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United States Government **Department of Energy**

memorandum

PWA-Revised Chapter 4, Meteorological Monitoring, of Guide DOE/EH-0173T

DATE: February 11, 2005

REPLY TO ATTN OF: Office of Air, Water and Radiation Protection Policy & Guidance (EH-41):Vázquez: 6-7629

SUBJECT: Availability of Revised Chapter 4, *Meteorological Monitoring*, of Guide DOE/EH-0173T

TO: Distribution

This memo is to inform you of the availability of revised Chapter 4, *Meteorological Monitoring,* of guide DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance.* The purpose of the guide is to support the implementation of radiological monitoring and surveillance activities needed for compliance with DOE Order 5400.5, *Radiation Protection of the Public and the Environment.* The revision of Chapter 4 was made to be consistent with the revised American National Standards Institute (ANSI) standard ANSI/ANS-3.11-2000, "American National Standard for Determining Meteorological Information at Nuclear Facilities", and recent EPA guidance in EPA-454/R-99-005, "Meteorological Monitoring Guidance for Regulatory Modeling Applications," 1999. The revision of Chapter 4 was led by members of the DOE Meteorological Coordinating Council (DMCC); it was subsequently reviewed by Federal experts in meteorology and related sciences. Chapter 4 is available for download at our website (http://www.eh.doe.gov/oepa).

We are currently reviewing and revising other chapters of DOE/EH-0173T, as necessary, to respond to technical improvements and updated requirements since the Guide's original publication in 1991. Once these updates are complete, guide DOE/EH-0173T will be reissued under the current directives management system. In the interim, we recommend that the attached chapter be used in place of the existing Chapter 4.

If you have any questions on revised Chapter 4, or if you are interested in being part of a team being formed by our Office to update DOE/EH0173T, please contact Gustavo Vázquez (202/586-7629; gustavo.vazquez@eh.doe.gov), or Steve Domotor (202/586-0871; steve.domotor@eh.doe.gov).

Andrew Wallo
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DISTRIBUTION: 01/25/05

For memo: Availability of Revised Chapter 4, *Meteorological Monitoring*, of Guide DOE/EH-0173T
Dated 2/11/05

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Center for Environmental Management Information

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4.0 METEOROLOGICAL MONITORING

4.1 METEOROLOGICAL PROGRAM DESIGN

Meteorological monitoring requires the proper siting of meteorological towers and equipment, the collection of valid meaningful data, the appropriate analysis and application of the data, and the permanent archiving of the data. Meteorological data are essential to characterizing atmospheric conditions at DOE and NNSA facilities and sites. These data are not only vital to environmental protection, emergency response, and consequence assessments, but are also vital for guarding the safety and health of workers and the general public. Meteorological data are also required to demonstrate compliance with applicable Federal, State, and local laws, enabling regulations (e.g., 40 CFR 51 Appendix W, 40 CFR 61 Subparts H and I, 40 CFR 68), and DOE Orders and Notices that relate to the protection of the environment, and safety and health. Moreover, this information is needed to assess the transport, dispersion, deposition, and resuspension of materials released to the atmosphere by a DOE-owned and NNSA-owned facility. In addition, meteorological information is also important to consider in the design of environmental monitoring networks.

As indicated in Section 3 of ANSI/ANS-3.11-2000 and Section 1.1 of EPA-454/R-99-005, the design of a meteorological monitoring system shall be based on the needs and objectives of the facility and the guiding principles for making accurate and valid meteorological measurements. Accordingly, each DOE and NNSA site (facility)[a] should* establish a meteorological monitoring program that is appropriate to the activities at the site, and which gives due consideration to the topographical characteristics of the site, the distance to each of the critical receptors (i.e., worker, co-located worker, maximally effected offsite individual), and planned future uses of the site. The scope of the program should* be based on an evaluation of the regulatory requirements, and a determination of meteorological data needed to support facility operations, environmental impact assessments, environment surveillance activities, safety analyses, environmental restoration activities, and the consequence assessment element of emergency preparedness and response. For each DOE and NNSA site, the following factors should* be considered:

- Type and magnitude of potential sources of hazardous materials;
- Possible pathways to the atmosphere;
- Topographic characteristics;
- Presence of complex flows (e.g., sea breezes, mountain-valley wind regime);
- Frequency of severe weather (e.g., lightning, tornadoes, hurricanes) conditions;
- Distances from release points to each of the critical receptors; and,
- Proximity of the site to other DOE and NNSA facilities, and other non-DOE facilities that handle toxic and/or radioactive materials.

The site's meteorological program should* be documented in a meteorological monitoring section of the Environmental Monitoring Plan (EMP) and in the Annual Site Environmental Report (ASER) (DOE O 231.1, DOE O 5400.5). The site's meteorological monitoring program should* be referenced in documentation in which it plays a role in the analytical results (e.g., authorization basis safety documents, emergency plan). It should* be noted that DOE O 450.1 does not require the preparation of an EMP, but only requires that an Environmental Monitoring Program is available.

(a) DOE usage of the terms "site" and "facility" is considered equivalent to 40 CFR Part 61 use of the terms "facility and "source".

* Denotes an action that is not mandatory

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The type of meteorological information required by DOE and NNSA facilities is not explicitly stated in laws, enabling regulations, or DOE Orders and Notices. However, there is an implicit recognition of the need for such information in several of the enabling regulations and directives of the type of information required. Meteorological data, which are needed to characterize atmospheric transport and dispersion conditions, are an integral part of the radiological dose assessment and chemical consequence assessment capabilities to assess impacts from both planned and unplanned releases. For example, 40 CFR 61.93, "National Emission Standards for Hazardous Air Pollutants; Standards for Radionuclides," states in part:

"To determine compliance with the standard, radionuclide emissions shall be determined and effective dose equivalent values to members of the public calculated using EPA approved sampling procedures, computer models CAP-88 or AIRDOS-PC, or other procedures for which EPA has granted prior approval…." For the evaluation of impacts from non-radiological releases, compliance with applicable standards shall be determined using EPA computer models such as ISCST3, AERMOD, TANKS, CALPUFF, or other procedures for which EPA has granted approval.

In general, sites should* have onsite measurements of basic meteorological data. These include, but are not limited to wind direction, wind speed, and an indicator of atmospheric stability (e.g., temperature lapse rate). This information is needed to:

- Calculate and evaluate atmospheric transport and dispersion in the vicinity of facilities;
- Perform the required dose calculations for routine gaseous releases, as specified in 40 CFR 61 Subpart H; and,
- Develop radiological and chemical consequence assessments per DOE O 151.1.

The vicinity of a facility is broadly defined as within 2 km (DOE G 151.1-1). Large, multi-facility sites and those sites with complex terrain, where one monitoring site location is inadequate to be spatially representative of atmospheric conditions for transport and dispersion computations (per Section 4.2 of ANSI/ANS-3.11-2000) are required to establish environmental monitoring programs that include additional meteorological measurements at more than one location. At some sites, additional monitoring may be required to provide supplemental information, in order to support safety aspects of operational programs (e.g., lightning protection, protection from cold and hot weather). Guidance on site-specific supplemental meteorological information is in Section 3.2 of ANSI/ANS-3.11-2000.

Some smaller sites with limited potential for the atmospheric release of radiological and chemical hazardous materials may choose to establish a meteorological program that makes use of meteorological measurements obtained from offsite sources such as a first-order National Weather Service (NWS) station or cooperative stations. For data from an offsite source to be an acceptable substitute for onsite data, it should* be spatially representative of conditions at the DOE and NNSA facility and provide statistically valid data consistent with onsite monitoring requirements. A determination of offsite data source(s) that is (are) acceptable and spatially representative should* be established by a qualified meteorologist and should* be included in the Environmental Monitoring Plan. This determination should* use guidance prescribed in Section 6.3 of ANSI/ANS-3.11-2000 and Section 3.1 of EPA-454/R-99-005.

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Specific meteorological information requirements for each facility should* be based on the magnitude of potential radiological and chemical source terms, the location, nature, and state of potential releases from the facility, possible paths to the atmosphere, local topography, distances from release points to critical receptors, and the proximity of other DOE facilities, and other non-DOE facilities that handle radioactive and/or other toxic materials. Radiological and chemical consequence assessment includes characterization of the transport, dispersion, deposition, and resuspension of material released to the atmosphere. Methods that are appropriate for calculating transport and dispersion at a facility depend on the type, size, and location of the facility and the local topographical characteristics. Moreover, some of the larger DOE sites may need comprehensive meteorological networks when distances between facilities and other activities are great, and when complex topography can induce widely different weather and climatic regimes.

Meteorological information requirements for facilities should* be sufficient to support environmental monitoring and surveillance programs. For example, meteorological information is required in the selection of locations for monitoring stations if monitoring is to take place at the projected points of maximum impact of a facility. EPA-450/4-87-013 provides useful guidance for the selection or prediction of the point or points of maximum impact of radiological or chemical releases.

The meteorological monitoring program requirements that need to be incorporated into the effluent monitoring and environmental surveillance programs at a DOE and NNSA site are presented in the balance of this chapter.

4.2 METEOROLOGICAL PROGRAM BASES

4.2.1 Overview

A primary use of meteorological and climatology data at DOE sites is to characterize atmospheric dispersion conditions for authorization basis safety documents, emergency preparedness consequence assessments, and National Environmental Policy Act (NEPA) evaluations. Such characterization is necessary to assess the following:

- Potential consequences of radiological and chemical releases from projected new or modified facilities;
- Consequences of actual routine radiological and chemical releases from existing facilities to demonstrate compliance with applicable regulations and standards; and,
- Consequences to the worker and public from actual accidental radiological and chemical releases.

4.2.2 Selection of Radiological and Chemical Consequence Models and Meteorological Data Requirements

Atmospheric models, used to determine consequences of airborne dispersion of material, simulate winds for bulk transport and turbulence for diffusion. Sometimes these two functions, transport and diffusion, are handled by separate models, and sometimes they are incorporated in the same model. The complexity of the models needed depends upon the application and the complexity of the atmospheric conditions, as well as the complexity of the mechanisms resulting in the release of material to the atmosphere.

Transport models may vary from being as simple as using a constant single wind speed and direction, to complex time-dependent three-dimensional models which explicitly treat divergence, vorticity, deformation, rotation and strain.

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The transport model may generate wind fields that:

- Represent the wind fields in one, two or three dimensions;
- Are time-dependent or time independent (i.e., constant);
- Employ analyzed wind fields, which may be generated by interpolation/extrapolation routines, mass conservation, or varying degrees of dynamic complexity and parameterization;
- Include radiation (i.e., non-ionizing long wave and visible), hydrostatic or non-hydrostatic effects, etc.; and,
- Employ analyzed and forecast wind fields

The diffusion models may also be very simple, with an assumed statistical distribution, or utilize varying degrees of complexity. The diffusion models may:

- Employ simple or complex turbulent closure methods;
- Employ Eulerian, Lagrangian, or hybrid Eulerian-Lagrangian methods;
- Include wet and/or dry deposition, with or without resuspension;
- Include airborne plume chemistry; and,
- Include health effects.

These models may also include or utilize a source characterization model.

Atmospheric transport and dispersion models used for dose assessment vary in sophistication and complexity from simple calculations that can be performed on a PC-based platform to extensive computations that require the use of highly sophisticated, high performance main-frame computers. In general, all Eulerian Gaussian-type atmospheric transport and dispersion models can be easily accommodated on the PC platform.

Similarly, the meteorological data required to drive the atmospheric transport and dispersion calculations range from wind speed, wind direction, and an indicator of atmospheric stability at one location and one measurement height for spatially-invariant Gaussian models, to extensive surface and upper air ensemble data sets for some of the computer-intensive Lagrangian complex terrain flow modeling techniques. Use of simple screening compliance assessment techniques (NCRP Commentary 8; NCRP Report 123), which are based on conservative assumptions and use "canned" meteorological data (i.e., wind speed and stability class), could be sufficient for some DOE and NNSA sites, especially those with limited radiological and chemical hazards. DOE and NNSA sites that have completed their essential missions and that are presently in decontamination and decommissioning programs will have their hazards reduced. For this situation, these sites may consider the use of simpler modeling techniques, commensurate with the remaining emergency management consequence assessment element requirements.

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For sites where onsite meteorological measurements are not required, its program should* include a description of the climatology in the vicinity of the site and should* provide ready access to representative meteorological data from a nearby station, such as an airport.

Data from offsite sources, such as the National Weather Service (NWS), the Federal Aviation Administration (FAA), or military installations, may be used in these situations if the meteorological instruments are well maintained and the data are readily available and representative of conditions at the site. It should* be noted that many of the NWS and FAA sites do not measure wind speeds below 2-3 mph and report these as “calm”. This may make such data unacceptable for some types of compliance and/or emergency response applications. In addition to NWS and FAA data, meteorological data is also available at other offsite locations. Data from other offsite sources also need to be examined for their quality and applicability prior to its application. As an example, the use of the CAP-88PC (see http://www.sc.doe.gov/sc-80/cap88/) or an EPA-approved alternative per 40 CFR 61.93 is required to demonstrate compliance with 40 CFR 61 Subpart H. The meteorological input to the CAP-88PC model includes the joint-frequency distribution of wind speed, wind direction and atmospheric stability. This model also requires an average mixing-layer depth and an average temperature.

The meteorological monitoring program for each site should* provide sufficient and appropriate meteorological data that are representative of the site and its intended application, for use in atmospheric transport and dispersion computations. Before any model is deemed appropriate for a specific application, the assumptions upon which the model is based should* be evaluated and the evaluation results documented in a modeling protocol. For example, assumptions that are reasonable in models used to demonstrate compliance with annual average concentration standards are most likely not reasonable in models used for emergency response applications. This is especially evident in locations with complex terrain that experience frequent airflow trajectory reversals (e.g., mountain-valley; proximity to large bodies of water).

As the maximum magnitude of potential releases from a facility increases, the use of more realistic, and therefore complex, models is necessary to either assess the consequences of the releases or to demonstrate compliance with Federal and State laws, enabling regulations, and DOE Orders and Notices. Complex terrain environments may require a comprehensive onsite meteorological monitoring program to provide sufficient meteorological data to allow complex terrain models to be employed. Additional informational requirements include location, release characteristics, release rates, energetics of the release (e.g., heated plume, jet rise, deflagration, detonation, explosion), distances from release points to multiple receptors, and meteorological conditions. Computational techniques based on straight-line Gaussian models (e.g., CAP-88) are appropriate for facilities that are located in simple topographic settings. Straight-line Gaussian models are described in detail in many reports, including Meteorology and Atomic Energy - 1968 (Slade 1968) and Atmospheric Science and Power Production (Randerson 1984).

At a minimum, these models require specification of wind direction, wind speed, and an indicator of atmospheric stability. Some models may require the specification of mixing-layer height to account for plume reflection from the capping layer. Remote sensing instrumentation (e.g., RASS, SODAR, LIDAR) is now available to assist in mixing height determinations as indicated in ANSI/ANS-3.11-2000 Appendix A. If the models estimate wet deposition (i.e., precipitation scavenging), they could require information on precipitation rates, and if the models compute mechanical and buoyant plume rise for stack releases, the ambient air temperature could be required to compare to the temperature of the effluent. For the evaluation of chemical accidents, especially with respect to pressurized liquid and gas releases, or releases of deliquescent chemicals, both the temperature and the relative humidity could be required to accurately assess the time-varying source term.

(Note: Once EPA approves and codifies the GENII code, it will be replacing the CAP88-PC code).

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For new sites with complex terrain or buildings with low stacks, onsite measurements (e.g., field tracer gas studies, wind tunnel experiments) could be used to help model atmospheric transport and dispersion and could also aid in model selection. The ARCON96 code (Ramsdell, J. V. Jr., 1997) has been developed with empirically adjusted horizontal and vertical dispersion coefficients based on field tracer studies and wind tunnel experiments.
The Directory of Consequence Assessment Models (OFCM, 1999) identifies the meteorological data requirements for 64 specific atmospheric transport and dispersion models. These 64 models represent a sample of the available atmospheric transport and dispersion models. This reference can be accessed at www.ofcm.gov.

For emergency response applications, which require real-time meteorological measurements for diagnostic consequence assessment evaluations, and weather forecasting information for prognostic consequence assessment determinations, straight-line Gaussian transport and dispersion models are inappropriate for facilities that are located in valleys, near coastlines or mountains, and on large sites with varying terrain. At some of the DOE sites with this type of topographic setting, there are significant radiological and chemical hazards in multiple locations. In these settings, strictly applied straight-line Gaussian models could not only underestimate the consequences of a release, but also can incorrectly identify locations where higher concentrations can occur. This can lead to the selection of inappropriate measurement locations or have undesirable effects on subsequent protective actions. Complex terrain trajectory models provide more realistic assessments in these settings, as they more accurately account for temporal and spatial variations in atmospheric conditions and release rates. Complex terrain models that are presently supported include, but are not limited to: APGEMS (C. Glantz 2000) CALPUFF (EPA-454/B-95-006), SCIPUFF (Sykes, R.I. 1995), HOTMAC-RAPTAD (Yamada, T. 1988), HARM-II (Pendergrass, W.R. 1991), CAPARS (Alpha-TRAC 2003), RAMS-LPDM and NARAC. The use of the CALPUFF code is generally limited to EPA compliance applications.

Complex terrain airflow trajectory models (NUREG/CR-0523; EPA-600/8-84-207; EPA-600/8-86-024; NUREG/CR-3344; NUREG/CR-4000) treat atmospheric transport and dispersion as separate processes. This additional complexity is necessary to consider spatial and temporal variations of the atmosphere. These models generally require the same types of meteorological data as the straight-line models. However, to make full use of their capabilities to characterize three-dimensional spatial variations, use of meteorological data from more than one location and at more than one height above the surface is necessary. In addition, input to complex terrain trajectory models is a series of meteorological observations at different levels in the atmosphere that include wind direction and speed, an indicator of stability class, temperature, and other important variables, rather than sets of frequency distributions.

4.2.3 Meteorological Data Requirements for Other Applications

Meteorological data and site-specific forecast services may also be needed to support daily operations and responses to actual emergency conditions. These include weather conditions that may:

- Produce a threat or challenge to personnel safety and health;
- Damage or destroy property and facilities;
- Lead to a variety of accidents that could result in injury or loss of life; and,
- Facilitate optimum plant operations.

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4.3 SPECIAL TRANSPORT AND DISPERSION MODELING CONSIDERATIONS

4.3.1 Plume Rise

Evaluation of the consequences of releases through free-standing stacks or from building vents may include consideration of the effective plume rise due to momentum and buoyancy. Generally accepted methods for estimating plume rise are described by Briggs (1984, 1988, 1993), although EPA models estimate plume rise using earlier methods developed by Briggs (1969) and others (EPA-450/4-87-013).

Estimation of plume rise requires air temperature and wind speed at release height, vertical temperature gradient to determine stability class, and, in some cases, an estimate of the mixing-layer thickness. Mixing layer thickness is only required to determine if the plume rise will be capped by the inversion, or if the plume is emitted above the inversion, in which case it will be lofted and prevented from reaching the ground level. To determine the mechanical component of plume rise, information is required on the stack diameter and volumetric flow rate, or stack efflux velocity, and effluent temperature. Basic straight-line plume models assume, except in computation of plume rise, that material is released from a point source. When it is necessary to evaluate the consequences of a release on receptors near the release point, the basic models should* be modified to account for deviations from this assumption. This will be discussed in the next section.

4.3.2 Aerodynamic Effects of Nearby Buildings

Dispersion in the vicinity of buildings and other obstacles may result in the need for model modification to account for wake effects. Building wake and cavity flow fields, and general aerodynamic effects of structures on the nearby local wind field are discussed by Hosker (1984), EPA-450/4-86/005a and EPA-450/4-87-013. For ground-level releases, the standard modifications increase the dispersion coefficients on the basis of dimensions of the structure. For elevated releases, the modifications adjust the height of release based on the ratio between the initial vertical velocity of the effluent and the wind speed at release height.

4.3.3 Plume Meander

Horizontal plume meander is a meteorological phenomenon that occurs under very light winds coupled with a deep inversion (i.e., stable conditions). Under these very restrictive dispersion conditions, horizontal plume meander has been documented by field tracer studies (Hanna 1983). Empirically derived meander factors from these field tracer studies have been developed and included in certain atmospheric transport and dispersion models (e.g., ARCON96).

4.4 DISPERSION COEFFICIENTS

4.4.1 Overview

Gaussian straight-line and complex terrain trajectory transport and dispersion models make use of dispersion coefficients, commonly referred to as σ_y and σ_z, to describe the spread of plumes. These dispersion coefficients are generally estimated on the basis of typing an atmospheric stability class and coupling that stability class with the distance the material has traveled since its release. The random atmospheric turbulence that causes dispersion in the horizontal and vertical planes is related to atmospheric stability. Gifford (1976) discusses various methods for determining dispersion coefficients.

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4.4.2 Stability Estimation Using Observations from First-Order NWS Stations

Routine meteorological measurements by the National Weather Service (NWS) and other private and public sector organizations typically do not include the direct measurement of atmospheric stability or the determination of stability classes. Instead, a method of estimating atmospheric turbulence intensities by typing stability classes has been developed. This methodology is based on wind speed and cloud cover (Pasquill 1961; Gifford 1961; Turner 1964; PHS Publication 999-AP-26), and can be used to estimate stability classes from routine NWS meteorological observations. The meteorological data required include opaque cloud cover, ceiling height, and wind speed.

4.4.3 Methods of Determining Stability Class

Common methods of determining stability class from onsite meteorological measurements include parameterization techniques using measurements of vertical temperature gradient (ΔT), the standard deviation of the wind direction (σ_Θ) coupled with wind speed, the standard deviation of the elevation angle of the wind (σ_φ) coupled with wind speed, Monin-Obukhov length, and solar radiation coupled with ΔT. A full treatment of meteorological monitoring and stability class determination can be located in ANSI/ANS-3.11 Appendix C. Nuclear Regulatory Commission (NRC) Safety Guide 23 and Irwin (1980) discuss the σ_Θ and σ_φ methods and present a method that uses both σ_Θ and wind speed. This method is also described in the EPA-454/R-99-005.

4.4.4 Atmospheric Turbulence Measurements

Numerous studies (NUREG/CR-0798; Lague et al. 1980; Lalas et al. 1979; Luna and Church 1972; Mitchell 1982; Sedefian and Bennett 1980; Skaggs and Robinson 1976; Weil 1979) have compared methods of determining stability classes. When hourly data are examined, the results of the various methods are not highly correlated. Dispersion coefficients for this type of application can be estimated directly from atmospheric turbulence measurements (Hanna et al. 1977; Irwin 1983; Hanna 1982; Hanna 1983; Pasquill 1979; Ramsdell et al. 1982).

Turbulence data for estimating the horizontal dispersion coefficient can be obtained from the same sensors used for wind direction and wind speed measurements with additional signal processing. Ultrasonic wind sensors with low threshold capabilities, which are relatively inexpensive, are capable of measuring wind speeds at lower thresholds than mechanical anemometry. Accordingly, σ_Θ turbulence typing at very low wind speeds can be established from sonic anemometer measurements. Obtaining turbulence data for estimating vertical dispersion coefficients can be calculated from measurements provided by three-dimensional sonic anemometry.

4.5 METEOROLOGICAL MEASUREMENTS

4.5.1 Introduction

This section provides guidance in selection and operation of meteorological instrumentation to obtain the required information for all applications at a DOE and NNSA site.

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According to Section 3 of ANSI/ANS-3.11-2000, and Section 1.1 of EPA-454/R-99-005, the meteorological monitoring system design shall be based on the needs and objectives of the facility and the guiding principles for making accurate and valid meteorological measurements. Meteorological measurements should* be made in locations that, to the extent practicable, provide data representative of the atmospheric conditions into which material will be released and transported. A qualified professional meteorologist or atmospheric scientist with experience in atmospheric dispersion and meteorological instrumentation should* be consulted in selecting measurement locations and in the design and installation of the meteorological monitoring system.

As indicated in Section 4 of ANSI/ANS-3.11-2000, and Section 3 of EPA-454/R-99-005, factors to be considered in selecting the appropriate measurement locations and for the installation of the instruments include the prevailing wind direction, the topography, and the location of man-made and topographic obstructions. Also, any special meteorological monitoring requirements imposed by other agencies (outside the DOE) should* be taken into consideration when designing meteorological measurement systems and establishing measurement locations. The instruments used in the monitoring program should* be capable of continuous operation in the expected range of atmospheric conditions at the facility. The frequency of thunderstorms, icing, or other chemical or physical agents that may cause damage or deteriorate performance should* be considered in selecting specific sensors and designing the sensor installation. An uninterruptible power supply should* be included in the system, and an alternate source of power should* be available in order to ensure a high level of data availability and recovery.

4.5.2 Siting and Location of Meteorological Measurements

Wind measurements should* be made at a sufficient number of heights in the Planetary Boundary Layer (PBL) to adequately characterize the wind at potential release heights. In general, wind measurements that are representative of ground level releases should* be made at a height of 10 m. If a vertical temperature difference (i.e., $\Delta T/\Delta z$) is used to type atmospheric stability, the temperature difference should* be determined over an interval of sufficient thickness to allow adequate determination of accepted stability classes. The temperature monitoring levels should* be selected so that they are spaced such that the profile is representative and characterizes the magnitude of atmospheric turbulence at the potential release height(s). Additional information on meteorological monitoring for stability class determination can be found in Section 3.4 on ANSI/ANS-3.11-2000, and Section 6.4 of EPA-454/R-99-005. For releases through stacks that are taller than 60 m, NRC Safety Guide 23 suggests that the temperature difference between the release height and the 10-m height be determined. Other necessary meteorological measurements should* be made using standard instrumentation in accordance with accepted procedures. Standard meteorological measurement techniques for the basic meteorological measurements (i.e., wind speed, wind direction, temperature, and precipitation) and site-specific supplemental meteorological measurements (i.e., atmospheric moisture, solar and net radiation, barometric pressure, mixing height, soil temperature, soil moisture) are outlined in Sections 3.1 and 3.2 of ANSI/ANS-3.11-2000, and Section 3.2 of EPA-454/R-99-005.

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4.5.3 Instrument Mounting

According to Section 4.3.1 of ANSI/ANS-3.11-2000, and Section 3.2.1.2 of EPA-454/R-99-005, monitoring site locations shall be chosen to reduce influences of obstructions and external influences that adversely affect the measurements. Wind measurements should* be made at locations and heights that avoid airflow modification by obstructions such as large structures, trees, or nearby terrain with heights exceeding one-half of the height of the wind measuring device. Air temperature and relative humidity measurements shall be made in such a way as to avoid air modification by heat and moisture sources (e.g., ventilation sources, cooling towers, water bodies, large parking lots). The tower should* not be located on or near man-made surfaces such as concrete or asphalt.

Wind instruments that are mounted on towers may be placed on top of the towers or on booms extending to the side of the towers to avoid confounding effects of tower-generated turbulence. Instruments mounted above a tower should* be mounted on a mast extending at least one tower diameter above the tower. If instruments are mounted on booms extending to the side of a tower, the booms should* be oriented in directions that minimize the potential effects of the tower on the measurements. The orientation of booms for wind instruments should* be determined after considering the frequencies of all wind directions. Orientation of the booms on the basis of only the prevailing direction might not minimize tower effects. In some locations, placement of wind instruments on opposite sides of the tower could be necessary to obtain reliable wind data for all wind directions. For locations with two distinct prevailing wind directions, the sensors should* be mounted in a direction perpendicular to the primary two directions.

Temperature sensors should* be mounted and placed in fan-aspirated radiation shields, and the shields should* be oriented to the north (in the Northern Hemisphere) and downward to minimize effects of direct and reflected solar radiation. The aspirated shields will minimize the adverse influences of thermal radiation and precipitation. The shield should* provide ventilation of the sensor at flow rates of between 3 meters per second and 10 meters per second. The shield inlet should* be at a distance at least 1.5 times the tower horizontal width away from the nearest point on the tower.

4.5.4 Measurement Recording Systems

According to Section 5 of ANSI/ANS-3.11-2000, and Section 4 of EPA-454/R-99-005, the onsite meteorological monitoring system should* use an electronic digital data acquisition system housed in a climatically controlled environment as a primary data recording system. It should* be noted that the current generation of data loggers are so well temperature compensated that environmental control is only required in very extreme conditions. For sites that require a high assurance and availability of valid data, the use of a backup recording system, preferentially digital, is recommended. In addition, the output of the instruments should* be displayed in a location where instrument performance can be monitored on a regular basis.

Digitally recorded data, except for σ_Θ and precipitation, should* be averaged over at least 30 samples taken at intervals not to exceed 60 seconds. The time period represented by the averages should* not be less than 15 minutes, although ANSI/ANS-3.11-2000 indicates that a 10-minute average is also acceptable. A minimum of 180 equally spaced wind direction samples is required for estimation of σ_Θ and σ_φ. For an hourly standard deviation value, the data should* be sampled at least once every 20 seconds. Additional guidance on the standard deviation of wind direction parameter is provided in Section 5.2 of ANSI/ANS-3.11-2000, and Section 6.4 of EPA-454/R-99-005. If the application (e.g., examination of turbulent wind fields) requires the use of sonic anemometers, the sample frequency should* be of a smaller duration (e.g., approximately 1 Hz).

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If strip charts are used as one of the recording systems, continuous-trace strip charts should* be used for wind data; multipoint strip-chart recorders may be used for the remaining data. If properly located, the strip charts may be used for the data displays. Due to the sophistication of electronic data acquisition systems, strip charts are generally only used as a back-up data acquisition system.

4.6 MEASUREMENT SYSTEM

The accuracies of the monitoring measurements should* be consistent with the specifications set forth in either ANSI/ANS-3.11-2000, or EPA-454/R-99-005, if EPA guidance recommends more stringent specifications. The minimum system accuracy and resolution requirements for digitally recorded data and instrument specifications contained in Table 1 of ANSI/ANS-3.11-2000, and Table 5-1 of EPA-454/R-99-005 include the following:

- Horizontal and vertical wind direction — ±5° in azimuth with a starting threshold of 0.45 m/sec (1 mph). If the sensor is to be used to determine σ_Θ, the damping ratio must be between 0.4 and 0.6, and the delay distance must not exceed 2 m;
- Wind speed — ±0.22 m/sec (0.5 mph) for speeds less than 2.2 m/sec (5 mph); within 5% for speeds of 2.2 m/sec (5 mph) or greater, starting speed of less than 0.45 m/sec (1 mph);
- Air temperature — ±0.5°C;
- Vertical air temperature difference — ±0.1°C/50 m; (b)
- Dew point temperature — ±1.5°C;
- Relative humidity — ±4%;
- Solar/Terrestrial radiation — ±5 watts/m^2 for <100 watts/m^2; ±5% of observed for >100 watts/m^2;
- Barometric Pressure — ±3 mb (0.3 kPa);
- Soil temperature — ±1°C;

(b) The vertical air temperature difference accuracy requirement is more precise since this parameter is generally used in turbulence typing where very small differences may result in different stability class determinations.

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- Soil moisture ±10% of actual;
- Precipitation ±10% of volume; and,
- Time ±5 min.

Additional system accuracy requirements are discussed in Section 7.1 of ANSI/ANS-3.11-2000, and Section 5.1 of EPA-454/R-99-005. System accuracy should* be estimated by calculation of the root-mean-square of the accuracy of the system's individual components.

4.7 INSPECTION, MAINTENANCE, PROTECTION AND CALIBRATION

Section 7.2 of ANSI/ANS-3.11-2000 and Section 8.3 of EPA-454/R-99-005 outlines the system calibration requirements. The meteorological monitoring program should* provide for routine inspection of the data and scheduled maintenance and calibration of the meteorological instrumentation and data acquisition system at a minimum, based on the calibration frequency recommendations of the manufacturers. Inspections, maintenance, and calibrations should* be conducted in accordance with written procedures, and logs of the inspections, maintenance, and calibrations should* be kept and maintained as permanent records. All systems should* be calibrated semiannually, unless the operating history of the equipment indicates that either more or less frequent calibration is necessary. Table 3 of ANSI/ANS-3.11-2000 provides guidance on field calibration checks for meteorological instrumentation.

Section 6.4 of ANSI-ANS-3.11-2000 and Section 5.3 of EPA-454/R-99-005 provide information on acceptable data recovery rates. The instrument system should* provide data recovery of at least 90% quality-assured data on an annual basis. The 90% rate applies both to individual parameters and to the composite joint frequency distribution of wind direction, wind speed, and stability class, and other meteorological elements required for consequence assessments. Data recovery rates for other meteorological parameters should* also be at least 90% on an annual basis. This rate should* also be maintained for remote sensing devices, if used.

The monitoring and data recording systems should* be protected from lightning-induced electrical surges and electrical faults, and severe environmental conditions (ANSI/ANS-3.11-2000; EPA-454/R-99-005). Functional checks of instrumentation should* be performed after exposure to extreme meteorological conditions or other events that may compromise system integrity.

4.8 SUPPLEMENTARY METEOROLOGICAL INSTRUMENTATION

Supplementary meteorological parameters may be needed to support site-specific programs, including, but not limited to, flows in complex terrain over large distances. Section 3.2 of ANSI/ANS-3.11-2000, and Section 3.3 of EPA-454/R-99-005 discuss the circumstances in which there is a need to monitor supplemental meteorological parameters. The topographic setting of a facility and the distances from the facility to points of public access should* be considered when evaluating the need for supplemental instrumentation. If meteorological measurements at a single location cannot adequately represent atmospheric conditions for transport and dispersion computations (i.e., spatial representativeness), supplemental measurements should* be made. Supplemental instruments need measure only those elements that have significant spatial variation.

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Additional meteorological data may be necessary for making estimates of atmospheric transport and dispersion for large distances. Data from spatially representative meteorological stations (e.g., military, NWS, cooperative stations) can be useful for these applications. The determination of the number of additional data sources and their location(s) is dependent on the heterogeneity of the terrain, the possibility if the presence of three-dimensional atmospheric flow phenomena, and the complexity of the application for which the data will be applied. These judgments require an extensive knowledge of atmospheric transport and dispersion principles. Accordingly, qualified meteorologists should* be consulted with respect to these judgments.

In some instances, in situ measurements may be augmented by measurements from remote sensing technologies (Section 3.2.7 ANSI/ANS-3.11-2000; Section 3.3 of EPA-454/R-99-005). These include various widely deployed (i.e., commonly used) systems, and less widely deployed systems. Additional information on remote sensing systems and their applicability to meteorological monitoring programs can be found in Appendix A.4 of ANSI/ANS-3.11-2000.

4.9 LARGE-SITE (MULTI-FACILITY INSTALLATION) METEOROLOGICAL PROGRAMS

Several DOE and NNSA field offices are located on large areas (e.g., Nevada Test Site [NTS] covers 1,350 square miles) with multiple facilities (e.g., Savannah River Site [SRS], Oak Ridge Reservation, Idaho National Environmental Engineering Laboratory [INEEL], NTS and the Hanford Site). Each of these field offices are in locations of potentially complex terrain flow characteristics. As a result, spatial variations in meteorological conditions must be considered in evaluating atmospheric transport and dispersion within the sites and to points of public access. A site-wide meteorological monitoring program, with supplemental instrumentation, and in some cases, remote sensing instrumentation, has been established at each multi-facility site to provide a comprehensive data base that can be used for all facilities located within the site. Consequently, it may not be necessary to establish a meteorological program for each individual facility.

Consequence assessments can be made for individual facilities using facility-specific source term and release characteristics and a multi-location multi-parameter meteorological database for the transport and dispersion analysis.

4.10 DATA SUMMARIZATION AND ARCHIVING

Section 6 of ANSI/ANS-3.11-2000 emphasizes that it is important that every facility have a valid and accurate meteorological database, which can be utilized to evaluate environmental impacts and consequence assessments. For licensing and other regulatory purposes, three to five years of data is recommended. For future facilities there should* be at least a one-year period of pre-construction data and one- to two-years operational data that meet the ANSI/ANS-3.11-2000 data recovery requirements.

Section 5.2 of ANSI/ANS-3.11-2000 and Section 6.1 of EPA-454/R-99-005 provide guidance on data sampling frequencies for digital data acquisition systems and multi-point recorders.

Data used in consequence assessments should* be collected as 15-minute averages for use in emergency response applications. The 15-minute averages can be combined into hourly averages for use in consequence assessments. The 15-minute data should* remain readily available in a temporary archive for at least 24 hours, especially after an incident, for forensic purposes. Then either the 15-minute or hourly averages should* be stored for entry into a permanent archive for future climatology summarization.

These data should* be examined and entered into the permanent archive at least monthly. Section 6.5 of ANSI/ANS-3.11-2000 and Section 7 of EPA-454/R-99-005 provide guidance on long term data archiving. Meteorological data should* be retained for a period of five years, while the validated data should* be retained for the life of the facility. The archived data should* be hourly-averages or 15-minute averages for annual time periods. Since data storage costs have decreased, archiving of 15-minute data has become more practical.

4.11 METEOROLOGICAL DATA PROCESSING

4.11.1 Overview

Designing environmental surveillance programs, establishing compliance with enabling regulations, and analyzing the consequences of potential or actual releases require information on a common set of meteorological elements. Typically these elements are wind direction, wind speed, an indicator of atmospheric stability, air temperature and temperature gradient, and mixing-layer thickness. Although the individual applications could require data for a common set of meteorological elements, the format in which the data are required will vary by application and assessment procedure.

4.11.2 Assessment of Routine Releases

Assessment of potential consequences of routine radiological releases from projected new or modified facilities should* be based on climatological data because the future meteorological conditions at the time of release are presently unknown. If the postulated release is continuous, the analyses should* be made using a joint frequency distribution of wind direction, wind speed, and atmospheric stability based on data from at least one annual cycle. When possible, the frequency distributions should* be based on 5 or more years of data. This approach could also be used for intermittent releases if the releases occur randomly and with sufficient frequency to make the use of an annual-frequency distribution appropriate.

Assessments of the consequences of routine releases from existing facilities and demonstrations of compliance are routinely made using climatology summaries, provided that a straight-line Gaussian atmospheric transport and dispersion model is appropriate. Climatology summaries used in the evaluation of consequences of an actual release should* be based on hourly-averaged data for the specific period of the release. For example, if a continuous release occurs from May 15 through June 26, the joint-frequency distribution should* be based on the meteorological observations during that period. Where straight-line Gaussian atmospheric transport and dispersion models are inappropriate, consequence assessments for routine releases and demonstrations of compliance should* be made using a time series of hourly-averaged data. These time series should* include all supplemental data required to account for spatial as well as temporal variations in atmospheric conditions. Refer to Sections 3.1 and 5.3.1 of EPA-454/R-99-005 for guidance on spatial representativeness, and temporal representativeness, respectively.

4.11.3 Assessment of Accidental Releases

Consequence analyses for postulated accidental releases should* be made for each downwind direction using conservative meteorological assumptions for each release scenario. For a ground-level release, these assumptions should* include coupled slow wind speed and stable atmospheric conditions (e.g., F stability at 1.0 m/sec); for elevated releases, a full range of wind speed-stability class conditions should* be evaluated since a moderate wind speed and neutral atmospheric conditions may be more conservative than a slow wind speed and stable conditions.

Straight-line Gaussian atmospheric transport and dispersion models may be appropriate for assessment of some postulated releases. Complex terrain airflow trajectory models may also be used if adequate supplemental data are available.

The joint-frequency distribution and choices of meteorological conditions for the accident analyses should* be based on a minimum of 5 years of hourly-averaged data acquired by a meteorological program that meets the objectives and principles of ANSI/ANS-3.11-2000 and EPA-454/R-99-005. However, if this onsite meteorological data base is unavailable, spatially representative offsite data may be used in lieu of onsite data. In this instance, the analyses may be based on 2 or more years of hourly observations of spatially representative offsite data, as long this data is acquired with well-maintained instrumentation under an adequate quality assurance program.

Consequence assessments during the course of an emergency should* be based on time series of actual (i.e., diagnostic) and forecasted (i.e., prognostic) atmospheric conditions. When necessary, data should* be included in the time series to represent spatial variations in the atmospheric conditions. An averaging interval of 15 minutes has been accepted by the Nuclear Regulatory Commission as appropriate for data used in emergency response applications. This interval is consistent with the averaging interval specification in Section 5.2 of ANSI/ANS-3.11-2000, and Section 6.1 of EPA-454/R-99-005. Instantaneous observations are too variable to be used with confidence, and hourly-averaged values do not reflect changes in conditions in a timely manner for emergency response applications. However, if the time-scale of the emergency is small, representative of a rapidly developing situation, or by a short-range transport, meteorological data averaged over a shorter time period (e.g., 5 minutes), if available, may be desirable. Correspondingly, if the evaluation involves long-range transports, such as the continental scale of the Chernobyl nuclear accident, a longer average period for meteorological data (e.g., hourly-average) may be applicable.

4.11.4 Meteorological Data Needs

Assessment procedures have varying meteorological data needs and a precise format in which the meteorological data must be entered. The meteorological data needs and format for 64 atmospheric transport and dispersion models can be referenced in "Directory of Consequence Assessment Models" (OFCM, 1999).

4.12 QUALITY ASSURANCE AND DOCUMENTATION

Section 7.4 of ANSI/ANS-3.11-2000 and Section 8 of EPA-454/R-99-005 provide guidance on quality assurance and documentation. As they apply to meteorological monitoring, the general quality assurance program provisions described in Chapter 10 should* be followed. Specific quality assurance activity requirements for the facility's meteorological monitoring program, sufficient to provide acceptable data recovery and accuracy, are to be contained in the Quality Assurance Plan associated with the facility. At a minimum, the following criteria should* be addressed:

- Owner organization;
- Indoctrination and training;
- Assessment programs;
- Procedures adherence;

- Maintenance;
- Corrective actions;
- Plant records management;
- Procurement and materials control;
- Measuring and test equipment;
- Traceability of standards; and,
- Software and database control.

Guidance in quality assurance related to meteorological measurements and meteorological data processing may also be found in Finkelstein et al. (1983), and ANSI/ANS-3.2-1994.

Quality Assurance Plans (QAPs) should* be reviewed every five years, or whenever substantive changes to the meteorological program are made.