AUSTRALIAN PORK LIMITED

National Environmental Guidelines for Indoor Piggeries (NEGIP)

May 2018

PROJECT TITLE:

National Environmental Guidelines for Indoor Piggeries (Third Edition)

PROJECT NUMBER:

APL 2015-2221

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This document should be cited as follows:
Tucker, RW 2018. National Environmental Guidelines for Indoor Piggeries - Third Edition, APL Project 2015-2221, Australian Pork Limited, Kingston, ACT, Australia

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Acknowledgements

Australian Pork Limited (APL) thanks the principal author of the Third Edition of the National Environmental Guidelines for Piggeries, Robyn Tucker of Livestock Environmental and Planning.

The significant contribution by Janine Price formerly of APL is also acknowledged.

The review of the NEGIP commenced with consultative meetings held in Melbourne on 20 & 21 June 2017 to discuss the findings of all recent Australian piggery environmental research and how these could be included in the Third Edition. The time and effort by the following people in developing the Third Edition of these guidelines is also acknowledged:

Rob Bayley	Blackwood Piggery
John Bourke	JW & GE Bourke Pty Limited
Laurie Brosnan	BettaPork
Paul Byrnes	Department of Water and Environmental Regulation Western Australia
Heather Channon	Australian Pork Limited
Greg Ferrier	Department of Economic Development, Jobs, Transport and Resources, Victoria
Darryl D'Souza	SunPork Farms
Mitchell Furness	Department of Agriculture and Fisheries, Queensland
Geordie Galvin	Astute Environmental (formerly Pacific Environment Limited)
Benjamin Gilmour	Department of Agriculture and Fisheries, Queensland
Zane Harper	CEFN
Mark Hogan	Mark Hogan Consulting
Melinda Hunt	Environment Protection Authority South Australia
Deb Kerr	Australian Pork Limited
Tim Kingma	Kerang East Piggery Investment Group Pty Limited
Bjorn Ludvigsen	SunPork Farms
Kristian Millar	Department of Economic Development, Jobs, Transport and Resources, Victoria
Steven Miller	Australian Pork Limited
Jayce Morgan	Department of Primary Industries, New South Wales
Paul O'Leary	Pig Improvement Company
Patrick Page	Agriculture and Food Western Australia
Neil Repacholi	Goulburn-Murray Water
Andree Rowntree	Wonga Piggery
Nigel Sargent	Environment Protection Authority, New South Wales
Selina Stillman	Department of Primary Industries, New South Wales
Wendy Tao	Environment Protection Authority Victoria
Jeremy Whitby	Queensland Natural Pork Holdings
Gary Whytcross	Environment Protection Authority, New South Wales
Denise Woods	Australian Pork Limited

Foreword

This Third Edition of the National Environmental Guidelines for Indoor Piggeries (NEGIP) aims to support the Australian pig industry's ongoing commitment to ensuring pig production in Australia is environmentally sustainable. The NEGIP are live, science-based guidelines that are updated regularly so that they can incorporate the latest scientific research outcomes and regulatory changes.

Pig producers in Australia need to demonstrate due diligence by taking every practical step to minimise the impact of their operations on the environment. There are complexities as environmental regulations vary between jurisdictions, from Commonwealth to State and Local Government. Generic guidelines used by government agencies are not always applicable to the management of environmental risks at piggeries. The NEGIP seek to provide a holistic approach to address jurisdictional requirements.

It is important that stakeholders are kept up to date with the latest industry research and development. The NEGIP provide guidance for environmental assessments for indoor piggery developments and options for existing piggeries to achieve positive environmental outcomes.

The realisation of the pork industry's environmental goals will not be possible without the support of all relevant stakeholders. Australian Pork Limited (APL) has received considerable stakeholder support for this update of the NEGIP, in particular from state government departments and environmental authorities, the research community and producers from all major pig-producing states. I trust that the Third Edition of the NEGIP will be adopted by all stakeholders to help the industry comply with due diligence requirements and meet environmental goals.

Enzo Allara
Chairman
Australian Pork Limited

Abbreviations

ACCU	Australian carbon credit unit
AI	artificial insemination
APL	Australian Pork Limited
BMP	biological methane potential
BOD	biochemical oxygen demand
CAP	covered anaerobic pond
CEC	cation exchange capacity
CHMP	cultural heritage management plan
CHP	combined heat and power
DB	dry basis
DM	dry matter
dS	Deci siemens
EC	electrical conductivity
EC_{se}	electrical conductivity of a saturated soil extract
EKP	exchangeable potassium percentage
EMP	Environmental Management Plan
EPA	Environment Protection Authority
ERF	Emissions Reduction Fund
ESP	exchangeable sodium percentage
FS	fixed solids, also called ash
GHG	greenhouse gases
GSF	gestation stall free
ha	hectare
HDPE	high density polyethylene
HLA pond	heavily loaded anaerobic pond
HRT	hydraulic retention time
K	potassium
kg	kilogram
LDPE	low density polyethylene
m	metre
m/s	metre(s) per second
m^3	cubic metre
mg	milligram (s)
mL	millilitre
mm	millimetre
ML	megalitre
MSDS	material safety data sheet
NATA	National Association of Testing Authorities
N	nitrogen
N_2O	nitrous oxide
NEGIP	National Environmental Guidelines for Indoor Piggeries
NEGROP	National Environmental Guidelines for Rotational Outdoor Piggeries

NH_3	ammonia
NH_4	ammonium
NO_3 or NO_{3-}	nitrate
NPI	National Pollutant Inventory
OU	odour unit
P	phosphorus
PBC	phosphorus buffer capacity
PIRMP	Pollution Incident Response Management Plan
PO_4	phosphate
PP	polypropylene
Pork CRC	Pork Co-operative Research Centre
RDS	rational design standard
SAR	sodium adsorption ratio
SEPS	sedimentation and evaporation pond system
SPU	standard pig unit
t	tonnes
t/ha	tonnes per hectare
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TKP	total Kjeldahl phosphorus
TS	total solids
TWL	top water level
UPSS	underground petroleum storage system
VFS	vegetative filter strip
VS	volatile solids
yr	year

Overview

Australian Pork Limited (APL) worked with industry, the community and government to develop the first edition of the National Environmental Guidelines for Indoor Piggeries, released in 2004. These guidelines provided a general framework for managing the environmental issues associated with piggeries and were tailored to the circumstances and conditions most commonly encountered. The Second Edition was released in 2010.

This Third Edition of the National Environmental Guidelines for Indoor Piggeries (NEGIP) includes updates based on the latest research findings and changes in acceptable design and management practices. It differs from the previous editions, provide siting and design guidance only for indoor piggeries, while the National Environmental Guidelines for Rotational Outdoor Piggeries (NEGROP) (Australian Pork Limited 2013) provide similar guidance for the outdoor sector. The NEGIP are supported by the Piggery Manure and Effluent Management and Reuse Guidelines (Australian Pork Limited 2015c), which provide management information.

The NEGIP are made up of seven parts:

Chapters 1-19
National Guidelines - provides advice on planning, siting and designing piggeries to minimise the risk of impacts to the environment

Appendix A:
National Odour Guidelines for Piggeries - details methods for assessing odour impact

Appendix B:
Environmental Risk Assessment - details methods for assessing the likelihood that the piggery will have an impact on the environment, allowing for preventative and mitigation actions to be taken

Appendix C:
Complaints Register - shows an example of a Complaints Register that can be used to keep track of complaints received, communications and corrective action taken

Appendix D:
Sample Analysis - describes methods for collecting samples (e.g. water, soil, manure and effluent) for analysis

Appendix E:
Useful Conversions - lists conversions that may be used in implementing the NEGIP

Glossary:
Definitions used in the NEGIP

Chapters 1-19

National Guidelines - provides advice on planning, siting and designing piggeries to minimise the risk of impacts to the environment

1. Introduction

The Australian pork industry is an important contributor to Australia's economy, adding some $5.2B to Australia's GDP in 2015-16. This included production of some 378,000 t/yr of pig meat worth $1.4B and a $3.8B indirect contribution (ACIL Allen Consulting 2017). The industry includes about 2700 farms spread mainly throughout the wheat-sheep belt. Approximately 90% of the Australian pig herd is kept indoors in either conventional or deep litter housing, with the remaining 10% in rotational outdoor piggeries.

Maximising opportunities for sustainable industry growth is a strategic focus of Australian Pork Limited (APL). To assist in this regard, APL worked with industry, the community and government to develop the first edition of the National Environmental Guidelines for Indoor Piggeries, which was released in 2004. A national approach promotes consistency in proposals for new developments and facility upgrades across the states and territories. It also helps producers to comply with licence and approval conditions and with current regulatory standards. APL is committed to regularly updating the National Environmental Guidelines for Indoor Piggeries to ensure they remain technically up to date to reflect changes in science, community expectations and piggery management. An updated (second) edition was released in 2010. The scope of the Third Edition of the National Environmental Guidelines for Indoor Piggeries (NEGIP) is different. It provides updated advice on planning, siting and best practice design of indoor piggeries to allow people developing these piggeries to minimise the risk of impacts to the environment. The NEGIP are supported by the Piggery Manure and Effluent Management and Reuse Guidelines (Australian Pork Limited 2015c) which provide management guidance. Detailed siting and management guidance for rotational outdoor piggeries are now provided in the National Environmental Guidelines for Rotational Outdoor Piggeries (NEGROP) (Australian Pork Limited 2013).

It is intended that the NEGIP will be used by local government and referral agencies in assessing piggery proposals. The guidelines have been tailored to the circumstances and conditions most commonly encountered by piggery proposals, although site specific risk assessment is recommended. While they provide specific siting and design recommendations, alternative approaches may achieve the same level of environmental protection and should be considered. Many of the environmental issues discussed in the NEGIP are interlinked, and siting and design must consider all aspects, not single issues in isolation, to optimise environmental practice.

The NEGIP may be used to complement, develop or update existing state piggery guidelines. However, it is important to realise that they may not fully cover or match all state requirements. Each state has its own legislation and guidelines for the siting and development of piggeries, and more general requirements for water use, land clearing, composting, waste management and other issues. Applicable local government departments and local government officers can identify relevant planning requirements, legislation, codes of practice and guidelines. The user is responsible for ensuring that a proposal complies with the specific requirements of the relevant state or territory regulatory authorities.

The NEGIP focus on environmental issues specific to piggeries. Legislative and planning requirements over-ride industry guidelines and codes of practice, including these national guidelines. Therefore, developers need to be aware that piggery developments may be assessed in a manner or scope outside that provided in the NEGIP. Operators must also meet their responsibilities for workplace safety, animal welfare and other relevant legislation.

2. Planning Principles

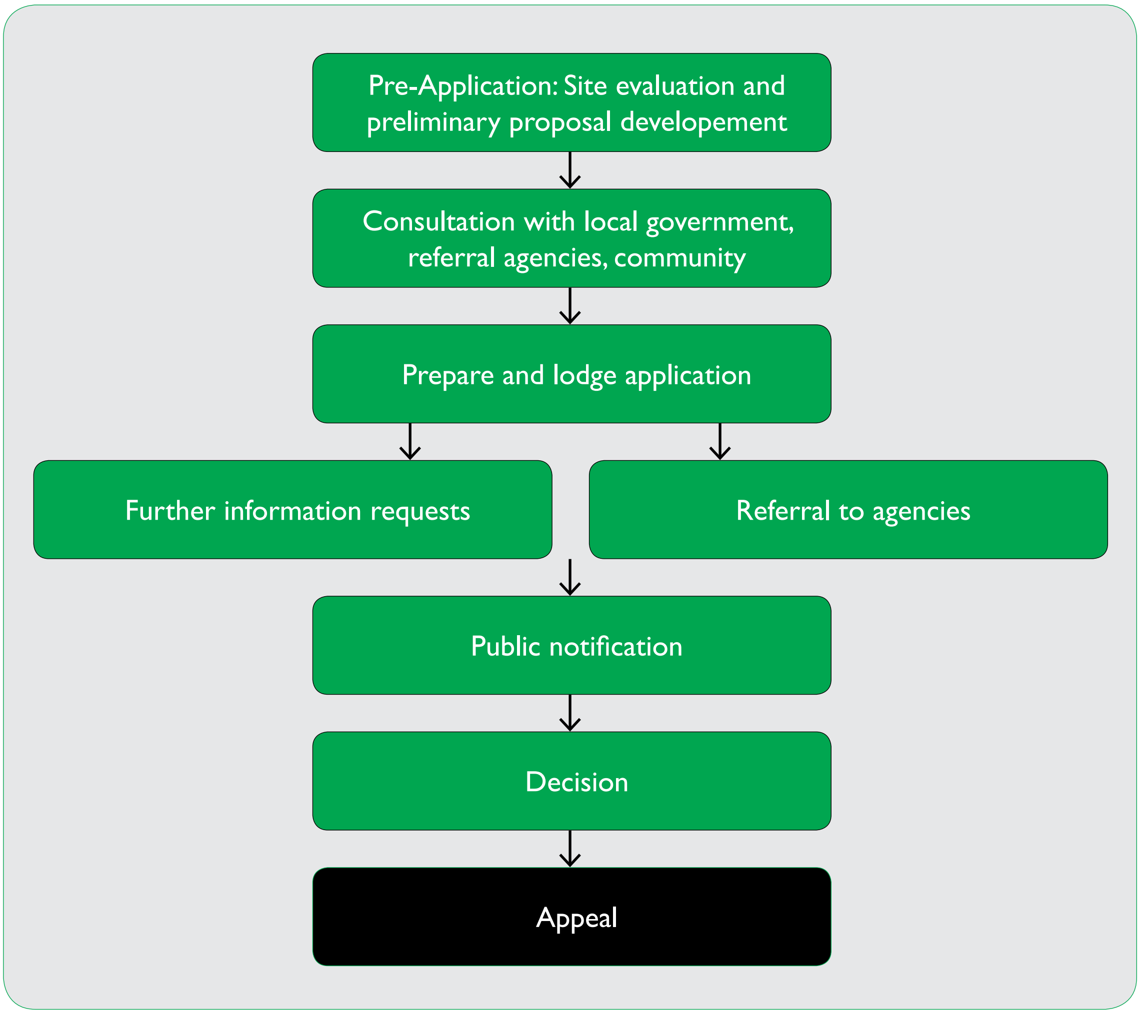
In all states of Australia, anyone keeping pigs will generally need a local council approval if they have more than pet pigs. The thresholds triggering the need for a planning permit vary between states and shires. Table 2.1 summarises the planning permit and environmental licence triggers for each state. **At the time of publication, multiple states were reviewing their planning systems, including definitions and thresholds affecting piggeries. Proponents should consult their responsible authority (council) for up to date guidance.**

TABLE 2.1 State Planning Permit and Environmental Licence Triggers at Publication Date

State	Class	Requirements
Queensland	Intensive Animal Husbandry	Less than 400 SPU – need for development approval depends on planning scheme. More than 400 SPU – need development approval and an environmental authority
New South Wales	Intensive Livestock Agriculture	Development approval is required where more than 20 sows or 200 pigs are to be kept. A council may also limit the number of pigs kept by a smaller operator and prescribe how they are kept. Environment Protection Licence needed: • more than 200 pigs or 20 breeding sows in a sensitive area • more than 2,000 pigs or 200 breeding sows.
Victoria	Intensive Animal Husbandry	A planning permit is needed to operate a piggery. Any piggery with >5000 pigs needs an EPA works approval.
South Australia	Intensive animal keeping	Council development approval is required. EPA licence needed if 5,000 or more pigs, or 500 or more pigs in a water protection area.
Western Australia	Animal Husbandry - Intensive	Planning approval is required. Works approval and registration needed for >500 but < 1,000 animals Works approval and licence needed for ≥ 1,000 animals. Offensive Trade Registration if the premises is situated in a prescribed area.
Tasmania	Intensive Animal Husbandry	Planning approval is required.
NT	Intensive Animal Husbandry	Development approval needed.

The planning process varies between states and territories but generally follows the process provided in Figure 2.1.

FIGURE 2.1 Generalised Planning Process



The same general process applies to new piggery developments, expansions or a change in material use (e.g. the construction of new housing and construction or significant modification of the effluent treatment system or a manure storage pad). The first step in planning involves site evaluation and preliminary proposal development. It covers the identification of site constraints including any land use or zoning issues (talk to the responsible authority, usually your local council), a preliminary assessment of the vulnerability of natural resources at the piggery site and planned reuse areas, determination of required and available separation distances to sensitive land uses (e.g. residential zones and houses) and basic design concept (size of the facility, type of housing and proposed manure and / or effluent management facilities).

The required separation distances can be determined using the methodology in Appendix A of these guidelines. Level 1 uses the most conservative approach, followed by Level 1.5, Level 2 and Level 3. Consequently, where a facility meets a lower level (e.g. Level 1), there is no need to demonstrate that other levels are met.

While the odour assessment process is primarily designed to confirm that a piggery proposal will be adequately separated from existing or approved sensitive land uses (e.g. town or rural residential zones or houses), councils may also apply the methodology when considering applications for rezoning, sub-divisions or houses to protect approved piggeries and avoid future nuisance complaints caused by sensitive land uses locating within the required separation distance in the future.

Communication and engagement with council, referral agencies, the community and neighbours is paramount to a positive outcome. A pre-lodgment meeting with the responsible authority and any referral agencies, ideally an on-site meeting, is essential in identifying if the site is suitable, and determining the major issues to be addressed in an application. The primary referral agencies in each of the main pig producing states at the time of publication are:

Queensland	Department of Agriculture and Fisheries www.daf.qld.gov.au
New South Wales	Environment Protection Authority https://www.epa.nsw.gov.au
Victoria	Environment Protection Authority www.epa.vic.gov.au
Tasmania	Department of Primary Industries, Parks, Water and Environment www.dpipwe.tas.gov.au
South Australia	Environment Protection Authority http://www.epa.sa.gov.au
Western Australia	Department of Water and Environmental Regulation www.der.wa.gov.au

Referral to water boards, state or main roads departments and other agencies may also be required, depending on the site. Council will be able to provide advice.

It is important to note that councils and referral agencies may have some requirements that are different or additional to the recommendations in these guidelines. Having the right conversations with councils and agencies will identify these requirements.

It is recommended that applicants consult with the local community, particularly immediate neighbours, following the pre-lodgment meeting. This consultation is mandatory in some states when an EPA Works Approval or licence application is required.

The next step is to gather and compile the information that will support the application. Table 2.2 summarises this information. The NEGIP provide recommended siting and design information, while the Piggery Manure and Effluent Management and Reuse Guidelines, the APL Nutrient Balance Calculator and the APL Environmental Management Plans (EMP) template and other resources on the APL website (www.australianpork.com.au) can be used to make management decisions. For large or complex applications, professional assistance will be necessary.

After the application forms and supporting information are lodged, and the application fee paid, the assessment process will commence. This may involve a request for further information and referral to relevant agencies before the public notification (advertising) stage commences. Once the responsible authority has evaluated the proposal, taking into account submissions from referral agencies and submitters, a decision will be made. The applicant and the submitters then have the opportunity to appeal the decision.

Table 2.2 Information to Accompany a Planning Application

Applicant details

Site description (including plans) and assessment

☐ real property description
- land tenure
- land area
- cadastral plan

☐ land zoning, and zoning of the surrounding land

☐ climatic data
- mean / median monthly rainfall
- monthly decile 9 (90th percentile) rainfall
- rainfall intensity data (1-in-20-year 24-hour storm)
- mean monthly evaporation
- mean monthly maximum and minimum temperatures
- seasonal wind speed and direction

☐ soil description for the piggery complex site (including applicable physical properties) and reuse areas (including chemical properties and texture)

☐ description of groundwater resources and geology of the site
- groundwater depth
- depth and type of soil or rocks overlying groundwater
- assessment of the suitability of groundwater for use in piggery
- details of any licences or allocations held

☐ description of surface water resources on the property or in the vicinity of the property (show designated watercourses and other waterbodies on a map)
- details of any bores on the subject property
- assessment of the suitability of surface waters for use in piggery.
- details of any licences held

☐ description of the current vegetation of the site and the extent of any proposed clearing and offsets

☐ identification of any items, sites or places of cultural heritage significance

Description of the proposed piggery operation

- ▢ total pig and standard pig unit (SPU) numbers
  - herd composition
  - numbers and weights of incoming and outgoing stock
  - expected mortalities
- ▢ description of housing and layout plans
- ▢ water requirements for drinking, cooling, cleaning, dust control and shandying with effluent for irrigation.
- ▢ bedding requirements and bedding sources
- ▢ feed requirements, sources and storage areas
- ▢ staff numbers

Environmental impact assessment

- ▢ community amenity - particularly odour, dust, noise, traffic and visual. Determine suitable separation distances to sensitive receptors. Evaluate measures for minimising and addressing amenity nuisance including ongoing consultation with neighbours and pro-active complaints management.
- ▢ surface waters – quality and quantity needed, potential impacts to water quality and any likely effects on other potential users
- ▢ groundwater – quality and quantity needed, potential impacts to water quality and any likely effects on other potential users
- ▢ vegetation – identify any clearing needed and the likely effects of this on rare and threatened species and communities. Detail any proposed offsets.
- ▢ protection of items, sites or places of cultural heritage significance
- ▢ evaluation of proposed effects on soils of reuse areas
- ▢ summary of design and management features to minimise adverse environmental impacts
- ▢ proposed environmental monitoring and reporting
- ▢ environmental Management Plan (EMP) - an EMP focuses on the general management of the whole farm, taking into account the environment and associated risks. It should
  - document design features and management practices;
  - identify risks and mitigation strategies (including biosecurity risks. For more guidance refer to www.farmbiosecurity.com.au.);
  - include a nutrient management plan for reuse areas that provides a nutrient balance (nutrients applied in effluent or manure, nutrients removed by crop harvest and allowable losses) and proposed management of the reuse areas;

- include ongoing monitoring to ensure impacts are minimised; and
- detail processes for ensuring continual review and improvement.

Note: The APL website includes an on-line template for a simple EMP. It also provides a nutrient balance tool for reuse areas.

Plans showing or describing:

- ☐ topographic details – relief, watercourses and drainage lines; and flood levels
- ☐ recent aerial photograph/s – showing subject property and location of nearby residences
- ☐ farm plan – showing current land uses; proposed sites for piggery complex, mortalities composting or burial site, reuse areas; property entry point and on-farm roads; on-farm bores; buffers; the location of dams and watercourses; and the location of any soil conservation or drainage works
- ☐ piggery complex layout plan - including the location of manure management areas and / or effluent treatment facilities and the mortalities management area
- ☐ pollution Incident Response Management Plan (PIRMP) for New South Wales producers.
- ☐ hygiene practices, for example frequency of hosing, flushing or pit emptying, or bedding top-up and replacement
- ☐ estimation of manure production and mass balance estimate of the nutrients in manure and effluent
- ☐ design of effluent collection, pre-treatment and treatment system
- ☐ sizing and proposed management of the reuse areas, including location; area (ha); buffers and other measures to protect runoff quality, amenity and health: reuse method and timing; and nutrient balance (nutrients applied in manure or effluent, nutrients that will be removed by crop harvest and allowable losses). Details of off-site reuse, including a product disclosure statement.
- ☐ description of mortalities management or disposal, including plan for managing a mass mortality event
- ☐ traffic - calculate heavy vehicle and car numbers, describe the routes that will be used including site access (consider road safety), and outline parking provisions. There is also a need to negotiate with applicable state and local governments regarding road upgrading and maintenance responsibilities

3. Over-Arching Environmental Outcomes

To operate in an ecologically sustainable manner, piggeries need to be sited, sized, designed, constructed and managed to ensure all aspects of the environment are protected. This includes protection of community amenity, soils, surface waters, groundwater, biodiversity and cultural heritage.

Piggeries also need to operate in a way that ensures all aspects of the environment are protected. This includes community amenity, soils, surface waters, groundwater, biodiversity and cultural heritage.

Proponents must be able to demonstrate that they will meet the following environmental outcomes.

Piggeries should be designed, sited, constructed and operated so as to:

- minimise the risk of amenity impacts
- identify properties of effluent and manure (e.g. water, nutrients and organic matter) and to develop systems for their effective use
- maintain or improve the capacity of reuse areas to grow plants, without deterioration in land quality by nutrient overloading, salinisation, soil structural decline, erosion or waterlogging
- protect groundwater and surface waters from nutrient, biological or salt contamination
- prevent adverse impacts to native vegetation and fauna as a result of clearing and manure and effluent reuse
- protect items, site or places of Aboriginal cultural heritage significance.

These NEGIP provide siting and design guidance specifically aimed at achieving these outcomes. However, alternative approaches that will also meet these environmental outcomes are encouraged.

4. Types of Piggeries

This section defines the different forms of pig production and piggeries, including an outline of the basic differences in design. It also defines a standard pig unit (SPU).

4.1 Pig Production

Pig production can be divided into three main production stages:

- breeding
- weaning
- growing / finishing.

The breeding unit of a piggery includes the boars,gilts, gestating or dry sows, farrowing sows, lactating sows and sucker pigs.

The dry sows are between litters and awaiting either mating (natural or artificial insemination) or confirmation of pregnancy and gestation. The Australian pork industry is committed to gestation stall free (GSF) housing. Sows are kept in loose housing from five days after mating until one week before they are ready to give birth.This can be in individual pens or group housing providing each sow has freedom of movement, meaning she can turn around and extend her limbs. In some cases, bedding may be provided. Generally, boars are housed individually.

The farrowing section of a breeding unit houses sows that are due to farrow (give birth) within one week, and lactating sows with their piglets from farrowing to weaning (typically 3-4 weeks). Generally, each sow and litter is kept in an individual farrowing crate with a creep area that is separated from the sow area by side rails.The creep area is needed to protect piglets from being crushed by their mother, and to provide the piglets with creep feed and additional heating.

Piglets are typically weaned at 3-4 weeks of age.Weaner pigs are generally aged up to 8-12 weeks.Weaners can be stressed by the change in diet from milk to solid feed, mixing with other pigs and environmental changes, increasing their susceptibility to disease.Therefore, newly weaned pigs must be housed in a warm, dry, draft-free environment to counter these abrupt changes.

Grower and finisher pigs are usually aged from 8-12 weeks up to 19-22 weeks of age but sometimes finisher pigs are older, depending on market requirements.These pigs require less environmental controls than newly weaned pigs.They are typically group housed.They are usually fed in 'phases', so that the diet is tailored to provide the optimal nutrition required for each growth stage.

Individual production units can include one or more of the above pig life cycle stages, but generally fall into one of the following categories:

- farrow-to-finish
- breeder
- weaner
- grower / finisher

A farrow-to-finish piggery includes the breeder, weaner and grower / finisher stages. Many farrow-to-finish piggeries operate with 'closed herds', where no new animals are introduced, and replacement breeding animals are selected from within the herd and / or from artificial insemination. Other farrow-to-finish piggeries bring in some or all of their replacement breeding animals from outside herds.

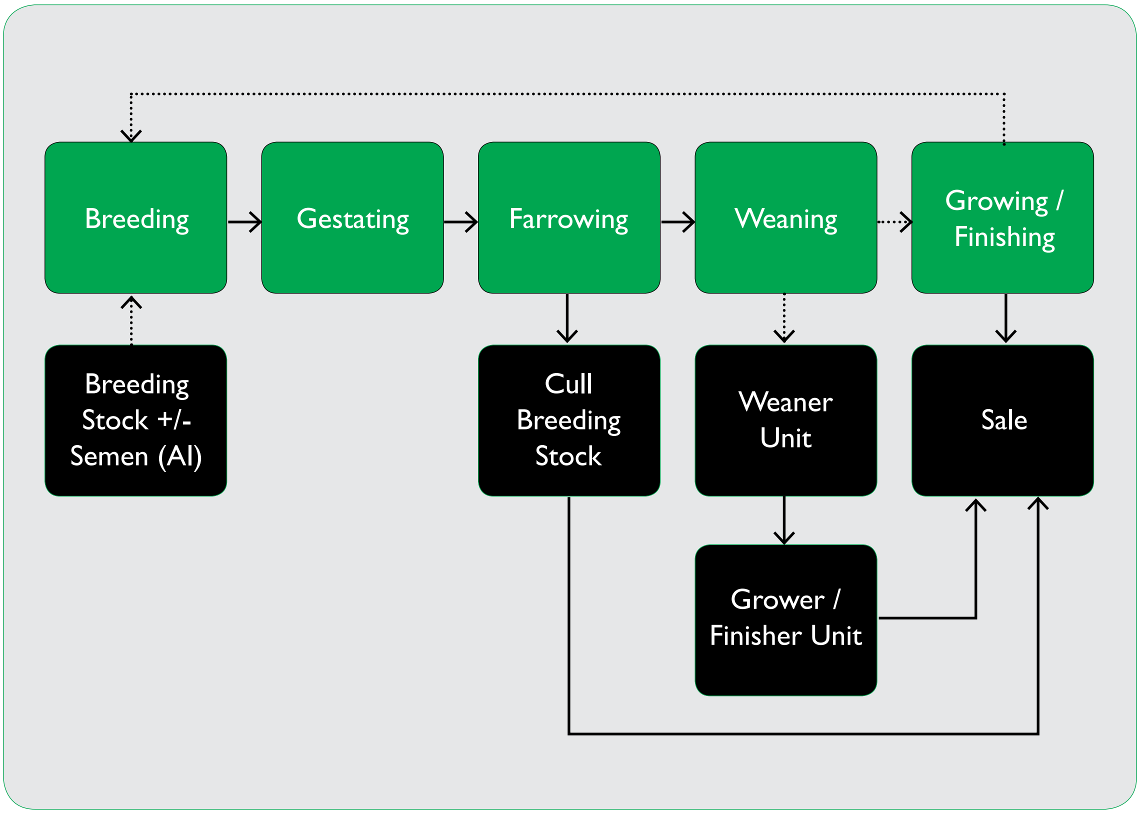
Multi-site piggery systems geographically separate different production stages.

A breeder piggery includes breeding stock, with the progeny being removed from the piggery at, or just after, the weaning phase.

A weaner or nursery piggery includes only weaner pigs. Most weaner pigs are raised in a controlled environment (mechanically ventilated) conventional shed or in deep litter housing.

A grower/finisher piggery may include weaners as well as grower and finisher pigs. The pigs live in conventional sheds or deep litter housing or in a combination of these.

FIGURE 4.1 summarises the most common pig production systems. The top row constitutes the elements of a farrow-to-finish unit.



4.2 Piggery Definitions

From a planning perspective, pig farming is generally regarded as intensive animal production or intensive animal husbandry because the pigs are fed for the purpose of production, relying primarily on prepared feedstuffs designed to meet their nutritional requirements.

A ***piggery*** or ***pig farm*** is defined as a property where pigs are kept or bred. Pigs may be kept in indoor piggeries or outdoor piggeries. In an ***indoor piggery***, the pigs are accommodated indoors in either conventional or deep litter housing.

Conventional piggeries typically house pigs within steel or timber framed sheds. The sheds usually have concreted under-floor effluent collection pits or channels that collect manure, waste feed and washwater. The pits are regularly flushed or drained to remove effluent from the sheds.

Deep litter piggeries typically accommodate pigs in shelters made up of hooped metal frames covered in a waterproof fabric, similar to the plastic greenhouses used in horticulture. However, skillion-roof sheds and converted conventional housing may also be used. The bases of the shelters are concrete or compacted earth. Straw, sawdust, rice hulls or similar loose material covers the floor, absorbing manure. The used bedding is generally removed and replaced when the batch of pigs is removed, or on a regular basis.

Outdoor piggeries the pigs live outdoors. While they can forage, they mainly rely on prepared feedstuffs to meet their nutritional requirements. The two types of ***outdoor piggeries*** recognised by Australian Pork Limited are: rotational outdoor piggeries and feedlot outdoor piggeries.

In ***rotational outdoor piggeries***, the pigs live outdoors in paddocks, with basic huts for shelters. The use of the paddocks is rotated between a pig phase and a pasture or cropping phase. During the stocked phase, the pigs are supplied with prepared feed, but can also forage. During the non-pig phase, the area grows pastures or crops that are harvested to remove the nutrients deposited in pig manure during the pig phase.

Feedlot outdoor piggeries continuously accommodate pigs in permanent outdoor pens, sometimes with partial roofing or basic huts for shelter. The pens must be located within a controlled drainage area. This is so the nutrient-rich stormwater runoff from within these areas is controlled and kept separate from stormwater runoff from areas outside the pig pens. The base of the pens must be sealed to minimise nutrient and salt leaching.

These NEGIP do not provide siting, design or management guidance for outdoor piggeries. This information is provided in the National Environmental Guidelines for Rotational Outdoor Piggeries (NEGROP). The APL booklet, "Rotational Outdoor Piggeries and the Environment" (Australian Pork Limited 2015d) provides a useful summary of the NEGROP.

A ***piggery complex*** includes:

- all buildings or areas where pigs are housed
- adjoining or nearby areas where pigs are yarded, tended, loaded and unloaded
- adjacent areas where piggery manure or effluent are accumulated or treated, pending reuse or transport off-site
- areas where feed is prepared, handled or stored (including feed mills).

The piggery complex does not include the reuse areas.

The ***reuse areas*** are land where effluent and / or manure are beneficially used as inputs to a cropping or forage system. Reuse areas may be on the same farm as the piggery, or on other land.

4.3 Defining Piggery Capacity in Standard Pig Units

A ***Standard Pig Unit (SPU)*** is a unit for defining piggery capacity by manure production where the manure and waste feed produced by one SPU contains the amount of volatile solids (VS) equivalent to that typically produced by an average size grower pig (90 kg VS/yr) (see Figure 4.2). VS is the biodegradable organic component of total solids (TS) or dry matter (DM). Fixed solids (FS), which are the inorganic or mineral components, make up the balance. SPU multipliers for other pig classes are based on their comparative VS production.

FIGURE 4.2 Piggery Manure and Waste Feed for One SPU

Grower pig manure ~64 kg VS/SPU/yr* + waste feed = 90 kg VS/SPU/yr ~26 kg VS/SPU/yr#

* based on feed consumption of 1.6 kg/hd/d and a wheat-based diet
# based on 5% feed wastage

This definition for SPU assumes that the pig is fed a standard diet, has a normal growth rate and has typical feed wastage.

There are two methods for specifying the total number of SPUs in a piggery. The first is to use the standard multipliers provided in Table 4.1 with the herd composition to determine the number of SPUs. Table 4.1 provides example pig and SPU numbers for a typical 100 sow farrow-to-finish piggery.

TABLE 4.1 SPU Standard Multipliers

Pig Class	SPU Standard Multipliers	Pig Numbers (and SPU) for typical 100-sow farrow-to-finish piggery
Gilt (100-160 kg)	1.8	12 (21.6)
Boar (100-300 kg)	1.6	5 (8)
Dry sow (160-230 kg)	1.6	87 (139.2)
Lactating sow (160-230 kg)	2.5	13 (32.5)
Sucker (1.4-8 kg)	0.1	142 (14.2)
Weaner (8-25 kg)	0.5	248 (124)
Grower (25-55 kg)	1.0	236 (236)
Finisher (55-100 kg)	1.6	311 (497.6)
Heavy finisher (> 100 kg)	1.8	-
		TOTAL 1054 (1073.1)

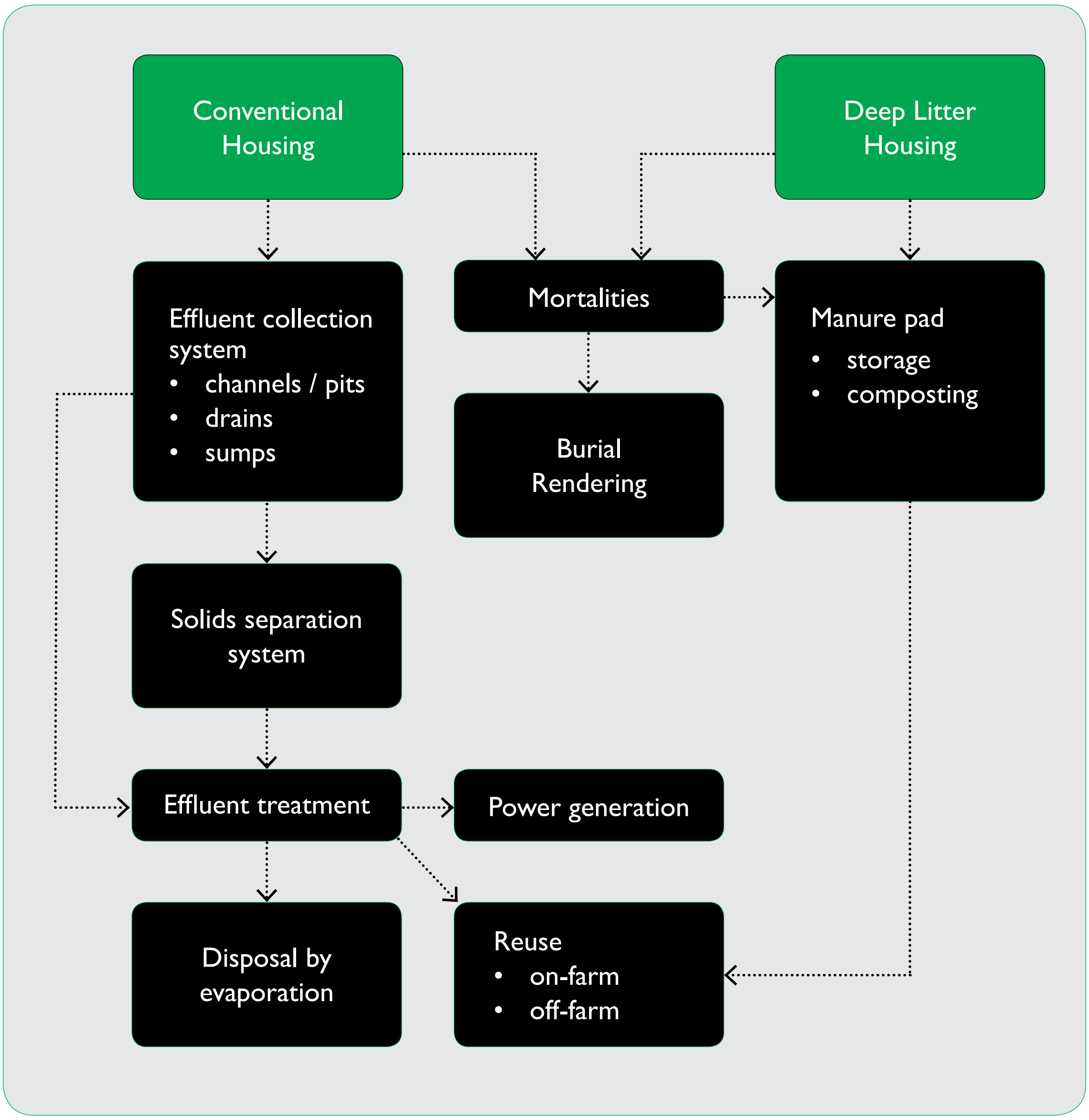
The second method is to use the PigBal 4 model to generate SPU numbers. PigBal 4, a Microsoft Excel® spreadsheet, is the national industry standard tool for estimating piggery manure production (for further details of Pigbal 4, see section 9.1). While PigBal 4 uses standard multipliers for the breeding stock and suckers, the multipliers for weaners, growers and finishers are produced using an in-built live weight regression formula. If using this method, the pig classes should be determined by the timing of major diet changes. The SPU regression equation then assigns multipliers accordingly. PigBal 4 displays the results on its Herds Details page.

4.1.3 Piggery Manure and Effluent Flow

Conventional piggeries and deep litter piggeries produce different manure streams that require different management.

Figure 4.3 shows the main elements of a piggery, including the possible flow of manure and effluent through the piggery complex and on to the reuse areas.

FIGURE 4.3 Piggery Manure and Effluent Flow Diagram



5. Site Suitability

Environmental advisers can provide guidance on the suitability of a proposed site for a piggery. The main factors to consider include:

- statutory land use planning restrictions
- availability of suitable land area for both the piggery complex and reuse areas
- availability of a reliable water supply
- road access
- access to power
- access to labour, inputs and markets
- climate
- the site's natural resources
- possible effects on community amenity
- any cultural heritage sensitivities
- any possible future expansion plans

Each of these factors is discussed below. It is important to realise that this list is not exhaustive. Consultation with key experts will identify additional important constraints.

***Environmental outcome:* Protection of natural resources and the community through good piggery siting.**

5.1 Planning Restrictions

When selecting a piggery site, the current and future land zoning of the property and surrounding land, and other land use constraints, should be discussed with the local council and referral agencies early in the planning process. This may save time and money by quickly identifying properties that are unsuitable because of land use zoning or other constraints such as planning overlays; mining leases; wind turbines or power lines; or underground pipelines, communications or electricity cables. It may also identify other development or building proposals that have recently been discussed or lodged with council. State government agencies, water boards and catchment management authorities may also have planning and flood level tools that can be helpful in assessing suitability for a piggery complex or for on-farm or off-farm reuse. Specialist advisers can provide professional assistance particularly with regards to planning legislation, water supply, soil assessments, separation distances to sensitive land uses and transport routes. They can also collate the available information to identify whether a site will be workable and identify potential constraints.

5.2 Available Land Area

Property size is an important consideration. Ideally, a property should be large enough to contain the piggery complex and any required areas for manure and effluent reuse, although it is possible to transport effluent and manure for off-site reuse. Owning land around the piggery complex prevents encroachment by nearby developments, although owning the required separation distances to sensitive land uses is not a pre-requisite. Hence, separation distances may go over the property boundary but should not impact on receptors including houses, rural residential zones and towns. The dimensions and shape of the property may limit siting due to boundary buffer requirements. Suitable sites on a long, narrow farm may be more limited than those on a square property with the same area (ha) due to boundary buffer requirements.

The suitability of land for effluent or manure reuse will depend on the land use capability, effluent or manure properties, proposed reuse system, availability of irrigation water (if required) and nearby sensitive land uses and natural resources. Applicants must demonstrate the suitability of proposed reuse areas, regardless of whether these are on-farm or off-farm.

5.2.1 Reliable Water Supply

Water is needed for drinking, shed cleaning, fire control and sometimes for summer cooling, road dust control and dilution of effluent for irrigation. It is essential to confirm that enough water of suitable quality is available at a proposed site.

The drinking water requirement varies depending on climate, season and drinker type. Approximately 8 L /SPU/day is required. The needs of a breeding herd may be 50% higher. An additional 10-50% should be allowed for drinking wastage.

On-site storage of at least one to two days drinking water should be provided. Shed flushing and hosing requirements vary widely, depending on shed type and design, whether pits or flush channels are installed, and whether treated effluent is recycled for flushing. They may represent a significant water demand.

It is essential to confirm that water can legally be used in a piggery. Water licensing requirements vary between states. The holding of a water entitlement or allocation may not guarantee the supply of that volume. Pump testing of bores is recommended.

Water quality influences herd health and performance, effluent pond function and manure and effluent reuse options. Potential water sources should be analysed to confirm the supply is fit for purpose. Suggested analysis parameters include:

- total dissolved solids (TDS)
- bicarbonate
- calcium
- fluoride
- magnesium
- nitrate
- nitrite
- sulphate
- hardness
- pH
- *E. coli* (for surface water supplies).

Check if the supply is susceptible to blue-green algal blooms. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000) provide specific guidance on water quality for stock drinking and irrigation purposes. However, a pig husbandry or veterinary consultant can also advise on drinking water suitability.

A reliable irrigation supply can promote more consistent, higher crop or forage yields from the reuse areas. This can reduce the required area (ha) for reuse due to higher nutrient uptake rates (kg/ha). Effluent can also be mixed or "shandied" with fresh water to suit specific crop requirements, prevent soil salinity issues or provide sufficient water to suit a particular irrigation system.

5.2.2 Suitable Road Access

Roads used by piggeries must be of a suitable standard for the trucks that will transport pigs, feed and any required bedding. The safety of all road users must be considered when selecting and designing property access points. These should provide good visibility in both directions and allow for safe entry and exit by vehicles. Where alternative local routes are available, those avoiding nearby houses and other sensitive locations like schools, school bus pick-up points and community areas should be considered. Routes with sealed roads generally have lower maintenance requirements and may also generate less dust at nearby houses. Discuss proposed routes and property entry points with council and the state roads department (if applicable) early in the planning process to identify any concerns or upgrade requirements.

5.2.3 Access to Power

If mains power will be needed for the functional operation of the piggery, then access to a supply should be considered during site selection. Connecting power can be very costly at some sites.

5.2.4 Access to Inputs, Labour and Markets

Piggeries need to be able to source labour to operate. They should also be located close to feed supplies. Choosing a site close to an abattoir may reduce pig transport stress.

5.2.5 Climate

Climate affects many environmental aspects of a piggery's operations. In particular, it can affect shed heating and cooling requirements. Rainfall patterns affect water availability for piggeries relying on surface waters. Rainfall patterns and evaporation influence the required wet weather storage capacity for effluent treatment ponds at conventional piggeries. The climate also affects the types and yields of crops grown on reuse areas. Odour dispersion is heavily dependent on wind speed and direction patterns as well as other factors. These are covered in detail in Appendix A.

The Bureau of Meteorology website (www.bom.gov.au) and the Rainman Streamflow Analysis tool (https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/cropping-efficiency/rainman) are useful sources of climatic data.

5.3 Natural Resources

5.3.1 Topography

The topography of a site and surrounds has implications for amenity and environmental protection, the layout of the piggery complex and reuse options.

Topographical barriers (hills, ridges etc.) between the piggery and sensitive locations are desirable. For some, the sight of a piggery is not aesthetically pleasing. For others, it is a reminder of the presence of a piggery, which may trigger complaints. Sites that are elevated and have a clear line of sight from nearby roads or neighbouring houses are less desirable than those that are visually shielded.

The movement and dispersion of odour from the piggery depends on the topography in the vicinity of the property. Under stable conditions, concentrated odour tends to gravitate down hills, so nearby receptors downslope from the source are more vulnerable. Odours can also travel significant distances with very little dispersion if the development is in a confined valley. These factors warrant serious consideration when selecting the site for a piggery complex.

The ideal site for an indoor piggery is relatively flat, to minimise the earthworks for the shed footings. If the housing site is higher than any effluent treatment or stormwater ponds, effluent and leachate can be conveyed into these by gravity. This can eliminate the need for effluent collection sumps and pumping equipment, which may be prone to blockages and breakdowns, as well as incurring ongoing energy costs. Excess soil removed during pond construction can be used to build-up the base of sheds, to allow gravitation of effluent into the pond system.

For reuse areas, it is important to consider drainage and soil erosion risk. A gentle slope will promote some drainage which may avoid water-logging and pooling, particularly in heavy soils. However, land that is too steep may promote nutrient loss through soil erosion or stormwater runoff. The ideal slope depends on soil properties, land use, vegetative cover, rainfall intensity, agronomic practices and the soil conservation measures that are in place.

5.3.2 Soils

A preliminary investigation should identify the range and distribution of soil types on the property. Consider the suitability of soils for building pads, effluent treatment systems, manure storage, carcass composting pads or burial pits and reuse. For example, loam to medium clay loam soils are often preferred for reuse areas, as they usually drain well and retain nutrients. Clays and clayey sands and gravels best suit earthen pads for deep litter piggeries, effluent ponds, manure storage sites and carcass burial pits, since these soils can be compacted to provide a low permeability base.

Doing a soil survey and chemical and physical analysis early in the planning phase helps to identify:

- the need for imported clay or synthetic liners for deep litter piggery pads, effluent ponds, manure storage areas and carcass burial pits or composting pads. For further guidance on analysis requirements, see Skerman et al. (2005): https://www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/constructing-effluent-ponds or Skerman (2005) https://www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation.

- the types of erosion controls and management that could be needed during construction and operation.
- the suitability of land for manure and effluent reuse. Table 16.1 provides recommended analysis parameters.

Soil analysis data for reuse areas also provides a benchmark for assessing future monitoring results.

FIGURE 4.4 Example of a typical soil profile

5.3.3 Water

5.3.3.1 Surface Water Protection

Good piggery siting, design and management practices will effectively protect surface water quality. This is important since the entry of manure nutrients, organic matter and sediment into surface waters may cause a number of environmental problems. They may:

- promote excessive algae and aquatic weed growth. When this growth dies, its decay strips oxygen from the water, killing aquatic life and creating offensive odours.
- affect the suitability of water for consumption by animals and humans, particularly due to elevated nitrate-nitrogen levels.
- trigger potentially toxic blue-green algae blooms where the phosphorus concentration is elevated.

Separating the piggery complex and reuse areas from watercourses, preventing uncontrolled releases of manure and effluent, and adopting good reuse practices will protect surface water quality.

Good design will also protect stormwater by keeping runoff that may be contaminated with manure or dust separate from clean runoff. The bases of sheds and shelters should sit above natural surface level to prevent entry of stormwater runoff. Roof runoff, which may contain dust, should be diverted using guttering; this can be used for shed cleaning. The banks of effluent ponds should sit well above natural surface level. Bunding around manure storage areas and mortalities composting areas should confine potentially contaminated water and preclude the entry of extraneous clean runoff water.

5.3.3.2 Flood Risk

Piggery complexes should be sited above the 1 in 100 year flood line, since flooding may cause stock losses, building damage and surface water contamination. All-weather access to the piggery complex is also essential for feed delivery and pig transportation. Hence, access should be above the 1 in 100 year flood line too. Information on land submerged by a 1 in 100 year flood is often available from the local government authorities, or state water resources agencies.

Piggery reuse areas should be above the 1 in 5 year flood level. Where this is not possible, levee banks may be constructed (with appropriate approvals/permits) to protect land from flooding.

5.3.3.3 Groundwater Protection

Groundwater is also protected through careful selection of the piggery site and reuse areas. Groundwater vulnerability depends on the depth to groundwater, soil type, geology, water quality and other factors. Sites with light soils and shallow groundwater pose a high risk for groundwater contamination. These sites should be avoided, as this may significantly increase the standard of design and management for effluent ponds, manure storage or composting pads, and effluent and manure reuse, and may increase groundwater monitoring requirements.

At vulnerable sites, effluent and manure need careful management to prevent nutrient leaching into groundwater. Nitrogen is highly mobile when in the nitrate form and is readily transported in drainage water. While most soils are capable of safely storing some phosphorus, excessive applications over prolonged periods may eventually result in leaching into groundwater. Potassium is also a readily soluble nutrient that leaches when oversupplied in the soil.

Ideally, effluent and manure reuse areas should be located on land where groundwater is deep, stored within confined aquifers or well protected by a clay layer. The risk to groundwater from reuse depends upon the protection afforded by soil type (e.g. a deep clay layer may afford good protection, a sandy loam soil provides relatively poor protection); the geology; the type of aquifer (e.g. a confined aquifer versus an alluvial aquifer); and the way effluent and manure are used.

The consequences of nutrient or salt leaching to groundwater depend on the quality of the groundwater (e.g. potable water versus brackish water) and its potential uses. However, it is important to protect all groundwater so that options for current and future use are not restricted.

5.3.3.4 Flora and Fauna

Native vegetation, including trees, shrubs, herbs and grasses, and the habitats it provides, can be environmentally sensitive. Proponents should consult with the local council and the applicable state government agency early in the planning process to identify any native flora or fauna sensitivities that may affect site suitability, and any specific measures that might be needed to protect these. At a federal level, vegetation clearing is controlled through the *Environment Protection and Biodiversity Conservation Act 1999*. The states also have their own land clearing legislation; the controls vary according to jurisdiction.

Where a site has relatively sensitive receptors, maintaining remnant vegetation between the piggery and receptors or planting a tree and shrub buffer around the piggery complex will help to visually screen the piggery and may promote odour, dust and noise dispersion depending on its location, structure and width.

5.4 Community Amenity

Most conflicts between piggery operators and neighbours relate to odour, but they sometimes relate to noise, dust, flies and rodents, pathogens or visual amenity. Conflicts arising from these issues are often very emotive, and the people involved sometimes experience great personal stress. In the long-term interests of community harmony and farm security, conflicts must be avoided and, if this is not possible, resolved. Good site selection is fundamental to minimising community amenity impacts. However, appropriate layout, design, management and a good communication strategy are also necessary. The main community amenity issues are discussed in the following section and should be considered carefully when selecting a site for a piggery development.

5.4.1 Odour

Odour nuisance is a very complex issue. Careful site selection is imperative in minimising the likelihood of odour nuisance. However, this should be supported by good design and management. An odour assessment can determine if nearby receptors are likely to be protected. Providing suitable separation distances is crucial (see section 6.2 and Appendix A).

5.4.2 Noise

Each state and territory has its own regulations or guidelines pertaining to noise. Noise is generated by the piggery itself, equipment used on other parts of the farm (e.g. pumps) and piggery traffic. On-farm noise sources should be well separated from sensitive land uses to minimise the likelihood of nuisance for nearby receptors. Careful selection of traffic routes and property entry points, and suitable scheduling of traffic movements will reduce the risk of nuisance traffic noise.

5.4.3 Dust and Smoke

Nuisance from dust should be minimised through good siting, design and management. Traffic movements along unsealed roads and spreading of dry manure can generate significant dust. Choosing routes with either sealed roads, or good separation to houses, lowers the risk of dust impacts. Selecting manure reuse areas that are well separated from receptors also reduces the risk of nuisance from dust. Burning of mortalities and rubbish, which creates smoke, is discouraged.

5.4.4 Flies, Rodents and Other Vermin

Siting piggeries away from sensitive land uses reduces the risk of flies, rodents and other vermin causing nuisance for neighbours. However, good management of manure, mortalities and waste or spilt feed is the primary control. Refer to the "Industry Rodenticide Stewardship Plan" (Australian Pork Limited 2016) before using rodenticides.

5.4.5 Pathogens

APL has investigated the pathogens present in pig effluent and the public health risks associated with effluent reuse (Blackall 2004 and Blackall 2001). The research found that the range of pathogens potentially present in Australian piggery effluent is much narrower than the range present in human sewage. Significantly, piggery effluent lacks many of the major pathogens that are of concern when reuse of human sewage is considered (e.g. *Vibrio cholerae* and human pathogenic viruses such as noroviruses). The only pathogens in piggery effluent that need consideration are bacteria, as the only virus likely to be present is rotavirus, and this virus does not generally cross the species-host barrier

Of the pathogens potentially present in piggery effluent, *campylobacter*, *salmonella*, *erysipelothrix* and *E. coli* (as an indicator organism) are probably of most interest from a public health perspective. Analysis of effluent from the effluent treatment ponds of thirteen south-east Queensland piggeries identified low campylobacter counts in eleven final ponds, and low salmonella counts in only three final ponds. *Erysipelothrix* and *rotavirus* were not detected in any final pond. The results were evaluated using a quantitative microbial risk assessment approach for a real-life scenario in which piggery effluent was being used to irrigate turf. The study found that relatively small separation distances (e.g. 125 m at a wind speed of 0.5 m/s and 300 m at a wind speed of 2.5 m/s) were needed to minimise any health risks from campylobacter and salmonella in the irrigation aerosols.

Providing appropriate buffers between reuse areas and sensitive land uses (see section 6) and adopting good reuse practices will limit the pathogen risk during reuse. Ensuring a suitable withholding period (three weeks) between reuse and grazing or harvesting will minimise health risks when the crop is eaten. For further details, refer to the APL "Piggery Manure and Effluent Management and Reuse Guidelines".

5.4.6 Visual Screening

Vegetative screening between the piggery and a neighbour or a road can mask the visual reminder of an odour, dust or noise source from view ("out of sight, out of mind"). Vegetative screens should be established early as part of the development to reduce the potential for land use conflicts. Take advantage of the topography and existing vegetation where possible. Vegetation around the complex can significantly improve the visual appeal of a piggery, and belts can help in dispersing odour, noise and dust.

Vegetative screens typically consist of a mix of indigenous shrub and tree species. Vegetative buffers that cover a significant area can also filter odour and dust from the air and enhance odour and noise dispersion. State authorities may have guidelines for appropriate vegetative screens and buffers. When placing these, be careful not to compromise airflow to naturally ventilated sheds in summer; provide sufficient space on the upwind side of the sheds.

In some cases, borrow material from the construction of effluent ponds or other dams will be available. This can be used to create earthen banks that screen the piggery from public view.

FIGURE 4.5 Example of a typical vegetative screen

5.5 Cultural Heritage

The likelihood of items, sites or places of Aboriginal or European cultural significance being present on a site must be considered early in the planning process. Councils and state government environment agencies keep records of significant sites and objects that provide a starting point for identifying whether these are likely to be present. They may also have tools for assessing the likely risk and whether a cultural heritage management plan (CHMP) is required.

If items, sites or places of cultural heritage significance are likely to be present at your site, further consultation with the appropriate bodies (including the traditional land owners) will determine the most suitable course of action. This may be as simple as properly recording, preserving or relocating special objects to allow development to proceed; siting the piggery complex away from the sensitive locations; or, in rare cases, permanently sectioning off parts of the property to protect these.

5.6 Future Expansion Plans

Consider any plans for possible future expansion during the site selection process. This may include applying the odour assessment tools in Appendix A to ensure separation distances will allow for an expansion, allowing extra area around the piggery complex for future sheds and effluent ponds and / or manure storage pads, and ensuring sufficient land is available for productive and sustainable reuse.

Where separation distances are a constraint, it may also be worth investigating the potential for acquisition of nearby land to protect or expand the separation distances available.

6. Separation Distances and Buffers

Good siting, design, construction and management are all important in preventing impacts to sensitive locations and receptors. Providing separation distances and buffers between piggeries and sensitive locations provide further insurance to minimise the risk of environmental and community amenity impacts.

Local authorities and state government agencies may have planning requirements that include specific separation distance and buffer requirements. **Contact your approved authority early in the planning process to identify any buffer or separation distances requirements. Consult with the council and the regional and state bodies responsible for water management to ensure all relevant designated watercourses are identified and considered.**

In the absence of specific advice from the approved authority, sections 6.1 and 6.2 provide guidance on buffers for surface water, groundwater and native vegetation, and separation distances for community amenity, respectively. **Specialist consultants can provide advice on suitable buffers and separation distances for a particular site.**

Environmental Outcome: The community, water resources and native vegetation are protected by providing separation distances and buffers that mitigate potential impacts from odour, and nutrient runoff and leaching.

These buffer and separation distances are for new developments and should not be applied to existing piggeries.

6.1 Buffer Distances from Surface Water, Groundwater and Native Vegetation

Streams, lakes, wetlands, groundwater and remnant native vegetation should be protected through good siting, design and management of piggeries and their reuse areas.

Buffers provide secondary protection against:

- effluent entry to surface waters or sensitive native vegetation through direct runoff of effluent from reuse areas
- nutrient rich stormwater runoff from reuse areas
- lateral movement of nutrient rich shallow groundwater from beneath reuse areas
- spray drift from irrigation with effluent
- dust from spreading dry manure.

Vegetative cover in the buffer area between the reuse area and any designated watercourse or waterbody should be maintained wherever possible, particularly riparian vegetation. Groundcover filters sediment and slows the movement of the water which promotes increased soil absorption, minimising the movement of nutrient rich runoff and eroded soil into surface waters. A designated watercourse can be defined as a naturally occurring drainage channel such as a river, stream and creek. It has a clearly defined bed and bank, with intermittent (ephemeral) or continuous (perennial) water flows.) **Also, refer to relevant state or territory Acts for legal definitions.**

The appropriate buffer width depends on the vegetative cover of the buffer area and the presence of other stormwater control devices, such as diversion banks and terminal ponds. Properly designed vegetative filter strips (VFS) can very effectively reduce nutrient entry to designated watercourses. They lower the nutrient concentration of runoff through particle trapping and reduce runoff volumes by increasing infiltration.

Redding et al. (2003) provide practical VFS design guidance. The VFS should be located immediately below the reuse area. It is also critical to place the VFS before any convergence of runoff. The vegetation should consist of non-clump forming grasses that provide a good level of groundcover, ensuring that there are no paths for water to run across land to designated watercourses or other sensitive areas. The required strip width depends on the slope of the land and the expected soil loss rate. Generally, wider VFS's can effectively trap larger quantities of soil eroded from upslope areas. However, for the same soil loss rate, areas with steeper slopes need a wider VFS than areas with gentler slope (see Table 6.1). These VFS widths are based on slope lengths of up to 200 m. They will not be effective where:

- slope length exceeds 200 m.
- soil loss rates exceed 50 t/ha/yr. Single rainfall events on vertosol soils can erode up to 90 t/ha of soil. Additional controls will be needed where the soil loss rate is higher.
- flow concentrates in depressions before running through the VFS. Even small depressions should be levelled or the filter strip developed along the contour.

For further information refer to Redding and Phillips (2005).

TABLE 6.1 VFS Widths (m) for Typical Values of Annual Soil Loss and Filter Gradients

Soil loss	Filter strip slope %							
(t/ha/yr)	1	2	3	4	5	6	7	8	9
10	5	5	8	8	9	9	10	10	10
20	6	12	15	15	15	16	16	16	16
30	12	18	21	21	22	22	22	23	23
40	18	24	27	27	28	28	29	29	29
50	25	>30	>30	>30	>30	>30	>30	>30	>30

Table adapted from Karssies L.E. and Prosser I.P. (1999) Guidelines for Riparian Filter Strips for Queensland Irrigators. CSIRO: Land and Water, Canberra. Technical Report 32/99 by Redding et al. (2003)

As a safeguard, buffers should be provided between the piggery complex and reuse areas, surface waters, groundwater bores and wells, and native vegetation. The required buffer distance should be assessed on a case-by-case basis with the aim of protecting sensitive waters, while not being overly onerous. For instance, only a relatively small buffer would be needed if there is a well-developed and maintained VFS between a reuse area and a designated watercourse. Similarly, good reuse practices only warrant a small buffer requirement. Where there is a greater risk, larger buffers or other measures may be appropriate. **Under some local government and state and territory requirements, fixed buffer distances may apply.**

Major stores of potable water and designated watercourses within drinking water catchments generally need the greatest protection. Piggeries should be 800 m from major water supply storages. Restrictions may apply in catchment areas for major water storages owned by water boards or local authorities. The measuring point for the buffer distance from a designated watercourse should be the maximum level the water may reach before overtopping of a bank begins (bank-full discharge level). **Relevant state or territory legislation should be consulted for the applicable legal definition.**

In all cases, the relevant approved authority should be consulted where a piggery is proposed within a government-declared catchment area or a government-declared groundwater area. A reduced buffer distance may be allowed if a risk assessment demonstrates that the feature will be protected. For highly sensitive or vulnerable resources, or under some state and territory requirements, the distance may need to be increased.

Native trees, shrubs, sedges and grasses can be very sensitive to nutrients, particularly phosphorus. Extra nutrients may also encourage weed growth. A buffer along vulnerable or endangered vegetation can protect against the decline of native species and communities. Avoid planting buffers with invasive species that could become weeds. Native vegetation patches can be enhanced by planting similar species in gaps or along the margins.

A small buffer around bores and wells will protect against the possibility of seepage of irrigated effluent or runoff down the sides of the casing.

Table 6.2 provides recommended buffer distances from reuse areas to surface waters, by reuse category. **These can be used in the absence of specific advice from an approved authority.**

The recommended fixed buffer distances surrounding reuse areas are only a guide. A site-specific risk assessment may be used to obtain dispensation for these distances from the approved authority. For example, terminal ponds designed to catch the first 12 mm of runoff from reuse areas, a whole farm drainage plan, banks or bunding may allow for a reduction in the required distance to designated watercourses.

TABLE 6.2 Buffer Distances from Reuse Areas

Reuse category	Distance from major water supply storage (m)	Distance from watercourse (m)
Category 1 Effluent that is discharged or projected to a height in excess of 2 m above ground level.	800	100
Effluent that is direct irrigated without pond or equivalent treatment		
Effluent that is irrigated from a short hydraulic retention time (HRT) system (<30 days of pond storage)		
Surface irrigation system without an effective terminal pond or diversion drain.		
Category 2 Mechanical spreaders and irrigators that project the discharged material to a height of less than 2 m above ground level, and irrigators with downward facing nozzles.	800	50
Manure products (e.g. separated solids, sludge or spent bedding) that will remain on the soil surface for more than 48 hours without being ploughed in.		
Surface irrigation systems with an effective terminal pond or diversion drain		
Category 3 Discharge by injection directly into the soil (to a depth of not greater than 0.4 m)	800	25
Spent bedding and manure solids that are incorporated into the soil within 48 hours of spreading		
Spent bedding and manure solids that are incorporated into the soil within 48 hours of spreading		
Surface irrigation systems with collection and containment of all tailwater and runoff		

Notes: distances should be measured from the perimeter of the area used for handling or reusing effluent or manure.

6.2 Separation Distances for Community Amenity Protection

An odour assessment can determine if receptors are likely to be protected from odour nuisance. The required separation distances can be determined using the methodology in Appendix A of these guidelines. Level 1 uses the most conservative approach, followed by Level 1.5, Level 2 and Level 3. Consequently, where a facility meets a lower level (e.g. Level 1), there is no need to demonstrate that other levels are met.

Appendix A also includes fixed separation distances to ensure appropriate buffers between the piggery and features such as roads and property boundaries. Both the variable and fixed separation distance to receptors (town, residential and rural) must be calculated, and the greater distance of the two applied.

It is important to note that the Level 1 and Level 1.5 odour assessment methodologies provided in Appendix A do not apply to effluent and manure reuse areas. These are considered separately from the piggery complex because reuse may occur infrequently and the risks can be managed by choosing the timing of irrigation or spreading and by considering weather conditions, particularly wind direction, when selecting which paddock to spread.

However, the success of a piggery development proposal also relies on community acceptance. Community consultation during the planning process will often provide enough information to allay community concerns. For community consultation to be effective, it is important to structure the process to suit the individual situation. Face-to-face consultation with immediate neighbours early in the planning process is recommended. However, it may also be necessary to consult more broadly, particularly for larger developments or proposals in sensitive locations.

Ongoing two-way communication between piggery operators, receptors (particularly neighbouring residents) and councils reduces the likelihood of complaints, can help in identifying when nuisance occurs and can assist in issue resolution. A complaints register (Appendix C) can assist in managing issues as they arise and demonstrate a commitment to working with neighbours.

7. Cleaner Production

Using resources more efficiently, reducing the amount of effluent and manure generated and carefully reusing effluent and manure can reduce costs and minimise the risk of impacts to the environment. Cleaner production involves continuously applying an integrated, preventative strategy to all processes, to increase overall efficiency and lower risks to the environment (including humans).

Environmental Outcome: Efficient use of resources, reducing manure and effluent production, and reuse and recycling of manure and effluent where appropriate.

7.1 Efficient Resource Use

In addition to the pigs and labour, major inputs to piggeries include feed, power, water and bedding (for deep litter units). Reducing feed wastage improves feed conversion efficiency, while decreasing the quantity of manure and effluent for treatment and the potential for subsequent odour and other environmental impacts.

Power represents a significant and increasing cost for piggeries, and its usage also contributes to the carbon footprint. Reducing energy usage and using on-farm alternative energy sources such as biogas, solar panels or wind turbines can reduce both operating costs and greenhouse gas (GHG) emissions. For further information, see the APL booklet "Reducing Energy Costs in Piggeries" (Australian Pork Ltd 2015d).

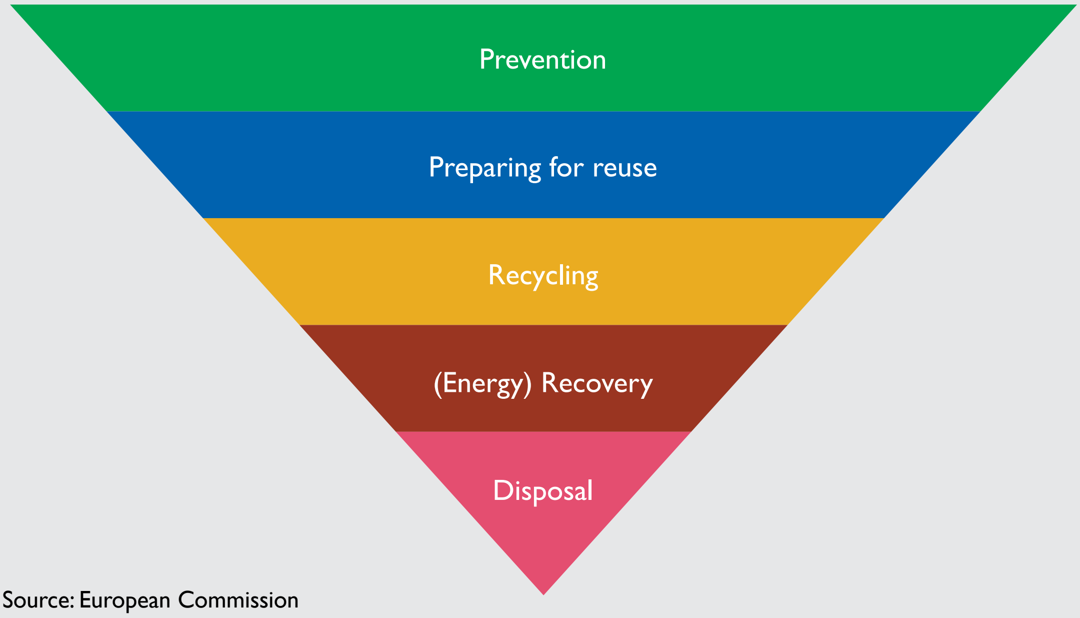
Water is used in piggeries for drinking, cleaning, cooling and diluting ("shandying") effluent for reuse. There may be opportunities to reduce the usage of this increasingly scarce resource without compromising shed cleanliness and pig welfare. For instance, recycling treated effluent as flushing water, or installing pull-plugs rather than flush channels, will reduce the clean water requirement.

To minimise odour, it is important to use suitable quantities of bedding in deep litter housing. The spent bedding can be a valuable input into farming systems, enhancing soil structure and providing nutrients for plant growth.

7.2 Waste Hierarchy

Waste prevention should be a priority, followed by reuse, then recycling (See Figure 7.1). Disposal should be a last resort.

FIGURE 7.1 Waste Hierarchy



Source: European Commission

There is generally very little waste disposal at piggeries. Effluent and manure production and mortality numbers can be minimised through good management and doing so lowers operating costs. Treated effluent, aged or composted manure and composted mortalities can be reused as valuable carbon and nutrient sources in farming systems. In some cases, treated effluent can be recycled as shed cleaning water. Heat and energy can be viably recovered from effluent ponds at larger farms with conventional housing, providing opportunities to reduce operating costs, GHG and odour emissions.

8. Pig Housing Design Principles

Environmental Outcome: Pig housing that is designed to optimise cleanliness, minimise odour, and protect surface water and groundwater quality.

Expert advice should be sought on the structural design and internal layout of piggery buildings, and the overall facility layout. Design should consider site constraints, the type of building foundations that suit the soil type, the number of pigs to be housed, functional layout, shed temperature regulation and ventilation.

There are two common forms of indoor piggeries – conventional sheds and deep litter housing.

Table 8.1 summarises shed design principles that apply to both types of housing. Sections 8.1 and 8.2 provide guidance for conventional sheds and deep litter sheds respectively. It is important to confirm the housing recommendations of the most recent edition of the Model Code of Practice for the Welfare of Animals Pigs (Primary Industries Standing Committee 2008 – currently under review). Minimum space allowances for adult pigs and growing pigs are provided in Appendix 3 of this Code.

8.1 Conventional Sheds

Conventional piggeries typically house pigs within steel or timber framed sheds with corrugated iron or sandwich panel roofing, and walls made from pre-formed concrete panels, concrete blocks, corrugated iron or sandwich panel (or some combination of these), sometimes with shutters or nylon curtains depending on the ventilation system. A fully environmentally controlled shed has enclosed walls with extraction fans and cooling pads, providing ventilation and climate control.

Conventional sheds have a concrete base, often with concrete under-floor effluent collection pits or channels. The flooring is usually partly or fully slatted, and spilt feed, water, urine and faeces fall through the slats into the underfloor channels or pits. These are regularly flushed or drained to remove effluent from the sheds. Sheds without slatted flooring usually include an open channel dunging area, which is cleaned by flushing or hosing. Ponds or other treatment systems coupled with reuse areas or evaporation ponds, are needed to manage the liquid effluent produced.

Conventional sheds suit all classes of pigs. Shed environment, nutrition and husbandry can be tightly controlled. The sheds generally need large quantities of water for cleaning. Ponds or other treatment systems coupled with reuse areas or evaporation ponds, are needed to manage the liquid effluent produced.

TABLE 8.1 Summary of Design Considerations for Piggery Sheds

Design Component	Considerations
Shed orientation	Orient buildings with their long axis east-west to minimise heat load.
General design materials	Construct new sheds from materials with good thermal properties that maintain shed temperatures in the required range, with minimal mechanical heating or cooling. The flooring and drainage system should exclude the ingress of clean stormwater runoff and prevent the discharge of effluent, manure or potentially contaminated stormwater to adjacent areas. Floors must be concreted for conventional sheds or have low permeability for deep litter sheds (preferably being concreted, otherwise soil compacted for a design permeability of 1×10^{-9} m/s for a minimum depth of 300 mm comprising two layers each 150 mm thick) to prevent seepage of effluent into soils and groundwater. See www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation (Skerman 2005) for guidance on how to achieve this design permeability. Site buildings so they are protected in the event of a 1-in-100-year flood.
Feeding system design	Automatic feeding systems should present feed to all animals simultaneously to reduce noise at feeding times. Ad libitum or continuous feeding systems also reduce feed wastage.
Ventilation	Adequate shed ventilation removes ammonia, dust and odour, controls air temperature and relative humidity, removes excess heat and moisture, dilutes and removes airborne microorganisms and maintains oxygen levels. Naturally ventilated sheds should be separated by a distance of five times their height to maximise ventilation.
Air quality	Dusty piggeries are more odorous. Piggery dust may be reduced through adequate ventilation, eliminating floor feeding and installing automated feeding equipment.
Visual impact	The material types and colours used for structures combine with landscaping to influence visual impact. Careful choices can produce structures that blend with the surroundings.
External landscaping	Strategic tree planting around the piggery complex can significantly reduce visual impacts of the piggery and may improve odour and dust dispersion.

8.2 Deep Litter Sheds

Deep litter piggeries typically accommodate pigs within a series of hooped metal frames covered in a waterproof fabric, similar to the plastic greenhouses used in horticulture. However, skillion-roof sheds and converted conventional housing may also be used. Pigs are bedded on straw, sawdust, rice hulls or similar loose material that absorbs manure, eliminating the need to use water for cleaning. The used bedding is generally removed and replaced when the batch of pigs is removed, or on a regular basis.

Deep litter housing may be established on a concrete base or a compacted earth floor. Impermeable flooring reduces maintenance, makes cleaning easier, and prevents nutrient leaching into groundwater. Extending the floor pad at least a metre beyond the shed end allows for bedding to be contained at cleanout.

Deep litter sheds with concrete floors are sometimes hosed after bedding removal. This is generally the only liquid effluent stream from these sheds. Like other effluent streams, this should be captured and managed.

Deep litter sheds best suit weaners, growers/finishers and dry sows. Weaners and rowers/finishers generally move through these sheds in batches ('all-in, all-out'), with spent bedding cleaned out only at the end of each batch. The spent bedding is generally reused in cropping systems.

Further information on deep litter sheds is also available in Payne (2000).

9. Estimating the Nutrient Content of Piggery Effluent and Manure

It is necessary to estimate the amount of total solids (TS), volatile solids (VS) and macro-nutrients in piggery effluent and manure in order to design treatment and storage facilities and size reuse areas.

The best available tool for estimating the quantity of solids, liquid, nitrogen, phosphorus and potassium in pig manure and effluent is the PigBal 4 model. PigBal 4 is a Microsoft Excel® spreadsheet that uses mass balances theory and diet digestibility data in its computations. It is a versatile model that can be tailored to suit individual piggery operations (Skerman, Willis et al. 2014). For existing piggeries, manure and effluent analysis results can be helpful in estimating the quantity of nutrients for reuse.

Environmental Outcome: Estimation of the total solids, volatile solids and macronutrients in manure and effluent to enable good design of treatment and storage facilities and sustainable reuse.

9.1 PigBal 4

PigBal 4 is the national industry standard tool for estimating piggery manure production. It is an easy-to-use Microsoft Excel® model that is suitable for:

- preparing new planning applications
- preliminary design of effluent treatment systems including pond and engineered digester systems
- assessing the likely power output and economic viability of piggery biogas systems
- estimating piggery greenhouse gas (GHG) emissions
- assessing GHG reduction strategies
- reducing the risk that uninformed, excessive regulatory or financial burdens will be placed on pork producers.

PigBal 4 provides:

- in-cell explanatory comments to assist the use in selecting input values
- the option of using up to six pig growth stages and corresponding diets between weaning and turn-off
- a range of standard growth curves and corresponding average liveweight gains
- an equation for estimating feed intake from pig liveweight
- estimates of grower herd feed wastage
- cleaning water use estimates based on typical effluent solids concentrations for different effluent management systems
- pig drinking water estimates

- pig cooling water estimates
- an extensive diet ingredient database
- the option to choose from a range of pre-treatment options with typical solids and nutrient removal rates
- estimates of manure production from deep litter housing, with a range of bedding options
- various options for sizing anaerobic ponds, including large conventional ponds, highly loaded anaerobic (HLA) ponds and covered anaerobic ponds (CAPs)
- baseline methane emissions estimates calculated according to the Carbon Credits (Carbon Farming Initiative) (Destruction of Methane Generated from Manure in Piggeries 1.1) Methodology Determination 2013 (Australian Government 2013).
- manure production estimates for a range of standard diets.

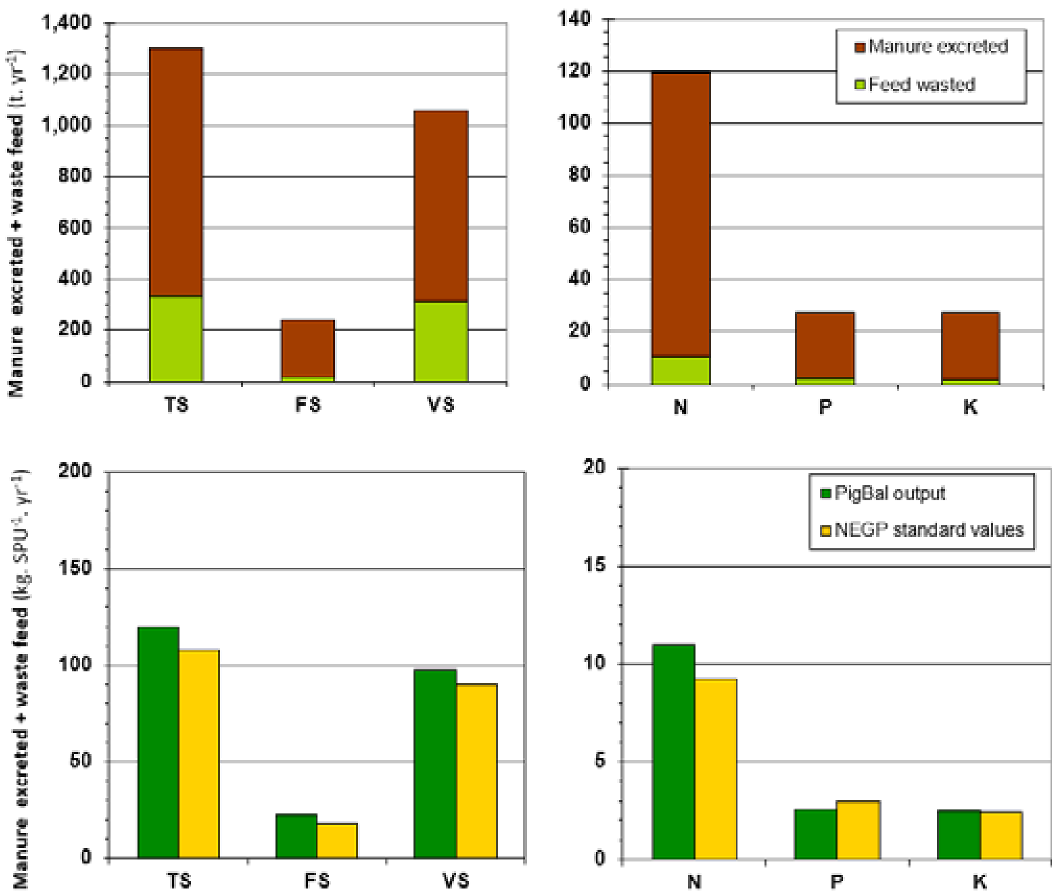
PigBal 4 was developed by Skerman, Collman et al. (2013). Skerman, Willis et al. (2014) developed the PigBal 4 User Manual. It is available for download at: http://australianpork.com.au/industry-focus/environment/waste-management-pigbal/

Figure 9.1 shows an example PigBal output summary for a 1000 sow conventional piggery.

FIGURE 9.1 Example PigBal 4 Output Summary

< > Menu **15. Output summary**

	Annual waste output (t. yr^{-1})					
	TS	FS	VS	N	P	K
User entered diet						
Feed ingested	5,732	300	5,432	174	37	32
Feed wasted	333	17	316	10	2	2
Manure excreted	968	225	742	109	26	25
Manure excreted + waste feed (excluding shed losses)	**1,301**	**243**	**1,058**	**119**	**28**	**27**
Effluent discharged from conventional sheds	1,275	243	1,026	107	28	27
Separated solids	255		256	9	3	0
Effluent discharged to primary pond	1,020		769	99	25	27
	83.12%					
Deep litter added to sheds	0	0	0	0	0	0
Spent litter removed from deep litter sheds	0	0	0	0	0	0
	(kg. SPU^{-1}. yr^{-1})					
Manure excreted + waste feed (excluding shed losses)	119	22	97	10.9	2.5	2.5
Effluent discharged from conventional sheds	117	22	94	9.8	2.5	2.5
NEGP standard SPU (grower pig) values (Table 9.1)	**108**	**18**	**90**	**9.2**	**3.0**	**2.4**



9.2 Estimating the Mass and Composition of Effluent and Manure

The use of PigBal 4 is recommended for estimating TS and VS for sizing effluent ponds, estimating GHG emissions and designing manure to energy facilities. Validation of PigBal 4 based on the work of Skerman et al (2016) showed that it provides reasonably accurate estimations of the TS, VS and fixed solids (FS) in the manure, assuming feed wastage of 15-29%. PigBal 4 also calculates the total volume of the effluent stream from the quantities of cleaning water, drinking water spillage, manure and waste feed, allowing for estimation of the concentrations of solids and nutrients in the effluent.

PigBal 4 is also the best available tool for estimating the mass of nitrogen, phosphorus and potassium in manure and effluent taking into account inputs (feed, pigs, water and bedding (if used)) and outputs (pigs, mortalities and emissions of nitrogen to air (10% for conventional sheds and 17% for deep litter sheds based on the work of McGahan et al. (2010))).

Table 9.1 shows the solids and nutrient content of manure and waste feed ex-sheds for the standard classes of pigs estimated using the PigBal 4 1000 sow farrow-to-finish example herd housed in a conventional piggery. Values can be refined by using piggery-specific inputs to PigBal 4. Similar data can be produced for deep litter piggeries; PigBal 4 includes inputs for bedding usage.

TABLE 9.1 Predicted Solids and Nutrient Output in Manure and Waste Feed Ex-Sheds by Pig Class – Example 1000 Sow Farrow-to-Finish Piggery (Conventional Housing) (t/yr)

Pig Class	No. of pigs (SPUs)	Pig weights: in-out (kg)	Total solids	Volatile solids	Nitrogen	Phos-phorus	Potas-sium
Gilts	73 (132)	115-160	17.6	14.3	1.12	0.36	0.31
Boars	54 (86)	115-300	10.0	7.7	0.82	0.25	0.23
Gestating sows	834 (1,334)	160-215	154.9	120.5	11.56	3.69	3.42
Lactating sows	165 (411)	215-160	55.4	43.9	4.45	1.12	1.26
Suckers	1,757 (171)	1.4-6.7	41.0	35.2	3.86	0.76	0.60
Weaner pigs	2,776 (1,429)	6.7-30	189.8	163.3	13.89	3.36	2.94
Porkers	1741 (1,872)	30-55	267.1	225.9	20.60	4.30	5.37
Growers	1,722 (2,544)	55-80	380.0	317.7	28.62	6.96	6.76
Finishers	1,704 (2,915)	80-104	480.6	399.5	31.48	9.03	8,18
Total	10,826 (10,896)	-	1,597	1,328	116.4	29.8	29.1

Notes: Estimates have been determined using the PigBal 4 sorghum-wheat diets and feed wastage values of 10% for gilts, 5% for breeding stock, 20% for suckers and 11% for weaners, porkers and finishers.

9.3 Manure Nutrient Dynamics

As soon as manure is excreted, some of the solids, water and nitrogen are removed through gaseous losses of volatile compounds. Table 9.2 shows the default PigBal 4 in-shed solids and nitrogen loss rates.

TABLE 9.2 PigBal 4 In-Shed Solids and Nutrient Losses

Shed type	Total solids	Volatile solids	Nitrogen
Conventional – flushing	2%	3%	10%
Conventional – pit	10%	12%	10%
Deep litter	20%	25%	17%

Further losses occur during treatment and there may also be partitioning of nutrients to different manure streams depending on the type of piggery and the manure management system.

9.3.1 Manure Nutrient Dynamics – Conventional Piggeries

When effluent enters a covered or uncovered anaerobic treatment pond, some of the solids and nutrients deposit to sludge, while the remainder stays suspended in the liquid fraction. Using data from McGahan et al. (2010), Table 9.3 shows the approximate percentages of nutrients partitioned between sludge and pond liquid.

TABLE 9.3 Estimated Percentages of Nutrients Partitioned Between Sludge and Pond Liquid

Nutrients partitioned to:	Nitrogen	Phosphorus	Potassium
Sludge	23.5%	90%	5%
Pond liquid	76.5%	10%	95%

Nitrogen is lost through ammonia volatilisation from uncovered anaerobic ponds and the secondary ponds following these. Total gaseous losses of nitrogen could range from 40% to over 90%, with higher rates expected for ponds with larger surface areas in warm climates. The accepted rate for planning purposes is 40%, except where an applicant can demonstrate a different loss rate.

Nitrogen losses from effluent irrigation will depend on the system. Spray systems will generally have higher ammonia volatilisation rates (say 20%), while surface methods will have lower loss rates (say 10%).

Manure solids that are stored or composted before spreading could experience nitrogen losses of about 20%. A further 20% of the remaining nitrogen could be lost on spreading.

9.3.2 Manure Nutrient Dynamics – Deep Litter Piggeries

The spent bedding removed from deep litter piggeries is usually stockpiled or composted before spreading; nitrogen losses of approximately 20% could be expected during these processes. A further 20% of the remaining nitrogen could be lost on spreading. Hence, total post-shed nitrogen losses are expected to be about 36%.

10 Effluent Collection and Treatment Systems

Raw effluent is conveyed from conventional sheds to treatment facilities by a collection system that may include pits or channels, drains and/ or pipes and sometimes sumps. These facilities must be large enough for the expected effluent volume and flow rate. Effluent should ideally move by gravity (rather than being pumped, which requires energy and maintenance) and along open channels (rather than through pipes that can block).

In some cases, larger solids are removed from the effluent ahead of pond treatment. This pre-treatment enables effluent to be pumped using conventional equipment (e.g. centrifugal pumps) and reduces the required size of the effluent treatment facilities.

Most conventional piggeries use some type of anaerobic pond to treat their effluent. However other systems, including sedimentation and evaporation (SEP) systems and biodigesters are also in use.

Environmental Outcome: Effluent from conventional sheds is collected, transported and treated without causing amenity nuisance or releases to surface water or groundwater.

10.1 Effluent Collection Systems

Effluent collection systems should be designed and constructed to prevent the entry of stormwater runoff, and the unintentional exit of effluent. They must be impervious to prevent seepage and the possibility of groundwater contamination. They should also be self-cleaning or be regularly cleaned to reduce manure build-up and to minimise the risk of excessive odour and fly and mosquito breeding.

10.1.1 Flushing Channels

Flushing channels sit underneath slatted shed flooring and catch manure, spilt feed, wasted drinking water and hosing water. These are flushed daily, to twice weekly, with large volumes of water or treated effluent recycled from the ponds. Drain length, width and slope must be considered when planning the flush volume to ensure effective removal of accumulated manure and cleaning of pits and drains. The maximum recommended flush length is 50 m, and box drains with a 1% slope are preferred. Alternatively, level box drains with a 50 mm lip at one end to retain some water in the base of the drain can be used. For drains up to 40 m long, the minimum recommended flushing water volume is 700-1000 L/m of drain width/flush. A water velocity of 0.9 m/s, an initial flow depth of 75 mm and a flush duration of at least 10 seconds will effectively dislodge and transport solids.

10.1.2 Pull Plug Systems

'Pull-plug' systems store effluent in underfloor pits that sit underneath slatted flooring in conventional sheds. The pits are drained regularly via gravity release pipes. Each shed may be divided into a number of cells serviced by individual pull-plug systems.

10.1.3 Static Pits

Static pits are common in older-style conventional sheds. They comprise underfloor pits that store effluent for up to several weeks before it is released via a sluice gate at the end of the shed.

10.1.4 Open Flush Gutters

Some older conventional sheds collect effluent in open flush gutters or vee-drains running along solid flooring within, or beside, the pens.

10.1.5 Dry Scraping Systems

Dry scraping systems consist of blades on cables that drag manure and wastewater from effluent channels under conventional sheds. Since flushing water is not added to the manure, the effluent volume is greatly reduced.

Dry scraping systems work best in climates with very low rainfalls and high evaporation rates, since an odour-controlling crust readily forms over the effluent discharged to a pond or basin.

10.1.6 Drains and Pipes

Drains or pipes are needed to move effluent from the sheds to sumps or treatment ponds. Drains are preferred to pipes, which can be more difficult to inspect and to clean.

Drains should be made of smooth concrete, fibreglass or other impervious material in spoon or vee channel sections. They should have at least a 0.5% slope to ensure solids removal and ease of cleaning and drying between uses. Enclosed drains or pipes should have a constant slope of ~1%, with minimal bends and joins.

10.1.7 Effluent Sumps

Sumps store effluent before pre-treatment, or before it is directed to ponds or irrigation. They must be made from strong, corrosion-resistant and impermeable materials such as concrete, fibreglass, stainless steel, poly-lined steel or enameled steel. They need to be designed to exclude the entry of stormwater runoff from surrounding areas.

When sizing sumps, consider the shed flushing frequency, flushing volume and pumping capacity. Contingency plans are needed in the event of equipment failure.

Mechanical stirrers or high velocity pumps are generally used to ensure that solids are kept in suspension to prevent settling, and to enable pumping of the resulting slurry.

10.2 Solids Separation Systems

Solids separation systems remove larger particles from the effluent stream before it is treated, recycled and used. This enables effluent to be conveyed using conventional equipment (e.g. centrifugal pumps) and increases the flexibility of reuse options. Solids removal also reduces the effluent's organic matter, and consequently the capacity required for effluent treatment.

10.2.1 Options for Solids Separation

Methods for separating solids from liquids include:

- gravitational settling, for example sedimentation and evaporation systems (SEPS) (for further details, see section 10.3.4),
- screens including static rundown, vibrating and rotating screens, and Baleen Filters®,
- presses such as screw presses and Z-filters® (see Payne 2014 for further information), and
- centrifugal separation including hydrocyclones and horizontal centrifuges.

Data from McGahan et al. (2010) and Payne (2014) has been used to develop Table 10.1, which summarises accepted nutrient removal rates from different types of solids separators. Detailed information on the various solids separation information is provided in the Piggery Manure and Effluent Management and Reuse Guidelines.

TABLE 10.1 Typical Solids and Nutrient Removal Rates for Different Types of Solids Separators

Technology	Removal rate (%)				
	Total Solids	Volatile Solids	Nitrogen	Phosphorus	Potassium
Screw press[a]	32	37	37	41	8
Rundown screen[a]	20	25	8	11	0
Vibrating screen[a]	20	25	8	11	0
Rotating screen[a]	15	20	5	10	0
Baleen filter[a]	30	37	12	17	0
SEPS[a]	77	82	36	89	4
Settling basin[a]	55	70	20	40	3
Z filter[b]	58	73	35	50	10

[a] McGahan et al. (2010) / Pigbal 4 default values

[b] Payne (2014)

10.2.2 Screenings Storage Areas

The solids separation system and the solids storage area should be located within a low permeability, controlled drainage area. For clay-lined areas, a design permeability of 1 x 10^{-9} m/s for a depth of 300 mm comprising two 150 mm deep layers is appropriate. For guidance and technical direction on pad preparation requirements see Skerman (2005): www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation. Impervious drains or pipes should convey all runoff, separated liquid and leachate from the separated solids to adequately sized storages.

10.3 EffluentTreatment Ponds

Pond-based systems are the most common way of treating piggery effluent. A wide range of designs is possible.

10.3.1 General Principles

The effluent pond system needs to provide treatment and wet weather holding capacity, with different ponds in the system sometimes providing different functions. The pond configuration may be limited by space and other site constraints. For instance, ponds at sites with shallow groundwater may need to be built partly above-ground (turkeys nest). When space is limited, the ponds may need to be deeper with steeper internal walls or have a particular shape.

The pond walls and banks need to be structurally stable and safe to work on. Skerman et al. (2008) recommends a batter (slope) no steeper than 2 horizontal to 1 vertical on the internal walls, with some soils needing flatter batters to ensure structural stability. The batter slope may also be limited by the safe operation of machinery during pond construction, and for later maintenance. The batter of the internal end-walls should 4 horizontal to 1 vertical or flatter to provide for safe access during construction and maintenance.

The pond walls and banks need to be impervious to prevent nutrient seepage. Most ponds are clay lined. Adequate soil compaction and the correct moisture content during construction are necessary to achieve the required design permeability of 1 x 10^{-9} m/s for a depth of 300 mm for ponds up to 2 m deep, or 450 mm for deeper ponds. (Some states may have different pond lining requirements). Compacted layers should not exceed 150 mm depth. Guidance and technical direction for clay lining and compaction of effluent ponds can be obtained at: www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/constructing-effluent-ponds (Skerman et al. 2005). Where the design permeability criteria cannot be met, the ponds can be sealed with imported clay or synthetic liners made from materials like high density polyethylene (HDPE) with a thickness of 1.5-2 mm or 1 mm thick polypropylene (PP). Regulatory agencies should be consulted to confirm the acceptability of alternative lining materials and methods. The structural integrity of the liner should be regularly checked and maintained as needed.

The lowermost part of the base of all effluent treatment ponds should be at least 2 m above the water table, taking into account seasonal variations in groundwater depth. An assessment of the groundwater contamination risk can be used to guide decisions on the type and standard of pond lining and any specific leakage detection measures.

Providing a minimum of 600 mm of freeboard allows the pond banks to contain wave action and prevents overtopping due to imperfections in the crest height. Freeboard should never be used for routine effluent storage.

The pond system must be able to contain effluent inflows plus rainfall during extended periods of wet weather. The design overtopping frequency must not exceed once every ten years for ponds with irrigation of surplus effluent, and once every twenty years for ponds relying only on evaporation for water disposal. However, the design overtopping frequency also depends on the sensitivity of the receiving environment. Some states may have more stringent requirements so it is important to discuss this with regulators. Entry of stormwater runoff and roof runoff should be minimised through the use of banks, and gutters and drains. The ponds should only collect effluent, other contaminated runoff (e.g. from a mortalities composting pad) and rain landing on the pond surface. Any additional inflows need to be considered when sizing the pond system. The wet weather capacity of pond systems is best determined using a water balance model (for example, WaterBal (Skerman 2018) or MEDLI (Department of Science, Information Technology and Innovation 2015) using long term, local climate data. Effluent spills must not enter any waterway or leave the property boundary.

Over time, sludge will accumulate over the base of the primary effluent treatment pond. Sludge removal needs to be considered in the design.

All effluent treatment ponds should be fenced to exclude children and stock. Signs should warn of deep water that may be hidden by a surface crust or cover.

In summary:

- the system needs to provide for treatment and wet weather holding capacity
- the pond walls and bank need to be structurally stable with a slope that is safe to work on
- the walls and base must be impervious
- the lowest part of the base should be at least 2 m above the highest seasonal water table
- provide at least 600 mm of freeboard
- consider sludge removal in the design.

10.3.2 Primary Anaerobic Ponds

Most primary effluent treatment ponds at piggeries are anaerobic ponds. Anaerobic ponds are a popular option as they are simple to build and operate and provide for effluent storage. These ponds use anaerobic bacteria, which function in the absence of free oxygen, to treat what is usually a high strength effluent with an absence of dissolved oxygen. Well-designed, properly-managed anaerobic ponds provide good effluent treatment (removing >70% VS) without causing odour nuisance or adverse impacts to water resources; store deposited sludge; and allow for effluent and sludge removal. A product of anaerobic digestion is a stabilised sludge that deposits in the bottom of the pond. Anaerobic ponds can be covered to reduce odour and GHG emissions, and to collect biogas that can be used as a heat and / or power source within the piggery.

When designing anaerobic ponds, there are four main aims. They are:

- to treat the effluent stream
- to provide for sludge storage
- to ensure that effluent and sludge can be removed as needed
- to protect amenity, surface waters and groundwater.

The first stage in primary anaerobic pond design is determining the required volume and the dimensions that will suit the site.

Until fairly recently, most primary anaerobic ponds at piggeries were sized using the Rational Design Standard (RDS) proposed by Barth (1985b), resulting in very large ponds. Although most ponds are now designed to be more heavily loaded, well-designed large (RDS-sized) primary anaerobic ponds:

- function effectively, removing >70% of volatile solids from the effluent
- usually have low to moderate ongoing odour emissions but have a relatively large surface area for emitting odours and greenhouse gases (GHG)
- have low management requirements
- provide for long-term sludge storage (e.g. 5-10 years) but can be difficult to de-sludge because of their size and dimensions.
- provide significant effluent storage capacity
- can occupy a significant land area
- may be expensive to line and cover (if required)

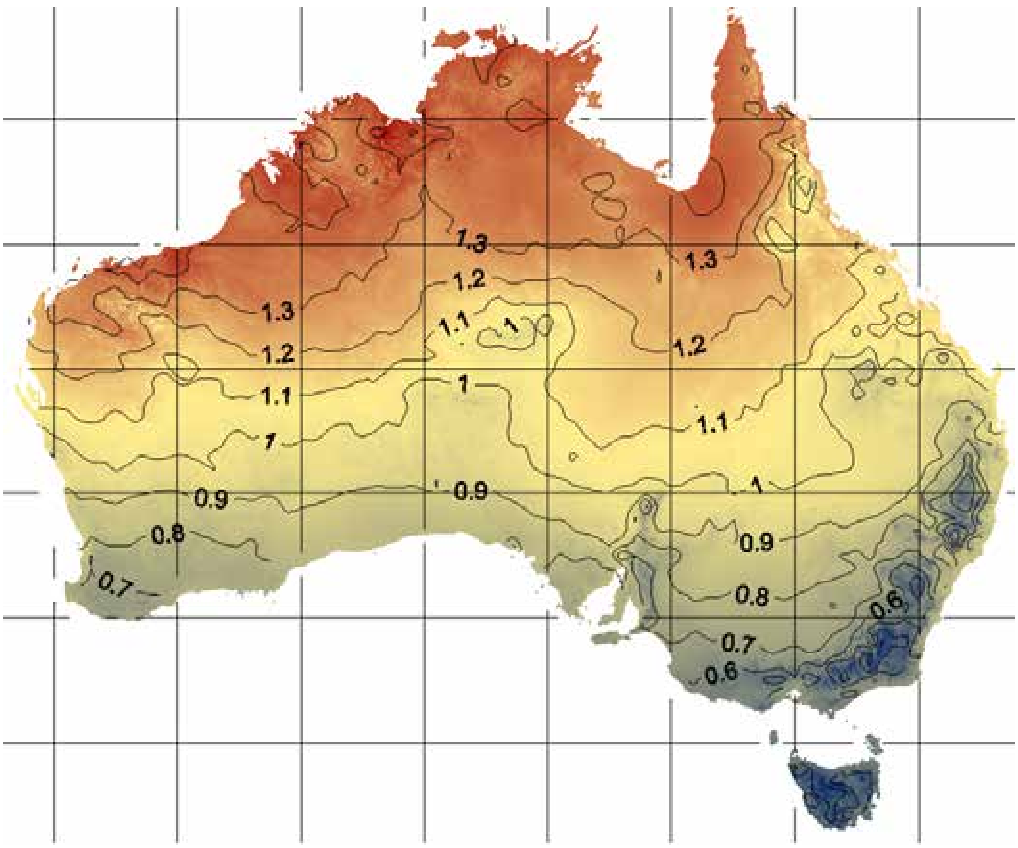
Table 10.2 provides sizing rates for large (RDS) primary anaerobic ponds in three broad climatic zones with different desludging frequencies, and with or without effluent pre-treatment. The treatment capacity component of these sizing rates has been determined using a baseline VS loading rate of 100 g/m^3/d, adjusted for the expected pond activity (K-value), which is higher under warmer conditions. Figure 10.1 provides a map of Australia showing the iso-K contour values that are used to adjust the VS loading rate to the primary anaerobic pond (Skerman 2018). Note that this VS loading rate method applies only to primary anaerobic ponds, and not to secondary ponds. The sludge storage volume is estimated by multiplying the sludge accumulation rate by the number of years between planned sludge removals. One SPU produces about 108 kg TS/yr as manure and waste feed. Using the ASABE (2011) sludge accumulation rate of 0.00137 m^3/kg TS, the sludge storage volume is 0.148 m^3/SPU/yr.

TABLE 10.2 Suggested Large Primary Anaerobic Pond Capacities for Different Climates, Desludging Frequencies and Pre-Treatment Options

Climate[a]	Desludging Frequency	Effluent Treatment and Sludge Storage (m3/SPU)		
		No pre-treatment	Screen[b]	Screw Press[c]
Cool	Annually	4.3	3.4	2.7
(K = 0.6)	5 yearly	4.8	3.8	3.1
	10 yearly	5.6	4.4	3.5
Warm	Annually	3.2	2.6	2.0
(K = 0.8)	5 yearly	3.8	3.0	2.0
	10 yearly	4.6	3.6	2.9
Hot	Annually	2.6	2.1	2.0
(K = 1.0)	5 yearly	3.2	2.5	2.4
	10 yearly	3.9	3.1	2.9

a refer to Figure 10.1 for climate of different locations
b assumes a screen removes 25% TS and 20% of VS
c assumes a screw press removes 32% of TS and 37% of VS

FIGURE 10.1 Map of iso-K Lines in Australia



source: Skerman (2018)

Skerman et al. (2008) investigated the concept of more heavily loaded anaerobic (HLA) ponds. Compared with RDS-sized ponds, more heavily loaded anaerobic ponds:

- achieve similar VS removal rates (>70% VS removal)
- generally emit less odour because they have a smaller surface area and because a surface crust may form (at loading rates exceeding about 600 g VS/m^3/d)
- usually occupy a smaller footprint
- are cheaper to build, line and cover
- may provide more desludging options.

Table 10.3, provides recommended minimum sizing rates for primary HLA ponds in three broad climatic zones with different desludging frequencies, and with or without effluent pre-treatment. These ponds are typically desludged frequently so sizing rates for annual, two yearly and three yearly desludging are provided. Providing too much sludge storage capacity negates the benefits of the heavy loading rate by increasing overall capacity and surface area. Using the minimum volumetric rate will produce the smallest pond volume; providing some extra volume may improve management flexibility. The pond capacities given in Table 10.3 are for primary HLA ponds only.

TABLE 10.3 Suggested Minimum Primary HLA Pond Capacities for Different Climates, Desludging Frequencies and Pre-Treatment Options

Climate	Desludging Frequency	Effluent Treatment and Sludge Storage (m^3/SPU)		
		No pre-treatment	Screen[a]	Screw Press[b]
Cool	Annually	0.7	0.5	0.4
(K = 0.6)	2 yearly	0.8	0.7	0.5
	3 yearly	1.0	0.8	0.6
Warm	Annually	0.6	0.4	0.4
(K = 0.8)	2 yearly	0.7	0.6	0.5
	3 yearly	0.9	0.7	0.6
Hot	Annually	0.5	0.4	0.3
(K = 1.0)	2 yearly	0.6	0.5	0.4
	3 yearly	0.8	0.6	0.5

a assumes a screen removes 25% TS and 20% of VS
b assumes a screw press removes 32% of TS and 37% of VS

Annual desludging of HLA ponds is recommended as this minimises required pond size and the sludge will usually have a consistency that allows its extraction with a vacuum tanker or pump without needing to take the pond off-line. Allocating more sludge storage capacity provides for increased operational flexibility but:

- requires bigger ponds that come with higher construction costs
- increases the pond footprint, using more land

- makes desludging more difficult. Older, compacted sludge with a TS concentration exceeding 15% cannot be pumped. The pond may need to be taken off-line to allow for sludge removal using earthmoving equipment.
- results in bigger pond surface areas and greater odour emissions.

The footprint of any pond depends on its volume, depth, batter (slope) of both internal and external walls and its length to width ratio. Building deep anaerobic ponds is generally recommended as this:

- minimises the pond surface area. For uncovered ponds this reduces odour emissions and heat losses and minimises the rainfall volume to be managed and evaporation that concentrates salts. For covered anaerobic ponds (CAPs) it reduces the size and cost of the cover.
- enhances mixing within the pond.
- provides a more stable pond temperature, improving the performance of the methanogenic bacteria that convert odorous compounds into odourless methane and carbon dioxide.
- usually ensures there is adequate depth in the treatment volume.

However, it is important to ensure:

- the lowest part of the pond base will be at least 2 m above the highest seasonal groundwater table.
- the depth and width are practical for desludging. A maximum depth of 6-8 m is suggested. Desludging will be much easier and less disruptive if the pond is narrow enough to remove solids from a bank using a pump, vacuum tanker or long reach excavator. Long reach excavators have a maximum range of around 18 m, which limits the maximum pond width at crest to about 30 m.
- the pond shape will retain the effluent long enough for effective treatment. Rectangular or long ponds with effluent discharge and removal at opposite ends are generally preferable as they provide a greater effective hydraulic retention time (HRT) than a square or round pond with the same volume.

The pond width at top water level (TWL) is determined by the base width, the internal batters and the depth. The minimum possible base width will generally match the width of the construction equipment (typically ~3 m).

PigBal 4 provides a simple method for determining the size and dimensions of a large primary anaerobic pond, a primary HLA pond or a primary covered anaerobic pond (CAP). The APL booklet "New Design Guidelines for Anaerobic Ponds" (Australian Pork Limited 2015b) also provides further guidance on determining primary anaerobic pond dimensions.

Effluent may be pumped through pipes into the anaerobic pond or may enter under gravity flow via channels or pipes. For gravity flow inlet pipes, the recommended minimum inside diameter is 150 mm. Larger diameter pipelines will discharge more quickly and are less likely to block. Providing multiple inlet points disperses the effluent within the pond which may enhance treatment and allow sludge to deposit more evenly within the pond. All effluent entry points should be well separated from the outlet pipe to minimise the likelihood of "short-circuiting" (influent following a shorter, or more direct path across the pond to the outlet, without fully mixing with the stored pond effluent, resulting in reduced retention time and ineffective treatment).

Since thick crusts may form over HLA ponds, inlet and outlet pipes need to be carefully positioned to prevent blockages. The ends of the inlet pipes should sit above the expected TWL and crust level and beyond the bank providing for free outfall into the pond.

Treated effluent may be removed from the pond using a gravity overflow pipe, a weir or by pumping. If an outlet pipe is used, a tee fitting will exclude the floating crust (see Figure 10.2). The base of the vertical pipe should be well below the crust and TWL but above the maximum sludge storage level to minimise carryover of sludge into secondary ponds. The bottom (invert) of the overflow pipeline sits at TWL height with a downwards slope towards the wet weather pond. This keeps the effluent volume in the HLA pond relatively constant and prevents spills.

If a weir will be used, an adjustable type should be considered with horizontal planks placed in a slotted opening. The planks can be inserted or removed to control the overflow level and thus improves management flexibility.

Pipelines for pumping of treated effluent for reuse, should have a minimum internal diameter of 50 mm and at least 75 mm if the pumping distance exceeds 100 m or if a greater head pressure drop is expected. For more information on pipework, refer to the APL booklet "New Design Guidelines for Anaerobic Ponds" (Australian Pork Limited 2015b).

FIGURE 10.2 Tee on Overflow Pipeline from HLA Pond to Wet Weather Pond

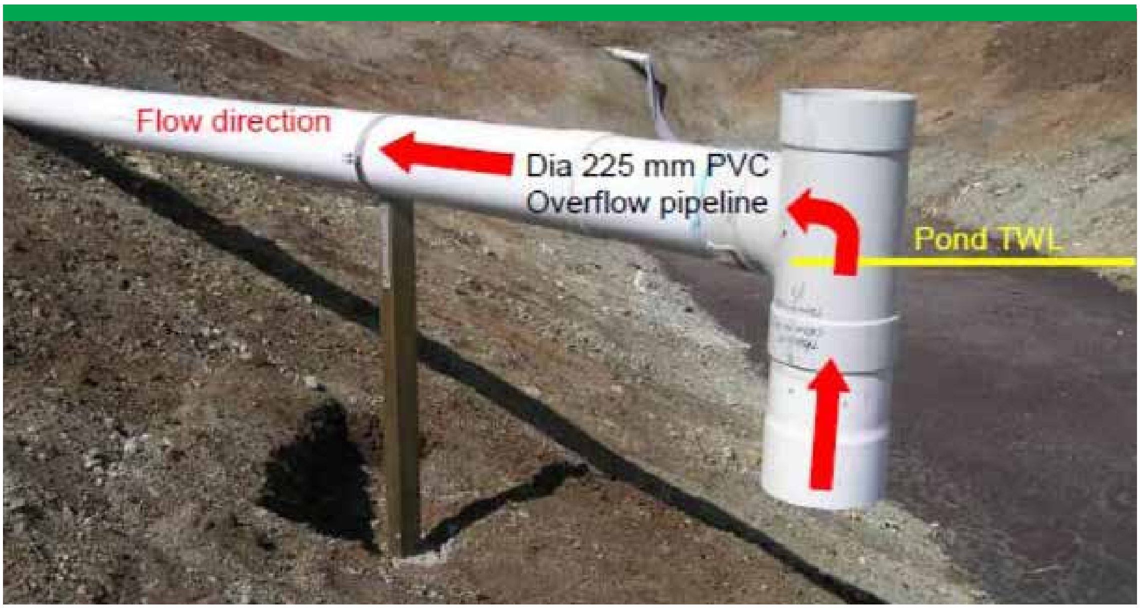


Photo courtesy of Alan Skerman.

10.3.3 Covered Anaerobic Ponds (CAPs)

Covered anaerobic ponds, or CAPs, are anaerobic ponds with an impervious cover that traps biogas for flaring or use as a heat and / or power. CAPs eliminate a significant odour source and minimise GHG emissions. This section provides design guidance for simple CAPs. However, Australian piggeries are also using CAPs with stirrers and heating to maximise biogas production (hybrid CAP systems).

CAPs are usually sized to provide an active volume baseline VS loading rate of 400 g/m^3/d, that is adjusted for temperature zone (see Figure 10.1), plus sludge storage. Table 10.3 shows indicative CAP sizing rates. PigBal 4 also provides for location-specific CAP sizing.

TABLE 10.4 Suggested CAP Capacities for Different Climates, Desludging Frequencies and Pre-Treatment Options

Climate	Desludging Frequency	Effluent Treatment and Sludge Storage Capacity (m^3/SPU)		
		No pre-treatment	Screen[a]	Screw Press[b]
Cool	Annually	1.2	0.9	0.7
(K=0.6)	2 yearly	1.3	1.0	0.8
	3 yearly	1.5	1.2	0.9
Warm	Annually	0.9	0.7	0.6
(K=0.8)	2 yearly	1.1	0.8	0.7
	3 yearly	1.2	0.9	0.8
Hot	Annually	0.8	0.6	0.5
(K=1.0)	2 yearly	0.9	0.7	0.6
	3 yearly	1.1	0.8	0.7

a assumes a screen removes 25% TS and 20% of VS
b assumes a screw press removes 32% of TS and 37% of VS

High Density Polyethylene (HDPE), Polypropylene and Low Density Polyethylene (LDPE) are suitable pond cover materials, although other materials may also work. HDPE is the cover material most commonly installed on Australian piggery ponds. HDPE covers for larger ponds should be at least 1.5 mm thick. Installing the cover during winter also reduces the risk of damage through thermal contraction in subsequent cold periods. Using dark coloured covers improves heating in winter. Warranties of 10-20 years with UV resistance are usual.

The cover must be large enough to go over the pond surface and be securely anchored in a trench excavated into the crest of the embankment around the perimeter of the pond. Typically, the trench will be 400 mm wide and 600-900 mm (800 mm min) deep. Ideally, the cover should line the inner wall and base and extend halfway up the far wall inside the trench, adding another 2.4-3 m to the length and width of a rectangular cover. For a pond with existing sludge extraction ports, the trench may need to run between the pipework and the inner edge of the crest to ensure the ports remain fully exposed. For a pond with a synthetic liner, provide 0.6-1 m of space between the liner trench and the cover trench. Otherwise, the distance from the inner crest may be 1 m or more. Hence a further 1-2 m generally needs to be added to the length and width of the pond cover; 3.4-5 m extra in total. Once the cover is in place, the trench can be backfilled with 200 mm layers of compacted bank material. Great care must be taken during installation since pond covers are easily damaged by rocks or rough surfaces.

Rainfall will collect on the pond cover and provision must be made for its removal. A series of weighted guide pipes securely installed over the cover can direct rainwater to a central collection point, often a sump welded into the cover (see Figure 10.3). Collected water is removed using either a submersible sump pump or a suction hose connected to a pump. The collected rainwater can supplement piggery cleaning water. The type of piping is important. These are commonly filled with water; heavy concrete-filled pipes should never be used. The size and arrangement of pipework ranges from a single 160 mm HDPE guide-pipe down the centreline of a pond, to a number of cross pipes that guide rainwater to either a pipe installed down the centreline or to one side of the cover. Guide pipes are typically held in place by straps welded onto the cover.

All CAPs must be fitted with a flare for combustion of surplus biogas (see Figure 10.3). Biogas is removed from under the cover using slotted pipe; 100 mm slotted HDPE pipe is suitable. Excess biogas is then burnt at high temperature using the flare. Safety vents may also be fitted in the cover to protect it from over-inflation.

CAPs are usually designed to allow for desludging without cover removal. The installation of sludge extraction ports through the pond bank often provides the most practical solution (see section 10.3.8 for more details). The pond width must take into account the effective reach for suction pipes from the vacuum tanker that will draw out the sludge.

CAPs need to be lined to be impervious.

CAPs need to be designed and managed to minimise the risks to human health. Refer to the Code of Practice for On-Farm Biogas Safety and Use (Piggeries) (Australian Pork Limited 2015a) and the Gas Safety Management Plan template (Gas Advisory Services Pty Limited 2014) for further information.

FIGURE 10.3 Guide Pipes Over a Pond Cover and an Operating Flare

10.3.4 Sedimentation and Evaporation Pond System (SEPS)

A SEPS is an alternative to a primary anaerobic pond. A SEPS consists of long, narrow, earthen channels built as embankments along the land contour. Usually two or three channels are built in parallel down the slope. At any time, one channel is in active use while the other one or two channels are drying and / or being cleaned. The piggery effluent is pumped or drained into one end of the active channel and is continuously drained or siphoned off at the other end of the channel into treatment or holding pond(s). The active channel is used continuously for six to twelve months. During this time, the manure solids settle out of the effluent into the base of the channel. At the end of the active period, the remaining liquid is drained or siphoned from the channel, leaving wet sludge. This dries by evaporation over the summer period. Dried manure is then easily removed using a front-end loader or excavator and stockpiled ahead of composting, reuse or sale. If the site constraints permit, leaving space between each channel will allow for temporary stockpiling of dry manure above the channels until this can be moved to a storage area or spread. Runoff from these areas should be directed back into the system.

In a two-channel SEPS, each channel must be able to store at least 12 months wet manure solids, which requires a capacity of 0.5 m^3/SPU. If three channels are used in parallel, each channel should be sized to store six months of wet solids, which requires a capacity of 0.25 m^3/SPU. The design VS loading rate for a channel providing 0.25 m^3/SPU is about 1000 g VS/m^3/day.

Each channel is typically 6 m wide at the base, with 3:1 internal batters and a maximum water depth of 0.7-1.0 m plus freeboard of 0.6 m. The base and sides of the channels must be impervious. Usually SEPS channels are lined with clay compacted for a design permeability of 1×10^{-9} m/s for a depth of 300 mm consisting of two 150 mm thick layers. For guidance regarding clay lining and compaction to achieve this design permeability see Skerman et al. (2005): www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/constructing-effluent-ponds. The base must also be trafficable to allow for cleaning.

A SEPS overcomes the difficulties and high costs involved in desludging large, deep anaerobic ponds. They can be constructed at a new piggery or may be integrated into an existing treatment system where site constraints permit.

While SEPS have mostly been used in southern-Australia, they are also suitable for use in summer-dominant rainfall regions such as southern Queensland and northern NSW. For further information, see Skerman (2013) and the APL booklet "SEPS: Sedimentation and Evaporation Pond Systems" (Australian Pork Limited 2015f).

10.3.5 Secondary Effluent Treatment Ponds

Some piggeries use secondary ponds as a further effluent treatment step. These ponds are often facultative, being aerobic near the surface and anaerobic at depth. This is because they are generally shallower than anaerobic ponds (depth of 1-3 m) with a greater surface area to volume ratio. The base and sides of these ponds must be impervious.

10.3.6 Wet Weather Ponds

Wet weather ponds store treated effluent at times when reuse is not possible (wet conditions), or not needed (e.g. when reuse areas are fallow or crops are close to harvest). In southern Australia, they need to store effluent over the winter months when rainfall exceeds evaporation and irrigation opportunities may be limited. The dimensions of a wet weather pond will depend on site constraints and reuse objectives; a deeper pond with steep internal banks will have reduced evaporation which increases the effluent volume for reuse.

The design spill frequency of the wet weather pond will depend on the sensitivity of the receiving environment, although this should not exceed once every 10 years on average. The required volume and dimensions of the pond can be estimated using daily or monthly water balance modelling, preferably using models such as MEDLI or WaterBal (Skerman 2018). The base and sides of these ponds must be impervious.

10.3.7 Evaporation Ponds

Shallow ponds or basins can provide for disposal of effluent by evaporation. This eliminates the need to irrigate effluent but will only be effective in sites with a relatively high evaporation to rainfall ratio.

The design spill frequency of evaporation ponds will depend on the sensitivity of the receiving environment. However, evaporation ponds should not spill more than once every 20 years on average. The required volume and dimensions of the pond can be estimated using daily or monthly water balance modelling, preferably using models such as MEDLI or WaterBal (Skerman 2018). The base and sides of these ponds must be impermeable.

10.3.8 Designing for Pond Desludging

Sludge is a mixture of water and solids (inorganic material, slowly digestible organic material and dead microbial cell mass) that accumulates in the bottom of effluent treatment ponds (particularly primary ponds) as a consequence of effluent treatment. Effluent treatment ponds need to be sized to provide for sludge storage, and sludge needs to be removed as needed to ensure the system has sufficient active treatment volume.

There are three options for removing sludge from an operating, uncovered pond. They are:

1. pumping with a pump or vacuum tanker located on the bank of the pond with or without sludge agitation.
2. dredging using a mobile pump located within the pond that provides access to all sections of the pond.
3. mechanical removal using a long-reach excavator or similar.

The options for removing sludge from CAPs are limited as the cover cannot be removed during the operational phase. They are:

1. in-situ desludging. The solids settle to the base of the CAP and are removed by pumping via a pre-installed pipeline.
2. suspension removal. The solids are not allowed to settle. They are kept in suspension using agitators inside the CAP. The solids are removed as part of the effluent flow out of the CAP.
3. life-time accumulation. In this approach, solids are allowed to settle but are not removed until the operational life of the pond cover is reached and the cover is removed (McGahan 2014)

Sludge removal ports installed through the banks of the pond are preferred over fixed suction pipes (see Figures 10.4 and 10.5). The ports typically consist of poly or uPVC pipes at least 300 mm in diameter that are permanently installed through the bank. The ports should have sufficient diameter to accommodate the suction pipe and an additional pipe for adding pressurised water for mixing and dilution. Ports spaced every 10-15 m along the pond length are suggested. Installing these at an angle can provide for a better reach. Such sludge extraction ports can also form a guide pipe for a 200 mm pipe attached to a pump or vacuum tanker to be threaded through the port for sludge removal. The suction pipes that are threaded through sludge removal ports offer better control over sludge extraction depth, more pump options and better flexibility for trouble shooting.

FIGURE 10.4 Sludge Extraction Ports Being Installed Through Pond Wall

Photo courtesy of Tom Smith.

FIGURE 10.5 Vacuum Tanker Pipe Threaded Through Sludge Extraction Port on Covered Pond

Photo courtesy of Tom Smith.

Because transportation costs will be greater for sludge with a higher moisture content, dewatering or drying of the removed sludge will often be desirable, particularly if the final reuse site is some distance from the source. Sludge can be dewatered or dried using:

1. long-term bulk storage
2. short-term drying bays
3. sedimentation and evaporation pond system (SEPS)
4. geotextile tubes.

Sludge dewatering or drying needs to be done in a way that prevent impacts to groundwater and surface waters. Consequently, the base of any bay or storage pad used to store sludge should have a design permeability of 1×10^{-9} m/s for a depth of 300 mm consisting of compacted layers not exceeding 150 mm depth. Guidance and technical direction for clay lining and compaction of basins or pads can be obtained at: https://www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/constructing-effluent-ponds (Skerman et al. 2005) or https://www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation (Skerman 2005). The dewatering facility must be large enough to store the estimated sludge volume. The sludge storage bay or pad should be bunded to exclude extraneous runoff. Stormwater and leachate caught within the area should be contained in an appropriate storage.

10.4 Biogas Systems

Biogas systems capture the gases emitted as a product of anaerobic digestion and convert them into heat and / or power. Biogas systems for piggeries can be CAPs, hybrid CAP systems or fully engineered biodigesters. Boilers and combined heat and power (CHP) systems are the main technologies providing for the utilisation of the collected biogas.

- CAPs include a covered anaerobic pond (see section 10.3.3), slotted pipelines that collect the biogas from under the pond cover, a blower that moves the biogas via a sealed pipeline through the pond bank, a scrubber to remove corrosive components and a boiler or generator. Biogas is commonly chilled to remove moisture by condensation. Underground pipelines may be used to cool the biogas and thereby remove at least some of the moisture. To claim Australian carbon credit units (ACCU), it is necessary to set up a project under an ERF-approved methodology that includes CAPs.
- Hybrid CAP systems are CAPs fitted with stirring and / or heating equipment. The stirring reduces solids settling, ensuring more of the material is exposed to treatment. Heating the ponds regulates the temperature of the effluent during the cooler months, providing more constant biogas production over the year. To claim ACCUs, it is necessary to set up a project under an ERF-approved methodology that includes engineered biodigesters.
- Engineered biodigesters consist of a sealed chamber in which microorganisms anaerobically digest effluent. Engineered biodigesters generally provide controlled conditions such as constant temperature that favour more complete degradation of the effluent and manure, and more uniform biogas production than the CAP or hybrid CAP options. To claim ACCUs, it is necessary to set up a project under an ERF-approved methodology that includes engineered biodigesters.

The Australian Pork Limited "Code of Practice for On-Farm Biogas Safety and Use (Piggeries)" aims to provide a consistent framework and guidance for the safe design, construction, operation, and maintenance of biogas systems. The Code of Practice is intended to complement, but not replace, relevant State and Territory legislation and requirements. The Code of Practice is available at: http://australianpork.com.au/wp-content/uploads/2013/10/2011_1013-423-CoP-Final-April15.pdf.

Because biogas poses risks to human health, a Biogas Safety Plan is recommended for all biogas developments and is mandatory in some states. A Gas Safety Management Template is available at: http://australianpork.com.au/industry-focus/environment/renewable-energy-biogas/. Signage around biogas infrastructure should alert people to the flammability and toxicity dangers. Expert assistance should also be sought during biogas system design and installation.

11. Manure and Spent Bedding Storage Areas

Spent bedding, separated manure solids and pond sludge may be stored or composted or treated before use. This section provides design guidance for manure and spent bedding storage areas. Carcass composting is addressed in section 15.1.

Environmental Outcome: Manure storage and composting areas should be sited, designed and constructed to provide sufficient storage space and to protect amenity, surface water and groundwater quality.

11.1 General Design Principles for Manure and Spent Bedding Storages

When choosing a site for a manure or spent bedding storage, consider the potential for impacts to amenity, surface waters and groundwater. Since stored manure will release some odour, locate the site away from sensitive land uses. Recommended fixed separation distances are provided in Appendix A: National Odour Guidelines for Piggeries. Provide a buffer to surface waters. The pad base should sit at least 2 m above the highest seasonal water table.

To protect water resources, manure should only be stored or composted within impermeable, bunded areas. These should have a design permeability of 1×10^{-9} m/s for a depth of 300 mm, comprising two layers each compacted to 150 mm.

For guidance on achieving this design permeability, see Skerman (2005): https://www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation.

The manure or spent bedding storage area needs to be sized to hold the maximum expected manure volume, with some contingency capacity. In most cases, space should be provided for at least six months manure production, to fit in with cropping cycles. The dimensions of the piles or windrows, and the space needed between these for any pile turning and loading onto trucks also affects the total area needed.

Bunding with a height of 0.3 m will generally be sufficient to divert extraneous stormwater around the storage and to contain rainfall landing within the area. Ideally, rainfall caught within the pad will be directed to the effluent treatment system or a separate runoff collection pond that is sized and managed for a 1 in 10 year spill frequency.

11.2 Manure and Spent Bedding Composting

Manure and spent bedding composting is generally undertaken using windrows that are 1.5-3 m high, 2-3m wide at the base and up to 1 m wide at the top. Sufficient space needs to be provided between these for windrow turning (if required) and loading onto trucks.

However, aerated floor composting is growing in popularity. The composting material is placed over moveable, perforated, above-ground pipes that deliver air into the manure or spent bedding. By removing the need to turn piles in order to introduce air, less space is required. The pipes can be easily removed for loading of the finished compost.

APL has also been investigating the use of compost pelletisation to allow for the delivery of manure nutrients in a more concentrated form that would be easier and cheaper for farmers to handle, transport and apply using an air-seeder. This will require an investment in new equipment and the experience to operate the pelletiser.

12. Reuse Areas

Reuse areas are land used to spread piggery effluent or manure. Effluent and manure contain valuable plant nutrients and carbon that can be applied to farming land to improve soil fertility, structure, health and microbial activity. These nutrients should be incorporated into a crop, hay or silage production system to achieve a balance between the amount of nutrients applied and the amount removed, or to optimise soil nutrient levels as determined by soil testing.

Environmental Outcome: Reuse areas are selected, sized and designed to enable sustainable and beneficial reuse of nutrients, salts and water in effluent and manure, while avoiding nutrient overloading, and preventing soil, land and water degradation.

Piggery effluent and manure are distributed onto land using irrigation systems, tankers or spreaders. Reuse can occur on-farm or off-farm. The piggery owner has a duty of care to ensure environmentally sustainable reuse is practiced on-farm. In some states, this duty of care extends to off-farm reuse areas. It is recommended that piggery operators have a written agreement with any off-site users and provide them with a product knowledge statement and typical chemical analysis data for the effluent or manure that they are receiving. Refer to the Piggery Manure and Effluent Management and Reuse Guidelines for further guidance.

12.1 Selecting a Suitable Reuse Area

Reuse areas need to be carefully selected to ensure they will be suitable for the purpose, while also considering soil, surface water and groundwater protection. A risk-based approach should be used to evaluate whether an area has appropriate properties. Seek early advice from a soil scientist.

Ideally, a reuse area should:

- have good agronomic properties making it suitable for pasture or crop production e.g. well-structured, non-rocky, non-saline and non-sodic loam to medium clay soil
- be separated from watercourses, waterways, wetlands and sensitive native vegetation
- not be prone to water logging
- be above the one in five year flood line
- have slopes that promote infiltration, rather than runoff and erosion
- provide at least 2 m clearance above the shallowest water table
- be well separated from neighbouring residences and other sensitive areas.
- provide sufficient area for sustainable reuse of the expected nutrients in the effluent or manure.

Land that does not have all these properties may still be suitable but may require better design and more intense management to minimise the risk of environmental impacts.

Agronomic soil testing is recommended for new reuse areas, to ensure soil properties (particularly nutrient status) are well understood. Refer to section 16.2 and Table 16.1 for recommended parameters.

12.2 Land Area Needed for Sustainable Reuse

Manure and effluent are rich in nutrients. The land area needed for sustainable reuse depends on the:

- composition of effluent and / or manure
- quantity of effluent and / or manure available for reuse
- expected uptake of nutrients by harvest of plants growing on reuse areas
- nutrient status of the soil
- expected gaseous nitrogen losses during and after irrigation or spreading.

The soils of reuse areas should be regularly monitored to confirm that practices remain sustainable. Section 16.3 provides soil monitoring recommendations.

12.2.1 Composition of Effluent and Manure

Table 12.1 and Table 12.2 show typical data for the composition of piggery effluent and sludge respectively. Data in Table 12.1 are measured from the final pond, from which effluent would usually be drawn for irrigation. While the data in Table 12.2 shows a dry matter range of 6.9-17.1% for sludge, recent analysis of a range of piggery sludge samples has measured dry matter contents as low as 3.2% (O'Keefe et al. 2013). Table 12.3 provides data for spent bedding from deep litter piggeries. The wide variation in results reflects the range of design, management, diets, water use and climate. Thus 'typical' composition data for pond effluent (irrigation water) and pond sludge cannot be provided. The moisture and nutrient content of spent bedding can also vary widely (Craddock and Wallis 2013). Once the piggery is operating, testing the effluent, sludge and / or spent bedding will provide better data for determining appropriate reuse rates for a particular farm.

12.2.2 Quantity of Effluent and Manure

The quantity of effluent or manure for reuse depends on a range of factors. Multiply the expected mass of manure or volume of effluent by the nutrient concentration to estimate the total mass of any nutrient. Use the dry matter mass when multiplying by a dry-basis nutrient concentration.

For example, from Table 12.3, straw-based spent bedding has a moisture content of 41.6% or a dry matter content of 58.4%, so every tonne contains 584 kg of dry matter (1000 kg X 58.4%). The total nitrogen concentration (dry basis) is 0.8%. Hence, every tonne contains 4.7 kg of nitrogen (i.e. 584 kg X 0.8%).

12.2.3 Expected Nutrient Removal by Plant Harvest

The type of crop grown on the reuse area determines the amount of nutrients removed through harvest, depending on the crop's dry matter yield and nutrient content. It therefore is a major determinant of the land area required for reuse. Table 12.4 shows typical dry matter nutrient contents and expected yield ranges for a variety of pasture, silage, hay, grain and horticultural crops. The yields presented are for typical cropping soils.

Inputs to nutrient mass balances should be conservative to provide a margin for error. In the absence of long-term average yields for the farm, use average district crop yields.

FIGURE 12.1 Soil nutrient removed during the cropping cycle

TABLE 12.1 Characteristics of Piggery Pond Irrigation Effluent

Element	Units	Effluent at Work[a]	DEEDI data[b]	
			average	range
Dry matter	mg/L	3623	7900	1100-44300
Volatile solids	mg/L	1809	1640	480-5290
pH		8.0	8.0	7.0-8.7
Total nitrogen or {TKN}	mg/L	{384}	584	158-955
Ammonium nitrogen	mg/L	249	144	25-243
Total phosphorus	mg/L	44	69.7	19.3-175.1
Ortho-phosphorus	mg/L	28.5	16.3	2.4 – 77.9
Potassium	mg/L	-	491	128-784
Sulphur	mg/L	22 (9 – 50)	-	-
Sulphate	mg/L	26	47.6	13.3-87.2
Copper	mg/L	-	0.09	0.00-0.28
Iron	mg/L	-	0.56	0.09-1.61
Manganese	mg/L	-	0.02	0.00-0.05
Zinc	mg/L	-	0.47	0.16-1.27
Calcium	mg/L	-	20.6	7.3 – 41.2
Magnesium	mg/L	-	25.0	6.6 – 72.3
Sodium	mg/L	603	399	41 – 1132
Chloride	mg/L	810	19.1	3.6 – 34.4
Conductivity	ds/m	-	6.4	2.5 – 11.7

DEEDI = Department of Employment, Economic Development & Innovation,
Qld, TKN = total Kjeldahl nitrogen
a Kruger *et al.* (1995) - samples from piggeries in New South Wales, Queensland and Western Australia.
b unpublished data – samples from 10 piggeries in southern Queensland.

TABLE 12.2 Characteristics of In Situ Piggery Pond Sludge

Element	Effluent at Work[a]	DEEDI data[b]	
		average	range
Dry matter	-	13.1% wet basis	6.9-17.1% wet basis
Volatile solids	-	6.9% wet basis	5.3-9.5% wet basis
pH	7.3	-	-
Carbon	-	28.1%	22.5-37.1%
Total nitrogen or {TKN}	{2617} mg/L	3.41%	2.84-4.02%
Ammonium nitrogen	1156 mg/L	2582 mg/kg	1472-4422 mg/kg
Total phosphorus	1696 mg/L	4.69%	2.83-5.9%
Ortho-phosphorus	1082 mg/L	-	-
Potassium	-	0.75%	0.27-1.33%
Sulphur	-	1.99%	1.53-3.08%
Copper	25 mg/L	1.02%	3.43-1.82%
Iron	-	1.17%	0.52 – 2.21%
Manganese	-	1050 mg/kg	786-1389 mg/kg
Zinc	-	3188 mg/kg	2184-3698 mg/kg
Calcium	2210 mg/L	7.08%	4.28-10.4%
Magnesium	-	1.93%	1.0-3.19%
Sodium	108 mg/L	0.52%	0.15-1.40 %
Selenium	-	0.59 mg/kg	0.07-2.41 mg/kg
Chloride	232 mg/L	-	-
Conductivity	8.5 ds/m	-	

DEEDI = Department of Employment, Economic Development & Innovation, Qld; TKN = total Kjeldahl nitrogen
a Kruger *et al.* (1995) - samples from piggeries in New South Wales, Queensland and Western Australia.
b unpublished data – samples from 10 piggeries in southern Queensland.

TABLE 12.3 Nutrient Content of Spent Bedding from Deep Litter Piggeries

Unit		Straw	Rice Hulls	Sawdust
Moisture	% wb	41.6 (18 - 64)	36 (21 - 53)	40.8 (21 - 50)
pH		6.8 (5.7 - 8.5)	7.1 (7 - 7.3)	6.3 (6.2 - 6.3)
Total nitrogen or {TKN}	% db	0.8 (0.2 - 1.3)	0.7 (0.1 - 1.6)	0.9 (0.6 - 1.3)
Ammonium nitrogen	% db	0.5 (0 - 1.2)	0.3 (0.1 - 0.5)	0.6 (0.4 - 1)
Total phosphorus	% db	1.1 (0.2 - 2.5)	0.9 (0.6 - 1.3)	1 (0.4 - 1.3)
Ortho-phosphorus	% db	0.4 (0.2 - 0.6)	0.4 (0.3 - 0.6)	0.4 (0.2 - 0.5)
Potassium	% db	1.8 (0.6 - 2.8)	1.8 (1.2 - 2.1)	1.8 (1.6 - 1.9)
Sulphur	% db	0.4 (0.1 - 0.7)	0.4 (0.3 - 0.5)	0.5 (0.4 - 0.5)
Copper	% db	0 (0 - 0.1)	0 (0 - 0)	0 (0 - 0)
Iron	% db	1.3 (0.1 - 3.2)	1 (0.7 - 1.6)	1.1 (0.5 - 1.6)
Manganese	% db	0.1 (0 - 0.8)	0.2 (0 - 0.8)	0.3 (0 - 0.8)
Zinc	% db	0.2 (0 - 0.4)	0.1 (0 - 0.3)	0.1 (0.1 - 0.2)
Calcium	% db	1.9 (0.4 - 3.1)	1.4 (1 - 2.1)	2.4 (2.1 - 2.7)
Magnesium	% db	0.7 (0 - 1.8)	0.4 (0 - 0.6)	0.4 (0 - 0.7)
Sodium	% db	0.4 (0.1 - 0.7)	0.3 (0.1 - 0.4)	0.4 (0.4 - 0.5)
Chloride	% db	0.8 (0.3 - 1.3)	0.6 (0.4 - 0.8)	0.7 (0.4 - 1.1)
Conductivity	ds/m	11.7 (6.6 - 15.6)	9.6 (9.2 - 10)	13 (12.6 - 13.4)

Notes:
wb = wet basis or percentage of the total weight of the spent bedding
db = dry basis or percentage of the dry matter content of the spent bedding
Data provided as average and range (in brackets).
Nutrient contents based on a combination of fresh, stockpiled and composted spent bedding
Source: Black (2000); and Nicholas et al. (2006).

TABLE 12.4 Nutrient Content and Anticipated Dry Matter Yield of Various Crops

Crop	Dry matter nutrient content (kg/t)			Normal yield rangea (DM t/ha)	Normal Nutrient Removal Range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Grazed pasture	20	3	15		7.1 - 19.0	0.9 - 2.2	0.1 - 0.6
Dry land pasture (cut)	20	3	15	1 - 4	20 - 80	3-12	15 - 60
Irrigated pasture (cut)	20	3	15	8 - 20	160 - 400	24 - 60	120 - 300
Lucerne hay (cut)	31	3	25	5 -15	155 - 465	15 - 45	125 - 375
Maize silage	22	3	20	10 -25	220 - 550	30 - 75	200 - 500
Forage sorghum	22	3	24	10 -20	220 - 440	30 - 60	240 - 480
Winter cereal hay	20	3	16	10 -20	200 - 400	30 - 60	160 - 320
Grain barley	19	3	4	2 – 5	38 - 95	6 - 15	8 - 20
Grain wheat	19	4	5	2 – 5	38 - 95	8 - 20	10 -25
Barley straw	7	0.7	24	5 – 10	35 - 70	7	119 - 237
Wheat straw	6	0.5	14	5 – 10	29-58	2.5-5	71-142
Grain triticale	19	4	6	1.5 – 3	29 – 57	6 -10	9 - 18
Rice	14	3	4	4 – 8	56 - 112	12 - 24	16 - 32
Grain oats	15	3	4	1 – 5	15 - 75	3 - 15	4 - 20
Grain sorghum	20	3	3	2 – 8	40 - 160	6 - 24	6 - 24
Grain maize	20	3	4	2 – 8	40 - 160	6 - 24	8 - 32
Chickpea	40	4	4	0.5 - 2	20 - 80	2 – 8	2 – 8
Cowpea	30	4	20	0.5 - 2	15 - 60	2 – 8	10 - 40
Faba beans	40	4	12	1 – 3	40 - 120	4 – 12	12 - 36
Lupins	45	3	8	0.5 - 2	22.5 - 90	1.5 - 6	4 - 16
Navy beans	40	6	12	0.5 - 2	20 - 80	3 – 12	6 - 24
Pigeon peas	26	3	9	0.5 - 2	13 - 52	1.5 - 6	4.5 - 18
Canola	33	0.3	12	1 – 3	33-98	0.3-0.9	12 - 36
Cotton	20	4	8	2 – 5	40 - 100	8 - 20	16 - 40

[a] yields may vary from these ranges (refer to historical data for the region for more accurate estimates).

[b] the grazing pasture example assumes a liveweight gain of 75 – 200 kg/ha/yr, with no ammonia volatilisation losses from the grazed animal's manure.

Sources: Reuter and Robinson (1997) and National Research Council (1984). Canola data: Assadi et al. (2010)

Grazing removes only low levels of nutrients from reuse areas, since most nutrients are recycled in manure. Thus, grazing systems typically require at least five to ten times more area than cut and cart systems. For this reason, grazing alone is not a recommended land use for reuse areas. If this system is used, nutrients should be applied only at levels that improve soil's nutrient status to good agronomic levels.

12.2.4 Nutrient Status of the Soil

Soil nutrient status should be considered when planning a reuse strategy. This provides an opportunity to identify nutrient surpluses or imbalances and address nutrient deficiencies and other concerns.

12.2.5 Expected Gaseous Nitrogen Losses

Reuse will result in some gaseous nitrogen (ammonia) losses. The extent of these losses will vary with the type of product being spread and the spreading method.

For effluent, total nitrogen losses could be:

- spray irrigation 20%
- surface irrigation 10%
- injection ~0%

For manure, nitrogen losses can be minimised by promptly incorporating solids. However, total nitrogen losses could be:

- manure spread fresh 20%
- aged manure 10%
- compost 5%

12.2.6 Calculating Areas Required Using Sustainable Application Rates

Mass balance is the recommended approach for determining sustainable effluent and manure reuse rates which can then be used to calculate the required size of the reuse areas. In the simplest form, effluent and manure application rates are considered sustainable if there is a plan to remove the applied nitrogen, phosphorus and potassium through crop harvest and unavoidable gaseous nitrogen losses.

Mass of nutrients to apply (kg/ha/yr) = crop uptake (kg/ha/yr) + expected nitrogen losses

The expected nitrogen volatilisation rate can be deducted from the mass of nitrogen in the effluent or manure before calculating spreading rates to ensure the net application rate matches the expected crop nitrogen removal rate. See section 12.2.5 for further details.

The APL website provides a Nutrient Balance Calculator for Conventional Piggeries that can be used to determine reuse rates and the required land area using these principles. Use long-term average yields representative of the local area in these calculations.

Once the target spreading rate is known, the land area needed can be determined by dividing the total mass of each macro-nutrient in the effluent and / or manure (nitrogen, phosphorus, potassium) by the spreading rate:

Minimum area required (ha) = total mass of nutrients in manure or effluent (kg) / spreading rate (kg/ha)

The nutrient requiring the largest area (ha) is the limiting nutrients and determines the minimum land area (ha) needed for reuse.

However, when determining annual reuse rates, consider soil nutrient status including the availability of nutrients in effluent and manure for uptake by plants. Where soil tests show that the soil is nutrient deficient, additional nutrients can be applied to achieve good agronomic levels. Hence, the mass balance equation becomes:

Mass of nutrients to apply (kg/ha/yr) = crop uptake (kg/ha/yr) + expected nitrogen losses +/- soil nutrient adjustments + soil phosphorus storage

Because phosphorus can usually be stored safely in the soil, it may be acceptable to apply up to five years' phosphorus in one years' irrigation or spreading provided there is a plan to remove it over time (i.e. the next reuse of that area occurs only when the applied phosphorus is removed). The maximum annual spreading rate may also be limited by the nitrogen or potassium rate, since these nutrients must be removed by the expected crop harvest in the 12 months after spreading. Site specific soil testing (e.g. P-sorption test) to a depth of at least 0.6 m can demonstrate the soils ability to safely store phosphorus. Soil storage capacity can then be estimated for the soil profile depth, to a maximum depth of 1 m. Redding (2003) provides further guidance for determining the phosphorus storage capacity of soils. Applying multiple years' worth of phosphorus in a single year won't change the total land area needed for reuse, just the area needed each year. Additional surface water protection measures (e.g. well designed and managed vegetated filter strips (VFS) may also need to be in place.

It is important to discuss soil phosphorus storage with your state environmental authority before planning to use this approach, since some states or regions may not accept any soil phosphorus storage.

Further guidance on manure and effluent reuse is provided in the "Piggery Manure and Effluent Management and Reuse Guidelines".

12.3 Secondary Control Measures and Reducing Nutrient Loss

Sound spreading and irrigation practices minimise the risk of nutrient exports from reuse areas. These practices include using appropriate application rates and systems, applying effluent or manure at suitable times (e.g. just before planting or when plants are actively growing and taking up nutrients) and providing buffers to sensitive land uses. Secondary control measures further reduce nutrient loss when the above practices are insufficient, and may include:

- putting VFSs downhill of the reuse areas
- putting terminal ponds downhill of the reuse areas
- installing contour banks on sloping land
- maintaining continuous ground cover
- incorporating manure into the soil.

These measures effectively reduce soil erosion and filter nutrients from runoff. The most appropriate methods will depend on the site, the properties of the reuse area and the irrigation method (where applicable). However, control measures such as VFSs and terminal ponds should not be used as a 'quick-fix' for poor practices. They provide secondary environmental protection to complement sustainable use practices.

12.3.1 Vegetative Filter Strips

VFSs are strips of dense grass between reuse areas and protected areas. Section 6.1 provides design details for these.

12.3.2 Terminal Ponds

Terminal ponds located at the bottom of effluent reuse areas are generally designed to catch the first 12 mm of runoff from a paddock, which may have a higher nutrient concentration than runoff received later in a large storm. The principle is to trap a significant proportion of the dissolved and suspended nutrients in the runoff from the reuse area. The stored runoff can then be re-irrigated. During storms producing greater than 12 mm of runoff, terminal ponds overflow through a properly designed spillway. However, they can still reduce nutrient export by slowing the flow velocity to enable some settling of suspended soil and organic matter particles. It is important to either irrigate or recycle runoff collected in terminal ponds back to the irrigation storage as soon as possible, to provide storage capacity for the collection of subsequent runoff.

12.3.3 Graded Banks

Banks constructed along height contours on sloping areas reduce the velocity of runoff and hence erosion. They capture and redirect runoff from smaller areas of a paddock, preventing it from concentrating into larger streams that erode large volumes of soil. While these may effectively prevent the loss of nutrients attached to soil, they do not prevent the loss of nutrients dissolved in runoff.

12.3.4 Groundcover

Maintaining continuous groundcover, either as pasture or through conservation tillage practices, promotes infiltration of rainfall and reduces runoff, water velocity and soil movement. Again, this reduces nutrient removal due to soil erosion, and reduce dissolved nutrient losses.

12.3.5 Incorporation of Manure

Incorporating manure reduces the nutrient concentration at the soil surface. This may lower nutrient losses by erosion or via stormwater runoff. However, manure incorporation does not fit with some farming systems (e.g. minimum or zero-till).

13. Mortalities Management

Rendering and composting are the preferred methods for managing mortalities, stillborn piglets and afterbirth. Suitable alternatives may include incineration and burial. Irrespective of the method chosen, dead pigs should be immediately removed from the access of other pigs, with disposal within 24 hours of death.

Poor mortalities management practices may contaminate groundwater and surface water, cause odour, spread infectious diseases, and attract vermin. Further details on mortalities management methods are provided in AUSVETPLAN Operational Manual: Disposal Version 3.1 (Animal Health Australia 2015).

Environmental Outcome: Mortalities management practices that prevent odour, vermin breeding and other amenity nuisance, and groundwater and surface water contamination.

13.1 Mortalities Composting

Composting is a safe and environmentally sound method for managing mortalities. The carcasses are efficiently converted into a soil amendment, and the heat generated during the composing process kills most pathogens.

Mortalities composting should be undertaken within a bunded area with an impermeable base that sits at least 2 m above the highest seasonal water table. A pad consisting of concrete or clay compacted for a design permeability of 1×10^{-9} m/s for a depth of 300 mm comprising two 150 mm deep layers is suitable. For guidance and technical direction regarding earth pad preparation requirements see: www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation (Skerman 2005). Significant stormwater volumes caught within the composting area should be directed into the effluent treatment ponds or other stormwater collection ponds.

Carcasses are generally composted in a series of above-ground bays or windrows. To size the pad, provide at least 4 m^3 of bay or windrow capacity for each tonne of carcasses. Ensure there will be sufficient space for vehicle maneuvering between and around windrows.

When the compost is reused on land, it should be spread evenly onto land at environmentally sustainable rates, adopting the same principles used for manure (see section 12). For further information, refer to the Piggery Manure and Effluent Management and Reuse Guidelines.

13.2 Rendering

Rendering is an excellent mortalities management method because there is little risk of adverse environmental impacts. Rendering must be undertaken in accordance with the Standards Australia (2007) "Australian Standard for the Hygienic Rendering of Animal Products".

A bunded area with a low permeability floor must be provided for storing carcasses before dispatch. This area needs to be well separated from live pigs. A pad consisting of concrete or clay compacted for a design permeability of 1×10^{-9} m/s for a minimum depth of 300 mm, comprising two layers each 150 mm thick will be suitable. Guidance regarding earth pad preparation requirements can be obtained from: www.daf.qld.gov.au/environment/intensive-livestock/piggeries/managing-environmental-impacts/earth-pad-preparation (Skerman 2005).

An agreement with the receiving company is needed to ensure regular (preferably daily) receipt of carcasses. A contingency plan is needed in the event that the rendering plant is unable to receive mortalities.

13.3 Burial

Burial pits should be situated on low permeability soils and / or low risk sites and the pit bases should be at least 2 m above the highest seasonal water table level.

Most burial pits are simple trenches excavated into the ground. An alternative to an earthen pit is an enclosed burial pit, constructed from concrete or high-density polyethylene or fibreglass and fitted with a watertight lid.

Some state government agencies only allow burial under specific conditions, for example, disease outbreaks or mass mortalities.

13.4 Burning or Incineration

The requirements for incineration of mortalities are similar to those for clinical waste. The incinerators are either complex multi-chamber units or pyrolysis process types. They typically have a final chamber that operates at 1000°C with a residence time of at least one second to incinerate the odorous gases that may result from the ignition of the carcasses.

Burning of carcasses in open fires is unacceptable, as it creates smoke and odour and is unlikely to maintain a sufficiently high temperature consistently.

13.5 Mass Mortalities Contingency Plan

Effective responses to emergency disease outbreaks require good planning. All piggery operators should identify a potential mass mortalities disposal site and have a contingency plan for managing the high death rates that may occur as part of a disease outbreak.

State government veterinary officers have the main responsibility and resources to combat an exotic disease incursion or endemic disease outbreak. They should be contacted immediately if a disease outbreak is suspected. The relevant state government department should be consulted regarding selection of a disposal method and site.

For further guidance, refer to the AUSVETPLAN manuals "Operational Procedures Manual: Disposal (Animal Health Australia 2015) and "Enterprise Manual: Pig Industry" (Version 3.0) (Animal Health Australia 2011).

In some instances, disposal to land fill may be mandated by a state veterinary officer.

14. Traffic and Parking

Trucks delivering feed and transporting pigs and staff vehicles need safe, all-weather access to the piggery. This requires suitable public roads, safe property access points, all-weather on-farm roads and suitable turning and parking areas.

Any gates or barriers at property entry must be positioned to allow full-length trucks to turn into the property and be clear of the road before needing to stop.

The standard of construction and required width of on-farm roads depends on the number and types of vehicles that will access the site. On-farm parking space must be allocated for staff vehicles, visitors and trucks; on-farm roadside parking may be suitable. On-farm truck turning points are needed to allow all vehicles to exit the property in a forward direction.

15. Environmental Risk Assessment

The purpose of an environmental risk assessment is to identify any actual, or likely impacts that a piggery development may pose to the environment. It must consider inter-related factors and how to minimise or mitigate all environmental risks through design, management or monitoring.

Environmental Outcome: Identification, minimisation and mitigation, and monitoring of the piggery's environmental risks.

The environmental risk assessment process commences with the identification of environmental aspects, or ways in which the piggery can cause environmental impacts. For example, discharge of nutrient rich stormwater (aspect) could result in elevated nutrient levels in watercourses (impact). Identified aspects then need to be evaluated to determine whether they are significant. This will depend on their likely impact on the environment, the probability of occurrence and relevant legal or regulatory requirements.

An example risk assessment process for piggeries is provided in Appendix B. Other methods are also possible. A basic Environmental Management Plan (EMP) template, which includes an environmental risk assessment, is available on the APL website: http://australianpork.com.au/industry-focus/environment/planning-and-development/.

Once significant environmental aspects have been identified, objectives and targets to address these can be developed. These also need to be prioritised depending on whether there are any legal or regulatory obligations, the level of environmental impact or risk and the technological options available. Implementation of solutions can then occur.

16. Monitoring and Assessment of Sustainability

Environmental monitoring, including using productivity and sustainability indicators to interpret results, is critical to the overall environmental management of a piggery. It provides a mechanism to assess the effectiveness of strategies chosen to minimise environmental impacts.

It is extremely difficult to identify indicators of sustainability that cover all situations. In some situations, indicators for determining sustainability may overstate the likely environmental risk. In some cases, alternative indicators or methods may provide a better indicator of sustainability. Consequently, where a significant level of environmental risk or impact is identified, it is critical to confirm that this result is accurate through further investigation or action.

Environmental Outcome: Monitoring systems that detect environmental impacts, evaluate the effectiveness of environmental risk minimisation and mitigation strategies and trigger changes to further mitigate risks.

16.1 Community Amenity

People living near piggeries have the right to amenity, or the comfortable enjoyment of life and property. Odour, dust and noise can create a nuisance, particularly if they occur at times when neighbours want to relax or socialise at home, and this can result in complaints. Good communication with neighbours, and pro-active responses to complaints, are fundamental to protecting community amenity.

16.1.1 Community Liaison

A good relationship with neighbours is helpful in preventing and addressing nuisance complaints. Aim to build and maintain a good, open relationship with neighbours so sensitivities are understood and issues can be headed-off or identified and resolved before they become a serious problem. In particular, aim to understand any particular sensitivities (e.g. odour, road dust or truck noise) and the days of the week and times of the day when the occupants are less likely to be home. Use this information to identify the best times to schedule odorous, dusty or noisy activities and suitable times to spread manure or effluent on paddocks close to sensitive neighbours. Also, keep neighbours informed if you need to undertake an activity that will result in short-term increased odour, dust or noise. Encourage two-way dialogue.

16.1.2 Handling Complaints

The number or pattern of complaints received is one measure of the impact of a piggery on community amenity. While this measure is imperfect, it helps to identify when receptors perceive that the piggery is unreasonably affecting their enjoyment of life and property.

Manage complaints by:

- talking with the complainant about the issue. Aim to find out what the problem is (e.g. odour, dust, noise), what date and time it occurred, how long the nuisance lasted, whether the complainant can help identify the cause and any other useful information.
- investigating possible sources. Consider what activities were being undertaken where, and the weather and wind conditions at the time the nuisance occurred.
- gathering evidence and identifying and implementing strategies to remedy the problem and prevent it from happening again.
- talking with the complainant about the identified cause and the corrective and / or preventative actions taken and asking the complainant if the issue is now resolved. (If not, repeat the process).
- recording all details of the complaint, the investigation, actions taken and communication with neighbours.
- monitoring the effectiveness of the implemented strategies on an ongoing basis and adjusting if necessary.

Many nuisance incidents are closely related to weather conditions, so consider daily weather monitoring if complaints are ongoing. It can also help in assessing the validity of complaints. Large enterprises, or those with a history of complaints, may find that an on-site automatic weather station, that continuously monitors wind direction and speed, along with other climatic conditions, can be useful for complaint validation.

16.1.3 Complaints Register

Full details of the complaints received, results of investigations into complaints, and corrective actions should be recorded in a 'Complaints Register'. An example of a Complaints Register form is provided in Appendix C.

16.1.4 Assessing Amenity Impacts

Impacts to community amenity are very difficult to measure. However, a change in the number or pattern of complaints received may indicate a change in nuisance levels. This may be the result of a change in the habits or composition of the neighbours. Consequently, complaints need to be carefully evaluated so that appropriate preventative action or mitigation can be adopted where the piggery is causing nuisance. Weather data, particularly wind direction and speed, can be very useful in assessing amenity complaints.

16.2 Soils

16.2.1 Soil Sampling Frequency

A risk assessment can be used to determine the likelihood of adverse impacts to the soils of reuse areas. Where the risk of soil-related impacts is low, and at least three years of annual monitoring shows the system is sustainable, representative soils from reuse areas should be tested at least every three years.

Where there is a medium risk of soil impacts, and at least three years of monitoring data shows the system is sustainable, soils from reuse areas should be sampled and analysed at least every two years.

Where there is a high risk of soil impacts, annual soil monitoring is imperative.

For sites that will be loaded with several years' crop phosphorus requirement in a single year, consider determining the phosphorus sorption capacity of the soil and determining its capacity to store phosphorus before spreading. Refer to section 12.2.6 for more detail.

Soil sampling should always occur at the same time of year. The end of the cropping cycle is a good time, since nutrients remaining in the soil at this time are vulnerable to leaching. Avoid sampling immediately after prolonged wet weather.

16.2.2 Soil Sampling Depths and Analysis Parameters

The recommended soil monitoring parameters are given in Table 16.1. Analysis results should be compared with the sustainability indicator limits given in section 16.5.4. Where soil analysis results exceed these limits, further investigation is triggered to identify whether effluent or manure reuse is sustainable.

TABLE 16.1 Recommended Soil Analysis Parameters

Soil test parameter	Depth (down profile)	Justification
pH	0-0.1 m 0.3-0.6 m or base of root zone	influences nutrient availability
EC_{se} (can measure $EC_{1:5}$ and convert to EC_{se})	0-0.1 m[a] 0.3-0.6 m or base of root zone[b]	measure of soil salinity
Nitrate-nitrogen	0-0.1 m 0.3-0.6 m or base of root zone	measure of nitrogen available for plant uptake, and also to detect leaching
Colwell phosphorus and phosphorus buffering index (PBI)	0-0.1 m[c]	measure of phosphorus available for plant uptake, and also to detect leaching
Potassium	0-0.1 m 0.3-0.6 m or base of root zone	measure of potassium available for plant uptake, and also to detect leaching
Sulfur	0-0.1 m	necessary nutrient for plant growth
Organic carbon	0-0.1 m	influences soil stability, and consequently, soil erosion
Exchangeable cations (calcium, sodium, potassium, magnesium) and cation exchange capacity (CEC)	0-0.1 m 0.3-0.6 m or base of root zone	Needed to calculate ESP, EKP and Ca: Mg, which have important implications for soil structure

EC = electrical conductivity; CEC = cation exchange capacity; ESP = exchangeable sodium percentage; EKP = exchangeable potassium percentage.

a EC_{se} level in the top soil is not intended to be a direct sustainability indicator but will provide useful agronomic information and information on soil salt movements.

B measuring chloride at 0.3-0.6 m (or base of root zone) may also be warranted if further investigations or actions for salinity are required.

c subsoil testing may be appropriate for very sandy soils.

16.2.3 Effluent and Manure Analysis Parameters

Effluent and manure utilised on-site should also be analysed annually. The results should be used to determine reuse rates. Table 16.2 and 16.3 provide the recommended monitoring parameters for effluent and manure, respectively.

TABLE 16.2 Recommended Effluent Analysis Parameters

Test parameter	Justification
Total nitrogen or TKN	measure of nitrogen applied for mass balance calculations
Ammonium-nitrogen	measure of nitrogen available or potentially lost as ammonia volatilisation
Nitrate-nitrogen	measure of nitrogen immediately available for plant uptake
Total phosphorus	measure of phosphorus applied for mass balance calculations
Ortho-phosphorus	measure of phosphorus available for plant uptake
Potassium	measure of potassium applied for mass balance calculations
Electrical conductivity and chloride	measure of effluent salinity
SAR	measure of effluent sodicity

TKN = total Kjeldahl nitrogen; SAR = sodium absorption ratio

TABLE 16.3 Recommended Manure Analysis Parameters

Test parameter	Justification
Dry matter	to calculate nutrient applied
Total nitrogen or TKN	measure of nitrogen applied for mass balance calculations
Ammonium-nitrogen	measure of nitrogen available or potentially lost as ammonia volatilisation
Nitrate-nitrogen	measure of nitrogen immediately available for plant uptake
Total phosphorus	measure of phosphorus applied for mass balance calculations
Ortho-phosphorus	measure of phosphorus available for plant uptake
Potassium	measure of potassium applied for mass balance calculations
Organic carbon	influences soil stability
Electrical conductivity and chloride	measure of solids salinity

TKN = total Kjeldahl nitrogen

Appendix D provides suggested sampling protocols and methodology for soils, effluent and manure. State environment departments may also have sampling methodologies and analysis requirements.

16.2.4 Evaluating Soil Monitoring Results

Most soil nutrient recommendations understandably focus on the nutrient levels needed to grow crops, and on other elements (e.g. pH, salinity, sodicity) that may impede crop growth or cause soil structural issues. Soil nutrient levels will fluctuate throughout the year depending on the stage of the cropping cycle, agronomic practices and other factors. Available nutrient levels will need to be higher while the crop is growing to optimise yields and will generally be lowest after harvest or at the end of the main growth phase when most of the available nutrients have been taken up.

Agronomic recommendations are different from environmental indicators. From an agronomic perspective, nutrients would ideally be applied at rates that optimise plant growth but do not provide excess nutrients. This is consistent with the environmental perspective, recognising that any nutrients in excess of crop needs pose some environmental risk. In practice, it is very difficult to ensure soil nutrient levels continuously match crop needs, particularly considering the range of factors affecting crop growth. It makes sense to apply nutrients at levels that match the expected crop needs. However, because these are applied in advance of that growth, available soil nutrient levels will often exceed the immediate needs of the plants. For this reason, higher nutrient levels can be tolerated during the crop or forage growth period. On the other hand, elevated nutrient levels at the end of the cropping phase may pose a significant environmental risk since no nutrient removal is occurring and available nutrients may leach or be removed in runoff or as soil erosion.

For this reason, environmental soil monitoring should occur after the end of the main crop or forage growth period, and before the major effluent and manure spreading time.

As well as providing information for assessing environmental risk, soil testing at this time provides useful information for planning sustainable reuse rates. The challenge is to specify soil nutrient, pH and salt trigger levels that indicate that the system may pose an environmental risk without being overly onerous.

To that end, this section provides suggested trigger values to assist in deciding if reuse practices are sustainable. A result exceeding a trigger value does not identify that the system is unsustainable or high risk, only that further investigation is warranted. Soil properties vary widely and the suggested trigger values will not always be the most appropriate measures of sustainability in all cases. Further investigation may well begin with a comparison with soil analysis data from a background data. The ideal site from which to collect background data would be close to the area of interest, have a similar soil type, have a similar land use to the reuse area, but would not have received piggery effluent, manure or unusually heavy fertiliser applications. It may be necessary to analyse soil samples from multiple background sites, or to use local land and soil management references, to interpret results for both background and effluent and manure reuse areas. Comparison with historical data and trend analysis may also be useful.

16.2.4.1 Nitrogen

Nitrate-nitrogen is extremely mobile and readily leached. Consequently, high nitrate-nitrogen levels in the subsoil pose a risk to groundwater quality.

A nitrate-nitrogen limit equivalent to a soil solution concentration of 10 mg/L below the active root zone is a trigger for further investigation or action. This is to protect the future uses of any receiving aquifer. The soil solution concentration of 10 mg NO3N/L is based on drinking water standards contained in the *Australian Drinking Water Guidelines* (National Health and Medical Research Council and National Resource Management Ministerial Council 2011). Applying a drinking water quality standard is likely to be too stringent in many cases. Also, this limit is commonly exceeded in normal agricultural soils. **Hence, this is a trigger for further investigation only.**

When assessing the sustainability of a reuse practice based on nitrogen levels, consider a number of factors, including:

- the value or use of surrounding groundwater resources (human consumption, animal consumption, irrigation etc.). Water containing less than 90 mg NO3N/L is generally suitable for livestock consumption (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000)
- the depth to groundwater and aquifer type; the risk is greater for shallow or unconfined aquifers
- the soil type overlying the groundwater (e.g. clay)
- baseline nitrate-nitrogen levels in the soil below the active root zone.

The root zone depth depends on the crop type, soil depth, climate and whether the crop is irrigated. In some cases, the active root zone depth may be 1.5–2.0 m and even deeper (e.g. dryland lucerne). Therefore, sampling below the root zone may not always be practically and economically feasible. Sampling to a depth of at least 0.6 m is recommended, although deeper sampling (to the base of the root zone) may be required if there are concerns about nitrate-nitrogen leaching.

For different soil types, Skerman (2000) calculated nitrate-nitrogen concentrations equivalent to 10 mg/L of nitrate-N in soil solution (see Table 17.1). This trigger value applies at a depth of 0.6 m, or at the base of the root zone. However, soil nitrate-nitrogen concentrations, both in reuse areas and conventional cropping systems using inorganic fertiliser, often exceed those shown in Table 16.4. A nitrate-nitrogen root-zone concentration of 20-50 mg/kg generally provides enough nitrogen for cereal cropping and intensive grazing. The highest nitrate-nitrogen concentration given in Table 17.1 is 4.5 mg/kg. Hence, depending on soil type, nitrate-nitrogen concentrations ranging from 1.2 mg/kg NO_3N to 4.5 mg/kg NO_3N at the base of the root zone would trigger further investigation. **It is important to measure the nitrate-nitrogen at the base of the root zone as these concentrations in the root zone are considered very low for crop production.**

TABLE 16.4 Nitrate-Nitrogen Concentrations Corresponding to a Soil Solution Nitrate-Nitrogen Concentration of 10 mg/L at Field Capacity

Soil Texture	Soil gravimetric moisture content at field capacity (g water / g soil)	Limiting soil nitrate- nitrogen concentration (mg NO_3N / kg soil)
Sand	0.12	1.2
Sandy-loam	0.15	1.5
Loam	0.17	1.7
Clay-loam	0.20	2.0
Light clay	0.25	2.5
Medium clay	0.35	3.5
Self-mulching clay	0.45	4.5

Nitrate-nitrogen levels throughout the soil profile provide an indication of nitrogen availability for crop growth and sustainability. Once nitrate-nitrogen moves below the plant root zone,it is no longer available for plant uptake,but can leach to groundwater.Compare the results for reuse areas with those for background sites. Alternatively, comparison with historical data and trend analysis may be useful. If the nitrate-nitrogen concentration below the active root zone shows signs of build-up over time, review reuse practices.

Other matters to consider when determining the nitrogen sustainability, include the risk of nitrate moving off-site in surface water and groundwater, the quality of the groundwater, and the amount of deep drainage through the soils. These need evaluation as part of the risk assessment of the reuse area.

16.2.4.2 Phosphorus

The main pathways of phosphorus loss are through erosion of soil particles or through runoff from manure or soil with a high surface phosphorus concentration. Macropore flow (leakage down cracks in the soil) also causes phosphorus loss below the plant root zone. Leaching and runoff can occur when the soil is heavily overloaded with phosphorus and/or when applied phosphorus is not being removed from a reuse area.

Moody (2011) reviewed the literature and concluded that there is no universally accepted environmental risk indicator for soil phosphorus status. He identified that the widely used Olsen-P, Colwell-P and phosphorus buffering index (PBI tests were useful for assessing the phosphorus status of the soil and the risk of off-site movement of dissolved and particulate phosphorus. He noted that the phosphorus soil levels needed to ensure optimal agronomic outcomes were well established, providing a link between the phosphorus levels needed for production, and environmental risk. However, he also observed that there is a need to set trigger values that reflect the likely impact of phosphorus in runoff or suspended sediment.

Moody and Bolland (1999) provide generalised interpretation guidelines for soil phosphorus based on crop demand using the combination of Colwell-P and PBI. They included values for three levels of soil phosphorus status (low, medium, high), two levels of soil phosphorus sorption capacity based on PBI (low or moderate to high) and three different crop phosphorus demands (low, moderate or high). These recommendations are for agronomic indicators; care is necessary when applying these as indicators of environmental sustainability. It is suggested that the upper values for soils with a medium soil phosphorus status for crops with a low and moderate demand for phosphorus could serve as preliminary triggers for further investigation for soil tested post-harvest or at the end of the main pasture growth period. The applicable values are presented in Table 16.5.

TABLE 16.5 Suggested Trigger Levels for Investigation for Phosphorus in Topsoil

PBI[1]	P Sorption Category	Colwell Phosphorus (mg/kg) by Crop Type[2]	
		Low demand (e.g. Dryland Pasture)	Moderate demand (e.g. grain crops)
Up to 140	Low	30	45
141-840	Moderate to High	60	90

Notes:

1. Some soils e.g. krasnozems may have very high PBI levels (>840). Higher Colwell P levels would be expected to be acceptable for these soils. Hence, these values should be regarded only as trigger values for further investigation only.
2. These levels are only applicable for soils sampled at the end of the main crop growth period. Under highly productive agricultural systems, considerably higher levels would be expected during the crop production phase.

To investigate any possibility of phosphorus leaching through sandy soils, measurement of available phosphorus levels at 0.5 – 0.6 m (or the base of the root zone) is also suggested.

Soils vary in their capacity to absorb and store phosphorus. If phosphorus storage is to be used, it should be regarded as a temporary measure. Phosphorus removal over a maximum of five years with good agronomic practices is recommended.

16.2.4.3 Potassium

Potassium is often determined to be the limiting nutrient for many cropping systems that use piggery effluent. Since salinity would generally cause environmental problems before potassium on its own, it is rarely considered when sizing sustainable reuse areas. However, if present in high concentrations, the resulting cation imbalance may induce dispersion, which may cause soil structural decline. Also, high exchangeable potassium levels, relative to exchangeable magnesium levels, may induce hypomagnesia (grass tetany) in grazing ruminants. Hence, it is recommended that effluent and manure should only be spread at very low rates on grazed pastures.

16.2.4.4 Salts

Electrical conductivity (EC) and total dissolved solids (TDS) provide a guide to the salinity of piggery effluent. However, it is important to recognise that these indicators measure a range of ions or solids dissolved in water, not just the harmful salts. Valuable plant nutrients like various nitrogen compounds, sulphate, magnesium, calcium, iron and manganese, and buffers like bicarbonate and carbonate, all contribute to EC or TDS, along with potentially harmful sodium or chloride compounds. In piggery effluent, ammonium and phosphorus are typically the most abundant cations, followed by sodium and then calcium and magnesium. A significant proportion of the ammonium will be lost as ammonia volatilisation upon irrigation, and the remainder will reduce as it oxidises to nitrate or taken up by plants. Because piggery effluent is so dominated by ammonium, its EC level should be considered more flexibly than that of irrigation waters where the cation composition is often dominated by sodium-chloride. It may be more appropriate to calculate a corrected EC including only the four alkaline cations, and to use this value when assessing the suitability of piggery effluent for irrigation. Nevertheless, even after this correction, the EC of piggery effluent remains relatively high (Smiles and Smith 2004).

Reuse areas should not show increases in soil salinity that will adversely impact on the productivity of the land over the long term. Pronounced increases in soil salinity, particularly in the topsoil layer, may result from additions of effluent or manure. These increases need to be offset by leaching losses to ensure no consistent and significant increases in soil salinity in the subsoil layers. In dry years in particular, leaching rates will decline and it will take longer for salt removal to occur. Soils with an EC_{se} of up to 1.9 ds/m fall into the 'very low' to 'low' salinity rating. Thereafter, any increase in EC_{se} of 2.5 ds/m would shift the soil salinity rating by less than one salinity class. Consequently, a trigger for further investigation or action is considered to be any EC_{se} increase of 2.5 ds/m, compared with similar soil sampled from background sites and any result that places the salinity rating at 'medium' or higher. Soil EC_{se} should be determined at a depth of 0.5-0.6 m (or base of root zone). Alternatively, comparison with historical data and trend analysis may be useful.

Soil sampling should occur at the end of the main growing season. EC_{se} at the base of the root zone would act as a sustainability indicator, but surface and upper subsoil levels should also be monitored for agronomic purposes, and to monitor salt movements through the soil profile.

If further investigation or actions are warranted, the soil sodium and chloride concentrations throughout the profile should be measured in both reuse areas and the background sites, since sodium chloride is the main salt of interest from a soil degradation perspective. The sodium and chloride concentrations of the soil should be less than 150% of background levels.

16.2.4.5 Sodicity

Sodicity is important in effluent reuse schemes because of the relatively high sodium content of the effluent, and the adverse effects of sodicity on soil structure.

The primary sustainability indicator for soil sodicity is the exchangeable sodium percentage (ESP) measured at depths of 0-0.1 m and 0.5-0.6 m (or base of root zone). ESP is defined as the percentage of a soil's cation exchange capacity occupied by sodium. A trigger for further investigation or action is a soil ESP exceeding 6%, in which case, comparison with the soils of a background site is necessary. Alternatively, comparison with historical data and trend analysis may be appropriate.

An ESP level exceeding 150% of background (e.g. from 6% to more than 9%) in any soil layer is considered unsustainable. It is acknowledged that soil with an ESP exceeding 6% is not necessarily dispersive, particularly if saline. However, non-dispersive saline soils with a high ESP can become dispersive if the soil salinity declines in the future. For example, during high rainfall, salinity may fall more rapidly than sodicity through increased drainage of the more soluble salts. Declines in soil salinity through drainage may also be more rapid than falls in sodicity after effluent is no longer used. Both these scenarios can lead to soil dispersion. Consequently, calcium application is recommended where the topsoil ESP exceeds 6%, and strongly recommended where it exceeds 9%.

16.2.4.6 pH

Soil pH influences the availability of some nutrients. Ideally, the pH throughout the profile should be within the range of 5-8 (1:5 soil: water). Soil pH may inhibit the availability of desirable nutrients to plants and may increase the availability of toxic elements. The application of lime will raise the pH. It is rarely economical to lower the pH of alkaline soils.

Further details on sustainability indicators for reuse areas are provided in McGahan and Tucker (2003) and Redding and Devereux (2005).

16.3 Surface Water

16.3.1 Surface Water Monitoring Requirements

Surface water monitoring is rarely relevant to piggeries because they do not discharge to waterways; manure and effluent are generally used as farming system inputs, replacing inorganic fertilisers. However, in specific high-risk situations (e.g. effluent pond spills, runoff of irrigated effluent into waterways) surface water testing may be appropriate. This would typically involve sampling and analysing the effluent or contaminated runoff and the affected waterbody. For a watercourse, sampling upstream and downstream of the effluent entry point is recommended. Careful sampling is needed to achieve meaningful results.

Vulnerable watercourses should also be inspected after rainfall events to identify algal blooms that are indicative of elevated nitrogen and phosphorus concentrations. Any blooms should be reported to the local council, state environment department, and the relevant water board or state government water department. Affected water should not be used as a pig drinking water source.

Appendix D provides suggested sampling protocols and methodology for surface waters. State environment departments may also have sampling methodologies and analysis requirements.

16.3.2 Surface Water Analysis Parameters

Typical analysis parameters include:

- total nitrogen
- total phosphorus
- electrical conductivity (EC) or total dissolved solids (TDS)
- pH
- biochemical oxygen demand (BOD)
- E. coli.

16.3.3 Evaluating Surface Water Monitoring Results

The state environment authority may specify particular contaminant levels or require the piggery to identify trigger values for watercourses or other surface waters. Otherwise, the most current edition of the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000) Australian and New Zealand Guidelines for Fresh Water Quality (under review at date of publication) and the National Health and Medical Research Council and National Resource Management Ministerial Council (2011) Australian Drinking Water Guidelines provide recommendations. Comparison of levels between upstream and downstream results can also be valuable in identifying whether watercourse contamination could be occurring, although it is important to consider other possible inflows.

Use of surface water should not exceed any allocations set by water authorities. Another sustainability indicator is the adoption of water-saving strategies that reduce overall water consumption, while still maintaining the production and hygiene standards of the piggery.

16.4 Groundwater

At most sites, groundwater monitoring is not warranted because the particular hydrogeology of the site and the design and management of the piggery provide confidence that the water is well protected. However, at vulnerable sites, groundwater monitoring may be relevant and meaningful.

16.4.1 Groundwater Sampling

Ideally, groundwater is monitored by comparing analysis results for water sampled located up-gradient and immediately down-gradient of the area/s of interest, which will often be the effluent treatment ponds or manure storage but could include reuse areas. The appropriate siting of the monitoring bores (piezometers) depends on the formation, depth, flow direction and connectivity of aquifers to other aquifers and / or surface waterbodies. Consultation with a certified hydrogeologist during the planning stage is recommended.

Where groundwater is very shallow, leakage detection systems for pond liners may be warranted. An engineer will be able to assist with the design.

For reuse areas, subsoil monitoring usually provides for earlier problem detection and remediation than direct groundwater monitoring, although groundwater monitoring may be warranted on sites with sandy soils and vulnerable groundwater.

The groundwater sampling and testing frequency should match the risk and could range from quarterly to annually.

Appendix D provides suggested sampling protocols and methodology for groundwater. State environment departments may also have sampling methodologies and analysis requirements.

16.4.2 Groundwater Analysis Parameters

Typical groundwater monitoring parameters include:

- depth to groundwater
- total nitrogen
- nitrate-nitrogen
- total phosphorus
- electrical conductivity (EC) or total dissolved solids (TDS)
- pH
- biochemical oxygen demand (BOD)
- *E. coli.*

16.4.3 Evaluating Groundwater Monitoring Results

Comparison of water test results up-gradient and down-gradient bores, and trend analysis for each monitoring point can be used to detect whether groundwater contamination may be occurring. Under these circumstances, professional help should be sought to further investigate and, if necessary, address the issue.

16.5 National Pollutant Inventory Reporting

Piggery operators must report emissions to the National Pollutant Inventory (NPI) if their unit emits over 10 t/yr ammonia, or for emissions to air associated with fuel and or waste combustion that exceed 400 t/yr, or 1 t/hr at any time in the reporting year (DEWHA 2009). From the National Pollutant Inventory Emission Estimation Technical Manual for Intensive Livestock: Pig Farming (Department of the Environment and Water Resources 2007), a conventional piggery with a capacity of 1100-1200 SPUs is likely to trigger responsibilities for reporting ammonia. A deep litter piggery that stockpiles spent bedding on-farm, triggers reporting responsibilities at a capacity of about 2000 SPUs.

To access the current technical manual, go to: www.npi.gov.au/system/files/resources/ab8604a5-fead-cad4-0da6-a818adb90f16/files/pork.pdf

NPI emissions are reported to the NPI office in the applicable state or territory. To report on-line, visit the NPI website: www.npi.gov.au/reporting.

17. Environmental Management Plan

An Environmental Management Plan (EMP) focuses on the general management of the whole farm, taking into account the environment and associated risks. While an EMP is not always mandatory, it is strongly recommended for all piggeries, and provides the evidence that the operator is committed to pig production in an environmentally sustainable manner.

An EMP provides a system for documenting:

- the environmental risks of a piggery
- how risks will be minimised (by design or management)
- contingency plans to address emergency situations that could cause environmental harm or impact on management practices
- measurement of the effectiveness of these strategies (by monitoring)
- how monitoring results will be reported
- action plans that specifies specific actions that will be undertaken to further reduce risk.

The EMP allows for dynamic, adaptive management and should focus on continuous improvement. It allows variations from the guidelines and includes the monitoring and feedback loops that provide assurances that environmental impacts can be detected and resolved. Proactive and genuine handling of complaints is an integral component of the monitoring and feedback loops.

An EMP typically includes:

- identification and contact details
- a brief description of the piggery
- a commitment that the piggery will operate in an environmentally sustainable manner
- identification of applicable consents, approvals and/or licences to operate the piggery
- description of the surrounding land uses and the natural features of the subject property, any off-farm reuse areas and the surrounding area. This should cover:
  - the location of nearby sensitive land uses (e.g. houses, rural residential areas and towns)
  - soil type
  - proximity to waterways and sensitivity of same
  - depth, vulnerability and quality of groundwater
  - native vegetation
  - areas of cultural heritage sensitivity.
- description of the design and management of the piggery
- identification of environmentally aspects and impacts on-farm or in the surrounding area, and any required mitigation or management strategies
- identification of the resources to be monitored
- a listing of contingency plans or emergency strategies
- details of any environmental training already undertaken by staff, and any areas where training would be beneficial

- a commitment to periodic review of the EMP to ensure that any changes in regulatory requirements, the environment (e.g. new houses), piggery design or management, and associated changes in environmental risk, are reflected in the plan.

APL has developed a simple template for preparing an EMP, although other EMP formats are also acceptable. Some state environment authorities have their own EMP templates. Appendix B of these guidelines provide a risk assessment process. Valuable guidance material is provided in the Piggery Manure and Effluent Reuse Guidelines. In addition, APL has developed a nutrient mass balance calculator that can be used to plan sustainable reuse of effluent, manure and spent bedding.

These resources are available on the APL website: http://australianpork.com.au/industry-focus-environment/national-environmental-guidelines-for-piggeries.

18. Chemical Storage and Handling

Each state has its own legislation and mandatory requirements for chemical storage and handling. Factors to consider to prevent risks to the environment include:

- minimising chemicals storage and usage
- storing and preparing chemicals in bunded areas with impermeable flooring
- using chemicals only for the intended purpose and in accordance with instructions.
- selecting chemicals with a low toxicity and low water contamination potential, where possible
- having an emergency response plan and spill kit in place in case of a chemical spill
- having material safety data sheets (MSDS) for all chemicals stored and used
- maintaining records of chemical use
- training staff in the safe use and handling of chemicals
- correctly installing underground petroleum storage systems (UPSS) and ensuring these have an effective leak detection system.

For further information on safe storage and handling of agricultural and veterinary chemicals, see Standards Australia (1998).

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Appendix A.

National Odour Management Guidelines

A1. Introduction

Odour has been identified as the principal community amenity concern in relation to piggery developments. The Australian pig industry has recognised the need to improve its environmental performance to comply with rising community expectations. A consistent regulatory approach that provides the latest and best technical information will facilitate new development proposals, upgrades to facilities, and compliance with licence and approval conditions, and current regulatory standards for operating piggeries in each state. The industry is driving this change by embracing environmentally sustainable practices and promoting self-regulation through active participation in the development and adoption of these National Odour Guidelines for Piggeries.

These guidelines are based primarily on existing state piggery guidelines and codes of practice but include ideas from other industries relevant to piggery odour assessment. They represent the best available options for assessing potential odour impacts, from the information that is currently available. However, the relevant approval authority should be contacted for information regarding the content or application of legislation, codes of practice or guidelines in a particular state.

Early contact with state and territory agencies is recommended to discuss regulatory requirements for any proposed operations or changes to existing operations.

In the absence of specific advice from the approved authority, these guidelines provide recommended methods to determine separation distances for community amenity.

These separation distances are for new developments and expansions and are not for retrospective application to existing piggeries.

A2. State Legislation and Guidelines

Each state of Australia has different legislation, codes of practice and guidelines that are relevant to odour impact assessment for piggeries. These guidelines have been developed to conform as much as possible to regulatory requirements around Australia. However, regulatory requirements do differ on some issues between states and territories, and regulatory requirements are periodically revised. Consequently, these odour guidelines do not conform to all regulatory requirements in every state and territory. Where there are differences, relevant state and territory requirements may override the odour guideline criteria and methodology unless approved by the local regulatory agency. Relevant acts and documents for each state are listed below.

A2.1 New South Wales

Protection of the Environment Operations Act 1997. Environmental Planning and Assessment Act 1979 (as amended)

Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales (NSW Environment Protection Authority, August 2016)

Assessment and Management of Odour from Stationary Sources in New South Wales (NSW Department of Environment and Conservation November 2006)

Technical Notes – Assessment and Management of Odour from Stationary Sources in New South Wales (NSW Department of Environment and Conservation, November 2006)

Note that the *Policy – Assessment and Management of Odour from Stationary Sources in New South Wales* provides odour assessment criteria and an odour assessment methodology to be used in NSW. It also provides a process for development of industry-specific odour criteria and variations to the preferred methodology. Before commencing an odour impact assessment in New South Wales, a proponent should contact the New South Wales Office of Environment and Heritage to discuss any changes to the odour criteria and / or preferred assessment methodology.

A2.2 Queensland

Environmental Protection Act (1994)

Guideline: Odour Impact Assessment from Developments (Department of Environment and Heritage Protection 2013)

A2.3 Victoria

Environment Protection Act 1970

State Environment Protection Policy (Air Quality Management)

A2.4 South Australia

Environment Protection Act 1993

South Australian Environment Protection (Air Quality) Policy 2016

Ambient Air Quality Assessment (Environment Protection Authority 2016)

Evaluation Distances for Effective Air Quality and Noise Management (Environment Protection Authority 2016)

A2.4 Western Australia

Environmental Protection Act 1986

Odour Guideline for Prescribed Premises (Department of Water and Environmental Regulation Western Australia 2018).

A2.5 Tasmania

The Environmental Management and Pollution Control Amendment (Environment Protection Authority) Act 2007

A3. Odour Assessment Process

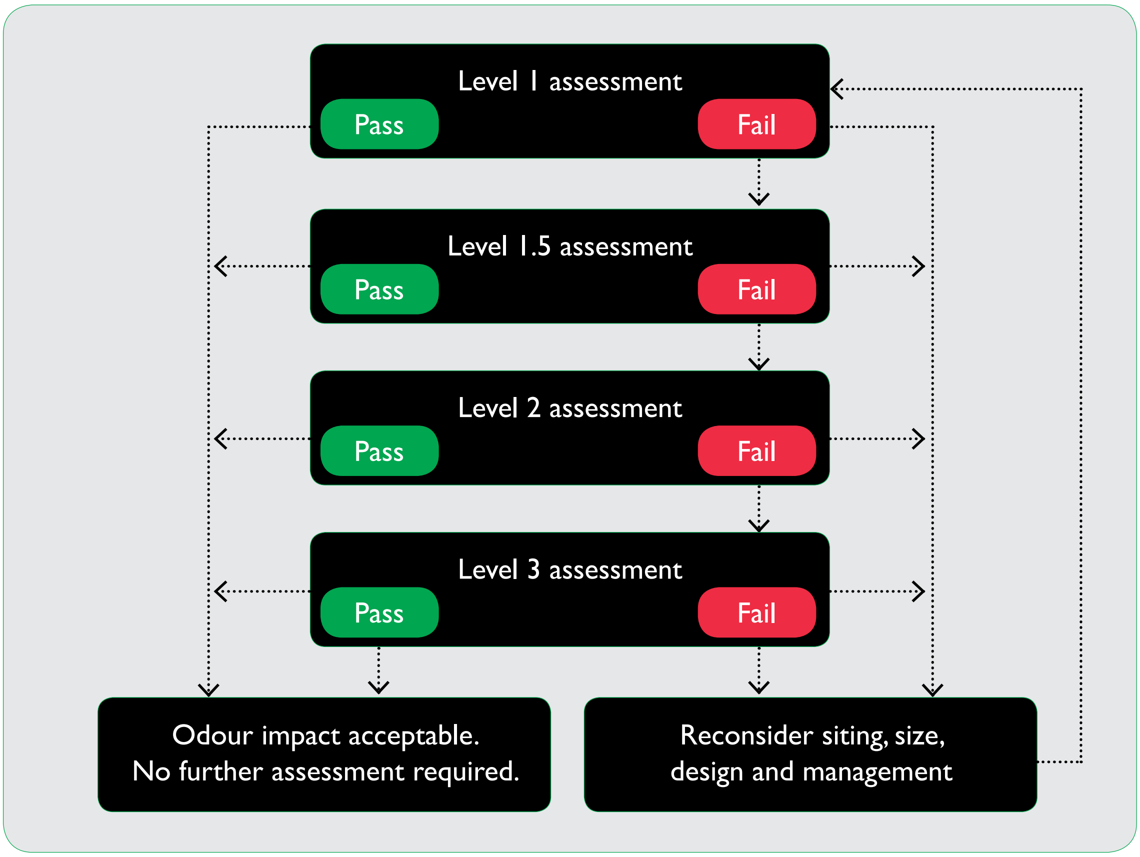
An odour assessment is used to establish whether odour generated by a piggery will have an unreasonable impact at off-site receptors. Odour nuisance may occur when the separation distances between a piggery and a receptor are less than those calculated using the methods set out here. A receptor is a sensitive location where people are likely to live, or to spend large amounts of time, including residences, schools, hospitals, offices or public recreational areas. These guidelines intend to limit odour at a receptor to prevent nuisance. This document provides an assessment methodology that will achieve this for the majority of sites; however, each site should be considered individually. Three levels of assessment are outlined in these guidelines:

- Level 1 uses a standard empirical formula and is suitable for all piggeries. Level 1.5, a variation which incorporates a wind frequency reduction factor into the formula, is also available.
- Level 2 involves modelling using the most appropriate computer dispersion model, a meteorological data file representative of the site and adopted 'standard' emission rates.
- Level 3 involves modelling using the most appropriate computer dispersion model, 12 months meteorological data measured on-site and non-standard odour emission rates or an odour concentration / odour intensity relationship.

Figure A.1 summarises the process a proponent would use in assessing odour impact for a particular development. A pass at any level is acceptable and means that no further assessment is required. A fail at any level means the proponent has the opportunity to apply a higher level of assessment or revise the application by changing the siting, scale, design or management. Since the simple impact assessment methods (Level 1 and Level 1.5) are less accurate than the site-representative assessment (Level 2), or site-specific assessment (Level 3), the separation distances calculated using the simple methods are designed to be more conservative. A fail at Level 3 means that the proposal must revise the siting, scale, design and / or management of the proposal.

While the odour assessment process is primarily designed to confirm that a piggery proposal will be adequately separated from existing or approved sensitive land uses (e.g. town or rural residential zones or legal houses), councils may also apply the methodology when considering applications for rezoning, sub-divisions or dwellings to protect approved or existing piggeries and avoid future nuisance complaints caused by sensitive land uses locating within the required separation distance.

FIGURE A.1 **Odour Assessment Process for New Piggeries or Piggery Expansions**



The methodology contained in these guidelines provides a planning tool suitable for assessing the potential for odour impacts from a proposed or expanding facility. They are not suitable to retrospectively assess the odour impact from an existing facility, and should never be used to retrospectively determine if a facility should continue to operate, or to determine whether any odour impacts being experienced warrant further action or are acceptable. They are not suitable for investigating odour complaints.

These guidelines assume that all piggery odour sources are accurately represented as either area sources (e.g. ponds) or volume sources (e.g. piggery sheds). Different modelling protocols may be required at some piggery sites, particularly those with complex terrain or meteorological conditions.

In these cases, advice regarding appropriate assessment methodology should be obtained from the relevant regulatory agency.

A3.1 Level 1 Assessment

Level 1 uses a standard empirical formula and is a simple, cheap and quick method that offers high levels of protection for community amenity. Hence, the formula is relatively conservative and it could be used as a first screen for a proposed development. It gives the largest separation distances of all three levels. If the Level 1 assessment proves unsatisfactory (i.e. a proposal for a given size and design does not meet the Level 1 assessment requirements), the proponent can apply the Level 1.5 methodology or the more detailed Level 2 or Level 3 assessment methods which use odour dispersion modelling to determine whether the risk of impact on the surrounding environment is acceptable.

A3.2 Level 1.5 Assessment

Level 1.5 uses the standard empirical formula approach (Level 1), with the addition of a wind frequency reduction factor which incorporates wind speed and direction data that is representative of the site. This intermediate factor is designed to improve the prediction of impacts, without the need for using a detailed dispersion modelling approach. If the Level 1.5 assessment proves unsatisfactory, odour modelling using the more detailed Level 2 or Level 3 assessment methods may be required to demonstrate that the risk of impact on the surrounding environment is acceptable.

A3.3 Level 2 Assessment

Level 2 involves odour modelling with 'standard' recommended emission data. This method more closely matches the actual site configuration, but still offers high levels of protection for community amenity. This assessment applies to situations where:

- piggery design or management is substantially different to the standard design used for the Level 1 and Level 1.5 assessments
- site-representative meteorological data are available (measured or generated)
- the piggery is of an irregular layout
- there is complex terrain or meteorology
- receptor locations are not accurately represented by the Level 1 and Level1.5 assessment (for example, prevailing winds may increase / decrease potential impacts at certain receptors).

The emission data used should be based on best available data. The APL odour research database provides recommended emissions. The meteorological file should be representative of the site and measured or derived in line with recognised methods.

Assessment under Level 2 can use steady state models such as AUSPLUME or AERMOD in situations where the assumptions underlying their use is met. However, in areas of complex terrain or meteorological conditions (i.e. katabatic drift or clam or frequent light winds), the use of other more advance models such as CALPUFF may be warranted.

A3.3 Level 3 Assessment

Level 3 involves a comprehensive risk assessment, including 12 months of measured on-site meteorological data with site-specific (or site-representative) odour emission data or a developed odour concentration / odour intensity relationship for the odour sources. This assessment applies:

- to situations where innovative or unusual piggery design or management processes are implemented on-site
- where odour emission rate data indicative of the proposal are not available and must be collected
- where particular odour reduction strategies are used
- where complex meteorological conditions exist.

The risk assessment process may also include a time-series assessment of the odour impact. This assessment would need to investigate the concentration, frequency and duration of odour impacts at individual receptors.

The modelling incorporates the use of site-specific or site representative emission data based on system measurements collected to appropriate standards. Meteorological data will consist of at least one year's data collected using an on-site weather station. In cases with complex meteorological conditions, multiple on-site stations might be needed (refer to section A6.4 for further details). The odour modelling results need to comply with the odour impact objective, or an appropriately designed odour intensity study.

The use of an odour intensity study (where intensity is compared to odour concentration) is not a required part of Level 3 assessment but is included as an option available for sites that are using innovative designs or management that change the nature of the odours released. An odour intensity study may provide a better method for assessing odours with non-irritating character (e.g. well-managed compost).

Assessment under this level can use a steady state model (e.g. AUSPLUME or AERMOD) in situations where these are expected to perform adequately. However, in areas of complex terrain or meteorological conditions, the use of other accepted dispersion models (e.g. CALPUFF) may be warranted.

A3.4 Piggery Definitions

Australian piggeries can be categorised as follows:

- conventional piggeries,
- deep litter piggeries,
- rotational outdoor piggeries,
- feedlot outdoor piggeries, or
- a combination of types.

Definitions for these types of piggeries are provided in section 4.2 of the National Environmental Guidelines for Indoor Piggeries. *These odour guidelines are designed only for indoor piggeries with conventional and / or deep litter housing.*

Rotational outdoor piggeries are not required to meet site-specific separation distances and are not covered by these guidelines. Separation distance requirements for rotational outdoor piggeries are provided in the National Environmental Guidelines for Rotational Outdoor Piggeries.

Since odour emission rates for Australian feedlot outdoor piggeries have not been reported, it has not been possible to develop the S1 factors needed to apply the Level 1 or Level 1.5 methodologies. Nor are 'standard' odour emission rates available for input into the Level 2 methodology; proponents will need to negotiate with regulators to determine appropriate inputs. The Level 3 assessment method included in these guidelines can be applied to feedlot odour piggeries.

A4. Modelling Protocols and Parameters

Before undertaking an odour assessment, the data and methods to be used in the assessment should be discussed with the relevant approved authority.

A4.1 Model Used

AUSPLUME has been widely used throughout Australia for performing piggery odour impact assessments, but other models are available that may more accurately represent the dispersion process, particularly in complex terrain where calm winds lead to katabatic drift or when there are multiple odour sources not in close proximity. As they are more advanced, models such as CALPUFF require more comprehensive meteorological data than AUSPLUME. An APL-commissioned report provides guidance in the selection and use of odour dispersion models (Pacific Air and Environment, 2003b).

AUSPLUME should not be used for proposals involving complex terrain or meteorological conditions. The relevant approved authority should be contacted before doing modelling to discuss the appropriate model to be used for each individual site.

A4.2 Odour Intensity

Odour intensity is a useful dimension to quantify, because some odours with the same strength are perceived as being stronger than others. All odours will be just detectable at a concentration of 1 odour unit (OU)/m^3. However, at twice the concentration, or 2 OU/m^3, some odours may be perceived as very weak, while others may be perceived as distinct. At 10 times the concentration, or 10 OU/m^3, one odour may be perceived as distinct, while another odour may be perceived as very strong.

An odour intensity study uses dynamic olfactometry to determine odour concentration and odour intensity at the same concentration. The data are used to establish an odour concentration / odour intensity relationship applicable to the odour sources site. Odour intensity studies need to comply with the German standard guidelines (VDI 1992) for determining odour intensity. This type of study would only be applicable to Level 3 assessments.

A4.3 Percentile Occurrence

A wide range of percentile occurrences is available for use in odour impact criteria, with different percentiles generally suited to different purposes. Very high percentile occurrences such as 99.9% (i.e. odour from a piggery does not cause impact 99.9% of the time each year), allow very few instances where the criteria may be exceeded, and the modelling results are thus sensitive to outliers and errors in the meteorological data.

Conceptually, such stringent criteria are suited to acute impacts caused by highly concentrated odours. Piggery odours are complex mixtures of odorants released from area and volume sources. As a result, these odours are at relatively low concentrations, at distances away from the odour sources. Consequently, any off-site receptors are more likely to experience a chronic impact (caused by repeated exposure to relatively low concentrations) than an acute impact.

Conceptually, such impacts are more accurately represented by lower percentile occurrences.

These guidelines use a 98-percentile odour concentration occurrence to provide a better assessment of repeated low level odour exposure, and to reduce the impact on results of outliers in meteorological data files. More detailed discussion on this topic is presented in Pacific Air and Environment (2003c).

A4.4 Averaging Time

These guidelines use an averaging time consistent with the meteorological data file averaging, which is generally one hour. The use of meteorological data that represents an average condition over the period of one hour means that the actual odour concentration during that hour will vary above and below the predicted average concentration. As human perception of odour typically occurs over very short time periods, odour impacts that do occur may take place at an odour concentration that is higher than the average concentration predicted.

Two main methods are available to account for short-term concentration variations – the use of a reduced averaging time (such as 3-minute averaging through the AUSPLUME dispersion model), or the use of more stringent odour impact criteria. These guidelines incorporate the potential effects of plume concentration fluctuations into the odour impact criteria, rather than using a separate factor.

A4.5 Assessment Point for Criteria

The assessment point for odour impact criteria should be based on a risk assessment process tailored to the site. For extensive rural areas with low population density, the risk of odour plumes affecting people is highest at houses and associated outdoor living areas. In more closely settled areas such as towns, where landholdings are much smaller, it is likely that all areas of the property will be more frequently used and this needs to be considered as part of a risk assessment along with the times of day these areas would be used, the potential activities in those areas and the odour potential of those activities. As most piggeries are in rural use areas, odour impact criteria would usually be applied at receptors.

It is important to assess likely future receptor points as part of the risk assessment process. For facilities sited close to towns, the local council should be contacted for an indication of the land zonings in the area surrounding the piggery site. A community consultation process is particularly useful as part of the risk assessment process, as it can assist in identifying future or pending developments on surrounding land.

A4.6 Odour Impact Criteria

For these guidelines, the standard odour impact criteria are:

- 3 OU, 98%, 1 hour average for a rural dwelling
- 2 OU, 98%, 1 hour average for a rural residential receptor
- 1 OU, 98%, 1 hour average for a town receptor.

These criteria are different from those used in most states. Section A.2 provides references for state requirements for odour impact assessments. These references should be consulted, or the approved authority contacted to determine the requirements that must be met. **These impact criteria relate to odour emissions measured to the Australian Standard 4323.3:2001 (Standards Australia/Standards New Zealand 2001).**

For Level 1 and Level 1.5 assessments, the impact criteria are equivalent to 75% of the standard impact criteria. These criteria were applied in developing the Level 1 assessment to provide conservative results for the standard formula, thus compensating for situations that are not covered well by some of the generalisations made within the formula. For Level 2 and Level 3 assessment, the standard impact criteria are used. Table A.1 lists the odour impact criteria used in these guidelines.

TABLE A.1 Impact Criteria Applied in these Guidelines

Impact criteria	Percentile occurrence	Odour Concentration in OU			Averaging time	Assessment point
		Rural	Residential	Town		
Level 1	98%	2.25	1.5	0.75	1 hour	receptor
Level 1.5	98%	2.25	1.5	0.75	1 hour	
Level 2	98%	3	2	1	1 hour	
Level 3	98%	3	2	1	1 hour	

A4.7 Meteorological Data

High-quality Australian meteorological data are scarce outside the major population centers. As most piggery operations are in rural areas, it is often difficult to obtain suitable measured wind speed and wind direction data for dispersion modelling. However, CSIRO has developed 'The Air Pollution Model' (TAPM) which can generate meteorological data files for dispersion modelling applications (Harris 2002). Other newer models such as the Weather Research and Forecasting model (WRF) (https://www.mmm.ucar.edu/weather-research-and-forecasting-model) are also available.

Meteorological data should only be generated by someone who understands the capabilities and limitations of the model used. Any data used in the Level 1.5 assessment and dispersion modelling must be assessed for errors, and to ensure they adequately represent meteorological conditions at the site.

For Level 2 assessments, validated data collected using a meteorological recording station located at a representative location within the area is the preferred source for modelling input data. However, each file should be examined to assess its suitability for a given site. Where no site-representative data are available from surface recording stations, two options are available:

- an on-site weather station or stations may be set up to record one year's worth of on-site data
- a computer-generated data file may be used, although care needs to be taken in the selection of model settings to obtain representative data.

For Level 3 assessments, 12 months data from an on-site 10 m weather station or stations is required.

The data proposed for use in modelling should be discussed with the approved authority. The APL-commissioned report, Pacific Air and Environment (2003a), provides guidance on meteorological data for odour dispersion models.

A4.8 Surface Roughness

Surface roughness values are an important parameter in dispersion modelling. For Level 1 and Level 1.5 assessments, values are tabulated and clearly explained. For Level 2 and Level 3 assessments, the guidance provided by the model being used should be followed. For example, AUSPLUME has a limited number of options to select, whereas models such as CALPUFF rely on coarse satellite-based data which need to be refined to a suitable resolution (~100m) for input into the model.

A4.9 Risk Assessment

During the initial stages of an odour impact assessment, it is important to establish the structure of the assessment and the procedures that will be used. A site risk assessment is useful to ensure that all relevant factors are considered during the assessment, including factors such as:

- location of receptors in all directions. It is important to consider downwind receptors in all directions, even if they are not the closest receptors.
- potential background odour levels from other intensive livestock or processing facilities in the area
- houses in air drainage lines downstream of piggery sites.

Most of these occurrences will be addressed in the environmental management plan for the site, and usually they can be prevented, or mitigated, through appropriate management.

A5. Level 1 and Level 1.5 Assessments

A5.1 Introduction

Odour has been identified as the principal community amenity concern in relation to indoor piggery developments. Separation distance requirements are thus generally determined on the basis of limiting the potential of nuisance odours to an acceptable level. Separation distances can assist in managing some of the community impacts of piggeries and are used to ensure the long-term protection of the receptor and the piggery enterprise. Optimum separation distances between the piggery complex and receptors depend on a number of factors, including the size of the piggery (number of standard pig units (SPU)), the topographical features, vegetation and surface roughness between the piggery and receptors, and the operating and management procedures at the piggery.

Separation distances specified in these guidelines are divided into site-specific and minimum distances. Site-specific separation distances from piggeries to receptors are based on the number of SPUs, receptor type, topography, vegetation (surface roughness), wind frequency and piggery design and operation. Minimum separation distances provide appropriate distances between the piggery complex and relevant features. Separation distances are measured from the edge of the piggery complex, not the center.

The minimum fixed distances are included largely to account for inaccuracies with predicting odour impact at close distances. Both the site-specific and minimum separation distance to receptors (each relevant receptor class) must be calculated, and the greater distance of the two applied for each receptor.

The piggery complex is generally considered to be any land, building or other structure, or any part thereof, whether temporarily or permanently used for the purpose of keeping, feeding or watering of pigs, including any effluent ponds and manure storage areas used in conjunction with the keeping of pigs, any loading or unloading facilities and carcass management sites. However, it does not include effluent and / or manure reuse areas. Reuse areas are not included as part of the piggery complex because application of effluent and manure to these areas often occurs infrequently, particularly if there are multiple reuse areas across a farm. Fixed separation distances between reuse areas and relevant receptors and features are included in these guidelines.

A detailed explanation on how the Level 1 assessment process was developed is presented in APL Project 1921 (Nicholas and McGahan, 2003).

A5.2 Calculation Method

The separation distance of the piggery complex from receptors depends on a number of factors, including:

- piggery size, defined as the number of standard pig units (SPU) in the complex. Refer to the National Environmental Guidelines for Indoor Piggeries (NEGIP) for methods for determining SPU.
- piggery design, particularly the shed type and the effluent or manure removal and treatment processes used at the piggery

- piggery siting:
  – receptor type and location (e.g. town, rural residence etc.)
  – topography features (hills etc.) between the piggery and the receptor
  – vegetation / surface roughness between the piggery complex and the receptor
  – wind frequency
  – terrain effects around the site, particularly the effects of terrain features on meteorology of the area.

Site-specific separation distances are based on the dispersion of odours from their source. Different air quality objectives were chosen for different receptor types, based on the assumption that there is more probability that people will be affected by odour in larger population centers, due to the higher population density in these areas. Calculation of separation distances for each receptor type follows the form:

$$\text{separation distance (D)} = N^{0.55} \times S1 \times S2 \times S3$$

N = number of standard pig units (SPU)

0.55 = piggery size exponent determined using the results of modelling

S1 = piggery design factor for estimating the relative odour potential for the piggery design selected for a particular site ($S1$ = effluent removal factor, $S1_R$ x effluent treatment factor, $S1_T$)

S2 = piggery siting factor for estimating the relative odour dispersion potential for the selected piggery site ($S2$ = receptor type factor, $S2_R$ x surface roughness factor, $S2_S$)

S3 = terrain weighting factor for estimating the potential changes to odour dispersion, in situations where meteorological conditions may be influenced by local terrain influences

The same formula is used for the Level 1.5 assessment with an additional S4 wind factor. Refer to section A5.9.

The S1, S2 and S3 factors to be used with this formula are presented in Table A.2.

The separation distance is the distance from the closest extent of the piggery complex to the receptor (e.g. town boundary, boundary of rural residential zone or legal house including any immediately adjacent outdoor living areas such as a barbeque area or pool). The available separation distances between the piggery complex and receptors are generally the key factors limiting the number of pigs that can be accommodated on a particular site. Separation distances to all relevant receptors must be assessed to ensure the potential for unacceptable odour nuisance is minimised. Where other significant odour sources are located in proximity to the proposed piggery, the cumulative odour impact from both sites may need to be considered.

TABLE A.2 Summary of S Factors for Use with Level 1 Calculations

Factor Description	Value	
S1 Factor = Effluent Removal System Factor, $S1_R$ * Effluent Treatment Factor, $S1_T$		
Effluent Removal System		
Conventional shed – static pit, pull plug or flushing system	1.00	
Deep litter system, pigs on single batch of bedding ≤7 weeks	0.63	
Deep litter system, pigs on single batch of bedding > 7 weeks	1.00	
Effluent Treatment		
Pond with >40% separation of volatile solids before pond	0.80	
Pond with 25 – 40% separation of volatile solids before pond	0.90	
Pond with <25% separation of volatile solids before pond	1.00	
Permeable pond cover	0.63	
Impermeable pond cover	0.50	
Deep litter system – spent bedding stockpiled / composted on-site	0.63	
No manure treatment or storage on-site – effluent / bedding removed from site	0.50	
S2 Factor = Receptor Type Factor, $S2_R$ x Surface Roughness Features Factor, $S2_S$		
Receptor Type		
Town	25	
Rural residential	15	
Legal house	11.5	
Surface Roughness Factor		
Limited ground cover, grass	1.00	
Crops	1.00	
Undulating terrain	0.93	
Open grassland (grass, scattered trees)	0.90	
Woodlands (low density forest)	0.70	
Open forest (canopy cover 30-70%)	0.60	
Forest with significant mid and lower storey vegetation	0.50	
S3 Factor – Terrain Weighting Factor		
Terrain	**Value**	
	Receptor Downslope of Site	**Receptor Upslope of Site**
Narrow valley (>1% slope)	2.0	0.5
Gently sloping (1-2% slope)	1.2	1.0
Flat (0-1% slope)	1.0	1.0
Receptor downslope in different sub-catchment	1.0	-
Sloping (>2% slope)	1.5	0.7
Significant hills and valleys	0.7	0.7

Notes: S1 factors for a feedlot outdoor piggery would need to be negotiated with the relevant approved authority. The term "legal house" means a dwelling that either has as-of-right use or building approval.

A5.3 Piggery Size

The equivalent number of SPUs is calculated using standard multipliers for each class of pig or Pigbal 4 modelling. Section 4.3 of the NEGIP provides details for determining the number of SPU.

A5.4 Piggery Design Factor, S1

A number of piggery design factors will influence the amount of odour emissions from a piggery. The factors having the most influence on the site emissions are discussed below. A composite 'design factor' for the site is obtained by multiplying the effluent treatment and removal factors together.

Effluent Removal, $S1_R$

The effluent removal factor relates to the odour potential of piggeries based on the management of effluent in the piggery buildings. Good shed management practices, including maintaining clean conditions within the sheds, are known to reduce odour emissions. Table A.3 lists effluent removal factors based on the effluent removal system used.

TABLE A.3 Values of Effluent Removal Factor, S1R

Effluent Removal System	Factor
Conventional shed – static pit, pull plug or flushing system	1.00
Deep litter system, pigs on single batch of bedding ≤ 7 weeks[a]	0.63
Deep litter system, pigs on single batch of bedding > 7 weeks[a]	1.00

[a] the effluent removal factor is 0.63 for deep litter systems, stocked at recommended rates, with good management practices for pigs kept for up to 7 weeks on a single batch of bedding. This assumes that sheds are maintained in a relatively clean condition (e.g. sufficient bedding equivalent to at least 0.5 kg of bedding/SPU/day), there is no liquid effluent treatment system and spent bedding is removed from sheds as soon as practical after the end of a batch.

Where low bedding rates are supplied (<0.5 kg/SPU/d), or pigs are housed >7 weeks between shed clean-outs, a factor of 1 should be used. However, where pigs are held for >7 weeks, but there is higher bedding usage or partial clean-out of the sheds between full bedding replacements, a factor lower than 1 is justified.

This table refers to the shed odour emissions at a site and represents the reduction in shed odour arising from the design and management of the sheds. The factor used is 1 minus 75% of the odour emissions reduction. For a deep litter piggery with bedding replacement at least every seven weeks, the reduction in shed odour emissions of 50% gives a factor of 1 – (75% of 50%) = 0.63. Where different building design or management practices exist within the piggery complex, the effluent removal factor should be weighted according to the number of SPUs included in each management system. The effluent removal factor could be adjusted if there is new odour-reducing technology employed that can be demonstrated and quantified.

Effluent Treatment, SI_T

The effluent treatment factor relates to the odour potential of piggeries based on the design of the effluent treatment system – the anaerobic pond for conventional shed systems, spent bedding management for deep litter systems. Table A.4 lists effluent treatment factors. For conventional piggery systems, these factors may change according to whether solids separation is used before the pond.

These guidelines assume the piggery has an anaerobic effluent treatment pond sized in accordance with the methods provided in the NEGIP. Where the pond volatile solids loading rate is significantly higher than this, the effluent treatment factor may need to be altered accordingly. Nicholas et al (2003) provides information for estimating the effect of different pond designs.

TABLE A.4 Values of Effluent Treatment Factor, SIT

Effluent Treatment	Factor
Pond with >40% separation of VS before pond[a]	0.80
Pond with 25 – 40% separation of VS before pond[a]	0.90
Pond with <25% separation of VS before pond[a]	1.00
Permeable pond cover[b]	0.63
Impermeable pond cover[c]	0.50
Deep litter system – spent bedding stockpiled / composted on-site	0.63
No manure treatment / storage on-site[d] – effluent / bedding removed from site[d]	0.50

VS = volatile solids

a solids separation efficiency should be based on results published in technical reports. Where VS removal is not reported, measures of total solids removal will generally provide a conservative estimate of vs removal efficiency. Summary information for a range of separators is available in Watts et al (2002). The reduction factors in this table assume that pond surface area is reduced as a result of the use of the separator. No reduction applies if the pond surface area remains unchanged.

b A permeable pond cover assumes a consistent odour reduction of at least 75%.

c An impermeable pond cover assumes a 100% pond odour reduction.

d No manure / effluent treatment on-site assumes that some temporary storage or mixing area exists near the sheds, but that design and management of the storage / mixing area minimises emissions from this source.

This table refers to the odour emissions from the effluent treatment system and represents the reduction arising from the design and management used. As shed odour emissions have already been considered, reductions in total site odour are presented in this table to ensure the formula calculations are sensible. For the purposes of these guidelines, a conventional piggery is assumed to have two main odour sources – ponds are assumed to contribute 75% to total site odour and sheds 25%. Therefore, a reduction in total pond odour emissions of 33% would reduce total site odour emissions by 25% (i.e. 33% of 75%), giving a factor of 0.81 (1 - (75% of 25%)). Where different building design or management practices exist within the piggery complex, the effluent treatment factor should be weighted according to the number of SPUs included in each management system.

Where permeable pond covers are used, they are generally only installed over the anaerobic pond, which is assumed to contribute 90% of the total pond odour at a conventional piggery (thus contributing 68% of total site odour (90% of 75%)). The factor used is 1 – (75% of the odour emissions reduction). For example, a reduction in anaerobic pond odour of 75% will reduce total site odour by 75% of 90% of 75% = 50%, giving a factor of 1 – (75% of 50%) = 0.63.

Piggery Design Factor, S1 Summary

The two factors listed above provide the basis for estimating the relative odour potential for the piggery design selected for a particular site. Multiplying these factors together gives a total piggery design factor (i.e. piggery design factor, S1 = effluent removal factor, $S1_R$ x effluent treatment factor, $S1_T$).

Example Calculation:

Consider a proposed 1000-sow (10,000 SPU) farrow-to-finish piggery growing pigs out to 24 weeks. Breeder pigs (2000 SPU) are housed in conventional sheds, with effluent passing through a run-down screen before entering an uncovered anaerobic pond. All progeny will be kept in deep litter housing from weaning; 1500 SPU of pigs aged 3-12 weeks will be on a single batch of litter and 6500 SPU of grower pigs aged 12-24 weeks will be on a bedding changed at least every 7 weeks. Bedding is added to the deep litter sheds at approximately 0.65 kg/pig/day, and spent bedding is stockpiled on-site before spreading.

The effluent removal factor for the site, $S1_R$ is 0.7595 i.e.

(2000 SPU/10,000 SPU x 1) + (1500 SPU/10,000 SPU x 1.0) +
(6500 SPU/10,000 SPU x 0.63) = 0.7595

A properly designed and maintained run-down screen will separate 25% of the VS from the effluent before the pond.

The effluent treatment factor for the site, $S1_T$ = (2000 SPU/10 000 SPU x 0.9)
+ (8000 SPU/10,000 SPU x 0.63) = 0.684.

The piggery design factor for the site, S1 = 0.7595 x 0.684 = 0.52. The relatively low value of this design factor reflects the fact that the piggery is housing most of its pigs on deep litter. Consequently, the size of the anaerobic pond at the site is very much smaller than it would be for a conventional piggery, substantially reducing the potential odour emissions from the site. The run-down screen also reduces the required pond size.

A5.5 Piggery Siting Factor, S2

A number of piggery siting factors will influence the dispersion of odour emitted from a piggery. These factors differ from site to site and have a substantial influence on the potential odour impact at receptors. The factors having the most influence on odour dispersion are discussed below. A composite 'siting factor' for the piggery is obtained by multiplying the factors together.

Receptor Type Factor, $S2_R$

The receptor factors presented in Table A.5 account for the variation in population density, odour sensitivity and risk of exposure for receptors located in the vicinity of a piggery. Different receptor factors have been adopted for the various receptor types.

TABLE A.5 Values of Receptor Type Factor, $S2_R$

Receptor Type	Factor
Town	25
Rural residential	15
Legal house	11.5

Notes: The receptor definitions should be based on local authority classification.

The separation distance is to be measured to the closest extent of the town or rural residential zone, not the centre. Where there is a cluster of houses in a rural or farming zone, consult with council to determine whether these should be considered rural residential for the purpose of odour assessment. The separation distance from a house should be measured to the edge of any immediately adjacent area used for living or entertaining e.g. a barbeque area or pool. When determining the location of the edge of the receptor, land zoning and pending development or building applications lodged, but not yet under construction, should be taken into account. Local councils can provide this information. Public areas, such as camping grounds or picnic areas, may need to be considered as part of the assessment. The frequency of use and the time of day the area is occupied, provide guidance to the level of protection required. For example, day-use only areas are a substantially lower risk for odour impact than areas frequently used at night.

Surface Roughness Factor, $S2_S$

The surface roughness factor varies according to the roughness of the earth's surface between the piggery and the receptor. The principle elements that determine surface roughness are vegetation density and surface topography. Recommended values of surface roughness are provided in Table A.6. The values presented in this table are not to be added; only the value for the single category that best represents the site conditions should be selected.

The roughness factors given in Table A.6 assume that the selected roughness is continuous between the piggery and the receptor. Where roughness is variable or non-continuous, judgement should be used in selecting an appropriate composite factor.

The values given in Table A.6 should be used with care and a number of qualifications apply to their use. For receptors located at larger separation distances, more than one surface roughness factor may apply over different sections of the separation. In this instance, the surface roughness factor applied should be selected after considering the relative weighting of the different factors. Proponents should carefully consider which $S2_S$ factor to use when relying on vegetation. The lower values for timbered country are only appropriate if the tree cover is likely to be permanent.

APL commissioned a report providing guidance on meteorological data for odour dispersion models (Pacific Air and Environment, 2003a). This report also provides some guidance regarding surface roughness factors for use in dispersion modelling.

TABLE A.6 Values of surface roughness factor, $S2_S$

Surface Roughness Features	Description	Factor
Limited ground cover, grass	Open country with few or scattered trees, grass	1.0
Crops	Cropped land that may be bare for about half the year	1.0
Undulating terrain	Continuous rolling, generally low level hills and valleys but without sharply defined ranges, ridges or escarpments (assumes minimal vegetation)	0.93
Open grassland (grass, scattered trees)	Grasses at least 1 m high with scattered trees (not a few isolated patches of trees). Little or no lower storey vegetation	0.9
Woodlands (low density forest)	Forest with a density sufficient to be considered a continuous belt	0.7
Open forest (canopy cover 30-70%)	Tree belts providing canopy cover of 30-70%	0.6
Forest with significant mid and lower storey vegetation	Continuous tall forests with dense timber stands and significant mid and lower storey vegetation	0.5

Piggery Siting Factor, S2 Summary

The factors listed above provide the basis for estimating the relative odour dispersion potential for the selected piggery site. Multiplying these factors together gives a total piggery siting factor (i.e. piggery siting factor, S2 = receptor type factor, $S2_R$ x surface roughness factor, $S2_S$). For sites with more than one receptor type located nearby, a piggery siting factor will be calculated for each receptor type.

Example Calculation:

Consider the proposed 1000-sow farrow-to-finish piggery described earlier. The site is located 8 km west of the nearest town and 2.5 km west of a rural residential subdivision. A number of farmhouses are sited on properties adjoining the proposed piggery site – the nearest is located 1150 m to the north, another is 1300 m to the north-east, another 1700 m to the west and another 1950 m to the south. The local council has been consulted regarding the boundary of residential zonings for the town and rural residential developments. The piggery site, town boundary and the boundary of the rural residential zone have been located using a GPS with +/- 5 m accuracy. The separation to the farmhouses has been estimated from maps.

The property has flat (0-1% slope) topography in all directions. To the east of the piggery site, the vegetation is forest with a well-developed understorey ("forest"). To the north and north-east of the site there are enough trees to form a continuous belt ("woodlands"). In all other directions there is grassed land with a few scattered trees ("limited groundcover"). In all cases, tree clearing is not likely.

Separation distances will need to be calculated for three receptor classes, town ($S2_R$ = 25), rural residential ($S2_R$ = 15) and rural dwelling ($S2_R$ = 11.5). Where different surface roughness categories exist for a particular receptor class, separation distances need to be calculated for each combination of receptor class / surface roughness category.

The surface roughness used for the town and the residential area (to the east) would be forest ($S2_S$ = 0.5).

The surface roughness used for the farmhouses to the north and north-east would be woodlands ($S2_S$ = 0.7).

The surface roughness used for the farmhouses to the south and the west of the residential area would be limited groundcover ($S2_S$ = 1.0).

The piggery siting factor for a town:
S2 = 25 x 0.5 = 12.5

The piggery siting factor for rural residential:
S2 = 15 x 0.5 = 7.5

The piggery siting factor for legal houses to north & north-east:
S2 = 11.5 x 0.7 = 8.05

The piggery siting factor for legal houses to south and west:
S2 = 11.5 x 1 = 11.5

A5.6 Terrain Weighting Factor, S3

The terrain weighting factor (S3) relates to the potential for a piggery odour plume to be exaggerated in particular directions, and relatively small in others. APL Project 1921 (Nicholas and McGahan 2003) provides a methodology for incorporating important wind features, based on the topography of a specific site. This method provides an estimation of the potential changes to odour dispersion in situations where meteorological conditions may be influenced by local terrain.

The recommended factors are shown in Table A.7, along with the direction in which each factor should be applied. The slope referred to is determined by the topographical features of each site. The use of these terrain weighting factors does not affect the application of surface roughness factors discussed in section A5.2.

TABLE A.7 Values of terrain weighting factor, S3

Terrain	New Weighting Factor	
	Downslope	Upslope
Narrow valley (>1% slope)	2.0	0.5
Gently sloping (1-2%)	1.2	1.0
Flat (0-1% slope)	1.0	1.0
Receptor downslope in different sub-catchment	1.0	-
Sloping (>2% slope)	1.5	0.7
Significant hills and valleys	0.7	0.7

Notes:

1. These factors may not apply where sea breezes have a significant influence on weather patterns (i.e. in coastal regions) or where odour is emitted from elevated vent sources.
2. Downslope factors should be applied across an angle of 90° centered on the terrain feature. Upslope factors should be applied across an angle of 60° centered on the terrain feature.

The topography between the piggery and receptors should be checked. For example, if the piggery is situated on land with a slope of >2%, a terrain weighting factor of 0.7 should be used for upslope receptors and 1.5 for receptors downslope of the facility.

Weighting factors should be applied for the range of distances applicable to piggery impacts. However, the application of these weighting factors is dependent on the homogeneity of terrain between source and receptor. For example, if the terrain remains similar between the piggery and receptor, the weighting factor can be applied for an indefinite distance. The weighting factor is, however, less reliable if significant terrain changes occur between source and receptor. In this situation, use a more conservative (larger) factor.

The terrain weighting factors apply to most locations. If, however, the site is not described by these factors, consult with the assessment agencies to determine which terrain weighting factor will be acceptable.

Example Calculation:

Consider the proposed farrow-to-finish piggery described in the previous example.

The terrain of the area is flat, thus the terrain weighting factor, S3 = 1.

The required separation distance (town) for the site:
$D = (10{,}000)^{0.55} \times 0.52 \times 12.5 \times 1 = 1030$ m

The required separation distance (rural residential) for the site:
$D = (10{,}000)^{0.55} \times 0.52 \times 7.5 \times 1 = 618$ m

The required separation distance (legal houses to north and north-east) for the site:
$D = (10{,}000)^{0.55} \times 0.52 \times 8.05 \times 1 = 663$ m

The required separation distance (legal houses to south and south-west) for the site:
$D = (10{,}000)^{0.55} \times 0.52 \times 11.5 \times 1 = 948$ m

A5.7 Maximum Pig Numbers

The maximum number of pigs allowed on the site can also be calculated, by rearranging the formula, as shown in the example below.

Example Calculation:

Consider the proposed farrow-to-finish piggery site described in the previous example. The factor values are calculated in the same manner as presented in the previous examples. Maximum pig numbers will need to be calculated for the distance available for each combination of receptor class / surface roughness category. For each combination of receptor class / surface roughness category, choose the closest receptor to use in calculations. The maximum number of pigs allowed for the site is equivalent to the smallest value from the calculations. The site is located 8 km west of the nearest town and 2.5 km west of a rural residential subdivision. The nearest farmhouses are 1150 m to the north, 1300 m to the north-east, 1700 m to the west and 1950 m to the south. the houses to the north and north-east have the same S factors. The houses to the north and north-east have the same S factors. It is only necessary to calculate maximum numbers for the closest house in each case.

Maximum pig numbers (N) = $(D / (S1 \times S2 \times S3))^{1/0.55} = (D / (S1 \times S2 \times S3))^{1.82}$

Maximum pig numbers (town) for the site:
$N = (8000 / (0.52 \times 12.5 \times 1))^{1.82} = 420{,}844$ SPU

Maximum pig numbers (rural residential) for the site:
$N = (2500 / (0.52 \times 7.5 \times 1))^{1.82} = 128{,}385$ SPU

Maximum pig numbers (legal house – north) for the site:
$N = (1150 / (0.52 \times 8.05 \times 1))^{1.82} = 27{,}466$ SPU

Maximum pig numbers (legal house – west) for the site:
$N = (1700 / (0.52 \times 11.5 \times 1))^{1.82} = 29{,}229$ SPU

The maximum number of pigs allowed on the proposed site, using the proposed design and management options, is the smallest number above - 27,466 SPU.

A5.8 Minimum Separation Distances

Minimum separation distances are included largely to account for inaccuracies with predicting odour im1 receptors (town, rural residential and rural dwelling) must be calculated, and the greater distance of the two applied. **The relevant approved authority should be contacted to determine the minimum separation distances applicable, or methods for calculating them.**

A5.8.1 Piggery Complex Separation

Minimum separation distances required for a piggery complex are shown in Table A.8. Sites that have separate piggery units on the one property should apply the separation formula to the combined units, and for each receptor apply the separation distances from the nearest part of the closest piggery complex. Guidance should be obtained from the relevant approved authority to apply the separation formula individually to separate units on the same property.

TABLE A.8 Separation distances from piggery complex to sensitive land uses

Feature	Distance (m)
Town	750
Rural residential area	500
Legal house	250

Notes:

These are minimum fixed separation distance to towns, rural residential areas and legal houses. The variable separation distance must also be calculated, and the greater distance of the two applied.

A5.8.2 Separation Distances from Effluent and Manure Reuse Areas

Separation distances between reuse areas and relevant receptors and features are not specified in these guidelines, primarily because the frequency and timing of reuse can be managed to minimise the risk of odour nuisance. However, separation distance should be discussed with the regulators who will assess the application.

A5.9 Level 1.5 Assessments – Wind Frequency Factor, S4

Tonkin Consulting (2008) developed a method for adjustment of the Level 1 separation distances determined by S factors to prevailing wind directions and wind direction frequencies. The method developed analyses wind frequencies for low wind speeds below a certain threshold, and not for all winds or prevailing wind directions.

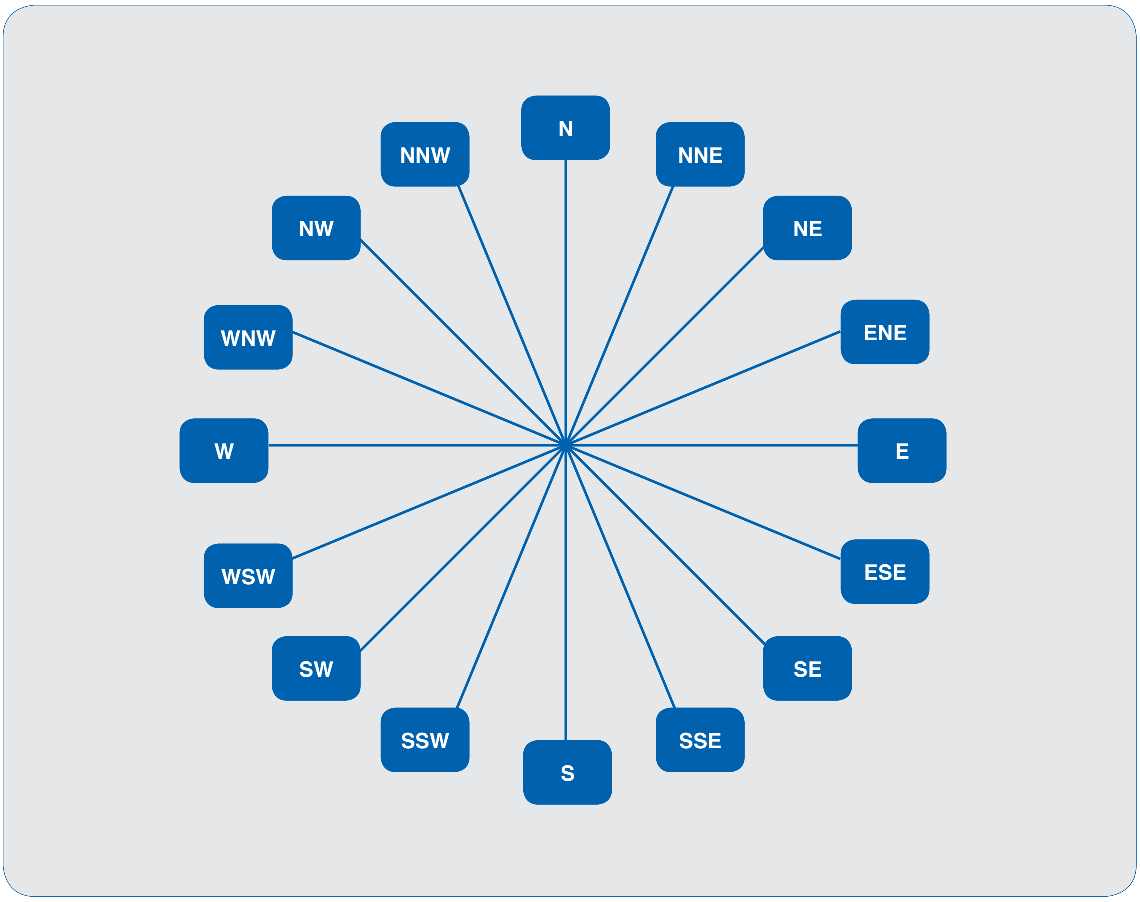
The method (Level 1.5 Assessment) applies wind direction frequencies to the Level 1 separation distances that are already calculated (as described in sections A5.1 to A5.6). This is done by calculation of the percentage of the wind direction frequencies for the sixteen compass points illustrated in Figure A.2 below, for wind speeds below a certain threshold. Wind speeds above a certain threshold are excluded, as the dispersion conditions predicting the greatest odour impact occur in low wind speed conditions.

Tonkin Consulting (2008) investigated the optimum wind speed cut off threshold, by comparing the contour for the calculated wind direction frequency adjusted separation distances to the contours for dispersion modelling (using AUSPLUME) results for the 98th percentile and 1 hour averages. It was found that a cut off threshold of 3 m/s presented the best match overall, between the dispersion modelling (using AUSPLUME) predicted odour contours for 1 OU, 2 OU and 3 OU and the wind direction frequency adjusted Level 1 separation distances for the three receptor types described in section A5.5.

For added conservatism, a safety factor of 20% was added to the calculated reduced separation distances, to cover sites with lower average wind speed. The appropriate safety factor to use may vary, and this should be discussed with the approved authority before calculating separation distances using this method. Also confirm the acceptability of the proposed meteorological data set with the approved authority before undertaking the modelling.

The Level 1.5 method used to calculate wind frequency factors (S4 factors) for a given site does not allow the calculated adjusted separation distances to be greater than the calculated separation distances using the Level 1 assessment.

FIGURE A.2 Compass Points Used for Adjustment of Level 1 Separation Distances



The steps used to calculate the 16 wind frequency factors (S4 factors) for a given site (Level 1.5 assessment method) are:

1. Obtain a meteorological file representative of the site (see section A6.3)
2. Calculation of wind direction frequencies for the 16 compass points (see Figure A5.7.1) for wind speeds ≤ 3 m/s. Thus, all wind speeds > 3 m/s need to be deleted before the analysis is conducted
3. Division of wind direction frequencies for each of the sixteen compass points by the direction with the highest frequency. This will achieve a reduction of the Level 1 separation distance from the highest frequency set to 1.0
4. Assigning of wind direction frequencies s to N, NNE to SSW etc., to account for wind blowing from odour source (piggery) to impact area (downwind). This means that wind direction frequencies need to be switched 180° to account for winds blowing from source to receptor
5. Presentation of wind direction frequencies result percentages in table (see column 2 of example below – Table A.9)
6. Addition of safety factor (agreed to by the applicable regulatory authority) to the wind direction frequencies (see column 3 of example below – Table A.9)
7. Division of adjusted wind speed frequency by 100 to determine the 16 wind speed frequency factors (S4 factors) for the site. See column 4 of Table A.9 below that shows the 16 wind frequency factors calculated for Roseworthy with a safety factor of 20%.

TABLE A.9 Calculation of Wind Frequency Factors for Roseworthy

Compass point direction	S factor wind direction frequency	S factor wind direction frequency including 20% safety factor	Wind frequency factors (S4) for Roseworthy
North	71%	91%	0.91
North north-east	71%	91%	0.91
North-east	67%	87%	0.87
East north-east	55%	75%	0.75
East	42%	62%	0.62
East south-east	41%	61%	0.61
South-east	54%	74%	0.74
South south-east	47%	67%	0.67
South	65%	85%	0.85
South south-west	66%	86%	0.86
South-west	100%	100%	1.00
West south-west	96%	100%	1.00
West	99%	100%	1.00
West north-west	79%	99%	0.99
North-west	50%	70%	0.70
North north-west	67%	87%	0.87

Calculation of separation distances for each receptor type follows the form:

separation distance (D) = $N^{0.55}$ x S1 x S2 x S3 x S4

Definitions for N, S1, S2 and S3 are provided in section A5.2. S4 is the wind frequency factor for estimating the relative odour impact due to the frequency of wind direction for wind speeds less than 3 m/s for a site.

Example Calculation:

Consider a 4000 SPU deep litter piggery located near Roseworthy. Bedding is added to the deep litter sheds at approximately 0.65 kg/pig/day and spent bedding is stockpiled on-site before spreading. The piggery is surrounded by limited ground cover / short grass and flat land. We wish to calculate the minimum distance to a legal house in the 16 compass points surrounding the piggery.

The piggery will have a maximum capacity of 4,000 SPU.

The effluent removal factor for the site, $S1_R$ = 1.0. The effluent treatment factor for the site, $S1_T$ = 0.63.

The piggery design factor for the site, S1 = 1.0 x 0.63 = 0.63.

The receptor type factor for the purpose of this example is a legal house, $S2_R$ = 11.5.

The surface roughness factor for the site $S2_S$ = 1.0

The terrain weighting factor for the site, S3 = 1.0

The required separation distance in all directions to a rural dwelling using the Level 1 assessment is:

D = $(4000)^{0.55}$ x 0.63 x 11.5 x 1.0 = 694 m

Now, applying the wind frequency factors (S4 factors) for the site (Roseworthy), gives the following 16 separation distances to a rural dwelling:

The wind frequency factor to the north, S4N = 0.91, thus DN = 629 m.

The wind frequency factor to the north-north-east, S4NNE = 0.91, thus DNNE = 629 m.

The wind frequency factor to the north-east, S4NE = 0.87, thus DNE = 600 m.

The wind frequency factor to the east-north-east, S4ENE = 0.75, thus DENE = 520 m.

The wind frequency factor to the east, S4E = 0.62, thus DE = 426 m.

The wind frequency factor to the east-south-east, S4ESE = 0.61, thus DESE = 421 m.

The wind frequency factor to the south-east, S4SE = 0.74, thus DSE = 510 m.

The wind frequency factor to the south-south-east, S4SSE = 0.67, thus DSSE = 461 m.

The wind frequency factor to the north-east, S4NE = 0.85, thus DNE = 590 m.

The wind frequency factor to the south-south-west, S4SSW = 0.86, thus DSSW = 595 m.

The wind frequency factor to the south-west, S4SW = 1.00, thus DSW = 694 m.

The wind frequency factor to the west-south-west, S4WSW = 1.00, thus D WSW = 694 m.

The wind frequency factor to the west, S4W = 1.00, thus DW = 694 m.

The wind frequency factor to the west-north-west, S4WNW = 0.99, thus DWNW = 689 m.

The wind frequency factor to the north-west, S4NW = 0.70, thus DNW = 486 m.

The wind frequency factor to the north-north-west, S4NNW = 0.87, thus DNNW = 605 m.

Figure A.3 shows the application of the wind speed frequency factor for the example 4000 SPU deep litter piggery located at Roseworthy, with the separation distance for a legal house calculated using the Level 1 method, and the adjusted separation distance with the inclusion of the wind frequency factors (S4 factors) of the Level 1.5 method.

FIGURE A.3 Application of Wind Speed Frequency Factor on a 4000 SPU Deep Litter Piggery Located at Roseworthy

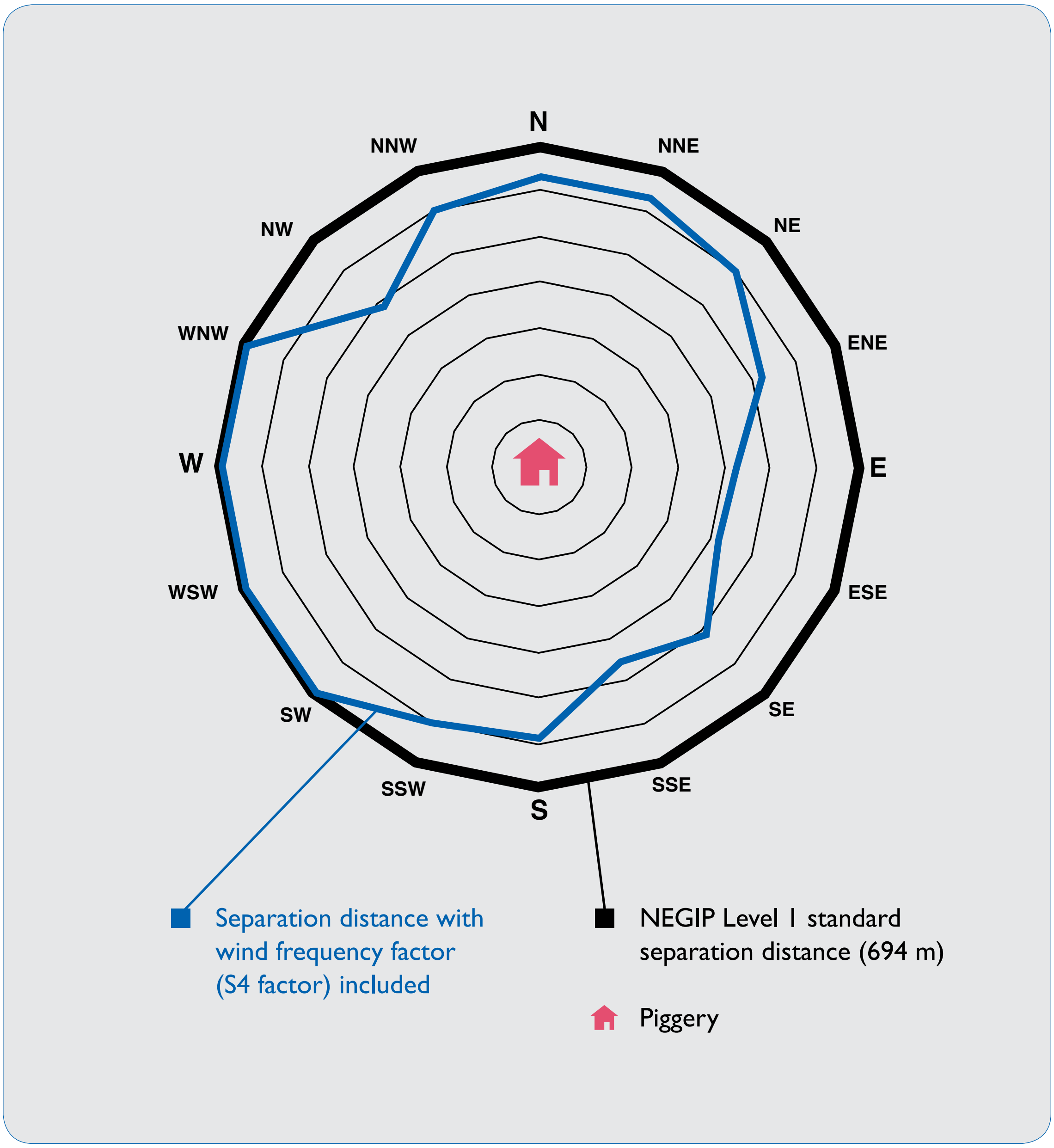


Table A.10 shows the calculated wind frequency factors for six different sites with agreed meteorological files and safety factors by the relevant regulatory authority. For calculation of wind frequency factors for additional sites, use the above methodology.

TABLE A.10 Wind Frequency (S4) Factors

Compass point direction	S4 Factors					
	Mt Gambier	Murray Bridge	Padthaway	Renmark	Rosewor-thy	Strathal-byn
North	1.00	1.00	0.84	0.87	0.91	0.82
North north-east	0.75	0.98	0.75	0.87	0.91	0.79
North-east	1.00	0.83	0.65	0.92	0.87	1.00
East north-east	0.95	0.65	0.74	1.00	0.75	0.90
East	0.98	0.57	0.77	1.00	0.62	0.86
East south-east	0.83	0.50	0.81	0.73	0.61	0.96
South-east	0.94	0.50	0.82	0.52	0.74	1.00
South south-east	1.00	0.69	0.83	0.38	0.67	1.00
South	1.00	1.00	1.00	0.52	0.85	1.00
South south-west	0.99	0.97	0.66	0.60	0.86	0.80
South-west	1.00	0.44	0.57	0.84	1.00	0.72
West south-west	0.72	0.32	0.55	0.85	1.00	0.59
West	0.73	0.34	0.48	0.84	1.00	0.64
West north-west	0.73	0.41	0.61	0.75	0.99	0.47
North-west	0.95	0.50	1.00	0.74	0.70	0.60
North north-west	0.77	0.76	1.00	0.74	0.87	0.63

A6. Odour Modelling

A6.1 Introduction

Dispersion models can provide concentration estimates over an almost unlimited grid of user-specified locations and can be used to evaluate emissions from proposed expansions or new developments. The results of the dispersion modelling analysis can be used to develop control strategies that should ensure compliance with the odour performance criteria. Dispersion models can also be used to estimate the cumulative impacts of various facilities that are located sufficiently close to one another.

Meteorological conditions govern the transport and dispersion of odour. It is therefore important, when modelling emission sources, to use meteorological data that are specifically representative of the site and the surrounding region in general. Sufficient meteorological data should be available to ensure that 'worst case' conditions are adequately represented in the model predictions. This requirement is especially important given that the odour performance criteria need to be determined and reported on a statistical basis. Meteorological data requirements are discussed further in section A2.3.

Steady state models such as AUSPLUME and AERMOD are commonly used for odour impact assessments on new and expanding premises. Where complex terrain exists, or where light winds needs to be considered, other **accepted models such as CALPUFF may be more suitable, but this should be checked with the appropriate approved authority** before conducting an assessment. More detailed discussion on the selection and use of odour dispersion models is provided in Pacific Air and Environment (2003b).

A6.2 Method

The general process for odour modelling is:

1. List all potential odour sources. Include all sources within the site boundary, and any nearby sources beyond the boundary, that could contribute to cumulative odour impacts.
2. Gather data for each release point. For each release point:
   – select area or volume source options within the chosen dispersion model
   – determine source location coordinates in meters relative to a fixed origin.
3. Determine appropriate impact criteria. Where a range of receptor types is present around a piggery, select the appropriate odour impact criteria for each receptor.
4. Estimate emission quantities. The APL Variable Emission File (VEF) maker software (Pacific Air and Environment 2004), which is available from APL, provides recommended emission rates for most piggery odour sources. Site-specific data should be used where available.
5. For all sites:
   – Odour emissions should be presented as mass emission rates in OU/ second.
   – Where applicable, include periodic variations in emission rates.
6. Estimate source release parameters. The APL VEF maker provides methods for incorporating emission release characteristics into odour modelling.

- For diffuse area sources, determine surface area, side length and release height.
- For diffuse volume sources, determine side length and release height.

7. Incorporate other dispersion modelling parameters:
   - appropriate averaging time (i.e. 1 hour).
   - location of receptors (and likely future receptors) such as rural dwellings, rural residential areas, schools and towns.
   - a meteorological data file for the site.
8. For all sites, consider what scenarios to include in analysis. alternative scenarios may be investigated to assess:
   - the odour reduction potential of different design and management processes source release parameters.
   - the sensitivity of model results to changes in key model parameters (e.g. different land use factors).
9. Prepare dispersion model input files and run computer-based model.
10. Process dispersion model output files.
11. Analyse dispersion model results. For Level 2 and Level 3 odour impact assessments, determine the impacts equivalent to the standard odour impact criteria (i.e. 3 OU, 98%, one hour average). Graphical and tabulated results should be compared to the impact criteria.
12. Prepare odour impact assessment report. an odour impact assessment report should address each of the following areas in detail:
    - site plan
    - description of the activities carried out on the site
    - description of meteorological data
    - emission inventory
    - dispersion modelling.
13. These guidelines assume all piggery odour sources are accurately represented as either area or volume sources. As a result, different modelling protocols may be required at some piggery sites particularly those that include:
    - point or line sources
    - receptors in the near-field (typically 10 x the largest source dimension)
    - complex terrain or meteorological conditions.

In these cases, advice regarding appropriate modelling protocols should be obtained from the relevant approved authority.

A6.3 Site Sources and Emission Rates

A6.3.1 Piggery Odour Emissions

These odour guidelines cover indoor piggeries which may have conventional housing, deep litter (bedded) housing or a combination of both.

The primary odour sources for a conventional piggery are:

- effluent treatment ponds
- pig sheds.

The secondary odour sources for a conventional piggery are:

- effluent reuse areas
- manure reuse areas
- areas for storing or composting carcasses / separated solids / sludge (some sites)
- effluent settling basins (some sites).

The primary odour sources for a deep litter piggery are:

- pig sheds.

The secondary odour sources for a deep litter piggery are:

- spent bedding storage / composting areas
- carcass composting areas (some sites)
- spent bedding reuse areas.

Piggery layouts vary substantially between sites. In some cases, the sheds, effluent treatment and effluent and or manure storage or composting areas are all located in close proximity. At other sites, effluent and / or manure treatment and storage or composting areas may be separated from the sheds. Some sites also separate the sheds for breeding stock from the sheds for growing pigs.

When using site-specific or site-representative data, key points for consideration include:

- data quality
- seasonal or other temporal factors that impact on odour emissions
- similarity of climatic conditions
- similarity of design and management practices
- possible effects of terrain features on the collection of the initial data
- odour measurement methodology and the general level of agreement on any adjustment factors.

Odour concentration measurements should be undertaken using dynamic olfactometry to the Australian Standard – Air quality – Determination of odour concentration by dynamic olfactometry, AS /NZS 4323.3:2001 (Standards Australia / Standards New Zealand 2001).

The recommended odour emission rates from the APL Variable Emission File (VEF) Maker software (Pacific Air and Environment 2004) should be used unless site-specific or site representative data are available. VEF Maker was developed by Australian Pork Limited (APL) for distribution to research and consulting groups. The software is designed to produce hourly varying emission files representing odour from pig sheds and effluent ponds, that can be used with dispersion models. This software includes the latest emissions data for the piggery industry in Australia for both buildings and treatment systems. VEF Maker calculates odour emission rates based on equations presented in Nicholas et al (2003).

Piggery odour sources are generally consistent, but intermittent high emissions may occur as a result of management (e.g. pond desludging) or other events. As these emissions rarely occur, it is more effective to assess these situations using a site risk assessment and manage the potential impact through a site management plan.

For site-specific sampling of odours, procedures should be discussed with the appropriate approved authority.

An Australian standard for sampling odours from area sources has been developed:

Stationary Source Emissions – Method 4: Area Source Sampling – Flux Chamber Technique (ASNZS 4323.4:2009).

Publications arising from APL project 1628 (e.g. Galvin et al 2002) have discussed the significant variability in odour concentration found from different sampling points on an anaerobic pond surface. For effluent treatment ponds, it is recommended that odour samples be collected from a minimum of six different points set out in a grid across the surface (excluding the surface above the side batters).

Smith et al (1999) discuss the variation in odour concentration within pig sheds. Substantial variation was found depending on ventilation design and wind direction. Therefore, sampling requirements will depend largely on the shed ventilation design.

Programs for collecting odour samples from piggery sources will need to factor background odours into their design. For downwind samples, this can be achieved by collecting samples of background air for analysis by olfactometry, or, for wind tunnels / flux hoods, by charcoal filtering of the air forced through the sampling equipment.

A6.3.2 Odour Intensity Measurements

Using dynamic olfactometry to determine odour concentration to the Australian Standard 4323.3:2001 (Standards Australia/Standards New Zealand 2001), and then odour intensity to the German Standard (VDI 1992), a suitable relationship between concentration and intensity can be determined, allowing different odour types to be compared. Stevens Law and the Weber-Fechner Law are examples of formulae that have widespread acceptance for defining the relationship between odour intensity and concentration for a particular odorant (including complex mixtures).

Once the odour intensity/concentration data are available, the Weber-Fechner Law (shown below) should be used to develop the mathematical relationship between intensity and concentration. This relationship may then be solved for the odorant concentration that corresponds to an appropriate criterion. Generally, an intensity of three ('distinct') is used, but this value may vary depending on the averaging time percentile used in the odour impact criteria.

$$I = k_w \log(C/C_o) + const$$

where:

I	intensity (perceived strength), dimensionless;
kw	Weber-Fechner constant;
C	concentration of odorant;
C_o	concentration of odorant at the detection threshold (by definition equals one when using odour units);
const	a constant which relates to the use of mean intensity levels. This constant is calculated from the line of best fit for each odorant.

The Weber-Fechner law has been chosen over Stevens Law because it is simpler to derive from experimental data. It is also described in the German Standard (VDI 1992) with a worked example.

Facilities that have multiple odour sources should determine the odour intensity concentration relationship for each source and, as a minimum, use the concentration that relates to the strongest odour (highest intensity) for modelling.

Odour intensity results are input into a dispersion model using a measurement of odour emission rate (OU/s) and the results compared to odour concentration at the receptor equivalent to an intensity level of 'weak', for the same averaging period and the same percentile as is used in the odour impact criteria. For sources that are intermittent and emit odour for only a fraction of the hours of the year, the variation in these emissions should be used to develop a criterion that is applicable for that source. By way of indication, the criterion would be likely to retain an intensity of 'weak' over the same averaging period, but with a higher percentile to reflect the degree of intermittency. Such an approach would give a level of protection against the highest events in the year, from intermittent sources similar to that given by the above criterion for continuous emissions.

An odour intensity assessment may be used as part of a Level 3 assessment.

A6.4 Meteorological Data

APL has commissioned a report providing guidance on meteorological data for odour dispersion models (Pacific Air and Environment, 2003a), which provides more detailed discussion on this topic.

For the AUSPLUME dispersion model, the meteorological parameters required are:

- wind speed (m/s)
- wind direction (°)
- ambient temperature (°c)
- atmospheric stability class
- mixed layer height (m).

Wind speed, wind direction and ambient temperature can be directly measured, but atmospheric stability class and mixed layer height need to be indirectly determined by using other meteorological parameters with empirical formulae.

If used, a meteorological station needs to measure and electronically log wind speed, wind direction and ambient temperature. In addition, for determining atmospheric stability class, either sigma theta (the standard deviation of the horizontal wind direction fluctuation) or total solar radiation, in conjunction with temperature measurements at two levels, must be measured and electronically logged. All parameters must be logged as one-hour average values, as a minimum requirement. An averaging time of no more than 5 minutes is necessary to determine the influence of mesoscale eddies on stable flows. With modern data logging facilities, many 'turbulence' characteristics can be computed continuously. If surface sources are likely to dominate the odour impact, serious consideration should be given to using a two-level (e.g. 10 m and 1 m) tower in order to estimate boundary layer characteristics and near-surface wind speeds, as these can affect dispersion and emission rates. All meteorological stations used to collect data for dispersion modelling purposes must use an anemometer that has a stall speed of 0.5 m/s or less.

Methods described in USEPA (2000) to calculate these factors are generally accepted by Australian regulatory authorities. The report should include a description of the meteorological data used, or alternatively, a reference to a publicly available report that contains this information. The description is to include details on the methodology used to derive stability classes and mixing heights and is to present (as a minimum) the annual wind rose and annual stability frequency distribution. The description should also include details on the quality of the anemometer used and its starting threshold.

It is generally accepted that a minimum of one year of either on-site measured data or site-representative generated meteorological data are required to obtain confident model predictions. As the data set is reduced, uncertainties and under-predictions increase in model estimates.

A Level 2 odour impact assessment requires at least one year of site-specific or representative meteorological data for impact assessments based on dispersion modelling.

To determine whether particular meteorological data are site-representative, it is necessary to confirm that the data adequately describe the expected meteorological patterns at the site under investigation (e.g. wind speeds, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift).

A Level 3 odour impact assessment requires at least one year of site-specific meteorological data for impact assessments based on dispersion modelling.

A6.5 Model Selection

APL commissioned a report providing guidance in the selection and use of odour dispersion models - APL Project 1980, Task 2 (Pacific Air and Environment 2003b) - which provides more detailed discussion on this topic.

The models, procedures and data used in the assessment must be demonstrably capable of simulating, or accounting for, all of the features that are important in determining the air quality impact of the project. The proponent is responsible for identifying and properly accommodating these. The following list includes some examples of complex situations that may require the application of alternative processes to those included in these guidelines:

- vertical plume dispersion in convective conditions
- sea breeze trapping, recirculation of odour
- near-surface dispersion under very stable calm conditions (a feature of Western Australian winter meteorology)
- topographic influences - impact of plumes on elevated terrain, effect on spatially varying wind fields, valley winds (anabatic and katabatic winds), ponding of air in stable conditions
- surface roughness
- effects of positive or negative buoyancy.

Steady state models such as AUSPLUME and AERMOD are commonly used for odour studies. However, as noted above, they have a number of limitations with regard to light winds and terrain effects. For situations where light winds or terrain will influence plume movement, complex models such as CALPUFF are recommended. Meteorological data for CALPUFF can be sourced via local weather stations, or via the use of prognostic meteorological models including The Air Pollution Model (TAPM).

A6.6 Multiple Odour Sources and Cumulative Impacts

Odours from intensive livestock facilities are typically complex mixtures of many odorants. The cumulative and interactive effects of individual odorants are not well understood, but it is generally assumed that where more than one source of a complex mixture of odorants are located in proximity, the potential odour impact on receptors is the sum of the potential individual impact of all odour sources. This approach is likely to provide a conservative assessment of the potential cumulative odour impacts.

Meat & Livestock Australia (2012) developed a simple method of assessing cumulative odour impact for two intensive livestock facilities (e.g. two piggeries or a piggery and a feedlot, poultry sheds or dairy freestall barns) that will be in close proximity to one another. This can be applied to assess the cumulative odour impact of two piggeries that are close together using the Level 1 or Level 1.5 methodologies described in these guidelines. Where other types of intensive livestock facilities are involved, recognised methodologies for determining separation distances for these should be used. For instance, for a cattle feedlot close to a piggery site, the methodology in Meat & Livestock Australia (2012) would be applied to determine the minimum separation distance for the feedlot.

Scenarios include:

- two intensive livestock facilities that will be so close together that they can be considered as a single entity. This applies where the two facilities are separated by less than half the shortest separation distance determined for each individual facility. See Figure A4.
- two intensive livestock facilities that are not so close together that they should be considered as a single entity, but the available separation distance to the receptor is within 120% of the sum of the separation distances determined individually for the two facilities. See Figure A5.
- situations where two intensive livestock facilities are separated from the closest receptor by a distance exceeding 120% of the sum of the separation distances determined individually for the two facilities. See Figure A6.

Figure A.4 shows two intensive livestock facilities treated as a single facility. The proposed piggery capacity is equivalent to the combined capacities of the two facilities and a single set of separation distances are determined on this basis. Receptors cannot sit within the calculated separation distances.

Figure A.5 shows two intensive livestock facilities that are not close enough to be considered one unit, but that are separated from the receptor by less than 120% of the sum of their individual separation distances. The 120% is a factor of safety to ensure the cumulative impact assessment is conservative. Receptors cannot sit within the calculated separation distances.

Figure A.6 shows two intensive animal facilities that are separated from the receptor by more than 120% of the sum of their individual separation distances. It is assumed that cumulative impacts do not apply.

Note that the cumulative separation distances apply only to the new or expanding development and not to the existing facility.

FIGURE A.4 Two Facilities Treated as One Facility

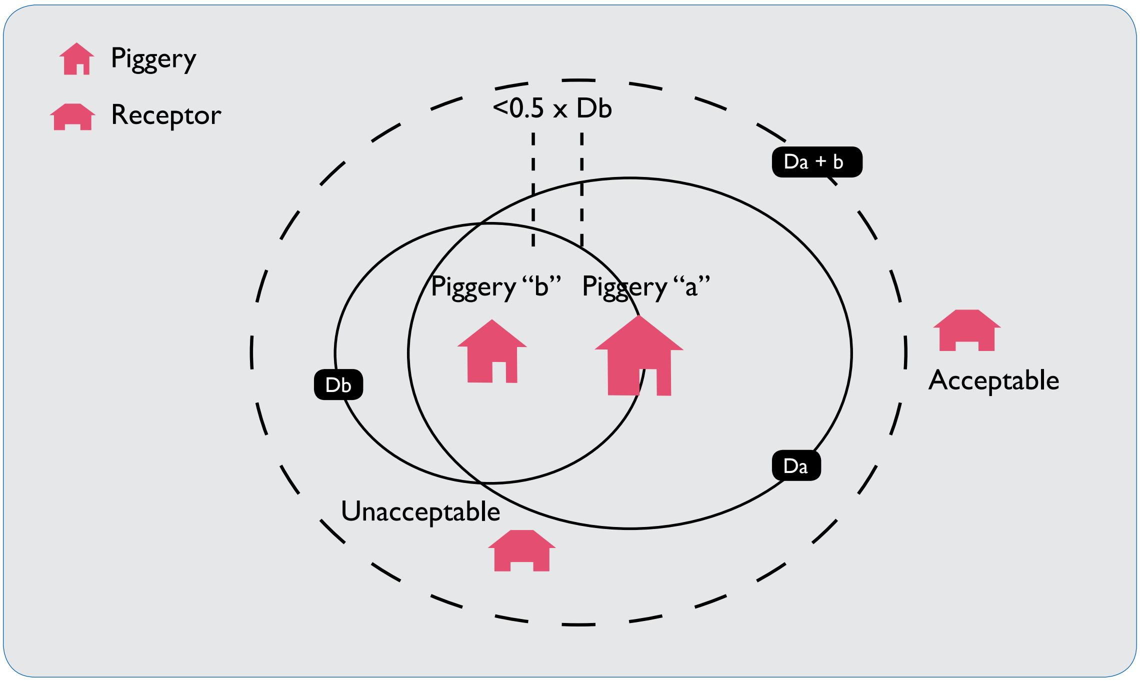


FIGURE A.5 Two Facilities Within 120% of the Shortest Individual Separation Distance

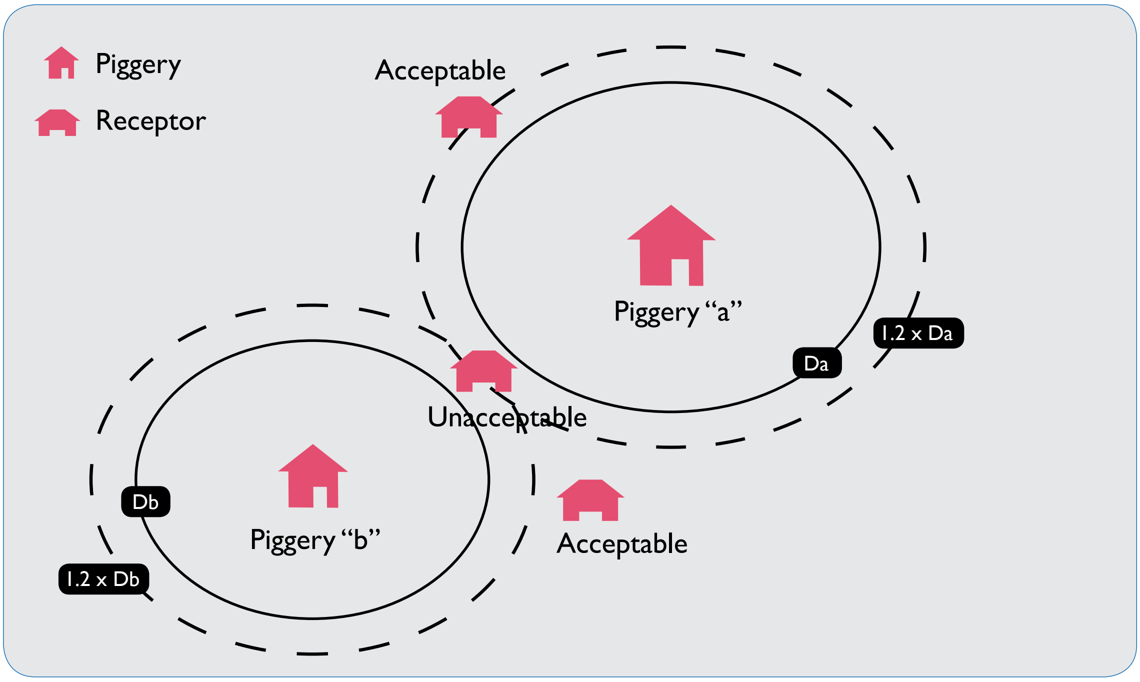
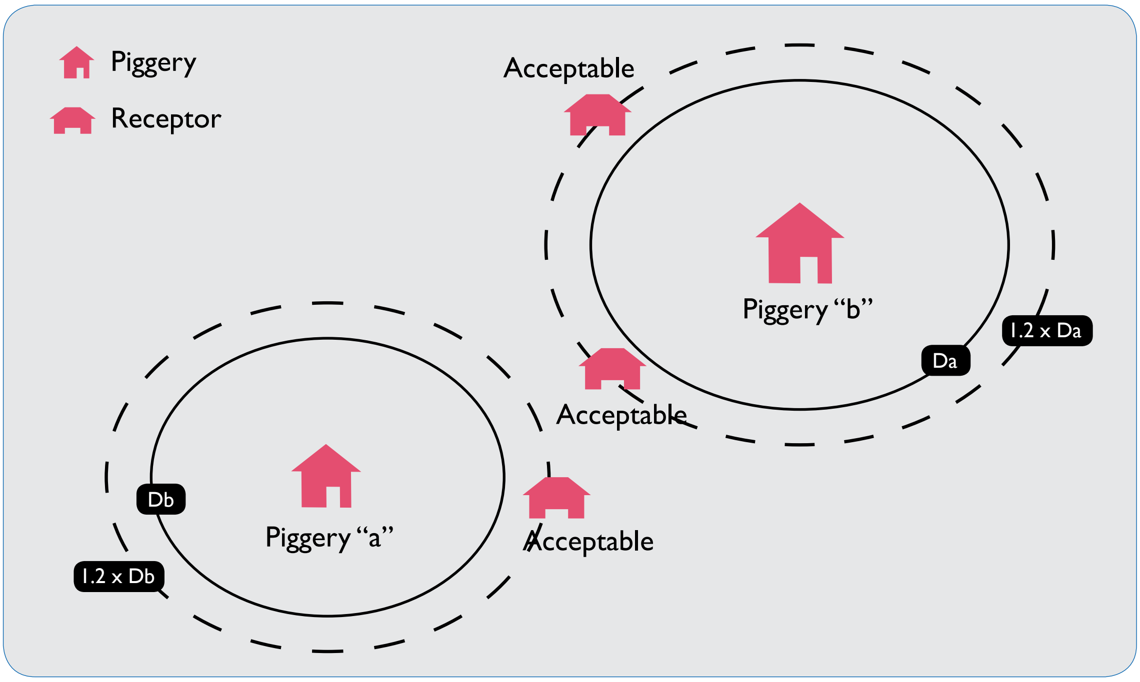


FIGURE A.6 Two Facilities Separated by More than 120% of the Shortest Individual Separation Distance



In more complex situations, odour modelling may be needed. APL commissioned Pacific Air and Environment (2003b) to provide guidance in the selection and use of odour dispersion models. From this report, the AUSPLUME should not be used for modelling multiple sites. More complex models such as CALPUFF are more appropriate for cumulative studies.

The necessity of including other odour sources in odour modelling will need to be judged according to individual site assessments. The major factors influencing the potential interaction of odour plumes will be:

- the size of each facility
- the prevailing meteorological conditions and topography of the area
- the design and management of each facility.

A6.7 Reporting Requirements

A6.7.1 Odour Sampling

Reports presenting results of odour sampling should include factors listed below.

A6.7.2 Objective

Before undertaking an odour measurement program, it is important to identify the objective of the program so that an appropriate program structure can be developed. The objective should be stated, and referred to, when justifying the sampling method and modelling undertaken.

A6.7.3 Sampling Program

Justification of sampling method in relation to the measurement objective should be included in the report. The sources sampled, and the timing of the samples taken, will depend on the objectives of the measurement program. Source conditions at the time of sampling should be appropriate for the purposes of modelling. For example, for most sources it will be necessary to sample during 'worst case normal' operating conditions.

A6.7.4 Contour Plots

The report should include plots of odour contours at appropriate intervals and values, to indicate the predicted impact of the piggery on the surrounding area. Contours should be overlaid on a map of the area, if possible, or should at least provide a clear indication of major features, such as the source, nearest receptors and major roads.

A6.7.5 Complaint Verification/Ground Truthing

Where complaints mapping has been used, a map showing locations from which complaints were received should also be included in the report and compared with modelled results. Maps and tables indicating results of any ground truthing (including comparison with modelled results) should be included in the report.

For environmental odours, ambient odour concentrations will generally be too low for determination using olfactometry, so ground truthing would typically involve qualitative assessment of ambient odour. Ormerod (2002) suggested that field observations can provide estimates of odour concentrations that appear to be similar in reliability to model predictions.

It was noted that this work was based on the odour emissions from a stack source, where the odour plume exhibited substantial variation in concentration. Piggery odour plumes typically have lower concentration variation within the plume, and more gradual changes in concentration. As a result, it would be difficult to detect concentration variation using field observation, and there would be a higher potential for odour habituation to reduce observation accuracy.

A6.7.6 Olfactometry Testing

All results of olfactometry analysis should include the following information:

- how 'worst case' normal operating conditions were captured by sampling
- confirmation of sampling methodology and protocols (what standards were used)
- confirmation of what, if any, sample dilution was used during sample collection
- laboratory where olfactometry undertaken
- confirmation of method used (Australian Standard 4323.3:2001 Stationary Source Emissions - Determination of Odour Concentration by Dynamic Olfactometry is the preferred method); to ensure rigorous quality assurance and quality control procedures are adhered to when using these methods, consultants should generally be accredited by the National Association of Testing Authorities (NATA)
- time between sample collection and olfactometry analysis
- number of panelists and identification code of each
- certified reference material used, and its concentration
- result matrices for odour intensity analyses (see Figure 1 of the German Standard
- (VDI 1992)
- plot of the odour intensity-concentration relationship(s).

A6.7.7 Odour Modelling

The dispersion modelling and impact assessment report should address the information requirements specified below:

Site Plan:

- layout of the site clearly showing all unit operations
- all emissions sources clearly identified
- plant boundary
- receptors (e.g. nearest residences)
- topography and large water sources in the area.

Description of the Activities Carried Out on the Site:

- plans clearly showing all operations carried out on the premises
- detailed discussion of all operations carried out at the site, including possible operational variability
- detailed list of all process inputs and outputs
- plans and descriptions that clearly identify and explain all odour control equipment, and odour control or management techniques used

- operational parameters of all potential emission sources, including all operational variability, such as location, release type (e.g. stack, volume or area) and release parameters (e.g. stack height, stack diameter, exhaust velocity, temperature, emission rate) and process type (e.g. batch or continuous).

Description of Meteorological Data:

- detailed discussion of the prevailing dispersion meteorology at the proposed site, typically including wind rose diagrams and an analysis of wind speed, wind direction, stability class, ambient temperature and joint frequency distributions of the various meteorological parameters
- description of the techniques used to prepare the meteorological data into a format for use in the dispersion modelling
- quality assurance / quality control analysis of the meteorological data used in the dispersion modelling. any relevant results of this analysis should be provided and discussed
- meteorological data used in the dispersion modelling supplied in a suitable electronic format.

Emission Inventory:

- detailed discussion of the methodology used to calculate the expected odour emission rates for each source
- where site-specific data is available, all supporting source emission test reports etc., methodologies used for the sampling and analysis for odour emissions
- where appropriate, a table showing all stack and fugitive source release parameters (e.g. temperature, exit velocity, stack dimensions and emission rates).

Dispersion Modelling:

- detailed discussion and justification of all parameters used in the modelling, and the manner in which topography, and other site-specific peculiarities that may affect plume dispersion, have been treated
- the value(s) of the roughness length and details on how this was determined
- detailed discussion of predicted odour impacts, based upon predicted concentrations at all receptors
- odour isopleths (contours) and tables summarising the predicted odour concentrations at receptors
- all input, output and meteorological files used in the dispersion modelling supplied in suitable electronic format.

A7. References

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Appendix B.

Environmental Risk Tool

B1. Introduction

An environmental risk assessment identifies any actual or likely impacts that a piggery, or proposed piggery development, may pose to the environment. This can help piggery managers to understand which aspects of their activities impact upon the environment, make informed decisions around environmental monitoring and make suitable choices about siting, design or management actions to prevent or mitigate impacts.

This tool is for use with the environmental risk assessment framework. It outlines the necessary tools and steps to identify, assess, manage, monitor and review piggery environmental risks. AS/NZS 31000:2009 provides further guidance.

B2. Environmental Risk Assessment Process

The steps in the environmental risk assessment process are described below, with two examples followed through each step.

B2.1 Identify the Risks

Risk identification involves:

- identifying the risk
- describing the risk including the main cause, event and consequence/s.
- defining the cause/s
- identifying the consequence/s including the worst foreseeable outcomes
- specifying key risk indicators – what information can help the business to predict when the risk event will occur before it happens?

APL has developed an environmental risk identification tool for piggeries which is provided as section 3. This tool provides practical guidance for identifying the risks.

Example 1:

if an effluent pond spill is likely to result in off-site water pollution, the consequence is "major". If this is expected to occur about once every year or two on average, the likelihood is "possible". If extra wet weather capacity is provided as a control, the spills would be smaller and less frequent. If it is now expected that smaller spills (off-farm but unlikely to significantly impact water quality in the creek) would only occur only every five years, the consequence would change to "moderate" and the likelihood to "unlikely".

Example 2:

spreading of spent bedding could impact on community amenity through odour nuisance. This could occur as a result of spreading fresh (rather than aged) bedding, spreading too close to neighbours, spreading under conditions that do not favour odour dispersion, spreading on a weekend when the neighbours are at home and / or spreading when the wind is carrying towards the neighbours. This could jeopardise the relationship with the neighbours; they might choose to lodge a nuisance complaint with council or EPA that could result in a pollution abatement notice or fine. Weather forecasts can help to predict when odour is less likely to disperse and thus pose an increased risk.

B2.2 Analyse the Risks

This involves considering:

- Initial risk – identify the likelihood and consequences of each risk if no particular controls are in place
- Controls – identify controls currently in place
- Current risk – identify the likelihood and consequence of this risk taking the initial risk and the controls into account.

Table B.1 provides a guide to ranking the consequence of each risk.

B2.1 Consequence Factors

Insignificant	No environmental impact occurring. Examples may include: • no community complaints • no corrective actions required • no breach of regulation.
Minor	Minor negative environmental impact. Minor or temporary environmental impact. Examples may include: • effluent release or other impact confined to site • minor action/control required • isolated unacceptable environmental monitoring result • warning letter from regulatory authority • an isolated community complaint or complaints.
Moderate	Moderate negative impact on environment. Off-site releases with no detrimental effects or short-term effects (less than one month). Examples may include: • contained off-site environmental damage (e.g. spill on road) with no detrimental effects • several unacceptable environmental monitoring results • local media interest • repeat community complaints (e.g. 2-5) • regulatory enforcement action (e.g. Fine, notice, order)
Major	Major negative impact on environment. An environmental impact that is severe and likely to impact beyond the immediate site and remain a problem in the medium term (less than one year). Examples may include: • uncontained offsite environmental damage (e.g. polluted water) • ongoing environmental monitoring result • ongoing local media interest or regional media interest • multiple community complaints (more than 5) • notification to authority required • civil prosecution
Catastrophic	Catastrophic impact on environment. Major environmental disaster that is severe and likely to spread beyond the immediate site and will remain a serious problem over a prolonged period (greater than 1 year). Examples may include: • long-term environmental damage • prolonged unacceptable environmental monitoring results • ongoing regional media interest or national media interest • criminal prosecution

B2.2 Risk Likelihood Factors

Likelihood rating	Event frequency*	Similarity
Almost certain	Event occurs on a weekly basis	Can be expected to occur in almost all cases
Likely	Event occurs on a monthly basis	Will occur in most cases
Possible	Event occurs on an annual basis	Might occur about half the time
Unlikely	Event occurs once every one to five years	Could occur at some time
Rare	Unlikely for the event to occur	Expected to only occur in exceptional circumstances

* The "event frequencies" in this table should only be considered a guide. *It is very important to consider industry context when selecting a likelihood rating.* For example, the National Environmental Guidelines for Indoor Piggeries recommend a design spill frequency of 1 in 10 years for pond-based effluent treatment systems with reuse, and 1 in 20 years for pond-based effluent systems that rely of evaporation to manage the liquid load. A spill once every 10 years might attract a "rare" likelihood rating for a system with reuse, while "unlikely" would be more appropriate for a system relying on evaporation.

Example 1:

if an effluent pond spill is likely to result in off-site water pollution, the consequence is "major". If this is expected to occur about once every year or two on average, the likelihood is "possible". If extra wet weather capacity is provided as a control, the spills would be smaller and less frequent. If it is now expected that smaller spills (off-farm but unlikely to significantly impact water quality in the creek) would only occur only every five years, the consequence would change to "moderate" and the likelihood to "unlikely".

Example 2:

if spent bedding spreading occurs annually and is likely to result in two or three odour nuisance complaints half the time it is undertaken, the consequence is "moderate" and the "likelihood" is possible. If the spent bedding is aged before spreading and care is taken with scheduling spreading events, the complaints might cease ("rare" likelihood) and the consequence reduce to "insignificant".

B2.3 Rate the Risks

Use the risk rating matrix provided as Figure B.1 to rate the risk by considering consequence and likelihood together, where likelihood x consequence = risk rating.

B2.3 Risk Rating Matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium (2)	High (3)	High (3)	Extreme (4)	Extreme (4)
Likely	Medium (2)	Medium (2)	High (3)	High (3)	Extreme (4)
Possible	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)
Unlikely	Low (1)	Low (1)	Medium (2)	Medium (2)	High (3)
Rare	Low (1)	Low (1)	Low (1)	Medium (2)	Medium (2)

Example 1:

Effluent pond spill:
consequence "moderate" x likelihood "unlikely" = medium (2) risk rating.

Example 2:

Odour nuisance from spent bedding spreading:
consequence "insignificant" x likelihood "possible" = low (1) risk rating.

B2.4 Evaluate the Risks

The colour-coded output of the risk rating matrix informs piggery management of the risks they need to act on, and the urgency needed. The tolerability or acceptability of the risk can be evaluated based on the following:

- Low (green) – acceptable. No corrective or preventative action is needed although further controls may be considered if this can be done with little cost and effort.
- Medium (yellow) – unacceptable risk but with sufficient controls in place. Evaluate the adequacy of the controls that are in place and decide whether further controls or monitoring are needed.
- High (orange) – unacceptable risk with insufficient controls in place. The risk needs to be managed through the implementation of appropriate corrective and / or preventative actions.
- Extreme (red) – unacceptable risk. Immediate corrective and / or preventative action is needed.

The risk acceptability or tolerability provides an indication of the risk taking the current controls into account. This can change if the controls change.

Example 1:

Effluent pond spill: medium risk level.

Example 2:

Odour nuisance from spent bedding spreading: low risk rating.

B2.5 Manage and Monitor the Risks

Table B.3 provides guidance for managing and monitoring risks depending on their tolerability or acceptability level.

B2.4 Risk Management Guide

Risk level	Action	Monitoring*
Extreme (rating 4)	Implement corrective and / or preventative actions immediately.	daily
High (rating 3)	Implement controls as a priority.	weekly
Medium (rating 2)	Evaluate the adequacy of controls and implement further corrective and / or preventative action, or monitor as needed.	fortnightly
Low (rating 1)	No additional controls needed although further controls could be implemented if this can be done easily and cheaply.	monthly

*The monitoring frequencies provided here are a guide only and will depend on the nature of the risk. For example, an extreme risk pertaining to nutrient contamination of soils would probably be monitored annually, groundwater contamination might be monitored quarterly and community amenity impacts might be monitored daily or weekly until the issue is resolved. At a minimum, monitoring needs to occur in accordance with the requirements of any permits, licenses or environmental notices.

Example 1:

Effluent pond spill: medium risk level → consider implementing controls e.g. further expanding wet weather storage capacity.

Example 2:

Example 2: Odour nuisance from spent bedding spreading: low risk level → no additional controls are needed but consider adopting further controls if this can be done easily and cheaply e.g. avoid spreading spent bedding on paddocks closest to the sensitive neighbours when the wind is carrying in their direction.

B3. Environmental Risk Identification Tool

This section provides a tool that APL has developed to help farmers identify those aspects of their operation that pose a risk to the environment. The environmental risk identification tool considers both the vulnerability of the surrounding community, surface water, groundwater and soils, and the major activities undertaken at piggeries to identify potential risk areas. It provides a starting point for completing the first step in the risk assessment process by helping to identify the risks (see section 2.1).

B3.1 Amenity and Natural Resources Vulnerability

Use the information in this section as a guide to the vulnerability of the:

- soils of reuse areas
- groundwater - quality and availability
- surface water - quality and availability
- community amenity.

Guidance for assessing the vulnerability of each area is supplied in the tables below. Since it is not possible to represent all situations that will occur on all farms, discretion should be used when evaluating the site vulnerability using these tables. To use the vulnerability assessment, read the statements in the individual rating criteria and select the most appropriate rating for your farm. Using the vulnerability templates will help you pinpoint areas where better design and management are likely to be needed to ensure the environment is protected.

B3.1.1 Vulnerability Rating: Soils of Reuse Areas

Rating Criteria	Rating
Reuse areas are:	
• suited to growing a broad range of broad acre crops and pastures	1 ☐
• suited to growing crops or pastures that can be cut and carted	2 ☐
• unsuited to producing crops or pastures that can be cut and carted	4 ☐
Reuse areas have a soil depth of:	
• at least 1m	1 ☐
• at least 0.75m	2 ☐
• at least 0.5 m	3 ☐
• less than 0.5 m	4 ☐
Reuse areas have soils that are:	
• well structured, non-rocky,non-saline and non-sodic	1 ☐
• non-rocky, non-saline and non-sodic	3 ☐
• rocky, saline or sodic	4 ☐
Reuse areas have soils that are:	
• loam (25-30% clay) to medium clay (45-55% clay) in texture	1 ☐
• sandy loam (10-25% clay) to heavy clay (>50% clay) in texture	2 ☐
• sandy in texture	4 ☐
Reuse areas are:	
• not prone to waterlogging	1 ☐
• prone to waterlogging	4 ☐
Reuse areas:	
• flood at a frequency of less than once every ten years	1 ☐
• flood at a frequency of less than once every five years	2 ☐
• flood more than once every five years on average	4 ☐
Reuse areas have slopes that promote:	
• infiltration, rather than runoff or erosion	1 ☐
• runoff or erosion	4 ☐

B3.1.2 Vulnerability Rating: Groundwater Quality and Availability

Rating Criteria	Rating
Depth to groundwater is:	
• always at least 20 m below the ground surface or the base of any piggery infrastructure, or always at least 10 m beneath the surface or the base of any piggery infrastructure, and protected by a significant rock or clay band	1 ☐
• always at least 10 m below the ground surface or the base of any piggery infrastructure, or always at least 5 m beneath the surface or the base of any piggery infrastructure, and protected by a significant rock or clay band	2 ☐
• always at least 5 m below the ground surface or the base of any piggery infrastructure, or always at least 2 m beneath the surface or the base of any piggery infrastructure.	3 ☐
• sometimes present at a depth of less than 2 m below the ground surface or the base of any piggery infrastructure	4 ☐
If groundwater is used in the piggery, there is:	
• ample allocation and supply that is of a suitable quality to meet requirements	1 ☐
• sufficient allocation and supply that is of a suitable quality to meet requirements	3 ☐
• marginal or insufficient allocation or supply (and no other water source), or the water is of a marginal quality to meet requirements	4 ☐

B3.1.3 Vulnerability Rating: Surface Water Quality and Availability

Rating Criteria	Rating
The piggery is located:	
• at least 200 m from the closest watercourse	1 ☐
• at least 100 m from the closest watercourse	2 ☐
• within 100 m of the closest watercourse	4 ☐
The piggery is located:	
• at least 800 m from the closest major water supply storage	1 ☐
• within 800 m from the closest major water supply storage	4 ☐
Reuse areas:	
• comply with the buffer distances specified in the National Environmental Guidelines for Indoor Piggeries, and there are additional protection measures (e.g. vegetative filter strips or terminal ponds) between these areas and the closest waterways	1 ☐
• comply with the buffer distances in the National Environmental Guidelines for Indoor Piggeries	2 ☐
• don't comply with the buffer distances in the National Environmental Guidelines for Indoor Piggeries, but there are effective VFSs, terminal ponds or other protection measures between these areas and all watercourses	3 ☐
• don't comply with the buffer distances in the National Environmental Guidelines for Indoor Piggeries and there are insufficient water protection measures in place.	4 ☐
The piggery is located:	
• above the 1 in 100 year flood line	1 ☐
• above the 1 in 50 year flood line	3 ☐
• within the 1 in 50 year flood line	4 ☐
Reuse areas are located:	
• above the 1 in 10 year flood line	1 ☐
• above the 1 in 5 year flood line	2 ☐
• within the 1 in 5 year flood line	4 ☐
If surface water is used in the piggery, there is:	
• ample allocation and supply that is a suitable quality to meet requirements	1 ☐
• marginal or insufficient allocation or supply (and no other water source) or the water is of a marginal quality to meet requirements	4 ☐

B3.1.2 Vulnerability Rating: Community Amenity

Rating Criteria	Rating
The piggery has received:	
• no complaints from the public or regulators for at least five years	1
• less than two complaints per year (on average) over the past five years	2
• less than four complaints per year (on average) over the past five years	3
• four or more complaints per year (on average) over the past five years	4
Levels of odour, dust and noise around the property boundary are:	
• checked at least weekly	1
• checked at least monthly	2
• checked occasionally	3
• not routinely monitored	4
Surrounding land is:	
• all designated rural, and is not designated for future development or rezoning	1
• all designated rural, but some is designated for either future development or rezoning	3
• not all designated rural	4
The piggery is:	
• well concealed from roads and neighbours	1
• fairly well concealed from roads and neighbours	2
• partly concealed from roads and neighbours	3
• clearly visible from roads and / or neighbours	4
The entrance point to farm provides:	
• at least 300 m good visibility in both directions	1
• at least 200 m good visibility in both directions	2
• at least 150 m good visibility in both directions	3
• less than 150 m good visibility in at least one direction	4
Vehicle movements and other noisy activities:	
• occur only during the day, except under exceptional circumstances	1
• are generally scheduled to occur only during the day	3
• occur at any time of the day or night	4

B3.1.2 Vulnerability Rating: Community Amenity (continued)

Rating Criteria	Rating
Mechanical equipment used on-farm is:	
• all fitted with manufacturer-specified exhaust devices	1
• generally fitted with manufacturer-specified exhaust devices	2
• mostly not fitted with manufacturer-specified exhaust devices	4
Dust from traffic movements, manure handling and reuse and feed milling is:	
• controlled as needed	1
• not specifically controlled but dust does not seem to cause nuisance	2
• not specifically controlled and dust is an issue at times.	3
There is:	
• a complaints management procedure in place that includes complaints recording, investigation and corrective action, along with appropriate consultation	1
• a complaints management procedure in place that includes complaints recording, investigation and corrective action	2
• no complaints management procedure in place, or the procedure that is in place does not include complaints recording and / or investigation and / or corrective action	4
Mediation is:	
• used to try to settle disputes with neighbours	1
• generally used to try to settle disputes with neighbours	2
• not generally used to try to settle disputes with neighbours	4

B3.2 Protection Provided by Design and Management

Use the information in this section as a guide to the protection offered by the design and management of:

- pig housing
- the nutrient content of manure
- the effluent collection system
- the manure solids separation system
- the effluent treatment system
- the manure storage/treatment
- carcass management
- design and management of reuse areas
- chemical storage and use.

Not all the factors will be applicable to all enterprises. For example, not all piggeries will have a solids separation system. Where factors are irrelevant for a given situation, they do not require evaluation. To evaluate the protection offered by design and management read the statements in the individual rating criteria and select the most appropriate rating for your farm. Not all elements will be applicable to all farms; do not allocate a score for elements that are not applicable. Use the scores in each of the design and management templates to identify the parts of your design and management that could be improved to further reduce environmental risks.

B3.2.1 Design and Management Rating: Pig Housing

Rating Criteria	Rating
Sheds:	
• are oriented east-west and are constructed to maintain temperatures within the required range with no mechanical heating or cooling	1
• are oriented east-west and are constructed to maintain temperatures within the required range with minimal mechanical heating or cooling	2
• are constructed to maintain temperatures within the required range but require significant mechanical heating or cooling to maintain temperatures at the required range	3
• have a strong reliance on mechanical heating or cooling to maintain temperatures within the required range	4
Sheds bases are:	
• concreted for conventional sheds and impervious for deep litter sheds (e.g. concreted or compacted for a permeability of 1×10^{-9} m/s for a depth of at least 300 mm)	1
• formed from well-compacted clay or other low permeability material for deep litter sheds	3
• not concreted for conventional sheds and / or not formed from low permeability material for deep litter sheds	4
Feeding systems:	
• minimise feed wastage	1
• rarely allow feed to be visible on the floor or in the bedding near the feeders	2
• often allow significant quantities of waste feed to be visible on the floor or in the bedding near the feeders	3
• significant quantities of waste feed are always visible on the floor or in the bedding near the feeders	4
Naturally ventilated sheds are:	
• well ventilated, as the sheds are separated by a distance of atleast five times their height	1
• quite well ventilated, as the sheds are separated by a distance ofat least four times their height	2
• reasonably well ventilated, as the sheds separated by a distance ofat least three times their height	3
• not well ventilated	4
Stocking densities:	
• meet the requirements of the Model Code of Practice for the Welfare of Animals: Pigs	1
• do not meet the requirements of the Model Code of Practice for the Welfare of Animals: Pigs	4

B3.2.1 Design and Management Rating: Pig Housing (continued)

Rating Criteria	Rating
Conventional sheds are:	
• frequently cleaned to maintain very clean lanes, pens and handling areas; pigs are clean	1
• regularly cleaned to maintain very clean lanes, pens and handling areas; pigs are generally clean	2
• regularly cleaned but the lanes, pens and handling areas are often visibly dirty and generally some pigs are dirty	3
• not regularly cleaned; pigs are generally dirty	4
The bedding in deep litter sheds (except for dunging areas):	
• is always kept dry and friable; pigs are clean	1
• is mostly kept dry and friable; pigs are generally clean	2
• causes most pigs to be dirty towards shed clean out, because of its moisture content.	3
• is frequently damp or wet and pigs are dirty	4
The inflow or outflow of effluent from sheds is:	
• prevented by controls	1
• mostly prevented by controls	3
• not well controlled	4
Water used to wash-down deep litter housing after spent bedding removal is:	
• always contained in a suitably sized sump or pond	1
• mostly well contained in a suitably sized sump or pond	3
• not well contained	4

B3.2.2 Design and Management Rating: Nutrient Content of Manure

Rating Criteria	Rating
The quantities of:	
• effluent and manure used on-farm are measured and recorded each time reuse occurs, and each type of effluent or manure product used is tested at least annually	1
• nutrients in the piggery effluent and manure have been estimated using conservative Figures in accepted industry nutrient mass balance models	2
• nutrients in effluent and manure that will be applied to land are estimated using general data in publications	3
• nutrients in effluent and manure are not generally measured or estimated	4

B3.2.3 Design and Management Rating: Effluent Collection System

Rating Criteria	Rating
Stormwater runoff, including roof runoff:	
• is excluded from entering the effluent collection system (or the system is designed to handle the runoff)	1
• is mostly excluded from entering the effluent collection system, and the system does not generally overflow as a result	2
• enters the effluent collection system, and the system sometimes overflows as a result	3
• enters the effluent collection system, and the system often overflows as a result	4
Effluent collection systems (e.g. channels, drains, pipes, sumps) for conventional sheds are:	
• impervious (no significant cracks)	1
• impervious and have good integrity (minimal cracking)	3
• are pervious because they are not made from concrete (or similar), or because of deterioration of the material they are constructed from	4
Effluent pits, sumps, pipes and drains are:	
• sized and managed so that they do not spill	1
• sized and managed so that they only spill infrequently	3
• inadequately sized or managed and spill at least once a year	4
Effluent pits and drains:	
• are self-cleaning and manure solids are not present in these after flushing or draining	1
• are not self-cleaning, but are cleaned at least weekly to remove manure solids	2
• have manure solids present in them after flushing or draining that are removed at least monthly	3
• have manure solids present in them after flushing or draining and these are removed less than once a month	4
There are:	
• appropriate contingency measures to prevent spills from the system	1
• contingency measures to prevent spills from the system, but these need improvement to reduce the spill frequency	3
• no specific contingency measures to prevent spills from the system	4

B3.2.3 Design and Management Rating: Effluent Collection System (continued)

Rating Criteria	Rating
Flushing channels are flushed:	
• at least daily and static pits and pull plugs are emptied at least weekly (or in accordance with design requirements), with pits emptied in rotation, to promote uniform loading of the effluent treatment system	1
• at least every second day, and static pits and pull plugs are emptied at least every three weeks	2
• at least twice a week, and static pits and pull plugs are emptied at least once every four weeks	3
• less than twice a week, and static pits and pull plugs are emptied less than once every four weeks	4
Drains, pits and sumps are:	
• inspected after each flush or draining for solids accumulation, leakage and deterioration	1
• inspected after every second flush or draining for solids accumulation, leakage and deterioration	2
• inspected at least monthly for solids accumulation, leakage and deterioration	3
• not regularly inspected for solids accumulation, leakage and deterioration	4

B3.2.4 Design and Management Rating: Effluent Pre-Treatment System

Rating Criteria	Rating
The solids separation system (including any short-term solids storage areas) has:	
• an impervious base (e.g. comprising two 150 mm layers of material each, compacted for a design permeability of 1×10^{-9} m/s, or other impervious material (e.g. concrete)	1
• a well compacted base	3
• an uncompacted base	4
The solids separation system (including any associated storage areas):	
• sits within a controlled drainage area, and there is no uncontrolled outflow of effluent	1
• does not sit within a controlled drainage area, or there is uncontrolled outflow of effluent	4
Effluent from the solids separation system and associated storage areas is:	
• directed to a storage designed to cater for this inflow	1
• directed to a storage	2
• not directed to a storage	4
The out-loading bay, where present:	
• is kept clean of excess solids; there is no significant spillage from transport vehicles	1
• is generally kept clean of accumulated solids; significant spillage from transport vehicles happens less than once a year on average	2
• frequently contains accumulated solids, or there is significant spillage from transport vehicles twice a year on average	3
• generally contains accumulated solids, or there is significant spillage from transport vehicles more than once every six months, on average	4
The solids separation system is:	
• checked daily and cleaned or maintained after this check,as needed, • to ensure it is performing to the design specification	1
• checked at least weekly and cleaned or maintained after this check, as needed, to ensure it is performing to the design specification	2
• checked at least fortnightly and cleaned or maintained after this check, as needed, to ensure it is performing to the design specification	3
• not checked and cleaned or maintained at least fortnight	4

B3.2.5 Design and Management Rating: Effluent Treatment System

Rating Criteria	Rating
The effluent treatment system:	
• is designed to capture, treat, store and reuse all effluent. It has no isolated sections. Inlets and outlets are positioned to prevent short-circuiting.	1
• is designed to capture, treat, store and reuse all effluent. It has no significant isolated sections. Inlets and outlets are positioned to minimise short-circuiting.	2
• is designed to capture and store all effluent. However, treatment capacity is compromised because the inlets and outlets are poorly positioned, or because significant isolated sections don't provide active treatment capacity	3
• does not capture,effectively treat or store all effluent produced by the piggery	4
The effluent treatment system:	
• is designed and managed such that odour emissions are acceptably low	1
• is designed and managed such that odour emissions are generally acceptably low	2
• sometimes produces strong odours,but these don't generally impact beyond the property boundary	3
• produces strong odours that can be detected beyond the property boundary	4
The effluent treatment system is:	
• designed to allow for ease of desludging,or to store at least ten years sludge	1
• designed to store at least five years sludge	2
• designed to store at least two years sludge	3
• difficult to desludge and designed with less than two years sludge storage capacity	4
The effluent treatment system:	
• has a design permeability of 1×10^{-9} m/s for a depth of at least 300 mm of compacted clay for ponds up to 2 m deep; 450 mm of compacted clay for ponds deeper than 2 m, or is fitted with a well maintained impervious synthetic liner	1
• has a design permeability of 1×10^{-9} m/s for a depth of at least 300 mm of compacted clay	2
• is lined with well compacted clay	3
• is not lined with well compacted clay or a well-maintained impervious synthetic liner	4
The depth to the water table from the base of the effluent treatment system is always:	
• at least 2 m	1
• Sometimes less than 2 m	4
The depth to the water table from the base of the effluent treatment system is always:	
• at least 600 mm is provided on any effluent treatment system	1
• less than 600 mm is provided on one or more effluent treatment system ponds	4
The effluent treatment system is designed for an overtopping frequency:	
• not exceeding 1 in 10 years where reuse is practiced, or not exceeding 1 in 20 years where effluent disposal is by evaporation	1
• exceeding 1 in 10 years where reuse is practiced, or exceeding 1 in 20 years where effluent disposal is by evaporation	4

B3.2.6 Design and Management Rating: Manure Storage

Rating Criteria	Rating
Manure storage areas:	
• sit within a controlled drainage area, and all leachate is directed to effluent ponds, or storages designed to receive this inflow	1
• sit within a controlled drainage area and leachate is directed to storages	3
• are not within a controlled drainage area, or leachate is directed to effluent ponds not sized to receive this inflow	4
The bases of manure storage areas are:	
• impervious (e.g. concrete or clay compacted for a design permeability of 1×10^{-9} m/s for a depth of 300 mm	1
• well compacted clay or other low permeability material	3
• not built from well compacted clay or other low permeability material	4
The depth to water tables beneath the base of manure storage areas:	
• exceeds 2 m at all times	1
• may be less than 2 m at times	3
Manure stockpiles/windrows are:	
• always managed to maintain low odour emissions	1
• generally managed to maintain low odour emissions, but significant odour releases occur about once a year on average	2
• generally managed to maintain low odour emissions, but significant odour releases occur up to four times a year on average	3
• not managed to maintain low odour emissions, and significant odour releases occur more than four times a year on average	4
Spilt or spoilt feed or leachate from wet feedstuffs is:	
• promptly cleaned up	1
• cleaned up within 4 days	2
• cleaned up within 7 days	3
• frequently present in the mill area	4

B3.2.7 Design and Management Rating: Mortalities Management

Rating Criteria	Rating
Dead pigs are:	
• always removed from the sheds or pens within 12 hours of discovery	1
• almost always removed from the sheds or pens daily	2
• usually removed from the sheds or pens daily	3
• frequently left in the sheds or pens for more than 24 hours	4
Mortalities management (e.g. placement in a composting pile, burial etc.,):	
• always occurs within 24 hours of death	1
• always occurs within 36 hours of death	2
• always occurs within 48 hours of death	3
• does not always occur within 48 hours of death	4
Mortalities management is by:	
• rendering or composting	1
• burial or proper incineration	3
• burning or dumping	4
Mortalities management areas:	
• always provide at least 2 m depth between base level and groundwater; and are impervious (e.g. concreted or sealed to a design permeability of 1×10^{-9} for a depth of 300 mm)	1
• always provide at least 2 m depth between base level and groundwater; and are lined or built from compacted clay or gravel	3
• sometimes provide less than 2 m depth between base level and groundwater; or are not on a well-sealed site	4
Where mortalities management is by composting or burial, carcasses are:	
• always promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered	1
• generally promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered	2
• generally not promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) or not continuously kept covered	4
Where mortalities management is by composting, burial or burning this:	
• occurs within a controlled drainage area with stormwater diverted away from the area	1
• does not occur within a controlled drainage	4

B3.2.7 Design and Management Rating: Mortalities Management (continued)

Rating Criteria	Rating
In the case of mass mortalities event, there is:	
• a suitable site selected and a detailed plan for managing mass mortalities including emergency contact details	1
• a suitable site selected and a plan for managing mass mortalities including emergency contact details	2
• a suitable site selected and a list of emergency contact details, but no real plan for managing mass mortalities	3
• no site selected or plan for managing mass mortalities	4

B3.2.8 Design and Management Rating: Reuse Areas

Rating Criteria	Rating
The nutrients in effluent and / or manure are:	
• budgeted to ensure they are applied at rates that are based on expected nutrient removals by crop or pasture harvest using average historical property crop / pasture yields with higher rates used if justified based on site-specific soil test results	1
• budgeted to ensure they are applied at rates that are based on expected nutrient removals by crop or pasture harvest using average district crop / pasture yields with higher rates used if justified based on site-specific soil test results	2
• budgeted to ensure they are applied at rates that are based on nutrient removals by crop or pasture harvest using generic yields	3
• are not budgeted using mass balance principles, or the recommendations from soil test results	4
Nutrient export from reuse areas is:	
• minimised through good management and physical barriers (e.g. appropriately designed VFS; terminal ponds to catch the first 2 mm of runoff; contour banks; or maintaining average groundcover over whole area of at least 70%) and good farming practices (e.g. conservation tillage)	1
• minimised through good farming practices (e.g. conservation tillage)	2
• not specifically prevented	4
Effluent irrigation occurs:	
• only when the soil is dry enough to absorb the water and when rain is not expected	1
• only when the soil is dry enough to absorb the water	3
• irrespective of soil moisture conditions or expected weather conditions	4

B3.2.8 Design and Management Rating: Reuse Areas (continued)

Rating Criteria	Rating
Effluent and / or manure are spread:	
• evenly and at times when active plant growth is expected	1
• evenly but not always at times when active growth is expected	3
• somewhat unevenly, but generally only spread when active plant growth is expected	3
• very unevenly or at times when active plant growth is not likely	4
High-pressure spray guns are:	
• not used	1
• used	4
Flood irrigation is used:	
• only on sites with an even grade and loam or heavier soils, and with good flow control and runoff collection	1
• on sites with uneven grades and sand-sandy loam soils, and/or inadequate flow control and runoff collection.	4
Effluent and / or manure are:	
• only irrigated / spread when weather conditions are conducive to odour dispersion, and not on weekends or public holidays.	1
• generally only irrigated / spread when weather conditions are conducive to odour dispersion, and not normally on weekends or public holidays.	2
• irrigated / spread at any time of the day, but not normally on weekends or public holidays.	3
• irrigated / spread at any time of the day, or commonly on weekends or public holidays.	4
Soils of reuse areas are:	
• tested at least annually, and the results considered when determining future reuse rates	1
• tested at least annually	2
• regularly tested	3
• not regularly tested	4

B3.2.9 Design and Management Rating: Chemical Use and Storage

Rating Criteria	Rating
MSDs, emergency response plans for spills and spill kits or suitable clean up equipment are:	
• provided for all chemicals used	1
• not provided for all chemicals used	4
Quantities of chemicals stored on-farm are:	
• minimised	1
• not minimised	3
Chemicals with a low toxicity and low water contamination potential are:	
• preferentially selected	1
• not preferentially selected	4
Chemicals and fuel are:	
• always stored and used in accordance with manufacturer's instructions and legal requirements, and only in accordance with the registered use. Records of use are maintained.	1
• not always stored and used in accordance with manufacturer's instructions or legal requirements, or are not always used in accordance with the registered use	4
Staff members are:	
• trained in the correct handling and use of all chemicals of relevance to their position	1
• not trained in the correct handling and use of all chemicals of relevance to their position	4
Empty container and sharps disposal is:	
• always in accordance with manufacturer's instructions	1
• generally in accordance with the manufacturer's instructions	3
• not generally in accordance with the manufacturer's instructions	4
Where there are underground petroleum storage systems (UPSs) on-site:	
• applicable regulatory requirements for monitoring are always followed	1
• applicable regulatory requirements for monitoring are not followed	4
Where chemical contractors are used:	
• only accredited contractors are engaged	1
• accredited contractors are generally engaged	2
• non-accredited contractors are commonly engaged	4

Note that the information in Appendix B is designed to provide a guide to the risk of an environmental impact only. It is not designed to provide a guide to risk in other areas (e.g. workplace health and safety).

Appendix C.

Complaints Register

C1. Complaints Register

The rate of complaints received cannot be used as a sustainability indicator,as it is an imprecise measure of community amenity impact. However, a change in complaints frequency may indicate an issue. Hence,any complaint should be taken seriously by the piggery operator and should be recorded and properly investigated. Full details of complaints received,results of investigations into complaints, and corrective actions should be recorded in a 'complaints register'.An example of a complaints register form is below.

Complaint Register

Complaint Details

Date of complaint: Time of complaint:

Nature of complaint:
☐ odour ☐ noise ☐ water ☐ dust ☐ other:

Name of person advising of complaint

Method of complaint:
☐ phone ☐ fax ☐ email ☐ in-person ☐ other:

Complainant Name (if known):

Complainant contact details (if known):

Investigation Details

Temperature at time of complaint:
☐ Cold ☐ Cool ☐ Mild ☐ Warm ☐ Hot ☐ Very hot

Wind strength at time of complaint:
☐ Calm ☐ Light ☐ Moderate ☐ Fresh ☐ Strong ☐ Gale

Wind direction at time of complaint:
☐ N ☐ NE ☐ E ☐ SE ☐ S ☐ SW ☐ W ☐ NW

Direction from piggery (or reuse area) to complainant (if known):

Distance to complainant (if known):

Person responsible for investigating complaint:

Investigating method:

Significant activities at the time of the complaint:

Findings of investigation:

Action Taken

Corrective actions:

Communications with complainant:

Appendix D.

Sample Collection and Analysis

D1. Introduction

This appendix details methods for collecting, storing, handling and treating samples of water, effluent, manure, plants and soil, in order to determine their composition.

Before any sampling, the following factors must be determined:

- sampling locations and the sampling frequency or triggers
- a suitable laboratory capable of undertaking the required sample analyses
- couriers that can transport the samples to the laboratory (if needed)
- sampling equipment
- sampling procedures
- monitoring parameters.

Many approved authorities have their own monitoring guidelines and requirements.

Advice should be sought from the approved authority when planning sampling and monitoring, particularly where requirements are specified a licence.

In the absence of specific advice from the approved authority, the following guidelines may be used.

D2. Laboratories

The National Association of Testing Authorities (NATA) Australia accredits laboratories, and those with this (or equivalent) accreditation, are preferred for sample analysis. Analysis methods vary between laboratories, which may affect results. For this reason, it is generally worth using the same laboratory each year. Some regulators may also have specific laboratory testing method requirements, so it is important to check your requirements thoroughly. It is worth contacting the laboratory about your analysis requirements, as they will often:

- provide suitable clean sample containers and preservatives (if required)
- issue analysis request forms
- advise which days are best for receipt of samples
- confirm requirements for storage (e.g. ice, preservatives) and transit times.

D3. Surface Water Sampling

D3.1 Sampling Location

Suitable sites that can be located and accessed for monitoring must be identified. Discuss selected sampling locations with the relevant approved authority before sampling, to ensure the results will be acceptable.

In the absence of specific guidance, samples should be taken immediately upstream, and approximately 100 m downstream of an area of interest. The downstream sample should be taken some distance from the area of interest, to allow for mixing of any runoff with the stream water. However, if the distance between sampling points is too great, inflows from other sources may affect the results. If another watercourse enters the relevant stream between the two sampling points, samples should also be taken from the secondary watercourse, close to its junction with the watercourse of interest.

D3.2 Monitoring interval

Surface water quality monitoring may be done at a set interval (e.g. quarterly, biannually or annually) or may be triggered by specific events (e.g. an overtopping effluent pond). Water quality varies with time of day, flow rate and recent weather conditions, so these factors should be noted at the time of sampling.

If a pond spill to a watercourse is the trigger for sampling, samples of effluent should be taken during the spill, as well as being from upstream and downstream from where the effluent enters the watercourse.

D3.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. Most laboratories will supply or advise on suitable sample containers and any necessary preservatives. obtaining sample containers or advice from the laboratory, reduces the chance of sample contamination and ensures the sample size is adequate
- a sampling rod. A rod with a large clamp for holding the sampling container allows greater reach when sampling liquids. the sample should be taken from upstream of your feet, to ensure that disturbed sediment is not collected
- cheap, styrofoam eskies
- plenty of crushed ice to pack around the samples in the eskies
- a waterproof pen to mark sample bottles
- waterproof tape to seal eskies
- personal protective clothing
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D3.4 Sampling Procedure

In most states, the government environmental agency will have a water sampling methodology that should be followed. In the absence of a suitable methodology, the following can be used:

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. Deep Creek upstream of effluent irrigation area) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.
2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.
3. Organise bottles and rods for sample collection. Grab samples should be collected directly into sample containers. A grab sample is a single sample collected at a particular time and place, that represents the composition of the material being sampled. Composite samples consisting of at least five grab samples should be collected if there is little movement in the watercourse or for a dam. Sub-samples to make up a composite sample should be collected using a sample bottle similar to the one that will be submitted to the laboratory. An equal quantity from each sub-sample can be poured into a second bottle to make up the composite sample. Stream samples should be collected midstream, clear of bank edges and other potential contaminant sources. Use a sampling rod to collect samples so that it is not necessary to enter the watercourse. (This can be dangerous and may also stir up sediment that contaminates the samples).
4. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Collect the sample by facing the mouth of the sampling container downwards and plunge into the water. Turn the sampling container to a horizontal position facing the current, preferably 0.2 m below the water surface (this avoids sampling surface scum). If necessary, create a current by dragging the container away from yourself. Remove the container as soon as it completely fills and empty it into the sample bottle. If you are taking a composite sample, pour a portion of the sample into a second sample bottle before discarding the balance and collecting the next sample. Repeat until all the sub-samples have been collected and combined. Add any required preservative and replace the lid. Note that for some samples (e.g. EC, pH, total organic carbon and BOD) the sample should be filled right to the top, whereas for other samples (e.g. most nutrients, turbidity and total suspended solids) the bottle should be filled only to the shoulder to provide air space. Two samples may be needed, depending on the testing requirements.
5. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid. Store the esky in a cool spot.
6. If samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Remember to leave some expansion space in the bottle. Do not store samples in a freezer used for food storage.
7. When all other surface water or groundwater samples have been added to the esky, seal it with the waterproof tape. Do not put effluent samples in the same esky as surface water samples.

8. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky.
9. Deliver the samples or arrange for courier delivery.
10. Contact the laboratory to confirm the samples have been received.

D3.5 Recording

At each sampling, record:

- the location and name of sampling site (clearly identified location allows return to the same site for future sampling)
- the date and time of day of sampling occurs (water quality varies over time)
- a general description of the flow rate (in watercourses) or approximate depth of water in dams or storages
- weather conditions at the time of sampling, as these may influence water quality
- the method of sampling (grab sample or composite sample)
- the name of the sampler
- the date and time that samples were dispatched to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D4. Groundwater Sampling

D4.1 Sampling location

If groundwater monitoring is to be undertaken, suitable monitoring bores or piezometers must be identified or installed. A piezometer is a non-pumping well, generally of small diameter, with a short screen through which groundwater can enter. These must be installed correctly with depth and casing particularly important. Monitoring bores or piezometers may also need to be registered before construction. The approved authority should be consulted.

As groundwater may move extremely slowly, bores or piezometers should be located in close proximity, and downstream, of the area for monitoring. It is also advisable to locate a bore or piezometer above the area of interest, to allow for comparison. Both bores should access water from the same aquifer. While a network of bores provides better information, this can become expensive. Hence, it is worth consulting a hydro-geologist, or specialist consultant, for advice on the location, installation and sampling of bores.

D4.2 Monitoring Interval

Groundwater quality monitoring is also usually done at a set interval (e.g. quarterly, biannually or annually).

D4.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. Most laboratories will supply or advise on suitable sample containers, as well as any necessary preservatives. Obtaining sample containers or advice from the laboratory, reduces the chance of sample contamination and ensures that the sample size is adequate.
- a sampling bailer, or pump, to draw water from the monitoring bores. A bailer is cheap. However, bailing is time consuming and impractical for deep bores. It is also important to ensure the bailer is clean before use. A pump is convenient to use and allows for samples to be quickly collected
- a tape measure and plopper, or fox whistle, to determine depth to groundwater
- cheap, styrofoam eskies
- plenty of crushed ice to pack around the samples in the eskies
- a waterproof pen to mark sample bottles
- waterproof tape to seal eskies
- personal protective clothing
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D4.4 Sampling Procedure

In most states, the government environmental agency will have a water sampling methodology that should be followed. In the absence of a suitable methodology, the following can be used:

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. upslope bore) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.

2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.

3. The standing water in the bore may be stratified and interactions between the water and the bore casing and the atmosphere may have influenced water properties. Therefore, it is recommended that you pump several bore volumes from the casing to ensure that you are not sampling stagnant water.

   Bore volume (L) = ((3.14/1000) x (radius m)^2) x water depth (m)

   For shallow piezometers, it may be appropriate to empty the piezometer

   1-2 days before sampling, and then to allow it to refill. Allow bore to recharge with groundwater before sampling. If it is not possible to purge the bore before sampling, the sampling process should not disturb the water within the bore.

4. Measure the depth to groundwater.

5. Collect a grab sample using a bailer or pump.

6. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Rinse the sample bottle with the water to be collected. Fill the bottle directly from the bailer or pump. Remove the bottle from the flow as soon as it completely fills. Note that for some samples (e.g. EC, pH, total organic carbon and BOD) the sample should be filled right to the top, whereas for other samples (e.g. most nutrients, turbidity and total suspended solids) the bottle should be filled only to the shoulder to provide air space. Two samples may be needed, depending on the testing requirements.

7. Add any required preservative and replace the lid.

8. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid.

9. If samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Do not completely fill the sample bottle if you intend to freeze the sample. Do not freeze samples in a freezer used for food storage.

10. When all other surface water or groundwater samples have been added to the esky, seal it with the waterproof tape. Do not put effluent samples in the same esky as groundwater samples.

11. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.

12. Deliver the samples or arrange for courier delivery.

13. Contact the laboratory to confirm the samples were received.

D4.5 Recording

At each sampling, record:

- the name and location of bore or piezometer
- the depth to groundwater
- the date and time of day that sampling occurs
- the name of the sampler
- the date and time of sample dispatch to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D5. Effluent Sampling

D5.1 Sampling Location

Effluent should be sampled from the sampling stopcock, priming plug or main outlet of the effluent irrigation pump. If this is not possible, collect the sample from the pond from which irrigation water will be drawn using a sampling bottle on a sampling rod.

D5.2 Monitoring Interval

The monitoring interval for effluent depends on soil test results for the reuse area to ensure sustainable nutrient levels. If soil test results are acceptable, and monitoring results for the quality of the effluent over several years indicates similar results, it may be possible to reduce the monitoring frequency.

D5.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. Most laboratories will supply or advise on suitable sample containers and any necessary preservatives. Obtaining sample containers or advice from the laboratory, reduces the chance of sample contamination and ensures that the sample size is adequate
- a sampling rod. A rod with a large clamp for holding the sampling container allows greater reach when sampling. the sample should be taken from upstream of your feet, to ensure that disturbed sediment is not collected
- cheap, styrofoam eskies
- plenty of crushed ice to pack around the samples in the eskies
- a waterproof pen to mark sample bottles
- waterproof tape to seal eskies
- personal protective clothing (disposable gloves)
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D5.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. secondary effluent pond) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.

2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.

3. Put on disposable gloves before sampling effluent. Avoid splashing eyes with effluent or sample preservatives. Avoid inhaling aerosols from the effluent being sampled or the preservatives. Do not eat, drink or smoke; carry out standard hygiene practices.
4. If sampling from a pump, start the pump and allow it to run for at least 10 minutes before collecting samples. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Sub-samples to make up a composite sample should be collected using a sample bottle. An equal quantity of ten grab samples can be poured into a separate sample bottle to make up a composite. Once this bottle is full, add any required preservative and replace the lid. Note that for some samples (e.g. EC, pH, total organic carbon and BOD) the sample should be filled right to the top, whereas for other samples (e.g. most nutrients, turbidity and total suspended solids) the bottle should be filled only to the shoulder to provide air space. Two samples may be needed, depending on the testing requirements.
5. If sampling from the pond use a sampling bottle on a sample rod to collect grab samples of effluent from 0.2 m below the water surface (this avoids sampling surface scum). Each grab sample should be taken from a different part of the pond. Add each grab sample to the bucket. When you have collected ten samples, thoroughly mix these by swirling the bucket before pouring the composite sample into a sample bottle. Add any required preservative and replace the lid.
6. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid.
7. If samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Do not completely fill the sample bottle if you intend to freeze the sample. Do not freeze samples in a freezer used for food storage.
8. When all other effluent samples have been added to the esky, seal it with the waterproof tape. Do not put clean water samples in the same esky as effluent samples.
9. Thoroughly wash your hands.
10. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. store the esky in the shade.
11. Deliver the samples or arrange for courier delivery.
12. Contact the laboratory to confirm the samples were received.

D5.5 Recording

Each time effluent is sampled for analysis, record:

- the location and name of sampling site (e.g. anaerobic pond pump to irrigation area)
- the date and time of day that sampling occurs
- weather conditions at the time of sampling
- the name of the sampler
- the date and time of sample dispatch to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D6. Manure

D6.1 Sampling Location

Separate samples are needed for each type of manure product. This could include screenings, sediment, sludge, spent bedding and compost. If manure is stored or composted before reuse, then only the stored or composted product would generally need to be analysed.

D6.2 Monitoring Interval

Generally, manure products should be analysed annually before the main reuse period. However, if soil test results for the reuse areas are acceptable, and monitoring results for the manure over several years indicates similar results, it may be possible to reduce the monitoring frequency.

D6.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. For samples with a fairly low moisture content, ziplock plastic bags may be suitable. Wet samples are best stored in wide mouthed bottles that a laboratory can supply. consulting the laboratory is recommended, as this should ensure the containers are suitable and the sample size adequate
- a sampling rod may be useful if sampling wet products (e.g. sludge)
- a shovel and trowel if sampling more solid materials
- a clean bucket
- cheap, styrofoam eskies
- plenty of crushed ice to pack around the samples in the eskies
- a waterproof pen to mark sample bottles or bags
- waterproof tape to seal eskies
- personal protective clothing (disposable gloves)
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D6.4 Sampling Procedure

1. Assemble the sample containers or bags and any required sample preservatives. With a waterproof pen, label the sample containers (not the lids) or bags with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. compost pile) and the date of sampling.

2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.

3. Put on disposable gloves and dust mask (if sampling dusty products). When sampling, do not eat, drink or smoke; carry out standard hygiene practices.
4. If sampling from a pump (e.g. sludge), start the pump and allow it to run for at least 10 minutes before collecting samples. Samples to make up a composite sample should be collected using a sample bottle similar to the one that will be submitted to the laboratory. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Pour an equal quantity of each of ten sub-samples into a second bottle to make up the composite sample, add any required preservative and replace the lid.
5. If sampling from a stockpile (screenings, spent litter, compost), use a clean shovel to collect at least 10 one-cup grab samples. Put each sample in the bucket and thoroughly mix with the garden trowel. Place about four cups of the mixed sample into a bag and seal. Put the bag inside another bag and seal well.
6. If high moisture samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Do not completely fill the sample bottle if you intend to freeze the sample. Do not freeze samples in a freezer used for food storage.
7. immediately place the sample in an esky, pack crushed ice completely around it, replace the esky lid and tape shut. Do not put any clean water samples in the same esky.
8. Thoroughly wash your hands.
9. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.
10. Deliver the samples or arrange for courier delivery.
11. Contact the laboratory to confirm the samples were received.

D6.5 Recording

At each sampling, record:

- the location and name of sampling site (e.g. compost area)
- the date and time of day that sampling occurs
- weather conditions at the time of sampling
- the name of the sampler
- the date and time of sample dispatch to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D7. Soils

D7.1 Sampling Location

Sampling locations should be chosen to represent the major soil types and

land management practices (including land use and effluent or manure reuse rates). Soil sampling should always occur at the same time of year. The end of the cropping cycle is a good time, since nutrients remaining in the soil at this time are vulnerable to leaching. Sampling should not occur immediately after prolonged wet weather.

The following steps will help decide how many sampling locations are needed:

1. Examine the soil type of each reuse area. Soil type may vary across reuse areas and different soils vary in their capacity to retain nutrients, and in their productivity. Dig some holes and compare the soils of each hole. (Recording information as you go is important!).
2. Consider the number and type of land uses across the reuse areas, since this affects the sustainable spreading rate. Areas with different land uses should be monitored separately. However, it is not necessary to provide a monitoring plot in each separate paddock if there are similar land uses between paddocks with the same soil type.
3. Divide each area on the basis of effluent or manure product type (e.g. effluent, screenings, sludge, spent litter or compost) and application rate.

   Example: If there is one soil type across the reuse areas of the farm, two land uses on these areas and only one manure or effluent product used on farm, the number of soil sampling sites would be 1 x 2 x 1 = 2.

D7.2 Monitoring Interval

The soils monitoring interval depends on the level of environmental risk, reuse practices and historical soil test results. Sampling should occur at the end of a cropping cycle, or before the time of year when nutrients are most vulnerable to leaching (before the onset of the wet season).

D7.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- a soil auger, shovel, post hole digger or hydraulic soil sampling rig (these can be hired)
- plastic sample bags. most laboratories will supply suitable sample bags
- a ruler or tape measure
- a hand trowel
- a plastic sheet
- two clean plastic buckets
- cheap styrofoam eskies

- a waterproof pen to mark sample bags
- waterproof tape to seal eskies
- personal protective clothing
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D7.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample containers with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. Paddock 5) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.
3. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bags), sampling location, sampling date and analysis parameters.
4. When labelling the sample bags, remember to include the sampling depth (e.g. 0-10 cm, 30-60 cm).
5. Collect samples. There is a range of acceptable soil sampling methods. These include variations on:
6. Monitoring plot: a 20 m diameter monitoring plot is selected in a location that is representative of the paddock or the area most at risk (e.g. the area likely to receive the highest effluent or manure application rate). The selected area should be free from stumps, atypical rockiness, tracks, animal camps and other unusual features. The location of each monitoring plot should be recorded on a property map, or GPs, so the same sites can be used in subsequent years. Collection of 20 grab samples of top soil (0-0.1 m) and at least five samples of subsoil (0.3-0.6 m or to bottom of root zone) to produce a topsoil and a subsoil composite sample for each monitoring plot, is recommended.
7. Grid: samples are collected from a series of parallel transects evenly distributed across the paddock. The pattern of sampling across the paddock forms a grid. The number of samples required depends on the area of the paddock. Collection of at least 20 topsoil and five subsoil grab samples is suggested. These are combined to produce topsoil and subsoil composite samples for each area.
8. Zigzag: samples are collected in a zigzag pattern across the paddock. The pattern of sampling across the paddock forms a zigzag or "W" shape. The number of samples required depends on the area of the paddock. Collection of at least 20 topsoil and 5 subsoil grab samples is suggested. These are combined to produce topsoil and subsoil composite samples for each area.
9. Random: samples are collected from random locations across the entire paddock. The number of samples required depends on the area of the paddock. Collection of at least 20 topsoil and five subsoil grab samples is suggested. These are combined to produce topsoil and subsoil composite samples for each area.

10. In some instances, it may be worth monitoring background soil nutrient levels on an area with a similar soil type that has not been used for effluent irrigation, manure spreading or conventional fertiliser spreading. The sampling method adopted for the reuse areas, or a monitoring plot, can be used. It is recognised that it is not always easy to find a suitable background plot. The location of each background plot should be recorded on a property map, or GPS, so the same sites can be used in subsequent years.

11. As you collect the samples, record a description of the soil sampled (one description will generally suffice if the monitoring plots method is used). Combine all of the topsoil samples in a bucket and thoroughly mix using a hand trowel. combine all the subsoil samples in a separate bucket and thoroughly mix. Remove rock fragments exceeding 2 cm diameter and large roots. Break up large clods. Never bulk (mix) soils of two different types. Never mix soil layers (profiles) that are clearly different from each other (e.g. sand and clay loam).

12. Pour the mixed composite topsoil sample into a pile on the plastic sheet. Divide the pile into four quarters. Discard three and thoroughly mix the remaining quarter. Repeat the procedure with the remaining quarter until the sample size is small enough to fill the sample bag (generally about 1 kg or 2 lb). Fill the sample bag and immediately place it in an esky. Repeat the process for the subsoil samples. Do not put effluent samples in the same esky as soil samples. Store the esky in the shade.

13. When all of the samples have been added to the esky, seal it with the waterproof tape.

14. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky.

15. Deliver the samples or arrange for courier delivery.

16. Contact the laboratory to confirm the samples were received.

17. While you are in the paddock, it is useful to record any unusual changes in the soils and plants of the reuse areas. These include:
    - free water on the soil surface. This may indicate waterlogging. Other signs include reduced plant growth, growth of weeds (dock, nutgrass) and drooping foliage with pale leaves
    - invasion of an area with nettles or fat hen. This may indicate a surplus of nitrogen
    - yellow or browned-off vegetation. This is indicative of toxic nutrient levels or nutrient deficiencies
    - bare patches in paddocks. These may indicate poor germination due to excess salinity, uneven nutrient distribution, inadequate nutrients or nutrient overloading.
    - White crusting on soil surface in dry times may indicate evaporation from a shallow saline water table
    - areas in effluent-irrigated paddocks that are consistently bare of vegetation may indicate too much salinity, inadequate nutrients or nutrient overloading.

D7.5 Recording

Original copies of soil analyses should be kept indefinitely, along with records of sampling locations and land use. This assists with long-term farm management.

D8. Plant Tissue Samples

Each time crops are harvested from effluent irrigation or manure spreading areas, the yield harvested should be recorded, and the dry matter yield and the approximate nitrogen and phosphorus removal rates should be calculated. *Hence, plant tissue samples should not generally need to be collected. However, for precision systems, plant tissue analysis can provide data for more accurately calculating the mass of nutrients harvested.*

Measure the yield of crops or fodder harvested by weighing or by estimating weight from the number of truck-loads removed. Record the yield per hectare (t/ha) and the total mass removed. The yield should then be converted to a dry matter yield. As a guide, grain crops have a dry matter content of about 88% and hay has a dry matter content of about 90%. Fresh harvested forage crops vary more.

Example:

If 4 t/ha of barley is harvested, the dry matter yield is approximately 3.5 t/ha (4 t/ha x 88/100). A 4 t/ha winter cereal crop removes about 80 kg N/ha and 12 kg P/ha. Hence, the 3.5 t/ha crop will remove about 70 kg N/ha and

10.5 kg P/ha (i.e. 80 kg N/ha x (3.5t/4t); 12 kg P/ha x (3.5 t/4t)).

D8.1 Sampling Location

Any plant samples taken should be representative of the material being harvested. For a grain crop, collect samples from the field bin (or similar). For a baled crop, collect samples of hay. For a silage crop, collect samples of freshly cut material from several bales or bins.

D8.2 Monitoring Interval

For most enterprises, analysis of plant composition should not be required. This is only suggested for precision systems.

D8.3 Sampling Equipment

The sampling equipment for plants may include:

- large paper sample bags. Most laboratories will supply suitable sample bags. Brown paper bags will also be sufficient
- disposable gloves
- a clean sampling cup
- a clean bucket
- analysis request forms
- an envelope that analysis request forms will fit in
- a pen to mark sample bags and complete analysis request forms
- cheap styrofoam eskies.

D8.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample bags with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. wheat from Home Paddock) and the date of sampling.
3. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.
4. Collect the sample. If possible, this should occur between 8 am and 11 am.
5. For grain, it is suggested that at least five samples be collected from the field bin (or similar). These should be placed in the bucket and thoroughly mixed with gloved hands. A sub-sample should then be used to fill the sample bag.
6. For hay or cut forage, collect five sub-samples, thoroughly mix together in a bucket using gloved hands, and sub-sample to fill the sample bag.
7. Leave the tops of the paper bags open to allow excess moisture to escape.
8. Put the bags in an esky and leave in the shade or a cool place. Do not seal plant or grain samples in plastic bags or leave samples in the sun as they will sweat and degrade.
9. When the samples are ready for delivery, fold the tops of the bags over and fasten with staples or sticky tape. Place back in the esky.
10. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.
11. Deliver the samples or arrange for courier delivery.
12. Contact the laboratory to confirm the samples were received.

D8.5 Recording

Original copies of plant tissue analyses should be kept indefinitely, along with records of sampling locations and land use. This assists with long-term farm management.

D9. Measuring Reuse Rates

D9.1 Effluent Reuse Rate

It is necessary to measure the quantity of effluent irrigated to each paddock.

A flow meter can accurately measure the effluent flow rate. In-line flow meters should be a non-corrosive type. Alternatively, non-contact ultra-sonic, doppler, and non-contact magnetic flow meters that clamp to the outside of the pipe are available, although they are expensive.

A depth gauge in the pond, used with a storage capacity curve, can provide an estimate of the irrigation rate when large volumes are irrigated at a time. The curve shows the volume of effluent in the pond when filled to any depth. The change in depth from the start to the finish of the irrigation should be measured.

For a single hand-shift type sprinkler, the pumping rate can be estimated from the time taken to fill a container of known volume. The flow rate must be measured from the irrigation nozzle. It can be very difficult to measure effluent volumes this way. A plastic hose fitted over the nozzle and a 10 L bucket will help. For a sprayline, the outflow from at least three nozzles should be measured. Both sides of double- sided nozzles should be measured. As long as there are not too many pipe-join leaks, this method will give a good estimation.

If effluent is pumped from a tank or sump of known capacity, daily or weekly irrigation volumes may be estimated from the sump or tank volume and the emptying frequency.

If bulk tankers are used to spread effluent, tanker volume and emptying frequency provide a good estimate of the irrigation rate.

Each time effluent is irrigated, record:

- the date of irrigation
- the paddock irrigated
- the irrigation rate (mm or KL /ha).

The annual reuse rate (ml/ha) needs to be multiplied by the nutrient content (mg/L) for each nutrient of interest, to calculate the nutrient addition rate (kg/ha) to each reuse area.

D9.2 Manure Reuse Rate

If a tanker of a known volume (L or m^3) is used to spread wet solids (e.g. sludge), then the number of loads per hectare multiplied by the volume, gives the as-spread application rate. This needs to be converted to a dry matter spreading rate, since this is how nutrient analysis results are generally expressed. If the dry matter content of the solids is determined, this is calculated by multiplying the spreading rate (L/ha) by the dry matter content (% or g/kg/1000).

For example, for manure with a dry matter content of 10% spread at a rate of 20,000 L / ha, this would be calculated as: 20,000 L /ha x 10/100 = 2000 kg/ha.

If the dry matter data was expressed as 100 g/kg (10%) the calculation would be: 20,000 L/ha x 100/1000 = 2000 kg/ha.

If a manure or fertiliser spreader is used, the reuse rate can be calculated by multiplying the number of loads applied per hectare by the estimated weight of each load. Again, the spreading rate should be converted to a dry matter rate. Multiply the as-spread application rate (t/ha) by the dry matter content (%) or g/kg to convert to spreading rate (kg/t).

Each time manure is spread on-farm, record:

- the date of spreading
- the paddock being spread
- the spreading rate (t/ha or m3/ha).

The annual reuse rate (t/ha) needs to be multiplied by the nutrient content (g/kg) for each nutrient of interest, to calculate the nutrient addition rate (kg/ha) to each reuse area.

D9.3 Off-Farm Reuse

Piggery operators have a duty of care concerning the effluent and manure products that go off-farm to third-party reusers. The APL Piggery Manure and Effluent Management and Reuse Guidelines and the companion Piggery Manure and Effluent Reuse Glovebox Guide provide more information to help with this.

If effluent or manure is provided to off-site users, record:

- date the material left the site
- quantity of material involved
- type of material
- recipient's name and contact details
- proposed use if known (e.g. where the material will be irrigated or spread, the land use of the area involved and the application rate).

Provide effluent and manure recipients with a product knowledge statement and analysis results for the material they are receiving, so that they can calculate appropriate irrigation or spreading rates and adopt environmentally sustainable practices.

Appendix E.

Useful Conversions

E1. Metric Conversions

Length

1 inch (in)	25.4 millimetres (mm)	1 mm = 0.04 in
1 foot (ft)	0.3 metres (m)	1 m = 3.3 ft
1 yard (yd)	0.9 m	1 m = 1.1 yd
1 mile (mi)	1.6 kilometres (km)	1 km = 0.6 mi

Weight

1 ounce (oz)	28.35 grams (g)	1 g = 0.035 oz
1 pound (lb)	0.45 kilograms (kg)	1 kg = 2.2 lb
1 t	1000 kg	

Area

1 square inch (in^2)	0.00065 square metres (m^2)	1 m^2 = 1,550 in^2
1 square foot (ft^2)	0.09 square metres (m^2)	1 m^2 = 10.8 ft^2
1 square yard (yd^2)	0.84 m^2	1 m^2 = 1.2 yd^2
1 acre (ac)	0.405 hectares (ha)	1 ha = 2.5 ac
1 hectare (ha)	10 000 square metres (m^2)	1 m^2 = 0.0001 ha

Volume

1 cubic inch (in^3)	16.4 cubic cm (cc, cm^3)	1 cc = 0.06 in^3
1 cubic foot (ft^3)	28.3 litres (L)	1 L = 0.035 ft^3
1 ft^3 = 6.2 gallon (gal) 1 gal = 0.16 ft^3		
1 cubic yard (yd^3)	0.8 cubic metres (m^3)	1 m^3 = 1.3 yd^3
1 acre foot (ac-ft)	1.23 ML	1 ML = 0.8 ac-ft
1 gallon (gal)	4.5 L	1 L = 0.22 gal

Pressure

1 gallon/hour (gph)	0.00125 litres per second (L/s)	1 L/s = 800 gph
1 pound/inch^2 (psi)	6.9 kilopascals (kPa)	1 kPa = 0.145 psi
1 pound/foot^2	47.9 pascals (Pa)(lb/ft^2)	1 Pa = 0.02 lb/ft^2
1 pascal (Pa)	1 newton/m^2 (N/m^2) (pressure units)	

Energy

1 ft-lb/spc	1.36 watts (W)	1 W = 0.74 ft lb/s
1 watt (W)	1 newton-metre/second (N-m/s)	
1 horsepower (hp)	0.75 kilowatts (kW)	1 kW = 1.34 hp
	550 ft-lb/sec	
	1 ft-lb/sec = 0.0018 hp	

Density

1 lb/ft^3	16 kg/m^3	1 kg/m^3 = 0.06 lb/ft^3
		1 kg/m^3 = 0.000036 lb/in^3

Force

1 pound force (lb)	4.45 newtons (N)	1 N = 0.22 lb

E2. Other Conversions

1 ML	1 000 000 L = 1000 m^3
1 m^3	1000 L = 0.001 ML
1 ML/ha	100 mm depth over 1 ha
ppm	mg/kg, mg/L
1 mg/kg	1 kg/t
1 mg/L	1 kg/ML

E3. SI Units

SI Units

Quantity	SI Unit	Other units
Length	metre (*m*)	inch (*in*), foot (*ft*), yard (*yd*)
Mass	kilogram (*kg*)	ounce (*oz*), pound mass (*lbm*)
Volume	$metre^3$ (m^3)	$inch^3$ (in^3), $foot^3$ (ft^3)
Time	second (*s*)	
Velocity	metre/second (*m/s*)	foot/second (*ft/s*), miles/hour (*mph*)
Acceleration	$metre/second^2$ (m/s^2)	$inch/second^2$ (in/s^2), $foot/second^2$ (ft/s^2)
Area	$metre^2$ (m^2)	$inch^2$ (in^2), $foot^2$ (ft^2)
Density	$kilogram/metre^3$ (kg/m^3)	pound $mass/in^3$ (lbm/in^3), pound $mass/ft^3$ (lbm/ft^3)
Force	newton (*N* [= $kg\text{-}m/s^2$])	pound force (*lb*)
Pressure	pascal (*Pa* [= N/m^2])	pound $force/inch^2$ (*psi*), pound $force/foot^2$ (lb/ft^2)
Power	watt (*W* [= *J/s* = *N-m/s*])	foot-pound/minute (*ft-lb/min*), horsepower (*hp*)

SI Unit Prefixes

Multiplication Factor		Prefix	Symbol
1,000,000	= 10^6	mega	M
1,000	= 10^3	kilo	k
100	= 10^2	hecto	h
10	= 10^1	deka	da
0.1	= 10^{-1}	deci	d
0.01	= 10^{-2}	centi	c
0.001	= 10^{-3}	milli	m
0.000,001	= 10^{-6}	micro	m

E4. Water Quality Conversions

TDS to EC	multiply TDS in mg/L by 640 to convert EC to dS/m
Nitrate-nitrogen	multiply nitrate-N (mg/L) by 4.427 to convert to nitrate
Nitrite-nitrogen	multiply nitrite-N (mg/L) by 3.284 to convert to nitrite
Phosphate-phosphorus	multiply phosphate-P (mg/L) by 3.066 to convert to phosphate
Sulphate-sulphur	multiply sulphate-S (mg/L) by 2.996 to convert to sulphate
Calcium	divide mg/L by 20.08 to convert to meq/L
Magnesium	divide mg/L by 12.15 to convert to meq/L
Sodium	divide mg/L by 22.99 to convert to meq/L
Potassium	divide mg/L by 39.1 to convert to meq/L

E5. Salinity Conversions

From ↓	To →	S/m	dS/m	mS/m	uS/m	mS/cm	uS/cm	TDS (mg/L)	meq/L
S/m		x 1	x 10	x 10^{3}	x 10^{6}	x 10	x 10^{4}		x 100
dS/m		x 0.1	x 1	x 100	x 10^{5}	x 1			x 10
mS/m		x 10^{-3}	x 0.01	x 1	x 10^{3}	x 0.01			x 0.1
uS/m		x 10^{-6}	x 10^{-5}	x 10^{-3}	x 1	x 10^{-5}			x 10^{-4}
mS/cm		x 10^{-3}	x 1	x 100	x 10^{5}	x 1			x 10
uS/cm		x 10^{-4}	x 10^{-3}	x 0.1	x 100	x 10^{-3}			x 0.01
TDS (mg/L)		x 1.56 x 10^{-4}	x 1.56 x 10^{-3}	x 0.156	x 1.56 x 10^{-2}	x 1.56 x 10^{-3}	x 1.56	x 1	x 1.56 x 10^{-2}
meq/L		x 0.01	x 0.1	x 10	x 10^{4}	x 0.1			x 1

Glossary

Glossary

Ad libitum allowing pigs to eat an unrestricted amount of feed.

Adult any pig over the age of nine months.

Anaerobic pond or lagoon a pond that uses anaerobic micro-organisms to treat the effluent. These are micro-organisms that do not need free oxygen from the air to function. These lagoons/ponds are usually quite deep (typically 4 m or deeper).

Approved authority local or state government entity with relevant statutory authority.

AUSPLUME Environment Protection Authority - Victorian regulatory Gaussian dispersion model.

Available nutrient that portion of any element in the soil that can be readily absorbed and assimilated by growing plants.

Background site the site that is close to the area of interest. It should have a similar soil type and land use to the reuse area, but should not have received piggery effluent or manure.

Boar an uncastrated male pig over nine months of age.

Breeder piggery a unit where breeding stock are kept, along with sucker pigs.

Buffer distance the distances provided between the piggery complex or reuse areas and sensitive natural resources (e.g. bores, watercourses and major water storages) as an important secondary measure for reducing the risk of environmental impact.

Bulking mixing of multiple soil samples from a paddock or plot to produce a representative sample.

Bund watertight wall designed to prevent liquid escaping as a result of seepage or leaks.

Cation exchange capacity (CEC) the total of exchangeable cations that a soil can absorb.

Community amenity the comfortable enjoyment of life and property, particularly in terms of air quality (i.e. odour and dust), noise, lighting and visual appearance.

Composite sample sample comprising several grab samples collected over minutes, hours or days according to a sampling program.

Compost is the product of the partial decomposition of organic matter by microorganisms.

Contamination the release of a contaminant into the environment in the form of gas, odour, liquid, solid, organism or energy.

Controlled drainage area an area that collects contaminated stormwater runoff or effluent and excludes clean rainfall runoff.

Conventional piggery these typically house pigs within steel or timber framed sheds with corrugated iron or sandwich panel roofing and walls made from pre-formed concrete panels, concrete blocks, corrugated iron or sandwich panel (or some combination of these), sometimes with shutters or nylon curtains depending on the ventilation system. A fully environmentally controlled shed has enclosed walls with extraction fans and cooling pads providing ventilation and climate control. Conventional sheds have a concrete base, often with concrete under-floor effluent collection pits or channels. The flooring is usually partly or fully slatted, and spilt feed, water, urine and faeces fall through the slats into the underfloor channels or pits. These are regularly flushed or drained to remove effluent from the sheds. Sheds without slatted flooring usually include an open channel dunging area which is cleaned by flushing or hosing.

Crate equipment designed for confining pigs for a number of husbandry functions, including weighing, handling for veterinary interventions, farrowing and assisting with other reproductive processes.

Creep area a separate area within a farrowing facility in which piglets are protected from crushing, or overlying, by the sow, and which is usually heated to provide a temperature that is more suitable for maintaining the welfare of piglets, while at the same time, maintaining the comfort of the sow.

Deep litter piggery a housing system in which pigs are typically accommodated within a series of hooped metal frames covered in a waterproof fabric, similar to the plastic greenhouses used in horticulture. However, skillion-roof sheds and converted conventional housing may also be used. Deep litter housing may be established on a concrete base or a compacted earth floor. Pigs are bedded on straw, sawdust, rice hulls or similar loose material that absorbs manure, eliminating the need to use water for cleaning. The used bedding is generally removed and replaced when the batch of the pigs is removed, or on a regular basis.

Desludging removing settled solids from the bottom of an effluent pond.

Dispersion modelling computer-based software modelling used to mathematically simulate plume dispersion of air emissions under varying atmospheric conditions; used to calculate spatial and temporal fields of concentrations and particle deposition due to emissions from various source types.

Dry basis the percentage or concentration of a component in the dry matter of a material (i.e. ignoring the weight of water in the material)

Dry scraping systems blades on cables that drag manure and wastewater from effluent channels under conventional sheds.

Dry sow a female pig that has been mated and has not yet farrowed.

Effluent liquid wastewater stream including manure, waste feed and cleaning water.

Effluent sumps pits that store effluent before pre-treatment, or before is directed to ponds or irrigation.

Electrical conductivity see 'salinity

Environmental management plan (EMP) an EMP focuses on the general management of the whole farm, taking into account the environment and associated risks. It should document design features and management practices; identify risks and mitigation strategies; include ongoing monitoring to ensure impacts are minimised; and processes for continual review and improvement.

Exchangeable sodium percentage (ESP) the percentage of a soil's cation exchange capacity occupied by sodium.

Facultative pond a pond or lagoon that uses facultative microorganisms to treat the effluent stream. These are microorganisms that can function in the presence or absence of oxygen from the air. Facultative lagoons are typically 2-3 m deep.

Farrow give birth to piglets.

Farrowing crate an enclosure closely related to the sow's body size, in which sows are kept individually during and after farrowing, to prevent a sow from overlaying her piglets.

Farrowing pen an enclosure for optionally confining individual sows and their litters during and after farrowing. Such pens contain a creep area and a farrowing crate, or other structure, for confinement of the sow.

Farrow-to-finish a production system incorporating a breeding herd, plus progeny, through to finished bacon weight (usually 100-110 kg).

Feeder equipment from which feed is dispensed.

Feedlot outdoor piggery a piggery where the pigs are continuously accommodated in permanent outdoor enclosures that are not rotated.

Finisher pigs generally above 50 kg live-weight, until they are sold or retained for breeding. Usually refers to pigs that are in the final phase of their growth cycle.

Flushing systems underfloor channels in conventional sheds that are flushed daily, to twice weekly, with either clean water or treated effluent recycled from the ponds.

Freeboard the height of the pond embankment crest above the design's full storage level. The freeboard protects the bank against wave action and construction inaccuracies.

Gestation the period when a sow is pregnant.

Gilt a young female pig, selected for reproductive purposes, before she has been mated.

Grab sample a single sample collected at a particular time and place that represents the composition of the material being sampled.

Groundwater all water below the land surface that is free to move under the influence of gravity.

Group housing a type of loose housing in which multiple pigs are kept in the same pen or area.

Grower pigs generally with live weights of 20-60 kg.

Growing pigs weaners, growers and finishers.

Grower / grow-out unit a production system where pigs are grown from weaner, or grower weight,through to pork or bacon weight.

Hydraulic load the input of water via precipitation and irrigation applications into a pond or onto land.

Indoor piggery piggery system in which the pigs are accommodated indoors in either conventional or deep litter sheds.

Katabatic drift drainage of air in the absence of wind,whereby odour may drift with minimal dilution to lower areas,following the topography in the same way as watercourses.

Katabatic winds winds that occur mainly on cloudless nights when the land surface loses heat by radiation. Air that is cooled by contact with the cold land becomes denser than the surrounding air. The force of gravity on it is relatively greater and the air begins to flow down the slopes of mountains and hills. This downward flow becomes particularly evident as the air moves down the bottom of river valleys that lead to lower levels. Generally,these are rather light winds.

Lactating sow a sow that has given birth and is producing milk to feed her piglets.

Leaching process where soluble nutrients (e.g. nitrogen) are carried by water down through the soil profile.

Loose housing housing that provides the pig with freedom of movement. It can be individual or group housing but the pigs must be able to turn around and extend their limbs.

Manure faeces plus urine. For the purpose of these guidelines, manure may also refer to solids separated from the effluent stream, effluent pond sludge and spent bedding.

MEDLI® a computer model for designing and analysing effluent treatment systems and reuse by land irrigation.

Multi-site production a production system where there is physical separation of the breeder, weaner and grower pigs. Typically piglets are weaned at 2-4 weeks of age and are transferred to a weaner unit. Weaner pigs are then transferred to a grower unit at 8-12 weeks of age for growing and finishing.

Nutrient a food essential for a cell, organism or plant growth. Phosphorus, nitrogen and potassium are essential for plant growth. In excess they are potentially serious pollutants, encouraging unwanted growth of algae and aquatic plants in water. Nitrate-nitrogen poses a direct threat to human health. Phosphorus is considered the major element responsible for potential algal blooms.

Odour units for measuring the concentration of odorous mixtures. 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 (1OU) is the numerical value at which 50% of a testing panel (see 'olfactometry') correctly detect an odour.

Offensive odour an odour that by reason of its nature, components, quality or strength, or at the time at which it is made, is likely to be offensive to, and/or to interfere unreasonably with the comfort or rest of people at, or beyond, the boundaries of the premises from which the odour originates.

Olfactometry a procedure in which a selected and controlled panel of up to eight respondents is exposed to precise variations in odour concentrations in a controlled sequence. The results are analysed using standard methods to determine the point at which half the panel can detect the odour (1 OU).

Open flush gutters open gutters, or vee drains, running along solid flooring within or beside the pens that collect effluent from conventional sheds.

Organic carbon a chemical compound making up organic matter. As organic matter is difficult to measure, it is estimated by multiplying the amount of organic carbon by 1.75.

Organic matter living or dead plant and animal material.

Outdoor piggery system in which the pigs are kept outdoors but are confined within an area with housing provided for shelter and fed for the purpose of production, relying primarily on prepared or manufactured feedstuffs or rations to meet their nutritional requirements.

Overtopping overflow or spill from dam or pond.

Pathogens microorganisms that can cause infections or disease.

Pen an enclosure for confining pigs in which they can turn around, which may be used for housing pigs in groups, housing boars individually, management purposes, such as mating or farrowing, or for confining pigs individually.

pH a measure of the acidity or alkalinity of a product. The pH scale ranges from 1 to 14. A pH of 7 is neutral, a pH below 7 is acidic and a pH above 7 is alkaline.

PigBal 4 a validated model for estimating the quantity and composition of effluent and manure streams from piggeries and for sizing effluent treatment ponds. The development and validation of PigBal 4 by the Queensland Department of Agriculture and Fisheries was funded by APL.

Piggery system in which the pigs are confined within a structure and fed for the purpose of production, relying primarily on prepared or manufactured feedstuffs or rations to meet their nutritional requirements.

Piggery complex this includes all buildings where pigs are housed, adjoining or nearby areas where pigs are yarded, tended, loaded and unloaded; areas where manure from the piggery accumulates or is treated pending use or removal; and facilities for preparing, handling and storing feed. This does not include the reuse areas.

Piglet a pig up to the time it is weaned from the sow.

Piezometer a non-pumping well, generally of small diameter, that is used to measure the elevation of the water table and for collecting samples for water quality analysis. It generally has only a short well screen through which water can enter.

Pollution direct or indirect alteration of the environment causing contamination or degradation.

Pull-plug systems underfloor pits in conventional sheds that store effluent until it is released, using gravity release pipes in the center of the pits.

Rational Design Standard (RDS) a pond sizing method base on volatile solids (VS) loading rate.

Receptor person or site that receives,and is sensitive to,community amenity impacts, including a residential dwelling,school,hospital,office or public recreational area.

Recharge the replenishment of a groundwater body by gravity movement of surplus soil water that percolates through the soil profile.

Reuse the act of spreading or irrigating manure or effluent on land for the purpose of utilising the nutrients and water they contain for crop or pasture growth.

Reuse area an area where effluent or manure are spread for the purpose of utilising the nutrients and water they contain for crop or pasture growth.

Riparian vegetation on any land that adjoins,or directly influences, a body of water. It includes the vegetation on land immediately beside creeks and rivers (including the bank), gullies that sometimes run with water, areas surrounding lakes and wetlands, and river floodplains that interact with the river during flood.

Rotational outdoor piggery an outdoor piggery where the pigs are kept in paddocks that are used in rotation with a crop, forage or pasture phase. During the stocked phase, the pigs are supplied with prepared feed, but can also forage.

Run-down screen a screen comprising of finely spaced stainless steel bars held on an incline by a steel frame. When effluent is poured onto the screen, the liquid and fine solids pass through, while the larger solids are retained on the screen.

Runoff all surface water flow, both over the ground surface as overland flow and in streams as channel flow. It may originate from excess precipitation that can't infiltrate the soil, or as the outflow of groundwater along lines where the water table intersects the earth's surface.

Salinity electrical conductivity (EC) is the generally accepted measure of salinity (i.e. of the concentration of salts in solution). The salts that occur in significant amounts are the chlorides, sulphates and bicarbonates of sodium, potassium, calcium and magnesium. In water these salts dissociate into charged ions, and the electrical conductivity of the solution is proportional to the concentration of these ions, providing a convenient means of measuring salinity. Salinity is usually expressed as decisiemens per metre (dS/m) or its equivalent, milisiemens per centimetre (mS/cm).

Screw press a cylindrical screen with a screw-conveyor in the center. The conveyor presses the solids against a screen to remove moisture. The conveyor also moves solids from one end of the press to the other, to a collection area.

Sedimentation the process of settling entrained solids from an effluent stream through the influence of gravity. A sedimentation system may be a pond, basin or terrace that discharges to a holding pond or evaporation system.

Separation distances the distances provided between the piggery complex and sensitive receptors (e.g. residences, recreational areas, towns etc.) as an important secondary measure for reducing the risk of amenity impacts.

SEPS Sedimentation and Evaporation Pond System. This is an effluent treatment system consisting of two or three long, narrow, shallow, trafficable earthen channels, designed to settle out solids and store effluent. Each channel is designed to receive effluent for a six to twelve-month period. At the end of this time, another channel is activated and the liquid is drained or siphoned from the first channel, allowing the settled solids to dry and be removed.

Shandying diluting effluent with clean water, usually for irrigation.

Sludge the accumulated solids separated from effluent during treatment and storage.

Sodium absorption ratio (SAR) a measure of the sodicity of water. It is the relative proportion of sodium ions to calcium plus magnesium ions. It is important because excess sodium in irrigation waters may adversely affect soil structure and permeability. A higher SAR value equates to a higher sodium content and higher potential for soil problems.

Sodicity an excess of exchangeable sodium causing dispersion to occur.

Solids separation systems for separating larger solids from liquid effluent before the effluent is treated, recycled and used.

Sow an adult female pig, which has had one or more litters.

Spent bedding a mixture of bedding and manure that is removed from deep litter shelters at clean-out.

Stall an enclosure, closely related to the pig's body size, in which sows are kept individually. The Australian pork industry is committed to gestation stall free (GSF) housing. Sows are kept in loose housing from five days after mating until one week before they are ready to give birth. This can be in individual pens or group housing providing each sow has freedom of movement, meaning she can turn around and extend her limbs. In some cases, bedding may be provided. Generally, boars are housed individually.

Standard pig unit (SPU) pig equivalent to a grower pig (average weight 40 kg) based on volatile solids production in manure.

Static pits underfloor pits in conventional sheds that store effluent for up to several weeks before it is released via a sluice gate at the end of the shed.

Surface waters dams, impoundments, rivers, creeks and all waterways.

Sucker or suckling piglet a piglet between birth and weaning (i.e. and unweaned pig).

Topography the shape of the ground surface as depicted by the presence of hills, mountains or plains; that is, a detailed description or representation of the features, both natural and artificial, of an area, such as are required for a topographic map.

Total dissolved solids (TDS) the inorganic salts (major ions) and organic matter/ nutrients that are dissolved in water, used as a measure of salinity.

Total solids (TS) dry matter content of a compound.

Volatile solids (VS) the quantity of total solids burnt or driven off when a material is heated to 600^{0}c for 1 hour. Volatile solids is a measure of the biodegradable organic solids content of a material. One standard pig unit (SPU) is equivalent to a grower pig based on volatile solids production in manure.

Waterbal is a water balance model used to size the wet weather storage capacity of effluent treatment systems.

Watercourse a naturally occurring drainage channel that includes rivers, streams and creeks. It has a clearly defined bed and bank, with intermittent (ephemeral) or continuous (perennial) water flows. Legal definitions can be found in relevant state or territory acts.

Weaner a pig after it has been weaned from the sow until it is approximately 30 kg in live-weight. Weaners are typically aged from 2-4 weeks to 8-12 weeks.

Weaning the act of permanently separating piglets from the sow.

Weaner unit a production system including only weaner pigs. Pigs are transferred to the unit after weaning (usually 2-4 weeks) and are transferred from the unit when they reach the grower stage (usually about 8-12 weeks, typically up to 30 kg).

Wet basis the amount of a component in a material expressed as a concentration or percentage of the total weight (dry matter plus water)

Z-filter a continuous filtering and dewatering system that can be used to separate solids from effluent.

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