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DI/FT/SG/RTB/mc
Ref: 109161 LetRep 20110725
27 July 2011

Lorelle Fitzpatrick
AconsulT
Email: lorelle@aconsultoz.com

Dear Lorelle,

Re: Response to the Matters Raised by Joint Regional Planning Panel Regarding Noise, Dust and Odour Reports

This letter report summarises our response to the matters raised by the Joint Regional Planning Panel (JRPP) in regards to the Noise, Dust & Odour Reports prepared by Benbow Environmental. Details are as follows:

DUST & ODOUR ISSUES

Peer review matters raised by Council's engaged Peer Reviewer, Air Noise and Environment, have been itemised as follows. Comments from Benbow Environmental follow after each item.

<u>*Matter No. 1*</u>

"The report identifies that the Prime building downwash algorithm has been utilised. Review of the modelling input file presented in Attachment 3 of the Odour and Dust Assessment report confirms that the Prime building downwash algorithm was not used. The ISC method was utilised, which can significantly underestimate plume downwash effects relative to the Prime algorithm. The use of the ISC method may have resulted in the predicted results being significantly lower than would be expected using the Prime algorithm."

<u>Benbow Environmental's Response for Matter No. 1:</u>

The Office of Environment (OEH) guidelines "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" is the guiding document for air dispersion modelling in air impact assessments, which includes guidance for dispersion modelling methodology to be utilised for poultry farms. Section 6.5 (page 24) of the OEH guideline state that ISC Rural Wind Profile is an acceptable option to use in the modelling. This suggests that the minimum requirements for air dispersion modelling under the OEH odour modelling guidelines have been met.

We understand that techniques for odour dispersion modelling have evolved in the past few months/years, given the need to increase the accuracy of the modelling outputs. And so we understand the need to compare between different options to use in CALPUFF. Further modelling works would have to be carried out in order to determine whether the ISC method utilised in the report has definitely underestimated the predicted results, by comparing side-by-side the ISC method results with the Prime algorithm method results. However, we anticipate that the results may potentially be similar between the two methods.

Matter No. 2

"In terms of terrain and receptor grid inputs, the overall methodology adopted for the preparation of the data inputs is consistent with standard approaches. The terrain resolution of 300m is considered insufficient to adequately describe the potential for terrain influences such as katabatic flows. Terrain data at a resolution of 100m or less is readily available, and would be considered best practice and more suited to capturing potential low wind speed phenomenon. There is a potential for under-prediction of odour impacts under near calm conditions."

Benbow Environmental's Response for Matter No. 2:

The Office of Environment (OEH) guidelines "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" is the guiding document for air dispersion modelling in air impact assessments, which includes guidance for dispersion modelling methodology to be utilised for poultry farms. The guidelines do not recommend 100m as the appropriate terrain elevation to use in CALPUFF. In fact, no guidance in terrain resolution has been provided in these guidelines. By default, the terrain resolution similar to what has been retrieved from TAPM (The Air Pollution Model) was utilised in CALPUFF, which is considered minimum requirements for air dispersion modelling.

Recent discussions have been made with another Air Quality expert (who is heavily involved with the developers of CALPUFF) regarding the use of terrain resolution in CALMET below than 300m and unfortunately, in some cases, using terrain resolution of such nature can sometimes produce unrealistic windfield results in CALMET especially with complex terrain (based from the experience of the Air Quality expert that have been approached). CALPUFF is a meso-scale air dispersion modelling program and, in theory, using meso-scale modelling programs for terrain resolutions below 300m can produce unrealistic results. Unrealistic events can include the production of high-wind speed values at high terrain elevation points in the modelling domain, and production of inaccurate wind directions.

In addition to the above, CALPUFF is very sensitive to the land-use values that are used as inputs into the modelling program. Unfortunately, land use values at a resolution less than 300m is not readily available and is often difficult or tedious to obtain.

Benbow Environmental wanted to avoid this issue, as these issues can only produce misleading results and using the suggestions from the OEH guidelines and default settings in CALPUFF would be the safest option to use in sensitive assessments. CALPUFF has its limitations along with TAPM, and Benbow Environmental acknowledges this. We also acknowledge grid nesting in CALPUFF can be used as an option, though this would only increase the resolution of the results but not the terrain resolution to be utilised in the modelling.

In addition, environmental consultants in the U.S. would commonly use CALPUFF with terrain resolutions of 300m and 500m, as they also acknowledge the limitations of using such a meso-scale dispersion modelling program.

Matter No. 3:

"The meteorological data that is provided in the report has been developed using standard methodologies. However, caution must be used with the use of TAPM as it is well documented that TAPM over predicts wind speeds and under-predicts low wind speeds and calm conditions. This has the potential to underestimate receptor impacts under low wind speed and near calm conditions. These are the conditions under which odour impacts are most likely to occur, hence an under-estimation of odour impacts can arise when TAPM meteorological data has been relied upon in a modelling exercise. Quantification of the degree of under-estimation resulting from this TAPM error is problematic, as alternative meteorological prediction methodologies are commonly not available. Therefore, while the use of TAPM for this study is supported, some caution must be adopted in interpreting the results of the CALPUFF modelling."

Benbow Environmental's Comments to Matter No. 3:

Care was taken to ensure that the TAPM data utilised in CALPUFF modelling was appropriate and accurate in predicting impacts. As per our response for Matter No. 2, we acknowledge the limitations of using the two air dispersion modelling programs.

Matter No. 4

"The use of a time varying emission file which has daily varying emission rates, against a full year of meteorological data has the potentially to significantly underestimate the worst-case receptor concentrations. This is because, unless by chance the peak emission rate coincides with poor dispersion meteorological conditions, the modelling will not account for the potential for peak emissions to occur under unfavourable meteorology. The modelling needs to be adjusted by shifting the start date of each batch of birds considered in the model emissions file, to allow iterative modelling for the batch start to occur on each week of the year (or preferably each day) to allow the potential for coincident worst-case meteorology and emissions to arise. Previous analysis has shown that this can increase the predicted receptor impacts by 10-30%."

Benbow Environmental's Response to Matter No. 4:

The use of time varying emissions file is the most effective way to realistically model the odour emissions from the proposed development. Time varying emissions file allows us to provide hourly odour emission rates from each of the poultry shed for each hour for each day of an entire year. This allows hourly emission rates to be modified based on meteorological conditions for each of these hours, as well as other factors that relate to the operation of the poultry sheds. Significant amount of time and effort was put into this aspect to ensure that odour impacts predicted for the proposed farm are realistic, and seems to be not acknowledged in the peer review.

From our experience, the effects of shifting batch times for naturally ventilated poultry farms to consider any other worst-case impacts would not be as critical as what would be obtained as outcomes from conducting modelling for tunnel ventilated sheds. Naturally ventilated poultry shed emissions are more dispersed (as odour emissions are conceptually distributed along the length and width of the sheds) compared to tunnel ventilated sheds. In addition worst-case impacts (which are still conditions with stability classes F, as indicated and highlighted by comments made by the Peer Reviewer for the Noise Report) tend to occur (if not, almost always) at night time, and night time hours have been included in the modelling to account for these potential worst case odour impacts. Hence, we believe from our experience that further remodelling works involving sensitivity analysis to determine scenarios according to various batch time starts would not be required and that the outcomes of the assessment prepared by Benbow Environmental would be sufficient in estimating odour impacts from the subject site.

Matter No. 5

"The odour emission rates utilised in the atmospheric dispersion modelling were determined from the average of two measurements completed by Benbow Environmental in a naturally ventilated poultry farm shed. The adopted emission rates are significantly lower that the emission rates identified in previous industry research for similar size naturally ventilated sheds. The Jiang et al research, based on 34 measurements at NSW naturally ventilated poultry farms, confirms that an emission rate of 311 – 322 ou/s/1,000 birds was measured on average per shed. The Benbow Environmental report confirms a maximum emission rate of 190-199 ou/s/1,000 birds has been adopted. As a result, the overall predicted results are expected to significantly under-estimate receptor concentrations (by approximately 50%)."

Benbow Environmental's Response to Matter No. 5:

Benbow Environmental would like to investigate the source of the information which reports an average of 311-322 ou/s/1,000 birds and whether or not it is applicable to the site. There are numerous factors that affect the determination of the most appropriate odour emission rates to use for a poultry farm. This does not only include the size, but also other factors such as the design of the sheds, the bird feed (which directly correlates with how odorous the litter would be from the birds), maintenance and farm management practices of the sheds, the type of birds, and the ventilation design. The quoted figures (311-322 ou/s/1,000 birds) has been indicated to be an average, which further supports the fact that odour emissions for each shed or each poultry farm varies according to the variable parameters stated above. The peer reviewer should also acknowledge that the odour emission rates in general, as we have discussed this in the recent odour workshop conducted in May 2011, that farm management practices and other practical variables affect the emission rate figures for each shed.

A report entitled "Odour and Ammonia Emissions from Broiler Farms" published by Jiang and Sands (2000) ascertained that the maximum odour emission rate applicable across all poultry farm shed designs including natural, tunnel and cross ventilation sheds is to be in the range of 311-579 OU/s/1000 birds. The same authors also quoted an average odour emission rate of 195 OU/s/1000 birds. Further evidence of the valid use of this average odour emission rate was provided in the report "Marsden Park Industrial Precinct, Level 3 Odour Assessment (July 2009)" authored by SLR Consulting. This report has been provided in the Attachments. This correlates well with Benbow Environmental's 190-199 OU/s/1,000 birds figure.

The measured odour concentration of 190-199 OU/s/1,000 birds is based on a well-managed poultry farm, and hence was applied to the subject poultry farm given that it will have an equivalent level of (if not, a better) environmental management system put in place. This is based on the experience from the Principal Consultant, which has been heavily involved in conducting assessments and research in the poultry industry for more than 10 years. Measurements that have been conducted by other authors that report higher average odour concentrations for naturally ventilated sheds may be due to poor management practices, with focus on determining worst-case impacts under these poor practice conditions.

Matter No. 6

"The time varying profile generated for the emission data is not considered to be entirely consistent with the more recent research. Aspects that are not accounted for include changes in odour emissions for bird thinning, however these issues are not considered to be of sufficient significance to warrant remodelling."

Benbow Environmental's Response for Matter No. 6:

The time varying profile established in the odour report, given the comments above, is then considered to be more conservative given that it has not taken into account the effects of bird thinning. Hence, the results from the modelling are actually more conservative than how it is being perceived to be, based on outcomes from the peer review.

Matter No. 7

"With respect to the peak odour emissions, it is noted that the new sheds are to contain four rows of foggers for use during the warmer months to assist in temperature control. The use of foggers has the potential to significantly increase odour emissions, as wet litter has the potential to generate significantly high odour emissions than dry, friable litter. This risk has not been commented on or addressed in the modelling or the analysis of mitigation measures."

Benbow Environmental's Response to Matter No. 7:

Fog released from water foggers would be anticipated to evaporate extremely quickly in hot weather conditions and so the litter within the sheds will not be wet, which what one can easily perceive. Foggers have been built and designed so that water particles are provided with a maximum surface area, allowing it to be in contact with heat readily that it will evaporate upon contact with heat. Absorption of heat by water particles would then slightly reduce the risk of birds from dying due to heat strokes and will not impact on the litter. In addition, water foggers will not be used except for days with hot weather, and hence there would be no risk in using these foggers at times during non-hot weather days. Water is a resource and shall not be spent more than what is required as it not only provides potential odour impact risks but can also provide potential water, soil contamination, and irrigation issues (if any). In summary, water foggers are only used as precautionary measures, which indicate that its frequency of use (and the nature of the water particles emitted) would provide less risk in terms of potential odour impacts.

Water foggers in sheds will be controlled and managed by standardised farm practices (which will be the case for the subject site), and most often these practices are driven by Environmental Management Plans (EMP) and Environmental Management Systems (EMS). It was envisaged that the site will establish EMP and EMS upon commissioning. There is practical reason as to why EMP and EMS are heavily encouraged for poultry farms in general. This is to ensure that potentially high risk events, scenarios and factors that affect the environmental impacts from the subject farm (which includes dust, odour and noise) will be appropriately and be consistently controlled, mitigated and monitored. Benbow Environmental have always in the past (and will continue to do so in the future) recommend that poultry farm operators to prepare and establish EMPs and EMS' as part of the development. We believe (and it is right and just) that poultry farmers have the responsibility to ensure that they do not harm nor disturb any of the adjacent / neighbouring premises, given that they have been granted the permission and opportunity to operate.

Matter No. 8

"The emission temperatures adopted in the emissions file include temperatures of up to 308K (equivalent to 35ºC). This is 4 degrees higher than the maximum target temperature of 31ºC nominated in the Benbow Environmental report. The adoption of higher than actual temperatures results in enhanced dispersion by buoyancy, resulting from the temperature differential between the emissions and the surrounding air. Over estimation of buoyancy will result in improved dispersion, particularly under cool external conditions, with a consequent underestimation of maximum predicted receptor concentrations likely to result from this over-estimation."

Benbow Environmental's Response to Matter No. 8:

Temperature of emissions from poultry sheds would directly correlate with the external temperature, depending on the meteorological conditions on the hour of the specific day. The variable emissions file utilised in the dispersion modelling was constructed so that it took into account the surface temperature of the site location using the meteorological data provided by TAPM. As discussed in our response for Matter No. 3 (and briefly in the Matter No. 2 response) that care was taken so that TAPM was utilised appropriately in the modelling, as well as in the construction of inputs into CALPUFF such as the variable emissions file.

TAPM was able to predict the maximum temperatures at the subject farm location, and these hourly temperature values were used in the modelling as these would the temperature of the odour emissions from the farm when it is released into the environment. A temperature of 31ºC on any air sample that is introduced into a volume of air that has an average concentration of 35ºC will have a resultant temperature of close to 35ºC, using chemical engineering calculations. It is impossible for 31ºC emissions to remain at this temperature when it is exposed to the sun, which would provide an external temperature of 35ºC during that specific hour.

Matter No. 9

"To achieve a guaranteed 40% reduction at all times from the proposed mitigation technique is considered optimistic on the basis of the currently available techniques. Recent research that considered available odour and dust control technologies for chicken sheds has identified that provision of dust control structures such as windbreak walls provides some improvement in dispersion and dust deposition, but the overall benefit cannot be quantified. Whilst some modelling studies have indicated that reductions of 35-56% may be achieved for particulates, only a proportion of poultry shed odour (some studies estimate up to 65%) will be carried on the particulates hence odour reduction would be significantly lower than the upper estimate of 56% particulate removal. Benbow Environmental confirms that previous studies they have completed resulted in 'approximately 40%' of odour impacts being removed by a combination of earth berms and vegetation belts. Details of these studies, particularly the circumstances under which the reported reductions were achieved, do not appear to have been published.

Furthermore, in the context of the issues raised in this peer review regarding the odour modelling, it is expected that significantly higher receptor odour concentrations will be predicted when the model inputs and variables are adjusted. Significantly greater mitigation requirements would be expected as a result of these adjustments, that would be beyond the 40% mitigation suggested by Benbow Environmental as achievable using this method."

Benbow Environmental's Response to Matter No. 9:

Research works conducted by a number universities in the U.S. have been included in the Attachments to provide evidence that vegetative odour control (synonyms to 'shelterbelts', 'vegetative environmental buffers', 'vegetative earth berms') are effective in mitigating odour. Based on our experience (especially from our Principal Consultant), the efficiency of odour control is site specific and the quoted approximate figure of 40% reduction would be permanent given that vegetative earth berms (which is our proposed odour control) would be a permanent structure on site.

There has been no acknowledgement of the science behind using trees (literature material has been provided in the Attachments to provide an introduction to this) from the peer review in terms of how useful these can be for odour control. It is common knowledge that poultry litter can be used as litter – this provides a layman's explanation of why vegetation in general can also be used mitigate odour emissions. Odour emissions are often caused by components within the litter that is naturally odorous by nature. One of these components is ammonia. Ammonia is also known to be naturally consumed by plants and by soil, specifically by nitrifying bacteria through a process called nitrification. There may be other components within the litter, but through other biological processes (there are various complex biological reactions that can occur with other compounds from the litter), these odorous substances are consumed by vegetation or would react with microbes or bacteria that reside in soil.

Using vegetative earth berms as an odour control takes advantage of this science (and must require extensive engineering works and planning strategies to ensure its success), converting odorous substances from litter into energy and food resources to be consumed by plants and trees. Furthermore, by having a physical structure such as dense shrubs and trees in place, it will further screen out particulates and would be forced to deposit (similar to the concept of windbreaks).

In one of the studies conducted by the University of Delaware has examined the effectiveness of vegetation in odour control (Malone et al, 2006). The study was conducted for a duration of 33 days over a 4 year period. Results from their studies show 49% reduction in dust emissions and 46% for ammonia concentrations (wherein ammonia was used as the surrogate for odour, given that olfactometry equipment to measure odour can be too difficult to use on the field).

With consideration to the results above, Benbow Environmental believes (based on the experience from our Principal Consultant) that, although achievable, these figures can vary depending on the extent of management practices established by the farm. Our findings from conducting our own odour survey for a farm in North Casino provided odour reduction efficiency results of approximately 40% using a field olfactometer device. Our Principal Consultant obtained these figures as a result of implementing an engineered vegetative earth berm at the North Casino farm.

Giving consideration to the above, this odour control method is not only potentially cost-effective, but it is also sustainable and helps reduce greenhouse gas emissions in general. No other odour control methods or strategies can compare to this when it comes to the overall benefits in sustainability.

Benbow Environmental believes that further mitigation requirements relying on power and energy such as electrostatic precipitators, air dispersion enhancers such as the use of fan-driven stacks, and other mechanical solutions are not considered to be attractive solutions when considering our future. Resources need to be conserved and the use of the recommended odour control allows us to achieve this.

Matter No. 10

"Overall, the location of the poultry sheds in very close proximity to existing receptors is considered to pose a very significant constraint on the proposed expansion. The ability to mitigate particulate and odour emissions from free-range naturally ventilated poultry sheds is largely restricted to measures of the types proposed by Benbow Environmental. This significantly limits the overall reductions likely to be achieved, as point of release emission controls are impractical."

Benbow Environmental's Response to Matter 10:

The controls recommended by Benbow Environmental are not considered 'impractical', given the supporting evidence and encouraging publications provided by a number of research scientists in U.S. universities such as the Iowa State University, the University of Delaware and the Natural Resources Conservation Service (NRCS) in Missouri. The science behind the use of vegetation, as discussed in our response for Matter No. 9, can be utilised as an advantage to reduce and mitigate odour emissions from a poultry farm.

Our Principal Consultant has indicated that Penrith City Council has previously engaged an environmental consulting firm to demonstrate that one of the poultry farms situated in Penrith did not provide odour impacts to the nearest resident which was almost adjacent to the poultry farm land. This alone demonstrates the possibility that poultry farms, if managed well and with appropriate engineered odour controls, can control odour emissions from the subject farm such that it will not cause any harm or nuisance to the nearest potentially affected receptors.

NOISE ISSUES

<u>Matter Number 1</u>

"The acoustic assessment has excluded consideration of stable meteorological conditions associated with temperature inversions. However, the meteorological analysis presented in the air quality report indicates 23.4% occurrence of F class stability for all hours. As the vast majority of stable conditions occur at night, this indicates that the frequency of occurrence of stable conditions is likely to be well in excess of 30% for the night time. In accordance with the NSW Industrial Noise Policy, this would require consideration of the influence of temperature inversion conditions on propagation of noise from the poultry farm. This is expected to result in a 1–3dB increase in predicted noise levels for the nearest receptors and the modelling and mitigation needs to be amended accordingly."

<u>Benbow Environmental's Response to Matter Number 1</u>

Chapter 4.1 (Meteorological Conditions) of the report 109160_Fnal_Rep_2 prepared by Benbow Environmental indicates:

"The meteorological conditions were analysed in accordance with the NSW EPA Industrial Noise Policy (NSW INP) and there is not a 30% occurrence of light winds or temperature inversions at night time during winter or other colder months of the year."

In accordance with the OEH's Industrial Noise Policy (INP) Chapter 5, inversion effects are considered to be significant and should be taken into account in the noise assessment if temperature inversions are predicted for al least 30% of the total night time in winter. This occurrence of 30% should be calculated from 6pm to 7am for the months of June, July and August. Therefore, weather data was obtained from Mangrove Mountain Weather Observation Station St. 61375 for years from 2004 to 2009. The following table shows the data for this period of time:

Table 1: Occurrence of Temperature Inversion for Total Night-time During Winter

Year	Percentage (%)
2004	9.8
2005	27.3
2006	23.3
2007	35.6
2008	33.4
Average	25.9

Although for years 2007 and 2008 the temperature inversion exceed the 30% of occurrence for the total-time during winter, the average for the studied period of time does not. For this reason, temperature inversions were not taken into account for the calculations.

The Industrial Noise Policy also indicates in Step 1 (pg 33):

"Detailed analyses of meteorological data are not required where there is little or no potential for impacts, as in the following cases:

1. *where the development in question does not operate during the night-time hours. As temperature inversions are usually prominent during night-time hours, there is no need to consider their effects for a development that does not operate at night (10 pm to 7 am),*
2. *where, by using the default values, (see Appendix C Table C1 for screening test default values), it can be shown that there would be no significant additional noise impacts during inversion conditions (for example, less than a 3-dB increase). In this situation, no further analysis of inversion effects is required. Situations where this could occur include: areas that experience only a slight increase in noise due to inversions or* ***areas where the most-affected premises may be located close to the development, thus negating the effects of inversions (which focus noise at relatively large distances).****"*

The bold statement above confirm that temperature inversions may be excluded in the noise assessment due to the most affected receivers are considered to be located within close proximity of the development and no significant increase in noise levels would be expected at these receivers.

Matter Number 2

"In terms of the proposed management measures, provision of an earth berm to manage noise emissions is considered to be an appropriate methodology. The management measures discussed for truck movements, particularly at night, are considered less practical. This is because there is a degree of reliance on management of behaviour (eg, travelling at no more than 40kph on a public road) and timetabling to minimising the number of vehicles on site at any one time. During night time bird pick ups, preventing more than one vehicle or forklift/loader operating at any given time may be impractical in reality."

Benbow Environmental's Response to Matter Number 2

Benbow Environmental conducted only an on-site noise impact assessment; therefore, a road traffic noise impact was not undertaken due to the minimal increase in road transport truck movements under the proposed site operations. For this reason, the recommendation of tucks not travelling at more than 40km/h does not affect at all the on-site noise levels and was simply suggested as a safeguard for a potential off-site noise impact.

Several assumptions were considered in order to asses the noise impact of the proposed development, which includes but is not limited to the following:

- Three trucks entering and leaving the site in a space of a 15 minute period. This represents 12 truck movements per hour, which is considered the worst scenario;
- 2 forklifts operating during 100 % of the time. The location of the first forklift is in-between the two existing sheds and the two proposed sheds, while the second forklift has been modelled in-between the four proposed sheds;
- Truck air brakes distributed along the site; and
- Truck speed on site of 10km/h.

Considering all the assumptions listed above, the modelled noise levels from the operations of the proposed development comply with project specific noise limits if the recommend noise controls are adopted. However, several safeguards such as farm management relating to timetabling, use of one forklift, among others was indicated by BE as a risk factor and are not strictly necessary to achieve compliance.

Benbow Environmental considers that the extension of the Poultry Farm located at 80 Bloodtree Road, Mangrove Mountain will not create any noise impacts above the project specific noise limits in the most affected premises if the noise mitigation measures recommended in the report 109160_Fnal_Rep_2 are applied.

We trust this clarifies matter.

Yours faithfully,
for Benbow Environmental

Duke Ismael
Environmental Engineer (Air Group)

Felipe T.

Felipe Torres
Acoustic Engineer

Samuel Grieve
Senior Acoustic Engineer

R T Benbow
Principal Consultant

ATTACHMENTS

ATTACHMENT 1: HEGGIES PTY LTD – MARSDEN PARK INDUSTRIAL PRECINCT
LEVEL 3 ODOUR ASSESSMENT

REPORT 10-7391-R2

Revision 1

Marsden Park Industrial Precinct
Level 3 Odour Assessment

14 JULY 2009

HEGGIES PTY LTD
ABN 29 001 584 612

Marsden Park Industrial Precinct

Level 3 Odour Assessment

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DOCUMENT CONTROL

Reference	Status	Date	Prepared	Checked	Authorised
10-7391-R2	Revision 1	14 July 2009	Martin Doyle	Ronan Kellaghan	Martin Doyle
10-7391-R2	Revision 0	5 February 2009	Martin Doyle	Ronan Kellaghan	Martin Doyle

EXECUTIVE SUMMARY

The Department of Planning has appointed a consultant to project manage the rezoning process and preparation of Environmental and Urban Landform assessments for the proposed Marsden Park Industrial Precinct (MPIP). The area of the proposed development is situated on Richmond Road, Marsden Park, within the North West Growth Area and will comprise primarily of employment land.

Heggies Pty Ltd has been commissioned to identify and assess the potential for odour impacts from the surrounding area in accordance with NSW Department of Climate Change (DECC) odour policy. Five operational poultry farms, located within a radius of 4 km from the proposed development, represent the most likely source of odour impacts to the industrial precinct.

The study has been divided into two separate stages, Stage One and Stage Two, with the necessity for progression to Stage Two to be largely dictated by the outcomes of Stage One. This report constitutes Stage Two of the study. The findings of Stage One indicated that odour criteria would be exceeded between 1.4 km and 3.4 km from the poultry farms to the immediate north of the MPIP, on South Street. This buffer zone extends across a large portion of the MPIP.

Stage Two of the study therefore requires the completion of a Level 3 odour impact assessment of the poultry farms, as defined by DECC document's *"Technical Framework: Assessment and Management of Odour from Stationary Sources in NSW"* and "*Technical Notes: Assessment and Management of Odour from Stationary Sources in NSW"*. A Level 3 odour impact assessment is a more detailed examination of odour impacts surrounding odour sources. Odour concentrations are predicted around the emission sources using a dispersion model and a full year of hourly meteorological data. Specific odour criteria can be identified and areas of potential impact assessed.

The results for Stage Two of the study indicate that odour levels of 2 OU to 3 OU are predicted to occur over the western and northern parts of the Project Site, based on *average* OERs for poultry operations. Given applicable odour impact assessment criteria, it is concluded that odour impact potentials are likely to be in an acceptable range in approximately 50% of the MPIP area, specifically within the south eastern corner.

Staging of the master plan should consider short and long term odour issues, taking into account zoning for areas surrounding the MPIP.

In the short term, the northern and western parts of the MPIP are less suitable for sensitive land uses such as residential development, as development may coincide with existing odour sources. These potential odour issues are identified and will be presented within the Development Control Plan. It is expected that where potential odour impacts may impact on specific development outcomes, additional odour assessment may be triggered as part of the DA process.

Consideration should be given to amelioration and mitigation strategies which focus on both reducing odour emissions from the poultry farms and reducing the impacts of these emissions upon any proposed future population.

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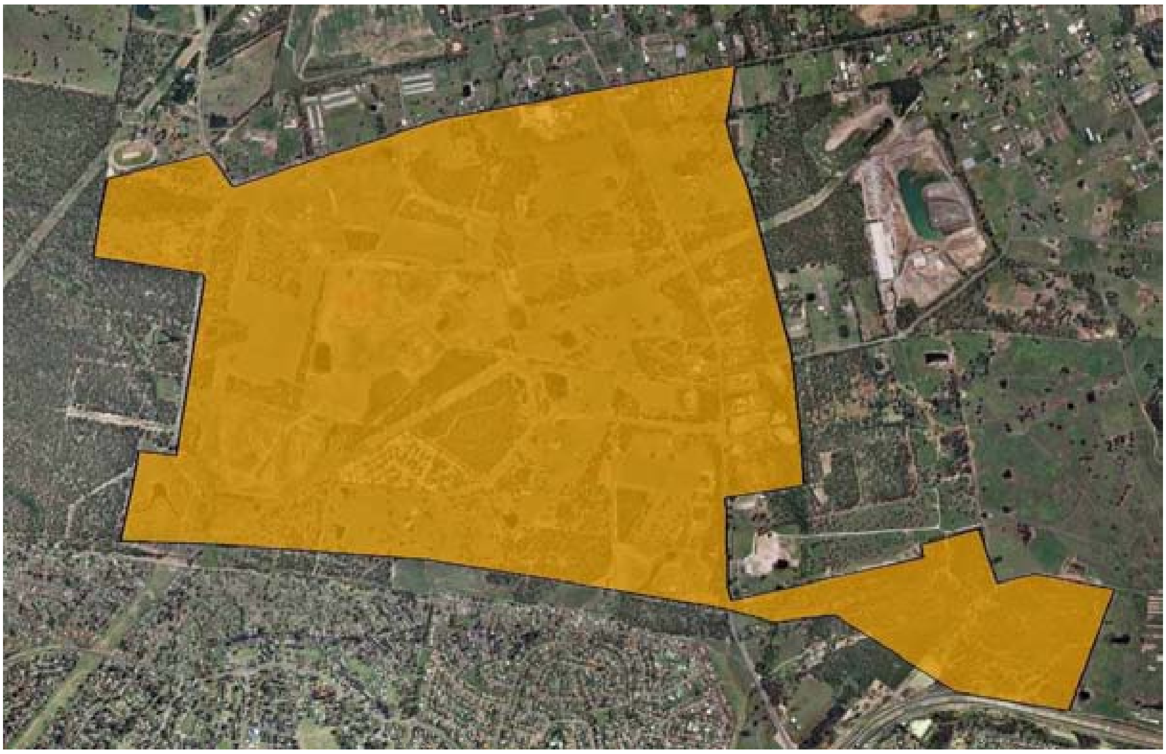
1 INTRODUCTION

The Department of Planning (DoP) seeks to carry out property development within an area of approximately 550 hectares (ha), in the southwest corner of the defined North West Growth Centre of Sydney. The development area, known as the Marsden Park Industrial Precinct (MPIP) will comprise primarily of employment land. The boundaries of the MPIP are shown in **Figure 1**.

Figure 1 Marsden Park Industrial Precinct (MPIP) Boundaries



DoP has appointed a principal consultant to project manage the rezoning process and prepare Environmental and Urban Landform assessments. Heggies Pty Ltd (Heggies) has been commissioned by the principal consultant on behalf of DoP to quantify and assess potential for odour impact across the MPIP, in accordance with NSW Department of Environment and Climate Change (DECC) odour policy.

1.1 Study Area

The MPIP is located on Richmond Road, near the Westlink M7, approximately 36 km northwest of Sydney CBD. Around 238 ha of the study area is currently controlled by DoP. Surrounding land use is primarily rural and comprises rural residential holdings and agricultural activities, specifically poultry operations, to the north and west of the site.

1.2 Study Objectives

The objectives of the study are to:

- investigate and identify any sources of odour on or in the vicinity of the subject land;
- investigate the implications of any existing odours for the staging of the development of the proposed industrial development; and

- recommend management strategies to maximise development opportunities both under the existing odour situation, and into the future.

1.3 Study Scope

The odour assessment has been divided into two stages with the necessity for the second stage being largely dictated by the outcomes of the first. The stages are identified as Stage One and Stage Two respectively. This report constitutes the Stage Two portion of the works.

1.3.1 Stage One

As part of Stage One, Heggies carried out the following tasks:

- Site visit and investigation of the area surrounding the proposed industrial development to identify potential odour sources.
- Completion of a Level 1 odour impact assessment as described in the DECC Policy: "*Assessment and Management of Odour from Stationary Sources in NSW"* (hereafter, "The Odour Policy") (DECC, 2006) and *Technical Notes: "Assessment and Management of Odour from Stationary Sources in NSW"* (hereafter, "The Odour Technical Notes") (DECC, 2006).
- Identification of the separation distance which would nominally be required between the poultry farms and the MPIP.

The results for Stage One of the study have indicated that a minimum separation distance of between 1.4 km and 3.4 km would be required between the existing poultry farms and the MPIP to ensure odour impacts are not experienced. The shortest distance from the poultry farms to the northern boundary is less than 400 m which falls well within the screening buffer established within the Level 1 odour impact assessment.

1.3.2 Stage Two

The results of Stage One indicate that odour emissions from activities at the poultry farms may adversely impact on the MPIP and therefore, further more detailed assessment is required.

As part of the Stage Two assessment, the following tasks have been undertaken:

- Quantification of the odour emissions from all sources in the vicinity of the MPIP using published odour emissions data.
- Undertake a Level 3 Odour Impact Assessment in accordance with the Odour Policy and the Odour Technical Notes – i.e. atmospheric dispersion modelling to determine the resultant impact of the odour emissions.

The current report represents Stage Two of the assessment process, and provides a more detailed assessment of the potential odour impact of poultry farm operations on the MPIP.

2 ODOUR ASSESSMENT CRITERIA

Impacts from odorous air contaminants are often nuisance-related rather than health-related. Odour performance goals guide decisions on odour management, but are generally not intended to achieve “no odour”.

The detectability of an odour is a sensory property that refers to the theoretical minimum concentration that produces an olfactory response or sensation. This point is called the *odour threshold* and defines one odour unit (OU). An odour goal of less than 1 OU would theoretically result in no odour impact being experienced.

In practice, the character of a particular odour can only be judged by the receiver’s reaction to it, and preferably only compared to another odour under similar social and regional conditions. Based on the literature available, the level at which an odour is perceived to be a nuisance can range from 2 OU to 10 OU depending on a combination of the following factors:

- *Odour Quality*: whether an odour results from a pure compound or from a mixture of compounds. Pure compounds tend to have a higher threshold (lower offensiveness) than a mixture of compounds.
- *Population sensitivity:* any given population contains individuals with a range of sensitivities to odour. The larger a population, the greater the number of sensitive individuals it contains.
- *Background level:* whether a given odour source, because of its location, is likely to contribute to a cumulative odour impact. In areas with more closely-located sources it may be necessary to apply a lower threshold to prevent offensive odour.
- *Public expectation:* whether a given community is tolerant of a particular type of odour and does not find it offensive, even at relatively high concentrations. For example, background agricultural odours may not be considered offensive until a higher threshold is reached than for odours from a landfill facility.
- *Source characteristics:* whether the odour is emitted from a stack (point source) or from an area (diffuse source). Generally, the components of point source emissions can be identified and treated more easily than diffuse sources. Emissions from point sources can be more easily controlled using control equipment. Point sources tend to be located in urban areas, while diffuse sources are more often located in rural locations.
- *Health Effects:* whether a particular odour is likely to be associated with adverse health effects. In general, odours from agricultural activities are less likely to present a health risk than emissions from industrial facilities.

Experience gained through odour assessments from proposed and existing facilities in NSW indicates that an odour performance goal of 7 OU is likely to represent the level below which “offensive” odours should not occur (for an individual with a ‘standard sensitivity’ to odours). Therefore, the Odour Framework recommends that, as design goal, no individual be exposed to ambient odour levels of greater than 7 OU. This is expressed as the 99th percentile value, as a nose response time average (approximately one second).

The proposed odour performance goals allow for population density, cumulative impacts, anticipated odour levels during adverse meteorological conditions and community expectations of amenity.

Where a number of the factors above simultaneously contribute to making an odour “offensive”, an odour goal of 2 OU at the nearest residence (existing or any likely future residences) is appropriate, which generally occurs for affected populations equal or above 2000 people.

A summary of odour performance goals for various population densities, as referenced in the Odour Technical Notes is shown in is given in **Table 1**.

Table 1 NSW DECC Impact Assessment Criteria for Complex Mixtures of Odorous Air Pollutants

Population of Affected Community	Impact Assessment Criteria for Complex Mixtures of Odours (OU)
Urban area (≥ 2000)	2.0
500 – 2000	3.0
125 – 500	4.0
30 – 125	5.0
10-30	6.0
Single residence (≤ 2)	7.0

Source: The Odour Technical Notes, DECC 2006

2.1.1 Project-specific Odour Criteria

The selection of a suitable Odour Impact Assessment Criteria for application in the current study is challenging due to such criteria being made contingent upon the future population of the affected MPIP. Although the existing population within the study area can be established, uncertainties are introduced in the projection of future population numbers in areas earmarked for development.

Considering future developments, including the development of the Project Site and establishment of low and medium density housing in part of the area, an odour impact assessment criterion of 2 to 3 OU would likely be applicable.

The DECC Air Policy Unit takes the general view that the Sydney Metropolitan region is a contiguous urban area for the purposes of odour assessment, thus recommending the implementation of an odour impact criterion of 2 OU for this region. Although it is not known for certain whether this criterion would be recommended by the DECC for the study location, it is evident that such a criterion would be appropriate given the earmarking of the broader region for development as residential and employment lands.

3 ODOUR SOURCES

The Stage One odour assessment identified two poultry farms located on the northern boundary of the MPIP. These were located at Lot 6, 306 South St and Lot 7, 264A South St. During the Stage One assessment, a screening (Level 1) odour assessment was undertaken according to the Odour Policy. Based on this assessment, a separation distance between these poultry operations and any residences was recommended.

This Stage Two (Level 3) odour assessment seeks to refine the predictions of the Stage One assessment by undertaking a more detailed dispersion modelling exercise (detailed in **Section 5**). An examination of the wider area surrounding the MPIP was carried out to identify any further odour sources. Three further poultry farm operations have been identified at 1132 and 1148 Richmond Road, and 51 Argowan Rd, Schofields. These sources have been included in the current modelling assessment. Odour emission rates have been calculated and applied as outlined in **Section 5.1**).

3.1.1 Poultry Operations

The biodegradation of accumulated faecal matter within the poultry sheds is a significant source of odour. Gaseous odorous compounds which are absorbed into litter or chicken bodies are transferred into the shed air at varying rates depending on the air velocity in the shed. Water is believed to act as a catalyst in the processes of odour generation, transfer and transport.

Poultry shed odour emissions typically comprise a complex mixture of odorous molecules. The types of compounds generated are dependent on whether aerobic or anaerobic conditions exist. The presence of oxygen at or near the litter surface creates aerobic conditions under which uric acid, proteins and animal fats biodegrade to produce nitrogen-containing odorants such as ammonia, amines, indole, skatole and volatile fatty acids. Under such aerobic conditions, sulphide containing compounds are also oxidised microbially into sulphur containing odorants such as hydrogen sulphide, dimethyl disulphide and dimethyl trisulphide (Jiang and Sands, 2000). Odour qualities of typical gases and vapours released are as follows: ammonia (pungent, irritating), hydrogen sulphide (rotten eggs), dimethyl sulphide (rotting vegetables), butyric acid (rancid butter), valeric acid (putrid, faecal smell), isovaleric acid (mouldy sneakers, old shoe character), skatole (faecal, nauseating) and indole (intense faecal).

When the supply of oxygen at or near the litter surface is limited and anaerobic conditions prevail, sulphur containing compounds are biodegraded into thiols, volatile organic sulphides and mercaptans (Jiang and Sands, 2000). Limited oxygen supply is associated with poorly managed farms where caked manure occurs. Such conditions can be limited by reducing the ingress of water into the litter, increasing the exposure of the litter to air by providing more space for bird movement, and by feeding balanced complete rations with sulphur compounds of high biological availability particularly early in the growth cycle of a batch (Jiang and Sands, 2000). Based on the measurement of several natural and tunnel ventilated broiler sheds (Jiang and Sands, 2000) concluded that ammonia and dimethyl sulphide are, by volume, the major odorous constituents inside the broiler sheds investigated.

4 CLIMATE AND DISPERSION METEOROLOGY

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading.

Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Oke, 2004).

To adequately characterise the dispersion meteorology of the study site information is needed on the prevailing wind regime, mixing depth and atmospheric stability and other parameters such as ambient temperature, rainfall and relative humidity.

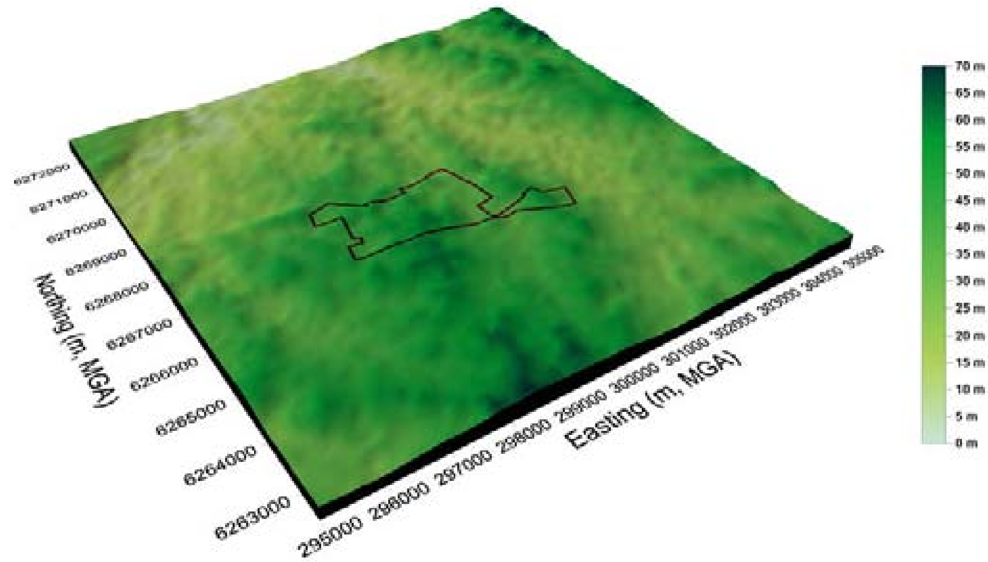
4.1 Meteorological Modelling

A diagnostic 3-dimensional wind field has been created for the western Sydney region including the area surrounding the MPIP site for a previous Heggies odour assessment. This diagnostic wind field incorporated surface observations from several Bureau of Meteorology meteorological monitoring stations in the region and included upper air data to accurately represent the 3-dimensional nature of the hourly wind field during 2006. From this file, a single point meteorological file was extracted for a grid cell located directly above the odour sources (poultry farms) to the north of the MPIP.

In areas with flat and uncomplicated terrain, the assumption of steady state meteorological conditions, particularly for use in a screening level dispersion modelling assessment, may be considered appropriate. Based on the terrain features presented in **Figure 2**, it could be argued that relatively uniform dispersion conditions would be expected across the modelling domain, between the odour sources and the MPIP, and the use of a single point file is therefore deemed appropriate.

Further information on the dispersion modelling undertaken as part of this assessment is provided in **Section 5**.

Figure 2 Local Topographical Features - MPIP (vertical exaggeration of 4)

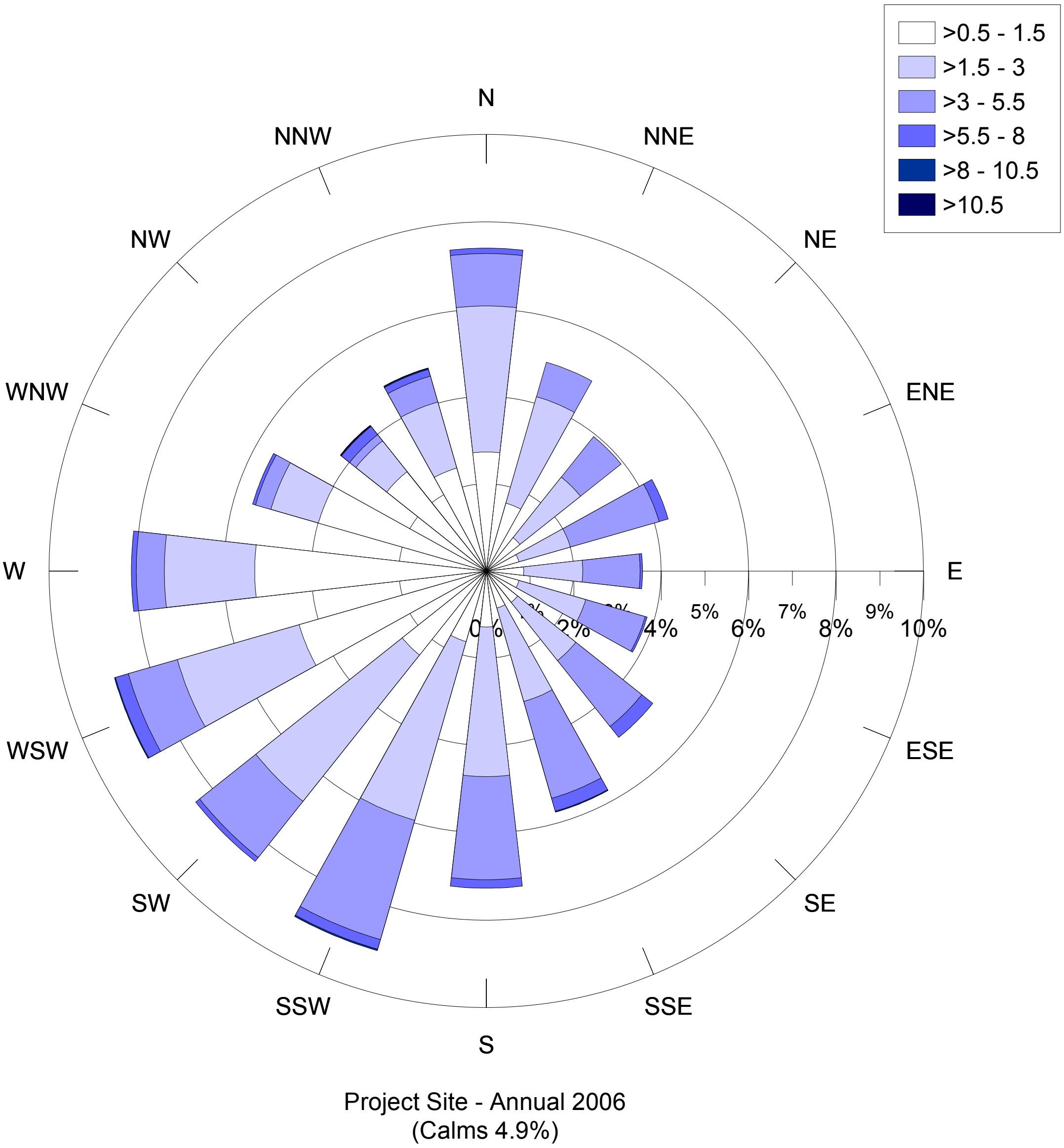


4.2 Wind Regime

A summary of the annual wind behaviour predicted for the Project Site (2006) is presented as a wind rose in **Figure 3.** This wind rose displays occurrences of winds from all quadrants.

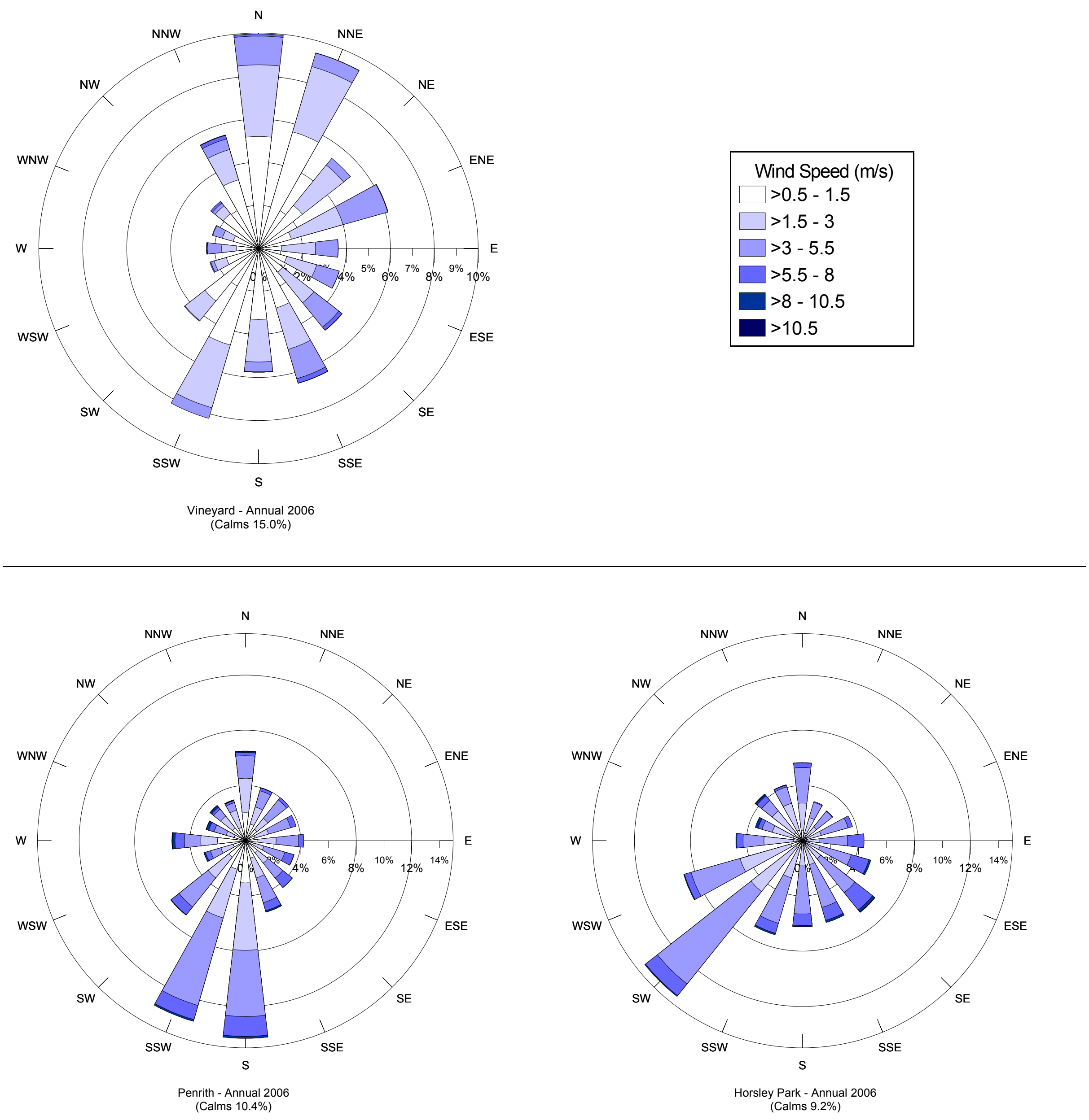
Figure 3 indicates that winds experienced at the site are predominately light to moderate winds (between 0.5 m/s and 5.5 m/s) from the southwest. Calm wind conditions (wind speed less than 0.5 m/s) are predicted to occur infrequently (4.9 %) of the time.

Figure 3 Annual Wind Rose – Project Site (Diagnostic Meteorological Data 2006)



The annual wind roses for the surrounding Richmond (13 km NNW of Project Site), Vineyard (8 km N of Project Site) and Penrith (13 km WSW of Project Site) meteorological monitoring sites for 2006 are presented in **Figure 4**. Although the wind roses for the wider area show differences to that predicted for the Project Site during 2006, the major features such as dominant wind directions are well captured and can be considered to be representative of the region.

Figure 4 Annual Wind Roses – Vineyard, Penrith and Horsley Park, 2006



The seasonal variation in wind behaviour at the site is presented in **Appendix A**. The seasonal wind roses indicate that:

- In spring, light to moderate winds (between 1.5 m/s and 8 m/s) are experienced predominantly from the north.
- In summer, light to moderate winds are experienced predominantly from the east nort-east and southeast.
- In autumn, light to moderate winds are experienced predominantly from the west-southwest.
- In winter, light to moderate winds are experienced predominantly from the west-southwest.

4.3 Atmospheric Stability and Mixing Depth

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Gifford assignment scheme identifies six Stability Classes, "A" to "F", to categorise the degree of atmospheric stability. These classes indicate the characteristics of the prevailing meteorological conditions and are used as input into various air dispersion models (**Table 2**).

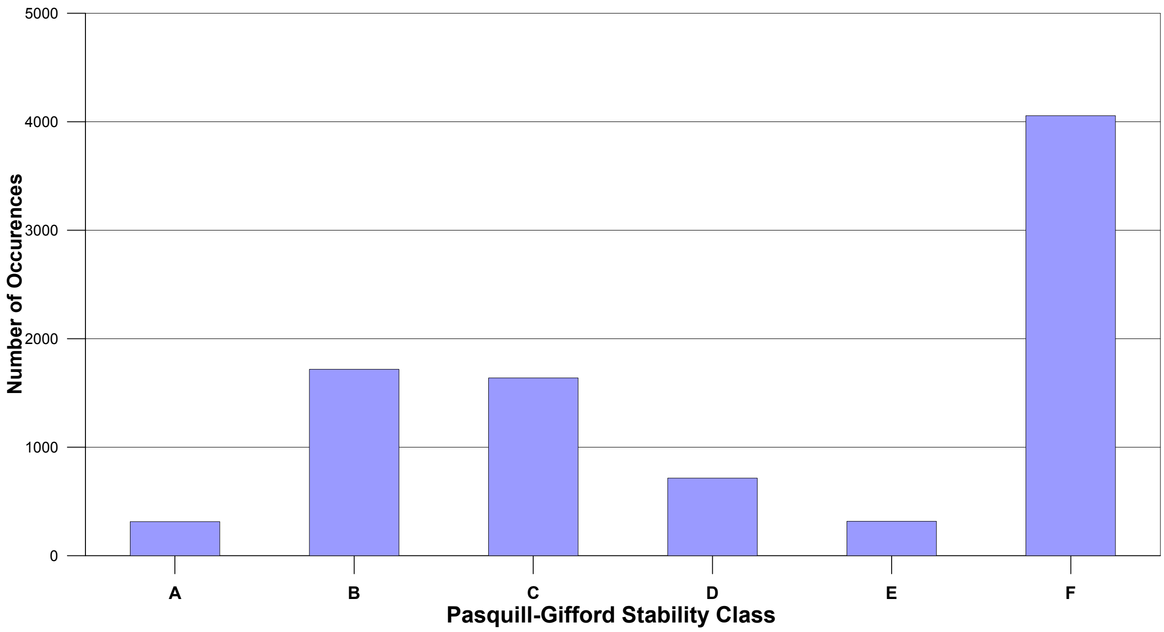
Table 2 Description of atmospheric stability classes

Atmospheric Stability Class	Category	Description
A	Very unstable	Low wind, clear skies, hot daytime conditions
B	Unstable	Clear skies, daytime conditions
C	Moderately unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	High winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions

The frequency of each stability class predicted at the Project Site is presented in **Figure 5**. The seasonal stability class distributions are included in **Appendix B**.

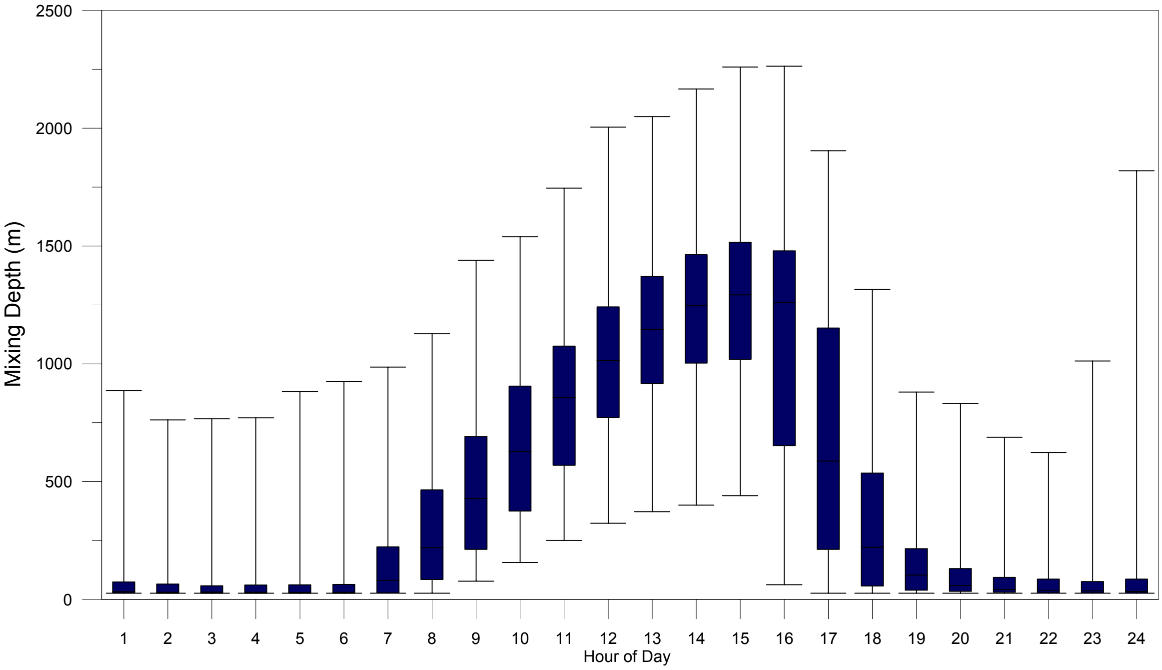
The results indicate a high frequency of conditions typical to Stability Class "F". Stability Class "F" is indicative of very stable conditions, providing little potential for atmospheric dispersion of pollutants due to a low level of mechanical mixing.

Figure 5 Predicted Annual Stability Class Distributions for the Project Site, 2006



Predicted diurnal variations in maximum and average mixing depths at the Project Site during 2006 are illustrated in **Figure 6**.

Figure 6 Predicted Diurnal Variation in Mixing Depth for the Project Site, 2006



It can be seen that an increase in the mixing depth during the morning, arising due to the onset of vertical mixing following sunrise, is apparent with maximum mixing heights occurring in the mid to late afternoon, due to the dissipation of ground-based temperature inversions and the growth of convective mixing layer.

5 DISPERSION MODELLING

CALPUFF, a puff dispersion model suitable for use in complex atmospheric dispersion situations, can be configured in screening mode, using a single meteorological input file such as an Ausplume meteorological input file. Using CALPUFF in screening mode assumes steady state conditions with a single one dimensional wind field applied across the entire modelling domain.

This approach is not considered appropriate for non-steady state conditions, such as in coastal locations or areas of complicated terrain where non-uniform wind conditions can be expected. However, as discussed in **Section 4.1**, the assumption of steady state meteorological conditions in this assessment is considered appropriate.

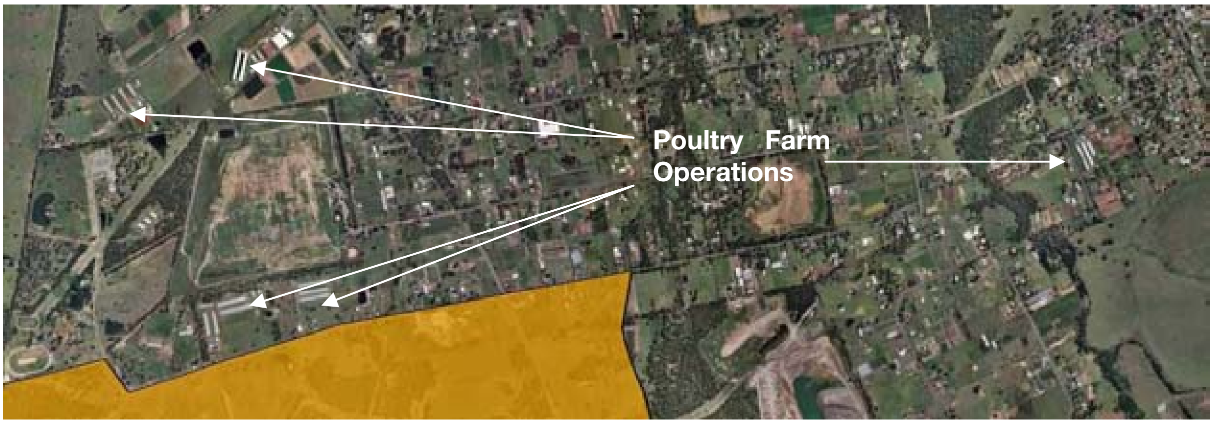
The current assessment utilises the CALPUFF (Version 6.1) modelling system run in screening mode using the single point meteorological input file. The advantages of using CALPUFF in screening mode (rather than using a steady state Gaussian dispersion model such as Ausplume) is its ability to handle calm (wind speeds less than 0.5 m/s) wind conditions. Ausplume cannot handle calm conditions because of the inverse wind speed dependence within the Gaussian plume equation. Under calm conditions, Ausplume will assume a minimum wind speed which shoots the plume to the edge of the modelling grid, even though the plume may not have moved at all under actual dispersion conditions (DECC 2005).

CALPUFF can handle these low wind speed conditions and will grow a plume by diffusion alone under zero wind speed conditions. It is often these conditions that are critical in odour assessment.

5.1 Calculated Odour Emission Rates

As discussed in **Section 3**, five poultry farm operations have been identified in the vicinity of the MPIP. The locations of these sources are shown in **Figure 7**.

Figure 7 Locations of Poultry Farm Operations surrounding the MPIP



No detailed information regarding the nature and scale of the poultry operations situated in the area could be obtained from the various local councils on which to estimate emissions. The extent of odour emissions from such operations had therefore to be calculated based on the observed number and size of sheds on each farm, with assumptions made regarding the number of birds likely to be housed in each shed based on experience gained for this sector. Based on the nature of farms and field observations for other poultry operations it was concluded that such operations were likely to comprise primarily broiler operations.

Information on the location and dimensions of poultry sheds were obtained from geo-referenced aerial photography and topographical maps for the area. The five shed groupings were simulated as volume sources within the dispersion model, the dimensions of which are given in **Table 3**.

A poultry shed which is approximately 100 m long and 15 m wide typically houses about 22,000 birds (Scorgie *et al*., 2007). The number of birds assumed to be housed in the various sheds identified were therefore scaled relative to their size. The estimated number of birds which can be housed in each of the poultry shed groupings is given in **Table 3**.

Jiang and Sands (2000) estimated *maximum* odour emission rates (OERs) to be in the range of 311 to 579 OUV/s/1000 birds across all broiler farm shed designs including natural, tunnel and cross ventilation sheds (housing between 19,500 and ~43,000 birds). Odour emission rates for naturally ventilated shed designs were in the range 311 to 405 OUV/s/1000 birds. *Average* odour emission rates were published by Jiang and Sand (1998) to be 195 OUV/s/1000 birds.

Table 3 Location and Size of Poultry Sheds in the Study Area, and Estimated Odour Emissions

Farm	Shed	Location and Dimensions of Volume Sources Simulated for each Shed Grouping						Estimated Number of Birds	*Average* Emission Rate (OUV/s)
		Easting	Northing	Shed Width (m)	Shed Length (m)	Horizontal Spread (m)	Vertical Spread (m)		
306 South St, Marsden Park	1	298493	6268099	15	90	3.75	0.75	19800	3861
	2	298530	6268107	15	90	3.75	0.75	19800	3861
	3	298616	6268160	20	140	5	0.75	41067	8008
	4	298595	6268193	15	120	3.75	0.75	26400	5148
	5	298489	6268175	15	62	3.75	0.75	13640	2659.8
264A South St, Marsden Park	1	298946	6268217	13	125	3.25	0.75	23833	4647.5
	2	298938	6268242	13	125	3.25	0.75	23833	4647.5
	3	298933	6268274	15	125	3.75	0.75	27500	5362.5
1148 Richmond Rd, Marsden Park	1	298154	6269076	15	62	3.75	0.75	13640	2659.8
	2	298133	6269037	15	95	3.75	0.75	20900	4075.5
	3	298100	6269014	15	95	3.75	0.75	20900	4075.5
	4	298058	6269005	15	62	3.75	0.75	13640	2659.8
	5	298122	6268915	15	55	3.75	0.75	12100	2359.5
	6	298162	6268930	15	67	3.75	0.75	14740	2874.3
	7	298212	6268951	50	60	12.5	0.75	44000	8580
1132 Richmond Rd, Marsden Park	1	298599	6269191	15	120	3.75	0.75	26400	5148
	2	298627	6269187	15	120	3.75	0.75	26400	5148
51 Argowan Rd, Schofields	1	302187	6268870	13	110	3.25	0.75	20973	4089.8
	2	302204	6268891	15	105	3.75	0.75	23100	4504.5
	3	302220	6268915	17	62	4.25	0.75	15459	3014.44

The difference between average and maximum OERs for poultry operations is due to such rates being highly variable throughout the year due to two main factors:

- Batch cycle. The emission rate is considered to peak just prior to the first harvest of birds (normally at weeks 5 to 6) when the bird mass in the shed is at a maximum.
- Ventilation rate. This rate is both directly and indirectly dependent on temperature and wind field.

Although factors are available to account for temporal variations in broiler shed emissions due to batch cycles, it is not possible to know how the batch cycles of the various poultry farms are likely to coincide in relation to each other. It is considered that the application of maximum emission rates for each shed is overly conservative and to better represent reality and to better guide concept plan options for the MPIP, average OERs have been applied to all sheds.

Average odour emission rates calculated for each poultry shed grouping based on the estimated number of birds and the emission factor (195 OUV/s/1000 birds) are summarised in **Table 3**.

An hourly emission rate file was generated for input in the dispersion modelling to take into account reductions in emissions during cool night-time hours when the flaps of naturally ventilated sheds are likely to be closed. Jiang and Sands (2000) observed that flaps are generally closed when the temperature drops below 15°C and that emissions reduce by 90% when flaps are closed.

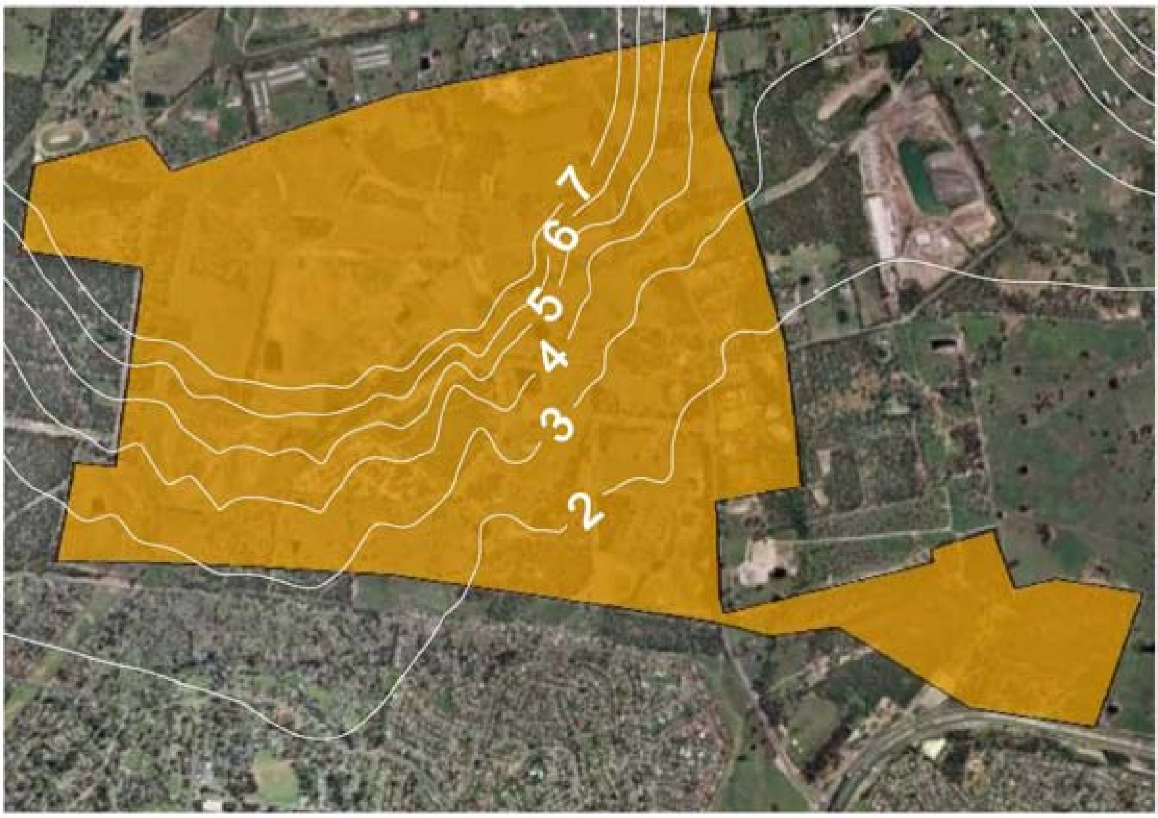
To estimate the effects of plume meandering and concentration fluctuations perceived by the human nose, a peak-to-mean ratio of 2.3 was applied to the emission rate as recommended by the DECC (2005) for volume sources. 99^{th} percentile odour concentrations (for nose-response times) were predicted across the MPIP and surrounding area.

6 DISPERSION MODEL RESULTS

Predicted 99th percentile odour units (for nose-response times) output by CALPUFF for the emission scenario outlined in **Section 5.1** are presented in **Figure 8**.

The odour contour plots for do not reflect odour concentrations occurring at any particular instant time, but rather illustrate the predicted frequency that odour concentrations are exceeded at the 99th percentile level. The plot therefore represents the concentrations that can possibly be reached under a combination of all meteorological conditions modelled.

Figure 8 Predicted 99th Percentile Odour Concentration Isopleths within the MPIP due to Poultry Farm Operations



As discussed in **Section 2.1.1**, Project specific odour criteria have been identified as being between 2 and 3 OU based on the likely numbers of residences (low to medium density housing) to be located in the MPIP. **Figure 8** demonstrates that the 3 OU criterion is exceeded across approximately 50% of the MPIP area with the west and north of the MPIP predicted to experience exceedances of this goal. The Project specific odour criteria are shown to be met in the south and east of the MPIP.

Higher odour concentrations are experienced closer to the northern boundary of the MPIP due to the proximity of the poultry farm operations on South Street. The impact of odour on the MPIP resulting from the poultry farm operations on Argowan Road, Schofields is shown to be low.

7 CONCLUSIONS AND RECOMMENDATIONS

An odour assessment was undertaken to provide clear guidance on whether odour criteria across the Marsden Park Industrial Precinct (MPIP) are expected to be within acceptable limits as a result of poultry farm operations to the north and north east of the MPIP. The main findings arising from the assessment and recommendations made in respect of such findings are presented below.

7.1 Key Findings

Odour levels of 2 OU to 3 OU are predicted to occur over the western and northern parts of the Project Site, based on *average* OERs for poultry operations, under certain meteorological conditions.

Given applicable odour impact assessment criteria, it is concluded that odour impact potentials are likely to be in an acceptable range in approximately 50% of the MPIP area, specifically within the south eastern corner.

Odour qualities of typical gases and vapours released by poultry operations include ammonia (pungent, irritating), hydrogen sulphide (rotten eggs), dimethyl sulphide (rotting vegetables), butyric acid (rancid butter), valeric acid (putrid, faecal smell), isovaleric acid (mouldy sneakers, old shoe character), skatole (faecal, nauseating) and indole (intense faecal).

7.2 Recommendations

7.2.1 Land Use Zoning

The NSW Department of Planning (DoP), through the Growth Centres Commission, has developed a long term, 20 year, Development Control Plan (DCP) for the area including the MPIP. It is assumed that within this timeframe, many of the odour sources considered in this report will not remain. This is in consideration of future rezoning planning for much of the North West Growth Centre.

In the short term, however, development within MPIP may coincide with the existing odour sources. The results of this odour assessment will be included within the DCP so that potential odour issues are presented at the master planning phase, and identified for further assessment during the development application (DA) phase. It would be expected that in cases where potential odour impacts would impact on specific development outcomes, additional odour assessment may be triggered as part of the DA process.

7.2.2 Odour Management and Mitigation

In the event that sensitive land uses are proposed for development in the northern and western areas of the Project Site, consideration should be given to odour management and mitigation measures which may aid in the reduction of odour concentrations within the MPIP.

It is suggested that DoP undertake a review of odour mitigation measures currently in operation in all poultry sheds to the north of the MPIP. During this review, additional measures could be identified for implementation. The funding of such works should be negotiated between poultry farm owners and DoP. A range of potential management and mitigation measures are presented in **Appendix C** for information. A detailed analysis of the potential odour reductions due to each measure or range of measures implemented could be undertaken to assess cost-effectiveness.

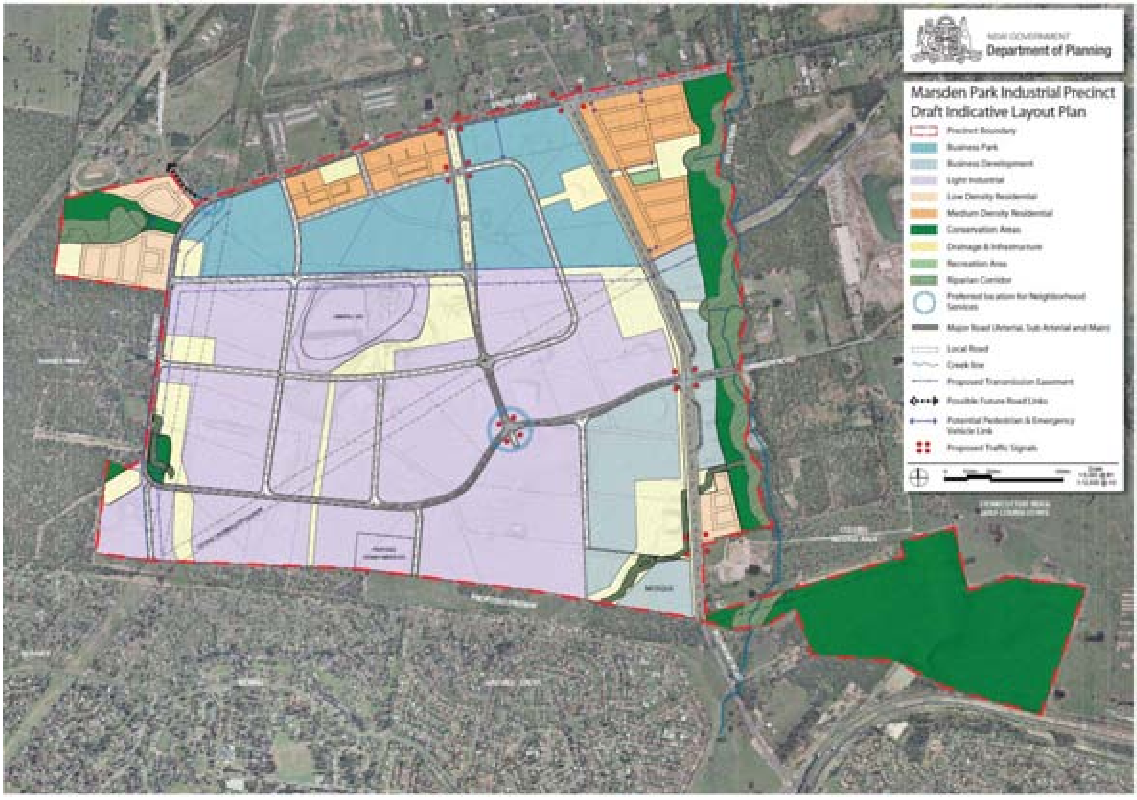
Prior to any construction works being undertaken on the MPIP, validation of odour modelling studies should be undertaken (e.g. odour intensity surveys) to confirm whether the conservative nature of the modelling undertaken is valid.

Mitigation measures could be applied within the MPIP, the aim of which would be to reduce exposure to odour; the options here are limited with installation of buffers (vegetated or concrete) between residences and poultry operations the most suitable measure.

7.3 Indicative Layout Plan Assessment

The Marsden Park Industrial Precinct – Indicative Layout Plan – dated 2 January 2009 is presented in **Figure 9**.

Figure 9 Marsden Park Industrial Precinct - Indicative Layout Plan



Given the predicted odour levels presented within this report, the following comment is provided on the master plan:

- The northern and western parts of the MPIP are less suitable for sensitive land uses such as residential development, in the short term.
- The most suitable areas for residential land uses are predicted to be in the south eastern area of the MPIP, in the short term.
- Staging of the master plan should take into account short and long term odour issues, taking into account zoning for areas surrounding the MPIP.
- Where potential odour impacts arise, further investigations may be triggered as part of the DA process for specific development outcomes.

8 REFERENCES

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NSW DEC (2006). *Technical Framework - Assessment and Management of Odour from Stationary Sources in New South Wales*, Department of Environment and Conservation (DEC), November 2006.

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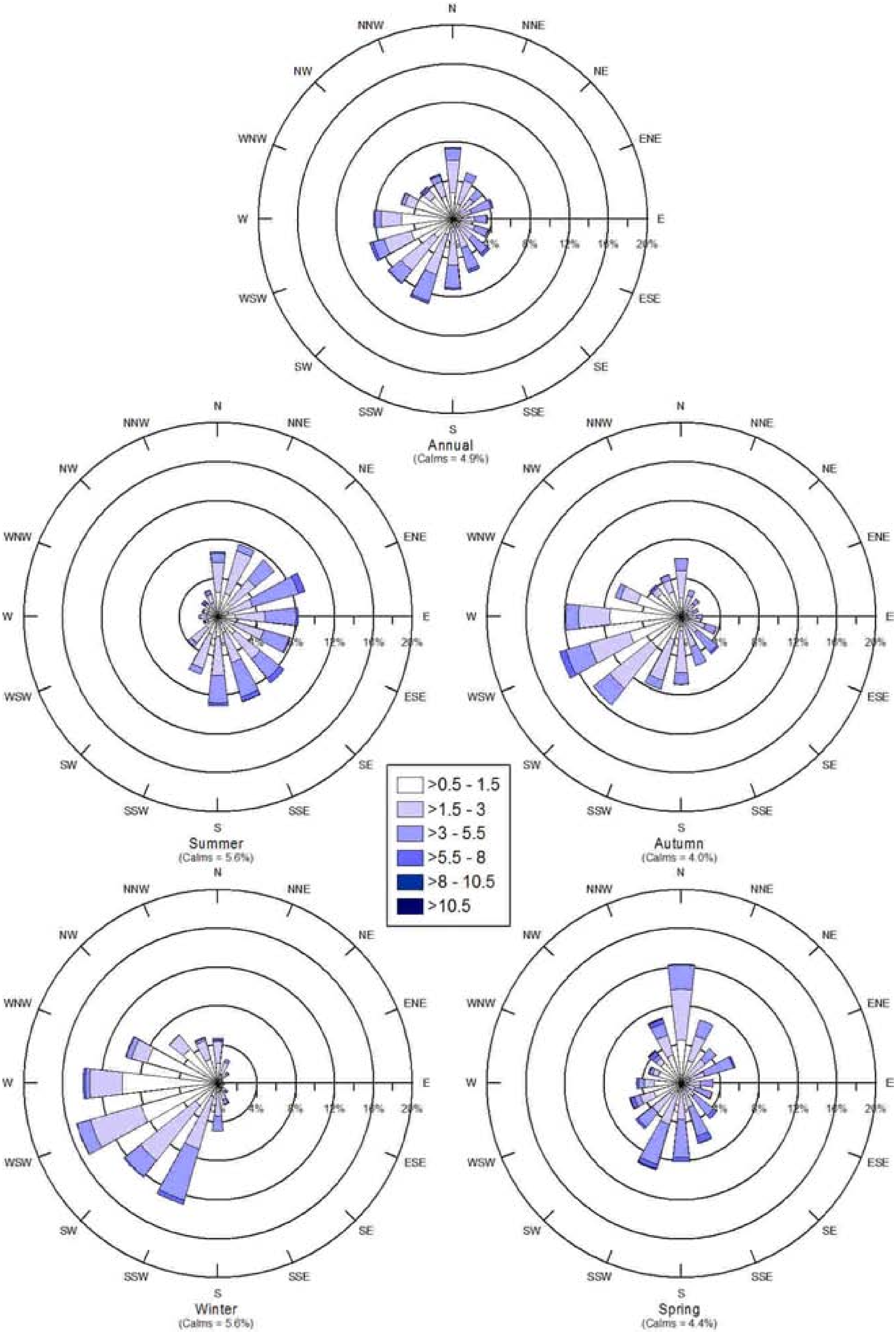
Oke T.T. (2004). *Boundary Layer Climates*, Second Edition, Routledge, London and New York, 435 pp.

9 ABBREVIATIONS AND ACRONYMS

AWS	Automatic Weather Station
BoM	Bureau of Meteorology
DA	Development Application
DCP	Development Control Plan
DECC	NSW Department of Environment and Climate Change (previously the Department of Environment and Conservation, DEC)
EPA	NSW Environment Protection Authority
Heggies	Heggies Pty Ltd
MPIP	The Marsden Park Industrial Precinct
µg	Microgram (g X 10^{-6})
µm	Micrometre or micron (metre X 10^{-6})
m^3	Cubic metre
OU	Odour Units; concentration of odorous mixtures in odour units. The number of odour units is the concentration of a sample divided by the odour threshold or the number of dilutions required for the sample to reach the threshold. This threshold is equivalent to when 50% of a testing panel correctly detect an odour
OER	Odour Emission Rate ($OU.m^3/s$)
OUV	Odour Unit Volumes; odour units are not concentrations but are a ratio. As such, they may not be used to represent an odour emission. It is necessary to multiply the source odour level (OU) by the volume of air emitted per second, to produce an odour emission rate. Typically odour emission rates may be expressed as OUV/s (point/volume sources) and $OUV/m^2/s$ (area sources) with units of $OU.m^3/s$ and $OU.m^3/m^2/s$ respectively.
VOC	Volatile organic compound

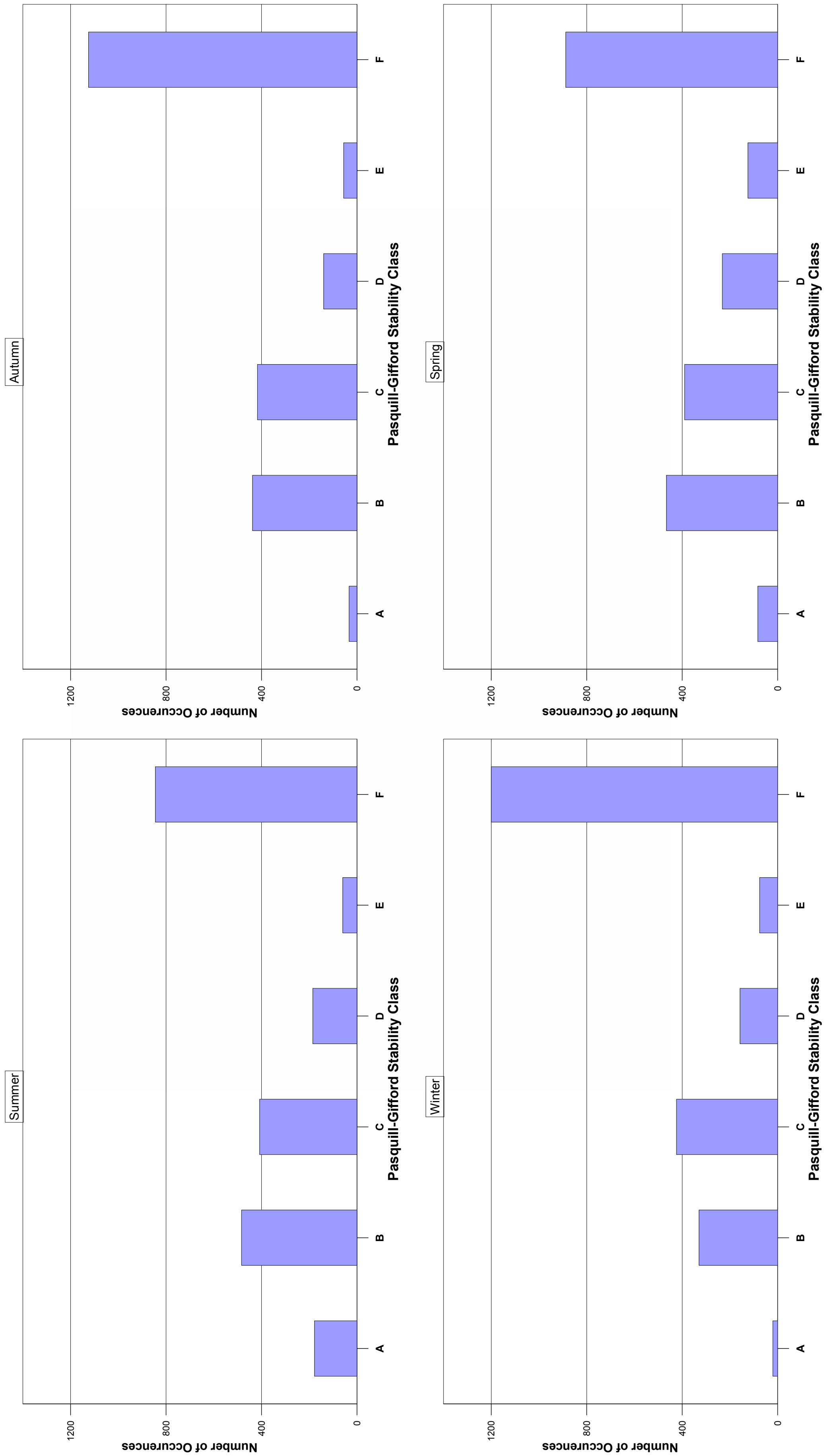


Heggies Pty Ltd	Designed by	Checked by	Approved by - date	Filename	Dated
Consulting Engineers and Scientists 2 Lincoln Street Lane Cove NSW 2066 Australia PO Box 176 Lane Cove NSW 1595 Telephone +612 9427 8100 Facsimile +612 9427 8200 Email Sydney@heggies.com	MD	SF		10-7391 P Site 2006	23/01/09

Appendix A: Predicted Annual and Seasonal Windroses for Project Site, 2006

Quality System
Quality Endorsed Company
ISO 9001 Lic 3238
Standards Australia

Predicted Seasonal Stability Class Distribution for Project Site, 2006



Management measures could be applied to the poultry farm operations, the aim of which would be to reduce odour emissions, increase atmospheric dispersion of odour emissions, or a combination of both.

Current odour management practices at all poultry operations are unknown although general recommendations are provided here which may be of use should MPD decide that this course of action be required, or is indeed achievable.

- Vegetation buffers and fencing, as illustrated in **Figure 1**, could be established between the poultry farms and the MPIP. This would act to increase mechanical turbulence and improve dispersion and also as a physical barrier onto which odours can be adsorbed.
- Litter could be covered with fresh absorbent material such as sawdust or shavings to minimise moisture content of the manure.
- Good housekeeping practice should be implemented. The poultry farm should avoid stockpiling of manure.

The European Union Best Available Technology (EU BAT) in terms of housing systems for broilers is: (i) the naturally ventilated house with a fully littered floor and equipped with non-leaking drinking systems, or (ii) the well-insulated fan ventilated house with a fully littered floor and equipped with non-leaking drinking systems. Within the EU BAT, emphasis is also placed on avoidance of wet litter (to minimise ammonia emissions) by tailoring drinking systems, controlling stock density and/or use of floor insulation.

Figure 1 Example of vegetation buffers adjacent to poultry sheds

- Ensure that internal shed temperatures are accurately recorded on an ongoing basis and try to maintain temperatures near to 22°C. This temperature is given by the NSW Department of Agriculture (2004) as being optimal in terms of reduced litter degradation and odour volatilisation and improved bird welfare (healthy birds produce drier and less odorous manure).

- In summer, bird density should be reduced if internal shed temperatures cannot be maintained at recommended levels.
- Overstocking of birds should be avoided as per the thresholds provided by the NSW DECC (DEC 2005).
- Ventilation during clean out should be designed to achieve the maximum amount of odour dilution. Maintaining the maximum possible airflow through the shed will keep the litter dry and help disperse odours.
- The moisture content of the poultry litter should be kept as low as possible (15% - 30% is ideal to prevent both odour and dust problems) and a litter pH above 7.5 maintained to inhibit anaerobic bacterial activity.
- Removing wet patches of poultry litter and / or covering litter with fresh absorbent material.
- Roof insulation can prevent excessive radiation heat gain during hot parts of the day. Optimal thermal insulation will also reduce the requirements for ventilation within the sheds. Roof insulation will also reduce condensation/rain dripping back to wet litter.
- Dead birds should be collected from sheds each day and refrigerated if not immediately disposed of.

Several measures could also be implemented including:

- use of odour neutralising or inhibiting agents through manure treatment or litter amendment (e.g. oil sprinkling, application of proprietary products);
- oxidisation methods (ozone and oxygen treatments);
- diet manipulation;
- conversions to a tunnel ventilated system (where naturally ventilated systems exist);
- conversions to a tunnel ventilated system with addition of windbreak walls; and
- conversion to tunnel ventilation system with air vented to a cleaning device (e.g. bio filters, bio scubbers, wet scrubbers, etc.).

A synopsis of various control technologies developed to reduce livestock emissions including odorous gases and dust, is given in **Table 1**.

Odour neutralising agents reduce odour potentials through masking or diluting odour concentrations, eg, by encouraging biological or chemical interactions or increasing dispersion. There are a range of proprietary products on the market which specifically target poultry operations, eg, Alum and Poultry Litter Treatment.

The use of ozone, distributed inside sheds at low concentrations to oxidize odorous gases, is the subject of on-going research (Ullman *et al.*, 2004). High control efficiencies are being reported in more recent literature for ammonia. Research conducted also suggests that ozone breaks down the highly odorous organic molecule indole, and reacts with a number of odorants with potential reductions in amines, ammoniacal compounds, lower aliphatic acidic compounds, sulphurous compounds and others.

Table 1 Measures to reduce atmospheric emissions from poultry operations and associated control efficiencies

Measure	Pollutant	Control Efficiency	Reference	Application
Manure treatments / litter amendments	NH_3	90% (immediately after application); 50% (2 weeks after application)	Ullman *et al*., 2004	Application of sodium bisulfate in form of proprietary product Poultry Litter Treatment. Sodium bisulfate was also found to reduce the frequency and populations of certain pathogens (Ullman *et al*., 2004).
	NH_3	64% (up to 48 days after application)	Ullman *et al*., 2004	
	NH_3	Up to 99%	Ullman *et al*., 2004	Application of proprietary product Alum, a granular poultry litter amendment. Laboratory study indicates a 99% reduction in ammonia volatilisation.
Oil sprinkling	Dust	Up to 90%	Godbout *et al*. 2000	Control efficiency highly dependent on application rate and frequency. Primary implemented at pig housing facilities to date but increasingly finding alternative applications.
	Dust	40%	Kirychuk *et al*. 1999	Iowa pig finishing barn
	H_2S, NH_3	20 -30%	Zhang *et al*. 1996	
Diet manipulation	NH_3	40 – 50%	Rom *et al.* 2000	Food additive (juice extract from Yucca Schidigera plant) used
	NH_3	28 – 79%	Sutton *et al*. 1999	Lower protein diets
Air filtration(a)	Dust	50 – 60%	Carpenter and Fryer 1990	Filtration of air during air recirculation
Biofilters(a)	NH_3	9 – 99%	Earth Tech 2001a	
	H_2S	50 – 90%	Earth Tech 2001a	
	Dust	Up to 86%	Earth Tech 2001a	
	Other organics	Up to 46%	Earth Tech 2001a	
Bio scrubbers(a)	NH_3	22 – 54%	Earth Tech 2001a	
Wet scrubbers(a)	NH_3	8 – 94%	Earth Tech 2001a	
	Dust	44 – 90%	Earth Tech 2001a	
Electrostatic precipitators(a)	Dust	40 – 60%	Earth Tech 2001a	

Table 1 (continued) Measures to reduce atmospheric emissions from poultry operations and associated control efficiencies

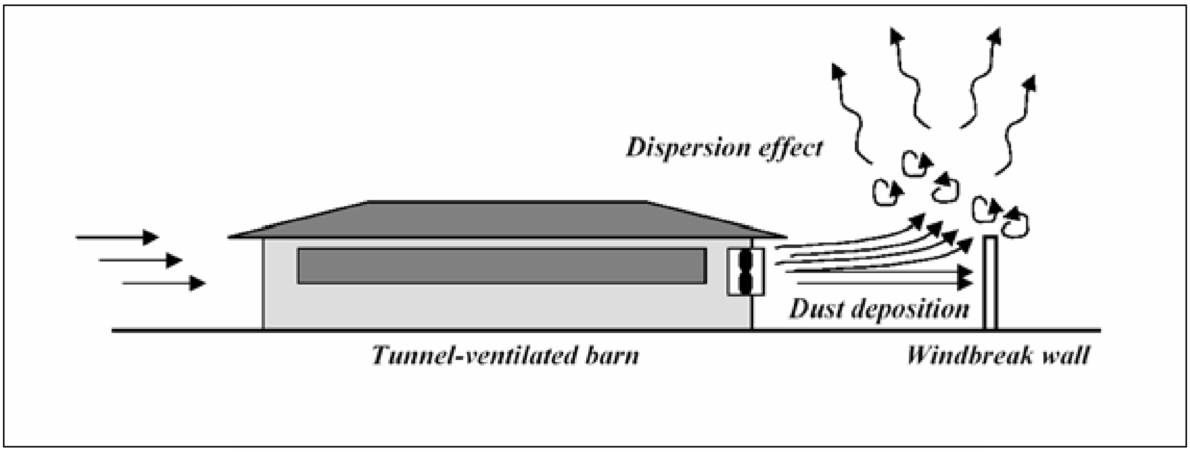
Measure	Pollutant	Control Efficiency	Reference	Application
Ozonation	NH_3	15 – 50%	Priem 1977	Odorous gases are oxidized by ozone that is distributed inside the shed at low concentrations. Care needs to be taken since ozone can be toxic to animals and humans at elevated concentrations. Earth Tech (2001a) noted that ozonation had not been thoroughly tested at that time and that additional research was needed to determine its efficiency and economic feasibility. The 15-50% control efficiency quoted by Earth Tech (2001a) was based on a 16-month experiment conducted by Priem in the 1970s at a swine barn. On-going research on the use of ozone to remove odours from livestock buildings has been conducted, e.g. in North Carolina. More positive reports are evident in more recent literature (Ullman *et al*. 2004). Gas chromatography analysis suggests that ozone breaks down the highly odorous organic molecule indole. Further studies indicate that ozone reacts with a number of odorants with potential reductions in amines, ammoniacal compounds, lower aliphatic acidic compounds, sulphurous compounds and others.
	NH_3	58%	Ullman *et al*. 2004	
	Dust	60%	Ullman *et al*. 2004	
Non-thermal Plasma(a)	H_2S, NH_3	Up to 100%	Earth Tech 2001a	Emission reductions achieved by creating highly reactive chemical species that convert targeted compounds to non-toxic molecules. 100% removal of NH_3 and H_2S concentrations during laboratory testing. Earth Tech (2001a) noted that this technology was still in its preliminary stages at that time and that additional research was needed to determine its efficiency and economic feasibility.
Wind break walls to be used with tunnel ventilation sheds	Dust, Odours	30 – 90% (odours)	Bottcher *et al*. 2000, 2001	Wind break walls constructed from tarpaulin can reduce odour concentration at sensitive receptors by 30-90% and the dispersion of dust emissions is promoted (Bottcher *et al*. 2000, 2001)
		Not given	Earth Tech 2001a	Wall made of wood panels, metal sheets or straw (etc.) placed about 10 to 20 feet from exhaust fans (Earth Tech 2001a).

(a) Require venting of air circulating within sheds to a cleaning device or treatment technology.

There is on-going research into manipulating feed additives to bind ammonia, change digesta pH, alter specific enzyme activity and mark odours. The majority of diet manipulation studies have focused on swine with less studies being conducted for poultry, dairy and beef. Some research has found such dietary modifications to either be costly or not consistently successful. Furthermore, it is argued that there is a trade-off to be made between animal productivity and odour reduction through diet manipulation (Earth Tech, 2001a). Much of the recent research on diet manipulation has been focussed on providing efficient and economic methods for reducing air emissions using diet manipulation thus not impacting on productivity. Certain researchers hold a positive view of the potential for dietary manipulation as a significant odour reduction measure based on recent work. Worley (2005), for example, states that odour control through dietary manipulation holds promise and "may revolutionise animal feeding practices within the next few years".

The installation of a tunnel-ventilation system could reduce odour potentials by directing exhaust vents away from residences. Wind break walls installed in front of exhaust vents can aid further in the dispersion of odour from these sources (**Figure 2**). Fan exhaust could also be vented to an abatement device, such as a water spray scrubber or chemical wet scrubber.

Figure 2 Tunnel ventilated shed with a windbreak wall (after Worley, 2005)



In conclusion, it is expected that significant emission reductions from poultry farms will need to be realised should odour performance goals be required to be met at the northern-most boundary of the MPIP. Such emission reductions will necessitate the investigation and adoption of additional measures, i.e. additional to "good practice" management of conventional shed operations.

Various options are available for the realisation of emission reductions. In the selection and tailoring of abatement options, care must be taken to investigate the technical feasibility and economic viability of such options in addition to obtaining realistic estimates of the site-specific control efficiencies likely to be achievable in practice.

Preliminary guidance is offered based on the project team's understanding of the poultry farms operations and documented abatement options. Dietary manipulation appears to require more conclusive local studies specifically with application for broiler operations. The cost of conversion to tunnel ventilated houses, with air vented to cleaning devices to ensure that the required control efficiencies are achieved, may be prohibitive and impractical.

It is therefore anticipated that litter amendment and manure treatment applications may represent the most cost-effective option for realising significant odour emission reductions in the short-term. The control efficiency to be achieved by such measures will depend on the specific product selected and the manner in which it is applied.

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ATTACHMENT 2: U.S. LITERATURE INFORMATION ON ODOUR CONTROL USING VEGETATION

Waste Management Featured Articles

Shelterbelts: Has Their Time Come ?

By G.T. Tabler, Poultry Science Department at the University of Arkansas's Avian Advice **- The increasing urban expansion into rural areas creates numerous challenges for livestock producers to various types of farming operations. A strong livestock industry is essential to the nation's economic stability, the viability of many small rural communities, and the sustainability of a healthful, plentiful and high quality food supply for the American public.**

Introduction

Farmers and ranchers view odors and dust associated with livestock as part of production agriculture and have come to accept them as part of their way of life. However, as urban dwellers are less likely to accept dust or odors, differences in lifestyles between farmers and city folks are becoming increasingly apparent. Although there will probably always be some odor and dust issues associated with animal production units, there are some simple, economical methods of reducing the frequency of complaints.

For poultry producers, shelterbelts offer an opportunity for poultry growers to be proactive in demonstrating good neighbor relations and environmental stewardship. Shelterbelts are typically vegetation (most often trees and shrubs) planted in purposeful rows to alter wind flow in order to achieve certain objectives. Planting trees and shrubs as screens around poultry houses will help remove them from public view (perhaps also the public's mind) and buffer odor, dust and noise.

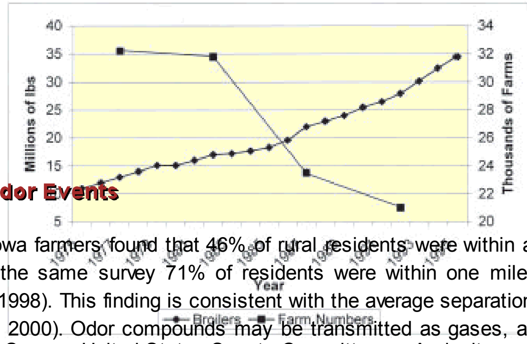
Livestock Production

In the United States about 130 times more animal waste is produced annually than human waste. Livestock in the U.S. produce more than 1.4 billion tons of manure annually (U.S. Senate Committee, 1997). Livestock production in the U.S. is characterized by fewer yet much larger production facilities. USDA data indicate that nationwide about 85% of estimated 450,000 agricultural operations with confined animals have fewer than 250 animal units (GAO, 1995).

Therefore, only about 15% of farms house the vast majority of the animal units nationwide. USDA estimates that only about 6,600 animal feeding operations nationwide have more than 1,000 animal units (GAO, 1995). From 1978-1992, the average number of animal units per facility increased by 56, 93, 134, 176, 148 and 129% for cattle, hogs, layers, broiler and turkeys, respectively, while during the same period the number of facilities dropped by over 40% in the cattle industry, and over 50% in the dairy, hogs and poultry industries (USDA and EPA, 1999).

Figure 1 demonstrates the increase in broiler production and decrease in broiler farm numbers from 1975 to 1995. Increased size of production facilities and greater numbers of livestock at each facility has meant larger amounts of animal waste, concentrated into relatively smaller geographic areas. This concentration of animals has increased the intensity, duration, and timing of odor events. The control of livestock odors has become of paramount concern for the public and livestock producers.

Figure 1: US Broiler production (lbs) and number of farms
1975 - 1995



Source: United States Senate Committee on Agriculture, Nutrition and Forestry, 1997

Understanding Odor Events

A recent survey of Iowa farmers found that 46% of rural residents were within a half mile or less of a livestock facility. In the same survey 71% of residents were within one mile of a livestock facility (Lasley and Larson, 1998). This finding is consistent with the average separation distances nationwide (Tyndall and Colletti, 2000). Odor compounds may be transmitted as gases, aerosols (a suspension of relatively small solid or liquid particles in gas) or dust (relatively large particles in gas or air). Efforts to control odors from animal production units fall into three basic strategies (Tyndall and Colletti, 2000):

1. Prevent odors from forming
2. Capture or destroy odorous compounds and
3. Collection, dispersion or dilution of odor compound.

In most cases the third strategy is the easiest and most economical procedure to implement in animal production units. In operations without protection wind or breezes often transmit odors gases, aerosols and dust to neighbors. Shelterbelts hinder this transmission, by trapping odors, redirecting air or creating turbulence so that odor compounds are diluted.

Odor Control using Shelterbelts

The source of animal odors is near the ground and tends to travel along the ground (Takle, 1983), shelterbelts can intercept and disrupt the transmission of these odors (Heisler and DeWalle, 1988; Thernelius, 1997). Shelterbelts also reduce the release of dust and aerosols by reducing wind speed near production facilities. Wind tunnel modeling of a threerow shelterbelt quantified reductions of 35% to 56% in the downwind transport of dust. However, shelterbelt density determines the degree to which dust and aerosols are reduced.

Density is a simple ratio of the porous area (the areas wind can pass through) to the total area of the shelterbelt. A density of approximately 40-60% is the most beneficial (Brandle and Finch, 1991). The trees or shrubs chosen for the shelterbelt and the spacing of those plants will determine the overall density. Remember that deciduous species tend to be more open closer to the ground and conifers have branch cover close to the ground (Griffith, 2001).

Shelterbelts physically also intercept dust and other aerosols. A forest cleans the air of micro-particles twenty-fold better than barren land. Leaves with complex shapes and large circumference to area ratios collect particles most efficiently. Shelterbelts attract and bind the chemical constituents of odor. Volatile Organic Compounds (VOCs) have an affinity to the cuticle of plant leaves. Microorganisms on plant surfaces can metabolize and breakdown VOCs.

Finally, shelterbelts provide a visual and aesthetic screen. A well-landscaped livestock operation is much more acceptable to the public than one that is not. Shelterbelts should be designed for the specific location, according to the expected and experienced odors, so that the tree and shrub species chosen can provide year round interception of odors and aerosols (Griffith, 2001).

Why Shelterbelts Now

Although shelterbelts have been used for many years in the Midwest to modify wind flow; control wind erosion, increase crop yields, protect farm buildings, and protect livestock, few in poultry producing areas considered their use.

However, urban encroachment is forcing changes in how poultry growers manage their operations and tunnel ventilated houses have made the use of shelterbelts feasible. Few recommended planting trees around poultry facilities for fear of blocking air flow through conventionally-ventilated houses, but today, with the poultry industry shifting to tunnelventilated, solid sidewall poultry houses, restricting natural air flow is much less of a problem.

Trees have a pleasing image across a large cross section of the American population. Planting trees around poultry houses may help foster a positive image of your farming operation. In addition, as the trees mature, less of your agricultural operation will attract attention, your farm takes on a more attractively landscaped appearance, and property values increase for both you and your neighbors (Malone and Abbott-Donnelly, 2001).

Plants used in Shelterbelts

Dense evergreen trees are perhaps the best choice for the tunnel fan end for maximum filtering during summer and screening year round. For greatest emissions scrubbing, shelterbelts should be as close to the tunnel exhaust as possible. As a general rule, to not interfere with fan efficiency, no trees should be planted closer than a distance of five times the diameter of the fans (Malone and Abbott-Donnelly, 2001). Check with your integrator before constructing a shelterbelt. Take into account the width of the shelterbelt at maturity and how this may affect roads, loadout areas, or chick delivery areas.

There are a variety of trees and shrubs suitable for Arkansas conditions that would work well to screen poultry houses. White pine, properly spaced, creates a dense shelterbelt, grows rapidly and is reasonably priced. Virginia pine and loblolly pine also do well. Various cedars also form a dense mat; however, some consider certain varieties a nuisance and the berries may attract wild birds. A variety of hollies and other ornamental shrubs such as Red Tip Photinia form highly effective screens and have a beautifying effect on the surrounding landscape. The plants you choose will depend on the site, soil conditions, available space, number of plants required, growth rate of plants, personal preference for landscaping effects and cost of the plants. For more information on trees and plants that do well in your area, contact your local county Extension office, local Conservation District, Arkansas Forestry Commission or a professional landscape nursery/garden center.

Air quality issues surrounding poultry production facilities are no longer a matter of “if”, but “when.” Arkansas poultry producers should take proactive steps to plan for management changes these issues will bring. The planting of trees in strategic locations around poultry houses is one method to help address these issues before and as they arise. In addition, research has shown that shelterbelts can reduce heating costs 10-40% and reduce cooling costs as much as 20%.

Strategically placed trees can also reduce wind speeds by 50%, adding protection from spring and fall storms. The leaves of trees physically trap dust particles that may be laden with nitrogen, and root systems will absorb up to 80% of the nutrients that might escape the proximity of the poultry operation (Stephens, 2003). Cost-share assistance for planting a shelterbelt is available in some states; unfortunately, Arkansas is not one of these states at the present time.

Barriers to Shelterbelt Adoption

Although shelterbelts around the perimeter of poultry houses offer many advantages, there are some barriers to adoption and some negative aspects to consider. For example, Malone and Abbott-Donnelly (2001) indicate:

- A limited amount of land will be taken out of production to support the shelterbelt
- There will be cost associated with purchasing the trees, labor for planting and maintenance
- You will encounter a restricted view of your houses access will be limited to designated roadways trees will create a potential habitat for wild birds.

Summary

Air quality issues will become an increasing concern to production agriculture with continued urban encroachment into previously rural, agricultural areas. Shelterbelts offer one method by which poultry producers can take proactive steps to address the issue; demonstrating good public relations efforts and environmental stewardship by buffering odor, dust and noise emissions from their facilities while improving farm aesthetics and property values.

Dense shelterbelts may detract attention from farming operations and help reduce air emission concerns surrounding poultry facilities by capturing dust particles and ameliorating odors. Consult your integrator concerning placement before constructing a shelterbelt. Select trees or shrubs suitable for your area. Your local Extension office, NRCS office, Arkansas Forestry Commission or local landscape nursery can be of valuable assistance on species information. If planted during warmer weather, be sure to provide plenty of water to assure successful establishment. A well-landscaped livestock operation is more pleasing to the public than one that is not.

A shelterbelt used as a pollution control device is visible proof that producers are making an effort to control what leaves their operation. This could prove valuable in the court of public opinion and perhaps reduce tension levels between farming and non-farming segments of the population.

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UNIVERSITY OF DELAWARE
College of Agriculture and Natural Resources

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December 2001

The Benefits of Planting Trees Around Poultry Farms

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WHY SHOULD I CONSIDER PLANTING TREES AROUND MY POULTRY HOUSES?

Planting trees as a visual screen, vegetative filter and windbreak around poultry farms is another opportunity for poultry growers to demonstrate their continued commitment to voluntarily implement a program to be good neighbors and environmental stewards. The major benefits of trees around the perimeter of houses include:

* Fosters good neighbor relations
* Demonstrates proactive environmental stewardship
* Increases production efficiency

Fosters Good Neighbor Relations

Increasing urban encroachment in many poultry producing areas will make maintaining good relations with neighbors even more of a challenge. Planting trees around poultry houses is a step toward creating a positive image for the poultry industry. As the trees mature, your farm takes on a more attractive landscaped appearance and creates an aesthetically pleasing view, while increasing property values, both for you and your neighbors. Given time, all aspects of your poultry operation will be obstructed from view (i.e., deliveries, live-haul crews, litter cleanout, etc.) The adage "out-of-sight, out-of-mind" may well be a major advantage of providing a visual screen for poultry operations.

Another important aspect of trees is their ability to filter the odor, dust, feathers and noise emitted from poultry operations. With urban encroachment, the likelihood of more odor- and noise-related complaints will increase. This is further exacerbated by the rapid adoption of tunnel ventilation, which concentrates the discharge from houses during summer. With increased ventilation during warm weather and more outdoor activities by the neighbors, summer is often the most sensitive time of year for nuisance-related neighbor complaints. If residential houses are in close proximity and downwind of tunnel exhaust fans, you may well have an explosive issue on your hands.

Trees provide a cost-effective, long-term means of reducing odor, dust, feathers, and noises associated with your daily operations. As shown in the photograph below, trees can be highly effective in scrubbing odor-laden dust particles from exhaust fans.

Noise complaints are becoming more of a concern as we convert to tunnel ventilation and operate the larger fans for prolonged periods of time during warm weather. Trees can absorb and diffuse noises resulting in sound levels one-half the original volume. While planting trees around the perimeter of your farm is not a substitute for good management practices, this natural barrier will reduce nuisance complaints and foster better relationships with your neighbors.

Demonstrates Proactive Environmental Stewardship

Planting trees around poultry farms offers many environmental benefits and presents a positive image of agriculture.

Ammonia emissions from poultry houses and its contribution to atmospheric nitrogen and fine particulates may be a major issue facing all animal agriculture in the future. Trees strategically planted on poultry farms may help reduce ammonia emissions by physically capturing both the ammonia gas and the ammonia-laden dust particles. Early adoption of a tree program may be one strategy in helping your operation deal with the emissions issue in the coming years.

Trees also have the ability to clean the air by capturing carbon dioxide, a greenhouse gas, storing the carbon in the wood and releasing oxygen back into the air.

In addition to the leaves' ability to capture various gases, the roots of trees are effective in absorbing nutrients that might escape the proximity of the poultry farm. Trees aid in filtering nutrients in the runoff and groundwater. More than 80% of nitrogen and phosphorus can be kept from entering adjacent water courses through root absorption or reduction in overland flow.

With continued environmental scrutiny of poultry operations, emission and nutrient discharge issues will likely increase. Planting trees is another opportunity for you to be proactive and demonstrate your desire to be a good environmental steward.

Increases Production Efficiency

Several years ago, no one promoted planting trees around poultry houses for fear of restricting natural air flow. However, as industry shifts toward tunnel ventilation, blackout and windowless-type housing, this is less of a concern.

Overlooked in the past were the potential energy savings of planting trees or windbreaks around houses. Previous research for other applications suggests properly established windbreaks are an energy-efficient, natural system that can reduce heating costs as much as 10%-40% and reduce cooling cost by 20%. Strategically placed, trees provide protection during late fall, winter and early spring by reducing wind speed by more than 50%. A 'wind-shadow' of approximately 200 feet is developed on the downwind side of an established windbreak.

Protecting houses from the wind may minimize structural damage. During summer, trees may offer some degree of roof shading and cooling the air around houses. As shown in the recent tunnel-retrofit photo on page 3, some innovative growers with conventional houses years ago recognized the benefits of shading roofs. Although this may not be as important for tunnel-ventilated houses, on sunny days, shading the area around houses can reduce the temperature of the ground by 20°F. While actual benefits in reducing intake air temperatures are limited, some preliminary data suggest summer air temperatures next to poultry houses having a shaded (wooded) area on the western exposure may be up to 7°F cooler in the afternoon than air around houses in an open area.

Properly designed windbreaks can also serve as a 'living' snow fence. A tree windbreak can capture up to 12 times more snow per foot of height than a picket fence, and it is 90% cheaper.

Another potential benefit of trees surrounding the poultry farm may be improved biosecurity. By restricting airborne particulates, trees may aid in blocking airborne poultry diseases from entering as well as exiting your farm.

Although trees around the perimeter of houses offer many potential advantages, there are some negative aspects to consider. These include: a limited amount of land will be taken out of production, cost of the trees, labor for planting and maintenance, restricted view of your houses, limit farm access to designated roadways, and a potential habitat for wild birds. A tree program may not be workable for some farms and on many farms the perimeter of the houses may already offer partial windbreak protection.

AT WHAT DISTANCE SHOULD TREES BE PLANTED FROM MY POULTRY HOUSES?

This depends on your farm situation, house orientation, type of ventilation system, tree species and width of the windbreak. For tunnel-ventilated houses and planned retrofits to tunnel ventilation, multiple rows of dense evergreens around the farm perimeter make a good visual screen, vegetative filter and windbreak.

On the tunnel fan end of the house, consider additional rows of dense evergreen or deciduous trees for maximum filtering during summer operation. For greatest emissions-scrubbing, tree lines should be as close to the tunnel exhaust fans as possible. As a general rule, to not interfere with fan efficiency, no trees should be planted closer than a distance of five times the diameter of the fans. On the inlet end of the house, consider planting tall evergreens or deciduous trees to provide a 'cooling' effect of the air and soil in summer.

Growers are encouraged to consult with their poultry companies to establish minimum distances of trees from houses. Service roads, loadout area and anticipated width of the tree spread at maturity are factors in spacing consideration.

Tree planting around conventional-ventilated houses requires strategies to meet different objectives. First, prevailing winds for your location need to be determined. On the prevailing wintertime wind side of the farm, multiple rows of dense evergreens may be used for a visual screen, vegetative filter and windbreak. For the summertime prevailing wind side of the farm consider planting tall evergreens and/or deciduous trees with no lower limbs. This will provide a partial visual screen and shade while minimizing air blockage. For houses having a western sidewall exposure, consider tall, wind-tolerant, deciduous trees for maximum roof shading. In some cases this may be an option between the houses. Plantings on the ends of houses will also require adequate distances to accommodate the loadout operation.

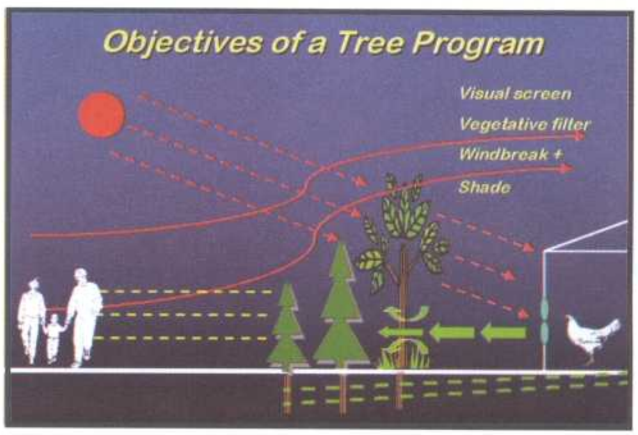
The maximum benefit from windbreaks is felt five times the height of the tallest trees growing in the windbreak when the trees reach about 20 years old. Therefore, if the total height of your tallest tree at age 20 is 30 feet, then the maximum windbreak effect will be 150 feet. If the prevailing winter winds are from the northwest, for best 'wind-lifting' effect, on the north and west rows of the windbreak, plant a progression of low evergreen shrubs or trees on the outermost row to taller evergreen trees for the inside row.

Several other factors need to be considered. On all farm types, a tree line is recommended to 'screen' manure sheds and dead-bird composters. For tunnel-ventilated farms this may involve two sets of tree lines, one near the tunnel fans and another to screen the manure and composter facilities. Property lines, dwellings, traffic visibility, surface and subsurface drainage rights-of-ways, overhead and below-ground wires also will enter into tree placement.

WHAT TYPE OF TREES ARE BEST SUITED FOR POULTRY FARMS?

Plant the RIGHT tree at the RIGHT place and for the RIGHT purpose! Every farm differs and a management plan must be developed to meet specific farm objectives and requirements.

As shown in the diagram below, there are three major objectives (visual screen, vegetative filter and windbreak/shade) that need to be considered for each side of your farm.



Desirable features of trees for poultry farms include maximum vegetative density with complex leaf shapes, waxy or "hairy" leaves for efficient filtering ability, tap or deep roots, wind tolerance, low maintenance and care, medium to fast growth and tolerance to nutrients found around houses.

You may want to avoid shrubs and trees that attract wild birds due to seeds or nesting site and those with a wide crown that obstructs traffic.

For information on recommended trees in your area, call your county Extension office or local Conservation District.

The urgency of implementing a 'privacy' screen, vegetative filter or windbreak may dictate both the selection of tree species and size of the stock to plant. Windbreaks should not be one single species, but contain a diversity of tree and shrub species. If you invest in larger stock or plant during warm weather, consider installing drip irrigation to ensure survivability. Do not plant any invasive species of shrubs or trees on your farm.

WHAT ARE THE PLANTING RECOMMENDATIONS AND MAINTENANCE REQUIREMENTS FOR TREES?

Planting recommendations depend on your location, particular situation and need.

Site preparation for weed management is a critical preparation step, especially during the first few years of establishment. Weeds compete for nutrients and water. Once the trees are established, maintenance requirements are significantly reduced. You may want to use tree shelters when planting hardwood seedlings.

The distance between trees within and between rows depends on such factors as plant species, objectives of the planting, farm situation and width of your mowing equipment.

The windward side of your windbreak should contain evergreen species that retain their lower branches close to the ground, or you may need to interplant evergreen shrubs to compensate for the opening. In some situations, it may be desirable to make plantings over multiple years, plant trees with different ages of longevity and, in some cases, thin the trees as the windbreak matures.

CAN I GET TECHNICAL AND FINANCIAL ASSISTANCE FOR PLANTING TREES?

If you are interested in obtaining federal, state, county or private cost-share assistance, contact your local Cooperative Extension or Conservation District office about potential funding opportunities. Long-range planning is essential when considering a tree plan for your farm. A tree plan will need to be developed and stock ordered well in advance of the ideal planting time for your location. Without prior notice, your trees/shrubs may not be available when you are ready to plant.

If you choose not to participate in a cost-share program, seek guidance on developing a tree plan for your poultry farm. Your Poultry Specialist, local Cooperative Extension office or Conservation District can assist you with your plan. The cost of planting tree seedlings on poultry farms is relatively inexpensive. However, there will be additional labor, site preparation and maintenance costs. Both hand and mechanical tree-planting equipment may be available from your state forestry department. Check to see the availability of the equipment and the cost of having them custom-plant your trees.

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Windbreak/Shelterbelt–Odor Control

Conservation Practice Information Sheet ***(IS-MO380)***

Using Windbreaks to Reduce Odors Associated with Livestock Production Facilities [1]

Introduction

Preliminary research and observations made by farmers suggest that windbreaks placed around livestock production facilities may effectively reduce movement of odors emitted by manure to neighboring properties. Essentially, trees can be 'put to work' to reduce the movement of livestock production odors off-site.

Although the idea of placing vegetative windbreaks and shelterbelts around agricultural buildings and farm fields is not new, additional benefits from farm windbreaks continue to be learned and tested. Windbreaks alone will not prevent odor problems associated with intensive livestock production but may provide farmers with one more tool to help reduce negative visual perceptions and detection of smell by neighbors and surrounding communities.

Figure 1. A windbreak of maturing conifers can significantly change the appearance of livestock production facilities and help filter out odor particles.

An odor-emitting source can include a livestock production barn, manure storage or a farm field where manure is being spread. Windbreaks have the ability to reduce odor concentrations significantly at or very near the source, which greatly improves the effectiveness of separation distances.

There are six ways that windbreaks and shelterbelts can reduce the effects of livestock odor and improve visual perception of production buildings:

1. Dilution and dispersion of gas concentrations of odor by a mixing effect created by windbreaks.
2. Deposition of odorous dusts and other aerosols (like snow fencing) to the windward and leeward sides of windbreaks.
3. Collection and storage (sinks) within tree wood of the chemical constituents of odor pollution.
4. Physical interception of dust and aerosols odor particles on leaves, needles and branches.
5. Containment of odor by placing windbreaks fore and/or aft of the odor source.
6. Aesthetic appearance:
   - Trees create a visual barrier to livestock barns
   - Trees can make cropped fields and pastures more pleasing to look at
   - Trees represent an 'environmental statement' to neighbors that the producer is making every effort to resolve odor problems in as many ways as possible.

[1] This information sheet is adapted from the following references: "Using Shelterbelts to Reduce Odors Associated with Livestock Production Barns" (January 2004) by Todd Leuty, Horticulture/Agroforestry Specialist, Ontario Ministry of Agriculture and Food. "Air Quality and Shelterbelts: Odor Mitigation and Livestock Production – A Literature Review" 1999. John Tyndall and Joe Colletti; Iowa State University."Designs for Windbreak Walls for Mitigating Dust and Odor Emissions from Tunnel Ventilated Swine Buildings" 2000. R. Bottcher, R. Munilla, G. Baughman, and K. Keener. North Carolina State University.

Windbreak/Shelterbelt–Odor Control

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Dilution and dispersion

Without wind management, odors emitted from livestock facilities and manure storage areas tend to travel along the ground as a plume with air movement, especially during atmospheric inversions with little or no dilution of odor occurring.

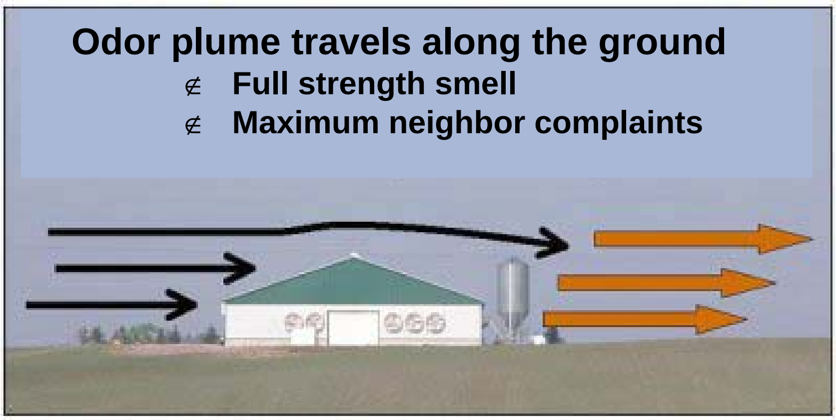

Figure 2. Without windbreaks and without wind management, the odor plumes are picked up by passing air masses and travel near the ground with little or no dilution or filtration.

Windbreaks create an obstacle for moving air masses. When designed properly, windbreaks force turbulent fresh air up and over the tree row and will also moderate and evenly distribute a more gentle airflow through the trees. Less air movement past barns will mean less pickup and movement of odor off site.

It is believed that windbreaks have the ability to lift some of the odor plume into the lower atmosphere where winds aloft mix and dilute the odor. The greatest dilution of odor occurs above and downwind from the quiet zone created by the action of wind passing over the windbreak. Beyond the quiet zone, more fresh air and less odorous air returns to the ground, thereby reducing movement of livestock odors off site.

Approximately 60 percent of the wind should be deflected up and over the windbreak and 40 percent should pass through the canopy of the trees. Two to three rows of trees can provide an ideal 60 percent density (or 40 percent porosity) through the tree canopy. Windbreaks are less effective for odor reduction when wind is minimal but the visual appearance remains in place.

Windbreaks create a 'quiet zone' of air that measures a distance of 8 to 10 times the height of the tree row downwind of the windbreak, and an additional moderation of wind speeds 10 to 25 times tree height, beyond the windbreak. Back-pressure created by the blocking effect of the tree row also creates a small quiet zone upwind of the tree line that is equal to 2 to 3 times the height of the trees.

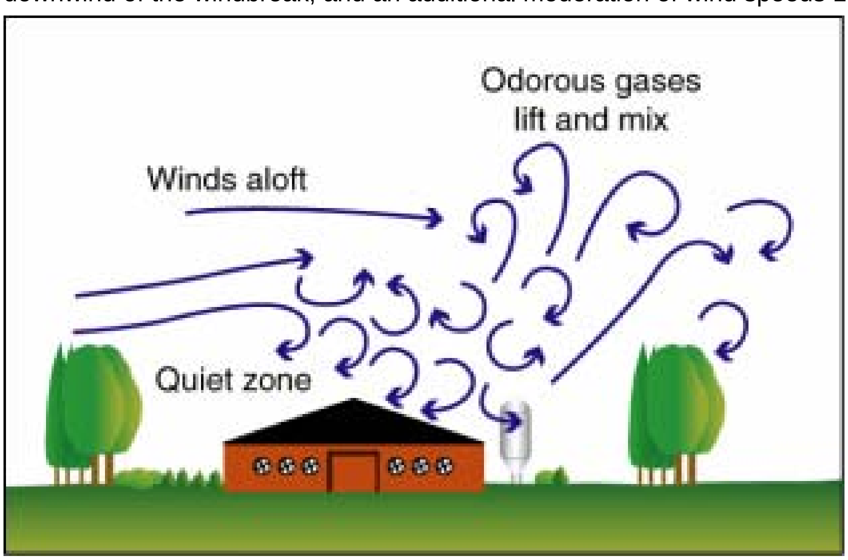

Figure 3. Windbreaks located upwind and downwind of livestock facilities will reduce and manipulate air flow around the facility to reduce the spread of odors. Overhead winds can lift particles and gases into the lower atmosphere to help dilute and disperse odors. Also, more clean air diverts up and over the source of odor.

Windbreak/Shelterbelt–Odor Control

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Livestock barns and manure storage areas are best located in the quiet zone 50 to 100 feet downwind of windbreaks. In addition, windbreaks located downwind of the odor source are also important for filtering, absorption and trapping odors. Therefore, placing windbreaks around the entire perimeter of livestock production areas is ideal. Windbreaks should also be at least 75 to 100 feet from access roads and driveways to prevent snowdrifts from blocking farm vehicles during winter.

Deposition of odorous dusts

Windbreaks create a physical barrier to wind and air movement. The trees absorb wind energy and reduce its speed near the ground. As a result, fewer dust particles and less odorous gases will be picked up by the air coming from livestock facilities. Also in calmer air, dusts and gases already caught up in the air will be more likely to settle back to the ground on the downwind side of the windbreak. This deposition effect is commonly seen with snow fencing where snow settles downwind of the fencing or trees due to reduced wind speed.

Figure 4. Reduced wind speed in the quiet zone that is created downwind from a windbreak allows odorous dusts and particles to settle to the ground, similar to what happens with settling and drifting of snow.

To be most effective for deposition of odorous dust, windbreaks need to be located upwind and downwind of odorous livestock facilities. Upwind windbreaks reduce the quantity of dust and odor that is picked up by wind, and windbreaks located downwind of the facilities will further reduce wind speeds to allow settling of odorous dusts that have become airborne.

For cropland, the same may hold true for reduction of odor movement where manure is being spread onto farm fields. Windbreaks established around the full perimeter of farm fields should reduce movement of odor and can accommodate winds that are approaching the farm from any direction.

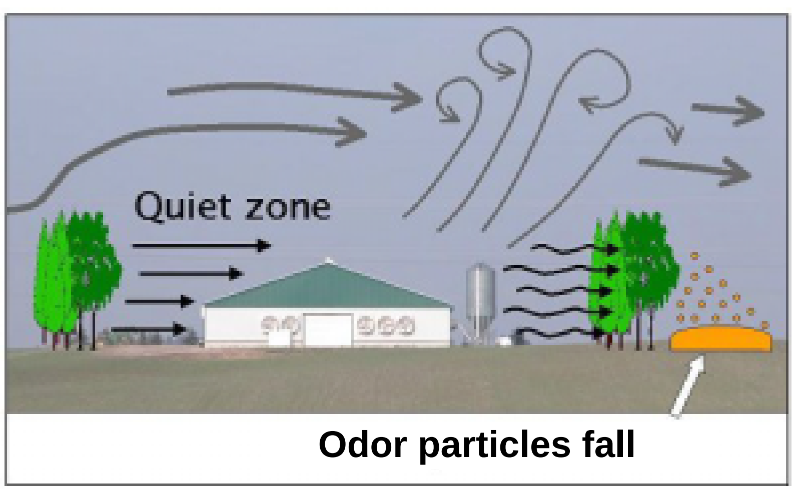

Figure 5. Windbreaks located downwind of livestock production barns allow settling of odorous wind-borne dust particles. Windbreaks should be located 75 to 100 feet away from barns.

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Wind tunnel studies of mass transport have shown that windbreaks can remove 35 to 55 percent of dusts being carried in moving air which would provide a substantial reduction of offensive odors carried off-farm. The amount of dust that is picked up or allowed to settle will depend on wind speed, direction of the wind, density of windbreak trees, height of windbreak trees and number of windbreaks.

Figure 6. Mature windbreaks around cropped fields may help lift and disperse odors during application of manure as nutrient soil amendment, in addition to sheltering crops from damaging wind.

Collection and storage of pollutant odors within trees (sink)

Scientific evidence of plant intake of livestock odors in field situations is limited, however there have been many studies done on the ability of plants to absorb air-polluting odors and chemicals. Trees and shrubs clean the air of micro-particles of all sizes by interception. Interception of air pollutants may be 20 times higher in treed or forested areas than non-forested cropped or barren lands. Conifers show a better ability to absorb air pollutants than deciduous trees.

Figure 7. In air pollution research, odorous gases and particles can be absorbed into the foliage of conifers and deciduous trees during the growing season. Pollutants diffuse inside leaves and needles through tiny openings called stomata or adsorb into waxy coatings that naturally cover leaf surfaces.

Odorous gases, chemicals and dust particles can become fixed to plant surfaces and can enter into the plant tissue in three ways: 1) gaseous diffusion through open stomata, 2) on wet leaves, soluble air pollutants can enter through stomata in a dissolved liquid form, 3) pollutants can absorb directly into plant tissues.

Windbreak trees and shrubs absorb air pollutants when they are healthy and not under drought stress. Trees and shrubs absorb more air pollutants when leaf surfaces are wet. Higher humidity can increase uptake of air pollutants into trees, which is commonly measured within tree canopies.

Micro-organisms cover plant surfaces and there is evidence that these micro-organisms associated with windbreak trees also contribute to absorbing odorous chemicals. Forests are often referred to as pollutant air filters. This may also apply to windbreaks trees.

Physical interception of odor particles

Trees are highly effective at physically intercepting dusts, gases and microbial particles that are carried in the wind. Windbreaks are commonly used to intercept and drop blowing snow, act as barriers to trap blowing sand and soil caused by wind erosion, catch spray drift of agricultural chemicals, and reduce and catch pollen drift from agricultural crops.

As leaf surface roughness increases, the capture ability of particles and odor increases. Leaves with complex shapes (large circumference to area ratios) collect particles most efficiently. Therefore, conifers may be more effective at intercepting livestock odors than deciduous tree and shrub species. Conifers also have leaves (needles) year around.

Figure 8. Like the air filters of home furnaces, windbreak trees, especially conifers, physically catch wind-borne odorous particles. Conifers have foliage year-round.

Windbreak design and planting

Selecting the species of trees and shrubs to plant will vary at each livestock facility and farm field site. Species selection should be based on the characteristics of each site including: soil type, natural drainage, common wind conditions, annual precipitation, natural range of each tree and shrub species and site needs. In addition, to maximize particulate trapping, select species based on high leaf surface roughness (plants with leaf hairs, leaf veins, small leaf size), complex leaf shapes, large leaf circumference to area ratios and medium to rapid growth rates.

It is usually best to select several species of trees and shrubs for use in windbreaks to prevent loss or destruction of the entire windbreak if attacking insect pests or tree diseases occur. Having diversity also offers a better chance for tree survival during alternating seasons of drought and wet soil conditions.

Windbreaks should consist of one to three rows of alternating conifer and deciduous species while windbreaks may be wider with more tree rows. Shrubs are generally planted in the outside or inside rows, followed by conifers with deciduous hardwoods towards the middle or along the downwind side where they can grow more efficiently. Tree varieties and placement for the windbreak should be managed to maximize odor interception and dilution of air, and reduce odor leaving the source.

Where site conditions allow, place plantings around the entire perimeter of the odor source.

Adjust windbreak porosities/densities to meet air movement needs for naturally ventilated livestock confinement systems.

Keep the inner row of windbreak plantings from all buildings and waste storage areas at least 10 times the exhaust fan diameter or 50 feet, whichever is farther.

Use wide “between row spacing” to increase particle surface area contact and foliage light levels.

Ideally once established, the tree barrier should have a density of about 60 percent for best results for wind management. Conifers such as spruce will provide uniform branch coverage from the ground level up. Tree rows should be spaced wide enough apart to allow access by a small tractor for mechanized management of vegetation.

Weed management is important during the first five years of tree establishment using herbicides, or plastic or organic mulch. Weed management is important until the young windbreak trees have overtopped most weed competition and are free to grow.

Managing Odor

Odor management is a result of the overall management of the farm operation. General maintenance of the buildings and the nutrition of the feed ration are normal farm management needs that can influence odor emissions. Waste management plans have become a standard part of livestock operations in recent years. Livestock odor management techniques fall into three areas:

1. *Preventing the generation of odor*, including feed additives, aeration, manure additives, etc.
2. *Capturing and destroying the odor*, including biofilters, waste storage covers, organic mats, etc.
3. *Dispersing or disguising the odors*, including vegetative or structural windbreaks, setback distances, site selection, etc.

In particular, structural or vegetative windbreaks placed near exhaust fans on tunnel-ventilated livestock and poultry buildings appear promising, primarily because the air jets issuing from the exhaust fans are diverted upward. This effect promotes mixing of the odorous, dusty airflow with the wind passing over the building, so that the plumes of air pollutants originating from the fans are made larger (extend higher) in addition to the physical trapping of odor particles on the windbreak.

Figure 9. Relevant design considerations and low-cost designs using UV-resistant tarpaulin or plastic material, roofing, or wood fastened to anchored pipe frames or posts are potential options for windbreak walls.

Windbreak structures may either be designed to withstand the same wind speeds as the buildings and be insured with the buildings, or lower wind speeds at reduced cost. If the windbreaks are not designed for maximum design wind speeds, a method of ensuring non-catastrophic failure is needed, such as breakaway ties fastening material to frames. The location of the windbreak affects the diversion of airflow from exhaust fans. Observations of windbreak action in several locations suggest that the windbreaks should be placed two to four fan diameters downwind from the fans to deflect fan airflow without back pressures, (Figure 11) and extend high enough to fully intercept the plumes of airflow issuing from the fans (e.g. 10-12 feet high for typical buildings).

Biofilters using biomass and microorganisms to treat ventilation air as it leaves the building have been used in the U.S. Some producers have installed windbreak walls using straw or other biomass. Windbreaks made from or incorporating straw have been installed on swine farms in North Dakota, Minnesota and Missouri and received favorable results. One facility in Minnesota with a biofilter achieved odor and H_2S reduction of 80-90% and NH_3 reduction of 50-60%. Weed control and rodent control were the primary problems experienced. A critical element in the use of biofilters is their dependence on power ventilated buildings where fans push the air through the filter. They don't work on naturally ventilated buildings.

Other benefits

In addition to odor management, vegetative windbreaks also act to reduce the seasonal cost of heating and cooling of farm buildings without disrupting ventilation in livestock barns.

Windbreaks may also reduce the spread of specific infectious disease of livestock by blocking, intercepting or diverting wind-borne infectious organisms away from buildings.

Windbreaks placed around farm fields reduce damage to forage and crops (preserve crop yield potential) caused by damaging turbulent winds while allowing normal air circulation to continue. Windbreaks reduce soil erosion by wind. Around pastures, mature windbreaks will relieve livestock of stress during hot summer days and cold windy winter conditions. Avoid planting trees and shrubs around livestock that are known to be poisonous.

Figure 10. Where barns are surrounded by solid forest plantation, it is important not to block ventilation fans with excessive tree growth. Thinning the plantation and pruning off lower branches can improve air circulation. Fifty to 100 feet is a good separation distance between trees and barn.

Acknowledgements

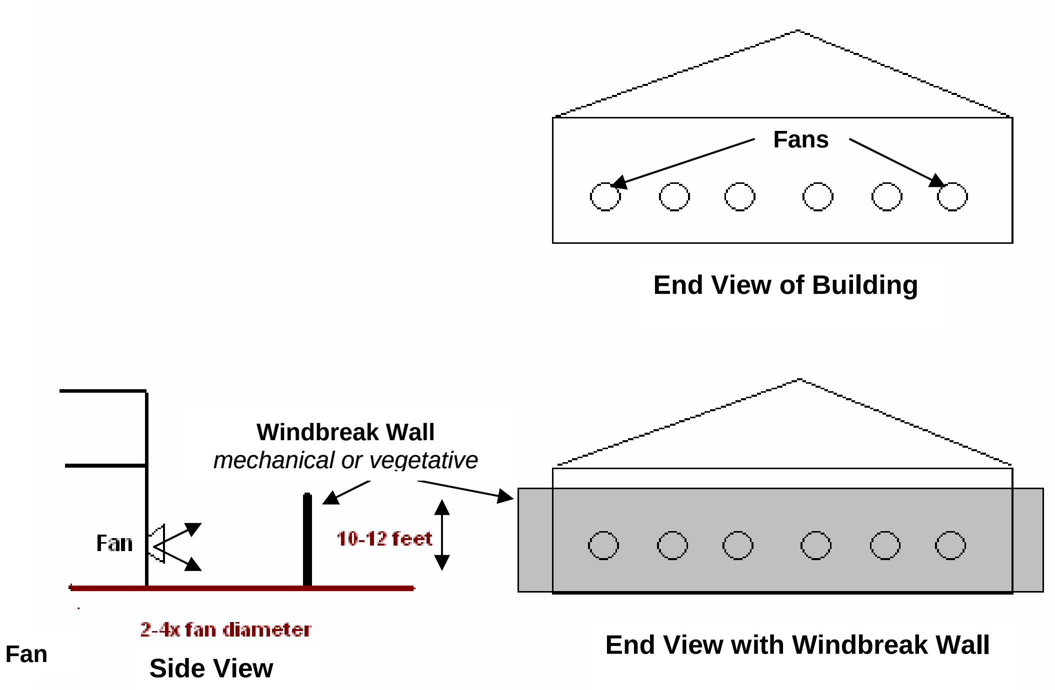
References used in this information sheet:

"Using Shelterbelts to Reduce Odors Associated with Livestock Production Barns" (January 2004) by Todd Leuty, Horticulture/Agroforestry Specialist, Ontario Ministry of Agriculture and Food.

"Air Quality and Shelterbelts: Odor Mitigation and Livestock Production – A Literature Review" 1999. John Tyndall and Joe Colletti; Iowa State University.

"Designs for Windbreak Walls for Mitigating Dust and Odor Emissions from Tunnel Ventilated Swine Buildings" 2000. R. Bottcher, R. Munilla, G. Baughman, and K. Keener. North Carolina State University.

Figure 11. Example layout of windbreak wall or biofilter for typical tunnel ventilated building.



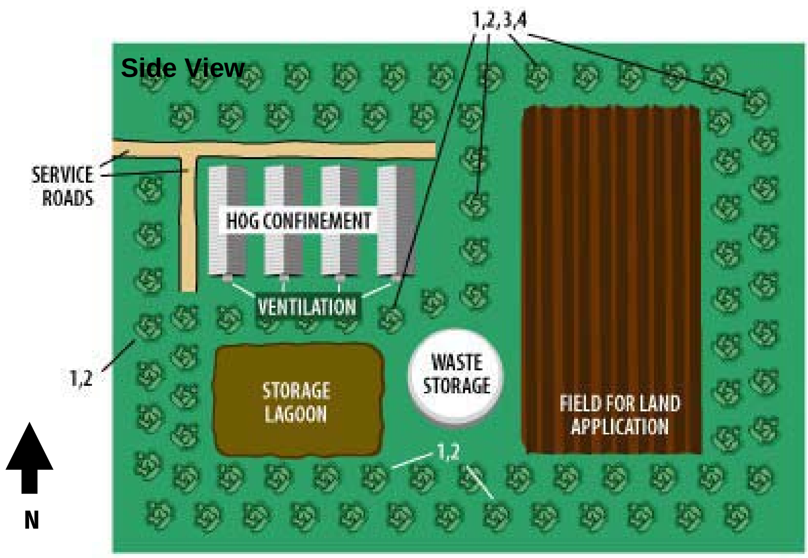


Figure 12. A hypothetical windbreak design for a swine facility. The numbers refer to the interaction and means by which the windbreak will mitigate livestock odor.

1. *Creation of air mixing turbulence*
2. *Dust deposition*
3. *Particulate interception*
4. *Pollution sinks*

Other important design considerations include: livestock type, odor sources, air/wind patterns, tree/shrub species, and aesthetics.

The Use of Vegetative Environmental Buffers for Livestock and Poultry Odor Management

J. Tyndall
Department of Natural resource Ecology and Management, Iowa State University

Species:	Swine, Poultry, Beef, Dairy
Use Area:	Animal Housing and Manure Storage
Technology Category:	Environmental Barriers
Air Mitigated Pollutants:	Particulate Matter, Odor and Ammonia

Description:

An odor mitigation technology that is drawing a lot of attention in Iowa and in other livestock producing states is the strategic use of shelterbelts – purposefully planted trees and shrubs usually arranged in linear patterns; a technical term for shelterbelts being used for odor mitigation is Vegetative Environmental Buffers or VEBs (Malone et al., 2006). Research evidence suggests that VEBs strategically located near and around livestock facilities can play an important incremental role in bio-physically and socio-psychologically mitigating odor in an economically feasible way (Tyndall and Colletti, 2007).

Mitigation Mechanism:

To a large degree the current livestock odor problem is characterized by high concentrations of odorous emissions (Volatile Organic Compounds – VOCs) that travel mostly unimpeded across highly modified agricultural landscapes. Research has demonstrated that tree barriers can impede, alter, absorb, and/or dissipate odor plumes and other emissions prior to contact with people. As air moves across vegetative surfaces, leaves and other aerial plant surfaces remove some of the dust, gas, and microbial constituents of airstreams. Trees and other woody vegetation are among the most efficient natural filtering structures in a landscape in part due to the very large total surface area of leafy plants, often exceeding the surface area of the soil containing those plants upwards of several hundred-fold (Tyndall and Colletti, 2007).

Vegetative Environmental Buffers have been shown to incrementally mitigate odors, particulates, and ammonia through a complex of dynamics (Tyndall and Colletti, 2007; Lin et al., 2006; Patterson et al., 2007). Among the most important dynamics are: 1) enhancement of vertical atmospheric mixing through forced mechanical turbulence – leading to enhanced dilution/dispersion of odor; 2) odor filtration through particulate interception and retention – odor largely travels by way of particulates; capturing particulates also captures odors; 3) odor/particulate fallout due to gravitational forces enhanced by reduced wind speed; 4) adsorption and absorption of ammonia onto and into the plant – this is due to a chemical affinity that ammonia has to the waxy coating on tree leaves; 5) softening socio-psychological responses to odor due to improved site aesthetics and creating "out of sight, out of mind" dynamics; and 6) improved producer/community relations by using highly visible odor management technology.

The quantification of odor mitigation via the use of VEBs is a difficult process and is approached in a multi-analytic way by means of field trials, wind tunnel examinations and computer simulation. Field quantification is particularly difficult and explains the general paucity of data available for assessment (Colletti et al., 2006). Still, a few studies have recorded incremental mitigation benefits in the form of reduced particulate and odor movement downwind. For example, at a working pullet facility in Delaware Malone et al., 2006 analyzed the impact of a simple VEB and recorded a 49% reduction in particulate movement, a 46% reduction in downwind ammonia concentration, and a 6% (but not statistically significant) reduction in downwind poultry odor concentration. Lin et al. (2006) discusses a 22% reduction in downwind swine odor distance and states that odor concentration was reduced by a factor of three in a series of Canadian field studies examining VEBs. Wind tunnel and computer simulations have also quantified reduced particulate and odor movement due to the presence of strategically located trees (Laird, 1997; Lammers et al., 2001); for example, at Iowa State University, Laird (1997) recorded via wind-tunnel modeling a 56% reduction in off-farm dust movement. Figure 1 below displays the general bio-physical dynamics.

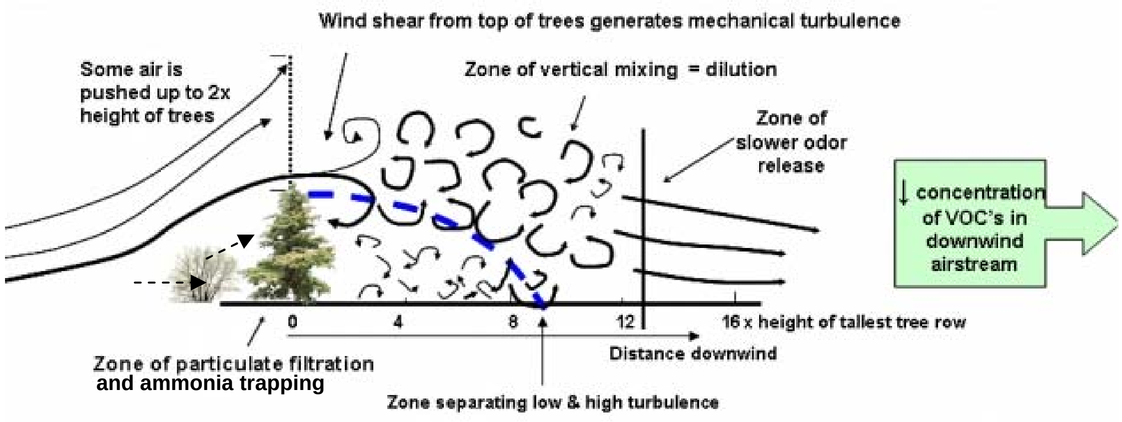


Figure 1. Generalized schematic of VEB odor mitigation dynamics. Note that the magnitude of dynamics listed in text above and shown here are site and VEB specific.

Applicability:

VEBs have been examined primarily in swine and poultry contexts (e.g. swine: Tyndall and Colletti, 2007; poultry: Malone et al, 2006), but have also been recommended for dairy producers (Bolinger and May, 2006). As an odor mitigation technology VEBs have advantages over many other approaches in terms of application. VEBs are adaptable to the landscape and production variability of different livestock production sites and production regions and are amenable to use near or around all sources of livestock odors (e.g. animal buildings, manure storage areas, and crop land receiving manure applications). A VEB is a technology that can be considered production technology neutral, in that producers who raise animals in a variety of ways—confinement (mechanically or naturally ventilated), hybrid confinement, hoop house, pasture—can plant designed VEB systems. There is also information that the presence of trees in agricultural landscapes has socio-aesthetic advantages that most other odor mitigation technologies lack completely (Tyndall and Colletti, 2007). VEBs are a size neutral odor mitigation technology, that is, production sites of all scales can plant trees. Furthermore, as opposed to other odor mitigating technologies that are mechanistic and tend to depreciate over time with concomitant higher maintenance requirements and cost, VEBs may be the only odor control technology that theoretically increases in effectiveness over time. The effectiveness of VEBs in mitigating odor comes from providing complex ecological infrastructure within an otherwise ecologically simplified system. As the trees grow larger and more morphologically complex their ability to mitigate odors through particulate filtration and increased landscape turbulence can become increasingly efficient. Of course, this implied improvement over time is contingent upon the long term health and management of the VEB system and continuance of appropriate manure management.

Limitations:

The physical effectiveness of VEBs in mitigation is extremely site specific and ultimately a function of a myriad of factors: VEB design, ambient weather conditions, landscape topography, direction and distance to nearest critical receptor (e.g. neighbors, communities), scale of emissions, manure management protocols followed and other odor mitigation technology utilized. Therefore, from an odor mitigation perspective, site specific VEB design is of critical importance. There is also a distinct difference between a production site that has a strategically designed VEB and a site that simply has “trees on it”. Studies have shown that “strategically” placed trees have a beneficial physical impact on downwind odor (Tyndall and Colletti, 2007), whereas trees used simply for visual landscaping or are naturally part of the landscape may not (Nicolai et al., 2004). Furthermore, “mitigation” does not mean odor elimination and the degree to which VEBs contribute to odor mitigation will vary from farm to farm. While VEBs have been shown to contribute in incrementally reducing the downwind concentrations of odorous chemicals/ compounds and particulates, what this means to the highly subjective perception of odor being a “nuisance” is a very difficult question to answer. The benefits of the incremental contribution of VEBs to odor reduction are likely to be found in variously reducing the combined effects of the FIDO factors of an odor event – the frequency, intensity, duration, and offensiveness of odor. Therefore the use of VEBs is not a substitute for comprehensive odor management strategies rather their use should be thought of as complimentary technology used within a “suite” of odor management strategies.

Cost:

Costs for VEB systems are highly variable and are site/design specific. There are three main categories of expenses associated with VEBs: 1) Site prep costs, 2) tree establishment costs, and 3) long term maintenance costs. Table 2 below outlines the typical expenditures that a producer might expect in establishing and maintaining a VEB system. It should be noted that the majority of the total cost (usually in the range of 40-70%) is "upfront" and is tied to the cost of the initial planting stock (e.g. older, larger nursery stock can be considerably more expensive than bare-root seedlings but such an investment may "buy time" in VEB establishment). Long term maintenance costs vary depending upon the design and overall health of the VEB. It should be recognized that there are expenditures that occur regularly throughout the life of a VEB and maintenance is an annual process, however as a VEB system matures the annual maintenance requirements will likely decrease over time.

Table 2. Custom rate survey of typical VEB transaction costs and year(s) in which they occur.

Cost item	Year(s)	Price/ Unit [1] (US 2008 $)	Source of Price Information [1]
Site Prep			
Plowing	0	$13.60/ac	a
Spray purchase	0	$1.25/ac	b
Spraying operation	0	$19.00/ac	c
Disking	0	$20.00/ac	c
Shelterbelt Establishment			
Tree purchase costs	1	Variable [2]	d,e,f [2]
Shrubs purchase cost	1	Variable [2]	d,e,f [2]
Tree planting cost	1	$1.00 – $5.00/tree	c
Shrub planting cost	1	$1.00 – $5.00/tree	c
Permeable plastic mulch	1	$633/linear mile	g
Long Term Maintenance			
Tree replanting	2-4	Variable [3]	d,e,f
Shrub replanting	2-4	Variable [3]	d,e,f
Weed control (e.g. mowing)	Annual	$31.46/linear mile	c
Tree Pruning	Every 3-5 years	$31.46/linear mile	c
Other relevant costs			
Overhead/management [4]	Annual	Variable	-
Land rent [5]	Annual	Variable [5]	h

[a] Iowa State University, 2008.; [b] Based on 2008 cost of 2.5 gallon container of generic glyphosate; [c] Iowa State University, 2003; [d] Cascade Forestry Nursery, 2007; [e] Kelly Tree Farm (online catalog), 2008; [f] Iowa Department of Natural Resources, 2007; [g] PFRA, 2008; [h] Iowa State University, 2007.

[1] Units are variable depending upon cost item; prices listed as per linear mile assume a treatment strip of 10' by 5280' or a "price/ acre" to "price/ linear mile" conversion factor of 1.21. All costs include labor and fuel where relevant. Unless otherwise given, all listed costs represent an average price presented in the various Custom Rate Surveys used; [2] Species and plant size specific; [3] It is assumed that tree and shrub mortality will equal 8% during the second through the fourth years after establishment; [4] Includes taxes, insurance, energy requirements, etc; [5] If any land is taken out of production for the planting of a VEB then land rent should be factored in.

Implementation:

When implementing a VEB, there are several key design issues. A proper VEB can serve as both a visual screen and an odor filter. To this end, one needs to account for prevailing summer and winter winds and key visual pathways (e.g. screening a manure storage area from passing traffic). Key planting zones can then be identified so as to maximize the effects of filtration and increased turbulence and provide screening from desired angles and directions. See Figure 2 below for an example VEB design and Table 3 for a financial analysis of this example system.

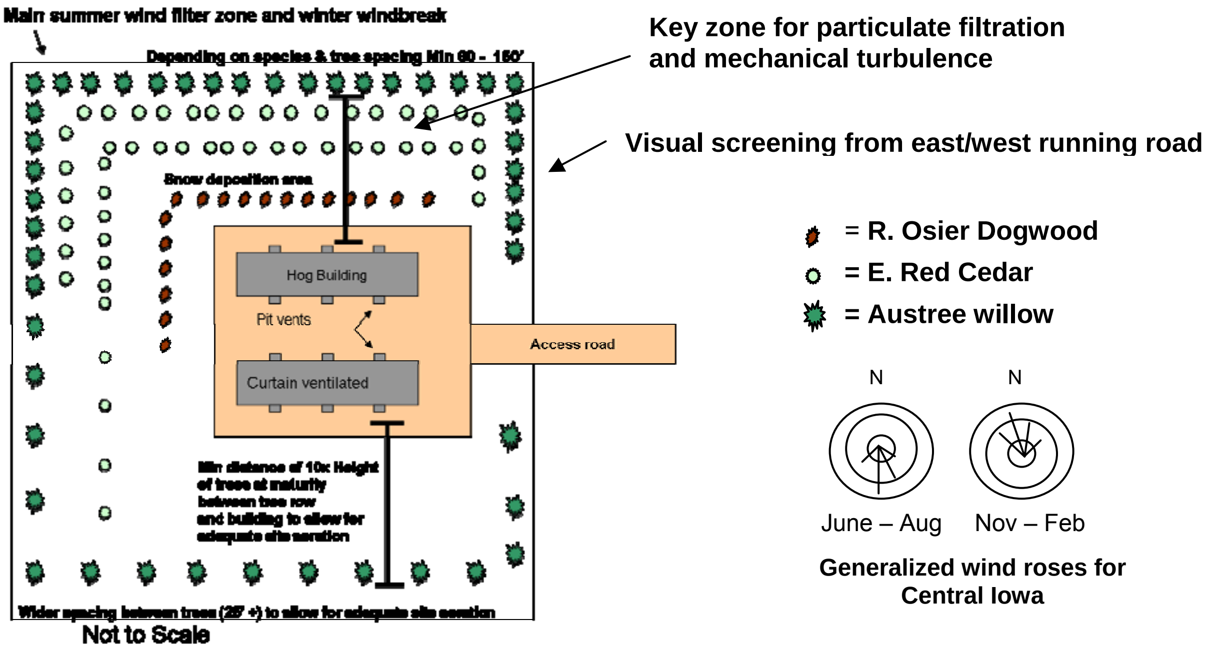


Figure 2. Example general VEB design for a two building swine finishing unit. VEB is designed for Central Iowa wind patterns. Ultimately VEB designs (e.g. planting patterns, locations, species used) will be variable and site specific. Figure modified from Tyndall and Colletti, 2007.

The calculated costs of the example VEB (Figure 2) are presented in a number of ways in Table 3 below. The present value of costs (at 7%) for each scenario was calculated to capture the total costs of establishing and maintaining the shelterbelts over a 20 year period. This was calculated with and without land rent factored in. Because 40% of the total costs of this example VEB comes during the site preparation and establishment phase (primarily from the costs of the planting stock) these "up-front" costs are isolated and presented. Total costs were also calculated as annual capital recovery payments (total costs in the form of uniform annual payments over a 20 year period). Additionally, costs per pig produced are also presented.

Table 3. General shelterbelt parameters and financial analysis for VEB in Figure 2. Summary of the total costs at 7% (real alternative rate of return). All costs are presented in 2008 dollars US.

Figure 2 VEB				Cost Presentation for Figure 2 VEB	
Total trees planted	140	81	33	Present Value Costs w/o land rent	$1,741
Space between trees (feet):	6 - 25'	15 - 25'	6'	Present Value Costs with land rent	$2,452
Species planted	Austree willow	Eastern red cedar	R. Osier Dogwood	Upfront costs (Site prep & establishment only)	$737
Initial planting stock size [1]	15" cutting	18"-24" bare root	2'-3' potted	Capital Recovery Costs (Annual cost over 20 years)	$164
General growth rate for species [1]	Very fast; 5-10 ft/yr	Medium; 1-2 ft/ yr	Medium to fast; 2+ ft/yr	Total costs per pig produced over 20 yr period	$0.05/ pig

[1] Larger planting stock is more expensive but with these initial stock sizes in 3 years Austree willow ≈ 25'-30'; Red cedar ≈ 6'- 9'; Red osier Dogwood ≈ 4' - 5'. Growth rates, however, are variable depending on site conditions, health of planting stock and region.

For the VEB shown in Figure 2 above, a VEB system as outlined in Table 2 would cost a producer over a 20 year period a little over $1,741, with about $737 (42% of the total cost) coming during the initial establishment phase. These total costs translate to about $0.05 per pig produced.

All VEBs need to be established in appropriately prepared planting areas (see section below on site preparation) using regionally appropriate nursery stock. As suggested in Table 2 above, all VEBs should have a well thought out long-term maintenance plan to ensure the overall health of the system and to keep long term costs/labor down. Another key design factor is mixing the species used. This is recommended for two main reasons: 1) increased species diversity reduces the risk of whole scale pest/pathogen loss, and 2) some species (e.g. hybrid willows and poplars) feature very rapid growth but often have relatively short healthy life spans (e.g. 15-20 years), mixing in slower growing but longer lived species will allow for a robust and mature VEB system to remain after other species are removed.

There are three main hazards that must be avoided when utilizing VEBs yet these are all easily avoided with proper VEB design and implementation. VEB designs need to prevent: 1) winter snow deposition problems by planting trees too close to access roads and buildings. In Central Iowa for example winter winds largely come from the North/Northeast. Therefore VEBs planted to the north and east of buildings/roads should plan for a planting distance anywhere from 50-200' away. 2) Trees should not be planted so close to buildings that they prevent appropriate air flow into and out of the buildings. For mechanically ventilated buildings trees can be planted as close as 5-6 times the diameter of the fans and avoid causing back pressure, but that distance may not be healthy for the trees. A minimum distance of 40 feet away from fans has been recommended (Malone et al., 2006). For naturally ventilated systems, one does not want to impede necessary summer winds (which in Central Iowa tend to come from the South/South east) blowing into the buildings. 3) Visibility into and out of the facility grounds is important, so keep the mature heights of trees in mind when planting trees near access roads.

Appropriate site preparation is one of the main keys to the long term health of tree plantings and will contribute toward lower tree mortality, faster tree growth and ultimately, lower time, money and effort in managing the system over the life of the operation. In many cases the grounds of a livestock facility - the area where trees are to be planted – features highly compacted soils, subsurface soil piling, poor drainage, etc. Many VEBs fail (e.g. high tree mortality) because of inadequate site preparation. When planting trees directly into tilled crop ground, site preparation requirements will likely be lessoned. Table 4 below outlines possible site preparation requirements prior to tree planting. It is always recommended that a producer seek advice from a forestry professional before proceeding with a VEB system.

Table 4. Generalized site prep requirements prior to tree planting for new livestock facilities:

1 year before VEB establishment (Fall: Oct-Nov):	Year 1 (Spring – late April/Early May)
– 4' Kill strip (e.g. Round Up) – Disk/cultivate (work soil to 8" depth) – Seed cover crop (e.g. clover, rye)	– Disk/ cultivate again & if possible rototill – Soil should have no clumps & minimal residue – Grass seed may be desired (sow outside of mulch and or weed mat zones)

Technology Summary:

Tree based Vegetative Environmental Buffers (VEBs) can be a cost-effective way for livestock producers to incrementally mitigate odors, particulates and ammonia emanating from their sites. Research supports the possibility of 6-15% reduction in odor and in certain situations possibly up to 50% reduction in ammonia and particulates. As air moves across vegetative surfaces, leaves and other aerial plant surfaces remove some of the dust, gas, and microbial constituents of airstreams while increased mechanical turbulence can boost the vertical mixing of air streams thereby enhancing dilution. VEBs are relatively inexpensive and straight forward to manage and therefore in many cases can easily fit into current odor management plans. While the physical effectiveness of a VEB in mitigating odors and the overall expense of establishing and managing a VEB are highly variable and site specific, their use can incrementally enhance (in an additive way) a livestock production system's ability to reduce negative odor impacts for just a few cents per animal produced.

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