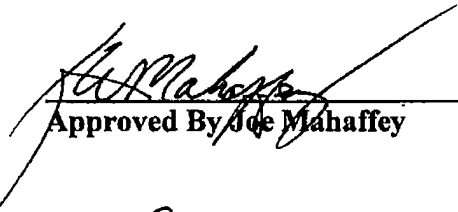
From 1<sup>st</sup> Qtr 2006 Report


6/14/06


WHITE PAPER  
ON THE  
RADIATION DOSE ASSESSMENT FOR FIREFIGHTERS  
DURING A GRASS FIRE

  
Prepared By Rick Roberts 12/1/00  
Date

  
Reviewed By Ed Wilkés 1 DEC 2000  
Date

  
Approved By Joe Mahaffey 12-5-00  
Date

  
Approved By Bob Nininger 12/14/00  
Date

  
Approved By Wil Zurliene 01/09/01  
Date





## ComRad Program Closeout Report



Prepared By:  
**MERCO, Inc.**  
1400 Simms, Suite 210  
Lakewood, Colorado 80401  
303-274-9686 303-234-0293 Fax  
Email: [mercoinc@merco-inc.com](mailto:mercoinc@merco-inc.com)  
August 2005

## TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
Background – Scope and Objectives	1
Equipment and Site Operations	5
Early Year Outreach Efforts-	7
Early Year Data Reporting-	8
MERCO equipment improvements and operation, 1999 – 2005 -	9
Later Year Outreach Efforts-	15
Radiation Data-	20
Significance of Results	21
Station Closeout and Removal	21
APPENDIX A – Bar Graph Plot Explanation	A
APPENDIX B – 1992 – 1998 Station Pu 239/240 Data	B
APPENDIX C – Plot of 1992-1998 Plutonium 238/240 values (aCi/m3)	C
APPENDIX D – Plot of 2001 – 2005 Quarterly Pu 238/240 values	D
APPENDIX E – Station Operational Site Check Data	I
APPENDIX F – Key Personnel	Z
Photo of COP Members	AA
Photos showing Station Managers and Alternates	BB
APPENDIX G – Aerial Photos of Stations	CC
APPENDIX H – Typical Wind Rose	DD

## FIGURES

	<u>Page</u>
Figure 1 – Ralston Station Revomal	1
Figure 2 – ComRad Station Location	2
Figure 3 – Two-stage Filter	4
Figure 4 – Laminar Flow Verification	4
Figure 5 – RAAMP Sampler	5
Figure 6 – Meteorological Station	5
Figure 7 – Relative Humidity Display	6
Figure 8 – Temperature Display	6
Figure 9 – Dewpoint Display	6
Figure 10 – Wind Direction Display	6
Figure 11 – Wind Speed Display	6
Figure 12 – Precipitation Display	6
Figure 13 – Atmospheric Pressure Display	6



Figure 14 – Station Upgrade	10
Figure 15 – Old MET Station	10
Figure 16 – Old RAAMP Station	10
Figure 17 – On-site Calibration	11
Figure 18 – Calibration of Wind Equipment	11
Figure 19 – Station Board Organization	12
Figure 20 – Access for Visually Impaired	12
Figure 21 – Gamma Detector	13
Figure 22 – Filter Preparation	14
Figure 23 – Applying Motor Oil to Filter	15
Figure 24 – One Month Exposed Media Stored in Transport Carrier	15
Figure 25 – Typical Sample Analysis Results	16
Figure 26 – 2003 Westminster Booth	19
Figure 27 – 2001 Northglenn Booth	19
Figure 28 – 2005 Scout Show	20
Figure 29 – 2005 Water Festival	20
Figure 30 – Northglenn Station Operational	20
Figure 31 – Northglenn Station Retired	20
Figure 33 – Northglenn Demolition	21
Figure 34 – Broomfield (Emerald Park) Station Operational	21
Figure 35 – Broomfield (Emerald Park) Station Semi-retired	21
Figure 36 – Emerald Park Demolition	21
Figure 37 – Westminster (Countryside) Station Operational	22
Figure 38 – Westminster (Countryside) Station Removed	22
Figure 39 – Countryside Demolition	22
Figure 40 – Arvada (Standley Lake) Station Operational	22
Figure 41 – Arvada (Standley Lake) Station Removed	23
Figure 42 – Standley Lake Demolition	23
Figure 38 – Arvada (Ralston) Station Operational	23
Figure 39 – Arvada (Ralston) Station Removed	23

## Background – Scope and Objectives

The U.S. Department of Energy (DOE)/Rocky Flats Environmental Technology Site (RFETS) and local community leaders began the Community Radiation Monitoring (ComRad) Program in 1990 as a cooperative effort. The Environmental Protection Agency (EPA) and the Colorado Department of Public Health and the Environment (CDPHE) also were involved.

ComRad provided an independent measure of environmental levels of airborne radioactivity in the northwest Denver metropolitan area. It operated initially with five monitoring stations located in the community surrounding the RFETS. These stations were located at: the Standley Lake Library (the first ComRad monitoring station that began operation in April 1991) and Ralston Recreation Center –both in Arvada. Other stations were in: Broomfield at Emerald Park; the city of Northglenn, at the Northglenn Recreation Center Complex; and the city of Westminster, at the Countryside Recreational Center. In 2001, the Ralston station was removed as requested by the city of Arvada.

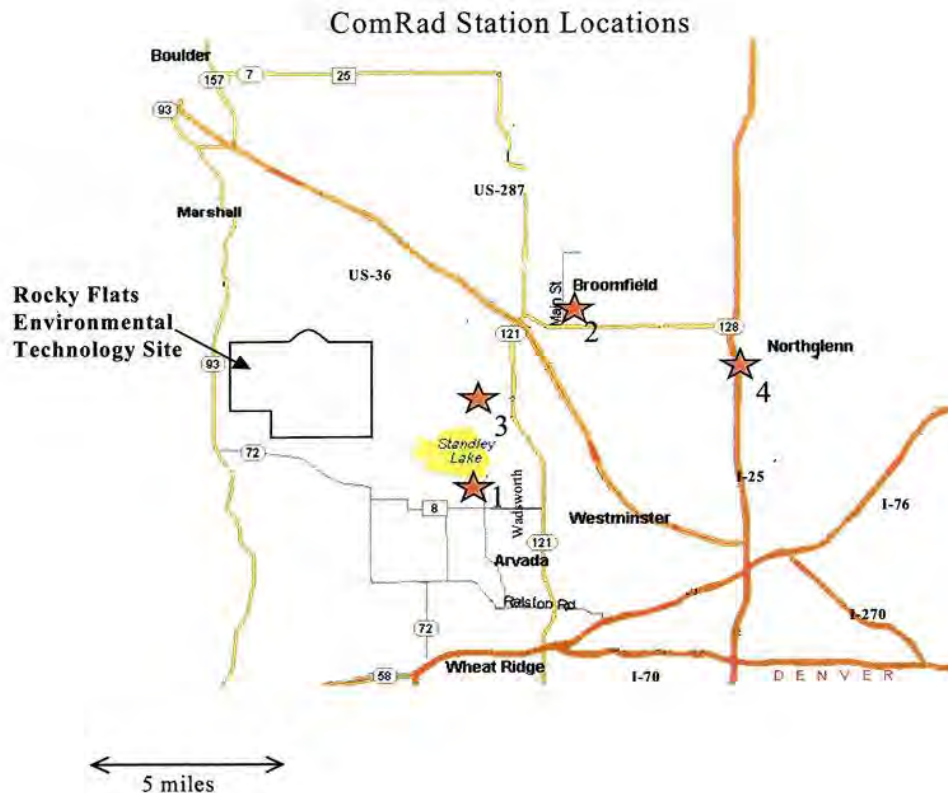


Figure 1 – Ralston Station Removal

Goals of the ComRad Program were: to provide an educational opportunity for local citizens, students and others to learn about the basic concepts of radiation; for them to learn about the existence, levels and significance of background radiation; and to understand the relative effects of the RFETS emissions to the total radiation within the surrounding community. Throughout its existence, ComRad educated more than 50 teachers on the basics of radiation. By 1998, Ms. Peg Roding was working with Metropolitan State College in helping train new teachers –thus opening new opportunities for the ComRad Program. Another major goal was to provide opportunities for surrounding communities to independently measure radiation levels at selected sites in the community that were independent of RFETS or the CDPHE programs. A third goal was to provide accurate, real-time weather data.

The ComRad Program was initiated by Mr. Robert Nelson, Acting Manager of the Rocky Flats Plant, in 1990. Five cities expressed interest in developing the monitoring program. Prior to 1999, Mr. Forrest Shoemaker directed the day-to-day Program oversight, as Program Coordinator between the local community and the Rocky Flats Field Office.

The Rocky Flats Citizens Advisory Board (RFCAB) was founded in 1993 as one of the Site Specific Advisory Boards (SSABs) for the Department of Energy Nuclear Weapons Complex and operated under the rules and provisions of the Federal Advisory Committee Act (FACA). The Board was funded through a grant from the Department of Energy and was organized as a Colorado non-profit corporation. It provided administrative funding and hired MERCO in 1999 to assume day-to-day operation of the ComRad Program for the ComRad Oversight Panel.



1. Arvada – Standley Lake Library – 8485 Kipling
2. Broomfield – Emerald Park – 295 Main Street
3. Westminster – Countryside Recreation Center – 10470 Oak Street
4. Northglenn – Recreation Center – 11701 Community Center Drive

Figure 2 – ComRad Station Location

A ComRad Oversight Panel (COP), consisting of technical representatives from the cities of Arvada, Broomfield, Northglenn, and Westminster, Jefferson County, and the Department of Energy, provided indirect oversight of the ComRad Program. The RFCAB had responsibility, as the grant recipient from DOE, to: oversee the selection of contractors and their program management; receive, review and pay all invoices; and other fiscal responsibilities. ComRad solicited teachers to manage the daily operations of the Program. The COP met at least quarterly to review Program progress.

An overriding emphasis throughout the early years was the degree of community service performed by the ComRad teachers. Teachers frequently gave presentations to faculty members



at their own and other schools, explained the Program to city officials, engaged in discussions at various civic groups, and staffed booths at educational fairs and city events.

During the early years, ComRad teachers completed 160 hours of training on radiation concepts, dose assessment, instrumentation, community and media relation, meteorology, atmospheric dispersion and air monitoring history of Rocky Flats. In addition, they toured the Nevada Test Site, had hands-on training at the EPA Laboratory in Las Vegas and the Los Alamos National Laboratory in New Mexico.

### **Equipment and Site Operations**

ComRad managers, primarily Mr. Jim Mitchell, the Assistant Program Coordinator, prepared monthly reports from March 1992 to April 1996. Mr. Mitchell stopped working for the Program in 1995 because of budget cuts. Subsequently, reports were issued on a quarterly basis from the Second Quarter 1996 until Second Quarter 1998. Initial reports identified Program participants, its purpose, equipment used, concentrations of air monitoring, weather/gamma radiation data, and had a glossary of terms. In August 1992, the Reports periodically began graphing the radioactivity concentrations and sample activities. That same month, it began listing points of contact (POCs) for the Department of Energy Field Office, Community Technical Representatives, POCs for the CDPHE, EG&G Rocky Flats, and addresses for the ComRad Station Managers. A Station newsletter began appearing in October 1992. An Executive Summary was added in February 1993. In March 1993, the Report began listing quarterly thermoluminescent dosimeter station readings for the previous year. Photographs and brief biographies of each Station Managers and Alternates appeared in the May 1993 issue. Periodic technical problems (e.g., the inability of bulletin board to receive weather data) were discussed in the First Quarter 1997 report. Reports were maintained at the Public Reading Room of the Front Range Community College at 3645 West 112<sup>th</sup> Avenue, Westminster and the Standley Lake Library, 8485 Kipling, Arvada. Copies of the early reported were transferred to the archive at the Front Range Community College in 2005.

Each ComRad RAAMP station used equipment similar to those positioned around RFETS and was designed to sample airborne, alpha-emitting particles and airborne, ambient Gamma radiation. Initially, each station's collector had a single filter that was collected and changed the first Thursday of each month.

During the first eight or nine years, filter media were mailed to the US EPA Radiation and Indoor Environments National Laboratory in Las Vegas, NV. The Laboratory analyzed and returned the results. ComRad teachers incorporated the results into monthly reports. In January 1994, the Countryside Station experienced a rather large concentration. Repeat analysis was impossible because, during analysis, the entire filter media was destroyed during analysis. The analysis procedure then was changed so that half of the filter was analyzed and the other half was saved—as a backup check in case the original analysis contained suspected abnormalities. Fortunately, none of the other stations experienced similarly high concentration in January 1994 (or subsequently) and the Countryside Station returned to normal levels during the next sampling period.

In 1995, a two-stage filter collection began. The top portion was treated with oil to trap particulates larger than approximately 10 microns (mm) in aerodynamic diameter. The bottom fiberglass filter trapped particulates less than 10mm. This permitted more accurate analysis of the finer particles that might actually migrate into people's lungs. The samples from the impact collector and the glass filter were composited — i.e., combined into one sample. If resolution between large and small particles were ever desired, the archived half filters were available for that purpose.

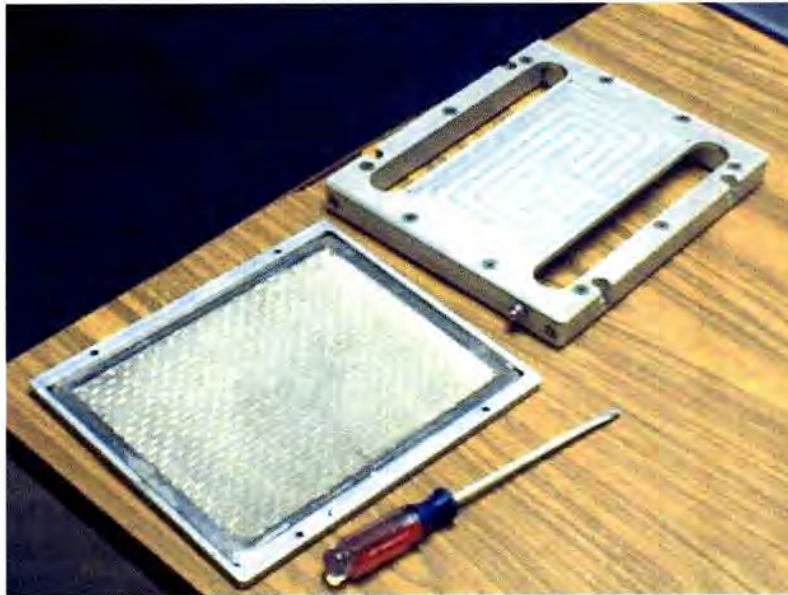


Figure 3- Two-stage Filter

A further upgrade involved the installation of volumetric flow-control and a more powerful blower that permitted a constant volumetric flow rate to be maintained throughout the sampling period. The critical flow control orifice at each of the five ComRad stations was checked for proper operation of the orifice once per quarter. Placing a calibrated laminar flow meter on top of the air intake checked the actual flow rate through the orifices. The airflow rate decreased as the filter became clogged during the month. Optimum flow rates of 40 cubic feet per minute (+/- 4 cfm) were maintained.

Results were reported in radioactivity measured as picoCurie (pCi) or attoCurie (aCi) per cubic meter ( $m^3$ ) of air. Each



Figure 4 – Laminar Flow Verification



sample typically collected 20,000-40,000 cubic meter of air each month. Results appeared to depend upon the season. Dry summer months allowed dust particles, along with radioactivity, to be collected by the sampling media. Snow and wet soils, during winter and spring, sometimes produced a reduction in the amount of radioactivity collected.

In 2002, the frequency of the filter analysis was changed from monthly to quarterly when tests demonstrated the ability to effectively analyze airborne concentration while spending approximately 70% less funds. Filters were still exchanged on a monthly basis.



Figure 5 - RAAMP Sampler



Figure 6 -Meteorological Station

Separate monitoring equipment at each station also sampled temperature, barometric pressure, humidity, wind speed/direction, and rainfall. The equipment balanced the needs of the northwest Denver metropolitan communities in providing a relative “hands free” sampling from that being done by RFETS yet provided low detection limits, reliability, and low operating costs. CDPHE and RFETS operated similar, but independent networks, of samplers for airborne particulate on the RFETS complex and in adjacent community locations.

Station displays cycled continually and provided visitors updates regarding the previously-mentioned meteorological values. Samples displays are shown below.

**Figure 7 - Relative Humidity in percent**



**Figure 8 - Temperature in Degrees**



**Figure 9 - Dewpoint in Degrees**



**Figure 10 - Wind Direction in degrees**



**Figure 11 - Wind Speed in Miles per Hour**



**Figure 12 - Precipitation in Inches**



**Figure 13 - Atmospheric Pressure in Inches**





### **Early Year Outreach Efforts-**

During the early years, ComRad instructors evolved some interesting tools and approaches in presenting information about Rocky Flats, radioactivity and data they collected. Some were:

- “Super C” began at Peck Elementary School (but was expanded to service clubs.) Sixth-grade students dressed in “Super C” costumes that were green (representing the environment), had a blue shield (representing the Colorado sky), and a gold C in the middle of the shield (for “Colorado, conserve, cleanup and care” of the environment.) Students, dressed in these costumes, would tell groups about manmade and natural radiation.
- ComRad produced a documentary video in 1994-95. It showed a close-up view of a ComRad station and educational aspects of the Program.
- ComRad teachers assisted the American Lung Association during their Clean Air Awareness Program and during annual events such as “Trade for Shade” and “Open Air-Ways”
- Station Managers meet with the Boulder Valley Challenger Lifelong Learning Center in 1995 to network the ComRad Program with the Center’s resources.
- Mr. Bill Jones, in 1996 at Arvada West High School, incorporated ComRad into his chemistry course by taking students on a tour of a ComRad Station. He also had speakers from Kaiser Hill (responsible for site management) and the DOE discuss the history, operation/cleanup of Rocky Flats, and nuclear waste disposal. Rocky Flats speakers gave demonstrations and discussed career opportunities.
- RFETS hosted an informational meeting for the station managers in 1996. Its goal was to acquaint ComRad teachers about future plans for RFETS, along with land use, safety and physical plant conversion. Individuals learned about the Accelerated Site Action Project that was designed to reduce plutonium risks to the public and employees in a rapid and economically viable fashion.
- Station managers expanded their expertise beyond radiation when, in the summer of 1995, members participated in annual training at Front Range Community College. Topics were water quality, water rights and law, water quality parameters, sampling techniques, and laboratory testing methods to detect chemicals and biological agents.
- Mr. Lonnie Newton developed a Life Science program for his seventh grade class that focused on ecology and wastewater treatment.
- Mr. Doug Smith, a Northglenn High School chemistry teacher, used ComRad stations’ gamma reading as part of his nuclear chemistry classes. Topics included natural



background radiation levels, nuclear decay, radon levels, radiation exposure and health. The school borrowed Geiger counters and radon meters from the ComRad Program.

- Program Managers discussed ComRad with Boy and Girl Scout groups.
- “Demo squads,” consisting of three students each, were started near the Countryside Station to train high school students and local residents about the fundamentals of radiation.
- Inquires regarding ComRad were received from as far away as Durango, CO.
- The teachers offered a radiation course through the Colorado School of Mines.
- Ecology became a major focus at Rocky Flats in 1996, especially regarding the Buffer Zone at Rocky Flats. ComRad participants learned that this 6200-acre zone consisted primarily of grassland, open water, marshes and a riparian forest habitat. One measure of a healthy ecosystem is its diversity index. The Buffer Zone was one of the richest and ecologically-healthy areas in the United States: having over 500 species of plants, 170 species of birds and about 40 mammal species. Two endangered species used this area as their home. Two dominant grasses are the rare big blue stem and little blue stem.
- In March 1997, Program Managers attended a training session concerning the RFETS cleanup progress. Issues included the Ten-Year Plan, the Rocky Flats Cleanup Agreement, ground- and air-monitoring efforts, and deactivation and decommissioning. The managers obtained added insight in being able to answer questions posed by concerned citizens.

### **Early Year Data Reporting-**

Appendix A contains tabulated and graphical radiation results, as reported by ComRad since 1992. If the reader inspects monthly reports, one will observe minor discrepancies between data. The author selected the most recent reports and values because it appears the data was reviewed later. Some weather data is also included for each station. More detailed weather data, such as wind roses, also were printed in quarterly reports. This Closeout Report chose not to include thermoluminescent dosimeter readings posted each year.

ComRad hired contractors for community liaison and to assist in developing public education and outreach programs, prepare written reports and present the surveillance data at Quarterly Exchange Meeting and at meetings (bimonthly or quarterly) of the ComRad Oversight Panel, or to other organizations, as requested. In addition, contractors participated in special meetings to inform the local communities about radiation surveillance and respond to citizen questions and concerns.

Periodically, the contractors met with the COP to update representatives and reconfirm both short- and long-term goals and objectives. Work was divided into: a) technical aspects of the monitoring program; and b) the community education and outreach aspects. Contractors made

recommendations to enhance the Program. They designed and implemented specific details to accomplish the COP-approved objectives. The COP ensured that the RFCAB-selected contractor was responsible for maintaining and conducting all aspects of the Program. Work included: making presentations to civic groups, school children, and cities that promoted an understanding of science—including environmental radiation and its effects on human health; promoting a better understanding of environmental monitoring of weather and radiation; writing educational modules designed to educate students and citizens at a tenth-grade level regarding weather and radiation; and maintaining and upgrading the stations (as needed) to provide for real time weather data. Activities included maintaining the high-volume, Radioactive Ambient Air Monitoring Program (RAAMP) samplers, performing filter analysis, and developing and implementing an adequate Quality Assurance/Quality Control program to meet the needs of the end data users. No regulatory requirements existed regarding the RAAMP sampling.

During the first eight or nine years of the Program, local school science teachers performed most of the work at the monitoring stations as a means to incorporate the program objectives into the classroom environment. The teachers gave an oral report at data exchange meetings. In addition, a computer bulletin board was operated with the very limited data available to the community. An outside assessment of the Program indicated that the bulletin board site required special software to access and the data was available in a format that was incomprehensible. An impression was the monthly exchange of data had no scientific value because the instrumentation was poor. Maintenance work was periodic and information indicates that some work was completed by union workers at RFETS, MBR Electric—and possibly Marquez Engineering (unverified.)

### **MERCO equipment improvements and operation, 1999 – 2005**

In 1999, the COP contracted both educational and technical management to MERCO, who teamed with Boulder Energy Conservation Center (BECC)—a non-profit organization with strong educational and outreach background. MERCO retained one teacher, Margaret (Peg) Roding, to continue as a consultant, teacher and author. MERCO's overall goal, according to the contract, was to "provide management, community relations, and technical support services for the Community Radiation Monitoring program." It subsequently developed a baseline-planning document, including schedules, backup plans, and procedures that it updated annually.

Upon beginning its involvement, MERCO met with the ComRad Oversight Panel to discuss the goals and objectives of the ComRad monitoring program. Subsequently, MERCO evaluated the monitoring operation with respect to EPA guidelines for ambient air monitoring. It also evaluated the physical condition of the stations and their siting, prepared writing recommendations, briefed the COP and completed COP-approved station improvements and upgrades. MERCO also met with the COP to discuss the goals and objectives of the ComRad education and public outreach program. It evaluated the existing education and outreach program, including data reporting methods. Improvements continued during subsequent years for both the technical and education portions of the Program.



Figure 14 - Station Upgrade

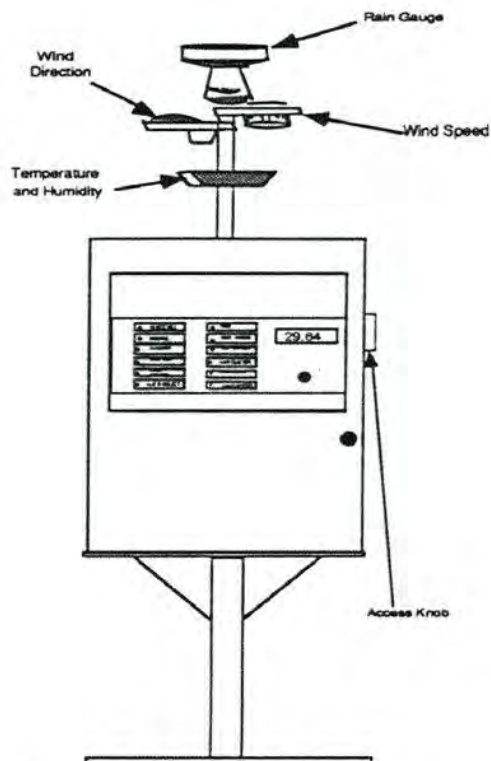


Figure 15 Old MET Station

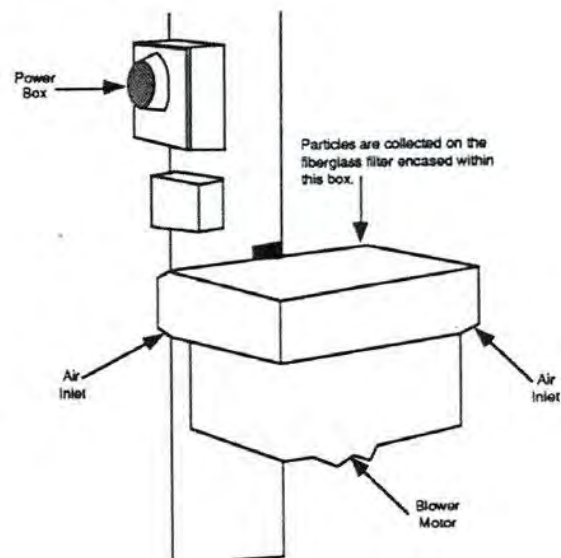


Figure 16 Old RAAMP Sampler

MERCO began maintaining the ComRad stations in October 1997 and upgraded the meteorological station at Standley Lake. Subsequently, MERCO was tasked to: develop an overall monitoring program framework, including tasks and schedules, with back-up plans for alternates; perform sample collection and laboratory analysis; analyze data and prepare a report; inventory station equipment, spare parts/equipment; recommend spare parts/equipment change out; and provide a quality assurance and quality control program for end data users. The COP immediately accepted MERCO's recommendation to upgrade the remaining stations because they did not meet either the overall goal of the ComRad program. These stations did not have



the capability of collecting data continuously, did not allow for data averaging or storage and weren't accessible through the Internet. Modems were installed. This permitted real-time data collection and transmission to and storage in MERCO computers. MERCO also added electronic bulletin boards to cycle through and display meteorological values.

The displays were replaced because the existing instruments could not be calibrated and they had passed their life expectancy. Rain gauges were not heated, consequently, snow precipitation measurements were not always accurate. Twice annually, MERCO calibrated the meteorology system. Wind direction sensors were checked for starting torque values and the linearity / orientation of the wind direction sensor. Temperature sensors were calibrated using a water bath at three distinct temperatures. The barometric pressure transducer was compared to a calibrated barometer. Introducing a known amount of water and comparing the output values from the data acquisition system against the calculated amounts calibrated the precipitation gauges. The relative humidity sensors were calibrated against a psychrometer.

The stored meteorological data was downloaded bi-weekly. MERCO performed quality assurance and quality control to validate the data as being meaningful and accurate. The contractor used the EPA recommended methodology and guidelines: *EPA QA Handbook for Air Pollution Measurement Systems* and EPA-450/4-887-013, June 1987, *On-Site Meteorological Program Guidance for Regulatory Modeling Applications*.



Figure 17– On-site Calibration



Figure 18– Calibration of Wind Equipment



MERCO continued the practice of producing monthly status reports, presenting sampling data at the Quarterly meetings, doing monthly filter exchanges and conducting weekly site inspections. Technicians recorded the hour meter readings, pressure gauge, wind speed/direction, wind chill, barometric pressure, dewpoint, humidity, temperature, rainfall, and battery voltage.

The log sheets indicated the condition of the RAAMP and meteorological equipment, the lighting system, power/wiring, paint, Plexiglas, instrument enclosure and overall cleanliness and appearance of the site. MERCO engineers continually validated the meteorological data. Averages, maximums, and minimums were calculated for parameters. Data were graphed and visually inspected for errors and deviations from expected behavior. Deviations were compared against like sensors to verify sensor performance. Wind direction, wind speed, precipitation and barometric pressure data were examined for similar trends. The relative humidity was graphed with temperature data and both were inspected for deviations from expected behavior (i.e., an inverse relationship versus temperature). Barometric pressure data also were graphed and examined for similar trends. Summary of this data collected during the weekly site visits at each station for the years 2002 – 2005 are presented in the Appendix. In addition, hourly values for the above weather parameters are included in the CD version of this report.

The stations displayed had a “Board One” that discussed radiation and metrological topics in general. The top of “Board Two” discussed the Department of Energy role in the ComRad Program. The middle portion briefly described the types of radiation. The bottom portion provided results of the previous quarter sampling. Similar information (excluding the quarter results) was presented in Braille along the display’s bottom.

MERCO was responsible for all of the instrumentation and associated wiring from the top of the electrical disconnect box to the systems; hence it maintained (or hired experts) to return components quickly to normal operation. Maintenance included quarterly flow verification checks. Samplers were checked on a quarterly basis to confirm proper operation and that they met the acceptance criteria of  $40 \text{ ft}^3/\text{min} \pm 4.0 \text{ ft}^3/\text{min}$  actual flow rate through the orifice.

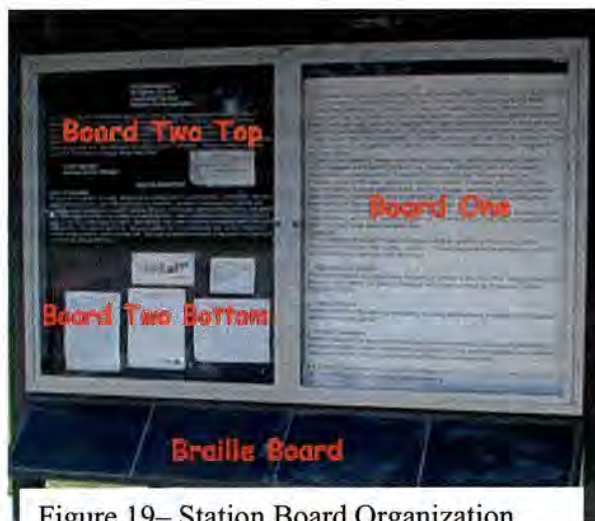


Figure 19– Station Board Organization



Figure 20 Access for Visually Impaired



Weekly field maintenance sheets recorded what stations were affected, the equipment needing repair, existing problems, the corrective action, parts used and length of time to correct the problems. Field sheets, whether weekly site checks, maintenance activity, calibration and flow verification information were quality checked (at a minimum) by the senior engineer or project manager. In addition, MERCO was responsible for the modem connection and the computer software used in the downloading of the meteorological data. The company also maintained the certification of the equipment (e.g., laminar flow meter) used to maintain the station.

The meteorological equipment at each station was calibrated at six-month intervals. The purpose of the equipment calibration was to verify the proper operation and orientation of the instruments. Each of the instruments on the tower was tested against a reference instrument to be sure it was reading accurately. The results had to be within a specified tolerance for that unit. Calibration included wind speed, wind direction, temperature, relative humidity, barometric pressure and precipitation verification.

The stations' meteorological and RAAMP monitoring equipment operated continuously since 1991. MERCO ensured the overall operation of the monitoring station equipment, completed routine troubleshooting and repair, calibration the equipment, and maintained a generally positive appearance of the stations and the nearby area.

MERCO maintained a log of station activities, prepared monthly written report of activities and delivered reports of quarterly flow verification tests and semi-annual calibrations to the COP.

The company logged all its maintenance activity, provided touch-up paint, repaired/replaced vandalized components and upgraded bulletin boards, as required. Use of gamma detectors, originally installed, was discontinued because the instruments had to be shipped outside of the United States for costly repair.

Once MERCO assumed management, they arranged for and procured Paragon Analytics, Inc. in Fort Collins, CO to analyze the filters for plutonium 238 and 239/240. MERCO obtained copies of Paragon's Quality Assurance and Quality Control procedures. Between 1999 – 2002, each month's media were analyzed separately. MERCO completed a filter exchange log each month that indicated: which numbered filter cartridge was installed and removed for the particular stations; the filter media number; the date/time the sampler was shut down and restarted; the elapsed hour meter reading; pressure gauge readings for zero, the old filter and the new filter; and general comments.



Figure 21 Gamma Detector



MERCO also maintained a complete set of Chain of Custody sheets for each month's media exchange. Beginning in 2002, filters from four RAAMP samplers were collected monthly from each RAAMP station, stored at MERCO and delivered to Paragon Laboratory once per quarter for quarterly composite analysis. Composite analysis means that the three monthly filters from each of the four stations were combined together to produce four composite samples that represented what material was collected at each station. Paragon reported the data to MERCO for interpretation and validation so that the plutonium activity data could be reported to the public. Plutonium data was available electronically at [www.comrad.org](http://www.comrad.org).

Great care was taken in preparing the filter media for the RAAMP sampler. The filter cartridges were prepared wearing powder-free Nitril or latex gloves. The oil impactor pads and the under-paper were cut to fit cartridges (8" x 4 3/4") by first cleaning the cutter blade and surface. The filter and oil impactor pads were installed by wiping down the filter cartridge with a paper towel and cleaning the cartridge with mild cleaner, if necessary. The filter cartridge was opened by

loosening four recessed bolts and removing the top part of the filter cartridge and then placing the quartz fiber filter in each cartridge—placing the “rough” side of the filter facing up. The top part of the filter cartridge was replaced and the recessed bolts were tightened. The under-paper and oil impactor pad were placed in position on top of each filter cartridge. Next, using a small oilcan, a small amount of synthetic motor oil was added to the impactor pad until it thoroughly covered and barely



Figure 22– Filter Preparation

saturated the pad. The filter cartridges then were placed in a plastic carrying case for transport.

Several quality checks occurred at each station. First, each air sampler was checked for external damage or evidence of electrical or mechanical malfunction. The sampler cabinet padlock was unlocked and the sampler was turned OFF only long enough to change the filters or for maintenance.

The new filter was rechecked to ensure it contained an oil impactor pad and fiberglass backup filter. Next, the IDs on the cartridges were checked to see that they matched the station ID. If the clean cartridge had oil on the rim, the cartridge was wiped clean. The zero reading of the digital pressure gauge, the hour meter reading and time off were recorded on the Air Quality Field Log. The exposed filter cartridge was removed by pulling it directly out of its compartment using finger pressure to gently release any built-up vacuum that was holding the filter. The fiberglass filter and oiled impactor pad were inspected for oil, tears, insects, damage and spots or abnormalities and observations were entered on the Log regarding the condition of both fiberglass filter and oiled impactor pad. Insect(s) were left on the filter or pad and their existence was noted on the Log. The old cartridge was placed in a plastic carrying case for





Figure 23– Applying Motor Oil to Filter



Figure 24– One Month Exposed Media Stored in Transport Carrier

transport; sliding the clean cartridge into the air sampler compartment, ensuring that the side labeled with the station ID pointed outward and was snug against the bottom gasket, seating the new cartridge. The cartridge compartment was closed and the sampler cabinet door was latched and locked. The sampler was turned back ON. The following information was entered on the Log: Date, Sampler number, ON time, Digital pressure gauge reading ON and problems (e.g., equipment failure, unusual observations, insects, site operations or weather conditions).

The old filter cartridges were handled with powder-free gloves. (If the gloves became contaminated with particulate matter from one filter cartridge, a new pair of gloves were substituted before processing a new filter cartridge.) Loosening the four recessed bolts and removing the top part of the filter cartridge opened the filter cartridges. The quartz fiber filter were carefully removed so as to not touch the exposed surface of the filter. The filters were carefully folded in half twice by folding the exposed surface on to itself and placing in a closed plastic zip-lock type baggie.

The impactor pad was removed from the top of the filter cartridge and the pad also was carefully folded in half by folding the exposed surface on to itself. Likewise, the folded filter was placed in a closed plastic zip-lock type baggie.

The samples then were placed in the appropriate envelope along with a Chain-Of-Custody form. These were labeled with the appropriate sample numbers having a SYMM code where: S = Station Identifier (a numeric value), YY = Year (i.e., 02 for 2002) and MM = Month (i.e., 04 for April). These envelopes were placed in a large envelope with a completed Chain-Of-Custody form and delivered to the Paragon representative.

Paragon analyzed the samples within five weeks and returned the results with a report. See below.

### **Later Year Outreach Efforts-**

Students at Standley Lake High School designed an impressive Web page for the ComRad program under the direction of Mr. Kim Natale. MERCO hired some of these students to enhance this Web page to include certain data files, such as the meteorological information and



the laboratory results of the sampling analysis. The ComRad Web site was linked to other relevant Web sites, such as the EPA because the Agency had developed curricula that encourage students to think more critically and creatively about air pollution problems and the alternatives for resolving them. MERCO added other pertinent Web sites as the Program evolved.

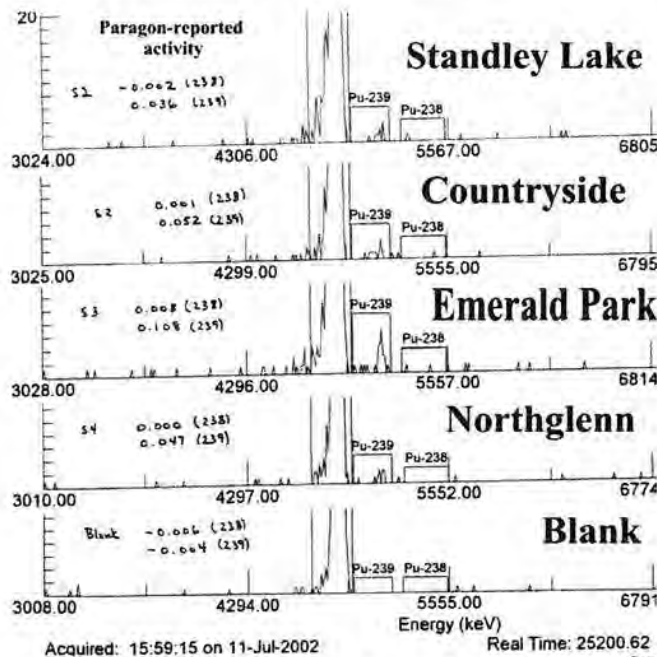


Figure 25– Typical Sample Analysis Results

MERCO also was tasked to: develop an overall program for community outreach; possibilities include, but are not limited to, station tours, school and civic group meetings, local government interface, and other public liaison. MERCO built on the existing positive resources and relationships with the previous teacher station managers and developed and continued to maintain a Web Page for information exchange, public information and communication outreach. MERCO presented analytical data at the community Quarterly Data Exchange Meeting. A key assignment was preparing written educational materials and serving as a technical liaison to the community. MERCO developed educational materials that summarized the impacts of Rocky Flats, basic concepts of radiation, and basic concepts of meteorology. MERCO was tasked to incorporate the ComRad stations into school curriculums. Both the COP and MERCO responded to citizens' questions.

Specific outreach activities between 1999 – 2005 included:

- *Eye on Northglenn video* – MERCO worked with the local cable channel in Northglenn to feature ComRad on a program hosted by the city's mayor.
- *Web site* – A ComRad web page was developed and posted by local high school students. The web page contained data collected from the monitoring stations, resources for teachers, radiation classroom activities, activities developed in Colorado School of Mines (CSM) Teacher Enhancement course, radiation related links, "Ask the Scientist"

interactive quiz and ComRad current events. This activity served several purposes: to get students involved in the program; to globally disseminate the information; and to have the data and activities available for the teachers to use in the classrooms.

- *Articles developed for local papers* – Eleven articles were developed in 2001-2002, seven were published in local newspapers and newsletters. The newspapers were interested in publishing general ComRad articles, but not the technical radiation articles. The papers felt the technical articles were too instructional and not something that would appeal to readers.
- *Station bulletin boards* – A display was designed and installed at each monitoring station. The display was changed at least quarterly to include current activities and to keep people interested. The display contained information about the program, the ComRad logo, the web site, CSM courses, quarterly plutonium data, a station map with addresses, contact information and pictures of recent activities. The display served as an avenue of communication with the community and attracted people stopping at the station.
- *Colorado School of Mines Teacher Enhancement Courses*- The Colorado School of Mines (CSM) Teacher Enhancement Program was researched and deemed a worthwhile activity. Two courses were developed and taught by ComRad, with a total of 16 participants. Both courses received excellent evaluations from the participants. MERCO followed up with participants from both sessions to discuss use of class materials and the need for additional resources. The CSM courses put MERCO in touch with teachers and indirectly with students and their parents; thereby extending ComRad information into the community. As part of the first course, a ComRad logo was developed to tie all of the program activities together and increase recognition of the whole program.
- *ComRad brochure* – MERCO developed a tri-fold, two-sided brochure. The brochure contained general, technical and educational information about the program, as well as contact information for further discussion. The brochure was developed to distribute at meetings and presentations.
- *Video* – ComRad worked with Westminster High School to develop a student-produced video, brochure and poster about the ComRad program. This activity was in association with an existing media program at Westminster High School. The final products of this activity were free to the ComRad program. This activity served three purposes: to have an informational ComRad video, poster and brochure; to involve students in the program; and to develop good public relations with the local school.
- *Contacts and presentations to local high schools* – ComRad developed a short presentation for high school principals. MERCO contacted high schools in the communities surrounding Rocky Flats and set up appointments to meet with the principals to discuss ComRad. This activity highlighted the ComRad program and its resources and presented the forum idea for feedback and feasibility. Six area high schools were sent introduction letters. The letters were followed up with phone calls and meetings with two of the high school principals. The principals at both of these schools were very receptive to the program and open-minded to the forum in which schools would compete regarding knowledge of radiation.
- *Mentoring program* –MERCO developed a mentoring program for students. Local businesses that used radiation were contacted. Twenty-three calls were made; eight of these companies were receptive to giving tours or presentations exemplifying radiation uses at their facility. The others were either not set up for tours or did not use radiation in

the way we anticipated. This program also had the potential to put students in touch with industry professionals to help with career guidance or school project support.

- *Colorado Alliance for Environmental Educators (CAEE)* –This organization was contacted to determine the potential for a partnership. They were in the process of developing a database of environmental education curricula in the state. They had an educational newsletter that was mailed.
- *Equipment loans* – Geiger counters and radon kits were loaned to teachers for use in their classrooms. This program served three purposes; to facilitate the addition of radiation curricula into local classrooms; to spread the word about the ComRad program; and to develop good public relations with the local community.
- *Teacher Recruitment* - The ComRad program historically involved teachers. Previously, the teachers were station managers. MERCO worked with Peg Roding and Kim Natale since the beginning of the contract. Rich Borinsky was briefly involved in the early stages of the contract. These three were involved in the program since the early 1990's. Mr. Natale's involvement was minimal due to his other commitments. Ms. Roding was a terrific asset to the program, being instrumental in the development of two CSM courses. None of the other managers were interested or available to join the Program. Lynda James was recruited into the program in February 2002. Ms. James was a participant in one of the CSM courses and exhibited interest in joining the program. She was involved in module development and outreach presentations.
- *Forum* - The idea of a high school forum was raised at a COP meeting. A student competition would be developed to discuss/debate a specific issue at RF, such as long-term stewardship of the site. MERCO evolved this idea and gathered information about logistics and feasibility of the activity. A detailed budget was developed to assess the feasibility of this activity. While making contacts for and developing the forum, MERCO identified several similar educational programs. In order to avoid duplication of existing programs and to learn from successful programs, some research of these programs was conducted. Programs researched include Mathematics, Engineering and Science Achievement (MESA), Science Olympiad, Destination Imagination and Odyssey of the Mind.
- *Educational modules* – MERCO developed a topic outline for educational modules. Topics were researched and articles, activities and resource sheets were developed to comprise a unit for each topic. Each of the modules contained articles accompanied by related classroom activities. An activity Answer Key also accompanied each module. The modules were written in a ninth-grade reading level to appeal to the general public, as well as high school students. Topics for the modules were: Introduction, Understanding Radiation, Natural Radiation, Human-made Radiation, Radiation Exposure, RFETS History, Radon, Weather, RFETS Closure, Radioactive Decay, ComRad Program, Radiation Health Risk, History of RF Buildings and a Teachers' Guide.
- *Quarterly report* - MERCO made significant changes to the quarterly report, including adding pictures of activities, adding comparisons so the reader could better relate to the data, adding historical data graphs and adding more detailed descriptions of the technical work. Windroses, showing the circular distribution of wind direction and velocities, were added in about 2001.



- *Informational Booths* – MERCO organized and hosted four booths at local community events, including Northglenn July 4<sup>th</sup> Festival, Westminster Faire, RFETS Family Day and Broomfield Days. The booths acted as an avenue to inform attendees about the program, station locations and the resources available. The booths contained program related informational handouts, the educational module binder, the metrological equipment demo, self-contained breathing suit from RFETS and a Geiger counter with every day radiation sources –such as a smoke detector.
- *Outreach Presentations* – MERCO organized two presentations to interested groups. City of Broomfield Day Camp was contacted and a presentation was arranged. Fifty children between the ages of 6 and 12 were given a presentation about the ComRad program including, hands on Geiger counter and MET station demonstrations and interactive question and answer sessions. MERCO also gave presentations to approximately 20 scout members in Northglenn, that was identified at a July 4th festival booth.



Figure 26- 2003 Westminster Booth



Figure 27- 2001 Northglenn Booth

Early ComRad budgets were \$200,000. This was reduced to \$150,000 for 1999-2002. This money paid for all project activities, including the Contractor's services and any expenses related to station upgrades, repair and maintenance, as well as analytical services. By 2002, MERCO developed detailed budgets that identified technical and educational categories. Each of these were subdivided into projection management, engineers and technicians. Other direct costs included telephone and web services plus postage, printing, travel expenses and other costs of doing business. The budget also accounted for annual inflation. The Contractor tracked work performance against each annual budget and reported expenditure monthly to the COP. In 2003, the budget was reduced to \$120,000. The COP then requested that both the Technical and Educational portion each provide four subentries, other direct cost, monthly expenses, cumulative year-to-date expenses, and monthly breakouts showing how much had been spent to date.





Figure 28– 2005 Scout Show



Figure 29– 2005 Water Festival

### Radiation Data-

The Minimum Detectable Concentration (MDC) typically reported was approximately 0.1 picoCurie /sample or 2.5 attoCurie/m<sup>3</sup>. This was extremely low. Results below these levels were not numerically significant. A couple of examples are given below for comparison purposes.

These numbers can be compared with the term derived air concentration (DAC) used by regulatory agencies for the protection of workers exposed to plutonium. According to the web site for the Federal Agency for Toxic Substances and Disease Registry (ATSDR), the DAC for plutonium is seven picoCuries per cubic meter or 7,000,000 attoCuries per cubic meter. Thus the MDC of 2.5 attoCuries per cubic meter is *two million times less* than the so-called "derived air concentration" given by ATSDR as protective of human worker health.

Using this information, and assuming each attoCurie per cubic meter is 1.0 inch in height on a graph; if the graph depicted the 7,000,000 attoCuries per cubic meter DAC, the DAC line would be located 110 miles above the top line (2.5 attoCuries per cubic meter) of the collected samples presented on the graph. To give the reader some perspective, 110 miles would be the distance, as the crow flies, from the capitol building in downtown Denver, CO to the southernmost suburbs in Pueblo, CO.

Peaks in the graphs can represent several factors. If there were a peak on one sampler, it was possible that a sampler picked up an unusually high number of radioactive particles or one very large (relatively speaking) particle. Indicators confirming this fact included: none of the other samplers peaked at the same time and normal readings were recorded in months following. See the earlier statement that, in January 1994, the Countryside Station experienced a rather large concentration. Because sampled plutonium is attached to particles in the air that ultimately come from the soil itself. One peak in an area, if it were due to increased pollution, should not dissipate in a short period of time. On the other hand, if the plutonium peak were due to some airborne source, such as the burning of a radioactive substance, one would expect to see peaks on

all the stations due to the extreme mobility of smoke. Peaks were often seen in drier periods on all the stations. In drier months, the soil was blown around and the samplers picked up more particles. In wetter months, moisture covering the soil kept it from becoming airborne; therefore, fewer particles were collected and lower readings are recorded.

### **Significance of Results**

Another number used in discussing radiation hazards is the *10 millirem standard*. Under regulations promulgated in 1989, National Emissions Standards for Hazardous Air Pollutants (NESHAPS) limited the radiation dose to the public from airborne radionuclide emissions from DOE facilities to 10 millirem per year (mrem/yr) effective dose equivalent (EDE). Rem is an abbreviation for *roentgen equivalent man*, and a millirem is one thousandth of a rem. The rem units take into account various pathways (such as breathing) and conversion factors that give the relative risks associated with different sources of radiation. The conversion factor, that takes into account how much air a person breathes, and the relative hazard of the types of radioactive particles breathed in, for plutonium is equal to  $5.71 \times 10^{12}$  rem/(Curie/m<sup>3</sup>).

10 millirem per year for 50 years is 500 millirem, or 0.5 Rem. Therefore, 0.5 Rem corresponds to 87,600 attoCuries per meter<sup>3</sup>. Thus, the MDC of 2.5 aCi/meter<sup>3</sup> and the current worst-case observed levels of about 1 attoCurie/meter<sup>3</sup> are below the "10 millirem standard per year" by a factor of several thousand.

Another perspective is given by the following consideration. According to the General Employee Radiological Training (GERT) manual used at Rocky Flats, exposure to radiation at the level of 100 millirem/year for 70 years would shorten life expectancy by 10 days. Thus, one could argue that exposure at the level of the MDC of 2.5 attoCuries/meter<sup>3</sup> for the same 70 years would shorten life expectancy by less than a minute.

Quarterly reports presented graphs showing historical data taken at the four ComRad stations. The Countryside station was closest to Rocky Flats and historically showed slightly higher concentrations than the other stations.

### **Station Closeout and Removal**

Remainder of this page and all of next two pages devoted Discussion of Station Removal including photograph (showing before and after) – probably of each station. I may go back and include the Ralston Station photo currently in Appendix F. Demolition photos will show different aspects from the four stations.

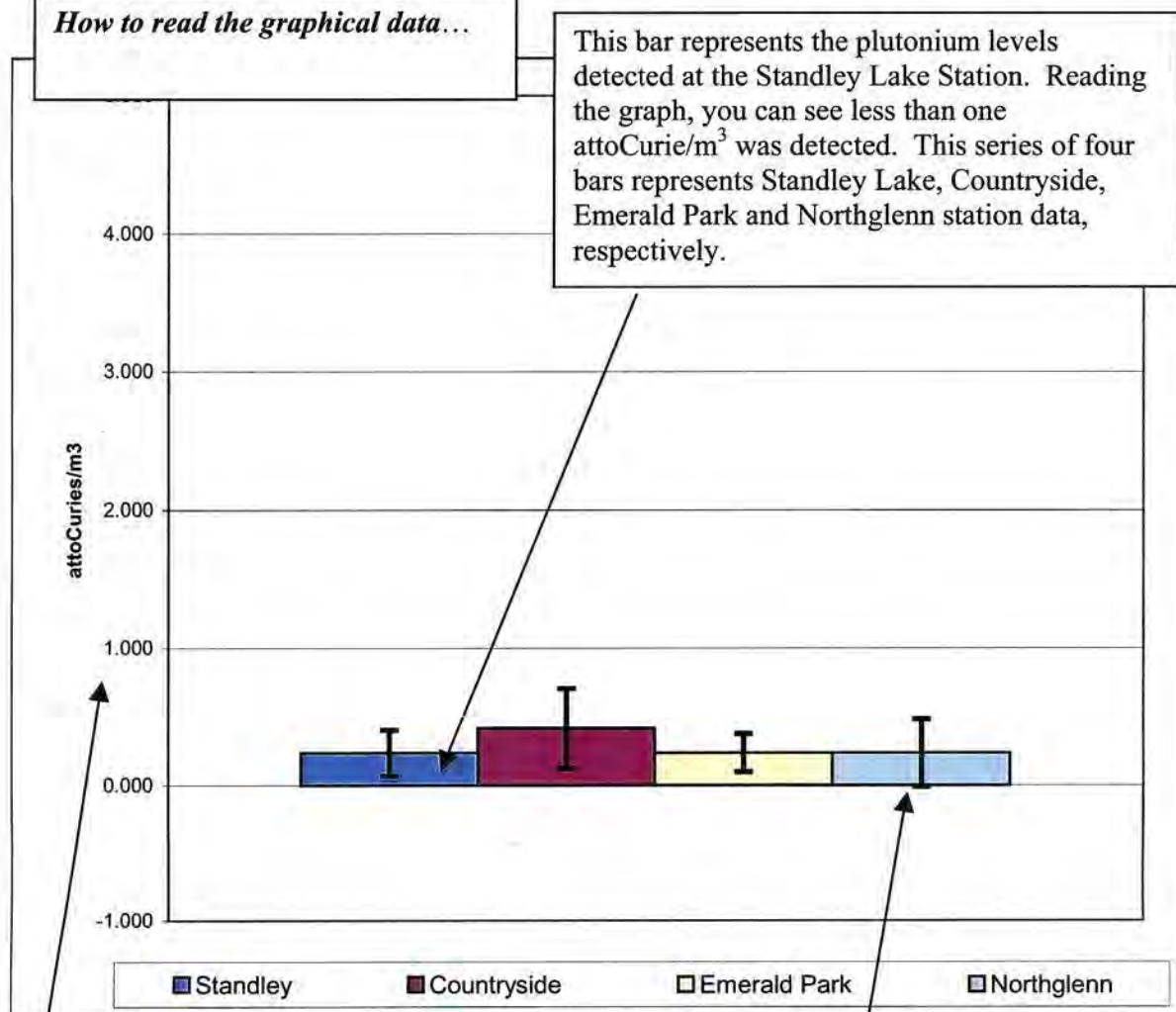


## APPENDIX A - BAR GRAPH PLOT EXPLANATION

Data collected by the teachers during the first half of the ComRad Program, along with data collected by MERCO is summarized in two sets of tables and two sets of graphs. Data is presented for each of the five stations during their operating period.

As an aid in understanding some of the plotted information found in achieved reports, key elements are highlighted below.

### *How to read the graphical data...*



Curies are the traditional unit used to measure the amount of radioactive material. One Curie is equal to  $3.7 \times 10^{10}$  radioactive disintegrations per second. Thus, an attoCurie is one billionth of a billionth of a Curie or  $3.7 \times 10^{-8}$  (0.000000037) disintegrations per second. To put this in perspective, this proportion would be like one teaspoon of vinegar added to a 35,000 gallon swimming pool, approximately 25' x 20' x 9' in dimension.

This "I" beam estimates how much the actual values may be in error from that reported. The length of the error bar represents the 95% confidence limit, i.e. there is a 95% probability that the exact value lies between these limits.

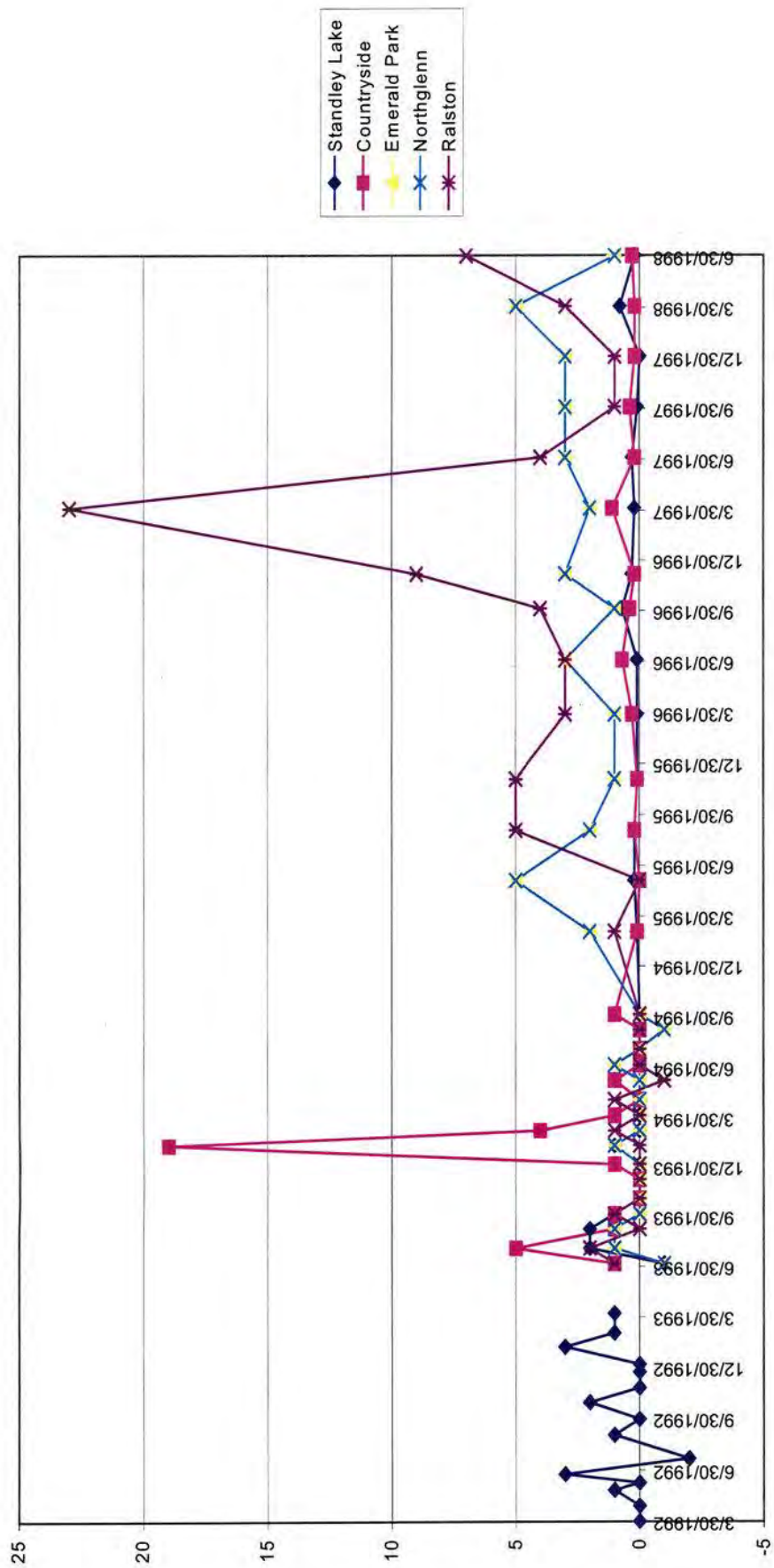
# APPENDIX B – 1992 – 1998 STATION Pu 239/240 DATA

## COMRAD MONITORING STATIONS' AMBIENT AIR MONITORING PUTONIUM 239/240 DATA

STANDLEY LAKE					COUNTRYSIDE					NORTHGLENN					EMERALD PARK				
Filters in Composite Sample	Volume of Air Filtered (m3)	End Sampling Period	[Pu] (aCi/m3)	Confidence Interval (CI)	Volume (m3)	[Pu] (aCi/m3)	Confidence Interval (CI)	Filters	Volume (m3)	[Pu] (aCi/m3)	Confidence Interval (CI)	Filters	Volume (m3)	[Pu] (aCi/m3)					
3	37780	3/30/1992	0	0.4	-	-	-	-	-	-	-	-	-	-					
2	32381	4/27/1992	0	0.5	-	-	-	-	-	-	-	-	-	-					
2	32458	5/25/1992	1	6	-	-	-	-	-	-	-	-	-	-					
2	33199	6/22/1992	3	0.9	-	-	-	-	-	-	-	-	-	-					
2	37524	7/20/1992	-2	0.8	-	-	-	-	-	-	-	-	-	-					
3	43943	8/31/1992	1	0.7	-	-	-	-	-	-	-	-	-	-					
2	32993	9/28/1992	0	0.1	-	-	-	-	-	-	-	-	-	-					
2	32403	10/28/1992	2	0.2	-	-	-	-	-	-	-	-	-	-					
2	28221	11/23/1992	0	0.1	-	-	-	-	-	-	-	-	-	-					
2	29230	12/21/1992	0	0.1	-	-	-	-	-	-	-	-	-	-					
1	15501	1/4/1993	0	0.1	-	-	-	-	-	-	-	-	-	-					
1	27059	2/4/1993	3	0.1	-	-	-	-	-	-	-	-	-	-					
1	36830	3/1/1993	1	0.5	-	-	-	-	-	-	-	-	-	-					
1	37002	4/5/1993	1	0.1	-	-	-	-	-	-	-	-	-	-					
Lost Sample					-	-	-	-	-	-	-	-	-	-					
1	38418	5/3/1993	0	0.1	-	-	-	-	-	-	-	-	-	-					
1	30019	7/5/1993	-1	0.2	1	29096	1	1	37958	0	0	1	30143	-1					
1	28623	8/2/1993	2	0.1	1	26260	5	1	32027	6	1	1	28719	1					
1	35751	9/6/1993	2	0	1	37388	1	0	1	38739	1	1	29407	1					
1	28872	10/4/1993	1	0.1	1	28018	1	1	1	32465	1	1	31268	0					
1	28872	11/1/1993	0	0	1	28872	0	1	1	36815	0	0	1	32505					
1	35759	12/6/1993	0	0.1	1	40972	0	0	1	36818	0	1	1	39675					
1	30889	1/3/1994	0	0.1	1	35394	1	1	1	39001	0	1	1	33327					
1	27694	2/7/1994	1	0.1	1	43361	19	3	1	38136	0	0	1	35245					
1	27193	3/7/1994	0	0	1	34169	4	2	1	39382	0	0	1	32825					
1	24216	4/4/1994	0	0	1	28436	1	1	1	36692	0	0	1	31695					
1	24319	5/2/1994	0	0.1	1	32380	0	1	1	37027	1	1	1	31844					
1	24311	6/6/1994	1	0.2	1	31954	1	1	1	33027	1	1	1	35205					
1	18523	7/4/1994	0	0.2	1	28182	0	0	1	34375	0	0	1	27554					
1	17701	8/1/1994	0	0.1	1	34670	0	0	1	33033	0	0	1	35113					
1	32591	9/5/1994	0	0.1	1	31737	0	0	1	34220	0	0	1	34807					
1	30309	10/3/1994	0	0.1	1	13408	1	1	1	34263	0	0	1	38016					
3	N.R.	3/2/1995	0.1	0.4	3	N.R.	0.1	0.3	3	N.R.	0	0.3	1	N.R.					
3	N.R.	6/2/1995	0.2	0	3	N.R.	0	0.1	3	N.R.	0.3	0.3	1	N.R.					
3	N.R.	9/1/1995	0.2	0.1	3	N.R.	0.2	0.1	3	N.R.	0.1	0	1	N.R.					
3	N.R.	12/2/1995	0.1	0.1	3	N.R.	0.1	0.1	3	N.R.	0	0.3	1	N.R.					
3	N.R.	3/27/1996	0.1	0.1	3	N.R.	0.3	0	3	N.R.	0.1	0.1	1	N.R.					
3	N.R.	7/3/1996	0.1	0.1	3	N.R.	0.7	0.3	3	N.R.	0.2	0.1	1	N.R.					
3	N.R.	10/3/1996	0.7	0.4	3	N.R.	0.4	0.2	3	N.R.	1.5	0.5	1	N.R.					
3	N.R.	12/5/1996	0.3	0.3	3	N.R.	0.2	0.2	3	N.R.	0.3	0.3	1	N.R.					
3	N.R.	4/3/1997	0.2	0.1	3	N.R.	1.1	0.5	3	N.R.	0.4	0.2	1	N.R.					
3	N.R.	7/3/1997	0.3	0.3	3	N.R.	0.2	0.2	3	N.R.	0.3	0.2	1	N.R.					
3	N.R.	10/2/1997	0.1	0.1	3	N.R.	0.4	0.2	3	N.R.	0.6	0.3	1	N.R.					
3	N.R.	1/1/1998	0	0.1	3	N.R.	0.2	0.1	3	N.R.	0	0.1	1	N.R.					



APPENDIX C - Plot of 1992-1998 ComRad Station Plutonium 238/240 values (aCi/m3)



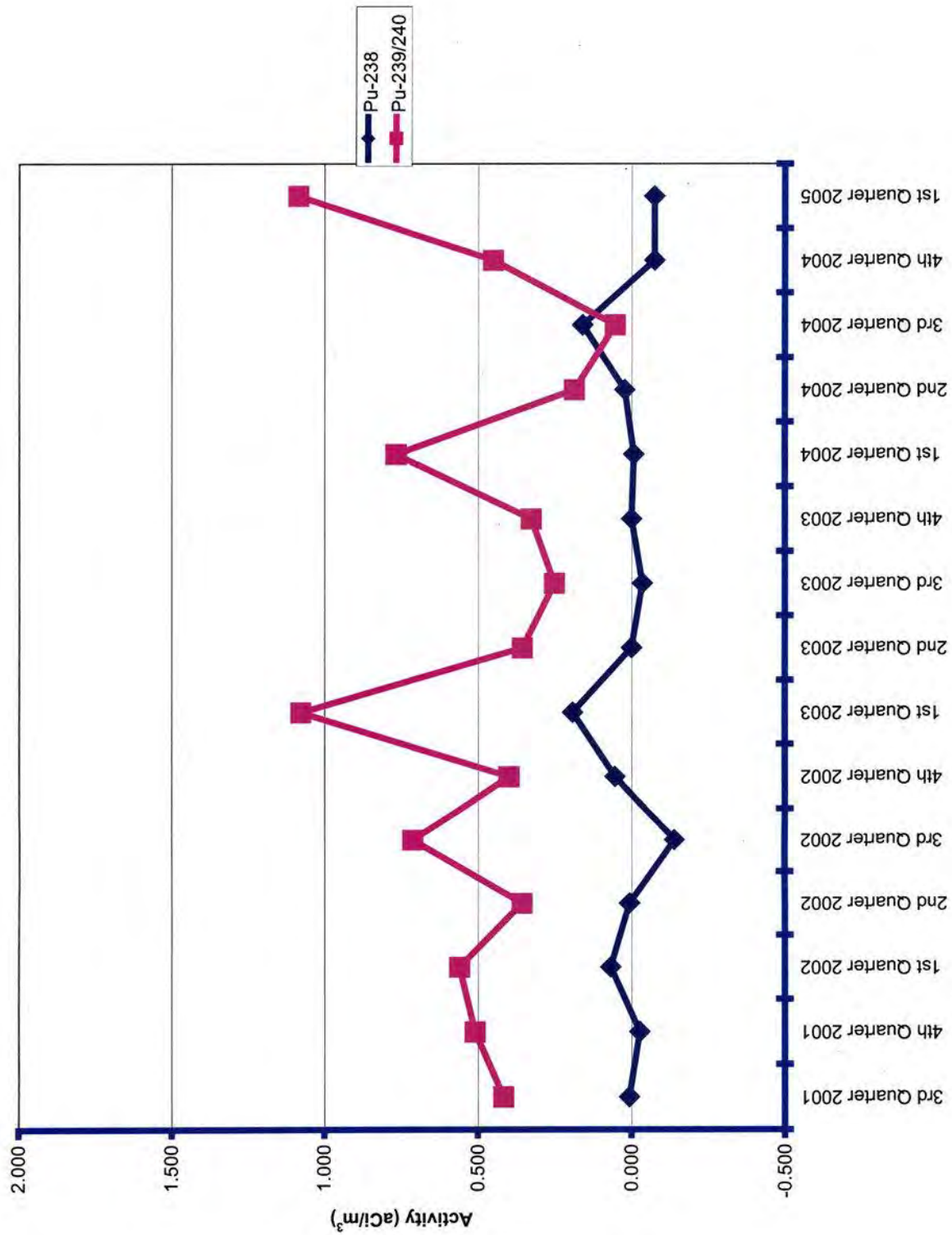
## APPENDIX D

### COMRAD STATION HISTORIC

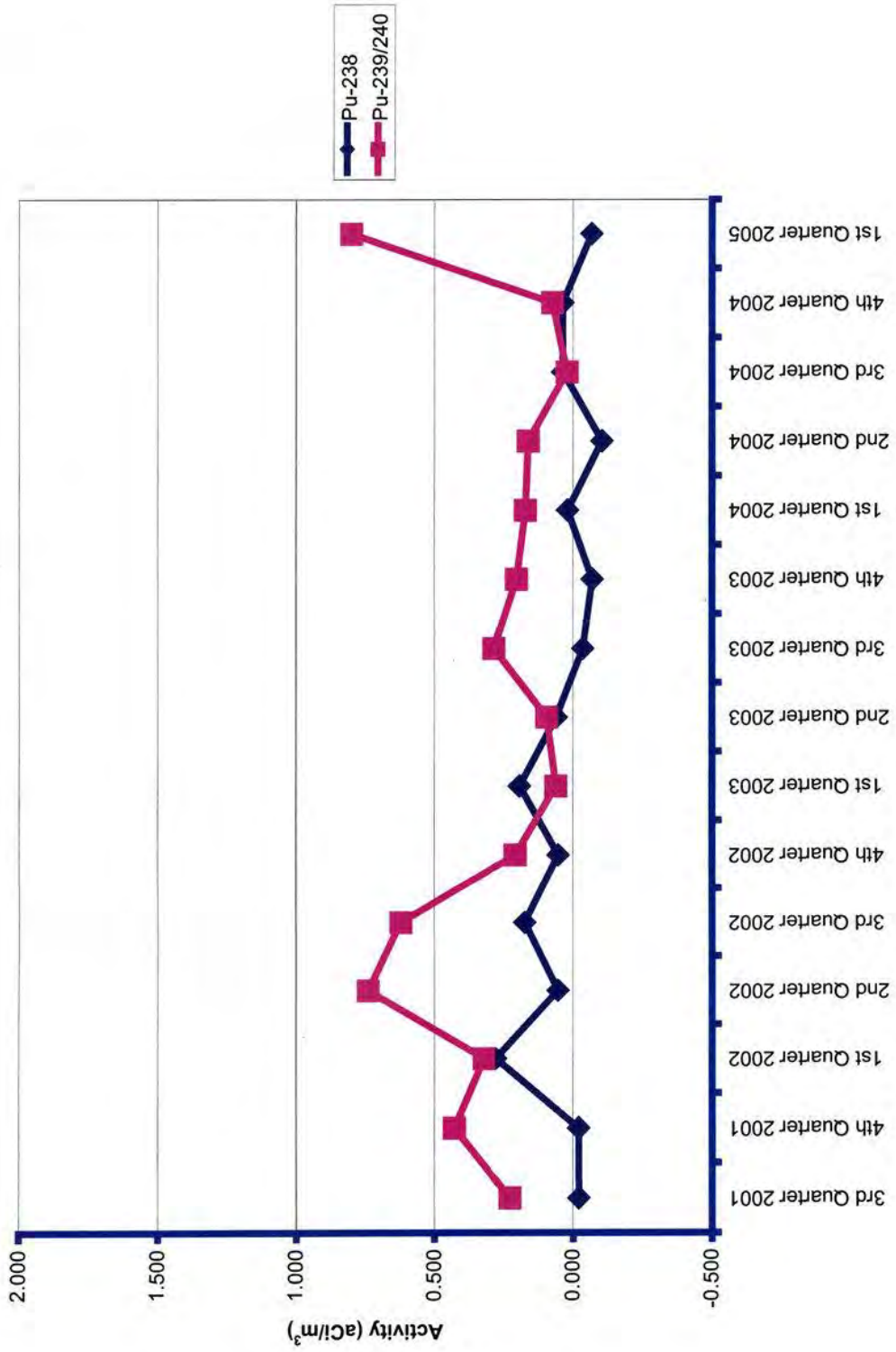
#### PU-239/240 QUARTERLY SAMPLING TREND

2001 - 2005

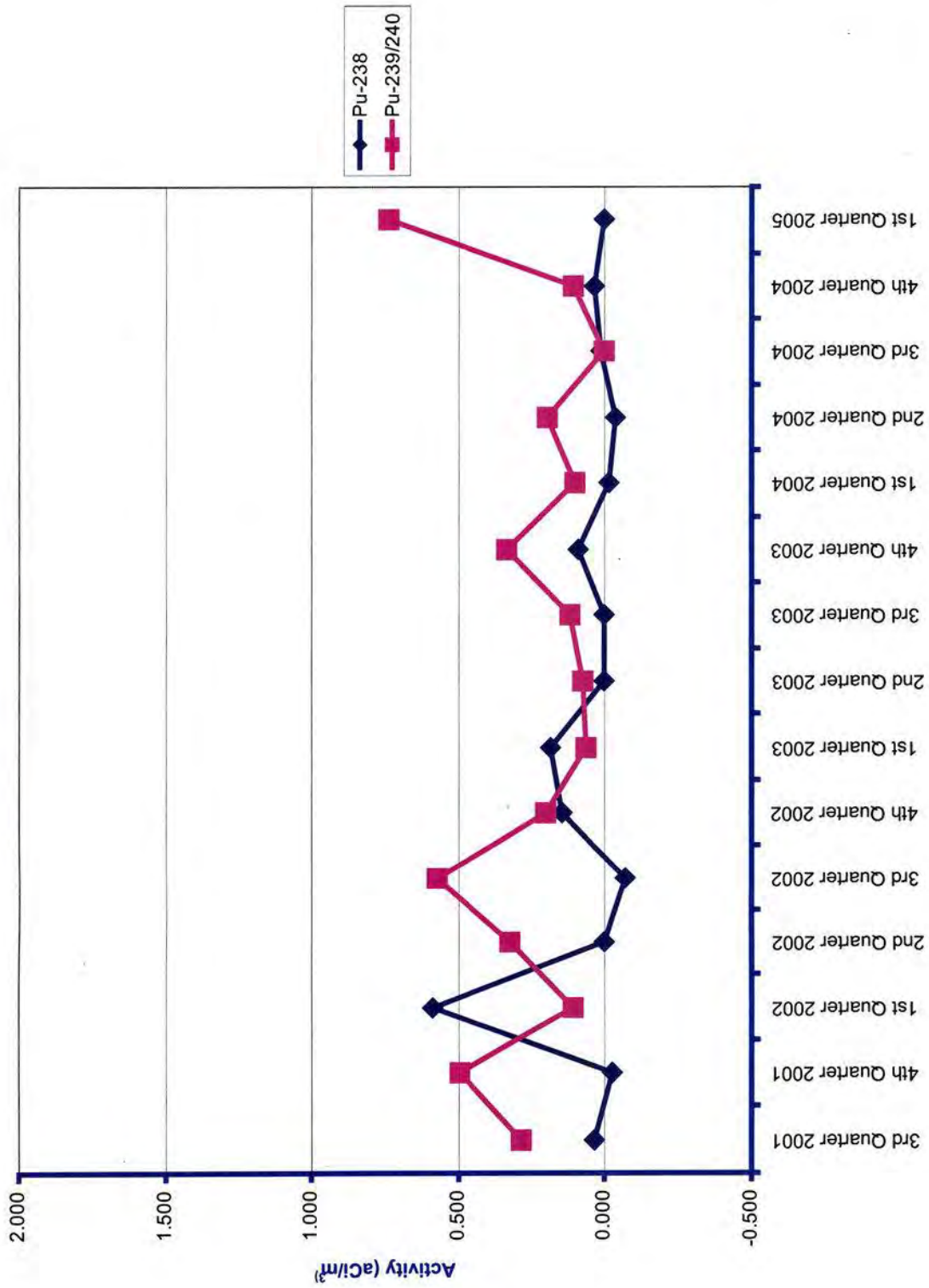
Countryside Pu<sub>238</sub> and Pu<sub>239/240</sub>  
3<sup>rd</sup> Quarter 2001 - 1<sup>st</sup> Quarter 2005



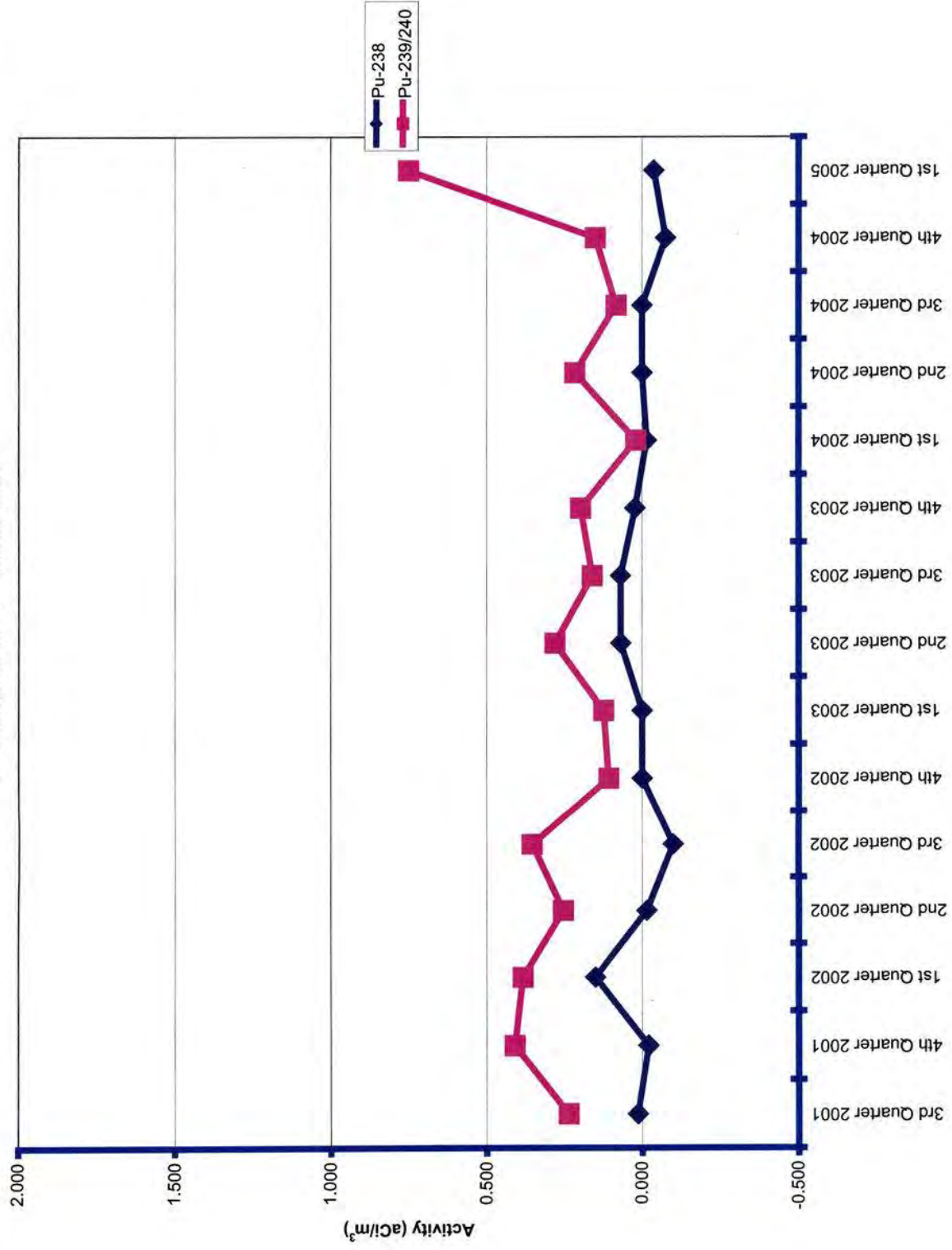
**Emerald Park Pu<sub>238</sub> and Pu<sub>239/240</sub>  
3<sup>rd</sup> Quarter 2001 - 1<sup>st</sup> Quarter 2005**



Northglenn  $\text{Pu}_{238}$  and  $\text{Pu}_{239/240}$   
3<sup>rd</sup> Quarter 2001 - 1<sup>st</sup> Quarter 2005



Standley Lake  $\text{Pu}_{238}$  and  $\text{Pu}_{239/240}$   
3<sup>rd</sup> Quarter 2001 - 1<sup>st</sup> Quarter 2005





**APPENDIX E –**

**STATION OPERATIONAL SITE CHECK DATA**

**COUNTRYSIDE, EMERALD PARK, NORTHGLENN and STANDLEY LAKE  
WEEKLY STATION OPERATIONAL SITE CHECK DATA**

**2002 - 2005**

# 2002-COUNTRYSIDE

Week of	Julian Date	Time	Hour	Press On ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
1-4	2	10:54 AM	1986.10	13.80	20.60	2.85	199.32	24.88	30.17	14.91	54.43	25.11	0.00	13.99
7-11	10	11:35 AM	2178.91	15.10		2.84	174.43	35.93	30.22	32.63	82.91	35.62	0.01	13.40
14-18	14	10:00 AM	2273.51	15.80		5.91	162.67	32.38	30.22	13.20	31.25	32.31	0.00	14.03
21-25	23	2:08 PM	2492.80	16.30		0.66	118.46	25.51	29.96	18.58	65.30	25.76	0.00	13.78
28-31	29	11:11 AM	2633.80	18.20		3.95	179.33	28.79	29.88	19.38	55.74	28.98	0.13	14.06
4-8	36	12:43 PM	2803.50	23.20		4.82	167.54	33.37	30.20	13.35	34.06	33.61	0.13	13.86
11-15	43	1:26 PM	2972.07	18.40		0.00	318.27	30.62	30.20	17.09	46.19	30.09	0.13	13.86
18-22	51	10:52 AM	3161.50	19.40		15.34	308.44	33.64	29.95	24.52	29.99	46.20	0.18	13.73
25-28	58	10:32 AM	3329.15	20.80		13.59	54.04	4.88	30.00	13.54	45.67	25.40	0.20	13.97
4-8	64	11:40 AM	3474.18	12.90	22.80	5.48	329.58	37.08	29.96	18.63	18.90	48.96	0.00	13.69
11-15	70	9:49 AM	3616.35	14.20		7.01	49.80	38.70	30.06	27.57	39.35	44.66	0.00	13.70
18-22	78	2:18 PM	3812.36	14.30		5.04	60.92	46.84	30.03	27.86	34.73	47.05	0.06	13.59
25-29	85	12:21 PM	3978.69	15.80		7.89	284.55	53.47	30.06	23.13	18.69	54.25	0.07	13.53
1-5	92	12:31 PM	4146.99	16.20		3.07	56.91	16.11	30.11	17.20	66.58	23.88	0.07	14.06
8-12	99	9:52 AM	4311.34	14.60		2.85	118.48	60.56	30.11	34.84	26.01	59.84	0.07	13.39
22-26	113	11:42 AM	4647.54	16.80		10.08	264.56	62.78	29.93	30.12	14.80	68.87	0.19	13.28
1-3	122	11:40 AM	4863.62	18.30		1.10	61.25	38.93	29.95	35.14	82.76	38.85	0.28	13.83
6-10	127	11:33 AM	4983.46	13.90		3.07	35.45	53.21	29.86	43.73	61.94	53.31	0.28	13.51
13-17	134	12:58 PM	5152.93	15.10		1.75	119.91	72.21	29.92	38.06	18.34	72.33	0.66	13.28
20-24	141	12:20 PM	5320.07	15.70		5.04	339.35	61.18	29.98	54.90	66.43	63.68	0.95	13.36
27-31	150	1:27 PM	5537.25	17.40		0.44	120.09	85.98	30.02	49.59	19.12	85.71	2.36	13.03
3-7	155	10:15 AM	5654.05	17.70		4.60	346.12	53.17	30.14	48.34	79.61	53.01	0.29	13.64
10-14	162	12:54 PM	5824.69	16.90		1.10	1.38	70.16	30.00	47.35	30.26	70.36	0.29	13.23
17-21	169	10:49 AM	5990.61	17.10		6.58	38.94	83.48	29.90	39.52	14.32	83.77	0.29	13.14
24-28	178	11:09 AM	6206.93	25.60		0.66	130.82	83.91	30.08	52.66	25.32	83.55	0.34	13.13
1-5	182	10:48 AM	6302.59	28.30		1.32	174.11	90.08	30.05	52.04	17.91	89.96	0.34	12.92
8-12	191	9:49 AM	6517.51	14.90		1.10	63.24	73.74	30.32	64.18	66.25	73.58	0.04	13.27
15-19	198	8:59 AM	6684.10	16.70		4.82	29.92	69.90	30.79	45.32	30.10	72.31	0.05	13.29
22-26	205	2:08 PM	6857.84	16.90		0.44	288.17	90.48	30.19	48.11	16.05	90.28	0.13	13.05
30	213	11:05 AM	6905.18	21.40		2.19	127.34	64.86	30.31	47.44	41.60	64.59	0.16	13.30
1-3	219	11:32 AM	7048.04	14.20		1.53	42.76	77.06	30.15	57.46	41.72	77.62	0.46	13.19
12-16	226	11:24 AM	7125.05	15.20		4.16	310.86	82.78	29.94	42.38	14.46	83.77	0.59	13.11
19-23	231	11:42 AM	7125.05	20.10		1.32	267.19	72.83	30.06	44.36	25.66	72.52	0.59	13.21
26-30	241	10:55 AM	7301.14	19.50		9.64	65.69	86.14	30.12	58.14	59.48	68.80	0.66	13.32
3-6	248	2:01 PM	7501.95	13.90		0.22	298.35	87.00	30.08	43.50	13.45	86.73	0.00	13.08
9-13	254	11:23 AM	7712.29	14.60		0.88	54.34	62.07	30.14	54.89	71.41	62.28	0.69	13.41
16-20	262	10:46 AM	7903.70	15.20		1.75	263.22	55.67	30.06	41.55	50.14	55.74	1.33	13.44
23-27	268	9:52 AM	8067.79	16.50		7.45	11.04	49.74	30.15	42.16	68.14	49.55	1.36	13.60
30-4	276	11:41 AM	8406.61	16.70		2.19	158.69	48.09	29.84	43.38	79.44	48.21	0.00	13.61
7-11	282	11:45 AM	8634.46	14.50		1.10	137.13	57.18	30.06	47.17	61.27	57.24	0.00	13.51
14-18	290	1:48 PM	8876.40	16.20		1.97	36.51	63.32	29.92	33.34	22.43	62.87	0.00	13.62
21-25	297	9:53 AM	9040.47	17.40		3.29	24.85	25.60	30.09	26.10	25.48	25.48	0.00	14.12
28-31	304	10:43 AM	9150.27	19.50		3.73	39.18	13.00	30.14	16.49	97.54	16.94	0.07	14.08
4-8	311	12:40 PM	9302.27	25.50		1.75	111.23	62.52	29.93	24.67	14.23	62.68	0.30	13.57
11-15	318	11:35 AM	9471.10	14.80		2.85	68.68	41.35	30.10	34.90	59.95	44.01	0.34	13.37
18-22	324	10:28 AM	9689.94	16.20		3.29	55.09	55.80	30.34	32.40	29.80	55.54	0.35	13.64
25-29	331	11:38 AM	9859.12	18.50		4.82	54.78	36.48	30.18	22.06	40.51	37.53	0.47	13.62
2-6	339	1:56 PM	10033.40	19.60		2.41	81.09	45.68	30.20	31.32	46.28	45.91	0.00	13.57
9-13	345	11:25 AM	10244.86	16.90		4.60	63.79	40.84	29.92	21.51	25.53	45.95	0.00	13.77
16-20	352	11:49 AM	10463.20	17.80		7.45	70.60	32.94	29.67	20.38	32.56	40.30	0.00	13.84
23-27	360	11:29 AM	10654.70	22.00		4.76	14.76	31.80	30.04	12.48	30.38	32.10	0.00	14.06



# 2002-EMERALD PARK

Week of	Julian Date	Time	Hour	Press On mmHg	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press mmHg	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 02	1-4	10:26 AM	21625.70	13.50	26.10	2.41	142.76	22.08	30.16	13.86	57.07	22.66	0.00	13.99
	7-11	12:33 PM	21819.90	15.10		3.72	142.64	31.36	30.12	30.94	67.53	38.01	0.17	13.29
	14-18	10:30 AM	21913.70	16.30		11.40	132.40	15.91	30.00	13.46	31.96	32.65	0.00	14.04
	21-25	1:34 PM	22132.90	18.10		1.97	139.15	25.38	29.96	19.24	70.70	25.10	0.08	11.87
	28-31	10:31 AM	22273.80	21.10										
February02	4-8	12:05 PM	22442.60	16.90	26.10	No power	Weather Instruments Cabinet has no power							
	11-15	1:47 PM	22612.10	18.60		6.14	113.82	22.48	30.34	17.51	44.01	31.18	0.00	13.70
	18-22	10:06 AM	22800.40	19.60		8.55	336.84	43.03	29.93	24.98	28.78	45.26	0.07	13.74
	25-28	9:58 AM	22968.20	21.50		4.16	55.75	20.66	30.05	11.34	41.52	25.51	0.08	13.96
March02	4-8	12:34 PM	23114.80	13.30	22.80	13.37	278.78	44.30	29.93	18.73	17.27	51.63	0.02	13.60
	11-15	10:28 AM	23256.70	14.70		1.97	39.45	47.05	30.06	27.02	33.47	47.37	0.02	12.39
	18-22	1:50 PM	23451.20	15.20		1.97	1.88	46.37	30.04	30.41	41.92	46.55	0.09	13.56
	25-29	2:50 PM	23620.10	16.60		10.30	247.48	55.56	30.01	19.81	13.22	57.36	0.10	13.39
April02	1-5	11:57 AM	23785.60	17.30		2.41	101.51	24.12	30.17	17.26	65.80	24.05	0.10	13.97
	8-12	9:30 AM	23950.10	14.60		4.60	167.02	61.03	30.11	35.81	28.34	61.43	0.10	13.56
	22-26	11:04 AM	24286.20	17.60		11.84	271.57	60.85	29.93	28.80	13.89	68.26	0.19	13.33
May02	1-3	11:12 AM	24502.40	19.10		3.73	341.81	38.52	29.94	34.12	78.79	38.45	0.27	13.77
	6-10	11:13 AM	24622.40	14.10		3.95	113.92	52.39	29.86	43.78	62.72	52.56	0.27	13.50
	13-17	12:22 PM	24791.60	15.40		2.85	87.36	67.76	29.90	41.39	29.26	67.86	0.60	13.31
	20-24	11:58 AM	24958.90	16.10		8.99	302.07	63.55	29.69	55.17	66.83	64.03	0.79	13.23
	27-31	1:04 PM	25176.10	18.30		3.51	122.37	83.68	30.02	49.71	20.03	83.63	1.98	13.08
Jun02	3-7	9:44 AM	25291.70	19.00		2.85	310.31	52.91	30.13	48.11	80.53	52.87	0.31	13.54
	10-14	11:56 AM	25461.80	17.30		3.07	129.53	68.05	30.01	43.56	33.74	68.11	0.32	13.24
	17-21	10:19 AM	25628.20	18.00		0.44	308.75	83.53	29.90	39.69	12.20	83.50	0.32	13.10
	24-28	9:52 AM	25843.80	23.70		2.85	106.93	77.39	30.08	50.99	32.57	77.21	0.43	13.10
Jul02	1-5	11:22 AM	25941.30	27.20		6.36	94.98	91.15	30.04	46.71	13.80	91.02	0.43	12.87
	8-12	9:23 AM	26155.30	15.40		3.95	21.18	72.55	30.31	63.15	65.42	72.92	0.02	13.14
	15-19	9:35 AM	26323.00	16.90		2.84	268.24	75.35	30.09	48.16	31.97	75.41	0.33	13.15
	22-26	10:46 AM	26492.60	18.30		3.73	112.97	84.14	30.19	55.12	28.60	84.74	0.33	11.49
	30	9:24 AM	26539.80	19.00		3.95	49.81	63.48	30.31	45.24	41.74	63.50	0.00	12.22
August02	1-3	11:01 AM	26685.30	14.70		3.07	141.58	76.63	30.13	57.34	42.02	76.46	0.37	13.19
	12-16	10:46 AM	26853.10	15.70		4.16	241.64	82.96	29.93	42.91	15.08	82.89	0.40	13.20
	19-23	12:10 PM	26974.40	20.40		2.63	341.42	74.25	30.04	45.88	26.42	74.18	0.40	13.25
	26-30	10:33 AM	27128.80	20.70		4.16	29.75	66.37	30.09	56.33	63.06	66.37	0.41	13.37
September02	3-6	1:09 PM	27383.30	23.70	23.70	5.92	102.43	87.16	30.07	43.03	13.67	87.28	0.04	13.13
	9-13	10:42 AM	27524.90	14.30		1.53	173.33	61.20	30.13	54.77	73.45	61.39	0.56	13.49
	16-20	10:23 AM	27716.50	15.10		0.66	307.68	56.04	30.04	41.84	49.90	55.89	1.46	13.60
	23-27	9:27 AM	27859.60	16.20		2.41	315.31	49.05	30.14	41.66	68.19	49.09	1.46	13.68
October02	30-4	11:11 AM	28053.30	17.10		4.60	1.22	41.78	29.82	41.00	89.61	43.22	0.00	13.77
	7-11	9:52 AM	28196.00	14.30		2.19	150.46	49.39	30.08	45.00	74.91	50.95	0.00	13.70
	14-18	2:11 PM	28391.10	16.30		6.14	106.56	59.21	29.88	34.19	23.95	63.17	0.00	13.63
	21-25	9:29 AM	28564.20	17.70		1.97	13.84	25.16	30.07	25.16	100.35	25.16	0.00	14.11
	28-31	10:18 AM	28724.10	19.50		3.51	344.99	17.24	30.11	16.21	94.19	17.13	0.06	14.15
November02	4-8	1:12 PM	28895.00	24.90		2.85	127.95	61.39	29.89	33.58	23.57	61.33	0.38	13.56
	11-15	10:25 AM	29060.20	14.40		5.92	118.93	35.38	30.10	32.97	66.31	40.32	0.42	13.86
	18-22	9:57 AM	29203.50	15.80		2.85	315.17	53.55	30.33	32.47	31.93	53.55	0.43	13.57
	25-29	10:35 AM	29371.80	18.40		5.04	352.47	21.94	30.16	20.21	51.20	31.92	0.59	13.94
December02	2-6	12:09 PM	29565.70	20.50		3.07	151.78	42.69	30.20	31.53	54.17	42.64	0.00	13.71
	9-13	11:41 AM	29709.20	16.90		2.63	25.80	46.56	29.89	20.76	23.52	46.59	0.00	13.47
	16-20	11:18 AM	29876.70	19.10		1.32	42.94	41.71	29.65	21.04	29.68	41.70	0.00	13.85
	23-27	12:36 PM	30070.10	23.60		5.48	319.21	35.08	29.98	10.95	22.72	35.66	0.00	13.84



# 2002-NORTHGLENN

Week of	JulianDate	Time	Hour Meter	PressOn ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
1-4	2	9:52 AM	16760.90	27.10		1.53	152.01	21.85	30.20	12.97	50.65	23.79	0.00	13.85
7-11	10	1:02 PM	16955.90	15.40		1.09	198.77	39.17	30.21	31.47	66.70	38.98	0.16	13.02
14-18	14	10:50 AM	17049.90	17.10		5.48	127.36	28.02	30.01	15.13	34.09	32.81	0.00	13.72
21-25	23	1:06 PM	17268.20	18.10		3.73	156.21	24.68	29.98	20.32	76.42	24.97	0.06	13.73
28-31	29	10:06 AM	17409.20	21.60		3.29	158.71	27.28	29.89	19.53	63.04	27.24	0.12	13.96
4-8	36	10:19 AM	17577.50	28.10		3.95	95.05	23.55	30.28	13.82	36.34	30.46	0.13	13.67
11-15	43	2:07 PM	17748.80	20.70		1.75	57.25	30.65	30.19	17.84	45.21	30.56	0.13	13.75
18-22	51	9:13 AM	17935.90	22.30		5.04	314.72	36.03	29.94	26.37	41.14	41.97	0.15	13.72
25-28	58	9:33 AM	18104.00	14.00		7.23	40.86	9.68	30.07	8.59	34.78	25.25	0.16	13.84
4-8	64	1:04 PM	18251.60	15.50	27.40	13.59	297.92	39.85	29.92	20.53	18.82	51.98	0.03	13.43
11-15	70	11:18 AM	18393.20	14.90		4.82	47.30	48.35	30.08	26.62	30.30	48.56	0.03	13.44
18-22	78	1:18 PM	18587.10	15.30		4.16	318.87	43.87	30.05	30.21	46.61	43.85	0.16	13.51
25-29	85	2:22 PM	18756.00	17.50		12.71	306.76	44.14	30.03	18.54	13.05	56.41	0.16	13.35
1-5	92	10:52 AM	18920.80	18.40		3.95	81.26	22.44	30.19	15.64	65.95	22.53	0.16	13.95
8-12	99	8:54 AM	19085.80	14.50		7.23	147.38	44.17	30.13	40.79	62.53	50.33	0.16	13.47
22-26	113	10:19 AM	19421.40	19.00		15.34	289.46	56.35	29.96	28.16	14.50	66.55	0.21	13.22
29-30														
1-3	122	10:37 AM	19637.80	20.30		1.53	117.48	37.22	29.96	34.25	84.21	37.38	0.29	13.75
6-10	127	10:47 AM	19758.00	13.80		2.85	30.33	45.05	29.89	42.66	72.86	49.68	0.29	13.47
13-17	134	11:44 AM	19926.10	15.80		2.41	172.23	67.93	29.96	42.11	29.02	67.83	0.61	13.27
20-24	141	11:34 AM	20093.70	16.70		3.07	291.06	67.18	29.73	54.69	57.41	67.34	0.86	13.20
27-31	150	12:32 PM	20310.70	21.30		3.73	35.02	81.89	30.06	51.32	27.53	81.96	2.07	13.04
3-7	155	9:11 AM	20427.40	20.30		1.97	4.84	51.99	30.15	48.96	85.73	52.04	0.25	13.55
10-14	162	9:37 AM	20595.80	19.40		4.60	85.39	57.20	30.05	42.86	38.82	61.15	0.26	13.25
17-21	169	9:47 AM	20763.90	20.20		1.75	140.70	82.74	29.93	37.53	12.57	82.64	0.26	13.01
24-28	178	9:16 AM	20979.40	27.90		0.44	87.99	76.90	30.11	51.99	33.35	76.95	0.38	13.04
1-5	182	12:10 PM	21078.30	30.30		7.89	69.19	91.48	30.06	47.14	13.75	91.50	0.38	12.84
8-12	191	8:47 AM	21290.90	15.40		2.19	45.53	72.19	30.34	63.70	68.31	72.30	0.58	13.10
15-19	198	9:53 AM	21459.90	18.00		5.26	295.11	73.51	30.12	52.78	34.11	75.68	1.31	13.03
22-26	205	8:18 AM	21626.40	19.10		1.53	253.18	77.32	30.23	54.92	36.73	77.23	1.35	13.04
30	213	10:28 AM	21820.60	24.70		10.52	76.54	58.53	30.34	44.05	38.14	62.96	1.36	13.22
1-3	219	10:35 AM	21964.60	14.70		5.70	66.30	74.59	30.16	56.86	45.61	74.46	0.27	13.12
12-16	226	9:43 AM	22131.80	16.10		1.53	192.93	77.79	29.99	49.10	27.21	77.77	0.29	13.06
19-23	231	12:38 PM	22254.50	23.00		7.23	352.53	75.15	30.04	49.69	30.78	76.23	0.29	13.12
26-30	241	9:55 AM	22491.80	22.40		1.32	41.34	64.83	30.12	56.77	68.67	64.96	0.57	13.21
3-6	248	11:23 AM	22661.30	14.00		4.60	127.48	83.58	30.14	45.15	17.34	83.47	0.00	13.04
9-13	254	9:50 AM	22803.70	14.80		5.04	10.99	51.49	30.17	53.34	83.58	56.82	0.51	13.38
16-20	262	8:54 AM	22994.80	15.90		1.32	308.92	52.51	30.08	42.10	60.41	52.06	1.03	13.41
23-27	268	8:57 AM	23137.60	17.70		6.58	344.30	48.37	30.16	41.88	69.63	48.91	1.03	13.51
30-4	276	10:26 AM	23331.10	18.20		2.63	67.68	42.28	29.87	41.26	94.88	42.19	0.00	13.69
7-11	282	9:09 AM	23473.80	14.70		2.85	21.13	48.52	30.11	44.64	80.19	48.68	0.00	13.53
14-18	290	2:32 PM	23671.10	18.10		4.60	56.34	63.42	29.90	35.66	23.27	63.72	0.00	13.68
21-25	297	8:57 AM	23833.50	19.60		1.10	67.31	24.81	30.10	25.15	102.21	24.79	0.00	13.99
28-31	304	9:44 AM	24003.30	21.80		5.04	19.64	10.93	30.13	16.01	98.06	16.42	0.08	14.04
4-8	311	1:39 PM	24175.30	28.40		0.00	147.76	67.56	29.91	25.19	11.40	67.52	0.41	13.47
11-15	318	9:41 AM	24339.10	14.90		5.92	80.25	32.36	30.13	32.65	71.70	38.82	0.46	13.67
18-22	324	9:33 AM	24483.00	17.10		1.97	161.44	54.24	30.35	32.57	32.47	54.37	0.46	13.38
25-29	331	9:31 AM	24650.90	20.20		2.41	298.27	35.91	30.18	19.72	37.91	36.13	0.63	13.77
2-6	339	11:12 AM	24844.60	22.30		7.67	201.75	30.16	30.25	32.26	64.56	40.01	0.00	13.55
9-13	345	12:05 PM	24989.50	17.40		4.60	96.83	42.57	29.90	22.18	27.49	45.24	0.00	13.49
16-20	352	10:35 AM	25155.90	18.50		2.85	127.08	39.37	29.68	24.17	43.03	39.35	0.00	13.58
23-27	360	1:05 PM	25350.40	25.00		4.16	302.20	35.91	29.90	11.39	22.40	36.10	0.00	13.68

Indirectly Measures Material Buildup  
End of Month Filter Changeout -  
This Column Shows Pressure At



# 2002-STANDLEY LAKE

Week of	JulianDate	Time	Hour Meter	Press On ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
1-4	2	12:01 PM	32761.30	13.20	19.40	4.38	155.23	26.21	30.11	12.91	34.03	30.74	0.01	13.78
7-11	10	10:59 AM	32952.01	14.40		3.50	179.59	32.67	30.23	30.36	80.50	34.32	0.13	13.63
14-18	14	9:20 AM	33046.20	15.00		1.75	188.28	27.37	30.02	11.21	36.08	27.18	0.00	14.03
21-25	23	2:35 PM	33267.40	15.80		3.73	129.86	23.36	29.97	17.76	62.84	25.32	0.03	13.77
28-31	29	5:30 PM	33414.30	17.60		0.88	9.21	28.09	29.86	17.51	52.20	28.09	0.08	13.95
4-8	36	1:27 PM	33578.20	18.80	19.50	4.16	175.02	32.75	30.16	12.80	25.49	35.59	0.08	13.67
11-15	43	12:38 PM	33745.00	19.40		0.00	210.91	30.06	30.22	16.62	44.31	30.58	0.00	13.87
18-22	51	11:24 AM	33935.50	20.20		8.77	328.76	37.43	29.95	23.41	26.69	47.10	0.12	13.71
25-28	58	11:12 AM	34103.20	22.00		9.21	13.67	21.69	30.06	14.21	47.11	26.67	0.12	13.89
4-8	64	11:03 AM	34247.10	13.60	22.30	5.04	304.78	42.06	29.97	18.71	20.46	46.91	0.01	13.76
11-15	70	9:18 AM	34389.20	14.60		3.29	305.92	46.58	30.05	25.12	30.43	46.79	0.04	13.75
18-22	78	2:50 PM	34586.10	15.10		2.85	71.20	47.44	30.03	27.63	33.66	47.73	0.11	13.42
25-29	85	11:50 AM	34751.70	16.00		8.11	326.43	47.00	30.01	19.76	14.28	55.37	0.11	13.50
1-5	92	1:03 PM	34920.60	16.60		3.51	42.40	17.78	30.17	16.74	63.12	24.20	0.11	14.00
8-12	99	10:23 AM	35084.60	14.50		5.70	200.67	57.10	30.13	31.31	21.71	61.13	0.11	13.49
22-26	113	12:33 PM	35418.50	16.50		7.89	258.10	65.93	29.93	26.59	10.57	70.74	0.14	13.25
1-3	122	12:10 PM	35629.30	18.30		2.41	243.90	40.51	29.94	34.35	71.60	40.98	0.18	13.71
6-10	127	11:57 AM	35767.40	14.10		5.26	11.99	52.59	29.62	43.58	56.46	54.29	0.18	13.37
13-17	134	1:31 PM	35908.60	15.30		10.52	249.18	65.70	29.24	36.62	21.18	68.50	0.51	13.29
20-24	141	1:20 PM	36064.00	16.00		22.97	142.30	69.23	29.57	41.04	18.58	76.71	0.71	13.25
27-31	150	1:56 PM	36261.90	17.10		3.73	74.62	86.52	30.05	47.35	18.80	86.76	1.90	13.01
3-7	155	10:45 AM	36371.20	17.80		1.75	350.23	52.78	29.89	46.80	74.36	52.80	0.28	13.64
10-14	162	1:53 PM	10808.70	15.90		5.26	189.58	71.42	30.01	43.89	27.68	71.21	0.29	13.12
17-21	169	11:26 AM	10974.30	16.40		5.48	74.62	86.36	29.92	38.92	10.83	86.64	0.29	13.04
24-28	178	11:38 AM	11190.20	23.10		4.60	148.32	84.84	30.09	47.62	17.97	85.76	0.32	13.08
1-5	182	10:14 AM	11284.80	28.20		1.75	143.67	86.81	30.09	53.41	23.23	86.97	0.32	12.85
8-12	191	10:20 AM	11500.80	14.60		3.73	81.05	75.56	30.33	64.29	59.31	75.84	0.01	13.20
15-19	198	8:33 AM	11666.90	15.70		3.72	16.08	70.70	30.58	44.31	30.91	70.94	0.02	13.38
22-26	207	1:45 PM	11888.30	16.70		5.92	327.12	84.51	30.05	49.41	20.76	85.48	0.03	13.08
30	213	11:33 AM	12030.10	19.00		8.33	119.25	61.67	30.32	44.07	35.04	65.44	0.03	13.20
1-3	219	12:35 PM	12175.00	14.10		3.73	307.52	81.31	30.14	55.55	32.19	81.36	0.43	13.10
12-16	226	11:53 AM	12342.40	14.70		5.26	11.34	83.91	29.95	38.01	12.09	83.70	0.52	13.11
19-23	231	11:03 AM	12461.40	18.20		1.97	331.07	70.00	30.09	41.04	25.00	70.06	0.52	13.26
26-30	241	11:45 AM	12702.10	18.10		5.92	33.28	69.90	30.13	56.44	54.29	69.70	0.57	13.22
3-6	248	3:02 PM	12873.30	13.60		5.26	1.49	87.66	30.09	40.82	12.29	87.83	0.00	13.01
9-13	254	11:58 AM	13014.30	14.10		1.97	72.13	63.24	30.13	54.51	66.34	63.12	0.50	13.37
16-20	262	11:16 AM	13205.60	14.60		5.26	13.57	56.29	30.06	39.71	44.53	56.56	0.84	13.43
23-27	268	10:23 AM	13348.70	15.30		2.19	44.80	51.24	30.15	42.33	63.88	51.27	0.85	13.58
30-4	276	12:07 PM	13542.50	15.80		3.95	46.48	49.23	29.82	42.80	67.20	51.07	0.00	13.67
7-11	282	1:46 PM	13688.10	14.90		0.66	340.84	64.71	30.02	44.30	38.16	64.38	0.00	13.48
14-18	290	12:59 PM	13879.30	16.10		2.85	345.39	60.05	29.95	33.20	25.02	60.07	0.00	13.66
21-25	297	10:17 AM	14044.60	17.10		1.53	43.14	26.03	30.08	25.59	97.58	26.02	0.00	14.11
28-31	304	11:07 AM	14214.40	18.00		4.38	20.64	17.24	30.12	15.71	90.85	17.20	0.00	14.12
4-8	311	11:16 AM	14382.60	20.90		1.97	328.57	55.34	29.98	29.12	24.75	55.32	0.00	13.61
11-15	318	12:08 PM	14551.40	14.50		5.26	96.21	42.50	30.08	32.94	55.12	43.63	0.00	13.73
18-22	324	10:57 AM	14694.20	14.40		3.95	140.16	56.01	30.33	29.65	24.70	56.25	0.00	13.46
25-29	331	12:07 PM	14863.30	16.30		1.10	0.93	39.82	30.16	21.92	36.06	40.08	0.13	13.75
2-6	339	2:21 PM	15057.60	17.50		4.16	129.29	41.93	30.19	29.89	42.54	45.38	0.00	13.55
9-13	345	11:01 AM	15198.00	14.60		2.41	21.57	47.00	29.93	19.24	20.26	47.14	0.00	13.68
16-20	352	12:54 PM	15367.90	15.40		8.33	118.98	30.29	29.67	23.69	42.02	39.59	0.00	13.72
23-27	360	11:00 AM	15558.00	17.60		2.63	74.02	31.78	30.03	10.98	28.32	31.75	0.00	13.93

End of Month Filter Changeout -  
Indirectly Measures Material Buildup  
This Column Shows Pressure At



# 2003-COUNTRYSIDE

Week of	Julian Date	Time	Hour Meter	Press On mmHg	Press Off	W Speed mph	W Direct degrees	W Chill °F	B Press mmHg	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
1-3	2	1:08 PM	3024.20	21.70		9.64	287.60	46.48	30.10	24.40	21.37	52.99	0.00	13.64
6-10	8	11:27 AM	3166.89	14.90		1.10	96.27	66.00	30.03	27.07	13.56	65.76	0.02	13.55
13-17	15	10:23 AM	3333.81	17.60		10.08	245.36	45.39	29.96	30.48	39.79	47.78	0.02	13.85
20-24	24	10:38 AM	3550.89	18.90		1.97	103.41	40.06	30.18	30.95	61.20	39.72	0.02	13.91
27-31	30	10:56 AM	3694.37	20.10		0.44	96.49	53.84	29.96	30.85	29.19	54.00	0.02	13.68
3-7	37	11:48 AM	3863.25	20.00		0.22	38.75	14.27	30.20	8.83	70.37	14.27	0.04	14.00
10-14	43	10:00 AM	4005.40	14.90		2.85	11.15	37.89	30.08	25.49	48.10	38.14	0.05	13.90
17-21	51	10:56 AM	4198.33	16.30		1.97	168.14	44.22	29.95	18.99	24.06	44.15	0.10	13.76
3-7	65	2:01 PM	4535.20	13.50	18.30	14.91	251.13	40.39	29.67	22.52	19.44	52.48	0.29	13.59
10-14	71	10:19 AM	4675.70	14.70		8.77	249.74	54.49	29.91	30.39	22.09	59.93	0.10	13.45
24-28	84	11:45 AM	4983.56	15.20		4.16	209.43	46.39	30.12	34.40	51.17	47.28	1.85	13.64
31-4	92	10:18 AM	5173.95	17.10	13.70	11.18	150.59	61.83	29.72	28.29	14.68	67.19	1.89	13.41
14-18	98	10:22 AM	5316.90	14.60		1.75	294.56	40.86	30.35	31.89	62.19	40.77	0.73	13.69
21-25	105	10:26 AM	5485.00	17.50		7.89	174.35	61.28	29.60	35.20	21.27	66.67	0.74	13.16
28-2	112	11:54 AM	5654.50	16.40		3.07	70.36	56.02	29.79	46.35	59.81	56.08	1.70	13.51
5-9	120	12:15 PM	5846.80	17.40		3.95	29.40	49.55	29.80	40.20	44.78	54.70	2.41	13.44
12-16	126	10:51 AM	5989.40	18.70	14.00	1.75	170.23	55.59	29.88	38.07	40.31	56.36	0.01	13.50
19-23	133	9:29 AM	6155.70	14.70		6.58	349.77	68.51	30.03	42.30	27.94	68.33	1.29	13.36
26-30	141	9:39 AM	6347.90	15.30		7.89	60.17	65.99	30.15	45.77	37.19	66.43	1.42	13.10
2-6	148	12:26 PM	6518.60	16.00		0.87	11.57	76.45	30.29	62.48	53.37	76.25	1.42	13.13
9-13	154	9:51 AM	6660.10	16.50	13.70	0.44	51.57	62.96	30.05	49.86	55.88	62.92	1.42	13.35
16-20	161	9:59 AM	6828.10	14.40		4.38	70.78	65.85	29.95	53.89	54.18	67.05	0.39	13.26
23-27	168	1:57 PM	6999.10	14.90		0.88	27.48	71.51	30.17	55.83	49.64	71.66	0.41	13.19
30-4	175	10:30 AM	7164.60	15.40		1.09	25.04	53.99	29.90	52.27	91.90	53.94	1.26	13.62
7-11	182	12:41 PM	7334.70	16.30	13.90	1.31	186.52	91.81	29.99	46.55	13.18	91.87	0.00	12.99
14-18	190	9:32 AM	7523.36	18.10		0.00	181.97	76.02	30.21	50.73	31.98	75.77	0.00	13.17
21-25	196	9:18 AM	7667.20	20.10		2.84	3.61	78.28	30.17	57.99	40.18	78.54	0.00	13.18
28-1	203	11:45 AM	7837.70	20.60		1.53	71.19	78.37	30.22	57.91	38.90	78.81	0.21	13.18
5-9	210	9:09 AM	8003.00	20.90		0.00	198.98	72.77	30.19	62.40	63.11	72.72	0.23	13.26
12-16	218	10:32 AM	8196.09	23.80	16.50	1.50	206.90	80.40	30.16	56.40	35.70	80.40	0.33	12.90
19-23	225	11:14 AM	8364.10	17.80		1.53	23.23	77.12	30.23	60.22	43.57	77.12	0.88	13.17
26-30	231	1:51 PM	8510.70	17.80		1.53	64.82	80.60	30.10	56.37	32.77	81.02	1.39	13.05
3-7	238	9:45 AM	8674.60	19.60		0.66	10.08	77.18	30.21	52.31	31.97	76.91	1.39	2.38
10-14	246	2:51 PM	8871.70	19.60	16.70	5.48	319.74	67.62	30.29	54.30	54.94	67.64	1.99	13.28
17-21	252	10:15 AM	9011.00	17.50		1.75	64.83	63.46	29.98	53.35	55.42	66.23	2.02	13.33
24-28	259	10:57 AM	9179.70	18.20		1.97	271.03	74.89	29.97	44.77	24.21	75.10	2.02	13.13
31-5	266	11:30 AM	9348.30	19.10		5.26	182.00	76.57	30.01	36.25	14.66	78.52	2.10	13.23
8-12	273	12:51 PM	9517.50	20.00	16.70	0.22	180.78	48.03	30.35	41.30	72.29	47.61	2.10	13.54
15-19	280	9:00 AM	9681.50	18.70		0.00	113.40	57.90	30.02	43.20	48.40	58.10	0.00	12.89
22-26	287	1:53 PM	9854.40	19.20		1.53	37.35	58.26	30.05	24.96	16.35	59.55	0.00	13.45
29-3	295	10:00 AM	10042.60	24.70		0.66	94.50	69.40	30.30	36.00	20.40	69.10	0.00	13.37
6-10	301	2:54 PM	10191.50	23.70		5.48	22.60	58.08	29.81	39.71	38.88	58.56	0.00	13.32
13-17	308	2:07 PM	10359.70	22.80	14.50	9.20	316.62	51.37	29.87	21.57	24.63	46.62	0.18	13.55
20-24	315	1:41 PM	10527.20	16.30		5.88	50.62	53.29	29.92	30.83	30.17	53.85	0.18	13.47
27-31	322	10:22 AM	10691.90	18.00		4.16	351.14	27.48	30.05	21.97	25.19	46.81	0.18	13.81
4-8	329	1:10 PM	10862.60	20.40		10.52	14.54	27.10	29.64	24.64	47.79	38.09	0.18	13.83
11-15	336	1:35 PM	11031.10	21.20	13.70	14.90	228.30	47.63	30.01	27.30	20.29	57.75	0.00	13.51
18-22	344	10:40 AM	11220.00	15.50		5.48	16.67	21.41	29.94	18.76	68.86	24.94	0.09	14.08
25-29	350	1:30 PM	11366.60	17.20		7.89	5.73	29.45	30.15	21.93	26.73	42.84	0.09	13.69
32-6	358	12:21 PM	11557.50	20.70		3.06	330.13	48.38	29.84	24.38	26.99	48.31	0.11	13.68
9-13	363	1:06 PM	11678.20	25.50	16.40	0.22	135.90	37.10	29.81	11.30	20.80	37.08	0.12	13.98



# 2003-EMERALD PARK

Week of	Julian Date	Time	Hour	Press On mmHg	Pres Off mmHg	W Speed mph	W Direct degrees	W Chill °F	B Press mmHg	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 03	1-3	12:30 PM	30237.80	24.30		7.01	236.31	48.14	30.08	23.28	19.41	53.49	0.00	13.64
	6-10	10:46 AM	30358.40	15.80		2.41	127.31	59.08	30.04	28.59	21.04	58.51	0.02	13.74
	13-17	9:37 AM	30525.30	18.60		3.29	106.36	32.60	29.92	26.58	69.86	32.91	0.02	14.06
	20-24	10:11 AM	30741.80	22.00		5.48	124.77	34.91	30.16	30.21	63.72	38.33	0.02	13.97
	27-31	10:35 AM	30866.30	23.60		10.30	325.19	47.44	29.93	30.05	25.19	56.41	0.02	13.66
February03	3-7	10:40 AM	31054.30	24.20		0.66	66.49	14.91	30.21	9.87	71.29	14.89	0.03	14.06
	10-14	9:23 AM	31197.00	15.00		2.41	328.78	34.75	30.08	24.41	55.34	34.59	0.06	14.08
	17-21	10:39 AM	31390.30	17.70		3.29	85.88	36.12	29.96	18.94	24.88	43.63	0.10	13.84
March03	3-7	1:19 PM	31727.80	17.50	21.10	11.39	251.23	43.13	29.66	21.93	19.01	52.53	0.43	13.65
	10-14	10:45 AM	31869.20	14.90		23.45	264.18	53.35	29.89	30.20	62.27	62.27	0.07	13.53
	24-28	10:20 AM	32180.80	16.30		4.60	172.02	37.98	30.13	31.55	53.36	43.31	1.60	13.76
April03	31-4	10:08 AM	32372.50	18.70	14.10	9.43	135.66	56.96	29.74	25.20	13.63	64.15	1.64	13.47
	7-11	9:43 AM	32516.10	14.80		5.26	113.18	40.25	30.34	30.62	55.99	40.13	0.44	13.84
	14-18	9:52 AM	32684.20	19.00		6.36	175.48	66.57	29.60	35.63	18.99	68.82	0.44	13.15
	21-25	11:26 AM	32853.80	18.00		2.63	62.80	56.66	29.78	45.82	58.63	57.13	1.27	13.50
	28-2	11:47 AM	33046.10	19.40		8.33	354.75	48.77	29.77	45.54	64.91	54.22	2.03	13.35
May03	5-9	11:40 AM	33190.00	21.00	14.00	5.04	148.55	53.69	29.86	34.41	33.16	56.13	0.00	13.53
	12-16	10:14 AM	33347.00	14.90		4.60	23.25	66.88	30.03	39.44	23.81	70.06	1.34	13.34
	19-23	10:22 AM	33539.10	15.90		11.18	145.53	61.39	30.13	40.04	26.56	67.71	1.41	13.06
	26-30	12:01 PM	33708.80	17.30		3.29	332.76	76.64	30.28	62.27	55.50	76.61	1.41	13.19
Jun03	2-6	9:17 AM	33850.00	18.20	14.10	0.44	166.07	58.96	30.06	49.20	62.94	58.69	1.47	13.43
	9-13	10:37 AM	34019.20	15.00		2.84	210.68	70.56	29.92	54.29	45.93	70.73	0.28	13.22
	16-20	1:17 PM	34188.90	15.90		0.00	55.54	74.24	30.17	56.11	45.24	73.74	0.31	13.19
	23-27	11:38 AM	34356.30	16.30		5.04	20.05	55.10	29.87	52.15	86.83	55.03	1.03	13.54
Jul03	30-4	11:51 AM	34523.80	18.70	14.50	2.19	48.95	89.97	29.98	52.65	19.89	89.91	0.00	12.98
	7-11	8:48 AM	34712.60	17.20		1.10	182.15	74.38	30.21	50.15	33.70	74.59	0.00	13.18
	16-18	9:51 AM	34857.60	20.20		1.53	56.19	79.56	30.14	55.08	34.17	79.38	0.00	13.10
	21-25	11:20 AM	35027.10	22.40		2.41	132.35	76.79	30.23	58.26	43.36	77.38	0.14	13.15
August03	28-1	9:44 AM	35193.50	23.40		2.41	40.10	74.35	30.20	63.18	61.08	74.30	0.17	13.20
	4-8	11:17 AM	35386.70	24.60	17.60	3.60	124.90	83.70	30.14	56.90	31.80	83.90	0.51	13.20
	11-15	10:53 AM	35553.60	18.70		1.97	1.88	76.13	30.22	58.18	44.18	76.27	0.62	13.21
	18-22	1:26 PM	35700.10	19.30		3.94	35.01	78.82	30.08	53.15	32.77	78.31	1.12	12.93
September03	26-30	10:21 AM	35865.10	20.60		1.97	8.37	79.35	30.18	53.26	31.03	79.06	1.13	13.18
	1-5	2:21 PM	36061.10	21.40	17.10	2.19	11.39	70.23	30.26	53.84	47.26	70.45	2.13	13.42
	8-12	10:44 AM	36197.00	18.10		6.13	61.94	66.61	29.97	52.62	48.72	67.51	2.13	13.38
	15-19	11:30 AM	36364.70	19.30		2.63	179.71	78.62	29.94	42.75	20.72	78.79	0.07	13.27
October03	22-26	12:14 PM	36533.40	20.60		9.86	256.15	79.57	29.98	34.46	9.92	81.89	0.14	13.17
	29-3	12:17 PM	36701.40	22.20	17.10	3.28	64.68	45.02	30.33	40.03	75.99	44.79	0.14	13.45
	6-10	7:51 AM	36864.40	18.60		0.00	166.10	46.40	30.00	38.70	65.80	46.30	0.00	13.14
	13-17	1:21 PM	37038.30	21.40		1.53	267.96	58.65	30.06	27.49	19.47	59.00	0.00	13.43
November03	20-24	11:08 AM	37228.10	26.40		0.43	87.60	73.80	30.21	35.91	16.30	73.60	0.00	13.41
	27-31	2:29 PM	37375.40	27.10		3.50	89.71	56.89	29.81	38.32	39.18	56.80	0.00	13.30
	3-7	1:39 PM	37543.70	26.40	16.80	9.20	280.31	34.44	29.85	20.99	24.64	46.91	0.19	13.57
	10-14	1:16 PM	37711.20	18.70		5.91	264.86	47.23	29.91	30.14	26.99	55.42	0.19	13.49
December03	17-21	10:48 AM	37876.70	20.40		14.28	259.93	39.88	30.01	22.38	23.87	47.70	0.19	13.78
	24-28	12:43 PM	38046.60	23.30		6.35	76.36	35.79	29.61	24.45	46.30	38.08	0.20	13.71
	1-5	1:09 PM	38215.00	24.20	17.10	2.63	271.53	56.82	29.98	26.26	19.53	57.02	0.00	13.50
	8-12	11:44 AM	38405.60	19.50		3.72	354.68	25.45	29.88	18.31	63.91	25.55	0.09	13.93
22-26	15-19	12:59 PM	38550.70	23.80		6.13	100.75	40.55	30.12	14.35	20.42	41.61	0.09	13.66
	22-26	1:18 PM	38743.00	27.80		4.38	20.90	49.71	29.82	24.96	26.45	49.88	0.12	13.54
	29-2	12:40 PM	38862.20	29.40	17.00	1.43	141.60	32.40	29.79	9.10	18.90	36.39	0.12	13.33



# 2003-NORTHGLENN

Week of	JulianDate	Time	Hour Meter	PressOn ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
1-3	2	12:08 PM	25517.30	25.10		10.74	297.10	46.79	30.10	21.89	19.27	51.78	0.00	13.39
6-10	8	10:14 AM	25659.60	15.50		2.41	131.37	56.08	30.07	28.83	23.64	56.40	0.00	13.37
13-17	15	9:10 AM	25826.50	18.40		2.63	323.88	29.78	29.92	25.58	77.47	29.84	0.00	13.80
20-24	24	9:43 AM	26043.10	21.50		1.97	102.59	36.91	30.18	29.71	66.70	36.83	0.01	13.77
27-31	30	9:19 AM	26186.70	23.80		18.63	282.46	44.34	29.96	31.17	29.96	54.90	0.01	13.56
3-7	37	10:06 AM	26355.50	24.90		4.16	26.81	13.26	30.22	10.62	83.52	13.24	0.02	14.02
10-14	43	8:57 AM	26498.30	13.50		1.31	269.21	33.07	30.10	22.34	55.79	32.97	0.03	13.81
17-21	51	10:05 AM	26691.40	16.70		1.97	106.51	40.26	29.96	20.23	30.11	40.63	0.08	13.56
3-7	65	12:44 PM	27028.20	20.30		15.78	294.85	34.27	29.67	22.66	18.08	51.87	0.23	13.49
10-14	71	11:17 AM	27170.70	15.30		14.47	273.17	53.59	29.91	28.60	18.02	62.08	0.03	13.27
24-28	84	9:23 AM	27480.70	16.70		3.28	120.19	31.51	30.15	33.16	63.53	41.91	0.97	13.55
31-4	92	9:26 AM	27672.60	21.00	10.80	6.14	196.16	55.50	29.78	26.22	16.17	61.29	1.12	13.37
7-11	98	9:14 AM	27816.40	14.20		1.97	153.70	35.97	30.36	30.08	54.72	40.13	0.31	13.56
14-18	105	9:22 AM	27984.50	19.70		8.55	175.51	60.22	29.65	35.15	19.73	67.62	0.31	13.05
21-25	112	11:53 AM	28154.00	18.00		3.84	119.54	52.45	29.83	45.39	63.71	54.66	0.99	13.41
28-2	120	12:17 PM	28346.40	19.50		5.69	354.52	51.69	29.81	46.12	64.28	54.38	2.22	13.29
5-9	126	12:35 PM	28491.70	21.90	14.10	2.19	4.28	56.61	29.87	35.55	30.41	56.57	0.01	13.37
12-16	133	10:37 AM	28657.40	15.20		7.45	18.16	64.97	30.06	43.97	30.33	68.48	1.32	13.19
19-23	141	10:47 AM	28849.60	16.20		7.45	118.25	67.06	30.16	37.39	23.11	67.18	1.46	13.06
26-30	148	11:17 AM	29018.00	17.40		7.89	136.05	71.97	30.33	60.35	53.54	73.75	1.46	13.11
2-6	154	8:19 AM	29159.10	18.50	11.70	0.43	274.12	56.66	30.10	49.20	69.65	56.75	1.50	13.35
9-13	161	11:52 AM	29330.60	14.60		3.94	168.45	74.35	29.90	51.68	35.21	74.75	0.24	13.12
16-20	168	12:35 PM	29498.40	15.60		1.97	74.14	71.68	30.18	56.46	52.60	71.88	0.28	13.05
23-27	175	12:25 PM	29667.20	16.30		5.04	303.36	53.87	29.92	52.45	87.23	55.22	1.32	13.45
30-4	182	11:19 AM	29834.00	18.30	14.00	0.88	103.09	89.00	30.02	51.68	19.64	88.91	0.00	12.87
7-11	190	8:14 AM	30022.80	17.40		1.97	342.76	70.78	30.24	50.38	38.72	71.02	0.00	13.08
16-18	196	10:20 AM	30169.00	20.30		0.66	242.56	80.89	30.16	56.42	33.88	81.17	0.00	13.02
21-25	203	10:49 AM	30336.70	22.40		7.01	14.80	73.33	30.27	57.42	44.08	75.09	0.02	13.09
28-1	210	10:07 AM	30504.00	23.80		1.75	332.23	73.57	30.20	63.58	64.67	73.48	0.17	13.11
4-8	218	12:00 PM	30697.80	26.80	13.10	2.20	133.30	90.20	30.13	53.00	25.30	90.30	0.60	13.14
11-15	225	10:26 AM	30863.30	18.90		3.28	40.97	73.61	30.24	57.04	49.37	73.68	0.65	13.09
18-22	231	1:04 PM	31009.90	19.50		3.28	98.32	77.86	30.11	54.22	36.86	77.37	0.70	12.98
26-30	238	11:16 AM	31176.10	22.60		1.75	99.16	80.17	30.21	52.76	29.32	79.93	0.71	13.05
1-5	246	1:47 PM	31370.60	23.20	17.20	5.48	81.28	67.46	30.31	54.09	55.08	68.79	1.76	13.26
8-12	252	11:13 AM	31512.00	18.30		1.75	135.20	67.06	29.98	53.88	50.98	68.60	1.78	13.16
15-19	259	12:01 PM	31680.80	20.00		2.19	106.81	77.57	29.94	37.42	15.29	78.83	0.13	13.07
22-26	266		31849.50	21.80		9.74	283.44	81.13	29.98	34.50	10.58	82.37	0.15	13.01
29-3	273	11:37 AM	32016.20	23.90	12.90	5.48	26.25	40.08	30.38	39.52	80.26	43.56	0.15	13.49
6-10	280	7:16 AM	32179.60	19.70		2.40	222.30	53.50	30.03	35.20	38.10	53.60	0.00	12.88
13-17	287	12:34 PM	32353.00	23.40		5.04	163.04	57.26	30.11	26.66	19.15	57.45	0.00	13.28
20-24	295	1:23 PM				3.10	77.10	77.80	30.19	78.00	16.78	78.10	0.00	13.34
27-31	301	2:01 PM	32690.40	29.50		4.82	185.86	57.13	29.84	38.52	39.33	57.02	0.00	13.25
3-7	308	12:42 PM	32858.10	27.30	16.10	6.57	301.51	45.05	29.89	24.11	31.19	45.20	0.18	13.49
10-14	315	12:45 PM	33020.40	19.70		13.81	273.94	44.39	29.91	29.97	25.69	55.54	0.18	13.35
17-21	322	11:10 AM	33186.70	21.70		22.13	263.03	39.70	30.03	22.70	24.38	48.85	0.18	13.45
24-28	329	12:07 PM	33355.70	24.80		7.45	56.13	31.19	29.65	25.62	53.58	36.94	0.18	13.66
1-5	336	12:33 PM	33524.10	26.30	12.00	4.16	306.14	52.21	30.01	28.92	29.15	52.16	0.00	13.45
8-12	344	12:21 PM	33715.90	18.00		7.23	309.18	12.41	29.87	19.14	70.47	24.97	0.06	13.73
15-19	350	12:17 PM	33859.60	23.60		4.60	134.16	32.43	30.14	12.98	20.34	39.95	0.06	13.56
22-26	358	1:45 PM	34053.10	29.10		2.19	4.37	48.00	29.85	26.27	30.74	47.91	0.07	13.48
29-2	363	12:08 PM	34171.40	31.10	17.10	1.53	158.62	34.70	29.82	9.40	21.30	34.80	0.07	13.45



# 2003-STANDLEY LAKE

Week of	JulianDate	Time	Hour Meter	Press On mmHg	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press mmHg	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
1-3	2	1:45 PM	15728.70	18.10		7.23	329.13	53.99	30.11	23.52	19.51	53.95	0.00	13.55
6-10	8	12:12 PM	15871.20	13.80		2.19	92.30	66.17	30.00	22.86	10.41	66.24	0.02	13.34
January 03	15	11:17 AM	16024.50	15.00		6.80	286.38	37.99	29.96	27.28	29.62	49.47	0.02	13.08
20-24	24	11:20 AM	16237.20	16.40		7.23	151.17	37.81	30.15	30.00	49.35	43.04	0.02	13.81
27-31	30	11:18 AM	16381.10	17.50		0.88	330.35	55.34	29.96	29.97	26.63	55.45	0.02	13.74
February 03	37	12:18 PM	16550.10	17.50		1.75	133.14	18.63	30.18	12.28	68.79	18.51	0.02	13.97
10-14	43	10:32 AM	16692.40	13.60		4.38	4.46	39.20	30.09	22.90	39.41	39.10	0.03	13.80
17-21	51	11:24 AM	16885.20	15.00		4.16	90.72	44.51	29.94	16.66	20.52	44.59	0.03	13.63
March 03	65	2:29 PM	17223.40	12.60	17.50	17.54	272.02	37.07	29.70	18.12	15.62	51.74	0.03	13.58
10-14	71	9:51 AM	17362.80	13.60		14.69	241.29	49.53	29.92	30.04	22.01	59.28	0.00	13.55
24-28	84	12:20 PM	17676.20	14.40		7.01	116.83	41.31	30.11	31.01	40.36	47.95	1.39	13.52
31-4	92	11:53 AM	17867.60	15.50	12.80	10.74	197.79	61.28	29.72	24.33	10.88	68.19	1.43	13.32
7-11	98	10:48 AM	18010.50	13.80		3.07	146.21	44.33	30.35	28.68	43.04	44.13	0.83	13.61
14-18	105	10:53 AM	18178.60	15.40		7.67	140.63	64.72	29.61	32.86	17.96	67.68	0.83	13.15
21-25	112	12:23 PM	18348.10	16.00		3.07	126.41	57.29	29.79	42.99	49.47	57.31	2.33	13.49
28-2	120	12:45 PM	18540.50	16.40		3.29	123.71	53.57	29.79	36.92	38.52	55.80	3.24	13.33
5-9	126	9:56 AM	18681.60	17.10	13.30	3.95	45.45	53.36	29.90	35.28	39.71	53.18	0.00	13.68
12-16	133	8:32 AM	18847.80	13.60		3.29	16.55	59.68	30.04	43.91	44.74	60.51	1.56	13.44
19-23	141	9:14 AM	19040.70	14.20		4.60	134.40	60.22	30.16	40.55	32.84	63.50	1.74	12.94
26-30	148	12:54 PM	19212.20	14.80		3.95	337.47	77.35	30.29	60.05	50.91	77.40	1.74	13.10
2-6	154	10:24 AM	19353.70	15.30	12.70	0.66	110.05	57.87	30.05	48.02	52.99	61.06	1.79	13.31
9-13	161	9:11 AM	19520.40	13.30		2.85	295.11	64.99	29.97	53.91	60.75	65.16	0.60	13.23
16-20	168	2:24 PM	19692.60	13.90		3.72	338.79	68.83	30.18	55.79	46.24	71.75	0.65	13.21
23-27	175	8:48 AM	19854.70	14.50		3.94	88.21	53.06	29.90	50.64	88.92	53.06	1.63	13.65
30-4	182	1:15 PM	20026.90	15.10	13.30	2.11	82.52	91.89	30.01	43.27	11.52	92.16	0.00	13.11
7-11	190	10:07 AM	20215.70	14.60		1.97	120.83	75.17	30.23	47.97	28.66	75.35	0.00	13.18
16-18	196	8:45 AM	20358.30	15.70		2.84	321.60	75.22	30.20	55.29	39.79	75.54	0.00	13.21
21-25	203	12:13 PM	20529.80	17.20		2.04	127.23	80.71	30.24	55.39	32.33	80.83	0.10	13.09
28-1	210	8:33 AM	20694.10	17.80		2.63	101.50	70.85	30.21	59.65	60.57	70.91	0.12	13.34
4-8	218	9:59 AM	20887.90	19.00	16.10	1.09	204.60	80.40	30.20	55.90	33.90	80.60	0.26	13.24
11-15	225	11:39 AM	21056.30	17.20		2.19	35.03	78.37	30.25	57.81	43.01	78.25	0.34	13.16
18-22	231	2:13 PM	21202.80	17.80		1.09	77.77	79.52	30.11	51.30	28.42	79.69	0.63	12.97
26-30	238	9:15 AM	21365.80	18.50		1.31	4.83	74.34	30.22	54.24	38.11	74.24	0.63	13.34
1-5	246	3:21 PM	21563.00	19.30	16.30	5.91	316.67	62.70	30.29	53.68	54.94	66.67	1.38	13.61
8-12	252	9:42 AM	21702.20	16.80		4.16	113.21	65.62	29.99	48.50	43.68	66.01	1.40	13.42
15-19	259	10:21 AM	21870.90	17.50		1.09	187.11	72.58	30.00	42.90	24.63	72.51	0.08	13.38
22-26	266	10:42 AM	22039.20	18.00		3.28	165.82	76.11	30.03	34.75	13.53	76.18	0.11	13.28
29-3	273	1:25 PM	22209.40	19.10	15.90	6.57	24.44	47.89	30.35	40.55	69.33	48.07	0.11	13.49
6-10	280	9:22 AM	22373.10	17.10		0.65	134.30	60.90	30.02	40.90	36.70	61.20	0.00	13.10
13-17	287	2:25 PM	22546.30	18.10		2.19	13.66	62.03	30.03	21.68	11.78	62.16	0.00	13.36
20-24	295	8:20 AM	22733.00	21.00		1.97	300.50	55.90	30.30	32.60	29.00	56.20	0.00	13.43
27-31	301	3:28 PM	22883.30	21.60		1.97	146.58	57.96	29.81	37.90	35.98	57.96	0.00	13.44
3-7	308	2:37 PM	23051.50	21.30	13.90	3.94	277.55	47.01	29.87	23.05	26.26	47.20	0.17	13.51
10-14	315	2:07 PM	23218.90	15.30		5.04	155.97	56.43	29.92	24.82	18.74	56.54	0.17	13.47
17-21	322	9:57 AM	23381.80	16.00		10.96	284.93	38.28	30.05	21.18	24.01	46.75	0.17	13.78
24-28	329	1:30 PM	23553.40	18.10		5.26	9.20	29.57	29.63	24.65	46.11	38.24	0.17	13.74
1-5	336	2:03 PM	23721.90	19.20	14.30	10.96	289.91	47.96	30.03	21.49	14.28	57.47	0.00	13.55
8-12	344	9:57 AM	23909.80	15.70		1.53	113.34	27.57	29.95	15.13	46.74	27.66	0.12	13.96
15-19	350	1:50 PM	24057.50	18.10		2.63	342.00	43.22	30.15	16.33	21.25	43.22	0.12	13.57
22-26	358	11:56 AM	24247.60	21.30		0.44	326.64	46.06	29.86	22.01	26.05	46.22	0.14	13.66
29-4	363	1:33 PM	24369.40	23.30	16.30	2.63	25.90	39.80	29.79	9.84	16.50	39.80	0.14	13.88



# 2004-COUNTRYSIDE

Week of

JulianDate	Time	Hour Meter	Press On ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
5-10 January 04	12:57 PM	11889.90	17.80		1.97	53.83	22.46	30.19	11.39	50.50	22.42	0.00	14.00
12-17	1:45 PM	12038.70	20.00		3.28	191.58	57.24	30.19	19.69	13.02	57.11	0.09	13.37
19-24	10:58 AM	12204.00	20.80		4.16	13.91	28.78	30.09	29.06	101.69	28.49	1.00	13.95
26-31	12:37 PM	12373.60	23.50		11.84	264.64	30.99	29.94	19.46	28.74	40.51	0.22	13.67
2-7 February04	11:43 AM	12540.70	26.60	9.90	1.53	5.84	29.76	29.88	18.31	50.13	29.65	0.00	13.96
9-14	1:39 PM	12710.60	12.40		0.66	22.72	41.79	30.04	16.88	23.18	41.92	0.15	13.66
16-21	2:01 PM	12879.00	14.30		12.06	274.78	58.24	30.17	35.97	27.03	62.54	0.16	13.30
22-29	12:03 PM	13045.00	13.80		3.51	34.08	34.66	29.97	33.06	72.47	38.98	0.37	13.87
2-7 March04	1:57 PM	13214.90	15.00	11.20	0.44	-0.11	44.06	29.93	28.55	43.69	43.75	0.00	13.60
9-14	1:01 PM	13381.90	12.40		0.88	148.47	64.37	30.13	37.40	26.43	64.12	0.27	13.44
16-21	12:42 PM	13549.50	14.50		17.76	280.63	43.73	29.99	28.80	23.50	56.60	0.27	13.57
23-29	1:04 PM	13717.80	18.20		0.00	154.94	68.70	29.90	39.56	23.69	68.47	0.27	13.42
30-4 April04	1:37 PM	13886.90	18.70		7.23	67.81	63.99	30.16	24.99	11.67	66.72	0.28	13.37
6-11	11:43 AM	14052.50	19.80	11.80	6.14	307.69	51.70	30.01	44.74	57.87	55.81	0.79	13.54
13-18	12:04 PM	14220.80	13.10		0.22	67.18	62.84	30.08	36.24	24.75	64.88	1.17	13.41
20-25	12:28 PM	14387.70	15.70		3.95	318.90	60.27	29.85	26.31	18.02	59.94	1.17	13.41
27-2	10:36 AM	14553.70	15.60		4.60	277.05	71.56	30.12	35.67	17.13	71.69	2.01	13.27
4-9 May04	12:48 PM	14724.00	17.10	11.70	1.32	181.68	68.62	30.05	50.19	41.28	68.65	2.32	13.29
11-16	1:16 PM	14892.40	13.80		9.57	205.41	77.41	29.54	31.02	9.99	79.62	0.12	13.15
18-23	12:13 PM	15059.40	13.90		6.58	93.18	61.89	30.05	55.69	59.42	66.34	0.90	13.68
25-30	12:48 PM	15228.00	15.60		5.69	2.55	50.74	30.00	45.01	70.53	51.25	0.98	13.62
1-6 Jun04	11:49 AM	15419.00	18.30	12.00	0.00	66.97	64.19	30.16	45.71	39.36	64.41	0.00	13.40
8-13	11:06 AM	15582.20	13.80		1.97	44.57	64.97	29.97	52.02	44.27	69.01	0.00	13.33
15-20	12:57 PM	15732.00	15.10		4.62	18.14	80.50	30.00	51.83	27.26	80.35	0.50	13.22
22-27	10:25 AM	15897.50	15.00		1.09	201.63	63.29	30.19	44.53	39.79	63.21	1.68	13.34
29-4	9:58 AM	16065.00	16.70		1.75	56.14	70.03	30.16	57.72	53.07	70.24	2.07	13.30
6-11 Jul04	10:13 AM	16257.30	19.60	12.40	2.63	184.19	82.45	30.01	44.64	18.65	82.52	2.77	13.15
15-18	11:39 AM	16402.70	13.90		1.10	166.59	92.34	30.13	53.06	19.11	92.10	0.00	13.07
20-25	9:55 AM	16568.90	14.40		3.51	194.39	84.88	30.08	59.27	33.09	84.77	0.49	13.13
27-1	9:39 AM	16736.60	15.10		3.07	50.41	71.42	30.07	54.45	47.40	71.38	2.58	13.33
3-8 August04	11:10 AM	16930.10	17.40	12.10	1.80	38.90	75.60	30.18	64.60	60.00	75.70	0.01	13.24
10-15	1:28 PM	17123.50	12.80		0.70	304.40	71.60	30.23	48.40	34.90	71.80	0.42	13.20
17-22	10:06 AM	17240.30	14.00		1.53	90.19	72.90	30.16	56.68	48.65	72.16	0.42	13.27
25-30	1:19 PM	17411.50	14.90		4.82	7.32	75.99	29.95	49.47	30.66	75.79	1.52	13.24
1-5 September04	10:33 AM	17600.70	16.80	12.40	0.22	36.50	75.11	30.25	52.09	35.72	75.09	1.79	13.24
7-12	1:00 PM	17795.10	13.80		1.09	0.21	81.73	30.09	45.04	17.72	81.66	0.10	13.21
14-19	1:19 PM	17939.40	14.40		1.09	122.79	68.06	30.04	41.42	25.28	68.16	0.15	13.36
21-26	12:37 PM	18082.70	15.50		3.29	17.19	39.85	30.18	39.09	96.35	39.82	0.63	13.89
28-3	10:16 AM	18248.30	16.30		2.63	0.00	52.23	30.31	48.42	82.03	52.21	1.47	13.65
5-10	10:42 AM	18416.70	18.20	11.80	3.29	71.01	56.41	30.15	45.76	59.57	56.35	0.00	13.57
12-17 October04	1:57 PM	18587.80	12.60		6.79	9.87	58.08	30.07	37.38	28.36	62.77	0.55	13.39
19-24	2:00 PM	18755.90	13.40		5.91	31.10	54.96	29.86	38.97	38.38	57.89	1.03	13.43
26-31	12:13 PM	18922.10	14.90		2.19	351.14	55.08	29.98	42.23	47.42	56.47	1.03	13.62
2-7 November04	11:46 AM	19090.70	16.40	11.60	6.79	184.61	34.63	30.30	18.27	25.34	43.34	0.00	13.79
9-14	8:46 AM	19255.55	13.10		3.10	67.80	50.50	29.95	38.60	52.30	50.50	0.14	13.10
16-21	10:43 AM	19449.60	15.30		0.88	77.18	52.98	30.19	38.78	48.64	52.83	0.38	13.71
23-28	12:40 PM	19594.60	16.30		5.26	13.59	33.44	29.89	29.24	65.78	37.12	0.60	13.81
1-5 December04	12:15 PM	19786.10	20.80	11.80	2.85	345.80	30.90	30.06	16.40	42.20	30.90	0.73	13.60
7-12	10:48 AM	19928.60	14.70		1.53	148.41	43.83	29.84	18.13	23.27	43.92	0.00	13.88
14-19	1:04 PM	20098.90	16.20		2.63	181.63	51.07	30.20	32.28	37.14	51.07	0.00	13.65
21-26	10:54 AM	20264.50	18.40										
28-2	12:15 PM	20433.30	21.60		2.41	49.89	55.55	30.03	31.84	27.67	55.39	0.09	13.64



# 2004-EMERALD PARK

Week of	Julian Date	Time	Hour	Press On mmHg	Pres Off mmHg	W Speed mph	W Direct degrees	W Chill °F	B Press mmHg	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 04	5-10	12-36 PM	39054.20	19.10		3.51	69.97	19.81	30.19	10.07	51.81	20.03	0.07	13.93
	12-17	1:06 PM	39222.70	22.60		5.70	151.79	52.45	30.19	19.76	14.91	55.15	0.14	13.30
	19-24	11:23 AM	39388.80	28.00		2.19	3.39	29.22	30.07	28.64	97.02	39.18	0.16	13.87
	26-31	12:16 PM	39557.70	29.70		6.57	274.72	32.27	29.91	18.07	28.98	39.83	0.25	13.66
February04	2-7	11:16 AM	39724.70	31.60	11.10		288.20	29.59	29.89	17.35	47.71	29.68	0.00	13.84
	9-14	1:18 PM	39894.70	14.80		1.32	7.06	38.47	30.04	21.69	37.90	38.63	0.20	13.71
	16-21	1:33 PM	40062.90	18.90		20.17	226.74	61.77	30.14	35.21	26.66	61.66	0.20	13.25
	22-29	11:37 AM	40229.00	23.30		1.10	300.62	37.13	29.96	31.80	74.31	37.15	0.39	13.82
March03	2-7	1:30 PM	40398.90	25.50	11.60		169.03	42.93	29.92	27.00	41.25	43.11	0.00	13.59
	9-14	12:25 PM	40565.60	12.90		2.63	133.05	62.27	30.14	37.90	29.47	62.72	0.27	13.43
	16-21	12:12 PM	40733.30	14.40		5.04	232.58	47.44	29.97	29.16	23.37	56.74	0.27	13.54
	23-29	12:22 PM	40901.40	20.10		5.48	147.25	63.44	29.90	39.50	26.25	66.54	0.27	13.44
April04	30-4	1:39 PM	41069.50	22.50		0.88	65.15	60.36	30.18	22.72	11.54	63.85	0.27	13.39
	6-11	11:18 AM	41236.40	22.30	11.50		333.06	47.62	30.00	44.41	54.86	56.23	0.54	13.51
	13-18	11:42 AM	41404.80	12.60		5.04	109.13	61.11	30.05	36.92	26.05	63.26	1.12	13.42
	20-25	12:04 PM	41572.10	15.00		4.60	259.39	60.43	29.85	30.52	20.61	60.93	1.12	13.42
	27-2	11:18 AM	41739.30	15.30		5.69	261.36	68.59	30.08	32.99	14.49	72.23	2.15	13.31
May04	4-9	12:19 PM	41908.40	17.40	12.50		151.01	63.25	30.04	49.40	44.15	67.35	2.52	13.30
	11-16	12:33 PM	42076.60	15.30		4.82	78.63	29.56	35.51	35.54	12.33	79.28	0.10	13.13
	18-23	11:48 AM	42243.80	15.50		7.45	81.06	60.94	30.04	53.54	61.27	63.99	0.75	13.64
	25-30	12:21 PM	42412.30	17.60		2.85	326.93	48.28	30.00	43.46	74.08	49.50	0.85	13.54
Jun04	1-6	11:10 AM	42603.20	21.40	11.80		53.95	59.95	30.14	44.34	41.14	62.36	0.00	13.39
	8-13	11:40 AM	42747.70	13.50		8.33	70.79	66.26	29.95	51.15	41.85	70.11	0.00	13.23
	15-20	12:34 PM	42916.40	14.90		6.36	64.49	79.63	29.98	50.82	28.35	80.09	0.44	13.09
	22-27	11:07 AM	43083.00	15.20		5.26	123.61	66.07	30.15	41.18	28.71	66.27	1.66	13.29
Jul04	29-4	10:24 AM	43250.20	16.80		4.60	109.31	71.14	30.14	56.77	54.23	70.71	2.05	13.19
	6-11	10:46 AM	43442.70	21.20	12.00		77.01	82.38	29.99	42.44	16.62	82.49	2.14	13.10
	13-18	11:16 AM	43587.10	14.00		11.17	141.88	89.73	30.12	54.96	22.25	90.34	0.00	13.05
	20-25	10:24 AM	43754.30	15.00		3.51	145.83	83.32	30.04	59.06	35.72	83.60	1.12	13.10
	27-1	10:03 AM	43921.90	16.40		2.19	58.56	74.84	30.03	50.64	33.84	74.86	3.12	13.16
August04	3-8	10:03 AM	44113.00	19.50	12.60		279.88	72.07	30.18	62.65	67.26	72.31	0.00	13.24
	10-15	1:15 PM	44308.20	13.60		2.60	330.50	69.60	30.21	46.80	33.20	69.60	0.39	13.14
	17-22	10:34 AM	44425.70	14.60		1.53	327.92	73.92	30.14	53.89	40.31	73.94	0.39	13.23
	25-30	12:57 PM	44596.10	16.10		2.19	26.27	74.51	29.94	45.86	27.29	74.42	1.67	13.16
September04	1-5	11:12 AM	44786.30	18.60	11.90		163.06	76.27	30.23	50.32	29.04	76.57	1.83	13.23
	7-12	12:36 PM	44979.60	13.50		1.32	276.23	83.44	30.06	42.84	16.28	83.52	0.26	13.09
	14-19	12:09 PM	45123.20	14.40		2.41	181.44	61.01	30.03	37.01	26.18	63.75	0.32	13.41
	21-26	12:12 PM	45267.20	16.00		1.97	304.19	39.59	30.16	38.73	93.34	40.09	0.79	13.82
	28-3	10:46 AM	45433.80	17.50		3.29	68.93	53.36	30.30	48.02	76.66	53.27	1.80	13.56
	5-10	11:25 AM	45602.40	20.40	11.70		58.09	55.85	30.10	46.18	55.53	58.14	0.00	13.48
October04	12-17	1:30 PM	45772.20	12.70		3.29	334.45	63.22	30.03	36.94	27.38	63.12	0.58	13.34
	19-24	1:39 PM	45940.40	14.00		1.97	282.02	57.83	29.83	39.09	40.15	57.87	0.97	13.41
	26-31	11:45 AM	46106.50	16.20		0.00	52.36	56.68	29.94	42.12	50.06	56.10	0.97	13.62
November04	2-7	11:16 AM	46275.00	18.90	11.70		143.53	36.95	30.27	18.33	27.17	41.68	0.00	13.82
	9-14	9:10 AM	46440.80	13.80		0.43	322.10	51.70	29.90	34.60	39.80	51.90	0.15	13.40
	16-21	10:21 AM	46634.10	17.00		1.31	24.58	52.56	30.17	38.27	48.60	52.65	0.39	13.69
	23-28	12:18 PM	46780.00	19.80		1.97	15.07	37.34	29.87	28.07	59.42	37.38	0.51	13.72
December04	1-5	12:57 PM	46972.70	27.20	11.30		1.01	28.80	30.03	16.40	46.90	28.80	0.67	13.80
	7-12	11:18 AM	47114.90	13.90		2.63	141.08	45.64	29.80	16.79	20.44	45.45	0.01	13.75
	14-19	12:36 PM	47284.20	15.50		1.75	182.97	49.11	30.18	31.30	38.38	48.77	0.01	13.65
	21-26	12:53 PM	47452.40	19.00										
	28-2	11:18 AM	47618.70	24.70		3.50	132.87	51.89	30.02	28.97	29.03	52.28	0.07	13.61



# 2004-N O R T H G L E N N

	Week of	JulianDate	Time	Hour	Meter	PressOn ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 04	5-10	6	12:15 PM	34363.50	19.50			4.82	85.83	19.88	30.21	10.16	51.61	20.18	0.10	13.74
	12-17	13	12:26 PM	34531.70	24.30			1.09	156.90	53.86	30.21	18.87	14.37	53.20	0.12	13.26
	19-24	20	11:45 AM	34699.00	26.70			4.16	338.56	28.51	30.09	29.13	100.24	29.08	0.14	13.77
	26-31	27	11:54 AM	34866.10	30.20			13.81	258.54	21.89	29.93	19.59	32.43	39.06	0.25	13.52
	2-7	34	10:39 AM	35032.90	33.20	8.10		3.51	288.87	27.29	29.92	17.28	54.91	27.36	0.00	13.75
February04	9-14	41	12:53 PM	35203.10	11.20			0.00	302.70	38.54	30.06	20.91	37.23	38.11	0.13	13.45
	16-21	48	1:02 PM	35371.20	14.40			16.00	307.84	45.83	30.19	34.92	29.87	58.32	0.13	13.22
	22-29	55	11:05 AM	35537.30	15.30			6.58	303.86	34.32	29.99	31.78	77.43	36.28	0.16	13.67
March03	2-7	62	12:51 PM	35707.00	19.00	11.30		5.92	161.53	40.75	29.95	26.75	43.62	41.44	0.00	13.45
	9-14	69	11:42 AM	35873.90	12.90			3.07	135.84	59.67	30.20	37.84	32.00	59.53	0.32	13.24
	16-21	76	11:36 AM	36041.60	14.60			18.19	271.58	48.45	30.01	29.09	24.79	56.23	0.32	13.39
April04	23-29	83	11:53 AM	36209.90	21.40			1.75	139.56	63.18	29.94	38.34	27.13	63.12	0.32	13.39
	30-4	90	1:30 PM	36377.70	22.70			7.01	85.38	57.98	30.22	24.53	13.72	61.92	0.32	13.30
	6-11	97	10:47 AM	36544.80	23.10	8.90		11.62	20.02	41.59	30.04	43.16	58.01	54.28	0.00	13.45
	13-18	104	11:08 AM	36713.10	12.30			2.85	126.81	56.62	30.11	35.76	27.97	61.49	1.00	13.32
	20-25	111	11:38 AM	36880.60	15.70			0.00	124.47	58.82	29.87	28.10	20.74	58.34	1.00	13.31
May04	27-2	118	12:44 PM	37049.70	17.30			13.15	279.66	68.47	30.06	34.14	15.03	74.59	1.59	13.12
	4-9	125	11:35 AM	37216.50	19.90	11.60		5.04	126.26	61.79	30.09	49.35	51.08	63.84	1.97	13.25
	11-16	132	12:03 PM	37384.90	13.90			1.53	153.56	78.40	29.60	35.55	12.71	79.42	0.10	13.08
	18-23	139	10:53 AM	37551.80	15.00			3.95	58.76	61.92	30.09	54.58	68.28	61.82	1.01	13.56
	25-30	146	11:42 AM	37720.60	17.70			9.43	312.08	45.95	30.04	44.47	77.31	48.93	1.02	13.51
Jun04	1-6	154	9:59 AM	37910.90	22.00	8.80		4.38	345.88	56.97	30.18	44.76	51.89	58.12	0.00	13.32
	8-13	160	12:56 PM	38057.80	13.10			4.60	321.91	68.51	29.29	53.08	40.84	71.98	0.00	13.15
	15-20	167	11:42 AM	38224.40	15.00			11.40	96.29	73.72	30.04	53.55	35.42	77.21	0.17	13.10
	22-27	174	11:33 AM	38392.30	15.70			5.26	115.00	64.97	30.20	40.58	29.34	65.16	1.20	13.20
	29-4	181	10:56 AM	38559.60	18.00			2.19	86.79	71.49	30.17	58.34	55.14	71.55	1.51	13.11
Jul04	6-11	189	11:32 AM	38752.30	22.60	12.00		3.07	54.76	83.82	30.00	43.76	16.48	84.06	1.61	12.98
	15-18	195	10:51 AM	38895.50	13.90			5.26	109.60	87.09	30.16	54.86	25.15	87.09	0.00	12.97
	20-25	202	10:44 AM	39063.40	15.20			2.85	92.84	84.38	30.09	56.98	33.88	84.30	0.63	12.98
	27-1	209	10:38 AM	39231.30	17.20			2.41	91.44	74.98	30.06	55.61	43.04	74.94	1.92	13.12
	3-8	217	8:38 AM	39421.30	20.80	9.90		0.00	11.08	67.95	30.23	63.04	79.46	68.24	0.00	13.23
August04	10-15	225	12:53 PM	39616.30	13.30			2.20	52.50	69.80	30.18	47.00	32.90	69.80	0.21	13.10
	17-22	230	11:02 AM	39734.70	14.40			0.88	190.79	78.23	30.17	56.52	37.00	77.83	0.21	13.04
	25-30	237	12:31 PM	39904.10	17.30			2.41	249.28	75.97	29.98	48.83	28.86	76.15	1.77	13.07
	1-5	245	11:45 AM	40095.40	20.60	12.30		5.69	112.68	75.33	30.25	50.08	30.12	75.26	2.05	13.09
	7-12	253	11:54 AM	40287.50	15.30			2.63	266.06	83.33	30.11	42.66	15.02	83.41	0.18	12.99
September04	14-19	259	11:41 AM	40431.20	18.70			4.82	171.80	55.96	30.07	37.13	29.42	61.47	0.24	13.33
	21-26	265	11:50 AM	40575.40	23.00			5.48	322.12	35.97	30.18	39.99	98.67	40.24	0.60	13.75
	28-3	272	11:17 AM	40742.90	24.80			2.63	35.38	54.81	30.30	49.32	75.83	54.91	1.64	13.41
	5-10	279	12:03 PM	40911.60	27.00	9.00		2.63	44.98	59.43	30.13	48.11	60.35	59.04	0.00	13.24
	12-17	286	12:39 PM	41080.10	12.70			5.26	351.54	60.95	30.10	40.39	34.76	61.27	0.68	13.16
October04	19-24	293	1:05 PM	41248.50	15.10			4.16	294.38	59.43	29.87	37.87	34.50	59.45	0.98	13.19
	26-31	300	11:05 AM	41414.50	19.80			1.75	90.78	55.09	29.98	41.90	51.56	54.87	0.98	13.33
	2-7	307	10:36 AM	41583.00	24.90	12.00		2.33	156.58	38.06	30.30	19.69	34.35	37.85	0.00	13.53
	9-14	314	9:35 AM	41749.80	16.70			0.00	295.10	55.00	29.94	38.35	42.40	55.30	0.08	12.90
	16-21	322	9:56 AM	41942.40	24.60			2.19	26.25	53.12	30.20	37.44	44.96	53.05	0.27	13.52
November04	23-28	328	11:53 AM	42088.30	27.80			5.48	109.58	30.51	29.92	29.10	66.27	36.52	0.34	13.66
	1-5	336	1:23 PM	42281.70	33.50	10.10		4.60	297.30	22.30	30.06	16.80	49.50	28.10	0.51	13.80
	7-12	342	11:47 AM	42424.10	13.10			3.51	137.53	44.85	29.80	17.23	17.63	48.20	0.00	13.45
	14-19	349	12:09 PM	42592.50	15.40			0.00	104.28	43.09	30.23	31.60	51.06	43.32	0.00	13.62
	21-26	354	2:02 PM	42762.30	19.60											
December04	28-2	363	11:47 AM	42927.00	25.10			6.14	106.53	44.93	30.06	28.99	30.67	51.24	0.06	13.48



# 2004-STANLEY LAKE

Week of	Julian Date	Time	Hour	Press On mmHg	Pres Off mmHg	W Speed mph	W Direct degrees	W Chill °F	B Press mmHg	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
5-10	6	1:20 PM	24560.90	17.80		1.75	37.93	25.03	30.18	13.07	44.61	25.32	0.01	13.76
January 04	13	2:17 PM	24729.80	18.80		2.41	132.26	58.23	30.20	14.93	9.32	58.21	0.18	13.25
19-24	20	9:51 AM	24893.40	20.60		1.09	68.43	30.07	30.08	28.77	92.62	30.13	0.18	14.03
26-31	27	12:58 PM	25064.50	22.00		10.74	299.26	27.83	29.93	19.14	29.37	40.68	0.40	13.68
2-7	34	12:13 PM	25231.60	23.60	11.30	3.51	343.55	29.97	29.86	17.02	46.25	29.94	0.00	13.86
9-14	41	2:06 PM	25401.40	13.10		3.73	138.96	43.03	30.02	11.74	16.39	42.98	0.22	13.58
16-21	48	2:27 PM	25569.80	14.10		11.84	335.35	51.14	30.18	33.85	26.93	59.26	0.26	13.28
22-29	55	12:36 PM	25735.90	14.50		4.16	338.03	41.36	29.94	31.72	60.87	40.94	0.55	13.74
2-7	62	2:31 PM	25905.80	15.80	10.80	1.97	317.52	42.78	29.92	26.39	40.77	42.61	0.00	13.62
9-14	69	1:36 PM	26072.90	11.70		2.63	65.90	65.46	30.12	35.54	22.29	56.66	0.46	13.25
16-21	76	1:06 PM	26240.30	13.20		16.07	302.08	48.13	29.99	26.09	21.14	56.71	0.46	13.46
23-29	83	1:33 PM	26408.70	15.40		2.85	146.48	68.99	29.92	35.73	20.20	68.88	0.46	13.39
30-4	90	1:20 PM	26576.90	16.80		0.88	193.24	68.10	30.16	20.69	8.27	67.69	0.46	13.20
6-11	97	12:12 PM	26743.30	17.40	11.50	5.92	354.59	50.17	30.01	43.55	52.83	56.35	1.52	13.44
13-18	104	12:32 PM	26911.60	12.30		4.16	119.34	64.88	30.08	35.19	19.96	66.31	1.94	13.24
20-25	111	12:56 PM	27079.10	13.80		9.43	311.28	52.18	29.86	25.98	17.44	60.05	1.94	13.39
27-2	118	9:46 AM	27243.90	14.10		3.07	266.39	69.72	30.16	31.19	14.18	69.78	2.94	13.78
4-9	125	1:19 PM	27415.40	15.40	12.30	4.60	99.45	71.77	30.06	50.03	35.34	71.71	3.35	13.21
11-16	132	1:41 PM	27583.70	13.80		2.85	175.95	79.35	29.56	30.37	9.27	79.21	0.17	13.14
18-23	139	12:39 PM	27750.60	14.20		5.92	199.99	66.95	30.05	53.09	53.03	66.97	0.98	13.71
25-30	146	1:16 PM	27919.30	15.60		7.23	348.86	46.52	30.00	44.95	70.64	51.61	1.09	13.51
1-6	154	12:16 PM	28110.30	17.10	11.70	0.66	200.76	66.50	30.17	43.73	33.06	66.29	0.00	13.27
8-13	160	10:20 AM	28252.20	12.50		5.26	354.87	64.69	29.98	49.97	43.44	66.52	0.00	13.31
15-20	167	1:25 PM	28423.20	13.60		0.22	205.88	80.74	30.02	48.92	23.63	80.79	0.68	13.11
22-27	174	9:55 AM	28587.70	13.80		1.53	164.52	62.83	30.19	43.81	40.21	62.77	2.02	13.40
29-4	181	9:26 AM	28755.20	14.80		0.88	129.86	67.26	30.17	53.54	52.28	67.33	2.57	13.34
6-11	189	9:41 AM	28947.50	16.30	12.10	1.53	288.57	80.57	30.04	40.71	15.89	80.57	3.46	13.19
15-18	195	12:04 PM	29093.80	13.30		1.53	122.41	93.63	30.15	47.78	13.55	93.66	0.02	13.04
20-25	202	9:26 AM	29259.20	13.60		4.60	121.30	80.16	30.11	57.27	38.04	79.99	0.46	13.21
27-1	209	9:13 AM	29427.00	14.30		1.75	27.40	71.56	30.09	52.85	43.18	71.49	2.68	13.23
3-8	217	12:25 PM	29622.10	15.60	12.50	2.84	153.36	79.55	30.18	59.42	39.88	80.25	0.03	13.13
10-15	225	1:59 PM	29815.00	13.00		2.41	82.40	70.80	30.24	48.20	34.30	71.40	0.68	13.00
17-22	230	9:37 AM	29930.80	13.70		0.44	41.79	70.79	30.18	52.32	43.89	70.65	0.68	13.34
25-30	237	1:46 PM	30103.00	14.60		2.41	213.41	75.66	29.96	47.22	28.67	75.87		
1-5	245	9:49 AM	30291.00	15.80	11.60	1.32	131.25	72.00	30.28	47.51	32.29	71.96	3.06	13.36
7-12	253	1:38 PM	30486.70	12.70		2.41	197.61	84.55	30.10	41.73	14.49	84.78	0.25	13.21
14-19	259	2:07 PM	30631.20	13.30		2.63	97.97	68.70	30.03	33.07	16.51	68.94	0.32	13.26
21-26	265	1:02 PM	30774.10	14.10		4.38	338.32	34.82	30.18	40.06	90.01	40.05	0.99	13.85
28-3	272	9:34 AM	30938.70	14.60		0.88	23.43	51.25	30.31	46.87	80.51	51.20	1.94	13.66
5-10	279	9:56 AM	31107.10	15.60	12.00	0.66	217.81	57.13	30.14	43.54	51.25	56.93	0.00	13.61
12-17	286	2:22 PM	31279.40	13.00		1.97	3.72	64.09	30.06	36.57	25.28	64.31	0.75	13.49
19-24	293	2:25 PM	31447.40	13.70		0.28	0.28	37.87	29.86	37.87	36.49	57.85	1.27	13.90
26-31	300	12:55 PM	31613.90	14.60		3.07	17.48	57.67	29.95	40.62	41.55	57.87	1.27	13.49
2-7	307	12:17 PM	31784.30	16.10	12.30	5.70	145.40	36.21	30.26	15.12	18.36	44.76	0.00	13.71
9-14	314	8:23 AM	31946.40	13.50		0.88	108.00	49.49	29.95	37.70	54.20	49.50	0.13	13.80
16-21	322	11:31 AM	32141.50	14.90		2.19	328.45	53.94	30.18	35.79	40.19	53.98	0.42	13.63
23-28	328	1:10 PM	32287.10	16.30		4.16	335.78	33.56	29.89	28.17	60.89	36.97	0.43	13.80
1-5	336	11:41 AM	32477.70	19.90	11.20	1.97	283.10	30.80	30.06	15.70	40.80	30.80	0.64	13.80
7-12	342	10:15 AM	32620.10	13.10		2.63	175.43	40.83	29.86	16.18	23.83	40.95	0.03	13.79
14-19	349	1:30 PM	32791.30	14.20		0.88	27.33	47.85	30.20	28.45	35.07	47.85	0.03	13.62
21-26	354	9:00 AM	32955.10	15.40										
28-2	363	12:43 PM	33151.10	18.20		3.51	147.16	55.52	30.03	26.73	21.91	55.41	0.12	13.53



# 2005 - COUNTRYSIDE

Week of	Julian Date	Time	Hour Meter	Press On ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 05	3-7													
	10-14	12:15 PM	20601.70	28.30	11.20	5.70	353.03	3.86	30.06	16.71	99.91	16.70	0.00	14.24
	17-21	2:39 PM	20819.80	12.30		4.38	332.55	32.10	29.93	17.05	25.85	40.43	0.13	13.65
	24-28	2:55 PM	20964.00	14.60		8.54	283.35	62.20	30.20	34.64	22.33	64.76	0.13	13.32
		1:04 PM	21106.10	17.70		7.01	67.30	46.94	30.03	27.44	21.16	56.62	0.13	13.54
February05	31-4	1:22 PM	21298.40	20.50	11.00	5.70	173.35	34.44	30.20	25.79	39.23	42.42	0.27	13.47
	7-11	1:18 PM	21442.30	12.00		3.51	40.56	31.20	29.97	25.57	70.56	31.44	0.01	13.91
	14-18	12:15 PM	21609.10	13.80		13.37	41.20	13.19	30.07	27.77	101.30	27.57	0.00	14.08
	21-25	11:53 AM	21800.70	16.10		2.84	318.60	36.90	30.14	28.01	60.11	37.12	215.28	13.89
		10:27 AM	21991.40	20.60	11.30	2.63	87.58	48.30	30.05	22.23	22.86	48.46	215.28	13.74
March05	28-4	11:54 AM	22112.80	12.40		4.16	181.26	33.74	30.12	34.04	86.29	36.79	0.01	13.83
	7-11	12:27 PM	22305.40	14.20		4.38	183.32	47.24	29.92	22.49	25.65	47.86	0.15	13.66
	14-18	11:48 AM	22496.70	14.90		7.01	51.39	25.74	29.87	30.50	91.22	30.61	0.28	13.66
	21-25	9:45 AM	22638.70	16.30		2.19	115.82	45.22	29.75	23.71	30.48	45.59	0.39	13.73
	28-1	1:12 PM	22809.10	18.70	10.50	6.79	20.69	47.86	30.30	31.54	34.65	54.51	0.00	13.57
April05	4-8	10:47 AM	22950.60	11.60		1.09	99.54	53.03	30.06	33.73	36.64	52.74	0.13	13.51
	11-15	10:09 AM	23117.90	14.50		7.23	14.12	52.60	29.88	47.97	66.66	56.19	0.13	13.53
	18-22	10:24 AM	23286.20	15.00		0.88	198.08	52.21	29.97	34.99	40.28	51.90	0.85	13.63
	25-29	9:25 AM	23477.10	18.00	11.40	4.16	272.45	56.45	30.09	40.25	44.31	56.60	0.15	13.62
		9:35 AM	23621.30	12.30		4.82	73.23	61.49	29.81	40.69	32.88	63.71	0.17	13.36
May05	9-13	11:03 AM	23862.70	14.20		4.82	176.56	82.16	30.08	45.44	18.93	82.49	0.44	13.42
	16-20	1:12 PM	23984.20	14.50		6.79	279.26	54.99	30.24	45.23	63.83	55.00	0.56	13.53
	23-27	1:52 PM	24153.00	15.70	11.60	5.69	156.62	77.30	29.79	43.86	21.79	77.44	0.00	13.22
	30-3	10:08 AM	24293.30	12.80		3.95	258.62	62.09	29.03	46.26	44.73	63.27	40.01	13.34
	6-10	12:48 PM	24488.00	13.60		3.07	123.30	78.32	30.03	52.34	30.92	78.22	77.42	13.24
Jun05	13-17	9:44 AM	24628.90	15.50		4.38	63.14	75.52	30.25	52.39	35.19	76.19	0.01	13.26
	20-24	9:26 AM	24796.60	17.30		0.88	249.36	74.05	30.06	55.08	42.51	73.96	0.28	13.23
	27-1	2:45 PM	24969.90	20.70	12.10	3.29	243.41	81.45	30.09	49.51	23.79	81.43	0.00	13.18
	4-8													
	11-15													
Jul05	18-22													
	25-29													
August05	1-5													
	8-12													
	15-19													
	22-26													
	29-2													
September05	5-9													
	12-16													
	19-23													
	26-30													
October05	3-7													
	10-14													
	17-21													
	24-28													
November05	31-4													
	7-11													
	14-18													
	21-25													
	28-2													
December05	5-9													
	12-16													
	19-23													
	26-30													

# 2005-EMERALD PARK

Week of	Julian Date	Time	Hour Meter	Press On ""H2O	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press ""H2O	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 05	3-7	12:13 PM	47787.20	31.60	12.00	4.82	330.82	17.69	30.05	17.14	96.97	17.69	0.00	14.14
	10-14	1:55 PM	48005.00	13.60		10.52	270.91	34.77	29.91	17.88	27.22	40.72	0.15	13.71
	17-21	2:33 PM	48149.30	16.20		2.63	256.46	65.53	30.16	33.73	20.45	66.28	0.15	13.29
	24-28	1:30 PM	48292.30	20.80		3.29	26.74	58.32	30.01	27.64	19.20	58.62	0.15	13.46
February 05	31-4	1:46 PM	48484.50	26.00	11.60	8.98	124.11	38.35	30.18	24.99	36.34	43.50	0.46	13.36
	7-11	1:41 PM	48628.40	13.30		4.38	79.68	31.97	29.95	24.55	66.44	32.18	0.01	13.82
	14-18	12:13 PM	48795.20	17.40		3.29	349.69	22.18	30.06	28.25	97.90	28.55	0.01	13.98
	21-25	12:12 PM	48986.90	21.30		9.86	53.89	31.91	30.12	27.34	50.23	39.13	0.07	13.78
	28-4	11:11 AM	49177.90	26.00	11.60	6.58	343.24	50.84	30.02	19.99	18.42	51.05	0.07	13.68
March 05	7-11	11:29 AM	49288.10	12.70		8.33	354.49	31.37	30.10	31.15	67.00	38.37	0.02	13.81
	14-18	12:00 PM	49490.70	15.40		2.63	343.33	45.81	29.92	20.52	24.46	45.65	0.22	13.67
	21-25	11:30 AM	49682.20	15.60		5.26	67.15	25.25	29.85	29.95	90.16	31.87	n/council/ac	13.95
	28-1	10:08 AM	49824.80	18.20		0.66	21.47	47.18	29.71	23.19	26.68	47.27	0.56	13.72
April 05	4-8	12:38 PM	49994.30	21.40	11.70	9.21	350.10	48.83	30.29	33.23	32.18	54.28	0.01	13.56
	11-15	11:47 AM	50137.40	12.70		7.24	131.55	49.63	30.02	31.13	31.29	52.97	0.21	13.54
	18-22	10:37 AM	50304.10	15.20		9.64	2.92	56.50	29.87	45.66	59.62	56.48	0.21	13.49
	25-29	10:52 AM	50472.40	16.10		4.15	115.61	53.95	29.93	33.59	37.59	53.68	0.81	13.56
May 05	2-6	9:53 AM	50663.40	18.20	11.80	1.53	191.80	58.03	30.06	41.06	42.49	57.90	0.05	13.50
	9-13	9:58 AM	50807.20	12.80		5.92	2.35	63.52	29.81	40.80	29.05	65.60	0.09	13.34
	16-20	12:02 PM	51049.20	15.50		4.82	135.57	83.24	30.02	45.18	16.95	83.48	0.36	13.39
	23-27	12:13 PM	51168.90	16.10		0.88	297.36	53.95	30.23	44.00	61.45	53.93	0.48	13.51
	30-3	1:17 PM	51192.80	0.10		3.07	156.47	78.48	29.77	44.42	20.11	78.55	0.00	13.12
	6-10	10:38 AM				4.16	93.30	64.81	29.80	42.16	31.65	64.81	0.67	13.28
Jun 05	13-17	12:26 PM				1.75	61.29	79.72	30.01	52.04	28.55	79.62	1.64	13.10
	20-24	10:44 AM				3.72	304.38	79.04	30.22	54.67	33.45	79.38	1.66	13.11
	27-1	9:49 AM				3.73	131.99	75.12	30.04	56.90	43.57	75.03	2.23	13.12
Jul 05	4-8	2:23 PM				5.69	113.16	83.01	30.06	52.44	23.99	82.96	0.00	13.08
	11-15													
	18-22													
	25-29													
August 05	1-5													
	8-12													
	15-19													
	22-26													
	29-2													
September 05	5-9													
	12-16													
	19-23													
	26-30													
October 05	3-7													
	10-14													
	17-21													
	24-28													
November 05	31-4													
	7-11													
	14-18													
	21-25													
	28-2													
December 05	5-9													
	12-16													
	19-23													
	26-30													

AIRBORNE  
CONTAMINANT  
SAMPLER  
PERMANENTLY  
SHUT DOWN  
JUNE 1 2005



# 2005-N O R T H G L E N N

	Week of	Julian Date	Time	Hour Meter	Press On "H2O"	Pres Off	W Speed mph	W Direct degrees	W Chill °F	B Press "H2O"	Dewpt °F	Humidity %	Temp °F	Rainfall Inches	Battery VDC
January 05	3-7	4	11:31 AM	43095.20	29.50	11.40	5.04	14.71	8.65	30.07	17.99	99.78	17.95	0.00	14.07
	10-14	13	1:21 PM	43313.10	13.10		10.96	308.30	24.62	29.94	18.01	28.63	39.35	0.12	13.72
	17-21	19	1:59 PM	43457.70	17.20		6.79	345.48	63.39	30.21	36.78	24.44	65.86	0.12	13.26
	24-28	25	1:56 PM	43601.60	23.80		3.07	73.29	57.52	30.04	28.51	22.65	57.47	0.12	13.31
February 05	31-4	33	2:12 PM	43793.80	28.70	8.80	2.63	138.83	47.14	30.19	26.58	32.98	47.23	0.43	13.28
	7-11	39	2:06 PM	43937.60	11.10		5.26	71.23	23.27	29.97	25.12	69.91	31.61	0.00	13.73
	14-18	46	12:53 PM	44104.40	13.90		9.86	6.89	17.54	30.09	26.95	101.46	26.86	0.00	13.85
	21-25	54	12:53 PM	44296.10	18.40		2.41	127.65	40.99	30.12	28.92	51.81	40.91	0.02	13.77
March 05	28-4	62	11:40 AM	44487.20	24.50	11.30	1.32	55.59	50.09	30.04	21.42	20.95	50.18	0.02	13.35
	7-11	67	11:10 AM	44606.60	13.10		12.71	17.87	15.81	30.13	31.03	65.57	38.45	0.20	13.81
	14-18	75	11:08 AM	44798.60	15.90		5.48	307.34	41.03	29.95	22.11	28.25	44.43	0.16	13.51
	21-25	83	11:07 AM	44990.60	16.80		7.45	61.16	31.33	29.87	31.49	98.46	31.76	1/council/ac	13.84
April 05	28-1	89	10:37 AM	45134.10	20.80		4.60	307.82	42.78	29.74	23.03	27.79	46.20	0.66	13.51
	4-8	96	12:02 PM	45302.50	24.50	9.50	8.99	23.56	47.08	30.33	32.87	36.07	52.62	0.03	13.47
	11-15	102	1:02 PM	45447.50	13.30		6.14	114.43	51.52	30.05	30.88	28.89	54.17	0.19	13.39
	18-22	109	10:59 AM	45613.40	16.70		9.64	15.18	47.62	29.85	46.24	62.76	55.67	0.19	13.37
May 05	25-29	116	11:23 AM	45781.70	17.90		1.53	102.42	55.38	29.97	33.79	33.08	55.74	0.92	13.39
	2-6	124	10:59 AM	45973.20	21.80	12.20	12.28	318.73	51.17	30.09	38.28	35.26	59.98	0.09	13.31
	9-13	130	10:19 AM	46116.70	13.70		6.14	40.70	64.34	29.84	41.90	31.26	65.84	0.17	13.18
	16-20	140	1:59 PM	46360.20	18.50		13.81	95.55	87.74	30.16	47.79	16.74	89.48	0.45	13.27
Jun 05	23-27	145	11:44 AM	46477.40	18.20		4.66	74.29	53.49	30.26	45.32	64.24	53.69	0.64	13.42
	30-3	152	12:35 PM	46646.30	19.60	9.10	5.26	96.48	75.62	29.83	41.54	19.33	77.07	0.00	13.08
	6-10	158	11:26 AM	46789.10	12.70		10.30	102.16	62.24	29.81	44.96	36.75	66.04	0.76	13.17
	13-17	166	12:01 PM	46981.70	14.30		2.63	18.53	78.17	30.06	52.16	32.77	78.15	1.60	13.06
Jul 05	20-24	172	11:11 AM	47124.90	18.40		5.26	322.41	80.12	30.26	55.66	31.44	80.51	1.82	13.03
	27-1	179	10:25 AM	47292.10	20.50		4.16	167.25	77.31	30.07	54.70	36.14	77.17	1.85	13.03
	4-8	186	1:52 PM	47463.60	24.10	11.60	5.04	102.71	79.36	30.15	53.83	32.42	79.90	0.00	13.07
	11-15														
August 05	18-22														
	25-29														
	1-5														
	8-12														
September 05	15-19														
	22-26														
	29-2														
	5-9														
October 05	12-16														
	19-23														
	26-30														
	3-7														
November 05	10-14														
	17-21														
	24-28														
	31-4														
December 05	7-11														
	14-18														
	21-25														
	28-2														
December 05	5-9														
	12-16														
	19-23														
	26-30														

# 2005-STANLEY LAKE

Week of	Julian Date	Time	Hour	Press On	Pres Off	W Speed	W Direct	W Chill	B Press	Dewpt	Humidity	Temp	Rainfall	Battery
			Meter	"H <sub>2</sub> O	"H <sub>2</sub> O	mph	degrees	°F	"H <sub>2</sub> O	°F	%	°F	Inches	VDC
January 05	3-7	1:10 PM	33293.90	25.30	10.70	5.48	2.60	16.78	30.04	15.77	93.71	16.83	0.00	14.21
	10-14	3:10 PM	33512.00	12.00		14.25	321.19	23.36	29.95	14.69	21.66	41.08	0.19	13.74
	17-21	3:17 PM	33656.00	13.80		5.92	316.58	60.17	30.22	31.47	19.63	63.58	0.19	13.39
	24-28	12:40 PM	33797.40	16.10		5.48	339.10	58.09	28.75	24.59	16.25	58.35	0.19	13.45
	31-4	12:59 PM	33989.70	18.70	10.70	1.97	150.04	37.75	28.76	22.90	33.42	42.03	0.54	13.34
February 05	7-11	12:49 PM	34133.50	11.40		1.10	14.13	30.50	28.24	23.66	66.59	30.53	0.01	13.94
	14-18	11:46 AM	34300.40	12.70		6.14	31.34	19.54	27.17	26.71	91.76	28.16	0.01	13.95
	21-25	11:14 AM	34491.90	13.90		5.48	7.07	35.57	28.15	25.14	53.67	36.05	0.08	13.89
	28-4	9:59 AM	34682.70	16.50	10.70	3.73	2.32	44.48	29.66	21.52	25.85	45.36	0.08	13.69
	7-11	12:17 PM	34804.90	11.80		4.60	242.68	25.24	30.14	33.69	87.24	36.38	0.11	13.85
March 05	14-18	12:57 PM	34997.60	13.40		1.32	273.12	46.51	29.92	22.23	23.55	46.64	0.32	13.56
	reacouncil.com/councilac	12:16 PM	35188.90	14.20		3.73	52.82	29.58	29.88	30.03	92.21	31.55	0.50	14.03
	28-1	9:17 AM	35329.90	15.00		5.69	1.39	43.96	29.76	21.12	26.64	44.33	0.61	13.74
	4-8	1:39 PM	35501.30	16.90	11.20	4.60	3.72	55.67	30.30	34.93	31.38	55.78	0.01	13.37
	11-15	10:00 AM	35641.70	12.00		1.97	112.30	51.24	30.06	27.08	27.06	51.21	0.47	13.59
April 05	18-22	9:38 AM	35809.10	14.30		7.45	12.92	51.04	29.89	45.60	59.94	55.21	0.47	13.59
	25-29	9:58 AM	35977.40	15.10		4.16	114.34	46.97	29.98	32.22	38.07	49.09	1.54	13.71
	2-6	8:52 AM	36168.40	16.40	11.90	3.51	25.19	54.35	30.09	39.35	47.79	54.26	0.09	13.64
	9-13	9:01 AM	36312.50	12.70		3.95	20.92	61.86	29.83	36.76	28.81	61.72	0.16	13.51
	16-20	9:34 AM	36553.00	14.20		2.85	125.20	74.19	30.11	46.21	27.41	74.12	0.45	13.46
May 05	23-27	1:39 PM	36675.90	15.00		3.29	222.07	56.84	30.25	44.82	54.67	56.45	0.63	13.42
	30-3	2:22 PM	36844.80	15.60	11.40	3.95	185.71	80.56	29.79	39.70	14.85	80.22	0.00	13.04
	6-10	9:25 AM	36983.80	11.90		2.63	147.14	62.91	29.86	44.27	39.30	63.21	0.85	13.38
	13-17	1:19 PM	37179.50	12.70		0.00	0.47	77.26	30.05	50.48	29.35	77.34	2.11	13.19
	20-24	8:38 AM	37319.00	13.70		1.75	350.61	69.87	30.27	54.32	49.49	69.89	2.69	13.36
June 05	27-1	8:50 AM	37487.30	15.10		2.19	60.97	70.98	30.08	54.04	46.98	70.99	2.89	13.27
	4-8	3:14 PM	37612.80	16.90	12.20	3.95	117.00	84.57	30.08	48.34	19.51	84.54	0.00	13.03
	11-15													
	18-22													
	25-29													
August 05	1-5													
	8-12													
	15-19													
	22-26													
	29-2													
September 05	5-9													
	12-16													
	19-23													
	26-30													
	3-7													
October 05	10-14													
	17-21													
	24-28													
	31-4													
	7-11													
November 05	14-18													
	21-25													
	28-2													
	5-9													
	12-16													
December 05	19-23													
	26-30													
	3-7													
	10-14													
	17-21													



## APPENDIX F – Key Personnel

Station managers identified in the monthly/quarterly reports included:

Program Coordinator – **Forrest Shoemaker**

Arvada – Ralston Station and Standley Lake - **Dudley Weiland, Lonnie Newton,**

**William Jones, Shawn Yasutake**

Broomfield – Midway – Emerald Park - **Richard Borinsky, Robert Morgenstern,**

**Mark Little**

Northglenn – Recreation Center - **Douglas Smith, Theodore Matsuo**

Westminster – Countryside - **James Natale, Forest Shoemaker, Margaret Roding**

Community Technical Representatives included:

Arvada (8101 Ralston Road) – **Jim McCarthy**

Broomfield (One DesCombes Drive) – **M. Anderson and Dorthy Noble**

Northglenn (2350 West 112<sup>th</sup> Avenue) – **Chuck Guilmette**

Westminster (6777 West 88<sup>th</sup> Avenue) – **Dave Cross**

Information during the last years of the Program was reported to:

Shirley Garcia City of Broomfield 1 Descombes Drive Broomfield, CO 80020	CDPHE Steven Gunderson 4300 Cherry Creek Drive South Denver, CO 80246
Standley Lake Library Rocky Flats Section 8485 Kipling St. Arvada, CO 80005	Al Nelson City of Westminster 4800 W. 92 <sup>nd</sup> Ave. Westminster, CO 80031
John Rampe Rocky Flats 10808 Highway 93, Unit A Building 460 Golden, Colorado 80403-8200	Front Range Community College Rocky Flats Reading Room College Hill Library 3705 W. 112 <sup>th</sup> Ave. Westminster, CO 80030
Tim Rehder US. EPA 999 18 <sup>th</sup> St., Suite 500 Denver, CO 80202	Melissa Anderson Coalition of Local Governments 8461 Turnpike Dr. Westminster, CO 80031
Superfund Records Center / Reading Room US. EPA 999 18 <sup>th</sup> St., Suite 500 Denver, CO 80202	CDPHE Rocky Flats Reading Room 4300 Cherry Creek Drive South Denver, CO 80246 Attn: Librarian
Chuck Guilmette/Mary Fabisiak Department of Public Works 11701 Community Center Dr. Northglenn, CO 80233-1099	Regional Air Quality Council 1445 Market St., Suite 260 Denver, CO 80202 Attn: Gerald Dilley
Clark Johnson City Managers Office 8101 Ralston Road Arvada, CO 80002	



ComRad Points of Contact 2000 - 2005

<b>Name/Title</b>	<b>Organization</b>	<b>Name/Title</b>	<b>Organization</b>
Darrel Cornell Project Manager	MERCO Inc.	Chuck Guilmette	City of Northglenn
Daniel Pring Engineer	MERCO Inc.	Al Nelson	City of Westminster
Mike Wheatley Technician	MERCO Inc.	Lori Pacheco	Paragon Laboratories
Lynda James Teacher		Shirley Garcia	City of Broomfield
Margaret Roding Teacher	Standley Lake	Mary Fabisiak	City of Northglenn

(PHOTO OF COP MEMBERS)

Photos showing Station Managers (SM) and Alternates (A) in Spring 1993



**Ralston Recreation Center Station**  
Lonnie Newton (SM) and William Jones (A)



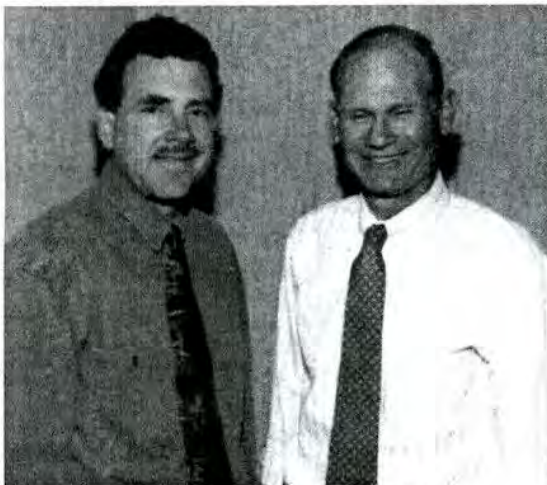
**Standley Lake Library Station**  
Shawn Yasutake (A) and Dudley Weiland (SM)



**Countryside Recreational Center Station**  
J. Kim Natale (SM) and Forrest Shoemaker (A)



**Northglenn Recreation Center Station**  
Theodore Matsuo (A) Kipp Scott, COP Member from Northglenn, and Douglas Smith (SM)



**Broomfield Emerald Park Station**  
Richard Borinsky (SM) – Robert Morgenstern(A)

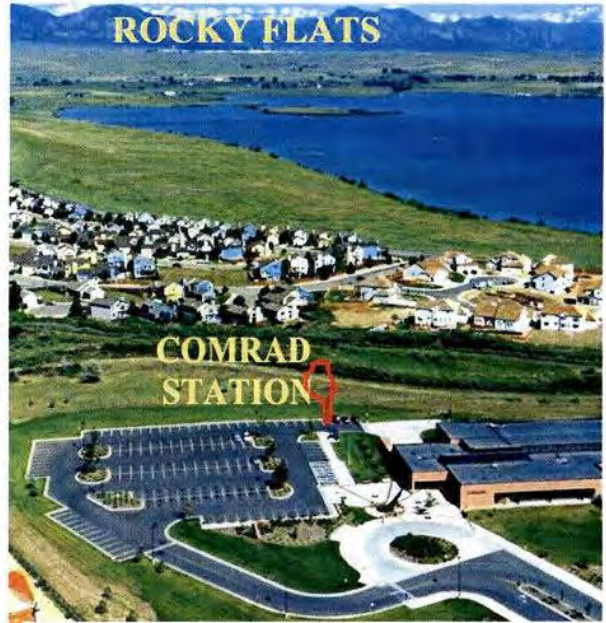


APPENDIX G – Aerial Photos of Stations

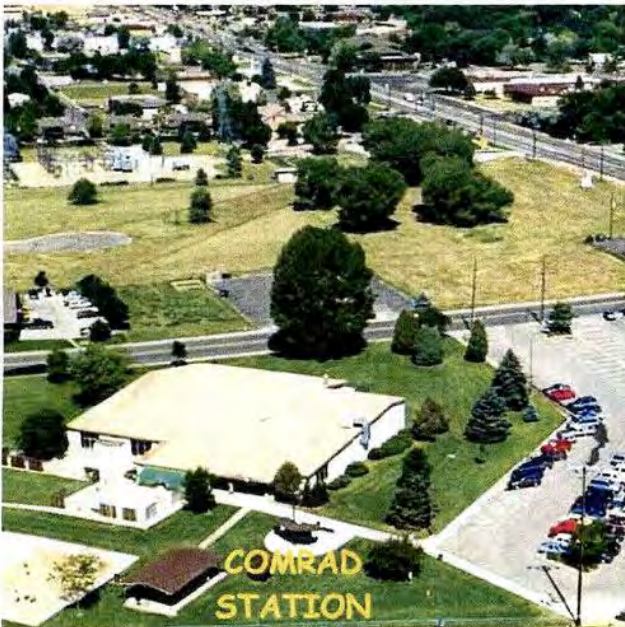
Figure CountrySide Station



Ralston Station



Standley Lake Station

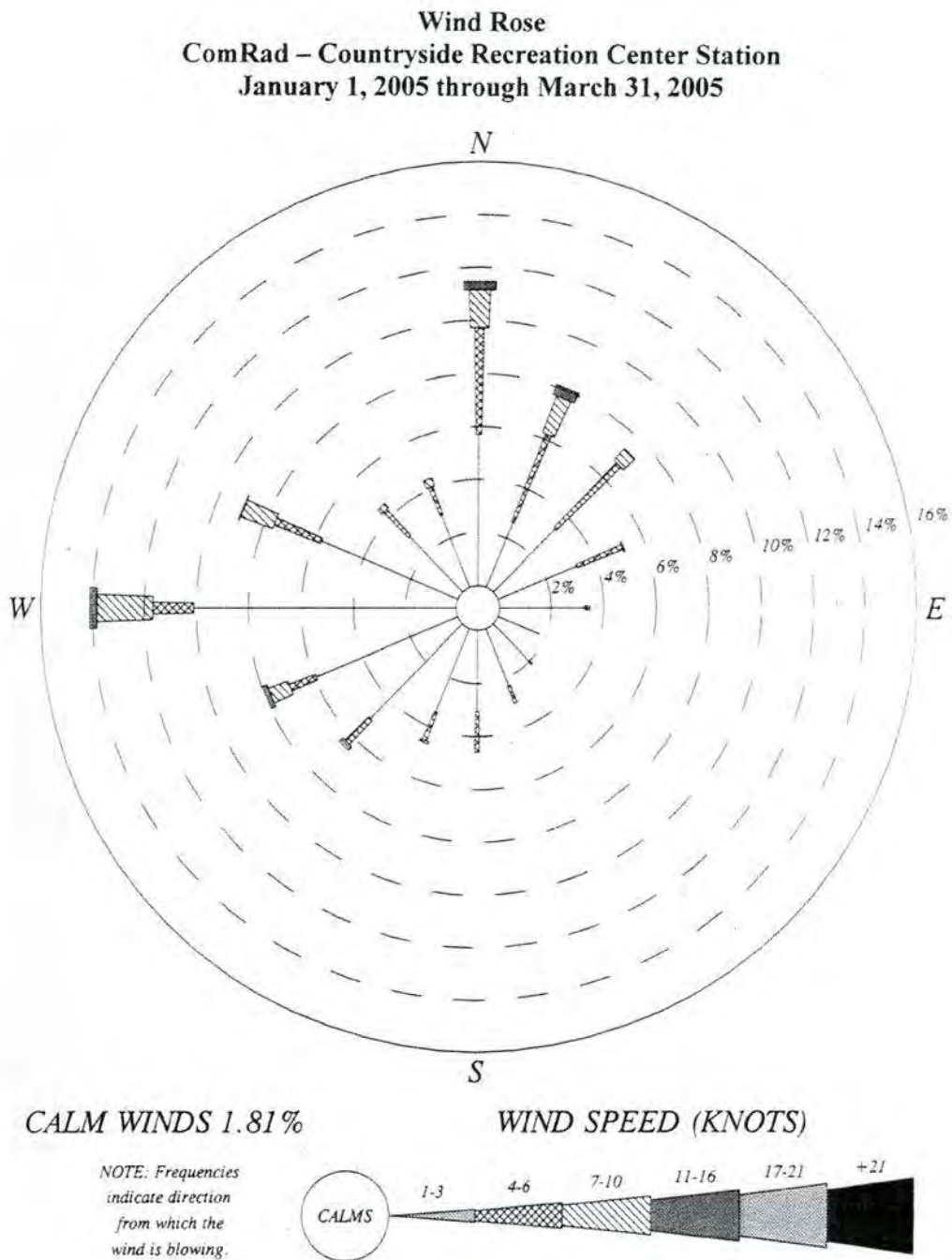


Ralston Station



Figure xx – Ralston Station (relocated to main body of Report)

## APPENDIX H – Typical Windrose



Graph xx – Windrose for Countryside 1<sup>st</sup> Quarter 2005

**NOTE:** This full report may be found in Attachment E - Feb 1, 2021, Staff Report (Attachment E - Soil Sampling Results Report) in this packet; this copy was deleted from this attachment to minimize duplication

# **Rocky Mountain Greenway Trail Crossings Soil Sampling Results Report**

*Prepared for:*

**Jefferson County**

100 Jefferson County Parkway, Suite 4500  
Golden Colorado, 80419

**and**

**City of Boulder**

**Boulder County**

**City and County of Broomfield**

**City of Arvada**

**City of Westminster**

*Prepared by:*



1600 Specht Point Road, Suite 209  
Fort Collins, Colorado 80525  
(970) 488-3111  
Fax (970) 488-3112

Project No. 110836

February 5, 2020



