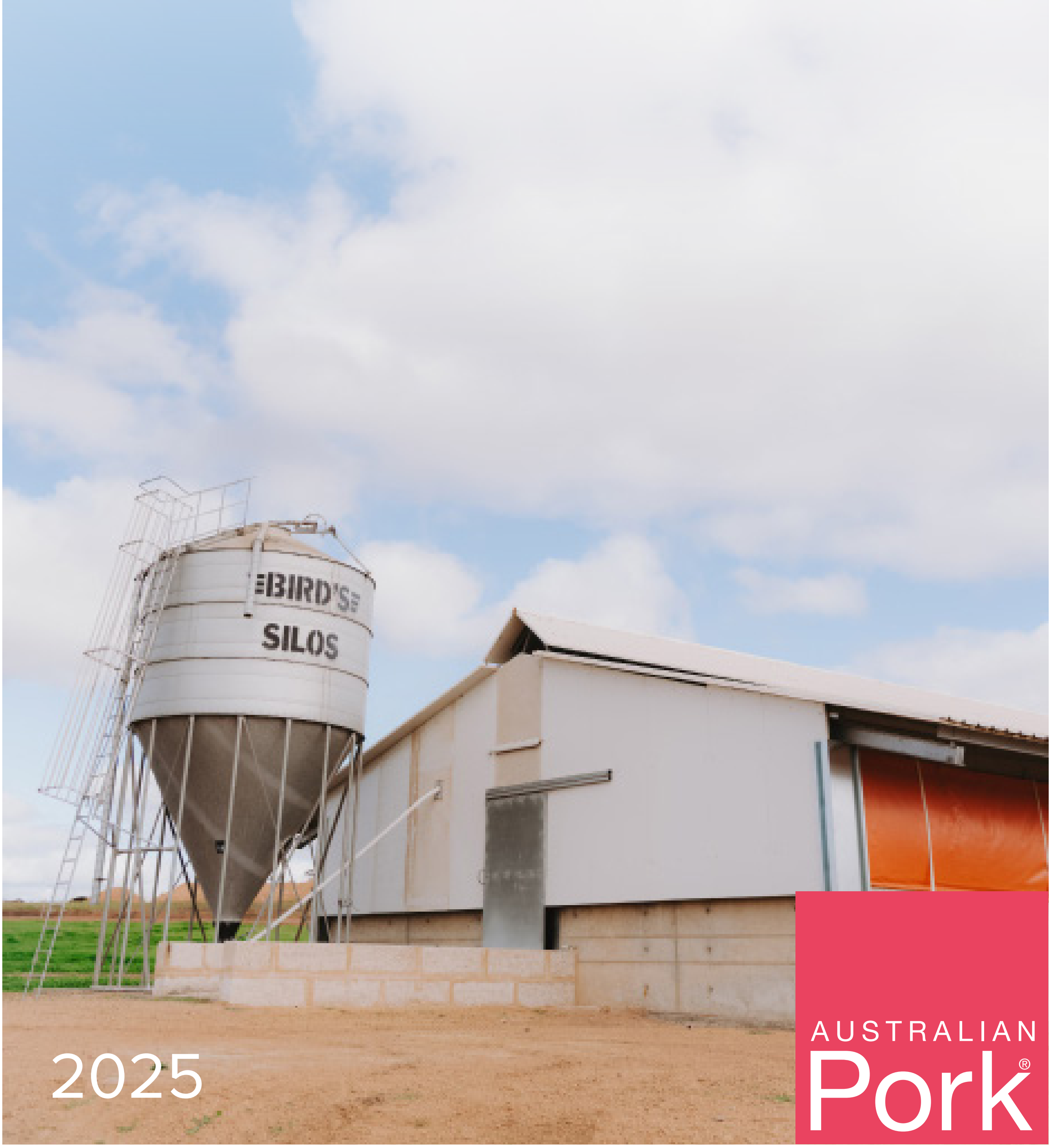
National Environmental Guidelines for Indoor Piggeries (NEGIP)

Siting and Design

Australian Pork Limited



2025

AUSTRALIAN Pork®

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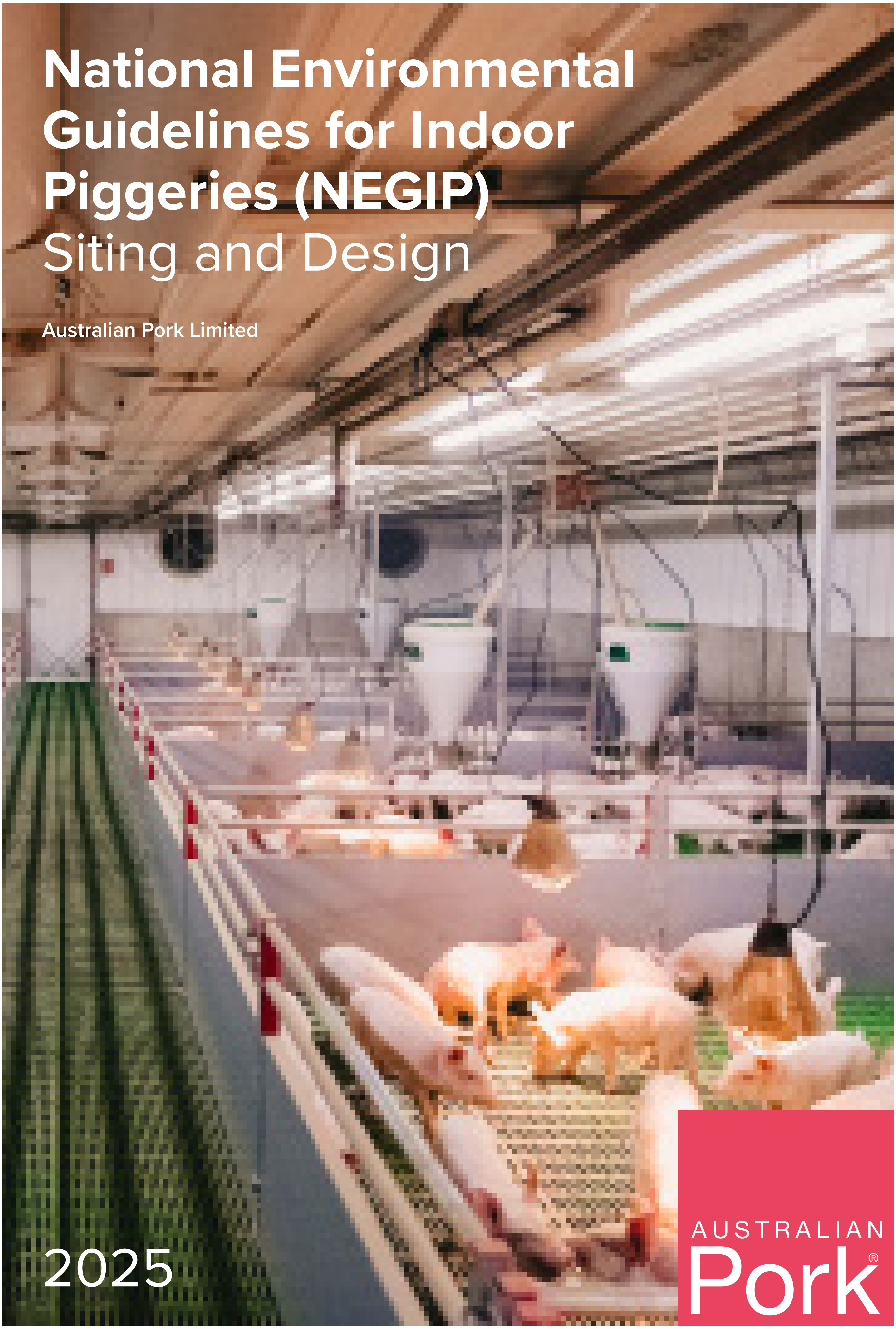

2025

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Foreword

The Australian pork industry utilises many different production systems. Pigs are housed in conventional sheds, deep litter systems or outdoors. These different production systems all operate under site-specific conditions and each site and production system has different potential environmental risks, which must be assessed and managed by producers. Regardless of the type or size of a system, the Australian pork industry supports and encourages all piggeries to operate in an environmentally sustainable manner.

This fourth edition of the *National Environmental Guidelines for Indoor Piggeries* (NEGIP) provides a national approach to the environmental management of indoor piggeries. The NEGIP are science-based guidelines that have been updated to incorporate the latest research outcomes and regulatory changes. They include best-practice environmental management for indoor piggeries and complement the industry's quality assurance program, APIQ, which provides certification of indoor pig production systems.

Pig producers in Australia need to demonstrate due diligence by taking every practical step to minimise environmental risk. There are complexities with this, as environmental regulations vary between jurisdictions, from Commonwealth to state, territory and local government. The NEGIP seek to provide an industry-specific approach to managing environmental risk. We encourage planners, state and territory government departments and producers to utilise them to address individual site requirements.

It is important that stakeholders are kept up to date with the latest industry research and development. This resource is supported by a range of documents on best-practice management on-farm, including the forthcoming update in the form of a consolidated NEGIP management document. Together, these documents provide guidance for environmental assessments of indoor piggery developments and outline 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 and territory government departments, researchers and producers from all major pig-producing states.

The NEGIP highlight the commitment of the pig industry to ensure all pig production - regardless of type and size - operates in an environmentally sustainable manner. The fourth edition of the NEGIP provides a clear framework for all stakeholders to help the pork industry comply with their general environmental duties and to manage and mitigate environmental risks.

Margo Andrae
CEO
Australian Pork Limited

Acknowledgements

Australian Pork Limited (APL) thanks the authors of the fourth edition of the *National Environmental Guidelines for Indoor Piggeries* (NEGIP), Robyn Tucker of Livestock Environmental and Planning, and Janine Price and Stephan Tait of Scolexia Animal and Avian Health Consultancy.

The significant contribution of the authors of former editions, Robyn Tucker, Eugene McGahan, Justin Galloway, Mick O'Keefe, Peter Watts, Peter Nicholas and Megan Howard is also recognised. We also acknowledge the contributions made by current and former APL staff including Tanya Pittard, Gemma Wyburn, Janine Price, Denise Woods, Bruce Edgerton and Jeya Jeyasingham.

The review of the NEGIP commenced with consultation with industry representatives, regulators and consultants. The broad support for the guidelines from all three groups across the country was very pleasing and is reflected in the high standard of the guidelines.

Abbreviations

ACCU	Australian carbon credit unit
APL	Australian Pork Limited
APIQ✓®	Australian pig industry quality assurance program
B0	biochemical methane potential
BMP	best management practices
BOD	biochemical oxygen demand
CAP	covered anaerobic pond
CEC	cation exchange capacity
CER	Clean Energy Regulator
CHMP	cultural heritage management plan
CHP	combined heat and power
C:N	carbon to nitrogen ratio
DB	dry basis
DM	dry matter
dS/m	deciSiemens per metre
EC	electrical conductivity
ECse	electrical conductivity of a saturated soil extract
EMP	environmental management plan
ERF	emissions reduction fund
ESP	exchangeable sodium percentage
FS	fixed solids, also called ash
GHG	greenhouse gases
GSF	gestation stall free
HDPE	high density polyethylene
HLA pond	heavily loaded anaerobic pond
HRT	hydraulic retention time
K	potassium
LDPE	low density polyethylene
m/s	metre(s) per second
m3	cubic metre
ML	megalitre
MSDS	material safety data sheet
NATA	National Association of Testing Authorities
N	nitrogen
N2O	nitrous oxide
NEGIP	*National Environmental Guidelines for Indoor Piggeries* (this document)
NEGROP	*National Environmental Guidelines for Rotational Outdoor Piggeries*

NH3	ammonia
NH_4 or NH_4^+	ammonium (an ionic chemical variant of NH3)
NO_3 or NO_3^-	nitrate
NPI	National Pollutant Inventory
OU	odour unit
P	phosphorus
PBI	phosphorus buffering index
PIRMP	pollution incident response management plan
PO_4 or PO_4^{-3}	phosphate
PP	polypropylene
RAM	restricted animal material
RDS	rational design standard
SAR	sodium adsorption ratio
SEPS	sedimentation and evaporation pond system
SPU	standard pig unit
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TKP	total Kjeldahl phosphorus
TP	total phosphorus
TS	total solids
TWL	top water level
UPSS	underground petroleum storage system
UPVC	unplasticised polyvinyl chloride
VFS	vegetated filter strip
VS	volatile solids
yr	year

Scope

The *National Environmental Guidelines for Indoor Piggeries* (NEGIP) provide prospective and existing operators of indoor piggeries with information to size, site and design their farms in a way that protects community amenity, public health and natural resources.

It is important to note that legislative and planning requirements override industry guidelines including both these guidelines and the latest edition of the *National Environmental Guidelines for Rotational Outdoor Piggeries* (NEGROP). In 2025 APL will release an updated and consolidated version of the NEGIP which will include guidance for ongoing management of indoor piggeries. This will build on the current *Piggery Manure and Effluent Management and Reuse Guidelines* (PMEMRG) (APL 2015c) which provide management information, and other technical resources located on APL's website. Each state and territory may have legislation relating to water use, native vegetation, composting, waste management, Aboriginal cultural heritage and other issues. Council planners, environmental regulators and industry consultants can assist in identifying application requirements for piggeries.

The updated and consolidated version of the NEGIP will include guidance for ongoing management of indoor piggeries. This will build on the current *Piggery Manure and Effluent Management and Reuse Guidelines* (PMEMRG) (APL 2015c) which provide management information, and other technical resources located on APL's website.

Specific requirements pertaining to workplace health and safety, biosecurity and animal welfare are outside the scope of these guidelines. However, producers need to understand and observe their obligations in relation to these matters.

Overview

Australian Pork Limited (APL) worked with industry, the community and government to develop the first edition of the *National Environmental Guidelines for Piggeries* released in 2004. These guidelines provided a general framework for managing environmental aspects associated with piggeries and were tailored to the circumstances and conditions most commonly encountered. The second edition was released in 2010. The third edition was released in 2018 and differed from previous editions in that it provided guidance only for indoor piggeries and was thus termed the *National Environmental Guidelines for Indoor Piggeries* (NEGIP). Its counterpart, the *National Environmental Guidelines for Rotational Outdoor Piggeries* (NEGROP) (APL 2013), provided similar guidance for the outdoor sector.

This fourth edition of the NEGIP, released in 2025, includes updates based on the latest research findings and changes in acceptable design, and incorporates recent regulatory developments and changes in approvals processes. Recently there has been a progressive regulatory shift towards the elimination, or at least minimisation of risks to the environment and public health. For this reason, this fourth edition provides practical options for mitigating risks so far as reasonably practicable. This does not necessarily mean that the most stringent risk mitigation options will be needed in all situations. Rather, the most appropriate siting, design and management options will depend on the site-specific characteristics.

The NEGIP are supported by the *Piggery Manure and Effluent Management and Reuse Guidelines* (PMEMRG) (Australian Pork Limited 2015c) which provide management information, and other technical resources located on APL's website.

The NEGIP are made up of 7 parts:

SECTIONS 1-24

National guidelines – advice on planning, siting and design of piggeries to minimise the risk of harm to the environment and human health.

APPENDIX A

National odour guidelines for piggeries – methods for assessing odour impact.

APPENDIX B

Environmental risk assessment – 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 – example of a complaints egister that can be used to record and manage complaints.

APPENDIX D

Sample collection – methods for collecting samples (e.g. water, soil, manure, compost, effluent and biogas) for analysis.

APPENDIX E

Useful conversions – conversions that may be used in implementing the NEGIP.

GLOSSARY

Definitions used in the NEGIP.

Sections 1-24

National guidelines – advice on planning, siting and design of piggeries to minimise the risk of harm to the environment and human health

1 Introduction

The APL is an important contributor to Australia's economy, adding some $5.5 billion to Australia's GDP in 2023 (Australian Pork Limited 2023). This included production of some 424,000 t/yr of pig meat worth $1.7-1.8 billion (Litchfield et al. 2023). The industry includes about 2,700 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**.

Over the last 4 decades, the Australian pig industry has achieved significant improvements in both environmental efficiency and productivity. These have been driven by improvements in feed efficiency and herd productivity, changes in housing and **manure** management practices, and improved water and energy efficiency. They have brought about a 69% reduction in GHG emissions, a 58% reduction in fossil fuel use and an 80% reduction in water consumption by the industry. The industry continues to work towards ongoing improvements in environmental performance.

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 Piggeries* (the Guidelines), which was first 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 Guidelines to ensure their technical content remains up to date to reflect changes in science, community expectations, the regulatory context, and **piggery** management. The *National Environmental Guidelines for Indoor Piggeries* (NEGIP) are supported by the *Piggery Manure and Effluent Management and Reuse Guidelines* (PMEMRG) (APL 2015c) which provide management guidance. APL has also developed the *Pork Industry Sustainability Framework 2021-2030*. The framework provides direction for the Australian pork industry's activities and reflects the collective position the industry is striving to attain (APL n.d.).
The NEGIP are designed to support this framework.

It is intended that the NEGIP will be used by local governments 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. Many of the environmental issues discussed in the NEGIP are interlinked, and siting and design must consider all aspects, not just single issues in isolation, so that overall environmental outcomes can be optimised and the risk of adverse impacts can be minimised. While the NEGIP provide specific siting and design recommendations, alternative approaches may also assist producers to minimise their environmental risk and comply with the **general environmental duty**. The general environmental duty is a responsibility shared by all individuals and businesses for the actions taken that affect the environment whereby any activity that causes or is likely to cause environmental harm cannot be carried out unless all reasonable and practicable measures are taken to prevent or minimise the harm.

The NEGIP may be used to complement, develop or update existing state-based 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 indoor 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 and environmental approvals

In all Australian states and territories, anyone keeping pigs will generally need local council approval if they have more than pet pigs. The thresholds triggering the need for a planning permit vary between states /territories and shires. Larger developments may also need an environmental registration, approval, permit or licence. Table 2.1 summarises the planning permit and environmental permission triggers for each state. These triggers were correct at the time of publication, however, proponents should consult their responsible authority (council) and the environmental regulator to confirm the requirements.

Table 2.1 State planning permit and environmental permission triggers at publication date

State	Class	Requirement
Queensland	Intensive animal industry	Need for development approval depends on planning scheme. However, anyone keeping more than pet pigs will usually require a development approval. Any piggery proposal for > 400 standard pig units (SPU) needs development approval and either an EPA development licence and an operating permit, or an exemption and an operating permit. (Department of Agriculture and Fisheries: www.daf.qld.gov.au)
New South Wales	Intensive livestock agriculture	Development approval is required unless piggery is under a size threshold specified in the local environmental plan (usually 20 pigs) and meets other requirements. A council may also limit the number of pigs kept by a smaller operator and prescribe how they are kept. Environment protection licence needed if: • >200 pigs or 20 breeding **sows** in a sensitive area • >2,000 pigs or 200 breeding sows. (Environment Protection Authority: www.epa.nsw.gov.au)
Victoria	Pig farm	A planning permit is needed to operate a piggery. Any piggery with >5,000 pigs needs an EPA development licence (or exemption) and an operating permit. (Environment Protection Authority: www.epa.vic.gov.au)
South Australia	Intensive animal husbandry	Council development approval is required. EPA licence needed if ≥6,500 SPU, or ≥650 SPU in a water protection area (Environment Protection Authority: www.epa.sa.gov.au).

State	Class	Requirement
Western Australia	Animal husbandry - intensive	Planning approval is required. An offensive trade registration may also be required. Works approval and registration needed for >500 but <1,000 animals. Works approval and licence needed for ≥1,000 animals. (Department of Water and Environmental Regulation: www.wa.gov.au)
Tasmania	Intensive animal husbandry	Planning approval is required in some land use zones. EPA approval is unlikely to be needed for a piggery. (Environment Protection Authority: www.epa.tas.gov.au)
Northern Territory	Intensive animal husbandry	Development approval needed.

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

Ancillary activities such as co-composting or co-digestion using organic wastes brought onto the site or off-site transport and **reuse** of **spent bedding** or **compost** may require separate environmental permissions under some circumstances. Advice should be sought from the applicable environmental regulators.

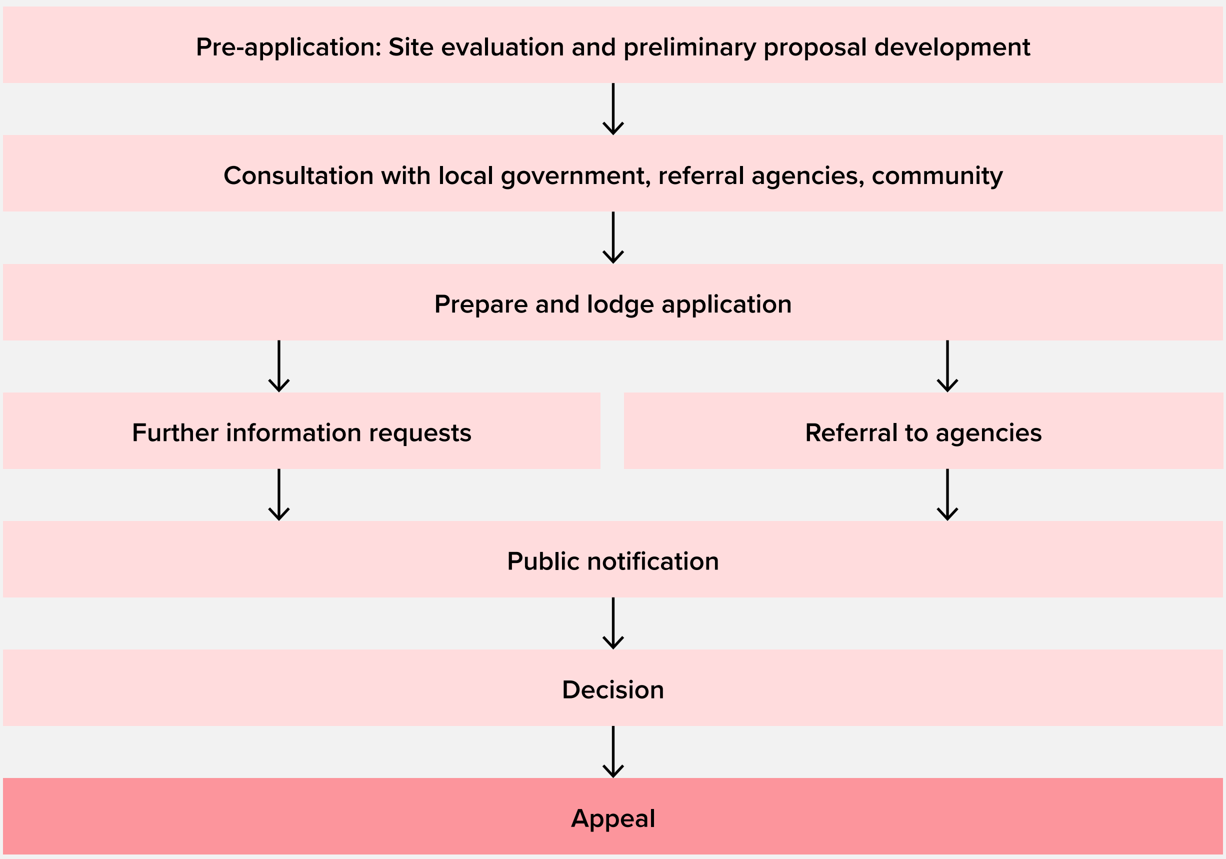


Figure 2.1 Generalised planning process

The same general process applies to a new piggery development, expansion, or material change in use (e.g. the construction of new housing and construction or significant modification of the effluent management 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 the 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 concepts (size of the facility, type of housing and proposed manure and or effluent management facilities).

The recommended 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. Where a facility meets a lower level (e.g. Level 1), there is no need to demonstrate that other levels are met. Consult with the state environmental regulator about the methodology to use for assessing odour before proceeding beyond Level 1.

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, subdivisions, or houses, to protect approved piggeries and avoid future nuisance complaints caused by sensitive land uses located within the recommended separation distance in the future.

Communication and engagement with council, referral agencies, the community and neighbours is important for a positive outcome. A pre-lodgement 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.

Referral to environmental agencies, water boards, state or main roads departments and other agencies may also be required, depending on the site. Councils will be able to advise on likely referral bodies.

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.

Applicants should consult with the local community, particularly immediate neighbours, following the pre-lodgement meeting. This consultation is mandatory in some states and territories where permission from an environmental regulator is required.

The next step is to gather and compile the information that will support the application. A detailed description of the proposal and measures proposed to mitigate risk are needed. The NEGIP provide recommended siting and design information, while the PMEMRG, the APL Nutrient Balance Calculator and other resources on the APL website (www.australianpork.com.au) can be used to support management decisions. For many 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, considering submissions from referral agencies and submitters, a decision will be made. The applicant and any submitters then have the opportunity to appeal the decision. Table 2.2 provides details of what should accompany a planning application.

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.
- Zoning and planning overlays for subject property and for the surrounding land.
- Climatic data:
  - Mean/median monthly rainfall
  - Monthly decile 9 (90th percentile) rainfall
  - Rainfall intensity data (one-in-20-year 24-hour storm)
  - Mean monthly evaporation
  - 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
  - Details of any bores on the subject property
  - Depth and type of soil or rocks overlying groundwater
  - Details of any licences or allocations held
  - Assessment of the suitability of **surface waters** for use in piggery.
- Property (show designated **watercourses** and other waterbodies on a map):
  - Description of surface water resources on the property or in the vicinity of the
  - Assessment of the suitability of groundwater 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**.
- Effluent for irrigation.
- Bedding requirements and bedding sources.
- Feed requirements, sources and storage areas.
- Description of shed cleaning (e.g. pressure washing, flushing systems or pit releases, bedding top-up and replacement).
- Estimation of manure production including quantity and nutrients.
- Design and management of effluent systems.
- Sizing and management of reuse areas including reuse method, **nutrient** balance and odour management.
- Description of mortalities management (routine numbers and mass mortalities event).
- Staff numbers.
- Traffic – heavy vehicle numbers, routes, access and parking.

Risk 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 proactive complaints management.
- Public health – evaluate the risk of public health impacts from the operation of the piggery. Consider how to change the size, siting, design or the management of the piggery to minimise any significant risks.
- Surface waters – quality and quantity needed, potential risks to water quality and any likely effects on other potential users.
- Groundwater – quality and quantity needed, potential risks 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 plantings or offsets.
- Protection of items, sites or places of cultural heritage significance.
- Evaluation of proposed effects on soils of reuse areas.
- Mitigation of greenhouse gas (GHG) emissions.
- Summary of design and management features to minimise adverse environmental risks.
- Proposed environmental monitoring and reporting.
- Environmental management plan (emp) – an emp focuses on the design and 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 includes **nutrient accounting**/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 risk are minimised
- detail processes for ensuring continual review and improvement.

Maps and plans

- Topographic details showing relief, watercourses and drainage lines and flood levels.
- Recent aerial photograph/s showing subject property and location of nearby residences including separation distances.
- Farm plans showing current land uses; proposed sites for piggery complex, mortalities management area, reuse areas, property entry point and on-farm roads, bores, buffers, dams, watercourses, any soil conservation or drainage works and any proposed landscaping.
- Piggery complex layout plan including the location of manure management areas and effluent and mortalities management areas.
- **Pollution** incident response management plan (PIRMP) for New South Wales producers.
- 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 may also be a need to negotiate with applicable state and local governments regarding road upgrading and maintenance responsibilities.

The success of a piggery development proposal relies on community acceptance. Community consultation during the planning process will often provide enough information to allay 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. Including a complaints register (Appendix C) in an application is recommended as this can assist in managing issues if these arise and demonstrate a commitment to working with neighbours.

3 Environmental risk

In all Australian states and territories, all individuals and businesses are subject to a general statutory duty to prevent environmental harm, or general environmental duty (GED). Good site selection and design reduces the inherent risk. However, all piggery operators must also operate their farms in a manner that reduces the risk of harm to the environment and human health as far as reasonably practicable. Farms that are already managing their environmental risk may not need to make any changes to how they operate. However, piggery operators should endeavour to continuously improve, adopting relevant new techniques and technologies that reduce environmental risk and improve profitability.

These guidelines represent the current state of knowledge for the siting and design of piggeries in Australia to minimise environmental risk. All producers should meet the environmental objectives and outcomes they contain. The guidelines provide flexible design and operating guidance, allowing producers to select options that will address the environmental risks at their site. Appendix B assists producers to identify, document and reduce their site-specific risks.

4 Environmental objectives

Environmental integrity is becoming increasingly important in today's society. Demonstrating that individual farms and the industry are environmentally sustainable is vital to ensuring long-term consumer confidence in pork products. This includes protection of community amenity, soils, surface waters, groundwater, biodiversity, human health and cultural heritage. Efficiently using inputs and minimising waste and emissions are also important sustainability considerations. As opportunities to adopt new technologies and management practices arise, piggery operators should embrace these to continuously improve the environmental performance of their business and enhance the reputation of the Australian pork industry.

Piggeries should be sited, designed, constructed, and managed to:

- minimise the risk of amenity impacts
- maintain or improve the quality of soils in reuse areas with beneficial reuse of effluent and manure
- use water resources efficiently
- protect groundwater and surface waters from nutrient, biological or salt **contamination**
- protect and enhance native vegetation and habitats
- utilise inputs and resources efficiently and minimise wastes
- limit GHG emissions
- protect public health
- protect items, sites or places of heritage significance.

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

5 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).

5.1 Pig production

Pig production can be divided into 3 main production stages:

- breeding
- **weaning**
- growing/finishing.

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

Dry sows are between litters and await 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 5 days after mating until one week before they are ready to give birth. This can be in individual **farrowing 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. Generally, each sow and litter are 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 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 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 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. This assists with herd health management.

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.

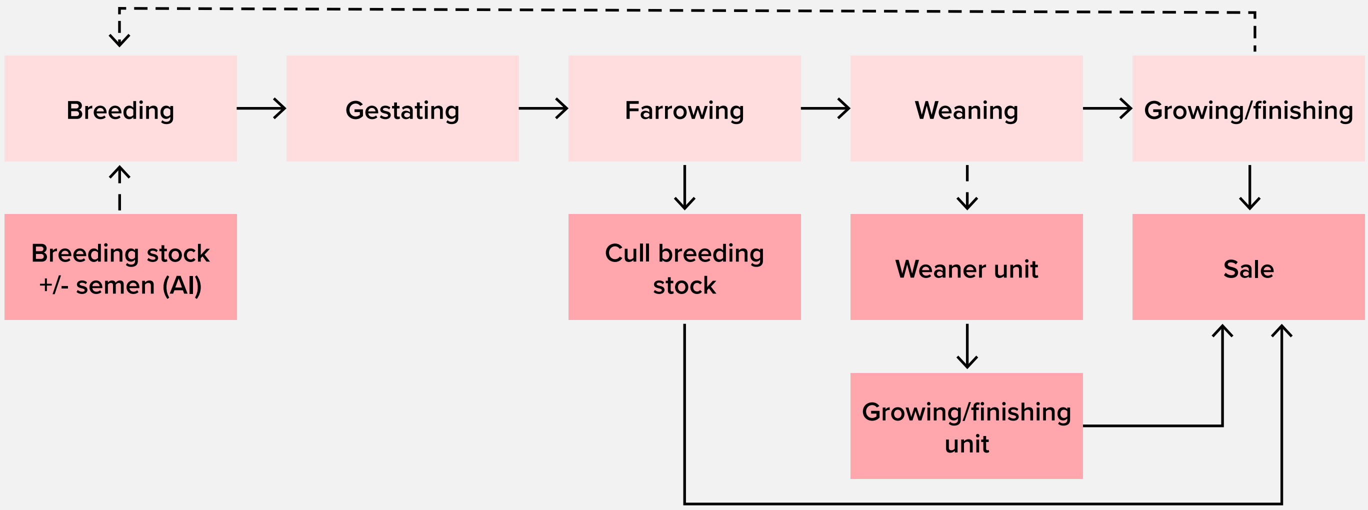


Figure 5.1 summarises the most common pig production systems. The top row constitutes the elements of a farrow-to-finish unit.

5.2 Piggery definitions

A **piggery** or **pig farm** is 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. Planning schemes and environmental regulations/Acts will have their own definitions.

Conventional piggeries typically house pigs within steel or timber framed sheds. The sheds usually have concreted under-floor effluent 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 have pigs living outdoors with access to shelter. While they can forage, they mainly rely on prepared feedstuffs to meet their nutritional requirements. The 2 types of outdoor piggeries recognised by APL are: rotational outdoor piggeries and feedlot outdoor piggeries.

In **rotational outdoor piggeries**, pigs live outdoors in paddocks, with basic huts for shelter. Paddocks are rotated between a pig phase and a crop-forage-pasture phase. During the pig phase, the pigs are supplied with prepared feed, but can also forage. During the pasture or cropping phase, the area grows plants 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, with partial roofing or basic huts for shelter. The pens must be located within a **controlled drainage area**. This is so that 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. Information on rotational outdoor piggeries only is provided in the NEGROP. The APL booklet, *Rotational Outdoor Piggeries and the Environment* (APL 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 offsite
- 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, manure or compost 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.

5.3 Defining piggery capacity in standard pig units

Standard pig unit (SPU) is a way of standardising pig numbers by equivalent manure output which influences the potential for environmental risk.

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 5.2). VS is the **organic matter** 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.

Grower pig manure ~64kg VS/SPU/yr*

+

Waste feed = ~26kg VS/SPU/yr#

* based on feed consumption of 1.6kg/hd/d and a wheat-based diet.

Figure 5.2 Piggery manure and waste feed for one SPU

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

There are 2 methods for specifying the total number of SPUs in a piggery. The first is to use the standard multipliers provided in Table 5.1 with the herd composition based on pig class and weights. Table 5.1 also provides example pig and SPU numbers for a typical 100 sow farrow-to-finish piggery.

Table 5.1 SPU conversion factors

Pig class	Mass range (kg)	SPU factor	Pig numbers (and SPU) for typical 100 sow farrow-to-finish (26 weeks) piggery
Gilt	100–160	1.8	12 (21.6)
Boar	100–300	1.6	5 (8)
Gestating sow	160–230	1.6	87 (139.2)
Lactating sow	160–230	2.5	13 (32.5)
Sucker	1.4–8	0.1	142 (14.2)
Weaner	8–25	0.5	248 (124)
Grower	24–55	1.0	236 (236)
Finisher	55–100	1.6	311 (497.6)
Heavy finisher	100–130	1.8	-
		Total	**1,054 (1,073.1)**

The second method is to use the **PigBal 4** model. 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 11.1). 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. Standard diets within PigBal 4 are representative of industry diets. However, feed usage and wastage should be adjusted where site-specific data are available. The SPU regression equation in PigBal 4 then assigns multipliers accordingly. PigBal 4 displays the results on its Herd Details page.

5.4 Piggery manure and effluent amounts

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. Not all piggeries will use all elements. For example, some piggeries have a solids separation step and some do not. Some producers wash out deep litter housing, others do not. These guidelines are intended to provide flexibility in design with scope for new or different technologies.

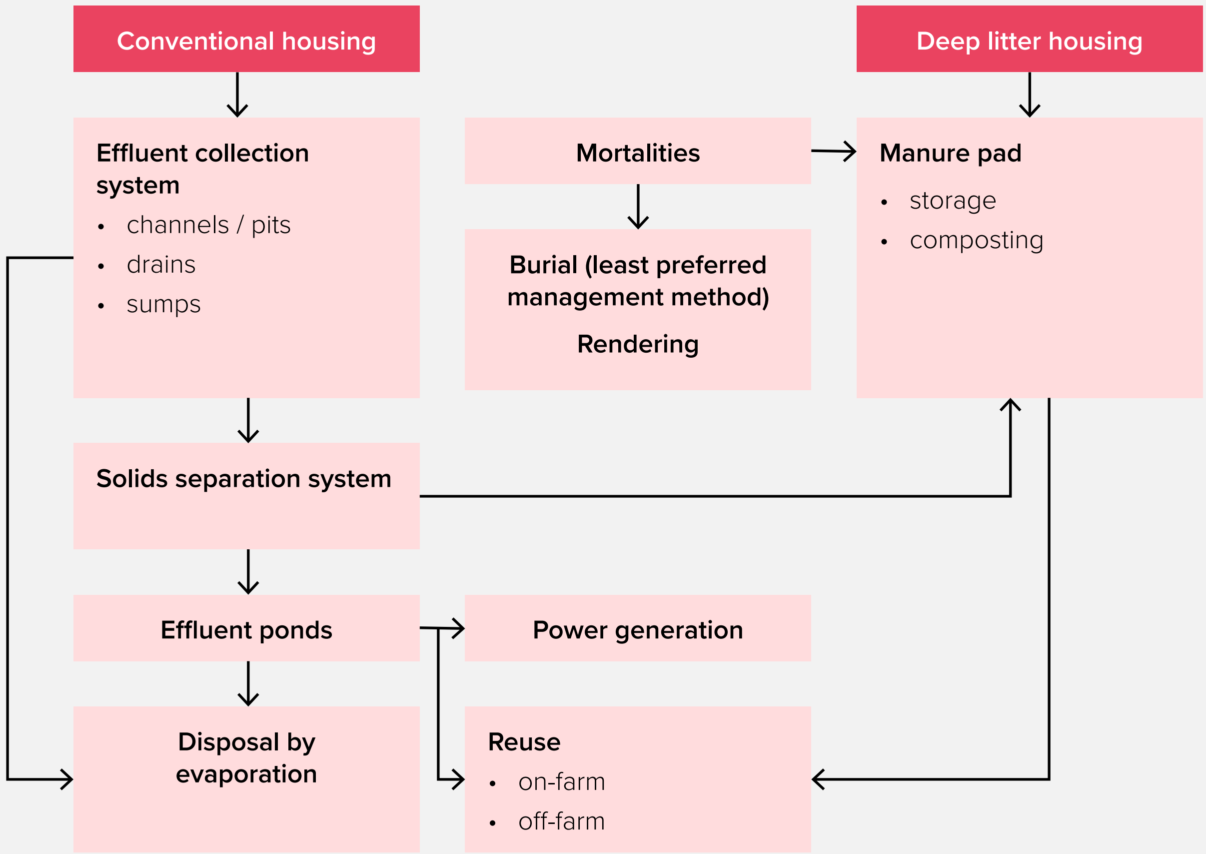


Figure 5.3 Piggery manure and effluent flow diagram

6 Site selection

A good site will be easier to manage, as the risk of amenity or environmental impacts will be lower. Environmental advisers can provide guidance on the suitability of a proposed site for a piggery. The main factors to consider include:

- land use zoning and planning requirements
- possible effects on community amenity
- buffer distances to sensitive natural resources (e.g. watercourses and native vegetation)
- availability of suitable land area for both the piggery complex and reuse areas
- availability of essential services, infrastructure and inputs
- climate
- the site's natural resources
- any cultural heritage sensitivities
- proximity to other intensive livestock operations or other similar industries
- any possible future expansion plans.

Each of these factors is discussed below, however 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.

6.1 Land use zoning and planning requirements

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. 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 site suitability. Specialist advisers can provide professional assistance and collate information, particularly with regards to planning legislation, water supply, soil assessments, separation distances to sensitive land uses and transport routes.

6.2 Community amenity

Most conflicts between piggery operators and nearby sensitive land uses relate to odour, but they are sometimes about noise, dust, flies, vermin, **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. Providing separation distances between the piggery complex and reuse areas and nearby sensitive land uses is a fundamental site selection consideration.

6.2.1 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 that considers the scale and design of the piggery, the distance to sensitive land uses, the **topography** and the vegetation will determine whether nearby sensitive land uses are likely to be protected (see Appendix A).

6.2.2 Noise

Noise is generated at the piggery, by equipment used on other parts of the farm (e.g. pumps, tractors) and vehicles. 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 will reduce the risk of nuisance traffic noise.

6.2.3 Dust

Traffic movements along unsealed roads and spreading of dry manure or compost can generate significant dust. Choosing routes with sealed roads and providing good separation distances between reuse areas and houses lowers the risk of dust impacts.

6.2.4 Flies and vermin

Separation distances provided to prevent odour nuisance are usually sufficient to minimise issue from flies and vermin.

6.2.5 Pathogens

Providing appropriate separation distances from the piggery complex and reuse areas to sensitive land uses and adopting good reuse practices will limit the pathogen risk. Appendix A provides a methodology for determining minimum separation distance from the piggery complex. 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 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 irrigation aerosols.

6.2.6 Visual amenity

Topography or tall vegetation can visually conceal the piggery complex and other areas from nearby sensitive land uses and roads. This can also remove the visual reminder of an odour, dust or noise source ("out of sight, out of mind").

6.3 Availability of suitable land area

Property size is an important consideration. Ideally, a property should be large enough to contain the piggery complex and any required reuse areas, although it is possible to transport effluent, manure and compost 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 prerequisite. 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 due to boundary buffer requirements.

The suitability of land for reuse will depend on the land use capability that influences the types and yields of crops that can be grown. Applicants must demonstrate that there is sufficient land area available and the suitability of proposed reuse areas, which could be on- or off-farm.

6.4 Availability of essential services, infrastructure and inputs

6.4.1 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 will be 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. Shed flushing and shed washing requirements vary widely depending on shed type and design, whether pits or flush channels are installed and whether treated effluent is recycled for flushing. On-site storage of at least 2 days' drinking water should be provided, with plans for contingency supply identified.

Water licensing requirements vary between states and territories but usually an industrial or commercial permission, rather than stock and domestic, will be required. 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 surface water supplies are susceptible to blue-green algal blooms. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2018) 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, provide sufficient water to suit an irrigation system and prevent soil **salinity** issues, although over-irrigation may also contribute to soil salinity issues.

6.4.2 Suitable road access

Roads used by piggeries must be of a suitable standard for the types of heavy vehicles that will service the site. 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, consider those avoiding nearby houses and other sensitive locations like schools, school bus pick-up points and community areas. 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 possible upgrade requirements.

6.4.3 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. This should also be a consideration for those contemplating the export of excess electricity generated from renewables.

6.4.4 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.

6.5 Climate

Climate change will present challenges to the operation of piggeries across Australia, with potential impacts that may include:

- increased biosecurity threats
- changes in growing seasons and conditions impacting availability of stock feed, the variety of stock feed available, or cost of feed due to crop damage during extreme weather events (droughts, floods)
- impact of extreme weather events on plant and buildings, including effluent collection and runoff systems
- reduced pig fertility and productivity and increased animal stress due to increased temperatures.

Good design and siting of your piggery can ensure you can build resilience against these impacts. This can be through:

- improving energy efficiency of sheds and equipment, and/or installing energy generation such as solar panels
- improving pig housing to allow better airflow and temperature management
- better management of effluent including methane collection and energy generation
- maximising reuse of effluents, manures and spent beddings for fertilisers to reduce reliance on chemical fertilisers
- recycling water for shed flushing to reduce potable water requirements
- adopting improved technologies such as feeders and drinkers to minimise water spillage and wastage
- maximising recovery and limiting waste to landfill
- collaborating with other agricultural industries such as diary and meat processing to understand opportunities to pool resources and work together on common goals.

Resources to help you build climate resilience in your farm business are available on the APL website.

The MyClimateView (https://myclimateview.com.au) and Bureau of Meteorology websites (www.bom.gov.au) are useful sources of climatic data.

6.6 Natural resources

6.6.1 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 or stormwater ponds, effluent 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. It can also be used to construct banks that form part of a visual barrier.

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.

6.6.2 Soils

A preliminary investigation should identify the range and distribution of soil types on the property. Consider the suitability of soils for various purposes. For example, loam to medium clay loam soils are often preferred for reuse areas, as they usually retain nutrients and water for crop growth while also having reasonable drainage. 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 Appendix 1: Pond and Pad Permeability Specifications of the PMEMRG
- the types of sediment and erosion controls and management that could be needed during construction and operation, particularly if the site or soils are erosion-prone
- the suitability of land for manure and effluent reuse. Table 21.3 provides recommended analysis parameters.

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

6.6.3 Water

6.6.3.1 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 surface water, preventing uncontrolled releases of manure and effluent, and adopting good reuse practices will protect water quality.

6.6.3.2 Flood risk

Piggery complexes should be sited above the one-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. Information on land submerged by a one-in-100-year flood is often available from local government, or state water resources agencies.

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

6.6.3.3 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 higher risk for groundwater contamination. 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, manure and compost reuse 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, 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, manure and compost are reused.

6.6.4 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. Land clearing is assessed under state legislation by the relevant state. Should the proposed land clearing be assessed as triggering a matter of national environmental significance it will also need to be assessed by the Commonwealth Government under the *Environment Protection and Biodiversity Conservation Act 1999*.

Protecting, maintaining and enhancing vegetation can provide multiple benefits. These include augmenting indigenous species and habitats, visual screening and assisting with odour dust and noise dispersion (depending on the location, structure and width of tree belts).

6.6.5 Cultural heritage

The likelihood of items, sites or places of Aboriginal or European cultural significance being present on or near a site must be considered early in the planning process. Councils and state government environment agencies keep records of areas and sites of cultural heritage sensitivity. They may also have tools for assessing the likely risk and whether a cultural heritage management plan (CHMP) is required. This is more likely on areas where significant ground disturbance will occur.

If items, sites or places of cultural heritage significance are likely to be present at a site, further consultation with the appropriate bodies (including the traditional land owners) will determine the most suitable course of action, which may depend on the traditional owner values. 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 location, or permanently fencing off parts of the property to protect these.

6.7 Proximity to similar industries

Consider the proximity of the proposed development to existing similar industries. The potential for cumulative odour impacts may limit size and design. Also consider biosecurity risks. To protect biosecurity, providing a buffer to nearby pig and poultry farms is recommended. Ideally, commercial poultry, cattle, sheep and goat operations should not operate on the same property as a piggery. If they do, they should be functionally separated from the piggery with a suitable biosecurity buffer. A pig veterinarian will be able to provide guidance on adequate buffers (Animal Health Australia 2021).

6.8 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 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.

7 Separation distances and buffers

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

Councils and state government agencies may have planning requirements that include specific separation distance and buffer requirements.

Contact the approval 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 and water bodies are identified and considered.

In the absence of specific advice from the **approved authority**, Sections 7.1 and 7.2 provide guidance on separation distances for community amenity and buffers for surface water, groundwater and native vegetation, 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 risks from odour, dust, noise and public health, and nutrient runoff and leaching.

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

7.1 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 sensitive land uses (legal house, rural residential area and town). Both the variable and fixed separation distance to sensitive land uses must be calculated, and the greater distance of the 2 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 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. Separating reuse areas and sensitive land uses and adopting good reuse practices will limit the pathogen risk during reuse.

7.2 Buffer distances from surface water, groundwater and native vegetation

7.2.1 Minimum recommended buffers

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

A **buffer distance** is the space provided between the piggery complex or reuse areas and sensitive natural resources.

Buffers provide secondary protection against:

- effluent entry to surface waters or sensitive native vegetation through direct runoff from reuse areas and effluent pond spills
- nutrient rich stormwater runoff from reuse areas
- soil erosion from reuse areas
- seepage of excess nutrients into groundwater
- spray drift from irrigation with effluent
- dust from spreading dry manure

A watercourse can be defined as a naturally occurring drainage channel such as a river, stream or creek. It will generally have a clearly defined bed and bank and may have a perennial (permanent), intermittent (semi-permanent) or ephemeral (occasional) flow regime. Refer to relevant state or territory Acts for legal definitions of watercourses. Mapped watercourses can be ephemeral drainage lines on arable land that have no clearly defined channel. Buffers may not be required for these mapped watercourses, however consultation with relevant regulators is recommended to confirm this.

The buffer distance from a watercourse, lake or wetland should be measured from the maximum level the water may reach before overtopping of the bank (bank-full discharge level) occurs. 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. Under some local government and state and territory requirements, different fixed buffer distances may apply.

Major water storages within designated drinking water catchments generally need the greatest protection. Piggeries and reuse areas should therefore be at least 800 m from these. Restrictions may apply in catchment areas for major water storages owned by water boards or local authorities.

A minimum buffer distance of 100 m from the piggery complex to any natural watercourse, wetland or lake and 800 m from a major water supply storage is recommended. Areas where effluent or manure are deposited, contained or reused should provide 2 m clearance from the highest seasonal water table. 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.

In all cases, the relevant authority should be consulted where a piggery is proposed within a government declared catchment area or a government-declared groundwater area.

Table 7.1 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. • 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.	800	100
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. • 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.	800	50
Category 3		
• Discharge by injection directly into the soil (to a depth of no greater than 0.4 m). • 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.	800	25

A reduced buffer distance to watercourses may be allowed if a risk assessment demonstrates that the feature will be otherwise protected. For example, terminal ponds designed to catch the first 12 mm of runoff from reuse areas, a whole farm drainage plan, vegetated filter strips (VFS), banks or **bunding** may allow for a reduction in the required distance to a watercourse. For highly sensitive or vulnerable resources, or under some state and territory requirements, the distance may need to be increased.

Vegetative cover in buffer areas should be maintained wherever possible. Groundcover offers better protection than trees as it 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 VFS is a specific type of vegetative cover (see Section 7.2.2 for design details).

Native trees, shrubs, sedges and grasses can be very sensitive to nutrients, particularly phosphorus. Extra nutrients may 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.

Australia's unique plants, animals, habitats, places, heritage site, marine areas and wetlands are managed under the *Environment Protection and Biodiversity Conservation Act 1999*. The protected matters search tool can be used to identify threatened plant and animal species, habitats, wetlands and heritage places, enabling their protection. The tool is available at: https://pmst.awe.gov.au/.

7.2.2 Vegetated filter strips

A vegetated filter strip (VFS) is a grassed area designed to reduce the nutrient concentration of runoff by trapping soil particles and reducing runoff volumes, which increases infiltration.

Redding and Phillips (2005) 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 VFSs 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 a gentler slope (see Table 7.2). 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 vertisol 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.

Table 7.2 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 and Phillips (2005).

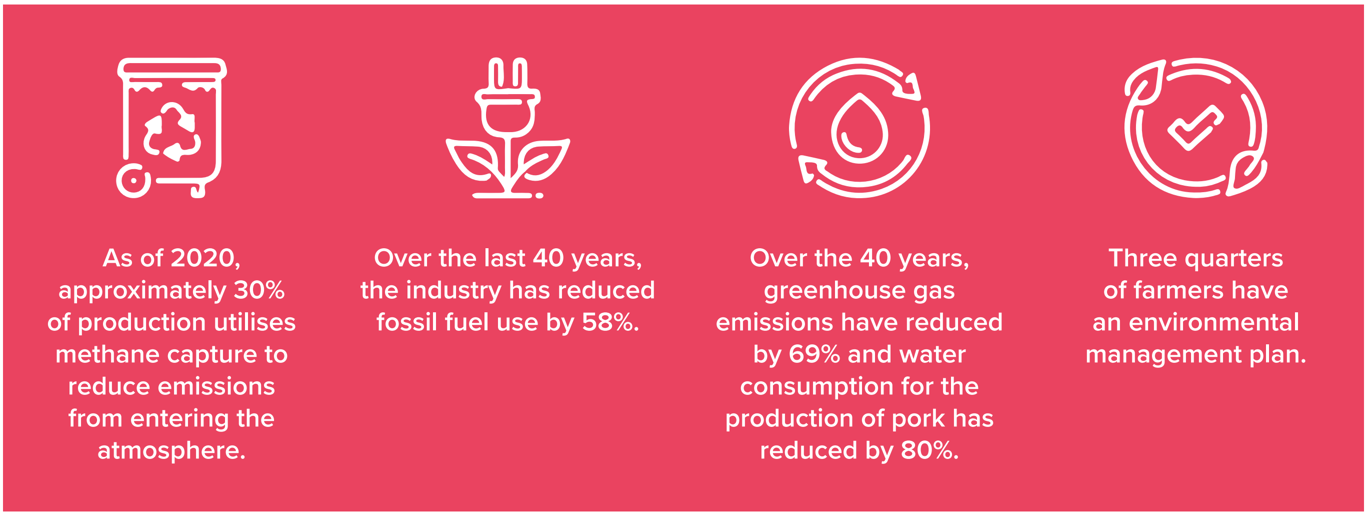
8 Resource efficiency

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

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

The industry has made significant gains in this area and some of the achievements are summarised in Figure 8.1.

Figure 8.1 Summary of trends in emissions and resource reduction



To drive ongoing improvement, APL has developed the Australian Pork Sustainability Framework that is centred around the 4 key pillars of industry:

- people
- pigs
- planet
- prosperity.

The planet pillar has 3 focus areas:

1. **Carbon cycling** and nutrient accounting
2. Farm biodiversity and natural resource stewardship
3. Closing the loop to reduce waste.

The following sections provide various strategies pertaining to these focus areas. These are based on APL research including: *Low Carbon Emission Roadmap for the Australian Pork Industry Manual* (Wiedemann et al. 2021), *Closing the Loop to Reduce Waste Roadmap for the Australian Pork Industry 2025 Manual* (McCormack et al. 2022) and *Solar Tools and Self Auditing Checklists* (Barnes 2021). The economic viability of these strategies is very dependent on site-specific factors and costs. In some cases, there are opportunities to benefit from the emissions reduction fund (ERF) or other incentive schemes that affect net cost and project viability. Resource efficiency is rapidly changing with technology constantly evolving. Consequently, the newest technologies may not be included in these guidelines. However, stakeholders should embrace new and effective solutions as they emerge.

8.1 Carbon cycling and nutrient accounting

The pork industry is aiming for pork to be the most emission-friendly animal protein industry. The industry has made significant gains through improvements in feed and water use efficiency, better manure management practices, capture of methane for energy and reductions in energy use. Nutrient accounting assists using inputs more efficiently and better managing the nutrients in manure and effluent as part of a whole farm system. Strategies to improve the carbon footprint and better utilise nutrients can yield significant economic benefits through improved productivity and more efficient resource usage. Strategies that could be adopted are described below.

Improving herd productivity:

- Increase the number of pigs born alive, weaned and slaughtered per sow.
- Increase the average daily gain in **growing pigs**.
- Reduce herd feed conversion rates.
- Make genetic improvements.
- Increase the turnoff weight at slaughter (which can also substantially reduce the environmental footprint).

Feed strategies:

- Improve feed digestibility to reduce total feed consumption and nutrient excretion.
- Reduce feed wastage by selecting low-wastage feeders and using good management practices. Liquid feeding systems have the lowest feed wastage followed by wet/dry feeders. For dry feed, electronic systems that provide for individual feeding have the lowest feed wastage.
- Management practices that can greatly reduce wastage include optimised **feeder** adjustment, maintaining clean conditions, auger monitoring and feeder pan coverage to reduce spills and overfeeding. Reducing feed wastage and promptly cleaning up any spills avoids odour that attracts flies and vermin that may carry disease.
- Reduce dietary crude protein levels in pig diets by increasing the usage of synthetic amino acids.
- Use local ingredients where possible.
- Use by-product feeds and human food waste in diets (**swill** cannot be fed).

Strategies to reduce energy usage include

- Understand site energy consumption and energy bills, to facilitate decision-making.
- improving heating efficiency by:
  - choosing the most efficient heating method and wattage can significantly reduce energy usage while substantially reducing costs
  - using thermostats in sheds to prevent excessive heating or cooling
  - installing creep covers to minimise heat loss
  - insulating sheds and excluding drafts where possible to reduce heat loss.
- Optimise ventilation by using energy efficient fans that are well maintained. Dirty shutters and fan blades can reduce fan efficiency by up to 30% resulting in higher energy usage.
- Use energy efficient lighting where possible.
- Ensure the power supply is suitably sized and set up for the site.
- Implement pumping strategies including:
  - using solar pumping in conjunction with a header tank/reservoir to take advantage of solar pumping
  - pumping during off peak periods into a reservoir
  - matching the pump performance (referring to the pump curve provided by the manufacturer) to site-specific requirements
  - regularly servicing and maintenancing of pumps to ensure optimal efficiency.
- Utilise alternative energy systems including:
  - biogas generation (energy and recovery of hot water for heating). Co-digestion products can increase biogas production
  - wind turbines
  - solar (photo-voltaic [PV] panels)
  - batteries to store energy generated from renewable sources.

- Adopt alternative effluent or manure management practices including:
  - covering ponds and flaring biogas or using biogas to produce power, which can reduce pork supply chain GHG emissions by up to 64% (Wiedemann et al. 2016)
  - separating solids from the effluent stream and managing these aerobically (e.g. composting)
  - converting grower pig housing from conventional sheds to deep litter sheds, which can reduce pork supply chain GHG emissions by up to 38% (Wiedemann et al. 2016)
  - the *Low Carbon Emission Roadmap for the Australian Pork Industry Manual* (Wiedemann et al. 2021) provides information for benchmarking.

8.2 Farm biodiversity and natural resource stewardship

Protecting biodiversity is of increasing interest to the broader community. Protecting and enhancing farm biodiversity offers multiple benefits for pork producers.

Considerations for farm biodiversity include:

- planting indigenous species to protect and enhance habitats
- enhancing planting by extending or connecting the areas to create corridors
- visual screening
- odour dispersion (thick stands of vegetation)
- erosion control through groundcover
- enhancing planting by extending or connecting the areas to create corridors
- controlling feral animals, particularly feral pigs, to improve biosecurity, protect native flora and fauna and minimise land degradation and habitat destruction
- controlling noxious or pest plant species
- maintaining or improving soil health by utilising manure, effluent and compost.

8.3 Closing the loop to reduce waste

Closing the loop involves using inputs efficiently and avoiding, reducing, reusing and recycling wastes where possible so that no resource goes to waste. Closing the loop helps to reduce the carbon footprint, emissions and cost of production. Some strategies for waste and resource reduction include:

- the actions detailed in the carbon cycling and nutrient accounting section above
- utilising effluent, manure and compost to replace synthetic fertiliser
- using alternative feeds or food waste as part of the diet to reduce waste to landfill (swill cannot be fed)
- buying only what is needed and considering reuse/recycle opportunities for packaging along with the cost of disposal of those materials
- returning containers to retailers where they can be reused, or disposing non-returnable clean containers to an appropriate collection point such as drumMUSTER
- storing materials for future reuse (e.g. wire, scrap metal) in areas where they are not going to cause impacts ahead of recycling through a scrap metal company
- separating recyclable materials e.g. plastics and cardboard into appropriate collection bins
- using water more efficiently by:
  - conducting a water audit to identify savings without compromising production or cleanliness
  - using recycled water where possible to reduce freshwater use (e.g. for shed cleaning)
  - separating stormwater from contaminated runoff
  - regularly inspecting and maintaining water supply systems (e.g. promptly repairing leaks)
  - installing low wastage drinkers
  - positioning drinkers to minimise wastage from pigs rubbing against or playing with the drinker.

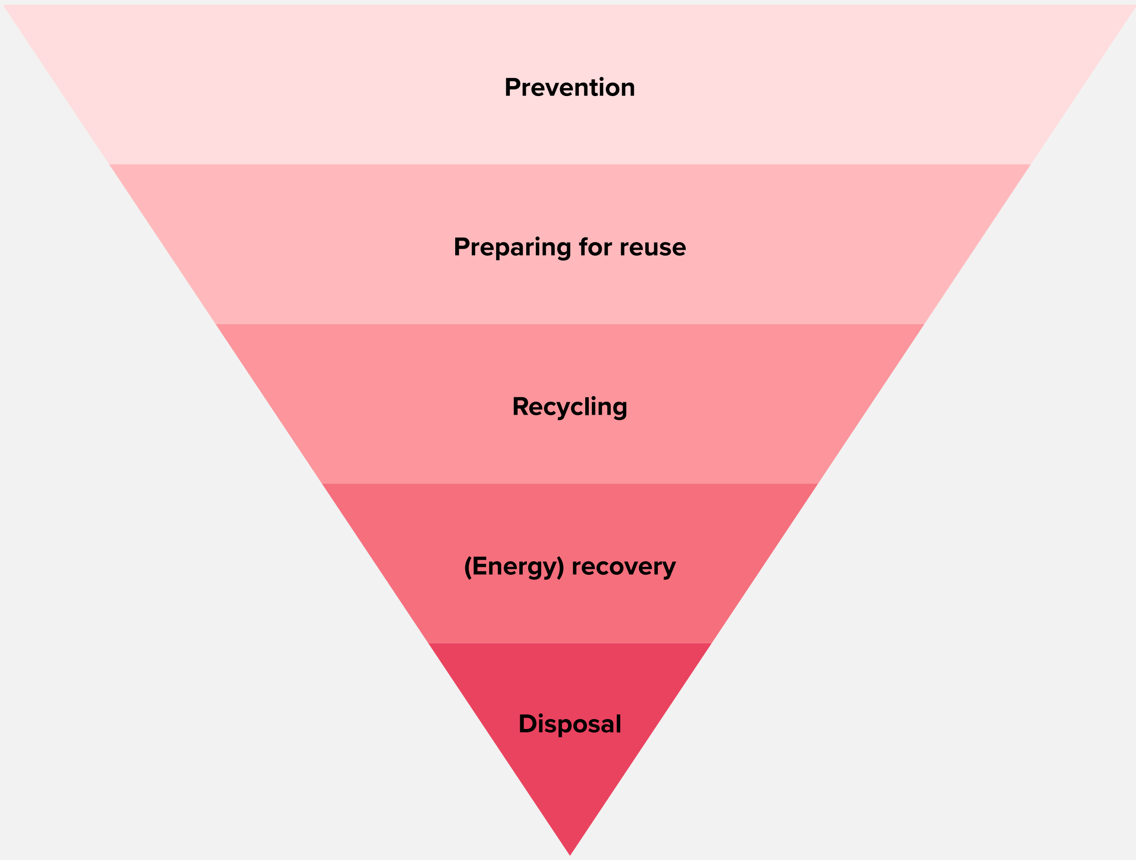


Figure 8.2 The waste hierarchy

Source: European Commission

9 Pig housing design principles

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 2 common forms of indoor piggeries – conventional sheds and deep litter housing.

Table 9.1 summarises shed design principles that apply to both types of housing. Sections 9.1 and 9.2 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). Minimum space allowances for **adult** pigs and growing pigs are provided in Appendix 3 of this Code.

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

Some producers are changing their housing to provide additional space for their pigs. These producers may need larger or additional sheds even though their herd size is not changing.

Table 9.1 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 concreted, otherwise soil compacted to form an **impermeable liner** with a permeability of 1x10-9 m/s for a minimum depth of 300 mm comprising 2 layers each 150 mm thick) to prevent seepage of effluent into soils and groundwater. Appendix 1 of the PMEMRG provides design information for earthen liners. Site or design buildings so they are protected in the event of a one-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. Note that increased ventilation for air quality control may compete with shed temperature control. This should be optimised during design and layout. Seek specialist advice. The long sides of naturally ventilated sheds should be separated by a distance of 5 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 their 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.
Biogas	The type of effluent collection (e.g. flushing channels vs. pull plug pits) can influence the amount of biogas energy that can be recovered from manure and effluent. Pig sheds should be sited well away from covered **anaerobic ponds**. It is generally more cost effective to convey biogas than to lay electrical cabling, meaning that a biogas generator system is ideally sited close to where the electricity generated will be used.

9.1 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 or perforated tiles and spilt feed, water, urine and faeces fall through the flooring 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 pressure washing. Under the **APIQ✓®** customer specifications for Coles Supermarkets Australia Pty Ltd (CSC) standard (CSC 1.4), manipulable and rootable material must be provided for all breeding pigs for at least part of the breeding cycle. This needs to be carefully managed to avoid blocking slatted or perforated flooring and effluent pits and pipes.

Ponds or other effluent 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.

9.2 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 absorb manure. 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 one metre beyond the shed end allows for bedding to be contained at cleanout.

Deep litter sheds best suit weaners, growers/finishers and dry sows. Weaners and growers/finishers generally move through these sheds in batches ('all-in, all-out'), with spent bedding cleaned out only at the end of each batch. For dry sows, bedding replacement occurs at regular intervals. The spent bedding is generally reused in cropping systems. Some producers pressure-wash concrete-floored deep litter sheds after bedding removal; others just replace the bedding. If washing is done, this is generally the only liquid effluent stream from these sheds. Like other effluent streams, this should be captured and managed.

10 Stormwater management

Environmental outcome: Stormwater is kept separate from manure, effluent or contaminated runoff enabling its beneficial use.

Stormwater is surface runoff from rain and storms. Stormwater should be kept separated from manure, effluent or runoff that may be contaminated with manure or dust where practical. This is good practice as it minimises the amount of effluent to manage in the effluent system (reducing the required size of these) and provides an additional clean water source. If stormwater cannot be kept separate, it must be collected in suitably sized ponds.

To keep stormwater separate:

- the bases of sheds and shelters should sit above natural surface level to prevent entry of stormwater
- roof runoff, which may contain dust, should be diverted using guttering. This can be used for shed cleaning or dilution of effluent for irrigation
- the banks of effluent ponds well above the natural surface level
- install bunding around manure storage pads and composting areas and control runoff from these areas.

Other designs or strategies may be used to achieve the objective.

11 Estimating the properties of piggery effluent and manure

It is necessary to estimate the amount of total solids (TS), volatile solids (VS) and macronutrients in piggery effluent and manure to design effluent and manure management systems (including biogas systems), and to size effluent and manure reuse areas.

The best available tool for estimating the quantity of TS and VS, 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. 2018). 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 management systems, biogas systems and sustainable reuse.

11.1 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 applications for planning and environment permissions
- preliminary design of effluent management systems including the primary effluent pond or a covered anaerobic pond (CAP)
- estimating baseline manure management methane emissions for a piggery as an important source of GHGs
- estimating manure total TS and VS from the pig sheds, for subsequent use as inputs into Pork **WatBal** (water balance model for ponds) or for sizing manure storage areas.

PigBal 4 provides:

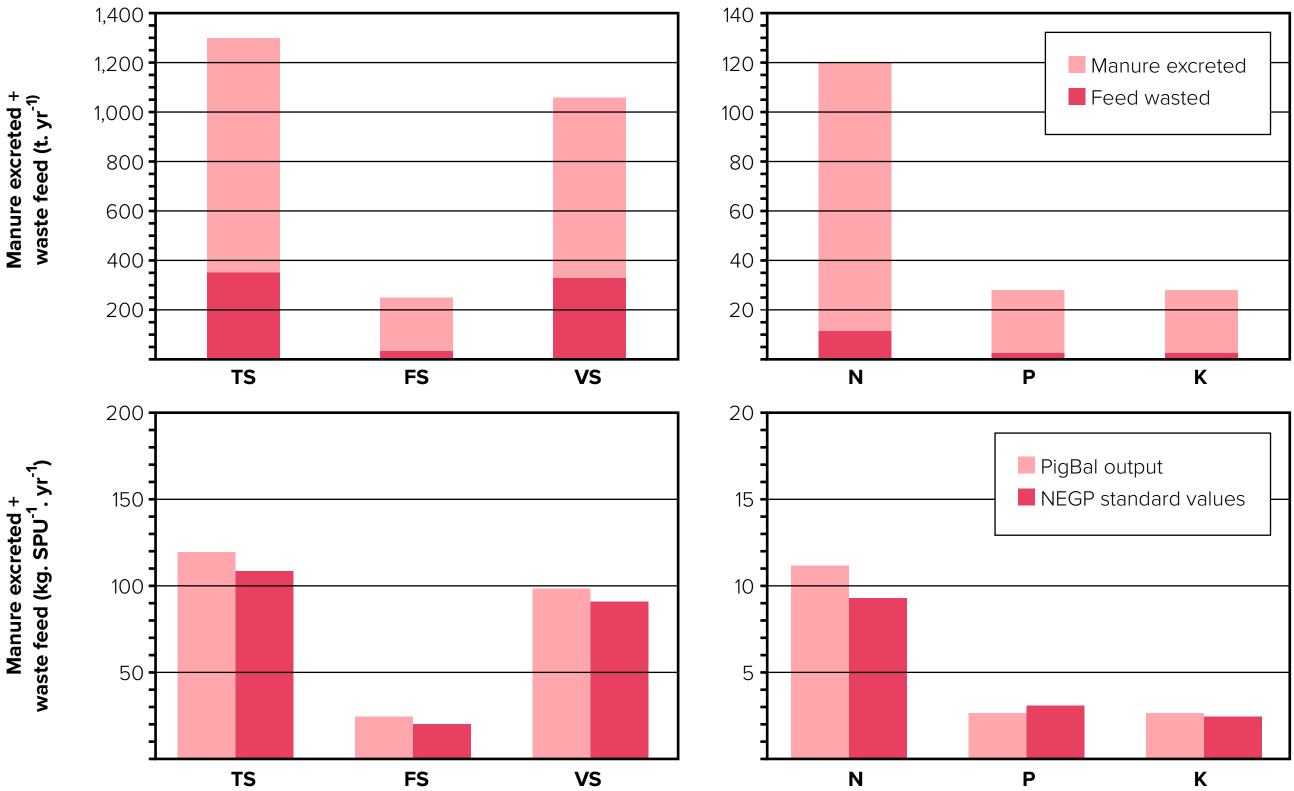
- in-cell explanatory comments to assist the use in selecting input values
- the option of using up to 6 pig growth stages and corresponding diets between weaning and turn-off
- a range of standard industry growth curves and corresponding estimated growth curves based on the entered data
- an equation for estimating feed intake from pig liveweight
- estimates of feed wastage by pig class
- cleaning water use estimates based on typical effluent solids concentrations for different effluent management systems with the capability of entering different volumes
- pig drinking water estimates
- pig cooling water estimates

- an extensive diet ingredient database and also a range of standard diets
- the option to choose from a range of solids separation (pre-treatment) options with typical solids and nutrient removal rates
- estimates of manure production from conventional housing and 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).

PigBal 4 was developed by Skerman, Collman et al. (2013). Skerman, Willis et al. (2018) developed the PigBal 4 User Manual. The PigBal 4 model and the manual are available for download at: https://australianpork.com.au/environmental-practices/waste-management.

Figure 11.1 Example PigBal 4 output summary

			Animal waste output (t. yr^{-1})			
User entered diet	**TS**	**FS**	**VS**	**N**	**P**	**K**
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 discharges 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**	**10.8**	**2.5**	**2.5**
NEGIP standard SPU (grower pig) values (Table 9.1)	**108**	**18**	**90**	**9.2**	**3.0**	**2.4**



11.2 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 11.1 shows indicative rates of solids and nutrients in manure ex-sheds for the standard classes of pigs estimated using the PigBal 4 model for a 1,000 sow farrow-to-finish example herd housed in a **conventional piggery**. A more accurate estimate can be produced by using piggery-specific inputs in PigBal 4. Similar data can be produced for deep litter piggeries; PigBal 4 includes inputs for bedding usage.

Table 11.1 Indicative solids and nutrient output in manure and waste feed ex-sheds by pig class — example 1,000 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	Phosphorus	Potassium
Gilt	73 (132)	115-160	17.6	14.3	1.12	0.36	0.31
Boar	54 (86)	115-300	10.0	7.7	0.82	0.25	0.23
Gestating sow	834 (1,334)	160-215	154.9	120.5	11.56	3.69	3.42
Lactating sow	165 (411)	215-160	55.4	43.9	4.45	1.12	1.26
Sucker	1,757 (171)	1.4-6.7	41.0	35.2	3.86	0.76	0.60
Weaner	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.

11.3 Manure nutrient dynamics

As soon as manure is excreted, some of the solids, water and nitrogen are removed through gaseous losses. Table 11.2 shows the default PigBal 4 in-shed solids and nitrogen loss rates.

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

Table 11.2 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%

11.3.1 Manure nutrient dynamics — conventional piggeries

When effluent enters a primary effluent pond (covered or uncovered), 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 11.3 shows the approximate percentages of nutrients partitioned between sludge and pond liquid.

Table 11.3 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 ponds, including any that follow CAPs. 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 justify 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%).

Nitrogen is lost from manure by ammonia volatilisation during storage and handling. 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.

11.3.2 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%.

12 Effluent collection and management

Raw effluent is conveyed from conventional sheds to the effluent system facilities by a collection system that may include pits or channels, drains and pipes and sometimes sumps and pumps. 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 before it enters the effluent ponds. This solids separation enables effluent to be pumped using conventional equipment (e.g. centrifugal pumps) and reduces the required size of the effluent ponds.

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

Most conventional piggeries use some type of anaerobic pond to manage their effluent. However other systems, including **sedimentation** and evaporation pond systems (**SEPS**), and biodigesters are also in use. Other effluent system designs that effectively meet the environmental outcome can also be suitable.

12.1 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.

The type of collection system selected will depend on water availability and the type of effluent system to be used.

It is important to provide regular inflow to the anaerobic pond to maintain pond function. If channels or pits will not be flushed or emptied daily, different sheds should be emptied sequentially (on different days) so that effluent enters the pond regularly, ideally every day.

12.1.1 Flushing channels

Flushing channels sit underneath slatted or perforated shed flooring and catch manure, spilt feed, wasted drinking water and shed washing water. These are flushed regularly (e.g. twice a day to weekly), with large volumes of water or effluent recycled from the final pond. 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 700-1,000 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.

12.1.2 Pull plugs

Pull plug systems store effluent in underfloor pits that sit underneath slatted or perforated 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**.

12.1.3 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.

12.1.4 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.

12.1.5 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 and the effluent is concentrated.

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.

12.1.6 Drains and pipes

Drains or pipes are needed to move effluent from the sheds to sumps or effluent 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.

For gravity flow pipes conveying effluent to ponds, the recommended minimum inside diameter is 150 mm. Larger diameter pipelines will discharge more quickly and are less likely to block.

12.1.7 Effluent sumps

Sumps store effluent before solids separation, 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 enamelled 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 for the storage and transfer of effluent 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.

12.2 Solid separation systems

Solid-liquid 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 primary pond capacity required. It also diverts VS away from the effluent ponds which may help in reducing GHG emissions.

12.2.1 Options for solids separation

Methods for separating solids from liquids include:

- gravitational settling, for example sedimentation basins or sedimentation and evaporation pond systems (SEPS) (for further details, see Section 12.3.4)

screens including static rundown, vibrating and rotating screens, and Baleen Filters®, presses such as screw, roller or belt presses and **Z-filters®** (see Payne 2014)

- centrifugal separation including hydrocyclones and horizontal centrifuges.

Screens can be used in conjunction with a press to maximise solids removal and provide stackable solids.

Data from McGahan et al. (2010) and Payne (2014) was used to develop Table 12.1, which summarises measured nutrient removal rates from different types of solids separators. Detailed information on the various solids separation information is provided in the PMEMRG. The performance of any solids removal system may vary widely from the rates in Table 12.1 depending on design and management. Where practical, use measured removal rates to design areas to store solids and ponds following solids separators (including when Pigbal 4 is used to size ponds).

Table 12.1 Typical solids and nutrient removal rates for different types of solids separators

	Removal rate (%)				
Technology	**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)

12.2.2 Screenings storage areas

The solids separation system and the solids storage area should be located within a controlled drainage area with an impermeable liner. For clay-lined areas, a design permeability of 1 x 10-9 m/s for a depth of 300 mm comprising 2 150 mm deep layers is appropriate. Refer to Appendix 1 of the PMEMRG for information on pad preparation requirements. All runoff and leachate from the solids storage area should be contained within an adequately sized storage.

12.3 Effluent ponds

Solid-liquid 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 primary pond capacity required. It also diverts VS away from the effluent ponds which may help in reducing GHG emissions.

12.3.1 General principles

Effluent pond systems need to be sized to remove organic matter and provide wet weather holding capacity, with different ponds in the system 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 (e.g. 3-4 horizontal to 1 vertical). 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 be 4 horizontal to one vertical or flatter (up to 10 horizontal to one vertical) 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 an impermeable liner which will have a maximum 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 state environmental agencies may require more stringent pond lining requirements, depending on risk). Compacted layers should not exceed 150 mm depth. Guidance and technical direction for clay lining and compaction of effluent ponds is provided in Appendix 1 of the PMEMRG. 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 base of all effluent 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 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 10 years for ponds with irrigation of effluent, and once every 20 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 and territories may have different requirements so it is important to discuss this with regulators. To minimise the size of the effluent ponds, entry of stormwater runoff and roof runoff should be avoided through the use of banks and gutters and drains. The ponds should only collect effluent, other contaminated runoff (e.g. from a manure storage/composting area or 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, WatBal [Skerman and McClymont 2019] or **MEDLI** V2.5.0.2 [Department of Environment and Science 2023]) using long term, local climate data. Effluent spills must not enter any watercourse or leave the property boundary.

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

All effluent 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 effluent 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 pond walls and base must be impervious
- the lowest part of the pond base should be at least 2 m above the highest seasonal water Table
- all ponds should provide at least 600 mm of freeboard
- consider sludge accumulation and removal in pond design.

12.3.2 Primary effluent ponds

Most primary effluent ponds at piggeries are anaerobic ponds. Anaerobic ponds are a popular option as they are simple to build and operate, and provide 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 remove organic matter (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.

When designing anaerobic ponds, there are 4 main aims. They are:

1. to treat the effluent stream
2. to provide for sludge storage
3. to ensure that effluent and sludge can be removed as needed
4. 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 VS from the effluent
- usually have low to moderate ongoing odour emissions but have a relatively large surface area for emitting odours and 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 12.2 provides sizing rates for large (RDS) primary anaerobic ponds in 3 broad climatic zones with different **desludging** frequencies, and with or without solids separation. 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 12.1 is 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 required sludge storage volume is 0.148 m^3/SPU/yr.

Table 12.2 Suggested large primary effluent pond capacities for different climates, desludging frequencies and solids separation options separators

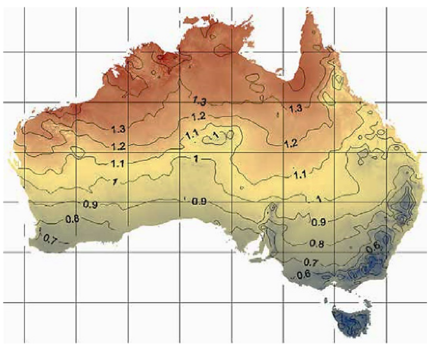
Climate[a]	Desludging frequency	Effluent treatment and sludge storage (m^3/SPU)		
		No solids separation	Screen[b]	Screw press[c]
Cool	5 yearly	4.8	3.8	3.1
(K = 0.6)	10 yearly	5.6	4.4	3.5
Warm	5 yearly	3.8	3.0	2.0
(K = 0.8)	10 yearly	4.6	3.6	2.9
Hot	5 yearly	3.2	2.5	2.4
(K = 1.0)	10 yearly	3.9	3.1	2.9

[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.

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.

Figure 12.1 Map of iso-K Lines in Australia



Source: Skerman (2018)

Table 12.3 provides indicative minimum sizing rates for primary HLA ponds in 3 broad climatic zones with different desludging frequencies with or without solids separation. These ponds are typically desludged frequently so sizing rates for 2, 3, and 4 yearly desludgings are provided. As a contingency measure, it is prudent to provide for at least 3 years sludge storage even when annual desludging is planned. However, 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 12.3 are for primary HLA ponds only.

Table 12.3 Suggested minimum primary HLA pond capacities for different climates, desludging frequencies and solids separation options

Climate[a]	Desludging frequency	Effluent treatment and sludge storage (m^3/SPU)		
		No solids separation	Screen[b]	Screw press[c]
Cool	2 yearly	0.8	0.7	0.5
(K = 0.6)	3 yearly	1.0	0.8	0.6
	4 yearly	1.2	1.0	0.7
Warm	2 yearly	0.7	0.6	0.5
(K = 0.8)	3 yearly	0.9	0.7	0.6
	4 yearly	1.0	0.9	0.7
Hot	2 yearly	0.6	0.5	0.4
(K = 1.0)	3 yearly	0.8	0.6	0.5
	4 yearly	0.9	0.7	0.6

[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. Allowing sludge to accumulate for longer:

- 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, minimises the rainfall volume to be managed and reduces the evaporation that concentrates salts. For 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 for anaerobic activity.

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 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 for 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.

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. This occurs when influent follows 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 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.

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. 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 between ponds, 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.

12.3.3 Covered anaerobic ponds (CAPs)

Covered anaerobic ponds, or CAPs, are primary ponds with an impervious cover that traps biogas for flaring or use as a heat or power while also lowering GHG emissions from the pond system considerably. CAPs also significantly reduce site odour emissions which may allow a site close to sensitive uses to develop or address ongoing odour issues. CAPs are a type of biogas system. Design details are provided in Section 13.

12.3.4 Sedimentation and evaporation pond system (SEPS)

A SEPS is an alternative to a primary anaerobic pond. A SEPS consists of a series of long, narrow, earthen channels built as embankments along the land contour. Usually 2 or 3 channels are built in parallel down the slope. At any time, one channel is in active use while the solids in the other one or 2 channels are drying 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 primary or holding pond(s). The active channel is used continuously for 6 to 12 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 dry season. For this reason, SEPS may not be an option in wetter locations. 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 2-channel SEPS, each channel must be able to store at least 12 months' of wet manure solids, which requires a capacity of 0.5 m3/SPU. If 3 channels are used in parallel, each channel should be sized to store 6 months of wet solids, which requires a capacity of 0.25 m3/ SPU. The design VS loading rate for a channel providing 0.25 m3/SPU is about 1,000 g VS/m3/day.

Each channel is typically 6 m wide at the base, with 3:1 internal batters and a maximum storage 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 clay lined. 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 effluent 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* (APL 2015e).

12.3.5 Secondary effluent 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 and because the effluent they receive has a lower VS concentration. The base and sides of these ponds must be impervious.

12.3.6 Wet weather ponds

Wet weather ponds store 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 industry benchmark models such as WatBal (Skerman and McClymont 2019) or MEDLI (Department of Environment and Science 2023). The base and sides of these ponds must be impervious.

Pipelines for pumping 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* (APL 2015b).

12.3.7 Evaporation ponds

Shallow ponds or basins can provide 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, because the effluent in these ponds may have a greater concentration of salts, 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 WatBal (Skerman and McClymont 2019) or MEDLI (Department of Environment and Science 2023). The base and sides of these ponds must be impermeable.

12.3.8 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 over time in the bottom of effluent ponds (particularly primary ponds). Effluent ponds need to be sized to provide for sludge storage, and sludge needs to be suitably managed to ensure the system has sufficient effective working volume. Removing sludge too frequently (e.g. every one to 6 months) may compromise pond treatment capability. As the sludge contains microorganisms that provide effluent treatment, it is very important to retain some sludge in the bottom of the pond so the pond microbiology remains healthy and balanced. If using a pump to extract sludge from the pond, stop drawing when the sludge noticeable thins as this indicates less solids are being removed. Removing sludge too frequently may also cause on-site odour issues if the solids will be stored prior to reuse. This is because the sludge will still have a high VS content due to insufficient breakdown.

There are 3 options for removing sludge from an operating, uncovered pond. They are:

- pumping with a pump or vacuum tanker located on the bank of the pond with or without sludge agitation
- dredging using a mobile pump located within the pond that provides access to all sections of the pond
- mechanical removal using a long-reach excavator or similar
- the properties of the sludge will change over time and this will affect sludge removal options.

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:

- long-term bulk storage
- short-term drying bays
- SEPS
- geotextile tubes.

Sludge dewatering or drying needs to be done in a way that minimises risk to groundwater and surface waters. Consequently, the base of any bay or storage pad used to store sludge should have an impervious liner which will usually be compacted clay. 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.

Piggery biogas systems

Environmental outcome: A piggery biogas system that captures biogas and manages it to reduce GHG emissions and provide energy.

13.1 Introduction to biogas systems

Anaerobic digestion is a natural process by which microbes break down organic matter in the absence of oxygen. A product of anaerobic digestion is biogas, a mixture of mostly methane and carbon dioxide along with other trace components such as water vapour, hydrogen sulphide and volatilised ammonia. The release of biogas to the atmosphere can be observed as bubbling from the surface of uncovered effluent ponds. These gaseous releases represent a major GHG emissions source at piggeries. The methane in biogas however also makes it a usable energy source for electricity generation and hot water production. A piggery biogas project aims to control the production of biogas, reducing GHG emissions and using the biogas as an on-farm energy source.

By capturing and utilising biogas, the GHG emissions from a piggery are significantly reduced, and fossil-fuel energy sources are also displaced with renewable biogas energy. This can reduce pork supply chain GHG emissions by as much as 64% (Wiedemann et al. 2016). At the present time, biogas systems are considered the “gold standard” to reduce GHG emissions across the pork supply chain. In recognition, a voluntary Australian Commonwealth initiative, the Emissions Reduction Fund (ERF), has incentivised piggery biogas projects by issuing Australian Carbon Credit Units (ACCUs) for GHG emissions abated. ACCUs have a potential market value, and to date this has paid for an estimated 30% or more of the infrastructure costs of several piggery biogas projects in Australia. To be eligible for ACCUs, implementation of a biogas project cannot begin prior to the project being registered with the Clean Energy Regulator (CER). Consultation with the CER prior to committing funds is strongly recommended.

Biogas projects are often only viable for larger piggeries (about 500 sows farrow-to-finish) (see Tait and McCabe [2020]), particularly those with significant power usage since considerable infrastructure is required at a substantial capital cost.

However, there have been biogas installations at smaller Australian piggeries because of other benefits such as odour reduction.

In the future, it may be viable to use biogas to produce biomethane that can be injected into the national gas grid or used in place of natural gas for commercial and domestic uses. Bio-carbon dioxide, which can be a by-product of this process, may also be a substitute for food-grade carbon dioxide. Currently commercial biomethane production systems (biogas upgrading) require a large amount of biogas and would only be viable for very large piggeries (>50,000 SPU).

Piggery biogas is flammable and contains highly toxic gases. The *Code of Practice for On-Farm Biogas Safety and Use (Piggeries)* (APL, 2015a) provides guidance for the safe design, construction, operation and maintenance of piggery biogas systems.

The infrastructure required for a piggery biogas project includes:

- a system to capture the biogas which could be an unmixed-unheated CAP or a digester
- equipment to convey the biogas (blowers and pipes)
- systems to dry and scrub trace contaminants from the biogas
- equipment to use the biogas, such as an electrical generator, a hot water system or a flare.

While there are a number of biogas systems in place in the Australian pork industry, this is a rapidly changing field. Emerging designs that effectively meet the outcome could also be suitable.

13.2 Systems to capture biogas

Systems to capture biogas could include:

- an unmixed-unheated CAP
- digester, which can be:
  - a mixed-heated CAP
  - an in-ground digester
  - an above-ground tank digester.

13.2.1 Unmixed-unheated covered anaerobic pond (CAP)

The simplest system to produce and capture biogas at a piggery is an unmixed-unheated CAP (See Figure 13.1). The pond cover operates under a slight pressure to form an inflated pillow, allowing storage of biogas that is then available when needed for on-farm energy. All CAPs need a flare to manage surplus biogas. The temperature of an unmixed-unheated CAP varies with ambient climate. This causes an increase in microbial activity and biogas production during warmer months, and a decrease in cooler months resulting in variable biogas production. As a result, a large proportion of the biogas often needs to be flared without any energy benefit. The simplest systems will flare all biogas rather than using it to generate power and heat.

High density polyethylene (HDPE), polypropylene and low density polyethylene (LDPE) are suitable pond cover materials, although other materials may also work.

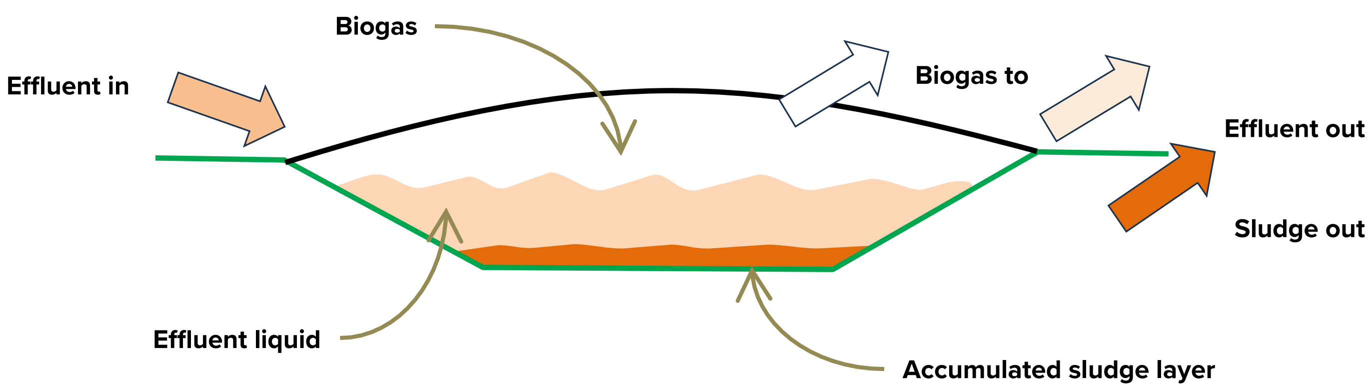
HDPE is the cover material most commonly used on Australian CAPs. The cover must be large enough to go over the pond surface and be securely anchored in a trench excavated into the crest of the embankment around the perimeter of the pond.

A set of water-filled ballast pipes placed on the cover can divide the space under the cover into even segments. This prevents excessive mechanical stress on the cover during windy days. These ballast pipes also direct rainwater captured on the cover to a central collection point, often a sump welded into the cover.

CAPs usually have a higher baseline VS loading rate (e.g. 300 g/m3/d) than traditional primary ponds, still adjusted for temperature zones (see Figure 13.1), plus a sludge storage allowance. PigBal 4 provides for location-specific sizing of CAPs. It is important to confirm that the length of time that effluent is retained within the CAP (hydraulic retention time or HRT), is not too short, which could result in sludge washout and loss of microbial activity.

The length to width ratio of a CAP is important. Making a CAP as deep and narrow as possible reduces the crest footprint and thus cover size and cost. A relatively steep slope on the sidewalls can help to minimise dead zones and encourage sludge accumulation in a confined area which helps to facilitate desludging.

Figure 13.1 Unheated and unmixed covered anaerobic pond



The excavated depth of a CAP should be at least 2 m above the highest seasonal groundwater Table, and the base and walls of the CAP must be impermeable.

Figure 13.1 shows a schematic representation of an unmixed-unheated CAP, with photos showing guide pipes over the cover an operating flare.

Figure 13.2 Unheated and unmixed covered anaerobic pond

Sludge management is very important in these systems. Over time, manure solids settle and accumulate as a sludge layer over the base of a CAP. Retaining some sludge in the CAP maintains pond function (Heubeck and Craggs 2010). Removing sludge too frequently also reduces biogas production. However, accumulating sludge may encroach on the liquid treatment volume and eventually it must be removed. As it is difficult to remove a pond cover during the operational phase, options to extract the sludge from CAPs include:

- designing the pond volume to allow for accumulation over the operational life of the cover, and when the cover is eventually replaced, the pond is re-excavated
- in-situ desludging, where sludge is periodically pumped out via pre-installed pipes connected to sludge extraction ports. Sludge ports can be installed through the banks of a pond or through the cover (see Figure 13.2).

Figure 13.3 Sludge extraction ports being installed through pond wall

Photo courtesy of Tom Smith

Recent APL research determined sludge accumulation rates for piggery effluent ponds ranging from 0.00054 to 0.00324 m^3/kg TS, with a mean value of 0.00228 m^3/kg TS (Skerman et al. 2019).

The sludge accumulation rate tends to be higher if sludge is extracted more frequently, which is typical for CAPs. Accordingly, a value of 0.00228 m^3/kg TS is considered an appropriate design value for CAPs with in situ desludging, while 0.00137 m^3/kg TS is suitable for CAPS designed to allow for sludge accumulation over the operational life of the cover.

Sludge extraction ports typically consist of polypipe or uPVC pipes with a diameter of ≥300 mm. As most sludge is likely to deposit in the third of the pond closest to the inlet, it is important to provide sufficient extraction ports near to the pond inlet. Ports away from the inlet can be spaced further apart.

Sludge is viscous and can be difficult to pump because of its high solids content. Moreover, sludge that is left to accumulate in an effluent pond for an extended period will settle and consolidate into a dense layer with an even higher solids content of up to 14% (Tait et al. 2013) making it extremely difficult to pump. For this reason, it is advisable to extract sludge at least every 2-3 years.

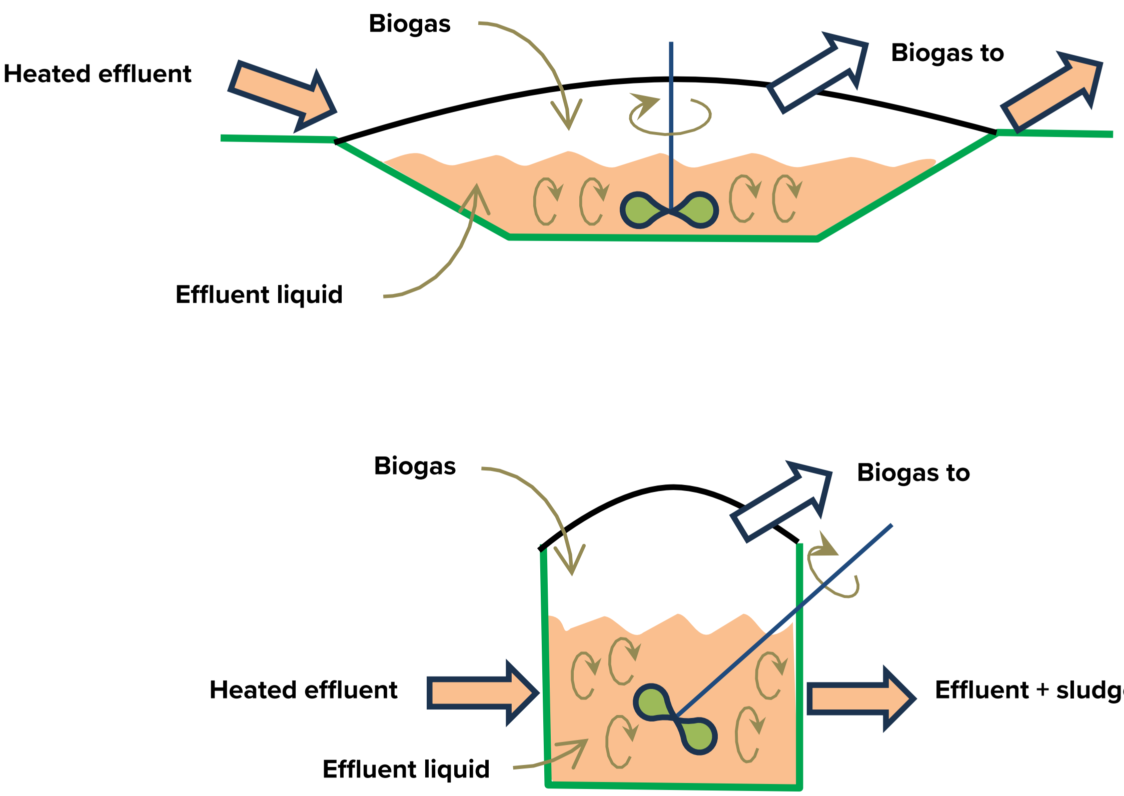
13.2.2 Digesters

Digesters are more sophisticated biogas systems that include mixing and heating to optimise biogas production. Mixed, heated CAPs and tank digesters have been installed at Australian piggeries. Mixed systems prevent the settling and accumulation of sludge, suspending manure solids by stirring the effluent. This maintains the liquid working volume and negates the need for a sludge volume allowance during system sizing, resulting in smaller system sizes. Mixers can be fitted within CAPs or tank digesters (Figure 13.3). Mixing can also be provided via an external recirculation loop that extracts a portion of the digester contents and reinjects it back into the digester, albeit at a lower mixing energy efficiency than with direct mixing using stirrers.

Heating a mixed CAP or tank digester (e.g. to 34-38^{o}C) speeds up microbial activity, ensuring manure solids are properly digested. A HRT of ≥30 days is also necessary to prevent washout of the digester microbial community. Because these systems are held at a constant elevated temperature year-round, biogas production is more consistent. This can help to reliably optimise biogas use for energy at a piggery. Heating can be achieved by pre-warming the effluent entering the system or by using a recirculation loop via a heat exchanger.

These systems are significantly more expensive to set up than unmixed-unheated CAPs. Mixing and heating equipment can also increase the requirements for skilled operation.

Figure 13.4 A schematic representation of a heated mixed CAP (top) and a mixed tank digester (bottom)



Other digester types that could be used at piggeries but typically at higher cost, include plug flow digesters and batch leach bed digesters. The operation of a plug flow digester would require pre-concentrating of the effluent to increase the solids content in the digester feed to 12-15%. Leach bed digesters suit manure that is stackable and mixed with a **bulking** agent such as straw, rice hulls, or sawdust, to maintain a bed structure during the digestion process. APL funded and co-funded research in Australia (Tait et al. 2021, Tait et al. 2009, Yap et al. 2016) has explored the application of plug flow digesters and leach bed digesters for spent bedding from deep litter systems, however these digester types are still at the experimental development phase for piggeries in Australia.

Other, high-rate digestion systems such as anaerobic filters, sludge blanket reactors and anaerobic membrane bioreactors are relatively complex and generally unsuitable for use at piggeries due to the demanding operational and maintenance requirements.

13.3 Biogas conveyance

Typical gas pressures under the cover over a CAP or a mixed-heated CAP, or under the dome roof of a tank digester are usually very low. This means that a biogas blower is usually needed to effectively convey the biogas to the point of treatment or use. The materials of construction and design and installation standards for biogas are referenced in the *Code of Practice for On-Farm Biogas Safety and Use* (APL 2015a).

13.4 Biogas drying and scrubbing

Prior to use in a boiler or generator, it may be necessary to remove corrosive ingredients such as hydrogen sulphide, and to dry the biogas. This increases the life of the equipment and helps decrease maintenance requirements.

13.5 Equipment to use the biogas

In Australian piggeries, internal combustion engine generators typically use the biogas to produce electricity, and to provide hot water recovered from the generator engine for in-shed heating. In some cases, excess electricity that cannot be used on-farm can be exported to the electrical supply network although the financial incentives for exported electricity have typically been low (Tait et al. 2021).

13.6 Other considerations

Other factors to consider in the siting, design and management of biogas systems:

- When siting a biogas project, it is more cost effective to convey biogas than effluent. However, it is more cost effective to convey effluent than to distribute electricity.
- Digested effluent and sludge from a CAP or tank digester that only receives piggery effluent are likely to have similar compositions to treated effluent and sludge from an uncovered effluent pond for reuse purposes.
- If a mixed-heated digester is used, sludge may collect in a secondary pond.
- From an economic perspective, reducing feed wastage is more beneficial than using wasted feed for biogas production (Skerman et al. 2016).
- The rapid introduction of anti-microbial feed additives or other chemicals, or rapid changes in salinity, may adversely affect CAP or digester microbiology and health.
- Co-digesting with other by-products can increase biogas production, divert wastes from landfill and provide income for receival. However, the addition of these materials may overload a system not designed to receive the load. The ERF Animal Effluent Management Method allows for co-feedstocks, but has additional monitoring requirements, and their inclusion may reduce the number of ACCUs that can be claimed. Refer to Tait et al. (2018) for details on co-digestion.
- Biogas systems need ongoing monitoring. Refer to Section 21.8 for recommendations.

14 Manure and spent bedding storage and composting areas

Spent bedding, separated manure solids and dried pond sludge usually need to be stored or composted before use. This section provides design guidance for manure and spent bedding storage areas. Carcass composting is addressed in Section 16.1.

Environmental outcome: Manure storage and composting areas that are sited, designed and constructed to provide sufficient storage space and to protect amenity, surface water and groundwater quality.

14.1 General design principles for manure and spent bedding storages

When choosing a site for a manure or spent bedding storage, consider the potential for risks to amenity, surface waters and groundwater. Since stored or composting manure will release some odour, locate the site away from sensitive land uses. Separation distance guidance is 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. If a clay liner will be used, this should have a design permeability of 1 x 10-9 m/s for a depth of 300 mm, comprising 2 layers each compacted to a depth of 150 mm. For guidance on achieving this design permeability, see Appendix 1 of the PMEMRG. The area should have a longitudinal slope of ~1-2% to promote drainage away from the windrows. Runoff should be captured and managed. Also consider any design guidance from the state environmental regulator.

The manure or spent bedding storage or composting 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 6 months manure production, to fit in with cropping cycles. Also consider any other co-composting materials that may be added. 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. In most cases, rainfall caught within the pad will be directed to the effluent management system or a separate runoff collection pond that is sized and managed for a one-in-a-10-year spill frequency.

Other designs for managing manure and spent bedding, including new composting technologies, that effectively meet the environmental outcome may also be suitable.

14.2 Manure and spent bedding storage

Manure and spent bedding storage and aging should be undertaken using windrows that are 1.5-3 m high, 2-3 m wide at the base and up to 1 m wide at the top. These may be static or can be turned but are managed less intensively than compost windrows.

14.3 Manure and spent bedding composting

Composting involves the active management of manure or spent bedding, sometimes with the addition of water, effluent or other co-composting materials. Active management involves turning the windrow after the core temperature is maintained at 55-65°C for 3 consecutive days and repeating at least 4 times. Most pathogens and weed seeds are inactivated at these temperatures. The addition of co-composting materials brought onto the farm from off-site may trigger the need for a separate environmental permission.

For further information, refer to the PMEMRG and the *Australian Standard for Composts, Soil Conditioners and Mulches* (AS4454) (Standards Australia 2012). AS4454 is a voluntary standard that specifies criteria for the physical, chemical and biological properties of compost that will minimise risks to the environmental and public health and provides labelling and marking guidance.

Composting is generally undertaken using windrows that are 1.5-3 m high, 2-3 m wide at the base and up to 1 m wide at the top. Making piles too tall may result in too much heat production, causing self-combustion. Sufficient space needs to be provided between the windrows for turning and loading onto trucks.

Aerated floor composting is another option. The composting material is placed in windrows 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.

If the same area is used for mortalities composting or if there could be restricted animal material (RAM) in co-composting materials, the area may need to be fenced to exclude ruminants.

APL has also been investigating 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 would require an investment in new equipment and the experience to operate the pelletiser.

15 Reuse areas

Reuse areas are land used to spread piggery effluent, manure and compost. For the purpose of this section, manure includes solids separated from the effluent stream, effluent pond sludge and spent bedding, while compost includes both manure compost and mortalities compost. These products contain valuable plant nutrients and carbon that can be applied to farming land to improve soil fertility, structure, health and microbial activity. The 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.

Piggery effluent, manure and compost are distributed onto land using irrigation systems, tankers or spreaders. In some cases, farmers have adopted GPS technology that allow for precision application and can notify them of equipment malfunction. Alternative reuse methods and equipment that effectively meet the outcome can also be suitable.

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

Reuse can occur on-farm or off-farm (see Section 15.4). The piggery owner has a duty of care to ensure environmentally sustainable reuse is practiced on-farm. The PMEMRG provide detailed information on reuse. Refer to these for further guidance.

15.1 Selecting a suitable reuse area

Reuse areas need to be carefully selected to ensure they will be suitable for the purpose, while also considering the location of nearby houses and soil, surface water and groundwater properties (refer to Section 7.2 and Table 7.1 for buffer distances). A risk-based approach should be used to evaluate whether an area has appropriate properties. Seek early advice from a soil scientist or agronomist.

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, wetlands and sensitive native vegetation
- not be prone to water logging
- be above the one-in-5-year flood line
- have slopes that promote infiltration, rather than runoff and erosion
- provide at least 2 m clearance above the highest seasonal groundwater 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 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 21.4 and Table 21.3 for recommended parameters.

15.2 Land area needed for sustainable reuse

The land area needed for sustainable reuse depends on the:

- composition of the material for reuse
- quantity of material available for reuse
- expected removal 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 21.4 provides soil monitoring recommendations.

Agronomic soil testing is recommended for new reuse areas, to ensure soil properties (particularly nutrient status) are well understood. Refer to Section 21.4 and Table 21.3 for recommended parameters.

15.2.1 Composition of effluent and manure

Tables 15.1 and 15.2 show typical data for the composition of piggery **effluent** and sludge respectively. Data in Table 15.1 are measured from the final pond from which effluent would usually be drawn for irrigation. While the data in Table 15.2 shows a dry matter range of 6.9-17.1% for sludge, analysis of a range of piggery sludge samples has measured dry matter contents as low as 3.2% (O'Keefe et al. 2013). Table 15.3 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 effluent and manure cannot be provided. The moisture and nutrient content of spent bedding can also vary widely (Craddock and Wallis 2013). Pigbal 4 can provide an estimate of the mass of nutrients in effluent, sludge or spent bedding. Once the piggery is operating, testing the effluent or manure will provide better data for determining appropriate reuse rates for a particular farm.

15.2.2 Quantity of effluent, manure and compost

The quantity of effluent, manure or compost 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 15.3, 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 wet tonne contains 4.7 kg of nitrogen (i.e. 584 kg X 0.8%).

It is important to recognise that not all nutrients in effluent and manure will be immediately available for plant uptake; nutrient availability typically ranges from 25-65% for nitrogen, 23-65% for phosphorus and >90% for potassium. Suitable **available nutrient** levels will be needed to optimise crop growth. In addition, if manure is not incorporated into the soil phosphorus deficiency may arise as the plant roots cannot access phosphorus near the soil surface. Start-up fertiliser may be needed at planting, particularly on new reuse areas (Wiedemann and Gould 2018).

15.2.3 Expected nutrient removal by plant harvest

The types and yields of crop grown on the reuse areas determine the amount of nutrients removed through harvest. These are therefore a major determinant of the land area required for reuse. Table 15.4 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 accounting or 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.

Table 15.1 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
Boar	54 (86)	115-300	10.0	7.7
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 and 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 15.2 Characteristics of in situ piggery pond sludge effluent

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.
* all data other than dry matter and VS are reported on a dry basis.

Table 15.3 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 15.4 Nutrient content and anticipated dry matter yield of various crops

Element*	Matter Nutrient Content (kg/t)			Normal yield range[a] (DM t/ha)	Normal nutrient removal range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Grazed pasture					6-16.5	0.8-1.9	0.1-0.7
Dry land pasture (cut)	17.1	2.6	17.6	1-4	17-68	2.6-10.4	17.6-70.4
Irrigated pasture (cut)	17.1	2.6	17.6	8-20	137-342	21-52	141-352
Clover hay	25.4	2.4	15.8	5-15	127-381	12-36	79-237
Lucerne hay (cut)	31	3	24	5-15	155-465	15-45	120-360
Maize silage	12	2	10	16-22	192-264	32-44	160-220
Forage sorghum	20.2	2.2	24	10-20	202-404	22-44	240-480
Grain barley	20	2.5	4.5	2-5	40-100	5-7.5	9-22.5
Barley straw	7	0.7	18	5-10	35-70	1.4-2.8	90-180
Grain wheat	20	3.5	5	2-5	40-100	7-17.5	10-25
Wheat straw	8	0.7	21	5-10	40-80	3.5-7	105-210
Grain triticale	21	3	5	1.5-3	31.5-63	4.5-9	7.5-5
Grain oats	17	2.5	4	1-5	17-85	2.5-12.5	4-20
Oats straw	6	1	22	5-10	30-60	5-10	110-220
Oats hay	13.8	2.6	18.7	5-10	69-138	13-26	93.5-187
Grain sorghum	25	2.3	4	2-8	50-200	4.6-18.4	8-32
Grain maize	15	3	4	2-8	30-120	6 - 24	8-32
Chickpea	34.5	3.3	9	0.5 - 2	17-69	1.7-6.6	4.5-18
Field peas	40	3.9	8	2-4	80-160	7.8-15.6	16-32
Faba beans	41	4	10	1-3	41-123	4-12	10-30
Lupins	51	4.5	9	0.5-2	25.5-102	2.3-9	4.5-18
Canola	40	7	9	1-3	40-120	7-21	9-27

[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:
Data for dryland and irrigated pasture (Rugoho et al. 2017)
Data for lucerne hay, clover hay, forage sorghum, maize grain, oats straw and oats hay (Morris and Staines 2017)
Data for grain, grain straw, oilseeds, peas, beans and maize silage was sourced from GRDC references.

Grazing removes only low levels of nutrients from reuse areas since most nutrients are recycled in manure. Thus, grazing systems typically require at least 5 to 10 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.

If a third party will be managing the crops grown on reuse areas, it is important that they understand the need to manage soil nutrient levels.

15.2.4 Nutrient and salinity status of the soil

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

15.2.5 Expected nutrient and salt losses

Some of the nitrogen applied to land as effluent, manure or compost may be converted to ammonia and lost through volatilisation. A portion of the soluble nutrients and salts may be lost through leaching. The extent of these losses will vary with the type of product being spread, the spreading method, the soil type and other factors.

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%.

Leaching of nutrients can be minimised through good management practices, particularly applying effluent, manure and compost at sustainable rates, at times when the crop or pasture will be actively growing (to maximise uptake) and through careful irrigation management. This is particularly important on lighter soil types. Leaching of salts is a natural process that helps to prevent soil salinisation.

15.2.6 Soil phosphorus storage

Effluent, manure and compost (but particularly manure and compost) often have a relatively high phosphorus content making it impractical to apply one years' crop requirement with an irrigator or spreader. As phosphorus is a conservative element that can tightly bind to clay particles in the soil, most soils with a reasonable clay content can safely store some phosphorus. However, applying phosphorus in excess may pose a risk of erosion, runoff or leaching losses.

Testing the soil for phosphorus buffer index (PBI) can confirm storage capability. It is suggested that phosphorus applications do not exceed 3-5 years crop removal rates. There must be a plan for the removal of excess phosphorus from the soil before reuse occurs again. Consequently, using the soil to store phosphorus does not reduce the land area required for the effluent, manure or compost reuse.

If phosphorus is to be stored in the soil, additional surface water protection measures may be warranted if the site is close to a watercourse. Refer to Section 15.3 for further information.

For new reuse areas, it may be necessary to apply start-up fertiliser at planting if manure is not incorporated into the soil since the plant roots may not be able to access phosphorus near the soil surface (Wiedemann and Gould 2018).

15.2.7 Calculating areas required using sustainable application rates

Nutrient accounting using mass balance is the recommended approach for determining sustainable effluent, manure and compost reuse rates which can then be used to calculate the required size of the reuse areas. In the simplest form, a reuse area can be considered suitable sized if there is a plan to remove the added nitrogen, phosphorus and potassium through crop harvest and unavoidable gaseous nitrogen losses.

The expected nitrogen volatilisation rate should be deducted from the mass of nitrogen in the effluent, manure or compost before calculating spreading rates to ensure the net application rate provides sufficient nitrogen for the crop. For example, if the volume of effluent for irrigation contains 1,000 kg of nitrogen and 20% volatilisation losses are expected, the mass of nitrogen potentially available for plant uptake is 800 kg/yr (i.e. 1000 kg x [1-20%]). See section 15.4 for further details of volatilisation rates for different reuse methods for effluent, manure and compost.

The crop nutrient removal rate can be calculated as: the crop removal rate (kg/ha) is the dry matter yield (t/ha) multiplied by the nutrient content of the crop (kg/t) (see Table 12.4). Use long-term average yields representative of the local area in these calculations.

Crop removal rate (kg/ha) = dry matter yield (t/ha) X nutrient concentration (kg/t)

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

Minimum area required (ha) = total mass of nutrients in effluent, manure or compost/crop removal rate (kg/ha)

The nutrient (nitrogen and phosphorus) requiring the largest area (ha) is the limiting nutrient and determines the minimum land area (ha) needed for reuse. Potassium causes few environmental issues unless present in the soil at very high concentrations, although it may cause metabolic disorders in grazing stock.

However, when determining annual reuse rates, consider soil nutrient status including the availability of nutrients in effluent and manure for uptake by plants. Soil tests are usually done prior to the main spreading or irrigation season. Where these show that the soil is nutrient deficient, additional nutrients can be applied to achieve good agronomic levels.

If phosphorus storage is planned, this also needs to be considered. Hence, the mass balance equation becomes:

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

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.

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

Regular soil testing should be used to understand actual soil nutrient levels. Further guidance on manure and effluent reuse is provided in the PMEMRG.

Not all of the nutrients in effluent and manure will be immediately available for plant uptake. For effluent, nutrient availability in the first year is typically 25-65% for nitrogen, 23-65% for phosphorus and 90% for potassium. Consequently, start-up fertiliser may need to be applied at planting, particularly in new reuse areas.

15.3 Secondary control measures

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, manure or compost 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 can also protect public health and livestock. Measures to further reduce nutrient loss and movement to the environment may include:

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

These measures effectively reduce nutrients leaving the farm by reducing soil erosion, filtering eroded soil from runoff or slowing the flow of runoff, allowing dissolved nutrients to be absorbed by the soil. 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 substitute for poor practices. They provide secondary environmental protection to complement sustainable reuse practices.

Secondary measures to protect public health and livestock health include:

- separation distances to sensitive land uses
- applying withholding periods between reuse and harvesting or grazing.

15.3.1 Vegetated filter strips

VFSs are strips of dense grass between reuse areas and protected areas. Section 7.2.2 provides design details for these.

15.3.2 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 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 to provide storage capacity for the collection of subsequent runoff.

15.3.3 Beds/constructed wetlands

Reed beds or constructed wetlands can be used to filter water and take up nutrients.

15.3.4 Contour 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 can 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.

15.3.5 Maintaining groundcover

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

15.3.6 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).

15.3.7 Separation distances to protect public health and livestock

Separating reuse areas and sensitive land uses and adopting good reuse practices will limit the pathogen risk during reuse.

15.3.8 Withholding periods to protect public health and livestoc

Ensuring a suitable withholding period (at least 21 days) between reuse and grazing or harvesting will minimise health risks when the crop is eaten. For further details, refer to the APL PMEMRG.

15.4 Off-farm reuse

Permissions or exemptions from the environmental regulator may be required for off-farm reuse. 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. Piggery operators have a duty of care concerning the effluent and manure products that go off-farm to third-party reusers. The PMEMRG and the companion *Piggery Manure and Effluent Reuse Glovebox Guide* (APL 2015d) provide more information to help with this.

If effluent or manure is provided to off-site users, record the:

- 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).

16 Mortalities management

Composting and rendering are the preferred methods for managing mortalities, stillborn piglets and afterbirth. Suitable alternatives may include incineration and burial, although these may require approval from the environmental regulator. Other methods that meet the environmental outcome may also be suitable. Irrespective of the method, dead pigs should be immediately removed from the access of other pigs, and disposed within 24 hours of death. If the property is also used for grazing stock, or has high feral animal numbers, the mortalities management area may need to be fenced to prevent their access.

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, public health concerns, vermin problems, and groundwater and surface water contamination.

16.1 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 liner that sits at least 2 m above the highest seasonal water table. A pad consisting of concrete or with an impermeable liner consisting of clay compacted for a design permeability of 1 x 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 Appendix 1 of the PMEMRG. Significant stormwater volumes caught within the composting area should be directed into the effluent ponds or other stormwater collection ponds.

Carcasses are generally composted in a series of above-ground bays or windrows. To size the pad, it is generally recommended to provide at least 4 m^3 of bay or windrow capacity for each tonne of carcasses. Ensure there will be sufficient space for vehicle manoeuvring between and around windrows. Grinding mortalities prior to composting is an emerging technology. This may significantly reduce both the quantity of co-composting material required and the size of the facility footprint. However, it carries inherent safety risks and suitable personal protective equipment must be used.

When the compost is reused, it should be spread evenly onto land at environmentally sustainable rates, adopting the same principles used for manure (see Section 14). Off-site reuse of mortalities compost may be subject to regulatory requirements in some states and territories. Ensure grazing does not occur within 21 days of reuse occurring. For further information, refer to the PMEMRG.

16.2 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 *Australian Standard for the Hygienic Rendering of Animal Products (AS 5008-2007) (Standards Australia 2007)*

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 compacted earth will be suitable. Guidance regarding earth pad preparation requirements can be obtained from Appendix 1 of the PMEMRG.

An agreement with the receiving company is needed to ensure regular receipt of carcasses. If daily collection is not possible, consider cold room storage. A contingency plan is needed in the event that the rendering plant is unable to receive mortalities.

16.3 Burial

Burial pits should be situated on low permeability soils 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. Carcasses must be covered with soil immediately after placement to prevent odour that may cause nuisance and attract scavengers. Earth should be mounded over filled pits to account for the subsidence that occurs as the bodies break down.

Above-ground burial may be an option for sites with shallow groundwater tables. The mortalities are placed in a shallow trench 0.5-0.6 m deep that is lined with a high carbon material (e.g. sawdust or straw). These are then covered with excavated soil.

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.

16.4. 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 1,000°C with a residence time of at least one second to incinerate the odorous gases that may result from the ignition of the carcasses. Emissions may need to be mitigated.

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

16.5 Mass mortalities contingency plan

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

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, off-site disposal may be mandated by a state veterinary officer or environmental regulator.

17 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 for the types of trucks that will access the site, safe property entry 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 should allow all vehicles to exit the property in a forward direction.

Environmental outcome: Safe all-weather access and suitable parking are provided.

Main roads and councils may have specific requirements for entry points, on-farm roads and parking.

To minimise the risk of noise nuisance, schedule traffic to occur during business hours where practical, noting that trucks may occasionally have to come outside these hours due to abnormal circumstances.

18 Landscaping

Landscaping can visually screen the piggery complex and other areas from nearby sensitive land uses and roads, removing the visual reminder of an odour, dust or noise source. It can also help protect native species and enhance habitats. Vegetative buffers with significant width may also filter odour and dust from the air and enhance odour and noise dispersion.

Take advantage of any existing vegetation and supplement it with additional plantings as needed. New plantings should be established early in the development phase. These should consist of a mix of indigenous shrub and tree species. Landcare groups and local native nurseries may be able to advise on species selection and plant care.

If available, borrow material excavated from the construction of effluent dams or ponds to create earthen banks for screening.

When locating buffers, be careful not to compromise airflow to naturally ventilated sheds in summer and provide sufficient space on the upwind side of the sheds. The use and height of banks may be limited in areas subject to inundation.

19 Public health considerations

Environmental outcome: Piggeries are sited, designed and managed to minimise public health risks.

APL has investigated the pathogens present in pig effluent and the public health risks associated with effluent reuse (Blackall 2004, 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 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 ponds of 13 south-east Queensland piggeries identified low campylobacter counts in 11 final ponds, and low salmonella counts in only 3 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 irrigation aerosols.

Measures that minimise public health risks include:

- providing separation distances from the piggery complex and reuse areas to sensitive land uses
- selecting low-risk crops for reuse, for example avoiding human food crops that may be eaten raw or without processing
- selecting an effluent irrigation method that minimise aerosols (e.g. low pressure spray or droplet irrigation with application of effluent close to the ground)
- aging or composting manure prior to spreading to reduce pathogen loads
- avoiding spreading dry manure or compost to minimise dust production
- avoiding effluent, manure or compost reuse under weather conditions that may carry aerosols or dust to sensitive land uses
- ensuring a minimum 21 day withholding period between reuse and plant harvest for broadacre crops to allow for UV and wind penetration desiccation
- adhering to Freshcare Standards (for human food crops)
- using good reuse practices. Refer to the PMEMRG for guidance.

Alternative measures that meet the environmental outcome are also acceptable.

20 Environmental risk assessment

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

The purpose of an environmental risk assessment is to identify risks that a piggery development or existing farm may pose to the environment and then managing these to minimise the likelihood of harm. It must consider inter-related factors and how to minimise or mitigate all environmental risks through design, management or monitoring. A risk assessment provides opportunities to demonstrate that risk is being minimised, or to improve design or operation to further reduce risk.

An environmental risk assessment process involves:

- identifying the hazards or ways in which the piggery may pose an environmental risk. For example, an effluent pond spill could pose a risk of elevated nutrient levels in watercourses
- considering the level of consequence if the hazard were to occur (low, minor, moderate, major or severe)
- considering the likelihood of occurrence (rare, unlikely, possible, likely or and certain)
- evaluating the risk level (low, medium, high or extreme) in light of the consequences and likelihood. If the risk is low, the siting, design and management are acceptable. If the risk is medium, additional controls should be considered and implemented to try to reduce the risk to low. If the risk is high, additional controls must be implemented to reduce the risk. If the risk is extreme, additional controls must be implemented immediately. For existing farms, this could include ceasing some site activities
- re-evaluating the risk level with the new controls in place.

An example risk assessment process for piggeries is provided in Appendix B.

21 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 risk.

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. They may also conflict with land productivity.

Some 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 further investigate the result.

Electronic monitoring equipment can also be used for day-to-day management. Alerts for power, water, effluent system and reuse equipment failures can help to mitigate environmental harm.

Environmental outcome: Assessment of environmental performance and identification of environmental impacts through ongoing monitoring, evaluation of results and evaluation of the effectiveness of management strategies.

Appendix C provides detailed sampling protocols and methodology for surface water, groundwater and soils.

21.1 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 proactive responses to complaints, are fundamental to protecting community amenity.

21.1.1 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 specific 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 bothered. 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. A weather station may assist with management. Some automatic weather stations can send notifications to a phone or computer when the wind is blowing in a certain direction or above or below a trigger speed, allowing for proactive management. Keep neighbours informed if an activity will result in short-term increased odour, dust or noise. Encourage two-way dialogue and open, frank discussion.

21.1.2 Managing 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 concern 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. In particular, sheds, sumps, effluent ponds, composting, mortalities management and reuse areas may warrant investigation. 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 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 these when evaluating 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 and investigation.

21.1.3 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.

21.1.4 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. Regular checking for odour, dust and noise at the property boundaries may detect potential issues, allowing for corrective action to be taken before they create a problem.

21.2 Effluent, manure and compost for reuse

21.2.1 Effluent, manure and compost sampling

Effluent, manure and compost for reuse should be analysed annually before the main reuse period. The results should be used to determine reuse rates. Reuse rates should also be measured or estimated. Analysis results should also be provided to offsite reusers.

21.2.2 Effluent, manure and compost analysis parameters

Tables 21.1 and 21.2 provide the recommended monitoring parameters for effluent and manure and compost respectively.

Compost may also need to be tested to demonstrate pasteurisation and other properties. Additional parameters for compost are included in *Composts, Soil Conditioners and Mulches (AS 4454-2012)* (Standards Australia 2012).

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

Table 21.1 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	Measures of effluent salinity
Sodium	Measure of effluent salinity
Chloride	Measure of effluent salinity
SAR	Measure of effluent **sodicity**

TKN = total Kjeldahl nitrogen; SAR = **sodium absorption ratio**

Table 21.2 Recommended manure and compost 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
Copper	Measure of trace nutrient
Zinc	Measure of trace nutrient
Manganese	Measure of trace nutrient
Boron	Measure of trace nutrient

TKN = total Kjeldahl nitrogen

21.2.3 Evaluating effluent, manure and compost results

The analysis results should be used to determine reuse rates. The total quantity of nutrients in effluent, manure and compost, along with their availability for plant uptake or loss are both important. Not all nutrients will be immediately available for plant uptake. Start-up nutrients may need to be applied at planting, particularly in new reuse areas.

The EC of piggery effluent is dominated by ammonium, so 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 4 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). Sodium and chloride levels may provide useful information. strategies on an ongoing basis and adjusting if necessary.

21.3 Reuse monitoring

21.3.1 Effluent

It is necessary to measure the quantity of effluent irrigated to each paddock in order to calculate the nutrient addition rate.

A flow meter can accurately measure the effluent flow rate. In-line flow meters should be non-corrosive. 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 must 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. A plastic hose fitted over the nozzle and a 10 L bucket will help. For a sprayline, the outflow from at least 3 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.

21.3.2 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/1,000).

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 = 2,000 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 = 2,000 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 m^3/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.

21.3.3 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 PMEMRG 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 the:

- 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.

21.4 Soils

21.4.1 Soil sampling

There are many guides available for interpreting soil tests, but they mainly focus on the quantities of nutrients needed to grow good crops. The application of manure and effluent to reuse areas changes the properties of soils and can result in an excess or imbalance of nutrients or concerns like sodicity. A risk assessment can assess the likelihood of adverse impacts to the soils of reuse areas. Where the risk of soil-related impacts is low, and at least 3 years of annual monitoring shows the system is sustainable, representative soils from reuse areas should be tested at least every 3 years.

Where there is a medium risk of soil impacts, and at least 3 years' of monitoring data shows the system is sustainable, soils from reuse areas should be sampled and analysed at least every 2 years.

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

For sites that will be loaded with several years' crop phosphorus requirement in a single year, testing for phosphorus buffering index (PBI) is recommended. Refer to Section 15.2.6 for more detail.

Soil sampling should always occur at the same time of year. Prior to planting, as this provides the best information on soil nutrient status enabling decisions on appropriate nutrient application rates. Avoid sampling immediately after prolonged wet weather.

21.4.2 Soil sampling depths and analysis parameters

Table 21.3 shows the minimum recommended soil monitoring parameters. However, as spent bedding and sludge may contain high levels of zinc and copper (Wiedemann and Gould 2018) consider testing for these metals along with manganese and boron, particularly if the manure is being sold. Appendix D provides a suggested sampling methodology. Analysis results should be compared with the sustainability indicator limits given in Section 21.5.4. Where soil analysis results exceed these limits, further investigation is triggered to identify whether effluent or manure reuse is sustainable.

Table 21.3 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
ECse (can measure EC1:5 and convert to ECse)	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] 0.5-0.6 m or base of root zone for sandy soils	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
Chloride	0-0.1 m	Measure of soil salinity
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 Na is a measure of soil salinity

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.

21.4.3 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 by interfering with the availability of other nutrients 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.

Matching nutrient levels to crop requirements is consistent with good environmental practice. However, 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 and nutrient availability. Not all nutrients in effluent and manure will be immediately available for plant uptake; nutrient availability typically ranges from 25-65% for nitrogen, 23-65% for phosphorus and >90% for potassium (Wiedemann and Gould 2018). For this reason, higher total nutrient levels may be needed at the start of 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 before planting or the main reuse period.

As well as providing information for assessing environmental risk, soil testing prior to planting or before the main reuse period 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. 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.

21.4.3.1 Nitrogen

Nitrate-nitrogen is extremely mobile allowing for uptake by plants but also ready leaching. Additionally, high nitrate-nitrogen levels in the subsoil may pose a risk to groundwater quality. If soil nitrogen and nitrate-nitrogen leaching rates are high, soil acidification may occur.

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* (NHMRC and NRMMC 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 risk 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 (ANZECC and ARMCANZ 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) and the expected deep drainage
- 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 NO3-N in soil solution (see Table 21.4). 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 21.4. 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 21.1 is 4.5 mg/kg. Hence, depending on soil type, nitrate-nitrogen concentrations ranging from 1.2 mg NO3N/kg to 4.5 mg NO3N/kg 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 21.4 Nitrate-nitrogen concentrations corresponding to a soil solution concentration of 10 mg NO3N/L at field capacity

Soil Texture	Soil gravimetric moisture content at field capacity (g water/g soil)	Limiting soil nitrate- nitrogen concentration (mg NO3N/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.

21.4.3.2 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 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 PBI tests were useful for assessing the phosphorus status of the soil and the risk of off-site movement of dissolved and particulate phosphorus. The PBI measures the soils ability to store phosphorus. Soils with a high PBI can bind more of the phosphorus, making it unavailable for plant uptake but also for leaching. Clay soils typically have a higher PBI than sandy soils, although site-specific testing is needed. 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 3 levels of soil phosphorus status (low, medium, high), 2 levels of soil phosphorus sorption capacity based on PBI (low or moderate to high) and 3 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. 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 21.5.

Table 21.5 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 before the main crop growth period. Under highly productive agricultural systems, considerably higher levels would be expected during the crop production phase.

To investigate the 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 5 years with good agronomic practices is recommended.

21.4.3.3 Potassium

Using a simple mass balance approach, potassium is often determined to be the limiting nutrient for cropping systems that use piggery effluent. Since salinity would generally cause environmental problems before potassium on its own, it rarely needs to be 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.

21.4.3.4 Salts

Electrical conductivity (EC) and total dissolved solids (TDS) provide a partial indicator of soil salinity. EC and TDS 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 is taken up by plants.

Reuse areas should not show increases in soil salinity that pose a risk to 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 ECse of up to 1.9 ds/m fall into the 'very low' to 'low' salinity rating. Thereafter, any increase in ECse of 2.5 ds/m would shift the soil salinity rating by less than one salinity class. Consequently, triggers for further investigation or action include any ECse 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 ECse 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 before the start of the main growing season. ECse 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.

21.4.3.5 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 (gypsum or lime) is recommended where the topsoil ESP exceeds 6%, and strongly recommended where it exceeds 9%.

21.4.3.6 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).

21.5 Surface water

21.5.1 Surface water sampling

Surface water quality monitoring is rarely relevant to piggeries because they do not normally discharge to watercourses. However, in the event of an incident (e.g. effluent pond spill, runoff of irrigated effluent into watercourses) where there is a possibility of organic matter and nutrients entering watercourses, surface water testing may be appropriate. There is also a close link between alluvial groundwater and watercourses and shallow groundwater on sloping land may also be able to enter watercourses and other surface waters. If nearby shallow groundwater has elevated nutrient levels, surface water monitoring may sometimes be warranted.

Surface water quality monitoring would typically involve sampling and analysing any effluent or contaminated runoff entering a waterbody as well as water from 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. Affected water should not be used as a pig drinking water source until tested and deemed safe.

Appendix D provides suggested sampling protocols and methodology for surface waters. Environmental regulators may also have sampling methodologies and analysis requirements.

Surface water usage should be monitored.

21.5.2 Surface water analysis parameters

Typical analysis parameters include:

- total nitrogen
- total phosphorus
- EC or TDS
- pH
- BOD
- *E. coli*.

21.5.3 Evaluating surface water monitoring results

Resources for evaluating surface water monitoring results include the most current edition of:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2018)*
- *Australian Drinking Water Guidelines (NHMRC and NRMMC 2011).*

Comparison of nutrient, BOD and *E. coli* 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.

21.6 Groundwater

At many sites, groundwater quality 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.

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 due to the higher leaching risk (nutrients may move more quickly through light soil and into groundwater).

21.6.1 Groundwater sampling

Ideally, groundwater is monitored by comparing analysis results for water sampled from up-gradient and immediately down-gradient of the area/s of interest, which will often be the effluent treatment ponds or manure storages 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 or surface waterbodies. Consultation with a 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.

The groundwater sampling and testing frequency should match the risk but once or twice a year is typical.

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

21.6.2 Groundwater analysis parameters

Typical groundwater monitoring parameters include:

- depth to groundwater
- total nitrogen
- nitrate-nitrogen
- total phosphorus
- EC or TDS
- pH
- BOD
- *E. coli*.

21.6.3 Evaluating groundwater monitoring results

Comparison of water test results for 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.

21.7 Monitoring during the composting process

21.7.1 Compost sampling

Composting involves the active management of manure or spent bedding. Full details of the recommended composting process for manure and mortalities are provided in the PMEMRG. However, monitoring needs to be undertaken throughout the active stage to optimise the process. Measuring temperatures and evaluating moisture content at least every 3 to 7 days is recommended. The final product also needs to be tested to quantify nutrient levels and confirm it meets other standards. Appendix D provides a sampling methodology.

21.7.2 Composting analysis parameters

The key parameters to monitor during the composting process are:

- carbon to nitrogen ratio (C:N) of the feedstocks
- temperature throughout the process
- moisture throughout the process.

The C:N of the materials for composting is essential in optimising decomposition, conserving nitrogen and minimising odours. C:N can be measured or found in various literature sources.

It is necessary to monitor the temperature and moisture content throughout the process to ensure the pile is heating sufficiently and to allow adjustment of these parameters to ensure an effective process and a quality product. Testing the final product is also recommended. This may include chemical, microbial and other tests depending on how the product will be marketed.

21.7.3 Evaluating composting results

An initial C:N of 25-40:1 is desirable for effective composting.

The core temperature within composting piles should be sustained at 55-65°C for a minimum of 3 days prior to turning. Maintaining these high temperatures reduces both pathogen levels and weed seed viability.

The moisture content of the composting material can be assessed at the same time using a squeeze test. If the material can be formed into a ball from which only a few drops of moisture can be squeezed, the moisture content is likely within the desirable range (50-60%).

If the temperature and moisture content are outside the target ranges in Table 22.6, corrective action should be taken (refer to the PMEMRG).

Table 22.6 Recommended composting parameters

Parameter	Acceptable range	Optimum range
Carbon : Nitrogen (C:N) ratio	15-40:1	25-40:1
Moisture content (%)	45-65	50-60
Core temperature (°C)	40-65*	55-60

* temperatures below the optimal range may provide for effective decomposition but may be less effective at destroying pathogens and weed seeds.

21.8 Biogas systems

21.8.1 Biogas sampling

It is necessary to monitor biogas systems to ensure they are working effectively and optimally and to meet emissions reduction fund (ERF) obligations.

Monitoring for biogas systems may involve:

- sampling the influent and effluent
- measuring biogas production or amount of electricity generated
- any measurements required for an ERF project, which may include:
  - the proportion of methane in the biogas being produced
  - records that confirm when biogas use equipment (e.g. flare, biogas-fired hot water system) was operational during a particular monitoring time period.

Influent and effluent are sampled in the same way as effluent for reuse (refer to Appendix D).

Biogas production, electricity and equipment usage are measured with meters. Continuous data records are needed for ERF reporting.

Biogas composition can be measured using a pre-calibrated biogas composition meter. It is important to collect a representative sample. To do this, take the sample from biogas flowing within the pipeline to the use equipment (e.g. flare or generator). If biogas will be manually sampled, a tap-off point should be installed on the biogas pipeline. Because biogas contains highly toxic (potentially fatal) gases, the tap-off point must be situated in a well-ventilated location and have a fine-gauge shut-off valve to minimise the flow of biogas. Some biogas composition meters (e.g. those with glass sorption tubes) are sensitive to the pressure of the biogas flow. The biogas should be collected into a bag specifically designed for the purpose. The meter is then connected to the bag. Applying light pressure to the bag allows gas to flow into the meter. In all cases, detailed instructions of the meter supplier should be followed.

Biogas composition should be measured at the frequency required for ERF reporting.

21.8.2 Monitoring parameters

Monitoring for biogas projects include:

- performance measurements, such as:
  - effluent pH
  - VS content in the effluent
  - volumetric production of biogas and/or amount of electricity generated
- measurements required of an ERF project where relevant. These could include:
  - the proportion of methane in the biogas produced
  - measurement records that indicate whether biogas use equipment was operational during a particular monitoring time period.

An example of instrumentation for monitoring biogas systems was outlined in Skerman and Tait (2019).

21.8.3 Evaluating results for biogas systems

A pH range of 6.8-7.8 indicates typical operation for a biogas system, whereas a pH falling outside of this range could indicate that the anaerobic digestion system is not performing optimally or is under stress.

The VS to TS ratio in the effluent varies between systems and may require expert interpretation. Generally, values less than 0.65 indicate that manure organic matter is being efficiently converted into biogas.

Biogas production is directly related to the amount of manure or co-digestion materials entering the biogas system. However, it typically takes 6-18 months for a new system to reach full operation depending on whether pond seeding was successful and whether or not any issues arose. If biogas production is substantially lower than the expected range, this could indicate inaccuracy in the load to the system. If biogas production is substantially higher than the expected range, this could indicate that extra organic matter is being added, biogas is elevated seasonally or inaccuracies in the inflow estimate.

The methane content in biogas can vary depending on inputs (e.g. by-products) but should be at least 50% by volume and should generally be between 60 and 75%. Values of less than 50% could indicate a significant leak, or stressed digestion microbiology. Values exceeding 75%, while atypical do not necessarily represent a process concern, but may indicate that meter calibration is required.

21.9 National pollutant inventory reporting

Operators of indoor piggeries 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 1,100-1,200 SPU is likely to trigger responsibilities for reporting ammonia. A deep litter piggery that stockpiles spent bedding on-farm is likely to trigger reporting responsibilities at a capacity of about 2,000 SPU, while one that sends the spent bedding off-farm without storage triggers report at a capacity of about 7,100 SPU.

To access the current technical manual, go to: https://www.dcceew.gov.au/environment/protection/npi/reporting/industry-reporting-materials/emission-estimation-technique-manuals/emission-estimation-technique-manual-intensive-livestock-pig-farming-version-20

NPI emissions are reported to the NPI office in the applicable state or territory. Refer to: https://www.dcceew.gov.au/environment/protection/npi/reporting.

22 Chemical use, storage and handling

Environmental outcome: Chemicals are used, stored and handled in ways that meet state requirements, and protect the community, air, water resources and soils.

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

- selecting chemicals with a low toxicity and low water contamination potential, where possible
- minimising the quantities of chemicals in storage and used
- storing and using chemicals and fuels in accordance with manufacturer's directions and workplace health and safety codes of practice
- having an emergency response plan and spill kits or absorbance material in place in case of a chemical spill
- storing and preparing chemicals in bunded areas with impermeable flooring
- correctly installing underground petroleum storage systems (UPSS) and ensuring these have an effective leak detection system
- using chemicals only for the intended purpose and in accordance with instructions
- ensuring fly and rodent baits are not accessible by pigs refer to the *Industry Rodenticide Stewardship Plan* (APL 2021)
- disposal of empty chemical/vaccine drums and containers in accordance with manufacturer’s instructions
- disposal of sharps in a suitable container and in an appropriate manner
- having material safety data sheets (MSDS) for all chemicals stored and used
- maintaining records of chemical use
- ensuring staff are suitably trained and hold current accreditation (where required) for the safe use and handling of chemicals
- providing staff with personal protective equipment to use when handling and using chemicals
- using accredited chemical contractors when required.

For further information on chemicals storage and handling see *The Storage and Handling of Agricultural and Veterinary Chemicals* (AS2507-1998) (Standards Australia 1998).

23 Environmental management plan

Environmental outcome: An EMP that identifies environmental risks and details how they will be monitored, managed and minimised.

An **environmental management plan** (EMP) focuses on the environmental risks of the whole farm and how they will be monitored, managed and minimised. An EMP is recommended for all piggeries as it helps to manage risk and demonstrates that the operator is operating 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 specify actions that will be undertaken to further reduce risk.

An EMP is not a static document. It provides for dynamic, adaptive management and should encourage continuous improvement. It includes the monitoring and feedback loops that provide assurances that environmental risks 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 under the same ownership and the surrounding area. This should cover:
  - the location of nearby sensitive land uses (e.g. houses, rural residential areas and towns)
  - soil type and properties
  - proximity to watercourses and sensitivity of same
  - depth, vulnerability and quality of groundwater
  - native vegetation
  - areas of cultural heritage sensitivity

- description of the design and operation of the piggery including manure and effluent management, nutrient management plan and mortalities management
- identification of environmental risks and any mitigation or management strategies
- identification of proposed monitoring
- chemical storage and monitoring
- biogas (if applicable)
- 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.

General guidance for each of these sections is contained in this document and the PMEMRG. Appendix B of the NEGIP provides a risk assessment process.

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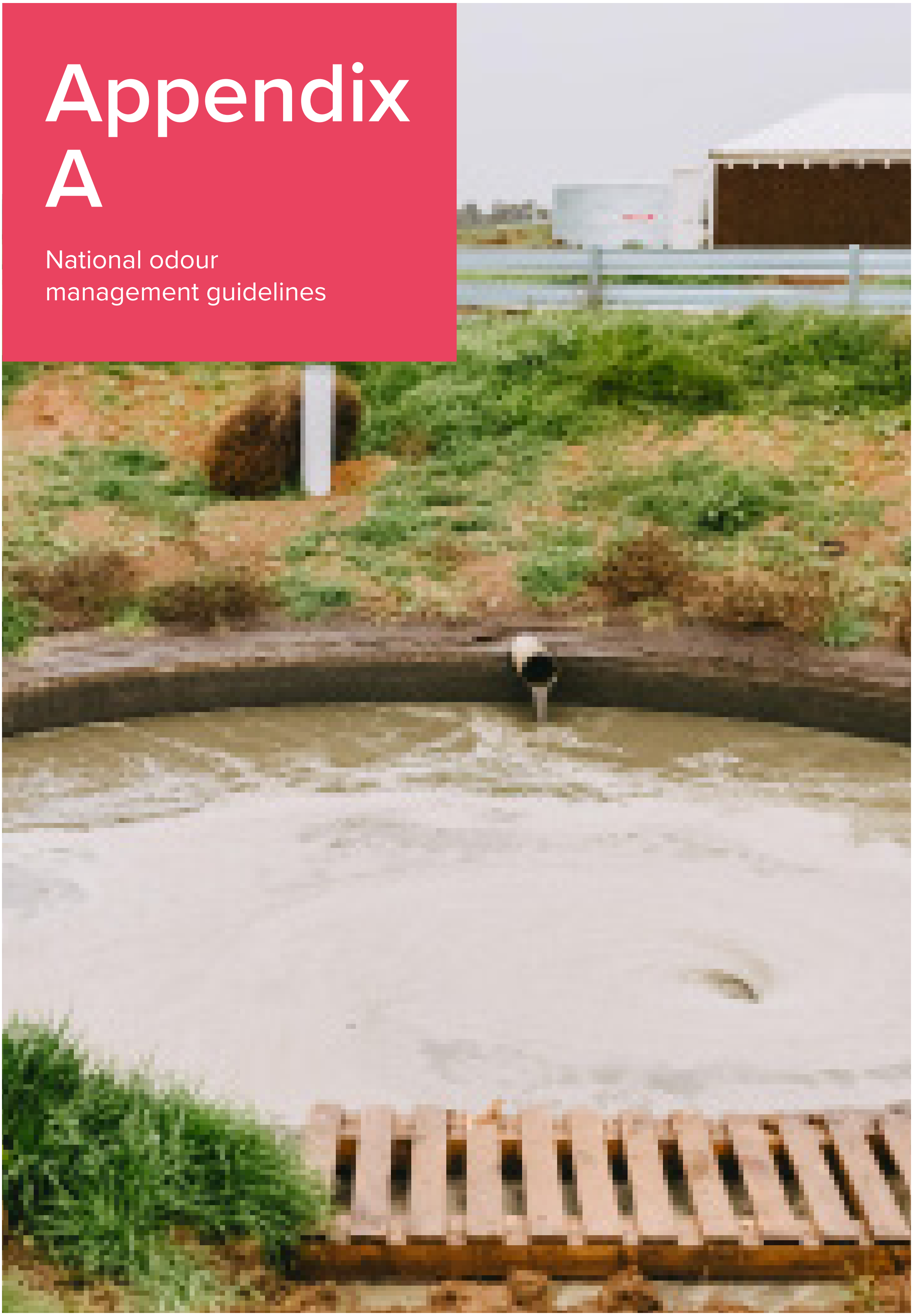
Appendix A

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 recognises the need to continually improve to meet 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 on industry research and represent the best available methodology for assessing potential odour risk from the information that is currently available.

Early contact with the relevant environmental regulator is recommended to confirm the appropriate assessment methodology to use.

In the absence of specific advice from the approved authority, these guidelines provide recommended methods to determine whether the provided separation distances are adequate to protect community amenity.

The separation distance methodology provided in this document is for new developments and expansions and not for retrospective application to existing piggeries.

A2 State legislation and guidelines

Each state of Australia has different legislation and guidelines of relevance for air quality. 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 for the Modelling and Assessment of Air Pollutants in New South Wales (NSW Environment Protection Authority, August 2022)

Technical Framework: 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)

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 2017

Guidance for Assessing Odour, EPA Victoria Publication 1883 (EPA Victoria 2022)

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, updated 2023)

A2.4 Western Australia

Environmental Protection Act 1986

Guideline: Odour Emissions (Department of Water and Environmental Regulation Western Australia 2019.

A2.5 Tasmania

The Environmental Management and Pollution Control Act 1994

Environment Protection Policy (Air Quality) 2004 (Environment Division, Department of Tourism, Arts and the Environment)

Tasmanian Planning Scheme – State Planning Provisions C9.0 Attenuation Code: 1 C9.0 Attenuation Code, (Government of Tasmania)

A3 Odour assessment process

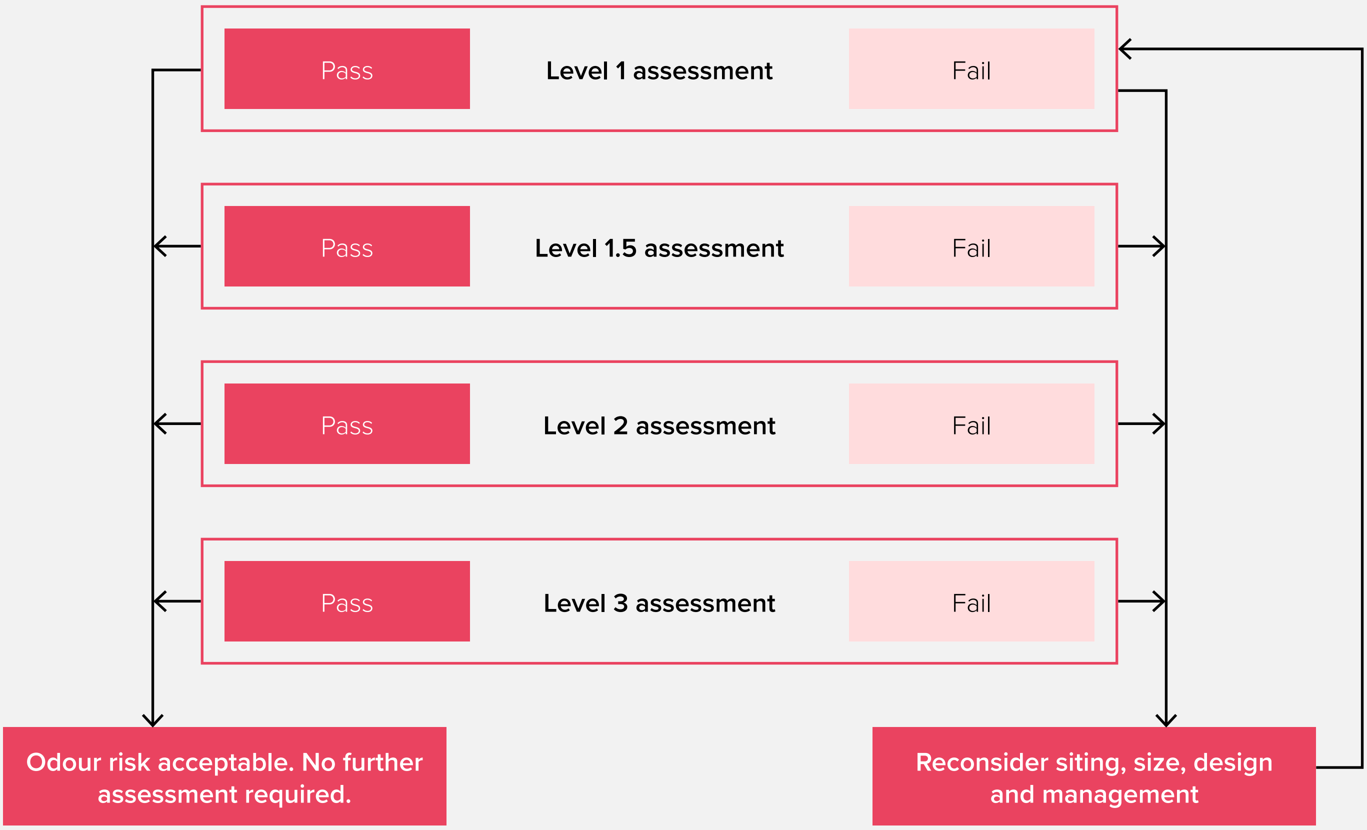
An odour assessment is used to establish whether odour generated by a piggery will have an unreasonable impact at off-site receptors. Odour nuisance may occur when the separation distances between a piggery and a receptor are less than those calculated using the methods set out here. A receptor is a sensitive location where people are likely to live or 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 most of sites. Three levels of assessment are outlined in these guidelines:

- Level 1 uses a standard formula and is suitable for all piggeries. Level 1.5 is a variation incorporating a wind frequency reduction factor.
- 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 of 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 risk using this approach. 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 risk 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 there is a need to revise the siting, scale, design or management of the proposal. However, it must be understood that some environmental regulators may have different requirements, particularly if the proposal does not pass a simple Level 1 assessment.

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 (reverse buffers).

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 risk from a proposed or expanding facility. They are not suitable to retrospectively assess the odour risk 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 risk 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 environmental regulator. It is also important to recognise that some environmental regulators have moved away from modelling as a primary odour risk assessment tool, preferring an evidence-based approach. This could include comparisons with similar operations, risk assessments, field odour surveillance data, complaint assessment, odour complaint case studies, community odour surveys or odour diaries. It is therefore essential to consult with the state environmental regulator before embarking on odour modelling.

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 3 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 that 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 Level 1 formula, with the addition of a wind frequency factor which incorporates wind speed and direction data that is representative of the site. This intermediate factor is designed to improve the prediction of risk, 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 using standard 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
- risk for receptors is not accurately represented by the Level 1 and Level 1.5 assessment (for example, prevailing winds may increase/decrease potential impacts at certain receptors).

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.

Complex models that are more able to account for complex terrain or meteorological conditions (i.e. **katabatic drift**, calm or frequent light winds), such as Calpuff, are usually more suitable than steady state models such as **AUSPLUME** or AERMOD. Consult with the relevant environmental regulator before selecting a model.

A3.4 Level 3 assessment

Level 3 odour modelling involves a comprehensive risk assessment, including 12 months of measured onsite 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
- odour emission rate data indicative of the proposal are not available and must be collected
- particular odour reduction strategies are used
- complex meteorological conditions exist.

The risk assessment may 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 would incorporate 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 an option for sites 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, more advanced models (e.g. CALPUFF) may be warranted. Consult with the relevant environmental regulator before selecting a model.

A3.5 Piggery definitions

Australian piggeries can be categorised as follows:

- Conventional piggeries
- Deep litter piggeries
- **Rotational outdoor piggeries**
- Feedlot outdoor piggeries
- A combination of types

Definitions for these types of piggeries are provided in section 5.2 of the National Environmental Guidelines for Indoor Piggeries. These odour guidelines are designed only for indoor piggeries with conventional or deep litter housing.

As rotational outdoor piggeries generally produce only low levels of odour, they do not need to meet site-specific separation distances and are not covered by these guidelines. Fixed separation distance requirements for rotational outdoor piggeries are provided in the *National Environmental Guidelines for Rotational Outdoor Piggeries* (NEGROP).

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 outdoor piggeries.

A4 Modelling protocols and parameters

Before undertaking an odour assessment, the data and methods should be discussed with the relevant environmental regulator. In particular, it is important to establish whether the regulator will accept odour modelling as a primary odour risk assessment tool.

A4.1 Model used

A model that accurately represents the dispersion process, particularly if there is complex terrain where calm winds may lead to katabatic drift, or when there are multiple odour sources, should be selected. Models such as CALPUFF are generally most suitable as they are able to account for most situations. Steady state models such as AUSPLUME or AERMOD are less flexible. An APL commissioned report provides guidance in the selection and use of odour dispersion models (Pacific Air and Environment, 2003b).

The relevant environmental regulator 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 one 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 (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 2021) for determining odour intensity. This type of study may be used in a Level 2 or a Level 3 assessment.

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. A very high percentile occurrence means that there will be 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, very stringent odour impact 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. Such impacts are more accurately represented by lower percentile occurrences.

These guidelines use a 98-percentile odour concentration occurrence to provide a representative 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 Average 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 a 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, 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 consider 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%, one hour average for a rural dwelling
- 2 OU, 98%, one hour average for a rural residential receptor
- 1 OU, 98%, one hour average for a town receptor.

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		

A4.7 Average time

High-quality Australian meteorological data are scarce outside the major population centres. 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) that can generate meteorological data files for dispersion modelling applications (Harris 2002). Also available are other newer models such as the Weather Research and Forecasting model (WRF) (https://www.mmm.ucar.edu/models/wrf).

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, 2 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.

Level 3 assessment require 12 months of data from an on-site 10 m weather station or stations.

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 (~100 m) for input into the model

A4.9 Risk assessment

During the initial stages of an odour risk 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:

- the 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 similar 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, the topography, 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 fixed 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 centre.

The fixed distances are included largely to account for inaccuracies with predicting odour risk at close distances. Both the site-specific and fixed separation distance to receptors must be calculated, and the greater distance of the 2 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 mortalities management sites. It does not include effluent or manure reuse areas since application of effluent and manure 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 the *National Environmental Guidelines for Indoor Piggeries* (NEGIP). 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
- piggery design, particularly the shed type and the effluent or manure removal and management processes used at the piggery
- piggery siting:
  - receptor type and location (e.g. town, rural residential, legal house)
  - topography between the piggery and the receptor
  - vegetation/surface roughness between the piggery complex and the receptor
  - terrain effects around the site, particularly the effects of terrain features on meteorology of the area
  - wind speed and direction (Level 1.5 only).

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 centres due to the higher population density in these areas. For Level 1, 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($S1$ = manure removal factor, $S1_R$ x manure management factor, $S1_M$)
S2	=	piggery siting factor for estimating the relative odour dispersion potential ($S2$ = 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

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 key factors limiting the number of pigs that can be accommodated on a particular site. Separation distances to all nearby receptors must be assessed; it is not always the closest receptor that limits the size of a piggery. Where other significant odour sources are located in proximity to the proposed piggery, the cumulative odour risk from both sites may need to be considered.

Table A.2 Summary of S factors for use with Level 1 calculations

Factor description **S1 Factor = Manure removal factor, $S1_R$* Manure management factor, $S1_M$**	**Value**
Effluent removal factor $S1_R$	
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
Manure management $S1_M$	
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 cover on primary pond	0.63
Impermeable cover on primary pond	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

Table continued		
S2 Factor = receptor type factor, $S2_R$ x surface roughness features factor, $S2_S$		
Receptor type		
Town		25
Rural residential area		15
Legal house		11.5
Surface roughness factor		
Limited ground cover, grass, few or no trees		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 number of SPUs is calculated using standard multipliers for each class of pig or Pigbal 4 modelling. Section 5.3 of the NEGIP provides details for determining the number of SPU.

A5.4 Piggery design factor, S1

A number of design factors influence the odour emissions from a piggery. The factors having the most influence on the site emissions are discussed below. It is assumed that the methods used for manure removal and management follow best practice as per NEGIP. A composite 'design factor' for the site is obtained by multiplying the manure management and removal factors together. The minimum composite S1 value allowed is 0.5.

Manure removal, $S1_R$

The manure removal factor accounts for the effect of the management of effluent within the piggery building on odour potential. 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, $S1_R$

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 manure 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 removal 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 one should be used. However, where pigs are held for >7 weeks but with higher bedding usage or partial clean-out of the sheds between full bedding replacements, a factor lower than one 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 one minus 75% of the odour emissions reduction. For a deep litter piggery with bedding replacement at least every 7 weeks, the reduction in shed odour emissions of 50% gives a factor of one – (75% of 50%) = 0.63. Where different building design or management practices exist within the piggery complex, the manure removal factor should be weighted according to the proportion of SPUs included in each management system. The manure removal factor could be adjusted if using new odour-reducing technology that can be demonstrated and quantified.

Manure management, $S1_M$

The manure management factor relates to the odour potential of piggeries based on the design of the effluent or spent bedding management system – the anaerobic pond for conventional shed systems and spent bedding management for deep litter systems.

These guidelines assume the piggery has a primary (anaerobic) effluent pond sized in accordance with the methods provided in the NEGIP. Where the pond volatile solids loading rate is significantly higher than this, the manure management factor may need to be altered accordingly. Nicholas et al. (2003) provides information for estimating the effect of different pond designs. Table A.4 lists manure management factors. For conventional piggery systems, these factors may change according to whether solids separation is used before the effluent pond.

Table A.4 Values of manure management factor, $S1_M$

Effluent management	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 on primary pond[b]	0.63
Impermeable pond cover on primary pond[c]	0.50
Deep litter system – spent bedding stockpiled/composted on-site	0.63
No effluent or manure management/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 on a primary pond assumes a consistent odour reduction of at least 75%.

[c] An impermeable pond cover on a primary pond assumes a 100% odour reduction from the primary effluent pond.

[d] No effluent or manure management 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 manure management 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 2 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 manure management factor should be weighted according to the number of SPUs included in each management system.

Where permeable pond covers are used, they are generally installed only over the primary (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 one – (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 one – (75% of 50%) = 0.63. If sludge is being regularly transferred from the covered pond to an uncovered pond or SEPS, it is important to ensure that the sludge has had sufficient residence time in the CAP. If this is not the case, for example if sludge is removed at intervals of less than 6 months, odour levels will likely be higher. In this instance, a higher factor should be used.

Piggery design factor, S1 summary

The 2 factors listed above provide the basis for estimating the relative odour potential for a piggery design. Multiplying these factors together gives a total piggery design factor (i.e. piggery design factor, S1 = effluent removal factor, S1R x effluent treatment factor, S1T).

Example calculation:

Consider a proposed 1,000-sow (10,000 SPU) farrow-to-finish piggery growing pigs out to 24 weeks. Breeder pigs (2,000 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; 1,500 SPU of pigs aged 3-12 weeks will be on a single batch of litter and 6,500 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 manure removal factor for the site, $S1_R$ is 0.7595 i.e:

(2,000 SPU/10,000 SPU x 1) + (1,500 SPU/10,000 SPU x 1.0) +

(6,500 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 manure management factor for the site, $S1_M$ = (2,000 SPU/10 000 SPU x 0.9) + (8,000 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 much smaller than it would be if all pigs were kept in conventional housing, substantially reducing the potential odour emissions from the site. The run-down screen also reduces the required pond size.

The minimum composite S1 factor for a site is 0.5.

A5.5 Piggery siting factor, S2

A number of piggery siting factors influence the dispersion of odour from a piggery. These factors differ from site to site and have a substantial influence on the odour risk 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 area	15
Legal house	11.5

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

The separation distance is measured to the closest extent of the town or rural residential zone. 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 legal house should be measured to the edge of the house or 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 should be considered. Local councils can provide this information. Public areas such as popular 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.

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 tree density not enough to provide a continuous canopy, but sufficiently dense to influence air movement. There would be little or no lower storey vegetation. The density is such that the vegetation can 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 design factorr, 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 since intervening surface roughness may vary in different directions.

Example calculation:

Consider the proposed 1,000-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 1,150 m to the north, another is 1,300 m to the north-east, another 1,700 m to the west and another 1,950 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 distances to the farmhouses have 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 3 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 and 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) is included since terrain has an important influence on odour dispersion. 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. 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 Weight Factor	
	Downslope	Upslope
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:

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° centred on the terrain feature. Upslope factors should be applied across an angle of 60o centred on the terrain feature.

The topography between the piggery and receptors should be considered. 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 depends on the consistency of the terrain between the 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:
$D = (10{,}000)^{0.55} \times 0.52 \times 12.5 \times 1 = 1{,}030$ 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 of these, 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 1,150 m to the north, 1,300 m to the north-east, 1,700 m to the west and 1,950 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:
$N = (8{,}000 / [0.52 \times 12.5 \times 1])^{1.82} = 420{,}844$ SPU

Maximum pig numbers (rural residential) for the site:
$N = (2{,}500 / [0.52 \times 7.5 \times 1])^{1.82} = 128{,}385$ SPU

Maximum pig numbers (legal house - north) for the site:
$N = (1{,}150 / [0.52 \times 8.05 \times 1])^{1.82} = 27{,}466$ SPU

Maximum pig numbers (legal house - west) for the site:
$N = (1{,}700 / [0.52 \times 11.5 \times 1])^{1.82} = 29{,}229$ S

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 Fixed separation distances

Minimum fixed separation distances are included largely to account for inaccuracies with predicting odour risk at close distances. Both the site-specific and fixed separation distance to receptors (town, rural residential area and rural dwelling) must be calculated, and the greater distance of the 2 applied.

The relevant approved authority should also be contacted in case they also have fixed separation distances for piggeries.

A5.8.1 Piggery complex separation

The recommended fixed separation distances for a piggery complex are shown in Table A.8.

A5.8.2 Separation distances from effluent and manure reuse areas

Fixed separation distances between reuse areas and receptors are not specified in these guidelines. Section 7.2 and Table 7.1 of the NEGIP include recommended buffer distances to major water supply storages and watercourses.

Table A.8 Fixed 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 2 applied.

A5.9 Level 1.5 assessments — wind frequency factor, S4

Tonkin Consulting (2008) developed a method for adjusting the Level 1 separation distances to account for prevailing wind directions and wind direction frequencies that was developed into an S4 factor used in the Level 1.5 assessment method.

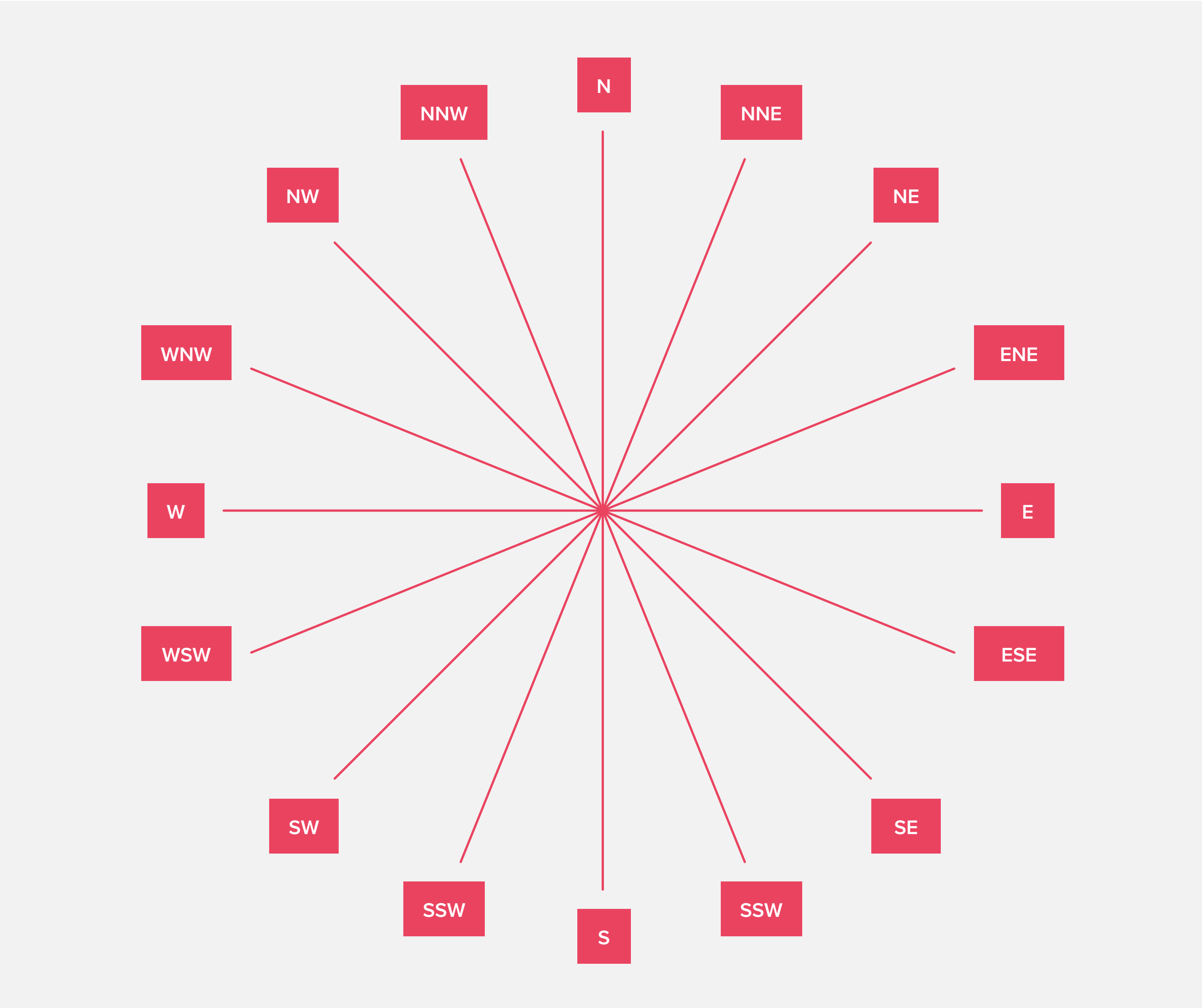
The S4 factor considers the frequency of winds in each compass direction (see Figure A.2), excluding winds with a speed exceeding 3 m/s. The dispersion conditions producing the greatest odour impact occur in low wind speed conditions. It is therefore necessary to properly account for these. The researchers used odour dispersion modelling (AUSPLUME) to find the optimum wind speed cut-off threshold. They compared the odour contours calculated using the wind direction frequency-adjusted separation distances to the contour for dispersion modelling for the 98th percentile and one hour averages. A cut-off threshold of 3 m/s presented the best match overall between the predicted odour contours for one OU, 2 OU and 3 OU and the wind direction frequency-adjusted Level 1 separation distances for the 3 receptor types described in Section A5.5.

The S4 factor used in a Level 1.5 assessment is determined by calculating the wind direction frequencies for the 16 compass points for wind speeds below 3 m/s threshold. Preparing the wind frequency data requires expert input.

For added conservatism, a safety factor of 20% is added to the calculated reduced separation distances to cover sites with lower average wind speed. The appropriate safety factor to use may varay, 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 distance in any direction to exceed the separation distances calculated 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. Calculate 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. Divide wind direction frequencies for each of the 16 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. Assign wind direction frequencies to N, NNE to SSW etc., to account for wind blowing from odour source (piggery) to impact area (downwind). The wind direction frequencies need to be switched 180° to account for winds blowing from source to receptor.
5. Present wind direction frequencies result percentages in table (see column 2 of example below – Table A.9).
6. Add a safety factor (agreed to by the applicable regulatory authority, but usually 20%) to the wind direction frequencies (see column 3 of example below – Table A.9). No value can exceed 100%.
7. Divide 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).

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
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) = N0.55 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 risk due to the frequency of wind direction for wind speeds less than 3 m/s for a site.

Example calculation:

Consider a 4,000 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, S1R = 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:

$D = (4{,}000)^{0.55} \times 0.63 \times 11.5 \times 1.0 = 694$ 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 4,000 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

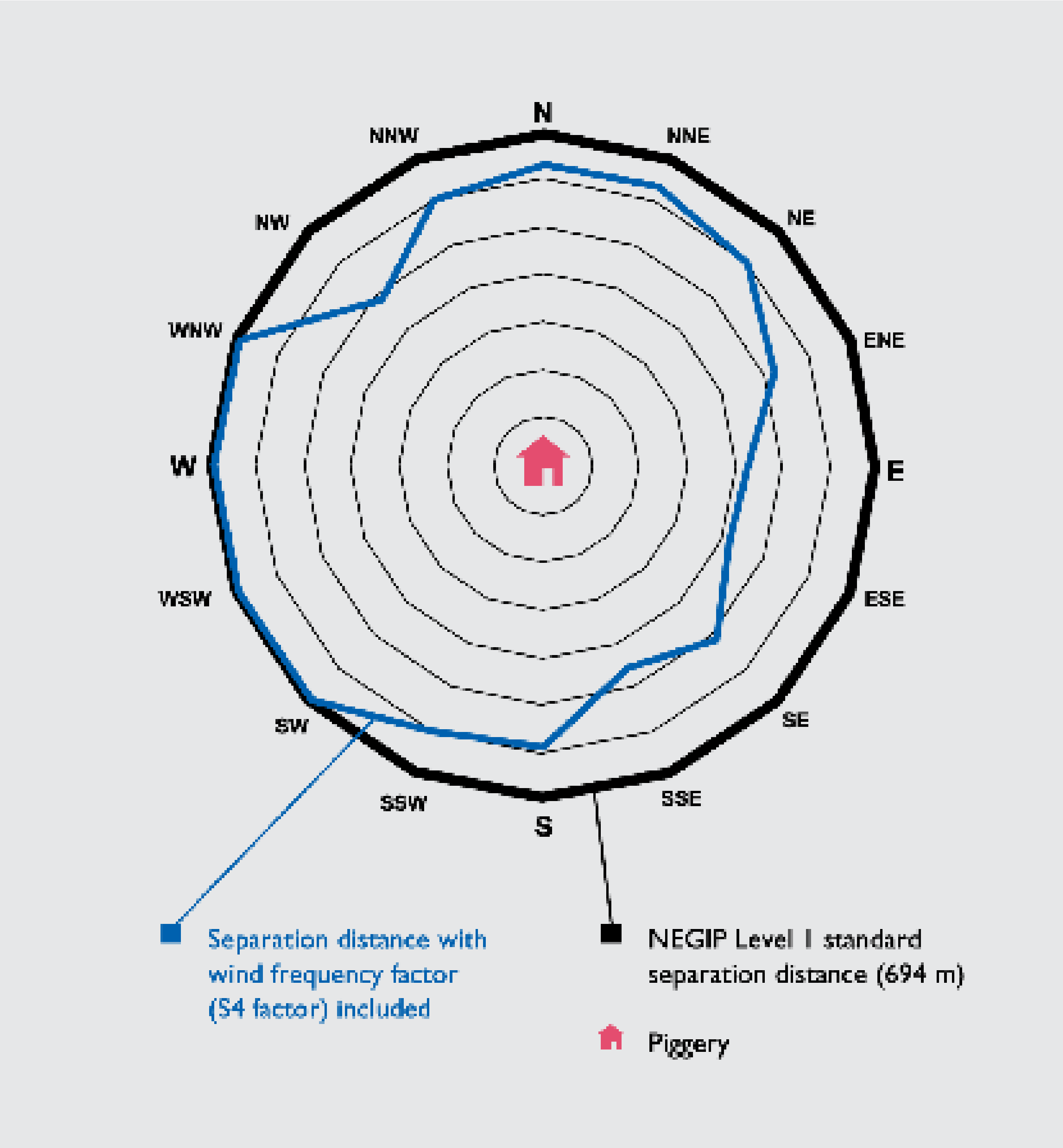


Table A.10 Wind frequency (S4) factors

Compass point direction	S4 Factors					
	Mt Gambier	Murray Bridge	Padthaway	Renmark	Roseworthy	Strathalbyn
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

A5.10 Assessing cumulative risk

Odours from intensive livestock facilities are 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 risk.

Meat & Livestock Australia (2012) developed a simple method of assessing cumulative odour risk for 2 intensive livestock facilities (e.g. 2 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 risk of 2 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 2 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 far enough apart to be considered different entities, but the available separation distance to the receptor is within 120% of the sum of the separation distances determined individually for the 2 facilities. See Figure A5.
- situations where 2 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 2 facilities. See Figure A6.

Figure A.4 shows 2 intensive livestock facilities treated as a single facility. The proposed piggery capacity is equivalent to the combined capacities of the 2 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 2 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 risk assessment is conservative. Receptors cannot sit within the calculated separation distances or within the overlap area of 120% of the separation distances.

Figure A.6 shows 2 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.

This method is not suitable for complex circumstances. For example, complex terrain or several facilities close together. For assessing risk in these situations, refer to Section A6.6.

Figure A.4 Two facilities treated as one facility

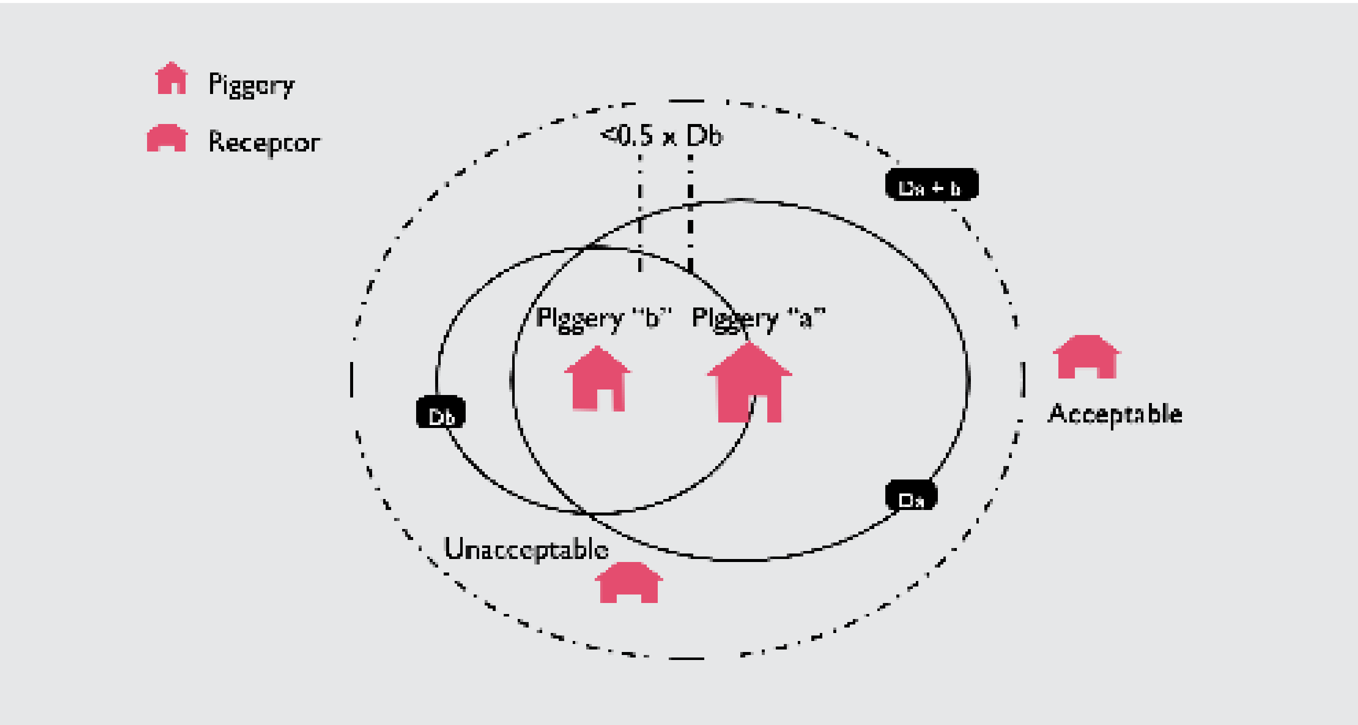


Figure A.5 Two facilities within 120% of the shortest individual separation distance

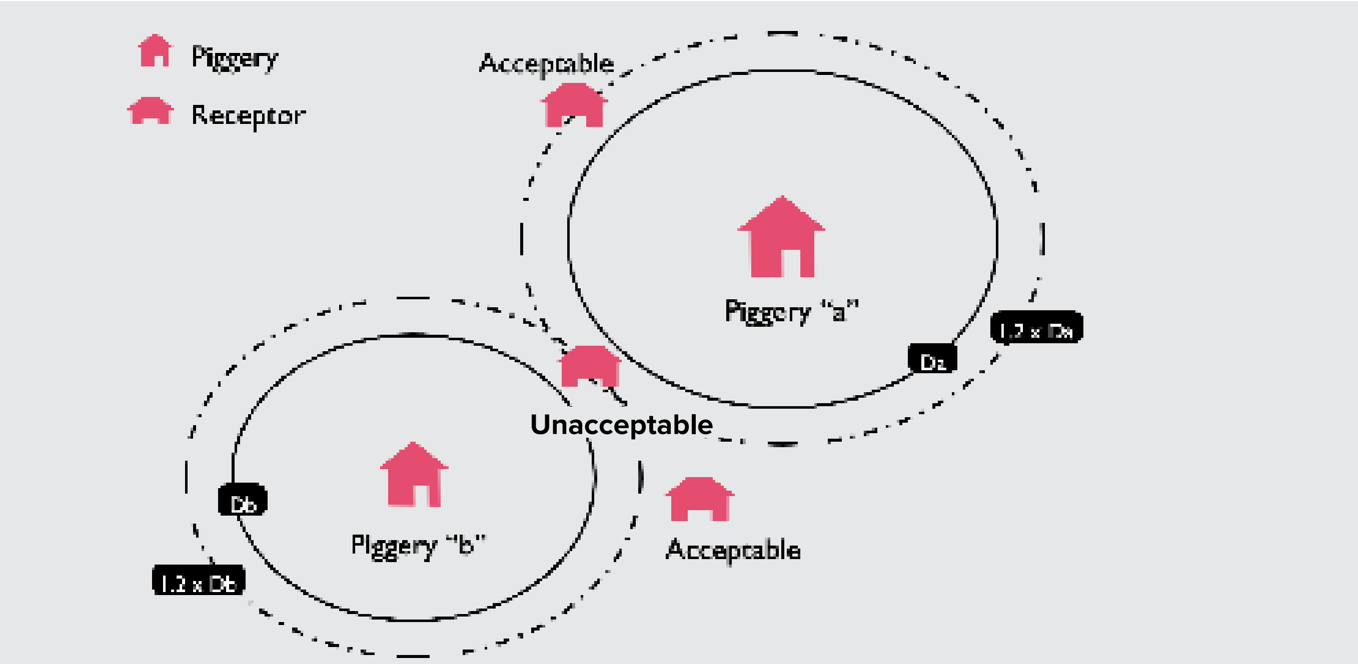
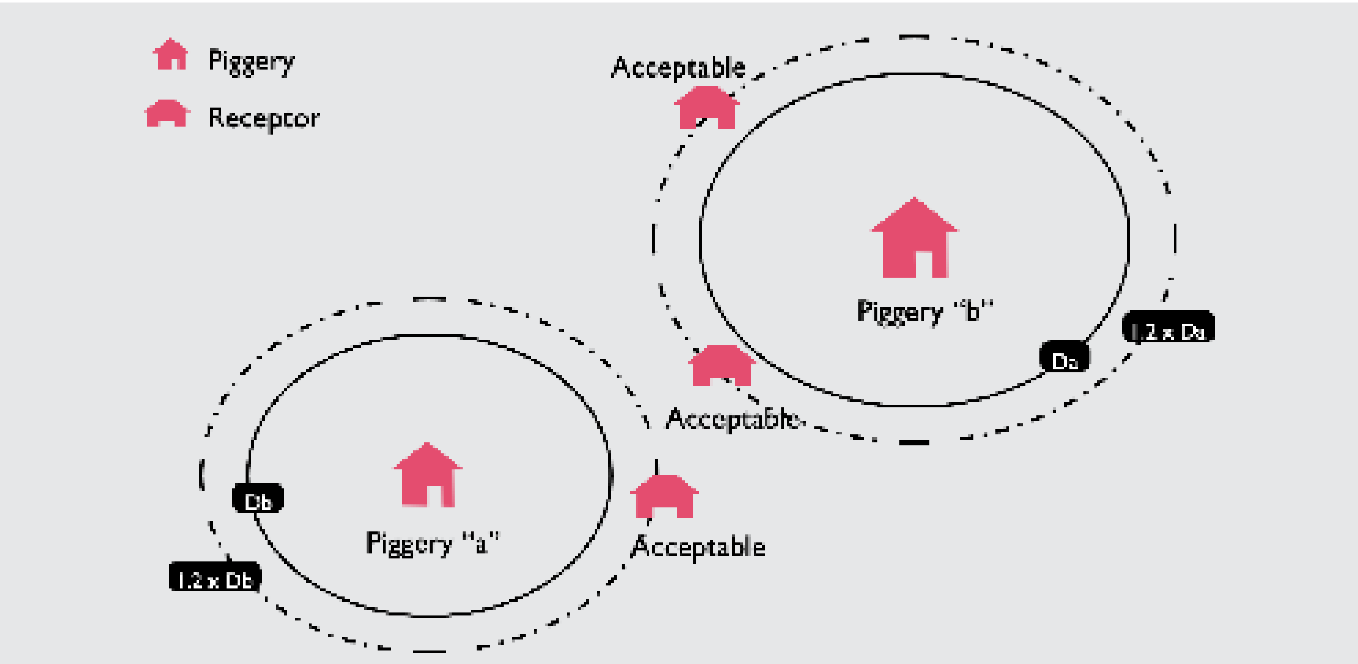


Figure A.6 Two facilities separated by more than 120% of the shortest individual separation distance



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

Whether it is necessary to consider other odour sources in modelling will need to be judged on a site-by-site basis. 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 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 risk from proposed expansions or new developments. The results of the dispersion modelling analysis can be used to develop management strategies that demonstrate that separation distances to sensitive land uses are sufficient. Dispersion models can also be used to estimate the cumulative risk 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' normal operating conditions are adequately represented in the model predictions. This requirement is especially important for determining and reporting odour performance criteria on a statistical basis. Meteorological data requirements are discussed further in Section A2.3.

In most cases, particularly where complex terrain exists, or where light winds need to be considered, models such as CALPUFF will be most 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).

As environmental regulators in some states and territories have moved away from modelling as a primary odour risk assessment tool, preferring an evidence-based approach, it is essential to consult with the state environmental regulator before embarking on odour modelling.

A6.2 Method

The general process for odour modelling:

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 at https://vefmaker.australianpork.com.au/, 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 legal houses, 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 environmental regulator.

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 ponds
- pig sheds.

The secondary odour sources for a conventional piggery are:

- effluent reuse areas
- manure reuse areas
- areas for managing of composting carcasses
- areas for storing or composting manure
- 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:

- areas for managing of composting carcasses
- areas for storing or composing manure
- spent bedding reuse areas.

Piggery layouts vary substantially between sites. In some cases, the sheds, effluent management systems and manure storage or composting areas are located in close proximity. At other sites, these facilities may be spread out. 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 and Standards New Zealand 2001).

The recommended odour emission rates from the APL 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 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 intermittent management events (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 risks through a site management plan.

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

For further guidance on sampling odours from area sources refer to *Stationary Source Emissions - Area Source Sampling - Flux Chamber Technique* (AS/NZS AS/NZS 4323.4:2009) (Standards Australia 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 ponds, it is recommended that odour samples be collected from a minimum of 6 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 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 and Standards New Zealand 2001), and then odour intensity to the German Standard (VDI 2021), 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 3 (‘distinct’) is used, but this value may vary depending on the averaging time percentile used in the odour impact criteria.

$$I = kw \log(C/Co) + const$$

I	**intensity (perceived strength), dimensionless**
kw	**Weber-Fechner constant**
C	**concentration of odorant**
Co	**concentration of odorant at the detection threshold (by definition equals one when using odour units)**
const	**a constant that 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.

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). The results are compared to an odour concentration at the receptor equivalent to an intensity level of 'weak' for the same averaging period and the same percentile 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, such as a time series plot, 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) that provides more detailed discussion on this topic.

For dispersion model, the meteorological parameters required include:

- 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. 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 2 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 2-level (e.g. 10 m and 1 m) tower 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 a reference to a publicly available report that contains this information. The description should include details on the methodology used to derive stability classes and mixing heights and 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 risk 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 of the site under investigation (e.g. wind speeds, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift).

A Level 3 odour risk 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) that 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 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).

A6.7 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 program objective so that an appropriate program structure can be developed. The objective should be stated and referenced when justifying the sampling method and modelling undertaken.

A6.7.3 Sampling program

Include the justification for the sampling method in relation to the measurement objective in the report. The sources sampled and the timing of sampling will depend on the objective of the measurement program. Source conditions at the time of sampling should be appropriate for the purposes of modelling. 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 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 to determine 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 preferred); 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 panellists 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 2021)
- 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 for 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.

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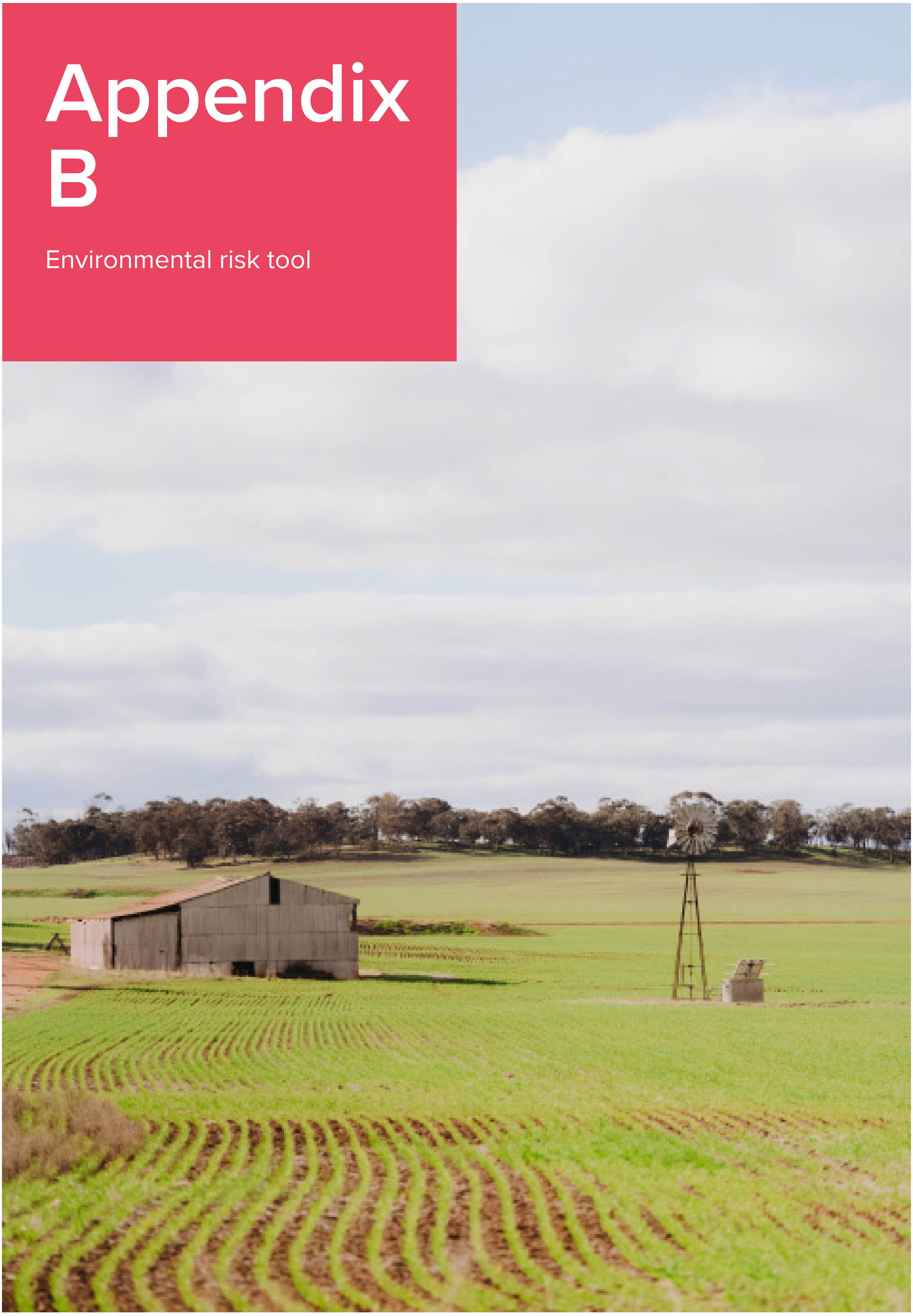
Appendix B

Environmental risk tool



B1 Introduction

An environmental risk assessment identifies any impacts or risks that a piggery or proposed piggery development may pose to the environment. It considers the likelihood and consequences of an impact occurring. This can help in selecting a suitable site and making design and operational decisions that reduce the likelihood of environmental harm.

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. The *Risk Management — Guidelines* (AS/NZS 31000:2018) (Standards Australia and Standards New Zealand 2018) provide further guidance.

Environmental risk assessment process

The steps in the environmental risk assessment process are described below, with 2 examples provided for each step.

B2.1 Process overview

Risk identification involves:

- identifying hazards
- considering the level of consequence if the hazard were to occur
- considering the likelihood of occurrence
- evaluating the risk level
- identifying practical controls that could be used to reduce risk
- re-evaluating the risk level with the new controls in place.

Figure B1 Summary of risk assessment process

B2.2 Hazards

Hazards are the ways in which the piggery may pose a risk to the environment or public health. For example, effluent might pose a hazard if it spills posing a risk of polluting a watercourse.

Common hazard categories could include the potential for risks from:

- effluent
- manure (including spent bedding)
- mortalities
- odour
- dust
- noise
- pathogens
- chemicals
- wastes (rubbish and sharps).

B2.3 Consequences

This involves considering the level of harm that could occur should the hazard eventuate.

Each consequence should be rated as low, minor, moderate, major or severe. When deciding the rating, consider the existing or planned siting, design or management.

Low	No or minimal environmental or public health impact.
Minor	Low environmental impact or potential for public health impacts. Examples include: • effluent spill that does not leave the property boundary or enter a watercourse • nuisance resulting in an isolated community complaint.
Moderate	Medium level of harm to the environment or public health over an extended period of time. Examples include: • contained off-site environmental incident (e.g. effluent spill on road) • nuisance resulting in repeated community complaints from one incident.
Major	Serious harm to the environment or public health. An environmental impact that is severe and likely to impact beyond the immediate site and remain a problem in the medium term. Examples include: • significant effluent spill into a watercourse • nuisance resulting in ongoing community complaints.
Severe	Something that causes permanent or long term serious environmental harm, life threatening or long term-harm to public health. Examples include: • significant volumes of effluent regularly entering a Ramsar wetland or potable water supply • worker death resulting from untrained staff working in a confined space or hitting overhead power lines with machinery.

B2.3.1 Risk likelihood factors

Next, evaluate the likelihood of the hazard eventuating.

Likelihood rating	Similarity
Rare	Could happen but probably never will
Unlikely	Not likely to happen in normal circumstances
Possible	May happen at some time
Likely	Expected to happen at some time
Certain	Expected to happen regularly under normal circumstances

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 5 years, the likelihood is “possible”. The risk is high. If controls were implemented to reduce the spill frequency to once every 10 years, the likelihood would change to “unlikely”. The risk is now medium.

Example 2

If spent bedding spreading occurs annually and results in odour nuisance complaints most of the time it is undertaken, the consequence is “minor” and the “likelihood” is likely. The risk is medium. If the spent bedding is aged before spreading and care is taken with scheduling spreading events, the complaints might reduce significantly (“unlikely” likelihood). The risk would reduce to low.

B2.4 Evaluating the risks

Use the risk rating matrix provided as Figure B.2 to rate the risk by considering consequence and likelihood together, where consequence x likelihood = risk rating.

Figure B.2: Risk rating matrix

Likelihood	Consequences				
	Insignificant	**Minor**	**Moderate**	**Major**	**Severe**
Certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

Example: moderate consequence x possible likelihood = medium risk.

The colour-coded output of the risk rating matrix identifies the overall level of risk:

- Low (green) – acceptable. The siting, design and management is acceptable. No corrective or preventative action is needed although further controls may be considered to further reduce risk if this can be done with little cost and effort.
- Medium (yellow) – at this risk level consider additional controls to reduce the risk to low.
- High (orange) – the risk is unacceptable. Risk will need to be mitigatedthrough the implementation of appropriate corrective or preventative actions.
- Extreme (red) – the risk is totally unacceptable. Immediate corrective or preventative action must be implemented which could include ceasing some site activities.

Figure B2.3: Risk action guide

Risk Level	Action
Extreme	Implement corrective or preventative actions immediately to lower the risk to an acceptable level, which could include ceasing some site activities.
High	Implement controls as a priority to reduce the level of risk.
Medium	Additional controls should be considered and implemented to reduce the level of risk.
Low	No additional controls are needed although controls could be implemented to further minimise risk.

B2.5 Identifying practical controls

Where a risk needs to be addressed, consider the causes and use these to identify options to minimise the risk to the extent that is reasonably practicable taking into account effectiveness, feasibility andcost. This could be achieved by eliminating or reducing the hazard consequence or the likelihood. Controls could involve changes to siting, design or management. For example, a risk to a watercourse could be reduced by relocating facilities or activities further away. A risk to groundwater from a manure storage area could be mitigated by constructing a bunded, impermeable pad for this activity. Odour nuisance could be mitigated by only irrigating effluent under conditions likely to promote good odour dispersion.

B2.6 Re-evaluating risk

This step involves re-assessing the risks using the risk matrix to determine if the new controls will eliminate or lower the risk to an acceptable level. If not, the process should be repeated. This is illustrated in the Figure below. The first example could be for a proposed or existing piggery that has an acceptable level of risk (suitable controls). The second example shows an unacceptable level of risk that is re-evaluated considering new controls to reduce the risk.

Risk rating with proposed or current controls					
Hazard	**Description of risk**	**Current controls**	**Likelihood**	**Consequence**	**Risk rating**
Effluent	Overflow of effluent to a watercourse	Effluent pond designed in accordance with NEGIP and located 200 m from creek	Rare	Moderate	Low
Leachate from manure storage	Groundwater contamination with nutrients (light soil, shallow groundwater)	Manure stored in piles in paddock	Likely	Moderate	High
Risk rating after new controls					
Hazard	**Description of risk**	**New controls**	**Likelihood**	**Consequence**	**Risk rating**
Effluent	Overflow of effluent to a watercourse	None warranted			
Leachate from manure storage	Groundwater contamination with nutrients (light soil, shallow groundwater)	Bunded low permeable pad, capture of runoff	Rare	Moderate	Low

Guidance to assist in risk assessment

This section provides guidance to assist in the identification and assessment of common hazards that could occur at pig farms.

B3.1 Amenity and natural resources vulnerability

The purpose of this section is to identify sensitive land uses and naturalresources that might be at greater risk from hazards. It provides a way to assess 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 sensitive land uses and natural resources is supplied in Tables B3.1.1 and B3.1.2. Since it is not possible to represent all situations that will occur on all farms, discretion should be used when evaluating site vulnerability. For each parameter of relevance, consider which option best represents the piggery being assessed. The options are ordered from lowest to highest risk. Using the vulnerability templates will help pinpoint areas where better design and management may be needed to minimise risks to environment.

Example: A hazard could be effluent that is being irrigated onto land. The groundwater vulnerability table includes a range of depths to groundwater ranked from lowest risk (deep groundwater) to highest risk (shallow groundwater).
If the groundwater is present at a depth of greater than 20 m the risk is inherently lower than if it is less than 2 m below the ground surface.

B3.1.1 Vulnerability: soils of reuse areas

Criteria
Reuse areas are:
suited to growing a broad range of broad acre crops and pastures
suited to growing crops or pastures that can be cut and carted
unsuited to producing crops or pastures that can be cut and carted.
Reuse areas have a soil depth of:
at least 1 m
at least 0.75 m
at least 0.5 m
less than 0.5 m.
Reuse areas have soils that are:
well structured, non-rocky, non-saline and non-sodic
non-rocky, non-saline and non-sodic
rocky, saline or sodic.
Reuse areas have soils that are:
loam (25-30% clay) to medium clay (45-55% clay) in texture
sandy loam (10-25% clay) to heavy clay (>50% clay) in texture
sandy in texture.
Reuse areas are:
not prone to waterlogging
prone to waterlogging.
Reuse areas:
flood at a frequency of less than once every 10 years
flood at a frequency of less than once every 5 years
flood more than once every 5 years on average.
Reuse areas have slopes that promote:
infiltration, rather than runoff or erosion
runoff or erosion.

B3.1.2 Vulnerability: groundwater quality and availability areas

Criteria
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
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
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
sometimes present at a depth of less than 2 m below the ground surface or the base of any piggery infrastructure.
If groundwater is used in the piggery, there is:
ample allocation and supply that is of a suitable quality to meet requirements
sufficient allocation and supply that is of a suitable quality to meet requirements
marginal or insufficient allocation or supply (and no other water source), or the water is of a marginal quality to meet requirements.

B3.1.3 Vulnerability: surface water quality and availability

Criteria
The piggery is located:
at least 200 m from the closest watercourse
at least 100 m from the closest watercourse
within 100 m of the closest watercourse.
The piggery is located:
at least 800 m from the closest major water supply storage
within 800 m from the closest major water supply storage.
Reuse areas:
comply with the buffer distances specified in the NEGIP, and there are additional protection measures (e.g. VFS or terminal ponds) between these areas and the closest watercourses
comply with the buffer distances in the NEGIP
don't comply with the buffer distances in the NEGIP, but there are effective VFSs, terminal ponds or other protection measures between these areas and all watercourses
don't comply with the buffer distances in the NEGIP and there are insufficient water protection measures in place.
The piggery is located:
above the one-in-100-year flood line
above the one-in-50-year flood line
within the one-in-50-year flood line.
Reuse areas are located:
above the one-in-10-year flood line
above the one-in-5-year flood line
within the one-in-5-year flood line.
If surface water is used in the piggery, there is:
ample allocation and supply that is a suitable quality to meet requirements
marginal or insufficient allocation or supply (and no other water source) or the water is of a marginal quality to meet requirements.

B3.1.4 Vulnerability: community amenity

Criteria
The piggery has received:
no complaints from the public or regulators for at least 5 years
less than 2 complaints per year (on average) over the past 5 years
less than 4 complaints per year (on average) over the past 5 years
4 or more complaints per year (on average) over the past 5 years.
Levels of odour, dust and noise around the property boundary are:
checked at least weekly
checked at least monthly
checked occasionally
not routinely monitored.
Surrounding land is:
all designated rural, and is not designated for future development or rezoning
all designated rural, but some is designated for either future development or rezoning
not all designated rural.
The piggery is:
well concealed from roads and neighbours
fairly well concealed from roads and neighbours
partly concealed from roads and neighbours
clearly visible from roads and neighbours.
The entrance point to farm provides:
at least 300 m good visibility in both directions
at least 200 m good visibility in both directions
at least 150 m good visibility in both directions
less than 150 m good visibility in at least one direction.
Vehicle movements and other noisy activities:
occur only during the day, except under exceptional circumstances
are generally scheduled to occur only during the day
occur at any time of the day or night.

B3.1.4 Vulnerability: community amenity (continued)

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

B3.2 Protection provided by design and management

The information in this section can be used to assess the risk mitigation 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 management system
- the manure storage/composting area
- 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. To evaluate the protection afforded by each element of design and management, read the statements and select the most appropriate one for the farm. These are ordered from lowest to highest risk. The guidance in these design and management templates can also be used to identify options to further reduce environmental risks.

B3.2.1 Design and management: pig housing

Criteria
Sheds:
are oriented east-west and are constructed to maintain temperatures within the required range with no mechanical heating or cooling
are oriented east-west and are constructed to maintain temperatures within the required range with minimal mechanical heating or cooling
are constructed to maintain temperatures within the required range but require significant mechanical heating or cooling to maintain temperatures at the required range
have a strong reliance on mechanical heating or cooling to maintain temperatures within the required range.
Sheds bases are:
concreted for conventional sheds and impervious for deep litter sheds (e.g. concreted or compacted for a permeability of 1 x 10-9 m/s for a depth of at least 300 mm)
formed from well-compacted clay or other low permeability material for deep litter sheds
not concreted for conventional sheds and / or not formed from low permeability material for deep litter sheds.
Feeding systems:
minimise feed wastage
rarely allow feed to be visible on the floor or in the bedding near the feeders
often allow significant quantities of waste feed to be visible on the floor or in the bedding near the feeders
significant quantities of waste feed are always visible on the floor or in the bedding near the feeders.
Naturally ventilated sheds are:
well ventilated, as the sheds are separated by a distance of at least 5 times their height
quite well ventilated, as the sheds are separated by a distance of at least 4 times their height
reasonably well ventilated, as the sheds separated by a distance of at least 3 times their height
not well ventilated.
Stocking densities:
meet the requirements of the *Model Code of Practice for the Welfare of Animals: Pigs*
do not meet the requirements of the *Model Code of Practice for the Welfare of Animals: Pigs.*

B3.2.1 Design and management: pig housing (continued)

Criteria
Conventional sheds are:
frequently cleaned to maintain very clean lanes, pens and handling areas and pigs are clean
regularly cleaned to maintain very clean lanes, pens and handling areas and pigs are generally clean
regularly cleaned but the lanes, pens and handling areas are often visibly dirty and generally some pigs are dirty
not regularly cleaned and pigs are generally dirty.
The bedding in deep litter sheds (except for dunging areas):
is always kept dry and friable and pigs are clean
is mostly kept dry and friable and pigs are generally clean
causes most pigs to be dirty towards shed clean out, because of its moisture content.
is frequently damp or wet and pigs are dirty.
The inflow or outflow of effluent from sheds is:
prevented by controls
mostly prevented by controls
not well controlled.
Water used to wash-down deep litter housing after spent bedding removal is:
always contained in a suitably sized sump or pond
mostly well contained in a suitably sized sump or pond
not well contained.

B3.2.2 Design and management: nutrient content of manure

Criteria
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
nutrients in the piggery effluent and manure used on-farm have been estimated using conservative figures in accepted industry nutrient mass balance models
nutrients in effluent and manure that will be applied to land on-farm are estimated using general data in publications
nutrients in effluent and manure are not generally measured or estimated.

B3.2.3 Design and management: effluent collection system

Criteria
Stormwater runoff, including roof runoff:
is excluded from entering the effluent collection system (or the system is designed to handle the runoff)
is mostly excluded from entering the effluent collection system, and the system does not generally overflow as a result
enters the effluent collection system, and the system sometimes overflows as a result
enters the effluent collection system, and the system often overflows as a result.
Effluent collection systems (e.g. channels, drains, pipes, sumps) for conventional sheds are:
impervious (no significant cracks) impervious and have good integrity (minimal cracking)
are pervious because they are not made from concrete (or similar), or because of deterioration of the material they are constructed from.
Effluent pits, sumps, pipes and drains are:
sized and managed so that they do not spill
sized and managed so that they only spill infrequently
inadequately sized or managed and spill at least once a year.
Effluent pits and drains:
are self-cleaning and manure solids are not present in these after flushing or draining
are not self-cleaning, but are cleaned at least weekly to remove manure solids
have manure solids present in them after flushing or draining that are removed at least monthly
have manure solids present in them after flushing or draining and these are removed less than once a month.
There are:
appropriate contingency measures to prevent spills from the system
contingency measures to prevent spills from the system, but these need improvement to reduce the spill frequency
no specific contingency measures to prevent spills from the system.

B3.2.3 Design and management effluent collection system (continued)

Criteria
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
at least every second day, and static pits and pull plugs are emptied at least every 2 to 3 weeks
at least twice a week, and static pits and pull plugs are emptied at least once every 4 weeks
less than twice a week, and static pits and pull plugs are emptied less than once every 4 weeks.
Drains, pits and sumps are:
inspected after each flush or draining for solids accumulation, leakage and deterioration
inspected after every second flush or draining for solids accumulation, leakage and deterioration
inspected at least monthly for solids accumulation, leakage and deterioration
not regularly inspected for solids accumulation, leakage and deterioration
contingency measures to prevent spills from the system, but these need improvement to reduce the spill frequency
no specific contingency measures to prevent spills from the system.

B3.2.4 Design and management: effluent solids separation system

Criteria
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 x 10-9 m/s, or other impervious material (e.g. concrete)
a well compacted base
an uncompacted base.
The solids separation system (including any associated storage areas):
sits within a controlled drainage area, and there is no uncontrolled outflow of effluent
does not sit within a controlled drainage area, or there is uncontrolled outflow of effluent.
Effluent from the solids separation system and associated storage areas is:
directed to a storage designed to cater for this inflow
directed to a storage
not directed to a storage.
The out-loading bay, where present:
is kept clean of excess solids; there is no significant spillage from transport vehicles
is generally kept clean of accumulated solids; significant spillage from transport vehicles happens less than once a year on average
frequently contains accumulated solids, or there is significant spillage from transport vehicles twice a year on average
generally contains accumulated solids, or there is significant spillage from transport vehicles more than once every 6 months on average.
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
checked at least weekly and cleaned or maintained as needed to ensure it is performing to the design specification
checked at least fortnightly and cleaned or maintained as needed to ensure it is performing to the design specification
not checked and cleaned or maintained at least fortnight.

B3.2.5 Design and management: effluent management system

Criteria
The effluent management 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
is designed to capture and store all effluent. However, treatment capacity is compromised because either the inlets and outlets are poorly positioned, or because significant isolated sections don't provide active treatment capacity
does not capture, effectively treat or store all effluent produced by the piggery.
The effluent management system:
is designed and managed such that odour emissions are acceptably low
sometimes produces strong odours, but these don't generally impact beyond the property boundary
produces strong odours that can be detected beyond the property boundary.
The effluent management system is:
designed to allow for ease of desludging, or to store at least 10 years' sludge
designed to store at least 5 years' sludge
designed to store at least 2 years' sludge
difficult to desludge and designed with less than 2 years' sludge storage capacity.
The effluent management system:
has a design permeability of 1 x 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
has a design permeability of 1 x 10-9 m/s for a depth of at least 300 mm of compacted clay
is lined with well compacted clay
is not lined with well compacted clay or a well-maintained impervious synthetic liner.
The depth to the water table from the base of the effluent management system is:
at least 2 m
sometimes less than 2 m.

B3.2.5 Design and management: effluent management system (continued)

Criteria
The depth to the water table from the base of the effluent management system is always:
at least 600 mm is provided on any effluent management system
less than 600 mm is provided on one or more effluent management system ponds.
The effluent ponds is designed for an overtopping frequency:
not exceeding one in 10 years where reuse is practiced, or not exceeding one in 20 years where effluent disposal is by evaporation
exceeding one in 10 years where reuse is practiced, or exceeding one in 20 years where effluent disposal is by evaporation.

B3.2.6 Design and management: manure storage

Criteria
Manure storage areas:
sit within a controlled drainage area, and all leachate is directed to effluent ponds, or storages designed to receive this inflow
sit within a controlled drainage area and leachate is directed to storages
are not within a controlled drainage area, or leachate is directed to effluent ponds not sized to receive this inflow.
The bases of manure storage areas are:
impervious (e.g. concrete or clay compacted for a design permeability of 1 x 10-9 m/s for a depth of 300 mm)
well compacted clay or other low permeability material
not built from well compacted clay or other low permeability material.
The depth to water tables beneath the base of manure storage areas:
exceeds 2 m at all times
may be less than 2 m at times.
Manure stockpiles/windrows are:
always managed to maintain low odour emissions
generally managed to maintain low odour emissions, but significant odour releases occur about once a year on average
generally managed to maintain low odour emissions, but significant odour releases occur up to 4 times a year on average
not managed to maintain low odour emissions, and significant odour releases occur more than 4 times a year on average.
Spilt or spoilt feed or leachate from wet feedstuffs is:
promptly cleaned up
cleaned up within 4 days
cleaned up within 7 days
frequently present in the mill area.

B3.2.7 Design and management: mortalities management

Criteria
Dead pigs are:
always removed from the sheds or pens within 12 hours of discovery
almost always removed from the sheds or pens daily
usually removed from the sheds or pens daily
frequently left in the sheds or pens for more than 24 hours.
Mortalities management (e.g. placement in a composting pile, burial etc.):
always occurs within 24 hours of death
always occurs within 36 hours of death
always occurs within 48 hours of death
does not always occur within 48 hours of death.
Mortalities management is by:
rendering or composting
burial in a clay-lined pit or proper incineration
burning or dumping.
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 1x10-9 for a depth of 300 mm)
always provide at least 2 m depth between base level and groundwater and are lined or built from compacted clay or gravel
sometimes provide less than 2 m depth between base level and groundwater or are not on a well-sealed site.
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
generally promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered
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.

B3.2.7 Design and management: mortalities management (continued)

Criteria
Where mortalities management is by composting, burial or burning this:
occurs within a controlled drainage area with stormwater diverted away from the area
does not occur within a controlled drainage.
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
a suitable site selected and a plan for managing mass mortalities including emergency contact details
a suitable site selected and a list of emergency contact details, but no real plan for managing mass mortalities
no site selected or plan for managing mass mortalities.

B3.2.8 Design and management: reuse areas

Criteria
The nutrients in effluent and 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
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
budgeted to ensure they are applied at rates that are based on nutrient removals by crop or pasture harvest using generic yields
are not budgeted using mass balance principles, or the recommendations from soil test results.
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)
minimised through good farming practices (e.g. conservation tillage)
not specifically prevented.
Effluent irrigation occurs:
only when the soil is dry enough to absorb the water and when rain is not expected
only when the soil is dry enough to absorb the water
irrespective of soil moisture conditions or expected weather conditions.

B3.2.8 Design and management rating: reuse areas (continued)

Criteria
Effluent and manure are spread:
evenly and at times when active plant growth is expected
evenly but not always at times when active growth is expected
somewhat unevenly, but generally only spread when active plant growth is expected
very unevenly or at times when active plant growth is not likely.
High-pressure irrigation guns that may create aerosols are:
not used
used.
Flood irrigation is used:
only on sites with an even grade and loam or heavier soils, and with good flow control and runoff collection
on sites with uneven grades and sand-sandy loam soils or inadequate flow control and runoff collection.
Effluent and manure are:
only irrigated/spread when weather conditions are conducive to odour dispersion, and not on weekends or public holidays
generally only irrigated/spread when weather conditions are conducive to odour dispersion, and not normally on weekends or public holidays
irrigated/spread at any time of the day, but not normally on weekends or public holidays
irrigated/spread at any time of the day, or commonly on weekends or public holidays.
Soils of reuse areas are:
tested at least annually, and the results considered when determining future reuse rates
tested at least annually
regularly tested
not regularly tested.

B3.2.9 Design and management: chemical use and storage

Criteria
MSDSs, emergency response plans for spills and spill kits or suitable clean up equipment are:
provided for all chemicals used
not provided for all chemicals used.
Quantities of chemicals stored on-farm are:
minimised
not minimised.
Chemicals with a low toxicity and low water contamination potential are:
preferentially selected
not preferentially selected.
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
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.
Staff members are:
trained in the correct handling and use of all chemicals of relevance to their position
not trained in the correct handling and use of all chemicals of relevance to their position.
Empty container and sharps disposal is:
always in accordance with manufacturer’s instructions
generally in accordance with the manufacturer’s instructions
not generally in accordance with the manufacturer’s instructions.
Where there are underground petroleum storage systems (UPSs) on-site:
applicable regulatory requirements for monitoring are always followed
applicable regulatory requirements for monitoring are not followed.
Where chemical contractors are used:
only accredited contractors are engaged
accredited contractors are generally engaged
non-accredited contractors are commonly engaged.

Note that the information in this Appendix is designed to help in assessing the risk of environmental harm. It is not designed to provide a guide to risk in other areas (e.g. workplace health and safety).

References

Standards Australia (2018) *Risk Management - Guidelines* (AS31000: 2018), Standards Australia, Homebush

Appendix C

Complaints register

C1 Complaints register

The number of complaints received is an imprecise measure of community amenity impacts because complaints can be difficult to validate. However, a change in the people complaining, the number of complaints or 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.

Complaints 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 ☐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 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

D1 Introduction

This appendix details methods for collecting, storing, handling and treating samples of surface water, groundwater effluent, manure, compost, 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
- transport of samples to the laboratory
- sampling equipment
- sampling procedures: there are 2 main types of samples. A **grab sample** is a single sample collected at a particular time and place, which represents the composition of the material being sampled. Composite samples consist of multiple grab samples that are bulked together to provide a representative sample
- 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 or other permission.

In the absence of specific advice from the approved authority, the following guidelines may be used.

Always consider personal safety when sampling and use appropriate personal protective equipment.

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, using the same laboratory each year is recommended. Some regulators may also have specific laboratory testing method requirements, so it is important to check any requirements thoroughly. It is worth contacting the laboratory about 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 Sampling equipment

The sampling equipment that may be required is listed below:

- Appropriate sample containers and preservatives. For liquid samples 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. For soil, manure or compost, ziplock plastic bags are generally suitable. Paper bags are needed for plant tissue samples.
- Personal protection equipment (e.g. rubber gloves and face mask).
- If sampling surface waters, liquid sludge or effluent directly from a source: a sampling rod. A rod with a large clamp for holding the sampling container allows greater reach when sampling liquids. If a sampling rod is not used, the sample should be taken from upstream of the feet to ensure that disturbed sediment is not collected.
- If sampling from bores or piezometers: a sampling bailer or pump to draw water from the monitoring bores and a tape measure and plopper or fox whistle to determine depth to groundwater. 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.
- If sampling manure, compost or soils: equipment to collect the sample (e.g. shovel, auger, post hole digger, hydraulic soil sampling rig), trowel, clean plastic sheet, ruler or tape measure and clean buckets.
- Cheap, styrofoam coolers.
- Plenty of crushed ice to pack around the samples in the coolers.
- A waterproof pen to mark sample bottles.
- Waterproof tape to seal coolers.
- Analysis request forms.

D4 Recording of sampling details

At each sampling, record:

- the location and name of sampling site (e.g. piezometer 3, compost area)
- the date and time of day that sampling occurs
- weather conditions at the time of sampling
- for surface waters, a general description of the flow rate or approximate depth of water in dams or storages
- for groundwater, depth to groundwater
- the method of sampling (grab or composite samples)
- the name of the sampler
- the date and time of sample dispatch to laboratory
- a method for preserving samples (e.g. sample immediately put on ice in cooler)
- analysis parameters requested (keep a copy of the original analysis request forms).

D5 Surface water sampling

D5.1 Sampling location

Sampling sites must provide representative samples and need to be accessible. Discuss selected sampling locations with the relevant environmental 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 2 sampling points, samples should also be taken from the secondary watercourse, close to its junction with the watercourse of interest.

D5.2 Sampling procedure

In most states and territories, the environmental regulator will have a water sampling methodology that should be followed. In the absence of a suitable methodology, the following steps can be used:

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, 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 (from the sample bottles), sampling location, sampling date and analysis parameters.
3. Organise bottles and rods for sample collection. Composite samples consisting of 5 grab samples should be collected, particularly if there is little movement in the watercourse or for a dam. These should be collected using a sample bottle similar to the one that will be submitted to the laboratory. An equal sub-sample from each grab 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 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. For some samples (e.g. EC, pH, total **organic carbon** and BOD) the bottle 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 cooler, pack crushed ice completely around it and replace the cooler lid. Store the cooler 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 cooler, seal it with the waterproof tape. Do not put effluent samples in the same cooler as surface water samples. Put the sample analysis form in an envelope and tape firmly to the top of the cooler.
8. Arrange for sample delivery to the laboratory. Confirm that they have been received.

D6 Groundwater sampling

D6.1 Sampling location

If groundwater monitoring will 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 hydrogeologist, or specialist consultant, for advice on the location, installation and sampling of bores.

D6.2 Sampling procedure

In most states and territories, 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, telephone number, a unique sample number, 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, pumping several bore volumes from the casing is recommended to ensure stagnant water is not being sampled.

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.

4. 1-2 days before sampling, and then to allow it to refill. Allow the 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.
5. Measure the depth to groundwater.
6. Collect a grab sample using a bailer or pump.
7. 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 bottle 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.
8. Add any required preservative and replace the lid.
9. Immediately place the sample in an cooler, pack crushed ice completely around it and replace the cooler lid.
10. 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 the sample will be frozen. Do not freeze samples in a freezer used for food storage.
11. When all other surface water or groundwater samples have been added to the cooler, seal it with the waterproof tape. Do not put effluent samples in the same cooler as groundwater samples. Put the sample analysis form in an envelope and tape firmly to the top of the cooler.
12. Arrange for sample delivery to the laboratory. Confirm that they have been received.

D7 Effluent sampling

D7.1 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.

D7.2 Sampling procedure

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, telephone number, a unique sample number, 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 (from 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 10 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 directly 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 10 samples have been collected, 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 cooler, pack crushed ice completely around it and replace the cooler 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 the sample will be frozen. Do not freeze samples in a freezer used for food storage.
8. When all other effluent samples have been added to the cooler, seal it with the waterproof tape. Do not put clean water samples in the same cooler as effluent samples. Put the sample analysis form in an envelope and tape firmly to the top of the cooler.
9. Arrange for sample delivery to the laboratory. Confirm that they have been received.

D8 Manure and compost

D8.1 Sampling location

Separate samples are needed for each type of manure product. This could include screenings, sludge, spent bedding and compost.

If manure is stored or composted before reuse, then the stored or composted product would generally need to be analysed prior to reuse.

D8.2 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, 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, 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 10 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 or trowel to collect at least 10 cup-sized grab samples spread throughout the pile or from along the windrow or pile. Put each sample in the bucket and thoroughly mix with the garden trowel. Place about 4 cup-sized samples 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 the sample will be frozen. Do not freeze samples in a freezer used for food storage.
7. immediately place the sample in a cooler, pack crushed ice completely around it, replace the cooler lid and tape shut. Do not put any clean water samples in the same cooler. Put the completed sample analysis form in an envelope and tape firmly to the top of the cooler.
8. Arrange for sample delivery to the laboratory. Confirm that they have been received.

D9 Composting process

D9.1 Sampling location

Compost needs to be monitored during the process to ensure suitable temperatures are being maintained for a minimum of 3 days after turns. Windrow temperature is very dependent on the moisture content of the material. A minimum of 2 measurements should be taken per windrow or pile. For windrows greater than 10 m in length, temperature measurements should be taken every 10-15 m along the pile.

D9.2 Sampling procedure

1. To measure temperature, a 1 m long temperature probe or sensor should be inserted to a depth of 1 m half way up the pile to ensure the core temperature is recorded.
2. The moisture content is assessed at the same time using a squeeze test. This involves taking a handful of material and squeezing it. The sample should be collected from within the pile, not the surface, and this material may need to cool before it can be squeezed. If the material falls apart, cannot be formed into a ball and no water is released when a handful is squeezed, it is too dry. If it feels wet and drips water, the moisture content is likely took high. If it can be formed into a ball from which only a few drops of moisture can be squeezed, the moisture content is likely within the desirable range (50-60%).
3. Because composting material should sustain a minimum temperature of 55°C for at least 3 days after each turn, with 5 turns typically required, record keeping is important.

D10 Soils

D10.1 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.
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, 2 land uses on these areas and only one manure or effluent product used on farm, the number of soil sampling sites would be 2.

D10.2 Sampling procedure

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample bags with the enterprise name, telephone number, a unique sample number, the sampling location (e.g. Paddock 5), the sampling depths (e.g. 0-10 cm, 30-60 cm) and the date of sampling.
3. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (from on the sample bags), sampling location, sampling date and analysis parameters.
4. Collect samples. There is a range of acceptable soil sampling methods. These include variations on:
    - 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 as GPS coordinates, so the same sites can be used in subsequent years
    - 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
    - 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
    - random: samples are collected from random locations across the entire paddock. The number of samples required depends on the area of the paddock
    - in all cases, collection of 20 grab samples of top soil (0-0.1 m) and at least 5 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 sampling site, is recommended.

5. 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 as GPS coordinates so the same sites can be used in subsequent years.
6. As the samples are collected, 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 2 different types. Never mix soil layers (profiles) that are clearly different from each other (e.g. sand and clay loam).
7. Pour the mixed composite topsoil sample into a pile on the plastic sheet. Divide the pile into 4 quarters. Discard 3 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). Fill the sample bag and immediately place it in a cooler. Repeat the process for the subsoil samples. Do not put effluent samples in the same cooler as soil samples. Store the cooler in the shade.
8. When all of the samples have been added to the cooler, seal it with the waterproof tape.
9. Complete the analysis request forms and keep a copy. Put the sample analysis form in an envelope and tape firmly to the top of the cooler.
10. Arrange for sample delivery to the laboratory. Confirm that they have been received.
11. While sampling, 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 the 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.

D11 Plant tissue samples

Each time crops are harvested from reuse areas, the yield harvested should be recorded, and the dry matter yield and the approximate nitrogen and phosphorus removal rates 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 the 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 barley crop removes about 20 kg N/t and 2.5 kg P/t. Hence, the 3.5 t/ha crop will remove about 70 kg N/ha and 8.75 kg P/ha.

D11.1 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 several samples of freshly cut material.

D11.2 Sampling Procedure:

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample bags with the enterprise name, telephone number, a unique sample number, 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, collect at least 5 samples from the field bin. These should be placed in the bucket and thoroughly mixed with gloved hands. A subsample should then be used to fill the sample bag.
6. For hay or cut forage, collect 5 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 cooler 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 cooler.
10. Complete the analysis request forms and keep a copy. Place the original forms in an envelope. Firmly tape the envelope to the top of the cooler. Store the cooler in the shade.
11. Arrange for sample delivery to the laboratory. Confirm that they have been received.

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 tonne (t)	1000 kilograms (kg)	

Area		
1 square inch (in^2)	0.00065 square metres (m2)	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)	0.84m^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)	11 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
1ft^3 = 6.2 gallon (gal) 1gal = 0.16ft^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)	1 km = 0.6 mi

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

Other conversions

1ML	1,000,000 L = 1,000 m^3
1m^3	1000 L = 0.001 ML
1ML/ha	100 mm depth over 1 ha
ppm	mg/kg, mg/L
1mg/kg	1 kg/t
1mg/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	metre³ (m³)	inch³ (in³), foot³ (ft³)
Time	second (s)	
Velocity	metre/second (m/s)	foot/second (ft/s), miles/hour (mph)
Acceleration	metre/second² (m/s²)	inch/second² (in/s²), foot/second² (ft/s²)
Area	metre² (m²)	inch2 (in²), foot² (ft²)
Density	kilogram/metre³ (kg/m³)	pound mass/in³ (lbm/in³), pound mass/ft³ (lbm/ft³)
Force	newton (N [= kg-m/s²])	pound force (lb)
Pressure	pascal (Pa [= N/m²])	pound force/inch² (psi), pound force/foot² (lb/ft²)
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	µ

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	µS/m	mS/cm	uS/cm	TDS (mg/L)	meq/L
S/m	× 1	× 10	× 103	× 10^{6}	× 10	× 10^{4}		× 100
dS/m	× 0.1	× 1	× 100	× 10^{5}	× 1			× 10
mS/m	× 10^{-3}	× 0.01	× 1	× 10^{3}	× 0.01			× 0.1
uS/m	× 10^{-6}	× 10^{-5}	× 10^{-3}	× 1	× 10^{-5}			× 10^{-4}
mS/cm	× 10^{-3}	× 1	× 100	× 10^{5}	× 1			× 10
µS/cm	× 10^{-4}	× 10^{-3}	× 0.1	×100	× 10^{-3}			× 0.01
TDS (mg/L)	× 1.56 × 10^{-4}	× 1.56 × 10^{-3}	× 0.156	× 1.56 × 10^{-2}	× 1.56 × 10^{-3}	× 1.56	× 1	× 1.56 × 10^{-2}
meq/L	× 0.01	× 0.1	× 10	× 10^{4}	× 0.1			× 1

Glossary

Glossary

Ad libitum allowing pigs to eat an unrestricted amount of feed

Adult any pig over the age of 9 months

Amenity the comfortable enjoyment of life and property, particularly in terms of air quality (i.e. odour and dust), noise, lighting and visual appearance

Anaerobic pond or lagoon a pond that uses anaerobic microorganisms 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

APIQ✓® the Australian pork industry on-farm quality assurance program

AUSPLUME steady state Gaussian dispersion model

Available nutrient the portion of any element in the soil that can be readily absorbed and assimilated by growing plants

Background site a soil monitoring 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 9 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

Carbon cycling the way in which carbon circulates through the piggery system

Cation exchange capacity (CEC) the total of exchangeable cations that a soil can absorb

Composite sample sample consisting of multiple grab samples that are bulked together to provide a representative sample

Compost the controlled microbiological decomposition of organic materials under aerobic and thermophilic conditions

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, hosing or pressure washing

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 solids separation, or before is directed to ponds or irrigation

Electrical conductivity see salinity

Environmental management plan (EMP) plan focusing 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 risks of impacts are minimised; and processes for continual review and improvement

Erosion the wearing away of the land surface by rain or wind, removing soil from one point to another (for example gully, rill or sheet erosion)

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 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

General environmental duty a responsibility shared by all individuals and businesses for the actions taken that affect the environment whereby any activity that causes or is likely to cause environmental harm cannot be carried out unless all reasonable and practicable measures are taken to prevent or minimise the harm

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

Hydraulic load the input of water via precipitation and irrigation applications into a pond or onto land

Impermeable liner material to line drains, shed bases, manure storage pads, effluent ponds or other area where manure may be conveyed, stored or held that has a maximum permeability of 1 x 10-9 m/s. This could comprise of concrete, compacted clay or synthetic materials like high density polyethylene (HDPE) or polypropylene (PP). For specifications clay liners, refer to Appendix 1 of the PMEMRG

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 piggery system a production system where there is physical separation of the breeder, weaner and grower pigs. Typically piglets are weaned at 3-4 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

Nutrient accounting a technique used to quantify nutrient inputs, storage and outputs at a farm or paddock scale using a mass balance approach

Odour units 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, 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 8 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

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 centre 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 plants growing 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 able 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 centre. 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

Sedimentation and Evaporation Pond System (SEPS) an effluent management system consisting of 2 or 3 long, narrow, shallow, trafficable earthen channels, designed to settle out solids and store effluent. Each channel is designed to receive effluent for a 6 to 12 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 5 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

Stormwater surface runoff from rain and storms

Surface waters dams, impoundments, rivers, creeks and all watercourses

Sucker or suckling piglet a piglet between birth and weaning (i.e. and unweaned pig)

Swill prohibited pig feed that is illegal to feed in Australia as it poses a disease risk. It includes food scraps, bakery waste, restaurant waste, untreated used cooking oils or other food waste that contains or has come into contact with meat or meat products

Terminal pond a pond located below the pig paddocks that is sized and located to catch at least the first 12 mm of runoff from a paddock which may have a higher nutrient concentration than runoff received later in a large storm

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°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

Watbal a water balance model used to size the wet weather storage capacity of effluent ponds

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 liveweight. Weaners are typically aged from 3-4 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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