DETERMINING SEPARATION DISTANCES USING THE ODOR FOOTPRINT TOOL
User's Manual for the Worksheet-Based Tool

Introduction:

Instructions are provided that will enable a person to determine directional setback distances using the worksheet-based version of the Odor Footprint Tool. A completed worksheet is also provided to illustrate use of the worksheet, tables, and directional setback distance curves for a specific set of livestock facilities and geographic region of Nebraska.

The Odor Footprint Tool (OFT) can be used to determine minimum separation distances that should be maintained in different directions around livestock and poultry production facilities to meet selected odor annoyance-free targets. The separation distances take into account the types and sizes of facilities on the site, use of proven odor control technology, historical weather records, risk-avoidance levels for odor annoyance, and local terrain. For background information on the Odor Footprint Tool, directional setback distances, and odor footprints, the reader is directed to the publication *Odor Footprints and the Odor Footprint Tool: An Overview*. A spreadsheet version of the Odor Footprint Tool is also available and instructions on its use are described in a separate publication, *Determining Separation Distances Using the Odor Footprint Tool: User's Manual for the Spreadsheet Tool*.

Determining Directional Setback Distances:

There are 14 steps in the general procedure for determining directional setback distances using the Odor Footprint Tool Worksheet. These steps are described in detail in the following sections. It may help to refer to the two worksheets - one blank and one filled out for an example scenario – and tables that accompany these instructions when reading through them. For a quick overview or refresher of the steps, refer to the summary sheet that accompanies the example scenario.

Before attempting to use the Odor Footprint Tool, the prospective user should gather essential information about the proposed operation, facilities, and planning criteria. To use the Odor Footprint Tool, you will need to have information available on the:

1) Proposed site location and what region(s) may be most representative of this location climate-wise;
2) Type of facility(ies) to be built on the site;
3) Basic dimensions of the facility(ies);
4) Type of odor control being considered, if any;
5) Desired or required annoyance-free frequency(ies) to be maintained; and
6) The terrain surrounding the facility.

Next, locate and assemble the Odor Footprint Tool Worksheet and related materials. Required materials for determining directional setback distances are listed below along with means of accessing each material:

Required material for using worksheet	Sources of required material
✓ Odor Footprint Tool Worksheet	A copy is appended to this document; also via OFT webpage
✓ OFT Tables 1-3	Tables are appended to this document; also via OFT webpage
✓ Calculator	Provided by user
✓ Directional setback distance curves	Available via OFT website

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First-time users should become familiar with the Odor Footprint Tool Worksheet. There are four main sections to the one-page worksheet. At the top, is a section in which the user enters descriptive information about the particular project. On the middle, left-hand side of the worksheet is a section for entering information about the facilities in the base plan. To the right of this section is a section for entering information about odor control alternatives being considered. Column headings indicate what values to insert and how to obtain the desired value. Lastly, along the bottom is a section for entering information about risk-avoidance targets for odor annoyance, local terrain, and resulting directional setback distances.

Step 1: Fill in general information describing the project.

Enter a project description or descriptive title in the lines provided at the top of the worksheet. This information should identify the type of operation (species, production phase, and number of animals), for whom setback information is being prepared, and a brief description of the scenario being evaluated (if more than one scenario is being considered). Descriptive information about the operation assists in documentation. A good description will prove especially helpful when multiple scenarios are considered.

It is also good practice to document who prepared setback information, as well as the date the information was prepared. This information may be noted in the footer section of the worksheet.

Step 2: Identify the site location and select a representative region.

Next, note the site location in the space to the right of the title. The location may be designated by the city and/or county or more descriptive information, such as township and section coordinates, may be noted. On the line below this, write in the name of the weather station location or region that best represents the general climate of the site location. Directional setback distances can presently be determined for the following six locations (regions) in Nebraska:

Scottsbluff (NE panhandle)	Ainsworth (north-central NE)	Norfolk (northeast NE)
North Platte (southwest NE)	Grand Island (south-central NE)	Lincoln (southeast NE)

In some cases, it may be appropriate to determine separation distances using information from two adjacent regions. In such situations, complete a separate worksheet for each region so records of calculations and setback distances are maintained for each region.

Step 3. Fill in information describing the facilities.

In Column A, provide very general notes about each animal housing facility and each manure handling facility. All pertinent odor sources on the site should be included, where possible. If one or more facilities in the Base Plan will include odor control technology, note the type of technology or practice to be implemented in the facility description in Column A. Write in the corresponding dimensions of each facility in Column B.

Basic information that is in the project description, such as species or a specific stage of production, need not be repeated here; but include other information about the facilities, especially descriptions about how manure is handled. The worksheet is designed to facilitate comparisons of odor control alternatives. In the typical scenario, no special odor control is included the base plan. Determining setback distances for a base plan without implementing odor control technology provides the user with information on the operation's

expected baseline odor impact and opportunity to easily evaluate the benefit of odor control in terms of reduced setback distances and risk-based impact area.

For building dimensions, enter the floor areas; for open lots, enter the top-view dimensions of the lot surface areas; and for manure containment/treatment facilities, enter the dimensions of the surface area when filled to the design capacity. Enter and identify the diameter of circular facilities. If an office, supply storage room, break room, etc. are to be attached to one of the buildings, these areas should be excluded from the plan dimensions since these areas should not be noteworthy sources of odor. Adjoining hallways, animal treatment pens, and handling areas, however, should be included in most situations.

When there are two or more facilities of the same type and size, it is preferable to note this and simply multiply the resulting surface area for one facility by the number of nearly identical facilities (in Step 5).

Step 4. Determine the plan area of each of the listed facilities.

Calculate the plan area (square feet) of each of the listed facilities (e.g. area = length x width) and list each area in the corresponding row of Column C. The area of a circular facility is $\pi d^2/4$ (or approximately 0.75 x diameter x diameter). When there are multiple facilities that are of similar type (e.g. two broiler houses), the combined areas can be used to simplify the calculations.

Step 5. Enter the odor emission number for each of the listed facilities.

Locate the appropriate animal species and most representative types of facilities using Table 1 for animal housing facilities and Table 2 for manure handling facilities. Then, read off the odor emission number for each facility listed in Column A and record it in the appropriate line in Column D of the worksheet.

The odor emission number represents the relative amount of odor released by the source facility into the air per unit of floor or surface area. The abbreviation 'OU' stands for 'odor unit', which is a standardized way of presenting the concentration of odorous air as determined by trained human panelists. The values listed in Tables 1 and 2 are based upon currently available emissions research data and have been calibrated for use with the Odor Footprint Tool. The Odor Footprint Tool is not calibrated to use raw, unscaled emission rates or emission numbers scaled for use with another setback estimation tool (e.g. OFFSET), so do not use these values. Odor emission numbers are not presently available for some facilities commonly found in Nebraska and other central plains states – such as open cattle feedlots ("dry lots") and anaerobic treatment lagoons. A reasonable amount of information is needed on both the amount of odor emitted by the facility and how odor leaves the site. In both cases, this information is less challenging to obtain from animal housing/buildings than from open, expansive surfaces that are directly influenced by the elements. As more research is conducted and more data becomes available, more categories of facilities may be added and listed values may be updated. Until then, recognize the implications of assuming scaled odor emission values.

Step 6. Identify base plan and optional odor control technology to be implemented and/or considered.

List the most likely scenario for odor control as the base plan in Column E. If odor control technology – above and beyond what's in the base plan – is being considered for one or more of these facilities, then identify the technology in the corresponding line of Column G.

A list of proven odor control technologies is provided in Table 3. Limiting odor control to one or two technologies per scenario better illustrates the effect of individual selections and better represents most realistic applications.

Step 7. Enter appropriate odor control factors.

Use Table 3 to locate the control technologies or practices, if any, that are to be implemented/considered for the given project scenario. Then, read off the odor control factor that is identified for each technology and record it in the appropriate line of Column E or Column H, tying the control technology with a specific facility [group]. When no special odor control is to be implemented for a facility, – as would generally be the case in the Base Plan - enter an odor control factor of "1".

An odor control factor accounts for utilizing proven odor control technology. The odor control factor is a decimal value between 0 and 1 that represents the fraction of odor from a facility that is released using the selected odor control technology relative to that released without the technology being in place. The smaller the odor control factor, the more effective the odor control technology. The odor control technologies listed in Table 3 have been evaluated by independent university research and field study to determine their effectiveness in reducing odor emissions. Several unproven technologies are on the market. Caution should be used when applying an odor control factor for a technology that has not undergone independent testing. If an odor control technology is not listed in Table 3 and its effectiveness has not been independently confirmed with field testing, use a conservative estimate of the odor reduction or set the odor control factor to 1.

Step 8. Calculate the scaled odor emission rate for each of the listed facilities.

Calculate individual scaled odor emission rates (OER) for the Base Plan and Odor Control Option using the following formula:

$$OER = [Plan\ Area \times Odor\ Emission\ Number \times Odor\ Control\ Factor] \div 1{,}000{,}000$$

For each facility listed in Column A, multiply the plan area (Column C) by the odor emission number (Column D) and by the odor control factor (Column E). Then, divide the calculated emission rate for each facility by 1 million and write the resulting number in Column F on the appropriate line of the worksheet. If optional odor control is being considered, then multiply the values in Column F by the odor control factors listed in corresponding lines of Column H to determine odor emission rates with odor control, and record these values in Column I.

The relative significance of various odor sources on the site can be approximated by comparing the size of individual scaled odor emission rates. For example, if a manure storage facility has a scaled odor emission rate of 2×10^6 OU/s compared to 3×10^6 OU/s for the housing facility, then the housing facility can be projected to have about 50% greater influence than the manure storage facility on the minimum desired

setback distance and the resulting overall odor impact on neighbors. The relative sizes of the scaled odor emission rates are typically good indicators of where odor control would be most beneficial.

Step 9. Determine the total scaled odor emission rates.

Add up the odor emission rate values listed in Column E and enter the total in the box at the end of this column. This value is the projected total scaled odor emission rate from the facilities for the Base Plan. When optional odor control is being considered, also add up the values in Column I to determine the total scaled odor emission rate expected with the optional odor control. Record this value in the box at the end of Column I.

Step 10. Select an odor annoyance-free frequency.

Circle one of the five numbers ranging from 90 to 99% in the lower left-hand area of the worksheet. If an odor annoyance-free frequency is being recommended or has been adopted locally, then circle that value. Otherwise, select a conservatively realistic target for the surrounding community.

The odor annoyance-free frequency selected will have a dramatic effect on the resulting separation distances. Wanting to be free of annoying odors 99% of the time may be unrealistic for some areas due to limited options for finding enough land to meet large required setbacks and challenges of applying this high standard to existing operations wanting to expand. In many areas, on the other hand, having annoying odor levels nearly 10% of the time may be equally unrealistic if good neighbor relations are desired.

As a general guide, when local residents have a strong affiliation with animal agriculture and are accustomed to modern agricultural practices, using an odor annoyance-free frequency near 94% may suit the local needs. When most residents are unaffiliated with animal agriculture, or when avoiding odor conflicts is a top priority, an annoyance-free frequency closer to 98% may be more appropriate.

Step 11. Access directional setback distance graphs and identify primary directions.

Access the set of four graphs for the weather station location or Nebraska region that was identified in Step 2 and circle the primary directions associated with these graphs on the worksheet - four directions each for the Base Plan and the Odor Control Option.

To make reading the graphs more convenient, graphs are available in two ranges: from 0 to $5x10^6$ OU/s (representing typical existing sizes of operations) and from 0 to $40x10^6$ OU/s (representing larger operations).

Primary directions are indicated by the shaded quarter circles in the upper-left areas of the graphs (refer to Figure 1). When considering the influence of the region selected, remember that the primary directions may change with the region (north, east, south, and west vs. northeast, southeast, southwest and northwest).

Step 12. Determine separation distances.

Determine the minimum separation distance for each of the four primary directions using the selected set of graphs, along with the total scaled odor emission rates of the facilities and the odor annoyance-free frequency selected for the situation. To use the graphs, follow this procedure (refer to Figure 1):

1) Select one of the four graphs and locate the total scaled odor emission rate for the Base Plan (number in the box at the end of Column F on the worksheet) along the horizontal axis of the graph.

2) Follow a vertical path upward to the curve for the selected annoyance-free percentage. Mark the spot of intersection.

3) From the spot of intersection, move horizontally to the left to the vertical axis; mark the location, read off the setback distance, and record the distance on the worksheet in the column that corresponds with the direction indicated on the graph. Interpolating base separation distances to the nearest 0.05 miles (1/20th of a mile) is reasonable.

4) Repeat the procedure to this point for the remaining three directions, using the appropriate graphs, and record the resulting minimum separation distances in the appropriate boxes.

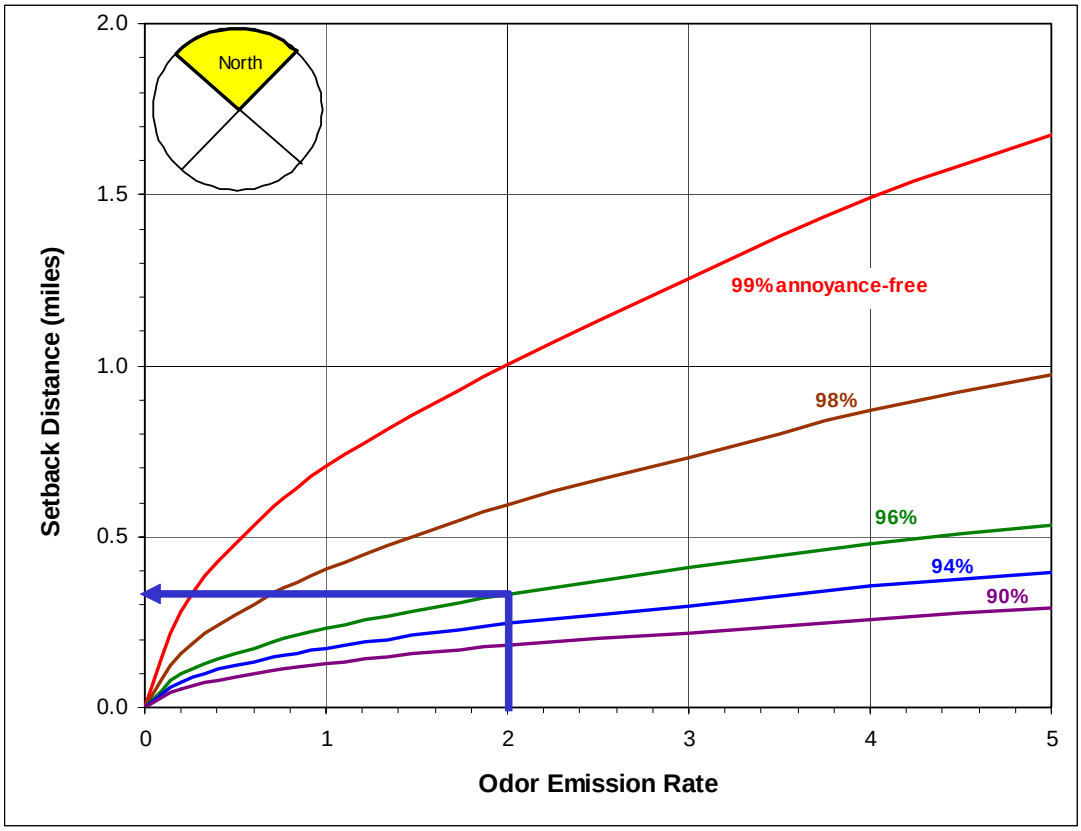

Figure 1. Example graph showing directional setback distance curves for the north direction.

5) Repeat the procedure to obtain separation distances for the Odor Control Option (using the total scaled odor emission rate in the box at the end of Column I), if applicable, and record these distances.

Step 13. Enter terrain factors.

Match up the terrain in each direction with the most appropriate description and illustration in Figure 2. Then, select a terrain factor from Table 4 for each of the corresponding descriptions and enter these values in the appropriate boxes (shaded row) near the bottom of the worksheet for both the Base Plan and the Odor Control Option (same set of four factors). The default terrain is "Flat terrain", so assign a terrain factor of 1 for all topography that does not match up with given descriptions.

Certain distinctive topography influences how odor travels, and will increase or decrease the frequency of neighbor exposure to odors in the direction of the given topography. Air is a fluid and tends to migrate downhill under stable atmospheric conditions. Conversely, when air is elevated, dispersion of contaminants can be enhanced. An adjustment may be made to account for terrain effects in given directions from the facility. Adjustments for terrain should definitely be applied when people reside in confined, low-lying areas relative to the animal production facilities and natural 'air drainage' toward these residences is likely to occur. Flat terrain should be used as the default terrain, since this is a conservative representation for rolling topography and other terrain that does not meet the illustrated descriptions.

Step 14. Calculate final, terrain-adjusted separation distances.

For each direction, multiply the base separation distance by the corresponding terrain factor to determine the separation distance adjusted for terrain. Do this for the Base Plan and the Odor Control Option, if any.

Adjusted separation distance = Base separation distance x Terrain factor.

Congratulations! You have determined risk-based minimum separation distances in four directions around the given livestock facilities. You also have numbers to help you evaluate the benefit of a specific odor control option.

What Next?

It may be appropriate to determine separation distances for alternative scenarios - using different facility specifications, odor control technologies, annoyance-free frequencies, and/or weather station locations – and evaluate the alternative scenarios based upon the setback distances needed. Refer to the publication *Evaluating Livestock Facility Plans Using the Odor Footprint Tool* for suggestions on scenarios to compare and example comparisons.

Often, it is beneficial to show directional setback distances on an aerial photograph or plat map to illustrate where local residences are relative to the risk-based odor impact area (dubbed 'odor footprint') defined by the given set of setback distances. Again, refer to the publication *Evaluating Livestock Facility Plans Using the Odor Footprint Tool* for suggestions on developing simplified odor footprints.

Table 1. Odor emission numbers for animal housing facilities.

Species	Type/Stage of Production	Type of Facility	Odor Emission Number
Cattle	Beef	Dirt/concrete lot (area is seldom dry)	20
		Dirt lot (area is regularly dry)	TBD
	Dairy	Scraped freestall barn Slatted-floor barn over deep pit Loose housing, scraped	30
		Tiestall barn	10
Swine	Gestation	Deep-pit building	245
		Shallow-pit building, (e.g. pull plug system)	145
	Farrowing	Shallow-pit building, (e.g. pull plug system)	70
	Nursery	Deep or shallow pit	205
	Finishing	Deep-pit building	165
		Shallow-pit building, (e.g. pull plug system)	95
		Hoop barn, deep-bedded & scraped Cargill / open front, scrape	20
		Loose housing, scrape Open concrete lot, scrape	55
Poultry	Broiler	Floor-raised on litter	10
	Turkey	Litter	10

Table 2. Odor emission numbers for manure handling facilities.

Type of Facility			Odor Emission Number
Manure storage facility	Earthen basin		65
	Steel or concrete tank, above or below ground		135
	Crusted stockpile		10
Treatment facility	Anaerobic lagoon	Low solids loading rate ()	TBD
		High solids loading rate ()	TBD

Table 3. Odor control factors.

Odor Control Technology		% Odor Reduction	Odor Control Factor
No supplemental odor control implemented on the facility		None	1.0
Biofilter used to treat air from exhaust fans	Fully mechanically ventilated facility; biofilter treats 100% of exhaust air	90	0.1
	Mild-weather airflow is provided by fans; biofilter treats all airflow from these fans	60	0.4
	Biofilter treats only airflow from minimum ventilation fans	30	0.7
Oil sprinkling used to control dust within building		20	0.8
Impermeable cover		90	0.1
Geotextile cover (at least 2.4 mm thick)		50	0.5
Straw or natural crust on manure	8” thick	70	0.3
	6” thick	60	0.4
	4” thick	50	0.5
	2” thick	40	0.6

Table 4. Terrain adjustment factors.

Type of area	Description of topography between source and receptors	Terrain factor
Flat terrain	Default scenario. Minimal change in topography exits. Use whenever the situation does not fit into another listed category or the local topography is not known.	1.0
Unconfined, low-lying area	Receptors are located down-slope of the source (below 2% grade line from site) without topography that would confine odors in the area.	1.2
Confined air drainage zone	Receptors are situated down-slope - below the 2% falling grade line from the source – within a valley having confining sidewalls that will restrict the dispersion of odors.	1.2 - 2.0*
Rolling terrain	Undulating country between source and receptor	0.9
High relief or intervening terrain	Receptor is at a higher elevation than the source (greater than 10% upslope from site) or significant hills and valleys are present between the site and receptor)	0.7

* Value depends on the degree of confinement presented: the steepness of the valley and confining walls, the width of the valley, and the continuity of the confining features should be considered in selecting an appropriate value.

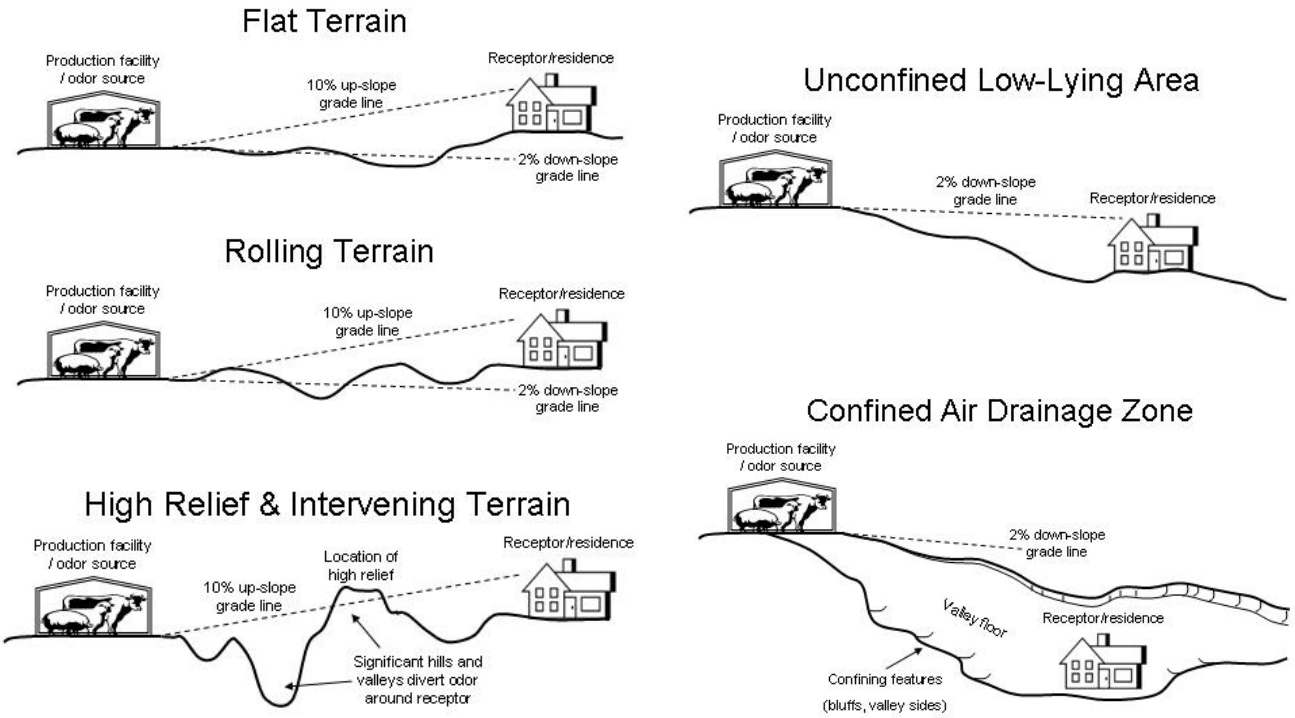

Figure 2. Illustrations of terrain characteristics for selecting terrain adjustment factors.

ESTIMATING SETBACK DISTANCES USING THE ODOR FOOTPRINT TOOL

Worksheet for Calculating Separation Distances for a Particular Animal Production Site

Project description: _____ Location: _____

_____ Region: _____

GENERAL INFORMATION FOR BASE PLAN						INFORMATION FOR ODOR CONTROL OPTION		
Column A	**Column B**	**Column C**	**Column D**	**Column E**	**Column F**	**Column G**	**Column H**	**Column I**
Source Facility *Describe*	Plan Dimensions (e.g. ft x ft) *Show*	Plan Area (sq. ft.) *Calculate*	Odor Emission Number ($OU/s \cdot ft^2$) *Tables 1 & 2*	Odor Control Factor *Table 3*	Scaled Odor Emission Rate ($\times 10^6$ OU/s) *C x D x E ÷ 1,000,000*	Odor Control Practice Being Considered *Describe*	Odor Control Factor *Table 3*	Scaled Odor Emission Rate ($\times 10^6$ OU/s) *F x H*
1)								
2)								
3)								
4)								
5)								
				Total scaled odor emission rate = *Sum of values in Column F*			Total scaled odor emission rate = *Sum of values in Column I*	

Annoyance-Free Percentage *Circle value chosen by you or by community* 90 94 96 98 99 %	Directional Setback Distances (miles or fraction thereof) *Locate using set of setback curves for region* North / NE	East / SE	South / SW	West / NW	Directional Setback Distances (miles or fraction thereof) *Locate using set of setback curves for region* N / NE	E / SE	S / SW	W / NW
Base separation distance *Read off of regional curves*								
Applicable terrain factor *From Table 4*								
Adjusted separation distance *Base distance x Terrain factor*								

Prepared by: _____ Date prepared: _____