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Odor Footprint Tool Progress: Regional Output Resources

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Summary and Implications

This article highlights practical applications for resources being developed using the Odor Footprint Tool and the effects of differing regional weather patterns on needed setbacks by describing resources created for the regions surrounding Norfolk and Lincoln, Neb. The Odor Footprint Tool is being developed to help people assess the odor impact of new and expanded animal production facilities on the surrounding areas and use science-based information to establish minimum setback distances. Progress continues to be made toward development of a system that can be used in the field to develop site-specific odor footprints. As an intermediate step in this process, regional sets of Odor Footprint Tool resources are being developed for more general use. Odor roses, directional setback distance curves, and odor footprints are being produced for six regions in Nebraska. Odor roses provide a descriptive picture of the directionality of odor annoyance within a region, independent of the type or size of livestock facility involved. Odor roses are well suited for general planning and educational purposes where mainly the directional fate of odor emissions is desired. Directional setback distance curves facilitate determining minimum setback distances in four 90-degree sectors around a site, based upon the total odor emission rate of the site. The total emission rate depends on the size and type of livestock housing and/or manure storage facilities involved, and whether any odor control technologies are

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implemented. Directional setback distance curves are especially useful when principal setback distances are desired, and when a number of preliminary comparisons are to be made. Odor footprints show curves similar to contour lines representing the locations around a livestock site that have common expected frequencies of odor annoyance. Odor footprints correspond to specific scenarios (having specific total odor emission rates) and are useful for visualizing the projected odor impact of an operation on the surrounding area. As livestock producers, their service providers, and regulatory officials begin to use these resources, they should be better able to make reasonable decisions regarding the odor impact of livestock operations on surrounding neighbors and rural communities. Odor impact at a given location is presented in terms of the likelihood that odor will exist at annoying intensity levels. Producers can use the frequency of annoyance information and the corresponding percentages of time that odor annoyance is not expected (odor annoyance-free frequencies) to help evaluate their risk of offending neighbors and to determine which neighbors are at greatest risk. This information will be helpful when evaluating sites and in determining the benefit of implementing proven odor control technologies. Also, regulatory officials will have access to science-based information that can form the basis of reasonable discussions at public hearings and be considered in decision processes for applications to build livestock facilities.

Background

As livestock and poultry producers have expanded and intensified their operations, the level of community concern and number of complaints registered about emissions of air pollutants, especially odorants, from animal production facilities have risen dramatically as well. One approach to deal with these concerns involves establishing minimum setback (separation) distances between production facilities and residences or public facilities. Many county governing bodies have implemented setback requirements through local zoning regulations, and most of these lack a sound scientific basis.

Current siting requirements for new livestock and poultry production systems in the United States are based mainly on the number and weight of animals on a site and the distance to the nearest neighbor. This approach does not account for existing odor sources in a community, the influence of localized meteorological or topographic factors on odor dispersion, or the use of improved odor management practices. Odor dispersion is a complex process that depends on emissions characteristics of the source, weather patterns, terrain, and the presence of other odor sources.

Atmospheric dispersion models can account for these factors and could provide rural communities and the livestock industry with the tools needed to incorporate science and objectivity into the odor management decision-making process. Air quality research groups at the University of Nebraska and the University of Minnesota developed the Odor Footprint Tool for estimating setback distances. The Odor Footprint Tool uses an EPA regulatory model (AERMOD), which was selected because it has considerable flexibility, and the regulatory community generally accepts its use. The Odor Footprint Tool uses meteorological data from sources such as the National Weather Service (NWS) and the Automated Weather Data Network (AWDN), which has numerous weather stations located throughout Nebraska. An interface was also developed to collect necessary information from the user and process it for use by AERMOD. The Odor Footprint Tool can then use the AERMOD output to generate *odor roses, directional setback distance curves*, and *odor footprints.* The Odor Footprint Tool has gone through an initial calibration stage to facilitate accurate prediction of odor intensities downwind of an odor source. Validation of the Odor Footprint Tool for use with a swine finishing facility in a community setting is underway in Nebraska.

Although the Odor Footprint Tool is being developed to handle more varied and specific situations, the focus of much of the effort to this point has been on producing output resources for generic situations within regions surrounding readily identified primary weather stations. Output resources are being developed for six regions encompassing the state of Nebraska (see Figure 1), three regions in South Dakota, and a region each within Iowa, Kansas, and Minnesota. These regional resources are being developed for educational purposes and in preliminary planning of livestock facilities — applications where local terrain and proximity to the regional weather station are not generally critical. This article highlights practical applications for the regional resources being developed using the Odor Footprint Tool and the effects of differing regional weather patterns on needed setbacks by describing resources created for the regions surrounding Norfolk and Lincoln, Neb.

Description of Output Resources

All of the information presented is based upon historical weather conditions from April 15 through October 15, sometimes referred to as the "odor season" in the Midwest. People are more likely to be exposed to odors during this period since the warm months of the year are generally when odors are most prevalent and people are active outdoors. The term "odor annoyance" corresponds to an intensity of 2 or higher on a 0-to-5 n-butanol scale as assessed by trained individuals. The term "odor unit," the value of which is

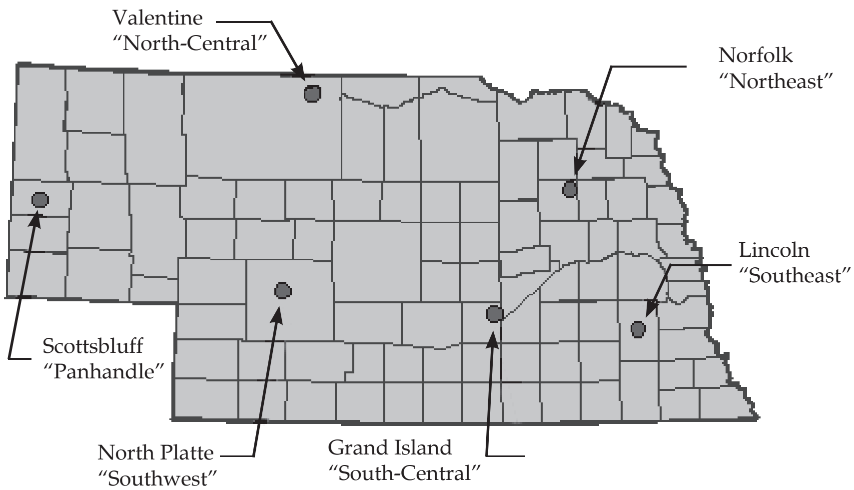

Figure 1. Weather station locations for the six Nebraska regions for which Odor Footprint Tool output resources are being developed.

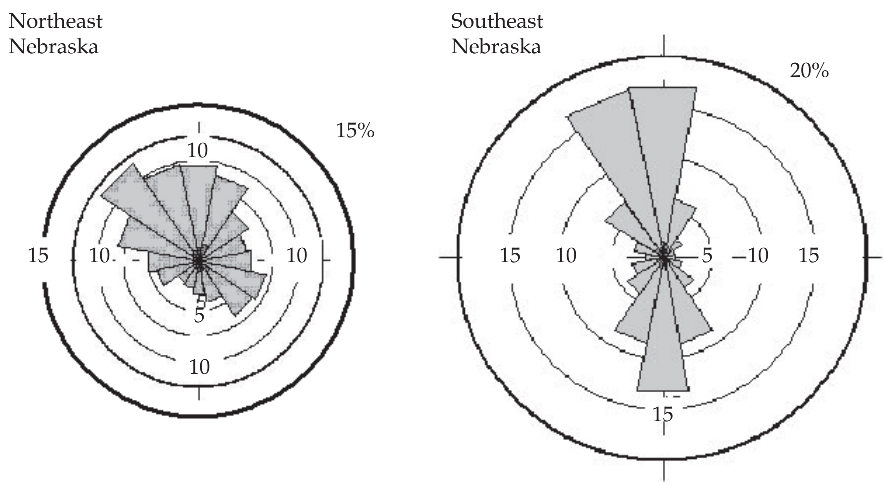

Figure 2. Odor roses for Norfolk (left) and Lincoln, Neb. (right). The extent of the radial bars represents the proportion of total annoying odors expected in that direction.

assigned by a trained odor panel, is used to quantify odor concentration and the rate at which odor is being emitted from a facility.

Odor Roses

An odor rose (Figure 2) shows the likelihood of annoying odors existing in a given direction from a livestock facility, independent of the size or type of operation. The likelihood of annoyance is expressed as the percentage of the total annoyance incidences for all directions, so the sum of the sector bars in all directions equals 100%. For example, the comparative likelihood of annoying odors existing directly to the south of an odor source is about 3% near Norfolk versus 13% near Lincoln.

The likelihood of being exposed to annoying odors is a function of both surface and upper air weather conditions in the region over an extended period of time (typically 10 years). Wind direction logically plays a key role in the directionality of odor annoyance. Influences of other factors such as humidity, cloud cover, and atmospheric stability also are evident, however, and the odor roses that have been developed are not mirror images of the corresponding wind roses for the given locations.

Near Norfolk, odor annoyance is likely to be most prevalent to the north of a source, with maximum odor annoyance to the northwest (Figure 2). In contrast, odor annoyance near Lincoln is expected to be very polarized with maximum annoyance to the north and north-northwest of an odor source followed closely by the due south direction. These differences in weather patterns have noteworthy implications for planning and assessing sites for livestock facilities in the two regions.

As a point of interest, each of the directional bars within the odor roses has a small, darkly shaded interior sector while the outer portion is lightly shaded. The interior sectors represent expected odor annoyance during daytime hours (8:00 a.m. to 6:00 p.m.), and the outer portion represents nighttime and transition hours. It is quite apparent from the odor roses shown that the potential for annoying odors is greatest during transition and nighttime hours, when the atmosphere is more likely to be stable. Near Norfolk, the total likelihood of annoying odors existing between 6:00 p.m. and 8:00 a.m. (a 14-hour period or 58% of a day) is about 86%, while between 8:00 a.m. and 6:00 p.m. it is only 14%. For the Lincoln area, these percentages are 88% and 12%, respectively. Therefore, the directional nature of odor annoyance for the transition and nighttime portions of a day is representative of the full day.

Directional Setback Distance Curves

Directional setback distance curves are used to determine minimum setback distances in the four principal directions downwind from an existing or proposed livestock facility. Directional setback

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distance curves were developed based upon the concepts presented with OFFSET, a groundbreaking setback-estimation tool developed at the University of Minnesota. Using a worksheet and graphs that apply for the geographic region in which the facilities are to be located, four directional setback distances can be determined for a specified odor-annoyance-free frequency. Each of the four distances represents the minimum setback desired for a corresponding 90-degree sector extending to either the north, south, east, or west of the site; or, alternatively, to the northeast, southeast, southwest or northwest. The alignment of the directions for a given region was selected to match the direction of maximum expected odor impact with one of the 90-degree sectors. For example, the odor roses shown in Figure 2 show that the maximum odor impact of a generic odor source near Norfolk would be expected to the northwest, while for the Lincoln area, the maximum projected impact would be more due north of the facility. Therefore, directional setback curves were developed for each of these two regions (Figure 3), but each set of curves is based on a different axis to highlight the direction of maximum odor impact.

Each set of curves shows curves for 90%, 94%, 96%, 98% and 99% odor-annoyance-free frequencies. The percentage values represent the minimum proportions of hours during the spring-through-fall period, during which a residence situated at or beyond the setback distance would not be exposed to annoying levels of odor coming from the livestock site. In other words, using the 96% curve, odors at locations inside the identified setback may be present at annoying levels more than 4% (100% - 96%) of the time, while odors at locations outside the setback would be expected to be present at annoying levels less than 4% of the time. The

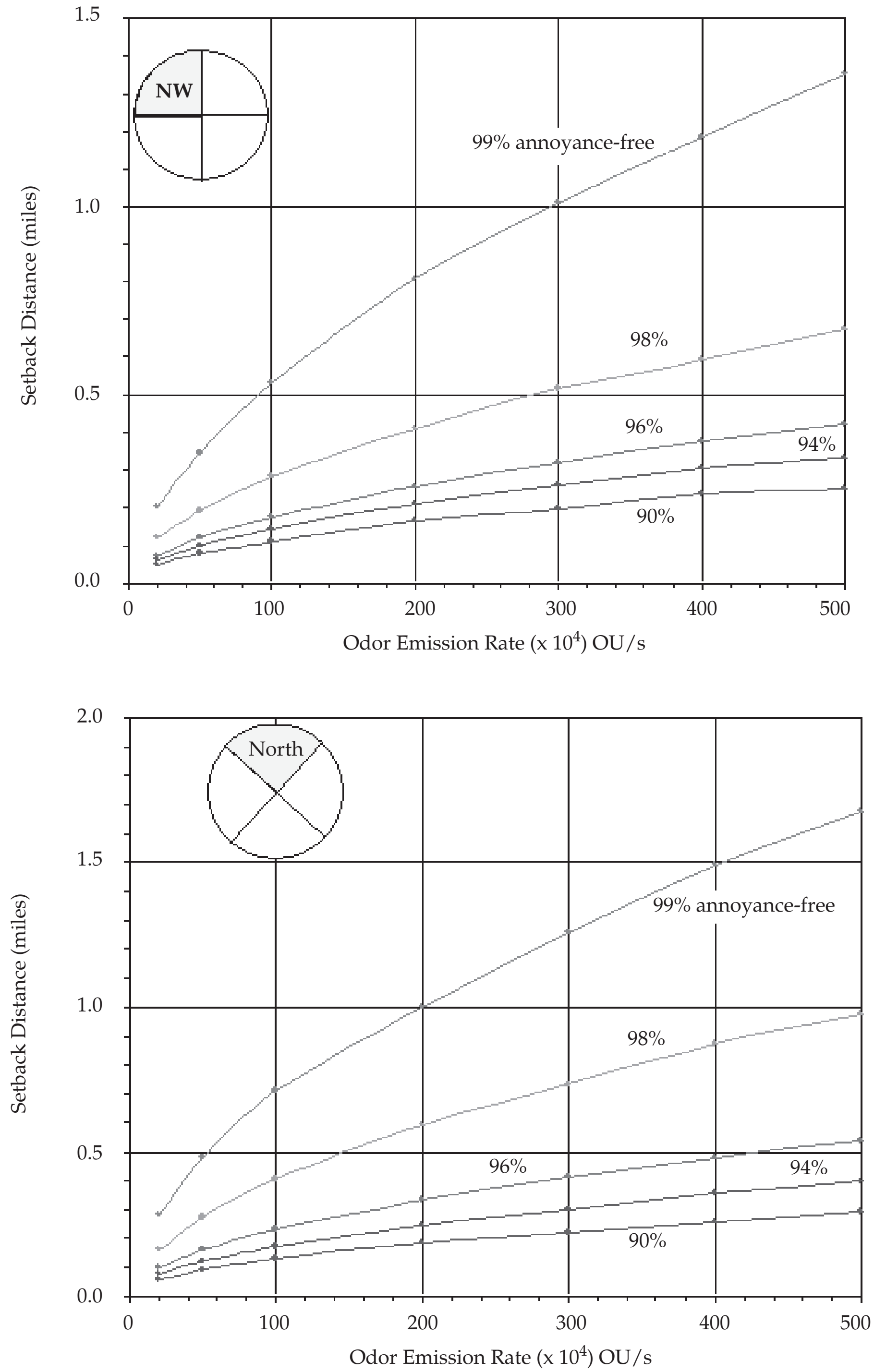

Figure 3. Directional setback distance curves for regions surrounding Norfolk (top) and Lincoln (bottom), Neb. Graphs shown are for the direction of maximum projected odor impact. Graphs showing curves for the other three primary directions are available but not shown.

listed percentages were selected as covering the practical range of acceptable odor annoyance, representing from two to 18 full days of odor annoyance every year from mid-April to mid-November. The separation distance required to achieve a greater odor-annoyance-free percentage increases significantly with each percentage point increase. For example, the difference between the setbacks for 98% and 99% odor-annoyance-free frequencies is at least twice that needed to move from 90% to 94%. Therefore, lower tolerance for risk of exposure to annoying odors is directly reflected by noticeably larger required separation between the source and receptor. Note that it is not possible to determine a setback distance for 100% odor-annoyance-free conditions.

The setback distances described by these curves take into consideration historical weather conditions that influence odor transport and dispersion in the selected region. If the influence of terrain and local weather conditions are required to obtain a more accurate determination of setbacks, then a site-specific footprint should be produced.

The setback distance for a livestock facility within a given region is determined based upon the total scaled odor emission rate from all noteworthy odor sources on the site – as shown along the horizontal axis of the graph. Scaled odor emission rates (OER) for individual facilities are found using the following formula:

> OER = Odor emission number x Plan area x Odor control factor

Two pieces of information about the facilities on a site are required to estimate directional setback distances: the types of [proposed] facilities on the site and each facility's floor or surface area. Most general types of facilities considered will have an odor emission number associated with them. The odor emission number represents the relative amount of odor one could expect to be released by the source facility into the surrounding air per unit of floor or surface area. These values are based upon currently available emissions data and as more data becomes available, these values may be updated. The odor emission numbers are scaled for use with AERMOD and are for use with the Odor Footprint Tool only.

An odor control factor (value between 0 and 1) also may be applied to assess the impact of using odor control technologies. The more odor reduction provided, the lower the odor control factor. Several odor control technologies have been evaluated sufficiently to determine their effectiveness in reducing odor emissions and assign appropriate odor control factors.

Using the appropriate set of directional setback distance curves, a calculated total odor emission rate, and a selected odor-annoyance-free frequency, one can read off the minimum setback distance for each of the four primary directions around the site. Information on odor emission numbers and odor control factors will be provided separately as it becomes available, along with a worksheet to use in making calculations and recording setback distances.

To illustrate the use of these curves, consider a swine finishing building housing 2,000 hogs and having slatted flooring over a deep pit. Assuming rough building dimensions of 45 ft x 400 ft (or 80 ft x 220 ft), the building has about 18,000 sq ft of floor area. Given that the odor emission number assigned this type of facility is 165 odor units (OU) per second per sq ft, the OER for the building is about 3,000,000 or 300 x 10^4 OU/s. Using Figure 3, the setback distance in the direction of maximum projected impact would be just over half a mile for a site near Norfolk and about 3/4 of a mile near Lincoln at 98% odor-annoyance-free frequency (fairly low tolerance for odor). These distances would jump to nearly 1 mile and 1.3 miles, respectively, at 99%. By employing additional odor control, one could reduce the odor impact of the complex and the setback needed. For example, spraying [vegetable-based] oil inside the pig space to control dust has been demonstrated to reduce odor emissions by about 50%, so the total OER of this complex could drop to about 150 x 10^4 OU/s [18,000 x 165 x 0.5 ~ 1,500,000] with oil sprinkling, and the setback distance at 98% would now be about 0.3 miles in the northwest direction near Norfolk and 0.5 miles to the north near Lincoln.

Odor Footprints

An odor footprint shows a plan [top] view of the projected odor impact of a livestock operation in terms of the extent of exposure to annoying odor in all directions from the source (Figure 4). Using the concept of contour lines, curves are plotted showing the locations of constant odor-annoyance-free frequency (100% minus the frequency of annoyance).

Odor footprints are tied to a specific odor emission rate, which was described in the previous section as a function of the number, types and sizes of facilities on a site, and whether any odor control technologies are implemented. Figure 4 contrasts odor footprints for the regions surrounding Norfolk and Lincoln, respectively, for facilities having a total odor emission rate of 500 x 10^4 OU/s. For illustrative purposes, the scaled emission rate from a 3,300-head swine finishing building with deep pits and no special odor control practice in place is about 500 x 10^4 OU/s. Note that the same total odor emission rate could be achieved for numerous combinations of facility types and sizes, or through the use

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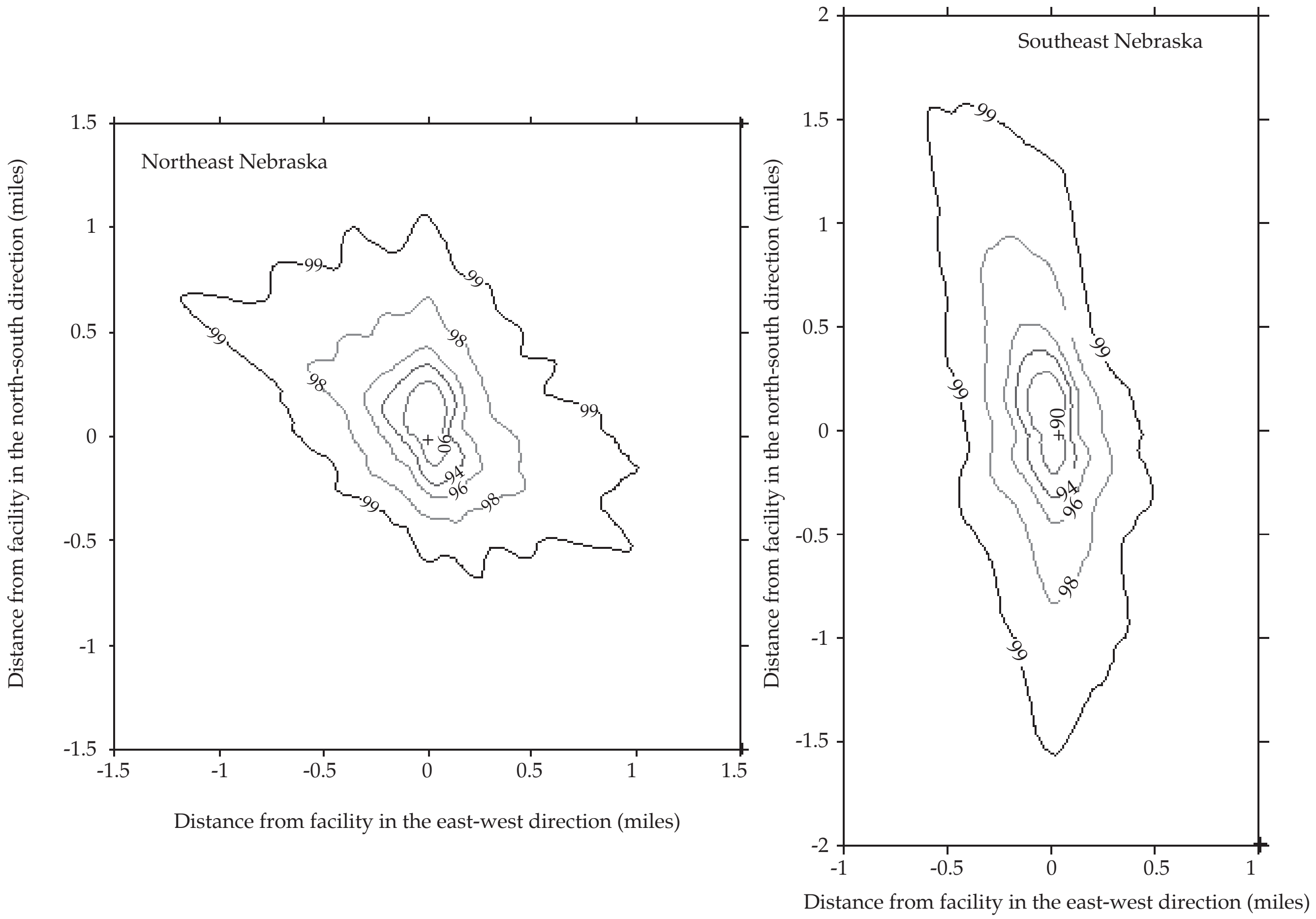

Figure 4. Odor footprints for Norfolk (left) and Lincoln, Neb. (right) at total odor emission rates of 500 x 10^4 OU/s. Curves show locations with common odor-annoyance-free frequencies.

of odor control on larger facilities. For example, a 3,300-head finisher with a shallow pit and lagoon would most likely have a different odor emission rate, as would a 3,300-sow gestation barn.

An immediate observation that can be made is that the shapes of the footprints in Figure 4 differ for the two regions, with each corresponding to the basic shape of the odor rose for that region. Looking at the detail of each footprint, both have five closed loops plotted representing locations having odor-annoyance-free frequencies of 90 to 99%. As the distance from the source increases, less odor annoyance should occur as indicated by greater odor-annoyance-free frequencies.

Both the extent of projected odor impact and the directions of maximum and minimum impacts differ noticeably for the two regions (Table 1). These differences, along with the fact that neither footprint shows a circular odor pattern around the source, highlight the deficiencies of employing a constant setback scheme or bulls-eye approach to account for odor. For the region surrounding Lincoln (southeast Nebraska), the practical outcome of using a constant setback distance would be having an excessively conservative setback requirement to the east and west of a source facility and potentially having insufficient or a nonconservative setback to the north and south of the facility.

Regional footprints do not consider the effects of local terrain, nor are these footprints necessarily based upon surface climatic data that are applicable for all locations within a given region. Enhancements to the Odor Footprint Tool will facilitate the development of site-specific odor footprints that can be used by consultants and technical service providers with individual operations for in-depth planning purposes.

Summary and Conclusions

The Odor Footprint Tool, which uses the AERMOD dispersion-modeling package, was used to develop regional resources for assessing odor impact from livestock and poultry operations. Three output resources — odor roses, directional setback distance curves, and odor footprints — were described, along with their respective practical applications.

Table 1. Sample ranges of setback distances (ft) for Norfolk and Lincoln, Neb., on regional odor footprints at total source emission rates of 500 x 10^4 OU/s.

	Norfolk (Northeast Nebraska)		Lincoln (Southeast Nebraska)	
Odor-annoyance-free frequency	Smallest setback distance Direction = SW	Largest setback distance Direction = NW*	Smallest setback distance Direction = East	Largest setback distance Direction = NNW
90%	300	1,200	300	1,200
98%	1,600	3,400	1,200	4,700
99%	2,200	7,100	2,200	8,700

*For 90%, the maximum separation distance is to the north of the source.

The odor rose offers basic insights into a region's directional risk for odor annoyance, independent of the nature of a source. Directional setback distance curves can be used to determine minimum setback distances in principal directions around a facility. Comparing of alternative sizes of operations, odor control options, tolerance levels for odor, etc. can readily be performed using these curves. Odor footprints can be developed for specific facility and odor control scenarios. Odor footprints are effective resources for visualizing the potential impact of a livestock odor source on the surrounding area. These regional resources will be made available to producers and other interested parties on appropriate Web sites and as extension materials.

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