National Environmental Guidelines for Rotational Outdoor Piggeries (NEGROP)

Siting and Design

Australian Pork Limited

2025

AUSTRALIAN Pork®

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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 second edition of the *National Environmental Guidelines for Rotational Outdoor Piggeries* (NEGROP) provides a national approach to the environmental management of rotational outdoor piggeries. Although currently they are only a small proportion of Australian pork industry production, there is increasing interest in rotational outdoor piggery systems.

The NEGROP are science-based guidelines that have been updated to incorporate the latest research outcomes and regulatory changes. They include up-to-date best-practice environmental management including site selection, land and nutrient management for rotational outdoor piggeries. The guidelines also complement the industry's quality assurance program, APIQ✓®, which provides certification of rotational outdoor piggeries as Free Range (FR) or Outdoor Bred - Raised Indoors on Straw (OB).

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 NEGROP seek to provide an industry-specific, science-based approach to managing environmental risk. We encourage planners, state government departments and producers to utilise them to address individual site requirements.

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 NEGROP, in particular from state and territory government departments, researchers and producers from all major pig-producing states.

The NEGROP highlight the commitment of the pig industry to ensure all pig production - regardless of type and size - operates in an environmentally sustainable manner. The second edition of the NEGROP 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 *National Environmental Guidelines for Rotational Outdoor Piggeries (NEGROP) - Siting and Design*, Robyn Tucker and Janine Price. The significant contribution of the authors of the first edition, Robyn Tucker and Michael O'Keefe is also recognised. We also acknowledge the contributions made by APL staff, including Tanya Pittard and Gemma Wyburn.

The review of the NEGROP commenced with consultation with industry representatives, regulators and consultants. The broad support for the guidelines from all three groups across the country is very pleasing and reflects the high standard of the guidelines. The time and effort of these people in developing the second edition of these guidelines is also acknowledged.

Abbreviations

APL	Australian Pork Limited
APIQ✓®	Australian Pig Industry Quality Assurance Program
BOD	biochemical oxygen demand
CEC	**cation exchange capacity**
CHMP	cultural heritage management plan
CO_2-e	carbon dioxide equivalent
dB	decibels
DM	dry matter
dS/m	deciSiemens per metre
EC	electrical conductivity
ECse	electrical conductivity of a saturated soil extract
EM	electromagnetic
EMP	environmental management plan
ESP	exchangeable sodium percentage
FR	APIQ✓® free range
FS	fixed solids, also called ash
GED	general environmental duty
GHG	greenhouse gases
m/s	metre(s) per second
ML	megalitre
MSDS	material safety data sheet
NATA	National Association of Testing Authorities
N	nitrogen
NEGIP	National Environmental Guidelines for Indoor Piggeries
NEGROP	National Environmental Guidelines for Rotational Outdoor Piggeries
NO_3 or NO_3-	nitrate
NPI	National Pollutant Inventory
OB	APIQ✓®outdoor bred, raised indoors on straw
P	phosphorus
PBI	phosphorus buffering index
PMEMRG	Piggery Manure and Effluent Management and Reuse Guidelines
RAM	restricted animal material
SPU	standard pig unit
TDS	total dissolved solids
TS	total solids
UPSS	underground petroleum storage system
VFS	vegetated filter strip
VS	volatile solids

Scope

The *National Environmental Guidelines for Rotational Outdoor Piggeries* (NEGROP) provide prospective and existing pork producers with the necessary information to size, site, design and manage rotational outdoor piggeries in a way that protects community amenity, public health and natural resources.

The guidelines cover systems where the entire herd is kept outdoors (e.g. systems certified as Free Range (FR) under APIQ✓®). They also cover the outdoor component of an operation where pigs are kept both indoors and outdoors (e.g. systems certified as Outdoor Bred Raised Indoors on Straw (OB) under APIQ✓®). The guidelines do not cover feedlot outdoor piggeries, including piggeries where pigs are continuously accommodated in permanent outdoor enclosures that are not rotated. This includes fixed shelters or sheds with verandas or small pens.

Rotational outdoor piggeries keep pigs in paddocks with appropriate shelter and nutritionally balanced rations. This system poses different and sometimes higher environmental risks than indoor piggeries if not carefully designed and managed. Odour, dust and noise are rarely an issue, however, there may be an increased risk of nutrient overload in soils and subsequent leaching or runoff of nutrients, soil structural decline through compaction and soil erosion.

Nutrients not used by the animal are deposited onto the paddocks as manure and, to avoid excessive accumulation of nutrients in soils and potential leaching into groundwater or water courses, paddocks are rotated with a crop-forage-pasture phase. During the crop-forage-pasture phase, plant material is grown and harvested from the area to remove excess nutrients.

It is important to note that legislative and planning requirements override industry guidelines with states and territories legislating on matters related 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 to comply with relevant legislation specific to rotational outdoor piggeries.

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

These *National Environmental Guidelines for Rotational Outdoor Piggeries* (NEGROP) provide a general framework for good siting and environmental management of these systems. The document is made up of 6 parts:

SECTIONS 1-23

NEGROP – advice on siting, planning and managing rotational outdoor piggeries to minimise the risk of impacts to the environment

APPENDIX A

Environmental risk assessment - method for assessing the risk of impacts to the environment

APPENDIX B

Complaints register - example of a Complaints register that can be used to record and manage complaints

APPENDIX C

Sample collection and analysis - methods for collecting samples (e.g. soil, spent bedding and compost and surface water and groundwater) for analysis

APPENDIX D

Useful conversions - conversions that may be used in implementing the NEGROP

GLOSSARY

Definitions used in the NEGROP

Sections 1-23

NEGROP – advice on siting, planning and managing rotational outdoor piggeries to minimise the risk of environmental impact

1 Introduction

Maximising opportunities for industry growth is a strategic objective of Australian Pork Limited (APL). APL has developed these NEGROP to assist industry in developing and operating environmentally-sustainable rotational outdoor systems.

In a **rotational outdoor piggery**, the pigs are kept in paddocks with **shelter**. The use of the paddocks for pigs is rotated with a **crop-forage-pasture phase**. During the **pig phase**, the pigs are supplied with prepared feed that contains large amounts of nutrients. Nutrients not used by the animal are deposited onto the paddocks as **manure**. During the crop-forage-pasture phase, plant material is grown and harvested from the area to remove excess nutrients.

These guidelines are intended to promote a uniform approach to proposals for new developments and expansions nationally and help producers comply with licence and approval conditions, and help producers meet their general **environmental duty (GED**). GED is a responsibility shared by all individuals and businesses for actions taken that affect the environment. 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 risk of harm.

These NEGROP provide general guidance for **best practice environmental management** under the circumstances and conditions most commonly encountered. However, site-specific conditions, management and risks must be considered when applying these guidelines. Many aspects of best practice environmental management are interlinked and must be applied to the suite of considerations, not just to single issues, to optimise environmental performance. The objectives in these guidelines apply equally to all rotational outdoor piggeries.

These NEGROP are updated as significant new research or information emerges. They therefore represent the current state of knowledge on best practice environmental management for rotational outdoor piggeries in Australia.

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 local government areas. 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 and territory. These triggers are correct at the time of publication. However, proponents should consult their responsible authority (council) and the environmental regulator to confirm requirements.

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

State	Class	Requirement
Queensland	Intensive animal husbandry	Need for development approval depends on the 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 EPA development licence and an operating permit, or an exemption and operating permit. (Department of Agriculture and Fisheries: www.daf.qld.gov.au)
New South Wales	Intensive livestock agriculture	Development approval is required unless the piggery is under the size threshold specified in the local environmental plan (LEP) (usually 20 pigs but sometimes less) and meets other requirements. A council may also limit the number of is 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 proposal for >5000 pigs needs an EPA development licence (or exemption) prior to development 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)

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 proposals involving ≥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.

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

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

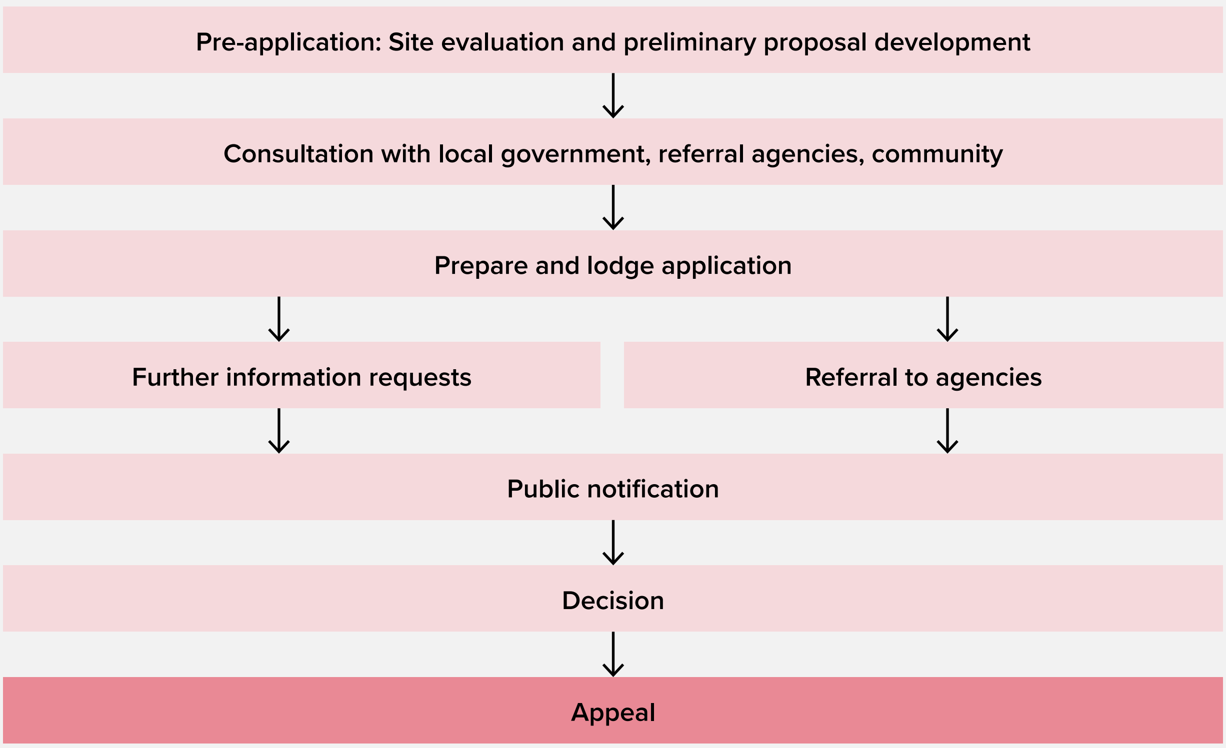


Figure 2.1 Generalised planning approval process

The same general process applies to a new piggery development, expansion or material change in use (e.g. the construction of a significant spent bedding storage area). The first step in the planning approval process 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, determination of required and available **separation distances** to sensitive land uses (e.g. residential zones and houses) and basic design concept (land area and any required infrastructure e.g. roads or permanent pipelines).

The recommended separation distances and **buffers** are addressed in Section 9 of these guidelines.

Communication and engagement with council, referral agencies and the community (particularly close neighbours) are important for a positive outcome. An on-site meeting with the responsible authority and any referral agencies is recommended to identify if the site is suitable and the major issues to be addressed in an application. Community consultation during the planning stage may identify other concerns and allow the proponent to address these in the application. For community consultation to be effective, it is important to structure the process to suit the individual situation. Consultation is mandatory in some states and territories when permission from an environmental regulator is required.

Referral to environmental agencies, water boards, state /territory 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.

It is recommended that applicants consult with the local community, particularly immediate neighbours, following the pre-lodgement meeting. This consultation is mandatory in some states and territories when permission from an environmental regulator is required.

The next step is to gather and compile the information that will support the application. Applicants must provide a detailed description of the proposal and proposed measures to mitigate risks. The NEGROP provide recommended siting and design information, while the *Piggery Manure and Effluent Management and Reuse Guidelines* (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 documentation are lodged, and the application fee paid, the assessment process will commence. This may involve a request for further information and referral to relevant agencies before the public notification (advertising) stage commences. Once the responsible authority has evaluated the proposal, taking into account submissions from referral agencies and others, a decision will be made. The applicant and any submitters then have the opportunity to appeal the decision.

Table 2.2 summarises the required information to accompany a planning application

Table 2.2 Information to accompany a planning application

Issues	Check
Applicant details	☐
Site description (including plans) and assessment	☐
Real property description	☐
Land tenure	☐
Land area	☐
Cadastral plan	☐

Land use zoning and planning overlays for subject property and surrounding land	☐
Climatic data	☐
Median annual rainfall	☐
Average monthly rainfall	☐
Rainfall intensity data (including one-in-20-year, 24-hour) (if **runoff** needs to be collected)	☐
Average monthly evaporation (if runoff needs to be collected)	☐
Seasonal wind speed and direction	☐
Description of soils, slope and **topography** of areas that will be used to keep pigs and any additional **reuse areas**. Include test results (if available) plus details of any structural or erosion issues	☐
Description of groundwater resources and geology of the site	☐
Details of any bores on the subject property	☐
Depth to groundwater and overlying geology	☐
Analysis of groundwater if it will be used in piggery	☐
Details of any groundwater licenses held	☐
Description of watercourses and other surface water resources on or near the property	☐
Details of any surface water licenses held	☐
Description of the current vegetation of the site, particularly any native vegetation including grasses. Extent of any proposed clearing, legal restrictions on any clearing and the visibility of the site beyond the property boundaries	☐
Identification of any items, sites or places that may have cultural heritage significance	☐
Description of current and past land uses	☐
Description of existing infrastructure that will be used in the development including on-farm roads, fences, powerlines, buildings, dams	☐
Description of the proposed piggery operation	☐
Total pig and **standard pig unit (SPU)** numbers	☐
Herd composition	☐
Annual production and stock movements including the numbers and weights of pigs expected to enter and exit the facility	☐
Description of piggery layout including total pig area, the area used by pigs at any one time (as part of the whole farm rotation), any permanent fence lines, infrastructure or other facilities and proposed vegetation plantings/screenings. Describe movable facilities including fences, shelters, **feeders** and water troughs	☐

Description of piggery management	☐
Feed requirements, sources and on-farm mixing and storage areas	☐
Water requirements for drinking, cooling and **wallows**	☐
Description of paddock management	☐
Measures proposed to retain groundcover	☐
Other measures to be used to prevent erosion from the pig paddocks (e.G. Contour banks)	☐
Planned paddock rotations	☐
Measures to promote more even distribution of manure nutrients (e.G. Regular movement of pig facilities within the paddocks)	☐
Nutrient budgeting considering nutrients added over the pig phase and removed over the planned crop-forage-pasture phase	☐
Description of mortalities management method, including plan for handling a mass mortalities event	☐
Staff numbers	☐
Estimated numbers of heavy vehicles and cars accessing the site each year and consideration of access and road safety	☐
Environmental impact assessment	☐
Community **amenity** impacts – evaluate the available separation distances to nearby houses, towns and other sensitive **receptors**. Assess whether there is a risk of significant impacts to amenity. If so, consider what changes in size, siting, design or management could minimise any significant risks.	☐
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 water impacts – evaluate the risk of surface water quality 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.	☐
Groundwater impacts – assess the risk of groundwater quality being impacted by the operation of the piggery. Consider how to change the size, siting, design or management of the piggery to minimise any significant risks.	☐
Vegetation impacts – assess the risk of impacts to significant vegetation. Consider protecting vulnerable trees, native grasses or habitats with fencing. Assess whether nutrients added to the paddocks might impact on native vegetation and propose protective measures.	☐
Consider any significant risks of impacts on items, sites or places of cultural heritage significance. If there is a significant risk, propose measures to minimise the risk.	☐

Identify and evaluate the risk of impacts to soils through **nutrient** addition, erosion and compaction. Consider how to change the size, siting, design or management of the piggery to minimise any significant risks.	☐
Summary of design and management features to minimise adverse amenity, public health and environmental impacts – summarise siting, design and management measures that will be used to minimise risks.	☐
Proposed environmental monitoring and reporting – where environmental risks exist, identify any environmental monitoring and reporting to measure and assess actual impacts.	☐
Environmental management plan (EMP) including a nutrient management plan (NMP) – an EMP focuses on the general management of the whole farm with special attention to the environment and associated risks. It should document design features and management practices, identify risks and mitigation strategies, include ongoing monitoring to ensure risks are minimised, and outline processes for continual review and improvement. An NMP focuses on the overall management of the nutrients on the farm. It should document the operation, propose a nutrient budget, evaluate how evenly manure nutrients are spread within pig paddocks, identify potential nutrient loss pathways and provide an action plan for managing the risks.	☐
Plans including:	☐
zoning plan – showing the land use zoning of the subject property and surrounding land	☐
topographic plan – showing watercourses and drainage location of nearby residences	☐
recent aerial photograph	☐
farm plan – showing current land location of any soil conservation or drainage works	☐
piggery layout plan – including location	☐
separation and **buffer distances** plan – showing perimeter of piggery complex* and separation distances to sensitive land uses e.g. houses and towns as well as buffers around sensitive natural resources.	☐

* A **piggery complex** includes:

- all paddocks or pens where pigs are housed
- adjoining or nearby areas where pigs are yarded, tended, loaded and unloaded
- adjacent areas where spent bedding, manure and runoff are accumulated or treated pending on-site reuse or transport off-site, including **terminal ponds**
- areas where pig-feeding facilities are maintained or areas where feed is prepared, handled or stored (including feedmills).

3 Environmental risk

In all Australian states and territories, everyone (including businesses) is subject to a general statutory duty to prevent environmental harm (GED). Good site selection and design reduces the inherent risk. However, all piggery operators must also operate their farms in a way that reduces the risk of harm to the environment 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 to reduce environmental risk and improve profitability.

These guidelines represent the current state of knowledge for the siting, design and management of piggeries in Australia to minimise the risk of environmental harm. 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. Designs or management not described in these guidelines that satisfy the environmental objectives and environmental outcomes may also be acceptable. Appendix A includes guidance to help producers identify and reduce their site-specific risks.

4 Environmental objectives

Environmental integrity is becoming increasingly important. 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 and public health impacts through odour nuisance, visual impacts, dust, flies, vermin, noise and pathogens
- maintain or improve the productive quality of soils during the pig and crop-forage-pasture phases considering nutrient levels, pH, **salinity**, **sodicity**, structure and **erosion**
- 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 greenhouse gas (GHG) emissions
- protect items, sites or places of heritage significance.

5 Amenity and environmental issues

Operators of rotational outdoor piggeries should integrate environmental considerations into all aspects of their siting, design and operation with the goal of minimising environmental risks. A summary of the most important amenity, public health and environmental issues applicable to rotational outdoor piggeries follows. The mitigation and management of these issues are covered in detail in Sections 8-23 of these guidelines.

5.1 Amenity and public health issues

Amenity refers to the comfortable enjoyment of life and property. People expect to enjoy their homes, work and the use of community areas. Amenity impacts sometimes associated with piggeries include odours, dust, noise, visual impacts, vermin, flies and pathogens. Amenity and public health risks are minimised by selecting a suitable site and layout, integrating best practice environmental management into the everyday operation of the piggery and providing adequate separation distances between the piggery complex and nearby sensitive land uses.

Rotational outdoor piggeries are very different from **indoor piggeries** (**conventional piggeries** and **deep litter piggeries**) and may pose different amenity risks.

5.1.1 Odour

Rotational outdoor piggeries generally produce very little odour compared with indoor systems. From odour research at Australian farms, emission rates from rotational outdoor pig farms were very low (study average of 0.036OU/m^2/s) compared to mean odour emissions measured from similar area sources (such as beef feedlot pens) (Banhazi 2013). Based on these results, the implementation of odour reduction strategies is not warranted for piggeries that are suitably sited and well managed.

5.1.2 Dust

Dust can be a physical irritant that poses a respiratory or allergenic risk for some. It may also carry pathogens. Bare paddocks in a rotational outdoor piggery can be a source of dust, although dust from these is unlikely to be worse than that from nearby cultivated paddocks. Traffic movements may also create dust.

APL research investigated dust levels at rotational outdoor piggeries (Banhazi 2013). Although, significant differences in dust concentrations were measured between different farms (p=0.049), all farms had very low dust levels (study average of 0.014 mg/m^3). Many of the peak concentrations were related to factors not directly associated with pig activity. One of the most frequent causes of high peak concentrations was tractor or machinery activities. These high peak concentrations typically lasted for a short period of time and the dust stirred up by machinery movement settled down quickly.

5.1.3 Noise

Most activities at rotational outdoor piggeries are not particularly noisy. In his Australian research, Banhazi (2013) found that noise levels did not vary significantly between farms (p=0.136), with mean levels ranging from 33 decibels (dB) to 41 dB. Most of the noise peaks were likely from machinery, but bird and insect noise also contributed to the general noise levels on farms. Additional observations indicated that wind and rain might contribute up to 10-15 dB to general noise levels. Very little vocalisation by pigs was observed during data recording. Given that 40 dB is typical of a quiet suburban environment, and 50 dB noise levels can be routinely measured in a typical home, it is highly unlikely that on-farm activities at rotational outdoor piggeries would cause noise nuisance.

Whether noise becomes a nuisance depends on the level and frequency of noisy activities, the distance between the noise source and sensitive receptors and the time of day the noise occurs. People living near piggeries may be more susceptible to noise during the early morning or night when they are trying to sleep. Noise from traffic movements should be managed through careful selection of traffic routes and scheduling of vehicle movements.

5.1.4 Visual impacts

The establishment of a rotational outdoor piggery may alter the landscape character, depending on its size, siting, design and management. If this is a concern, it can be managed through vegetative screening or landscaping.

5.1.5 Flies, vermin and pathogens

Rotational outdoor piggeries may attract flies, rodents, predators and wild pigs. There is a need to manage these pests to prevent amenity impacts and protect public health, but also to protect biosecurity and minimise **piglet** losses. Good management of areas where feed is prepared, stored and fed can help minimise fly and rodent breeding. Boundary fencing that excludes feral pigs should be implemented in locations where these pose a risk. An integrated pest management program is recommended for all farms.

Pathogens can be carried by dust or runoff. If paddock dust is not an issue and there are suitable measures to prevent manure entering waterways, the risk of off-site pathogen transport is low.

5.2 Soils

Nutrients deposited in manure need very careful management both due to the quantities added (which are very dependent on **stocking density** and the length of the pig phase) and the dunging habits of the pigs. Without active management, nutrients and salts from manure are not evenly spread over the paddocks of rotational outdoor piggeries (Rate 2000; Zadow et al. 2010; Galloway 2011; Wiedemann 2016). Unless dunging patterns are controlled, most nutrients and salts will concentrate over a relatively small area of each paddock extending from the shelter/s to the feeding area and wallow. Under these circumstances, soil nutrient concentrations in the dunging areas may reach unsustainable levels quite quickly. Regularly rotating paddock infrastructure (e.g. **huts**, feeders, wallows and watering points) during the pig phase is crucial in distributing nutrients more evenly over the paddock.

Soil erosion is also an important consideration as this carries topsoil from the site. As well as reducing land productivity, this may result in increased turbidity and nutrient levels in watercourses. In any agricultural system, groundcover provides the front-line protection against soil erosion. Groundcover levels vary naturally with seasonal conditions, although management also plays an important role for rotational outdoor piggeries. Because of their ground rooting habits, it is very difficult to retain groundcover under pigs.

In some soil types, climate and management combinations, pig trampling and machinery movements can result in erosion or soil compaction.

5.3 Surface waters

Surface waters include water in rivers, creeks, wetlands and dams. Transfers of nutrients and sediment from paddocks poses a risk to water quality. Elevated nutrient levels promote the growth of algae and aquatic weeds that strip oxygen when they die and decay. This may kill aquatic life and create odours. High nitrate or ammonia levels may be directly toxic to animals. High nitrogen and phosphorus levels are associated with toxic blue green algae blooms.

Nutrients may move off paddocks of rotational outdoor piggeries after dissolving in **stormwater** runoff or through erosion. Good management of soil nutrient levels and measures to prevent soil erosion are essential.

5.4 Groundwater

Groundwater is any water below the land surface. Water quality may decline if nutrients leach through the soil into groundwater. The risk depends partly on how well the groundwater is protected by depth and overlying rocks and soils.

5.5 Native vegetation and habitats

Sites with significant native vegetation need to be excluded from the piggery area. Pigs can physically destroy trees, shrubs and grasses by rooting and chewing. Since native plants are not always tolerant of elevated soil nutrient levels, a buffer should be maintained between pig paddocks and vulnerable vegetation. Nutrients need to be managed to minimise the risk of elevated soil levels beyond the buffer.

5.6 GHG emissions

The major contributing sources of GHG at rotational outdoor piggeries are feed production, enteric (digestion) emissions, manure management, energy and purchased inputs (Wiedemann et al. 2021). Rotational outdoor piggeries have very low total GHG production of ~2.2 kg CO_2-e/kg liveweight, including scope 1, 2 and 3 emissions, minus losses or sequestration associated with using or changing land management. Further improvements could be achieved by feeding diets that reduce emissions (e.g. substituting local protein meal for imported soy meal) and by improving feed conversion efficiency.

Piggeries that wish to become carbon neutral may do so under the Australian Government Climate Active certification process. Purchasing carbon credits allowed under the program may help achieve carbon neutrality.

5.7 Cultural heritage

Items, sites or places of cultural heritage significance need to be identified and protected. Refer to Section 8.7 for further information.

6 Types of outdoor piggeries

There are a range of outdoor pig production systems in place in Australia. These guidelines apply to rotational outdoor piggeries only. Under APIQ✓®, APL has developed specific definitions for 2 types of rotational outdoor piggeries, Free Range (FR) and Outdoor Bred – Raised Indoors on Straw (OB).

6.1 Rotational outdoor piggeries

In a rotational outdoor piggery, the pigs are kept in paddocks, with shelter. The paddocks are rotated with a crop-forage-pasture phase. During the pig phase, the pigs are supplied with prepared feed, but can also forage. The prepared feed supplied to the pigs represents a significant import of nutrients. Nutrients not used by the pigs are excreted onto the land as manure. Harvest of plant material grown during the crop-forage-pasture phase removes the nutrients deposited in manure during the pig phase.

The rate at which nutrients accumulate in the soil depends on the stocking density, the amount and composition of feed used, and the amount and composition of bedding material used (if spent bedding is spread or left in the pig paddocks). Nutrients are added at a lower rate (kg/ha/yr) if the stocking density is very light, compared with a system with a heavier stocking density. However, nutrients accumulating in the soil need to be removed when they reach elevated levels. Hence, all paddock-based systems need to include a crop-forage-pasture phase to remove deposited nutrients.

6.1.1 Free range piggeries

Some rotational outdoor piggeries may be eligible for APIQ✓® **Free Range** (FR) certification. The APIQ✓® definition of FR is that pigs are kept permanently outdoors for their entire life with shelter from the elements provided, furnished with bedding. FR pork production consists of outdoor paddocks, which include rooting and foraging areas, wallows (where state and territory regulations and seasonal climates permit) and kennels or huts for shelter. The huts allow the animals to seek shelter from environmental extremes. They also provide additional protection for the piglets when very young.

The APIQ✓® standards manual includes environmental standards and performance indicators for FR piggeries. It is necessary to satisfy the requirements of these to achieve and maintain FR certification.

The **weaners** and **growers**, and the sows, from which they have been bred, have access to paddocks at all times for their entire life. Shelter, food and water must be provided and all pigs must be able to move freely in and out of the shelter and move freely around the paddocks, unless they are to be confined for short amounts of time for routine husbandry or diagnostic procedures to be conducted.

All pigs raised under FR conditions must comply with the latest edition of the Model Code of Practice for the Welfare of Animals – Pigs to show compliance with state/territory animal welfare regulations and use good land management practices as per these guidelines.

Shelters or sheds with verandas or small pens attached are NOT considered FR as they do not comply with the APIQ✓® Standards. They are considered to be a "**Feedlot Outdoor Piggery**".

6.1.2 Outdoor bred — raised indoors on straw piggeries

APIQ✓® **Outdoor Bred** – Raised Indoors on Straw (OB) production is based on the APL OB definition that adult breeding sows live in open spaces with free access to paddocks for their entire adult life, with rooting and foraging areas, wallows where conditions and local regulations allow, bedded shelter and adequate feed and water provided. Piglets are born and raised under these conditions until **weaning**. At weaning, the piglets move to bedded grow-out housing with adequate feed and water provided where they remain until sale or slaughter. Housing can be permanent or portable structures or outdoor pens with shelter. The shelters must have an impermeable base or be located and moved regularly to minimise nutrient **leaching** and runoff. Pigs may be temporarily confined to pens for routine health treatments and husbandry practices, or when directed by a veterinarian. Paddocks and soils are managed to meet the APIQ✓® FR environmental standards and performance indicators including soil monitoring, nutrient management, promoting even nutrient distribution and land and water protection.

These NEGROP only cover the pigs run outdoors. They do not extend to the indoor component of OB systems.

6.2 Feedlot outdoor piggeries

Feedlot outdoor piggeries continuously accommodate pigs in permanent outdoor pens, sometimes with shelter. Shelters or sheds with verandas or small pens attached are a type of feedlot outdoor piggery. Feedlot outdoor piggeries should have a low permeability pad to protect groundwater. They should also be located within a **controlled drainage area** so that the nutrient rich runoff from these areas is controlled and kept separate from stormwater runoff from areas outside the pig pens.

This type of system is not covered by these guidelines.

7 Defining piggery capacity in standard pig units

A standard pig unit (SPU) is a way of standardising pig numbers by manure output which influences the potential for environmental risk. The manure and waste feed from one SPU contains the amount of **volatile solids (VS)** equivalent to that produced by an average-sized grower pig (90 kg VS/yr) (see Figure 7.2). 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 = ~26 kg VS/SPU/yr#

* Based on feed consumption of 16 kg/hd/d and a wheat-based diet
# Based on 5% feed wastage

Figure 7.2 Piggery manure and waste feed for one SPU

This definition assumes that the pig is fed a diet typical of indoor piggeries with similar feed wastage. Outdoor piggeries may have different diets and feed usage than indoor piggeries. This definition for SPU assumes that the pig is fed a standard diet, has a normal growth rate and has typical feed wastage. There are 2 methods for specifying the total number of SPUs in a piggery. The first is to use the standard multipliers provided in Table 7.1 with the herd composition based on pig class and weights. Table 7.1 also provides example pig and SPU numbers for a typical 100 sow **farrow-to-finish** piggery.

Table 7.1 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	5 (9)
Boar	100–300	1.6	5 (8)
Gestating sow	160–230	1.6	83 (133)
Lactating sow	160–230	2.5	17 (43)
Sucker	1.4–8	0.1	177 (18)
Weaner	8–25	0.5	253 (127)
Grower	24–55	1.0	249 (249)
Finisher	55–100	1.6	330 (528)
Heavy finisher	100–130	1.8	82[a] (148)
		Total	**1,201 (1,263)**

[a] For this example, it is assumed that the heavy finishers are sold at 26 weeks of age.

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. 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 should generally be representative. 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.

8 Site selection

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

A good site will be easier to manage as the risk of environmental, amenity or public health 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
- availability of suitable land area
- community amenity
- buffer distances to sensitive natural resources (e.g. watercourses and native vegetation)
- availability of essential services, infrastructure and inputs
- 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.

8.1 Land use zoning and planning requirements

When selecting a piggery site, the current and future land use zoning of the property and surrounding land, and other planning 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. It may also identify other development or building proposals that have recently been discussed or lodged with council. State and territory 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, land management and transport routes.

8.2 Available land area

The farm must be large enough to accommodate the paddock area, access for feeding and stock movements and related facilities needed to operate the piggery. The area required will depend on the size of the piggery and the herd composition, and the types and yields of crops that can be grown during the crop-forage-pasture phase. This is very site specific and is determined by a nutrient budget and soil testing. Generally, there will need to be a number of areas for pigs to rotate onto as it is likely to take longer than one pig phase to remove the nutrients deposited as manure. The shape of the property and other physical constraints also influence both the piggery layout and the separation distances and buffers to nearby sensitive land uses and features.

8.3 Community amenity

Good site selection is fundamental to minimising community amenity impacts. Rotational outdoor piggeries generally pose lower amenity risks to those of indoor piggeries (see Section 5.1). However, appropriate layout, design, management and a good communication strategy are nonetheless necessary to prevent conflicts with neighbours. Section 9.1 provides recommended minimum separation distances to reduce the risk of amenity impacts.

8.4 Availability of essential services, infrastructure and inputs

8.4.1 Water supply

Rotational outdoor piggeries need water for stock consumption, cooling (wallows, spray or drip cooling) and sometimes for dust control. Water may also be used to irrigate crops grown during the crop-forage-pasture phase of the rotation.

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. 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 2000) provide specific guidance on water quality for stock drinking and irrigation purposes. However, a pig husbandry or veterinary consultant can also advise on drinking water suitability.

8.4.2 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 using 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. Discuss proposed routes and property entry points with council and the state/territory roads department (if applicable) early in the planning process to identify any concerns or likely upgrade requirements.

8.4.3 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.

8.4.4 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.

8.5 Climate

Australia's climate has warmed since 1910, when national records commenced. The mean temperature has risen by more than 1.4° with the frequency of very hot days increasing. Since 1950, every decade has been warmer than the one before. While Australia's rainfall is highly variable, long-term trends show drier conditions in the south-west and south-east, with higher rainfall across northern Australia. Extreme rainfall events and floods are becoming more common. The likelihood of bushfire risk has also increased. The changing climate, particularly the increase in extreme weather-related events such as floods and bushfire danger days, affects climate impact and associated risks.

Figure 8.1 Ideal climatic locations for outdoor piggeries

Temperature and rainfall should be considered when selecting a site for rotational outdoor piggeries. In general, they are better suited to temperate climates. The risk of the heat wave conditions linked to summer infertility is lower if the mean maximum summer temperatures are less than 28°C. A location in which the mean minimum winter temperatures exceed 3°C has a lower likelihood of water pipelines freezing and provides a more comfortable environment for stock and staff. Sites with an annual rainfall of less than 760 mm are generally preferable (McGugan and Fahy n.d.).

Based on these climatic constraints only, the most ideal locations for rotational outdoor piggeries are the south coast of New South Wales; northern Gippsland and south-western Victoria, the Eyre Peninsula and south-eastern South Australia; and parts of the lower south-west, great southern and south-eastern regions of Western Australia (see Figure 8.1). However, the constraints used to draw this map relate mostly to animal welfare and productivity, rather than environmental concerns. Outdoor piggeries can operate successfully in other locations with appropriate management. However, the environmental risks are likely to be higher and require more management if the piggery is located in a high rainfall area, particularly if the soil is heavy or the land has significant slope.

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

8.6 Natural resources

8.6.1 Topography

Gently sloping or undulating sites promote good drainage in outdoor piggeries. Flat sites may be subject to localised flooding or waterlogging. Sites with a steeper slope may be more prone to soil erosion and nutrient loss through both erosion and stormwater runoff. The ideal slope depends on soil type, the amount of vegetative cover it is possible to maintain and soil conservation measures.

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. Undesirable sites are often elevated and cleared, providing a clear line of sight between nearby roads or neighbouring houses and the piggery.

8.6.2 Soils

Suitable soils provide acceptable paddock conditions for stock in wet weather, allow for all-weather access, can be used to grow pastures, forage or crops, have low erosivity and have a reasonable water holding capacity. Heavy clays (>50% clay) are often less suitable as they tend to stay wet and get puggy after wet weather. They may also be prone to compaction. Very sandy soils (<10% clay) are also less suitable as they tend to drain rapidly which may move nutrients below the root zone of future crops and potentially pose a risk to any groundwater beneath the site. Sandy soils with a clay subsoil on sloping land may also pose a risk of lateral movement of drainage water to nearby watercourses or water bodies.

A preliminary investigation should identify the range and distribution of soil types on the property. Doing a soil survey and chemical and physical analysis early in the planning phase helps to identify the suitability of land for the purpose. Section 20.2 provides recommended soil analysis parameters.

8.6.3 Surface water protection

Good nutrient management is essential in minimising the risk of surface water contamination. Erosion minimisation is also important. Buffers provide secondary protection for watercourses and other surface waters.

Rotational outdoor piggeries should be sited above the one-in-100-year flood line since flooding may not only harm the operation, but also pose a risk of surface water contamination. Information on land submerged by a one-in-100-year flood is often available from the local government authorities, or state/territory water resources agencies.

8.6.4 Groundwater protection

Groundwater is also protected through careful site selection. 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 required management standard and monitoring requirements. Some sites may not be suitable. This is because 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 may result in leaching into groundwater. Potassium is also a readily soluble nutrient that leaches when oversupplied in the soil.

8.6 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 or territory government agency early in the planning process to identify any native flora or fauna sensitivities that may affect site suitability, and any specific measures that might be needed to protect these. At a federal level, vegetation clearing is controlled through the *Environment Protection and Biodiversity Conservation Act 1999*. The states and territories also have their own land clearing legislation. Offsets may be required if clearing is needed. Pigs can quickly destroy trees, shrubs and other vegetation by chewing, rooting, soil compaction and nutrient deposition. Destruction of native vegetation including native grasses by pigs may be considered vegetation removal.

Protecting, maintaining and enhancing vegetation can augment indigenous species and habitats and provide visual screening.

8.7 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 and territory 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 in 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. 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 the cultural heritage.

8.8 Proximity to similar industries

Consider whether any nearby existing similar industries may pose a biosecurity risk. 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).

8.9 Future expansion plans

During the site selection process, consider any future expansion plans. In particular, consider the land area needed for additional paddocks and for buffers and separation distances to sensitive land uses.

9 Separation and buffer distances

Environmental outcome: The community, water resources and native vegetation are protected by providing separation distances and buffers that mitigate potential odour, dust, noise, nutrient runoff and leaching risks.

Good siting, design and management are the most important factors for preventing impacts to sensitive land uses and natural resources. Providing adequate separation distances and buffers between rotational outdoor piggeries and sensitive locations allows for secondary controls to minimise the risk of environmental and community amenity impacts.

Local authorities and state and territory government agencies may have planning requirements that include specific separation distances and buffers. Contact the approval authority early in the planning process to identify any requirements. Also consult with the council and the regional and state or territory 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 9.1 and 9.2 provide recommended minimum separation distances for community amenity and public health, and buffers for surface water, groundwater, and native vegetation, respectively.

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

9.1 Separation distances for community amenity

Odour, dust and noise levels from well-managed outdoor piggeries are generally very low (Banhazi 2013). Providing separation between the pig paddocks and sensitive land uses helps to minimise the risk of amenity impacts. While each state and territory provides its own legislation, codes of practice or guidelines for undertaking site-specific piggery odour impact assessments, these are generally designed for indoor piggeries.

Separation distances must be provided to places where people live. The separation distance is measured from the closest extent of the piggery complex to the closest extent of the sensitive use (e.g. boundary of town or rural residential zone, or legal house including any immediately adjacent outdoor living areas such as a barbeque area or pool).

Recommended minimum separation distances for rotational outdoor piggeries are provided in Table 9.1.

Table 9.1 Recommended minimum separation distances from piggery complex

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

Some rotational outdoor piggeries collect spent bedding or manure for reuse on other parts of the farm. This is generally an intermittent activity. Separation distances for reuse areas are specified in Table 9.2.

Table 9.2 Recommended minimum separation distances for reuse areas

Feature	Distance (m) by category		
	Bedding spread fresh after removal from shelters	**Stockpiled bedding**	**Compost OR spent bedding that is incorporated into the soil immediately after spreading**
Town	750	750	300
Rural residential area	500	400	150
Legal dwelling	250	200	100

Notes:

1. Distances to be measured from the perimeter of the reuse area.
2. The separation distances surrounding reuse areas are a guide. Dispensation for these distances may be obtained from the relevant approval authority following a site-specific risk assessment.
3. Where more than one category is used, the more (or most) stringent category controls apply.

For piggeries that are irrigating runoff collected in terminal ponds, refer to the NEGIP for separation distance and buffer guidance for reuse areas.

9.2 Buffer distances from surface water, groundwater and native vegetation

9.2.1 Minimum recommended buffers

A buffer distance is the space provided between the piggery complex or reuse areas and sensitive natural resources. Buffers provide secondary protection against:

- nutrient rich stormwater runoff from pig paddocks and reuse areas entering surface waters or areas of sensitive native vegetation
- soil erosion from pig paddocks and reuse areas entering surface waters
- seepage of excess nutrients into groundwater
- dust from spreading dry manure and compost entering surface waters.

A **watercourse** is a naturally occurring drainage channel such as a river, stream or creek. It has a clearly defined bed and bank, with intermittent (ephemeral) or continuous (perennial) water flows. State and territory Acts have their own legal definitions. 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 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. Some local government and state and territory regulations may specify minimum buffer distances.

Major stores of potable water and watercourses within drinking water catchments generally need the greatest protection. Restrictions may apply in catchment areas for major water storages owned by water boards or local authorities.

A minimum buffer distance of 30 m from the piggery complex to any natural watercourse, wetland or lake and 800 m from a major water supply storage is recommended. If manure or spent bedding are to be spread on reuse areas a minimum buffer of 800 m from a major water supply storage and 25-50 m from a watercourse (depending on whether the material is promptly incorporated) is recommended. Greater buffers may be warranted for ecologically sensitive areas. Areas where manure is deposited, contained or reused should provide 2 m clearance from the highest seasonal water table.

Table 9.3 provides recommended minimum buffer distances that should be provided between the rotational outdoor piggery complex and separate spent bedding reuse areas, and major water supplies, watercourses and bores. These buffer distances can be used in the absence of specific advice from the approved authority.

Table 9.3 Recommended minimum buffer distances

Category	Distance from major water supply (m)	Distance from watercourse (m)	Distance from bore (m)
Piggery complex Rotational outdoor piggery complex	800	30*	20
Separate reuse areas Reuse area used to spread manure or spent bedding – manure not incorporated within 48 hours of spreading	800	50	20
Separate reuse areas Reuse area used to spread manure or spent bedding – manure incorporated within 48 hours of spreading	800	25	20

Notes: Distances are measured from the part of the piggery complex or reuse area that is closest to the sensitive area.

* Ideally, the buffer should include a vegetative filter strip (VFS) – refer to Section 9.3 for design recommendations.

A reduced buffer distance to watercourses may be allowed if a risk assessment demonstrates that the feature will otherwise be protected. For example, terminal ponds designed to catch the first 12 mm of runoff from paddocks, a whole farm drainage plan, **vegetated filter strips (VFS)**, reed beds or constructed wetlands, 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 9.3 for design details).

Native trees, shrubs, sedges and grasses can be damaged by pig behaviours, such as rooting and chewing. They can also 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 sites, 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: pmst.awe.gove.au

9.3 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 velocity and 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 a steeper slope need a wider VFS than areas with a gentler slope (see Table 9.4 based on the work of Redding and Phillips 2005). These VFS widths are based on slope lengths of up to 200 m. They will be less 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 expected to be 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 9.4 VFS Widths (m) for typical values of annual soil loss and filter gradients

Soil loss (t/ha/yr)	Filter strip slope (%)								
	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 LE & Prosser IP (1999) Guidelines for Riparian Filter Strips for Queensland Irrigators. CSIRO: Land and Water, Canberra. Technical Report 32/99 by Redding and Phillips (2005).

A minimum VFS width of 10 m is recommended.

10 Resource efficiency

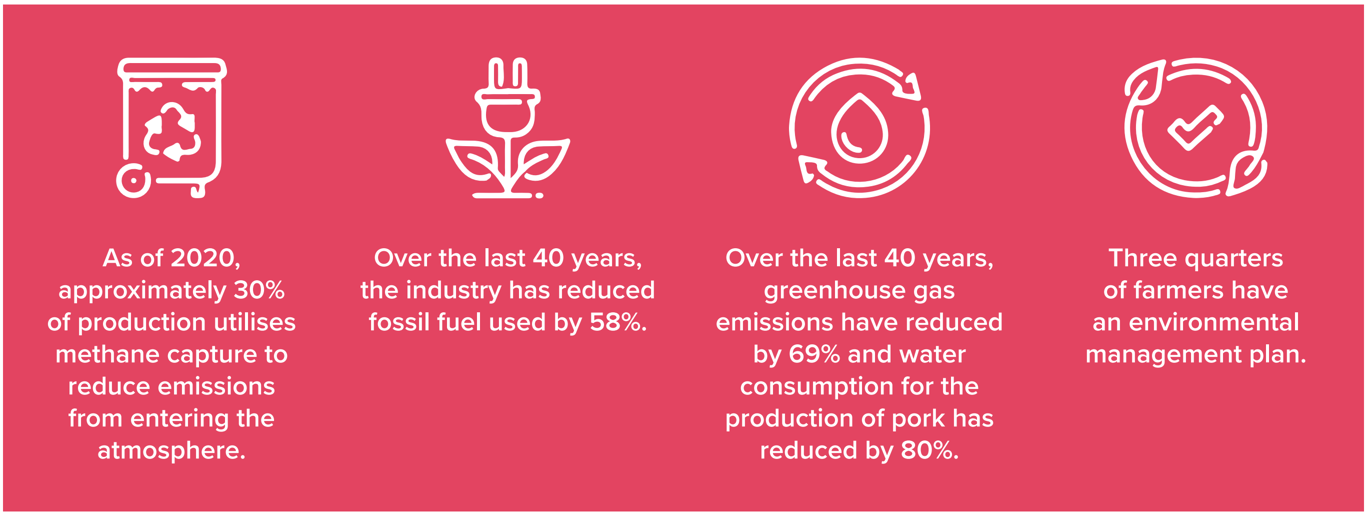
Rotational outdoor piggeries produce low levels of GHG emissions and have a significantly smaller carbon footprint than indoor piggeries due to lower resource usage (e.g. water for cooling and cleaning, energy for heating and cooling) and lack of effluent and manure storage (in most cases). There are still opportunities for rotational outdoor piggeries to improve land and nutrient management and farm biodiversity due to the direct relationship of the system with the land (i.e. manure deposition to land) and to reduce inputs (e.g. improving feed efficiency, using less synthetic fertilisers during the crop-forage-pasture phase, and recycling and reusing where practical).

Using resources more efficiently and managing and utilising nutrients deposited as manure more effectively 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, amenity and public health.

Environmental outcome: Efficient use of resources, reduced manure production, and reuse and recycling of manure.

The industry has made significant gains in this area and some of the achievements are outlined in the Sustainability Framework Baseline Report and summarised in Figure 10.1.

Figure 10.1 Summary of improvements in resource efficiency



To drive ongoing improvement, APL has developed the 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. The economic viability of the suggested strategies is very dependent on site-specific factors and costs.

10.1 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, and better manure management practices. Nutrient accounting assists with more efficiently using inputs and better managing the nutrients in manure 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 by rotational outdoor piggeries are outlined 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:

- Understand site energy consumption and energy bills, to facilitate decision-making.
- Improve 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.

10.2 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 biodiveristy include:

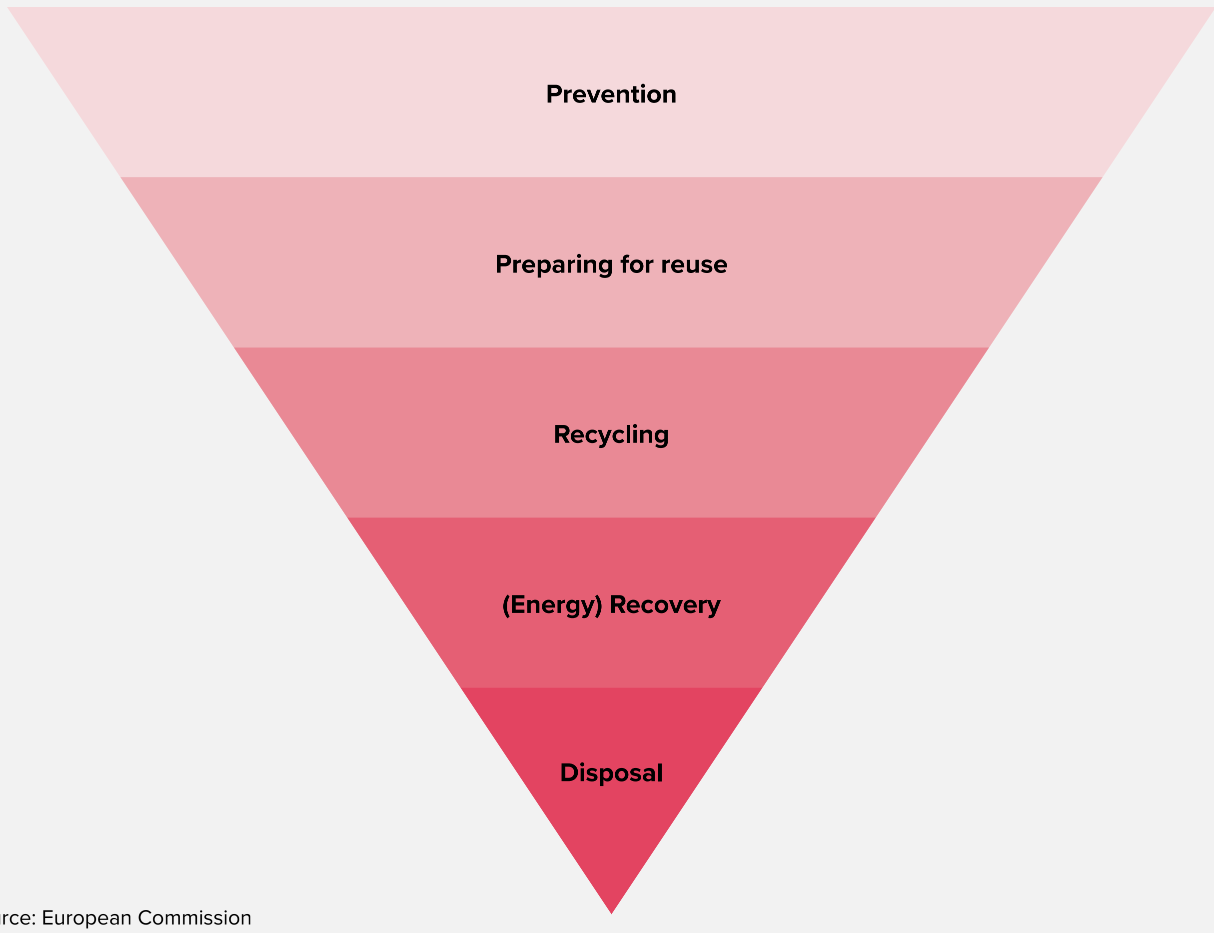
- planting indigenous species to protect and enhance habitats
- enhancing plantings by extending or connecting areas to create wildlife corridors
- opportunities to visually screen the piggery
- use of vegetation to minimise erosion
- controlling feral animals, particularly feral pigs and predators, to improve biosecurity, keep young pigs safe, 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 and compost.

10.3 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 Section 10.1: Carbon cycling and nutrient accounting
- utilising manure and compost to replace synthetic fertiliser
- using alternative feeds or food waste as part of the diet to reduce waste to landfill
- buying only what is needed and considering reuse or 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 suitable areas ahead of recycling through a scrap metal company
- separating recyclable materials (plastics, cardboard) into appropriate collection bins
- using water more efficiently by:
  - conducting a water audit to identify savings without compromising production or cleanliness
  - regularly inspecting and maintaining water supply systems (e.g. promptly repairing leaks, installing alarms)
  - installing low wastage drinkers
  - positioning drinkers to minimise wastage from pigs rubbing against or playing with the drinker.

The waste hierarchy provided as Figure 10.2 summarises the preferred order for managing wastes.



Source: European Commission

Figure 10.2 The waste hierarchy

11 Pig paddocks and facilities

Environmental outcome: Pig paddocks and facilities that are designed and managed to prevent risks to the environment and amenity from manure accumulation and pig behaviour.

In rotational outdoor piggeries, pigs are kept in open paddocks with rooting areas, wallows or alternative cooling (e.g. drip or spray systems) and shelters or huts with bedding that provide shelter from environmental extremes and protect young piglets from predation.

For any rotational outdoor piggery, the optimal paddock layout depends on site constraints like soil type, topography, buffer and separation distance requirements (see Section 9), herd size, production system (e.g. breeder, grower or farrow-to-finish unit), stocking density, farm or paddock shape, infrastructure (e.g. roads, electricity) and the planned pigs-crop-forage-pasture rotation.

The paddocks and facilities need careful management to avoid uncontrolled nutrient movements. Maintaining suitable soil nutrient levels and groundcover over the paddocks are the primary ways to prevent water contamination, although it is important to acknowledge that it is very difficult to maintain groundcover under pigs. Structures like VFS banks, bunding and terminal ponds can be useful secondary measures (see Sections 9.2 and 9.3 for further details). However, nutrient runoff and leaching are far more likely if manure nutrients are unevenly spread over paddock areas. Manure nutrients tend to concentrate around the shelter and in the area bounded by the shelter, the feeding facilities, the waterers and the wallows of rotational outdoor piggeries unless actively managed (Benfalk et al. 200; Eriksen et al. 2006; Galloway 2011; Wiedemann 2016; Quintern and Sundrum 2006). Sourcing paddock facilities that are readily movable and regularly relocating these within the paddocks is important. For further details, refer to Section 13.

Regularly relocating movable structures such as shelters, shade, feeding points, waterers, wallows and spray or drip cooling facilities within the paddocks promotes more even manure deposition. This has implications for the design and installation of these paddock facilities.

Paddock infrastructure should therefore be designed to be movable where practical and should be relocated at least every 6 months in breeder paddocks, and every 3 months in grower paddocks.

11.1 Rotation regime

Rotational outdoor piggeries operate with a pig phase followed by a crop-forage-pasture phase that is primarily used to remove nutrients added during the pig phase as manure. Because nutrients can accumulate quickly (depending on stocking density), the length of time pigs can stay on one land area must be limited to control nutrient levels and minimise the risk of nutrient losses. In most cases, the length of the phase should not exceed 2 years. If high stocking rates are used or soils have poor nutrient retention capability (e.g. light or shallow soils), more frequent paddock rotation may be required depending on site specific risk factors (e.g. depth and quality of groundwater). Conversely, systems with very light stocking densities may be able to stay on an area longer. Nutrient budgeting and soil testing will provide for site-specific management.

The crop-forage-pasture phase that follows the pig phase is intended to remove surplus nutrients added during the pig phase. The length of time needed to remove these nutrients depends mainly on the nutrient levels in the soil at the start of the crop-forage-pasture phase and the types and yields of crops that can be grown. As well as stripping nutrients, this phase may also be used to address other soil concerns. Incorporating a fallow into the crop-forage-pasture phase once surplus nutrients have been removed will build soil carbon levels, which will improve soil structure and enhance soil health.

Prior to the commencement of a pig phase, good groundcover should be established over the area to be used. Groundcover is very difficult to maintain in rotational outdoor pig paddocks, but having good groundcover at the start of the pig phase will reduce soil erosion and associated nutrient losses.

11.2 Stocking density

Stocking density is the number of pigs on a land area during a pig phase (SPU/ha). It does not include land that is in the crop-forage-pasture phase of the rotation. Nor does it include land on the farm that is not part of the use.

Stocking density is the main factor controlling the rate of nutrient deposition. It also influences groundcover retention. Stocking density is therefore an important determinant of the length of the pig phase. Nutrient budgeting and soil testing should guide site specific management.

Some farms divide their paddocks into strips or cells and move the pigs frequently (e.g. weekly or monthly) between these. While this helps with maintaining groundcover, it is generally not practical for larger operations. Farmers who use these systems may use a relatively high stocking density on each strip or cell. However, if the pigs only stay on an area for a short time, nutrient loads can be effectively managed using a nutrient budget for the whole area used.

11.3 Paddock layout

The most common layouts for rotational outdoor piggeries are blocks of radial paddocks and blocks of rectangular or square paddocks, although other layouts can be used to fit site constraints and practical requirements. Figure 11.1 shows a combination of radial farrowing paddocks (front left), rectangular **dry sow** paddocks (front right) and deep litter shelters (rear right) in an Australian OB piggery.

Figure 11.1 Combined rectangular paddock and radial paddock layout

11.3.1 Radial paddocks

Radial paddocks consist of wedge-shaped paddocks that radiate from a central hub with yards for handling and treatment. A road around the perimeter of each radial provides access for feeding and for servicing the paddocks. This design is often used for dry sows with each paddock providing a group shelter, feeding and watering facilities and a wallow.

11.3.2 Rectangular or square paddocks

Farrowing sows, weaners, growers and finishers are often kept in blocks of rectangular or square paddocks. Farrowing sows are generally kept in small groups (e.g. 6-8 sows) per paddock, usually with individual huts provided. Weaners, growers and finishers are generally kept in larger groups with shared huts. Feeders (self-feeders or troughs), water troughs, wallows and any drip or spray coolers are shared by the pigs in each paddock.

11.4 Paddock facilities

11.4.1 Fencing

Because the land use of the paddocks alternates between a pig phase and a crop-forage-pasture phase, most operators use electric fencing that is readily movable, allows for a flexible layout and does not interfere with machinery movements during the crop-forage-pasture phase. However, other types of fencing are suitable if they meet functional requirements, contain the pigs and protect against predator and wild pig access.

11.4.2 Shelters

While the stock kept in rotational outdoor piggeries must live outdoors, they need shelter that provides protection from weather extremes. The shelters must meet the welfare needs (including space and bedding) prescribed in the latest edition of the *Model Code of Practice for the Welfare of Animals – Pigs*.

Farrowing huts with bedding provide protection for very young piglets. These typically consist of a box-like hut with a small outdoor run. The hut is bedded to provide warm, dry conditions for the piglets in their first weeks of life. The run allows the piglets access to the outdoors while protecting them from predation for the first 7-14 days. A fender at the front of the run is generally removed after this time to allow the piglets paddock access. Usually the huts are moved after each litter is weaned and the bedding either removed from the paddock or dispersed. Some farms use open huts for farrowing, although these offer less protection from the weather and from predators.

The simple group shelters typically provided for dry sows, weaners, growers and finishers are usually bedded with straw, sawdust or rice hulls. Regular bedding top-up is needed to maintain dry, low odour conditions within the shelter. A wide range of shelters designs and construction materials are in use. These shelters should be readily movable and regularly relocated to assist in distributing manure nutrients over the paddock area.

Ideally, shelters should be moved at least every 6 months in **breeder paddocks**, and every 3 months in grower paddocks. More frequent movement may be beneficial in some situations (e.g. heavy stocking density).

11.4.3 Feeding facilities

Feeding facilities in outdoor piggeries can include self-feeders, feed troughs and ground-feeding areas. Generally, the pigs in a paddock share feeding facilities, although **lactating sows** may be hand-fed in the hut.

Self-feeders and troughs need to provide good access for the pigs they are servicing. The design should minimise wastage. Feeders should be readily movable and regularly relocated to assist in distributing manure nutrients over the paddock. Feeders should be relocated at least every 6 months in breeder paddocks, and every 3 months in grower paddocks.

Some outdoor piggeries ground feed, spreading pellets with an augur or blower. The feed should be dispersed either along a perimeter fenceline or over a broad part of the paddock.

Feed spills or wastage may attract vermin and generate odours, particularly if the feed becomes wet.

11.4.4 Water troughs

Water troughs need to provide sufficient access for all pigs. Burying main water supply pipes helps to keep water cool. Ideally, water troughs should be readily movable and regularly moved to assist in distributing manure nutrients over the paddock. This is achievable by running a length of above-ground flexible piping from the main pipe to light weight troughs.

11.4.5 Wallows and other cooling

Wallows should be provided for outdoor pigs unless this poses a significant environmental risk due to unsuitable soil type or groundwater depth. Wallow bases should have a reasonable clay level to reduce the risk of nutrient leaching. For sites on lighter soils, clay may need to be imported to line the wallows. Spray or drip cooling facilities may be a more suitable alternative.

Wallows and spray or drip cooling facilities should be movable where practical to assist in distributing manure nutrients over the paddock. Wallows may become very deep and need replacement during the pig phase. At the end of the pig phase, wallows will generally need rehabilitation to allow for cropping (refer to Section 14.4).

The provision of additional shade in summer could also be considered. Shade structures should be readily movable and regularly moved to assist in distributing manure nutrients over the paddock.

12 Nutrient budgeting

Environmental outcome: Nutrient budgeting is used to avoid excessive levels or imbalances in the soils of pig paddocks.

Nutrient budgeting is a tool for protecting the productive qualities of soil and guarding against eutrophication (excessive nutrient levels) of water resources. Nutrient budgeting is needed to plan sustainable combinations of stock numbers, stocking density and land use rotations (length of pig phase and crop-forage-pasture phase). The budget should include:

- the additions of macro-nutrients (nitrogen [N], phosphorus [P] and potassium [K]) to each separate area of the piggery (e.g. farrowing, dry sow, weaning, growing) as manure over the pig phase
- the quantities of N, P and K that will be removed by growing and harvesting plants during the crop-forage-pasture phase
- the difference between N, P and K applied and N, P and K removed (nutrient budget)
- an interpretation that considers the nutrient budget in the context of soil nutrient levels, nutrient availability (e.g. a nutrient surplus in the budget at the end of the pig phase may be justified if that nutrient is either deficient or not available at levels that will meet crop needs) and environmental risk (e.g. it may be reasonable to store several years of P in the soil if it has a reasonable clay content). This stage should also identify likely fertiliser requirements for the crop-forage-pasture phase
- modification of stock numbers, the stocking density or the length of the pig phase and revision of the nutrient budget if excessive nutrients will be added or build-up over time.

Nutrient budgeting is a theoretical exercise and many factors will affect actual soil nutrient levels. Nutrient budgeting should be supported by regular soil testing.

12.1 Estimating nutrients added to paddocks

Mass balance principles can be used to estimate the quantity of nutrients in manure as the difference between inputs brought onto the farm (pigs, feed, water and bedding) and outputs leaving the farm (pigs, nitrogen volatilisation and possibly spent bedding). Each of these elements is important in estimating the nutrient load.

The mass of nutrients excreted by pigs can be most accurately estimated using PigBal4. PigBal4 is a Microsoft Excel® spreadsheet that uses mass balance theory and diet digestibility to estimate manure production. It can be tailored to suit individual piggeries (Skerman et al. 2018). A nutrient mass balance for the pig phase can also be determined manually by calculating nutrients added as manure and bedding.

A separate mass balance should be prepared for each different management area (e.g. dry sows, farrowing, weaners, growers). Table 12.1 provides PigBal4 estimates for the quantities of solids and nutrients in the manure of different classes of pigs. These should be considered an approximation only. Herd composition data and the data in Table 12.1 can be used to estimate the nutrients added annually. These values are based on data for pigs in conventional piggeries that are fed typical diets. Higher values should be used if feed usage by outdoor pigs is expected to be greater. Also consider the nutrients added by the bedding (particularly potassium if straw is used). Typical nutrient composition data for bedding materials are provided in Table 12.2. Use these data and the bedding quantity to estimate the amount of nutrients added by bedding.

Dividing the total mass of nutrients added to each paddock (kg/yr) by the paddock area gives the nutrient addition rate (kg/ha/yr). This must be multiplied by the length of time (in years) that pigs will stay on each paddock to produce the total nutrient addition rate (kg/ha).

The nutrient application rates calculated using this method assume even nutrient distribution over a paddock. It is important to recognise that this will not occur without active management (i.e. regular movement of paddock facilities).

In most cases, the length of the phase should not exceed 2 years. If high stocking rates are used or if the paddocks have light or shallow soils, more frequent paddock rotation may be required. However, site risk factors should be considered. Conversely, systems with very light stocking densities may be able to stay on an area longer. Nutrient budgeting and soil testing will provide for site-specific management.

Calculations follow in Example 1.

Table 12.1 Estimated solids and nutrient output for each class of pig

Pig class	Solids and nutrient outputs (kg/hd/yr)					
	Total solids	Volatile solids	Ash	Nitrogen	Phosphorus	Potassium
Gilts	197	162	35	12.0	4.6	4.0
Boars	186	151	35	15.0	5.3	3.8
Gestating sows	186	151	35	13.9	5.2	3.7
Lactating sows	310	215	95	27.1	8.8	9.8
Suckers	11.2	11.0	0.2	2.3	0.4	0.1
Sow and litter	422	325	97	50.0	13.0	11.0
Weaner pigs	54	47	7	3.9	1.1	1.1
Grower pigs	108	90	18	9.2	3.0	2.4
Finisher pigs	181	149	32	15.8	5.1	4.1

Note: Refer to Table 7.1 for approximate animal numbers in each pig class per 100-sow production unit.

Table 12.2 Typical solid and nutrient content of clean bedding materials

Bedding material	Content (kg/t dry matter)				Content (kg/t fresh basis)		
	Total solids	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Hardwood sawdust[a]	90	2.2	0.1	0.5	20	0.1	0.5
Softwood sawdust	90	1.4	0.1	0.3	1.3	0.1	0.3
Rice hulls[b]	92	19	4.8	8.1	17.5	4.4	7.5
Barley Straw[c]	91	7.0	0.7	18	7.4	0.64	16.4
Wheat straw[c]	89	8.0	0.7	21	7.1	0.62	18.7

[a] Based on unpublished data from Department of Primary industries and Fisheries – Queensland
[b] Based on data from Tyopine 2014
[c] Based on Morris and Staines 2017

EXAMPLE 1

A farmer operates a 1,000 sow breeder unit including 830 dry sows, 170 farrowing sows and 1,725 suckers. He uses a 2-year pig phase. At any time, the farrowing sows are kept on a 68 ha area. 90 t DM/yr of barley straw bedding is used. No fertiliser will be used in the crop-forage-pasture phase. Calculate the nitrogen inputs as follows:

Estimate nitrogen added as manure:
Multiply the number of pigs in each class by the amount of nitrogen in their manure (from Table 12.1), e.g. for the farrowing unit:

170 lactating sows x 27.1 kg N/hd/yr = 4,607 kg N/yr
1,725 suckers x 2.3 kg/hd/yr = 3,968 kg N/yr
Total nitrogen added as manure = 8,575 kg N/yr

Plus nitrogen added as bedding:
Use the fresh barley straw composition data in Table 12.2 and the straw usage: 90 t straw DM x 7 kg/t = 630 kg N/yr

Add the nutrients in the manure and bedding to get an estimate of the total nutrients added to the soil. e.g. for the farrowing area, the nitrogen added as manure and bedding would be calculated as: manure N (8,575 kg N/yr) + bedding N (630 kg N/yr) = 9,205 kg

Estimate net nitrogen additions after accounting for ammonia volatilisation (gaseous) losses from manure (calculation applies only to nitrogen and not to phosphorus and potassium):
Assuming 20% of nitrogen is lost by volatilisation, net nitrogen is: 9,205 kg N/ha * (1-[20/100]) = 7,364 kg N/yr

Convert to a net nitrogen application rate (kg/ha/yr):
Divide the net mass of nitrogen (kg) by the area (ha) e.g.: 7,364 kg N/yr / 68 ha = 108 kgN/ha/yr

Determine net nitrogen rate over the length of the pig phase (kg/ha):
Multiply the annual net nitrogen application rate by the length of the pig phase (years) to determine the total net N applied during the pig phase: 108 kg N/ha/yr x 2 years = 216 kg N/ha

Repeat this process for P and K, omitting the volatilisation losses step.

12.2 Nutrient removal by the crop-forage-pasture phase

To maintain a sustainable system, nutrients added during the pig phase or afterwards as fertiliser need to either be removed by growing and harvesting crops, forage crops and pastures at the end of the pig phase or used to build soil nutrient reserves to healthy levels. In simple terms, the system is in balance if nutrient removal by plant harvest matches the addition of nutrients. However, in some cases the soil may be deficient in some nutrients and addition to these nutrients is beneficial. In some cases, nutrient availability may also be an issue. A regular soil testing program should be used to understand and manage the soil nutrient levels. Elevated levels should be managed as soon as practicable by appropriate crop selection. The data to estimate nutrient removal by plant harvest are provided in Table 12.3 and in Example 2 that follows. The types of crops grown determine the amount of nutrients removed through harvest, depending on the yield and nutrient content.

Table 12.3 shows typical dry matter nutrient content, expected yield ranges and nutrient removal rates for a variety of pasture, silage, hay and grain crops. The yields presented are for typical cropping soils. Grazing removes nutrients at very slow rates since most nutrients are recycled in manure deposited by the grazing animals. Thus, grazing alone is almost never a suitable nutrient removal system for rotational outdoor piggeries.

Table 12.3 Approximate nutrient removal rates for various crops and yields

Crop	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	179-358
Grain barley	20	2.5	4.5	2-5	40-100	5-12.5	9-22.5
Barley straw	7	0.7	18	5-10	35-70	3.5-7	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

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

EXAMPLE 2

A crop-forage-pasture phase consists of 3 years of barley grain yielding 3 t DM/ha followed by one year of pasture which will be cut once for hay prior to the pig phase (yield 5 t DM/ha). Calculate the nitrogen removed by the entire crop-pasture-forage phase.

Estimate nitrogen harvested from barley grain annually:
Multiply the barley yield (t DM/ha) by the N content (kg N/t)
3 t DM/ha x 20 kg/t = 60 kg/ha

Estimate nitrogen harvested from pasture annually:
Multiply the pasture yield (t DM/ha) by the N content (kg N/t)
5 t DM/ha x 17.6 kg/t = 88 kg/ha/yr

Calculate the estimated mass of nitrogen removed by the entire crop-forage-pasture phase of the rotation:
This is the sum of the nutrient removal rate for each crop multiplied by the number of crops harvested. In this case, 3 years of barley and one year of pasture hay are grown and harvested, so the nutrient removal rate over the whole crop/forage/pasture phase is: (3 x 60 kg/ha) + (1 x 88) = 268 kg/ha.

Repeat this process for P and K.

12.3 Nutrient budget

It is necessary to find the crop, forage and pasture combination that removes enough nitrogen, phosphorus and potassium to achieve good agronomic nutrient levels. In many cases, nutrients will be abundant and readily available within the first 2 years (at least) after the pig phase, although soil testing should be used to confirm levels. Regular soil testing will detect any deficiencies or availability concerns. If an important nutrient is deficient or unavailable, plant yields will be compromised which in turn reduces nutrient uptake. Because pig manure is not a balanced fertiliser, it is very difficult to match the quantity of nutrients applied and readily available to plants with the quantity removed by harvest for all macro-elements. It may therefore be necessary to add nutrients from a different source (fertiliser). Hence, there is a need to consider the soil nutrient status, including nutrient availability, when developing a nutrient budget.

The nutrient budget is determined from nutrient additions less nutrient removals, taking initial soil nutrient status into account. Example 3 shows a nutrient budget.

EXAMPLE 3

Example calculations for nitrogen only are provided below using the 68 ha, 170 sow farrowing area from the previous examples. The net nitrogen application rate over the 2 year pig phase was 216 kg/ha. No nitrogen fertiliser was applied.

The total nitrogen removal rate over the crop-forage-pasture phase is 268 kg N/ha. Hence, the nitrogen budget is:
N budget = 216 kg N/ha - 268 kg N/ha = -52 kg N/ha

The nitrogen removal rate exceeds the nutrient addition during the fourth year of the crop-forage-pasture phase. Consequently, there would be a need to provide nitrogenous fertiliser before the pasture is planted.

If the land area used for the pig phase was reduced from 68 ha to 30 ha, the nitrogen input changes to: Net N added as manure and bedding is 7,364 kg N/yr. Convert to a net N application rate (kg N/ha/yr) based on 30 ha 7,364 kg N/yr / 30 ha = 245 kg N/ha/yr.

Determine total N added by pig phase by multiplying rate by length of pig phase (years). 245 kg N/ha/yr x 2 = 490 kg N/ha.

Undertake revised nutrient budget:
N budget = 490 kg N/ha - 268 kg N/ha = 222 kg N/ha

This leaves a significant nitrogen surplus. This example (30 ha) demonstrates an unsustainable system. Changes in management would be needed to minimise environmental risk.

Repeat this process for P and K.

If there are elevated nitrogen levels in the soil after the pig phase, vegetative growth can be very high. Growing a high-yielding forage crop (for hay or silage) after the pig phase in the first and perhaps the second year of the crop-forage-pasture phase will help to take up nitrogen and other readily available nutrients. Areas likely to have higher nutrient loads should not receive fertiliser applications until soil testing and crop performance indicate that this is necessary. In some cases, a third party, such as the owner of land that is leased to the piggery operator or other external party, will manage the crop-forage-pasture phase. It is essential that they understand nutrient levels in the soil at the start of this phase, and also the need to strip the nutrients.

13 Promoting more even distribution of manure nutrients

Environmental outcome: The piggery promotes distribution of manure nutrients over the whole paddock area.

Rotational outdoor piggeries always accumulate nutrients in the soil during the pig phase because of the quantities of nutrients brought in as feed. Australian and international research shows that manure nutrients are not distributed evenly across the paddocks of outdoor piggeries.

APL projects have used electromagnetic (EM) induction survey technology coupled with soil sampling and testing to map the distribution of nutrients in the paddocks of rotational outdoor piggeries. In an initial study, Galloway (2011) measured the distribution of nutrients in a dry sows paddock without regular movement of paddock facilities. As Figures 13.1 and 13.2 show, most of the nitrate-nitrogen and Colwell phosphorus were deposited close to the shelter, feeding area and wallow. To promote more even nutrient distribution, it is necessary to change the excretory behaviour of the pigs.

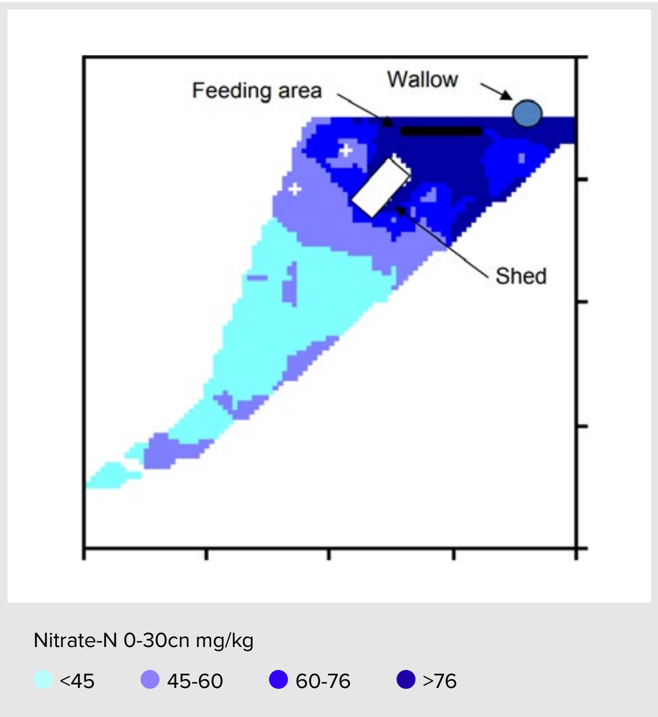


Figure 13.1 Nitrate-nitrogen distribution in rotational outdoor piggery paddock

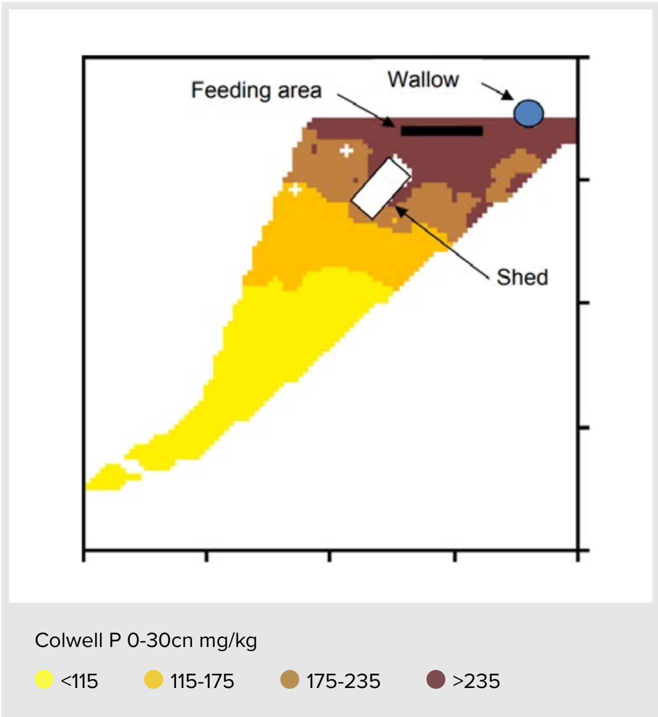
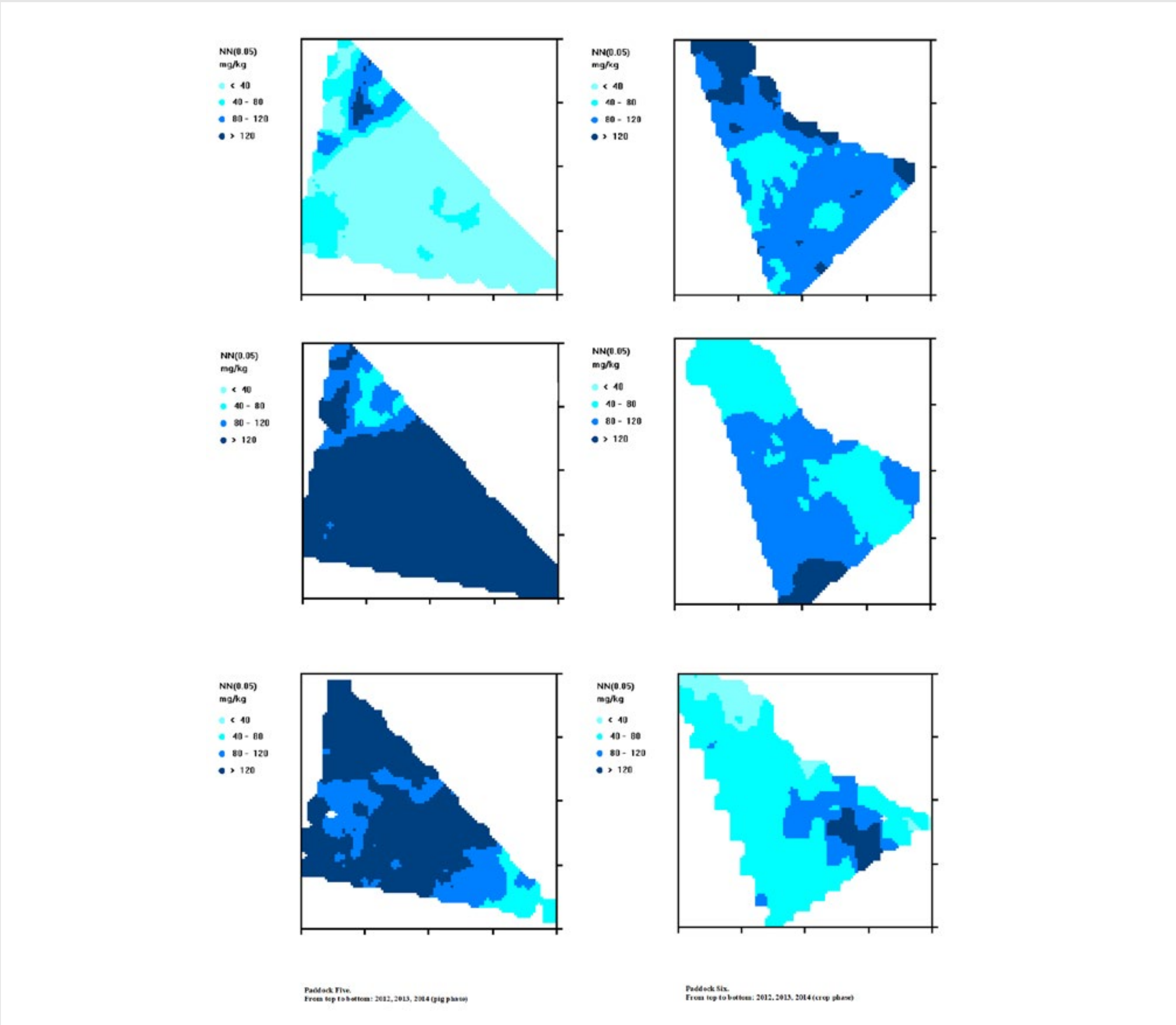


Figure 13.2 Colwell phosphorous distribution in rotational outdoor piggery paddock

A follow-up study (Wiedemann 2016) demonstrated the effect of 6-monthly movement of shelters and feeding points on manure nutrient distribution. Figure 13.3 shows levels of nitrate-nitrogen in paddocks during the pig phase (paddock 5) and the crop-forage-pasture phase (paddock 6) over a 3 year period. This clearly shows far more even nutrient distribution with regular movement of paddock facilities. It also shows nutrient accumulation during the pig phase and nutrient removal during the crop-forage-pasture. Figure 13.4 shows Colwell phosphorus levels in the pig phase over a 3 year period. Moving the facilities regularly resulted in more even nutrient distribution over the whole paddock. This lowers environmental risk during both the pig and the crop-forage-pasture phases by reducing nutrient hotspots that can promote nutrient leaching or runoff. It also assists with crop nutrition management during the crop-forage-pasture phase since nutrients are more evenly dispersed across the paddock area. It may also reduce issues with uneven growth patterns and associated poor nutrient use efficiency in crops that follow the pig phase.

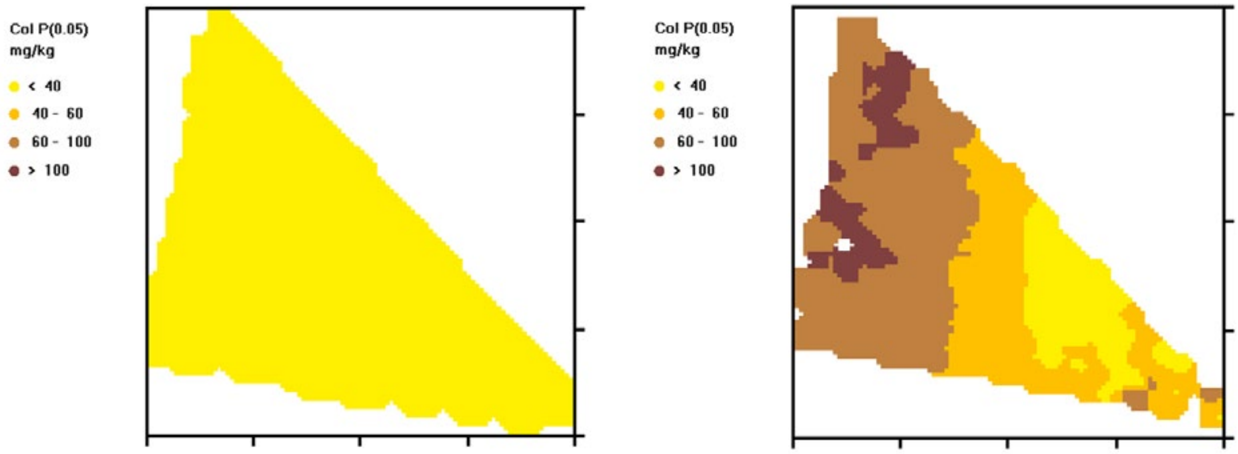
Unless action is taken to promote more even nutrient distribution over the paddocks, nutrient budgets are of limited value in preventing nutrient losses because of elevated soil nutrient concentrations in parts of the paddocks and lower levels in other parts. The potential for leaching of nitrate-nitrogen and other nutrients from the hotspots is of particular concern.

Paddock infrastructure should be designed to be movable and should be relocated at least every 6 months in breeder paddocks, and every 3 months in grower paddocks.



(Wiedemann 2016)

Figure 13.3 Distribution of nitrate-nitrogen in the surface soil during the pig phase (Paddock 5) and during the crop forage-pasture-phase (Paddock 6)



(Wiedemann 2016)

Figure 13.4 Distribution of Colwell P in the surface soil measured over 3 years

Spent bedding from shelters can be spread within the pig paddocks or reused on other parts of the farm or offsite. If this is spread within the pig paddocks it should be dispersed over areas that are expected to have lower nutrient levels. For other reuse areas, nutrient budgeting principles should be used to determine application rates. The buffers specified in Table 9.2 also apply.

14 Land and water protection measures

Environmental outcome: Land and water are protected by minimising soil erosion and nutrient loss from paddocks used for pig production by rehabilitating the site after the pig phase, using water protection measures and properly constructing and managing wallows.

Rotational outdoor piggeries may pose a risk to the environment through unsustainable soil nutrient levels coupled with soil structural decline and poor land protection measures. Adopting good land protection measures will help to preserve or enhance the productive qualities of the soil and prevent surface water and groundwater contamination. Suitable siting, good design, active management and a commitment to site remediation reduce the risk of land degradation. While this section describes the types of land water protection measures typically used on Australian farms, alternative designs or methods that meet the environmental outcome are also suitable.

14.1 Preventing nutrient loss

Nutrients may be carried from the site with soil particles (erosion) or may dissolve in runoff or leachate.

14.1.1 Minimising soil erosion

It is important to prevent soil erosion throughout both the pig and the crop-forage-pasture phases of the rotation. Erosion reduces land productivity by removing the nutrient-rich topsoil. It may also increase turbidity and nutrient levels in nearby watercourses. Erosion is difficult to remedy and prevention is imperative.

Erosion risk increases with steeper slopes, higher rainfall and wind intensities and reduced groundcover, with some soils being more erosion-prone than others. Land that is flat or with a gentle slope is preferred, while land with a steep slope may be unsuitable. Erosion may be more difficult to manage on sites with dispersible or light soils or if the rainfall or wind intensity is high.

Maintaining groundcover over the land helps to protect against erosion but is very difficult to sustain over the entire pig phase. Groundcover is any material on or near the soil surface that provides protection for the soil against the erosive action of rainfall runoff or wind. It may include plant material (alive or dead), spent bedding and other cover materials providing these will not be carried away in rainfall runoff or blown away by the wind. Since attached plant material is more effective than dead plant material or other light matter lying on the soil surface, it is recommended that it makes up the majority of the groundcover. Groundcover prevents erosion by leaving soil less exposed to wind and rainfall runoff, promoting soil properties that increase rainfall absorption, and intercepting runoff preventing it from becoming erosive. Because is very difficult to maintain groundcover over paddocks throughout the pig phase, starting the pig phase with good paddock coverage is important.

Secondary controls that will assist in preventing nutrients in eroded soil or runoff reaching watercourses are detailed in Section 14.1.2.

14.1.2 Preventing nutrient losses in runoff and via leaching

There is a greater likelihood of nutrient removal in runoff or leachate if the soil has elevated nutrient levels. These may pose a risk to nearby watercourses and shallow or poorly protected groundwater. Nutrient budgeting (Section 12) in conjunction with regular movement of paddock facilities (Section 11) and soil monitoring (see Section 20) can be used to manage soil nutrient levels. More intense management may be needed for erosion-prone soils or very light soils, although the risk should be assessed on a case-by-case basis.

VFS or vegetated buffers below pig paddocks can prevent nutrients in eroded soil and runoff from reaching watercourses. VFS are continuous vegetated buffer strips that are located immediately downslope of the entire paddock area. A minimum VFS width of 10 m is suggested. However, for sites with greater slope, higher rainfall intensities or erosive soils wider VFS are recommended. For design details for VFS, refer to Section 9.3.

Contour banks may be used to slow the flow of water down sloping land, reducing its erosivity.

As an additional control, or where there is high risk of watercourse contamination, terminal ponds sized and located to catch the first 12 mm of runoff from the piggery paddocks and other land within the same catchment area can effectively minimise nutrient contamination of surface water resources. These work primarily by capturing the runoff containing the most nutrients. However, they also slow the flow velocity, promoting settling of suspended soil from the runoff. Runoff caught in terminal ponds needs to be irrigated on land not in use as pig paddocks. Nutrient budgeting principles should be used to determine application rates. The buffers specified in Table 9.2 also apply.

Reed beds or constructed wetlands may also be useful for filtering runoff in some situations.

Nutrient leaching poses a risk to groundwater (if present) and may also pose a risk to surface water if shallow groundwater is connected to watercourses, wetlands or lakes. Preventing nutrient leaching relies mainly on good soil nutrient management. Nutrient leaching is a greater risk on light soils and when nutrient levels are allowed to become very elevated. Wallows can also be a nutrient hot spot and should either be located on areas with loam to clay soils or lined with compacted clay to reduce the leaching risk.

14.1.3 Preventing nutrient losses from spent bedding storage areas

If spent bedding is stored or composted before spreading on other areas, it should be kept within a designated storage area. This should be bunded and either be concreted or have a design permeability of 1 x 10-9 m/s for a depth of 300 mm comprising 2 layers each compacted to 150 mm. For guidance on achieving this design permeability, see Appendix 1 of the PMEMRG. The base of the spent bedding storage or composting area should be at least 2 m above the highest seasonable groundwater table. Drainage water or leachate from this area should be contained within bunding, a holding pond or basin. Any storages should also have a design permeability of 1 X 10-9 m/s for a depth of at least 300 mm comprising two 150 mm thick compacted layers. For design parameters for clay lining holding ponds or basins, refer to Appendix 1 of the PMEMRG.

For information on composting spent bedding refer to the latest edition of the NEGIP, 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.

14.2 Weed control

Weeds can become an issue during either the pig phase or the crop-forage-pasture phase. Regularly monitor paddocks and control weeds.

14.3 Feral pig control

Rotational outdoor piggeries may attract feral pigs. As well as posing a significant biosecurity issue, these may damage land and vegetation. Boundary fencing that excludes feral pigs, and an integrated feral pig management plan, is recommended for locations where these pose a risk.

14.4 Paddock rehabilitation

Paddock remediation may be needed during the pig phase to address soil erosion, structural decline or large wallows. It may also be needed on completion of the pig phase to prepare the land for the crop-forage-pasture phase.

Depending on the location, soil properties and facility management, soil compaction can be an issue. This can promote erosion and may impede plant germination and root growth. Paddocks should be regularly monitored for signs of soil erosion or structural decline during the pig phase. If necessary, eroded areas should be fenced-off, backfilled and replanted.

Remediation at the end of the pig phase may be necessary to prepare the land for the crop-forage-pasture phase. This may involve the removal of electric fencing, shelters, feeders and other paddock facilities, remediation of compacted or eroded land and wallow remediation.

If the soil is compacted or eroded, growing an ungrazed ley pasture crop after the pig phase may be helpful, although this must be balanced against the need to manage nutrients. The soil should only be cultivated when the moisture content is between wilting point and field capacity. Other soil compaction remedies will depend on the soil type and may include deep ripping and spreading gypsum. Badly eroded areas may need to be fenced off and excluded from agricultural uses.

Wallow remediation may involve discing or deep ripping the base and possibly applying gypsum, filling in the wallow with soil and levelling to match the slope of the surrounding land.

A forage crop or pasture must be given time to establish before commencement of the next pig phase.

15 Mortalities management

Environmental outcome: Mortalities management practices that protect against odour nuisance, public health concerns, vermin problems or groundwater and surface water contamination.

From an environmental perspective, composting and rendering are the preferred methods for disposal of mortalities, stillborn piglets and afterbirth. Suitable alternatives may include incineration and burial (subject to state or territory government regulations). Approval from the local government authority or environmental regulator may be required. Other methods that meet the environmental outcome may also be suitable. Irrespective of the method chosen, dead pigs should be immediately removed from the access of other pigs with disposal occurring within 24 hours of death. If the property is used for grazing stock, or if access by feral animals is a concern, the mortalities management area may need to be fenced.

15.1 Mortalities composting

Well-managed mortalities composting is an environmentally acceptable method and has the advantage of producing a soil amendment.

Mortalities composting should be undertaken within a bunded area with a low permeability base that could either be concrete or clay compacted for a permeability of 1×10^{-9} m/s for a depth of 300 mm comprising two 150 mm deep layers. For guidance and technical direction regarding earth pad preparation requirements refer to Appendix 1 of the PMEMRG. The depth to the water table from base ground level should exceed 2 m at all times. Any leachate or stormwater runoff caught within the composting area should be captured within bunding or in a holding pond. For design parameters for holding ponds refer to Appendix 1 of the PMEMRG.

Mortalities are generally composted in a series of above-ground bays or windrows. To size the pad, it is generally necessary to provide at least 4 m^3 of bay or windrow capacity for each tonne of mortalities expected. Ensure there will be sufficient space for vehicle manoeuvring. 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 used as a soil amendment, it should be spread evenly onto land at sustainable rates. Off-site reuse of mortalities compost may be subject to regulatory approval. Ensure grazing or harvest cannot occur within 21 days of spreading.

For further information on mortalities composting and reuse of mortalities compost, refer to the PMEMRG.

15.2 Rendering

Rendering is an excellent mortalities management method because there is little risk of adverse environmental impacts and a product (meat and bone meal) is generated. Rendering must be undertaken in accordance with the *Australian Standard for the Hygienic Rendering of Meat Products* (Standards Australia 2007).

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 must be in place to manage situations where mortalities cannot be collected, dispatched or received by the rendering plant.

15.3 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 level of the highest seasonal water table. Most burial pits are simple trenches excavated into the ground. Carcasses must be covered with a good layer of 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 subsistence that will occur as the bodies break down. Above-ground burial may be an option for sites with shallow groundwater tables. The mortalities are placed in a trench 0.5-0.6 m deep that is lined with a high carbon material (e.g. sawdust or straw). The bodies 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 or territory government agencies only allow burial under specific conditions, for example disease outbreaks or mass mortalities.

15.4 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 carcases.

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

15.5 Mass mortalities disposal

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 in place a contingency plan for managing the high death rates that may occur as part of a disease outbreak or other incident.

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

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

In some instances, off-site disposal may be mandated by a state/territory veterinary officer or environmental regulator.

16 Traffic and parking

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

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

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

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.

17 Landscaping

Environmental outcome: If required, landscaping is used to visually screen the piggery complex from sensitive land uses and enhance biodiversity.

Rotational outdoor piggeries may not require landscaping due to the lack of large permanent buildings and works. However, landscaping can be used to visually screen parts of the piggery from nearby sensitive land uses and roads if warranted. It can also be used to protect native species and enhance habitats.

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 plant nurseries may be able to advise on species selection and plant care.

18 Public health considerations

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

Australian piggeries generally have a very high health status and adhere to strict biosecurity protocols, minimising disease transfer risks. Feeding swill to pigs is illegal in Australia since foods that either contain meat or have been contaminated by meat may contain viruses that are extremely harmful to the health of pigs, other livestock and even humans. In most cases, dust is probably the most likely path for the transport of pathogens from rotational outdoor piggeries to the public. However, rotational outdoor piggeries generally produce only very low levels of dust (Banhazi 2013), so the public health risk is inherently low.

Measures that minimise public health risks include:

- providing adequate separation (see Section 9) distances from the piggery complex to sensitive land uses
- selecting low-risk crops for the first part of the cropping phase, for example avoiding human food crops that may be eaten raw or without processing
- using good reuse practices if spreading spent bedding or compost. Refer to the PMEMRG for details, although these include:
  - aging or composting spent bedding prior to spreading to reduce pathogen loads
  - avoiding handling or spreading dry manure or compost to minimise dust production
  - avoiding 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).

Alternative measures that meet the environmental outcome are also acceptable.

19 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 any 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, soil erosion from steep pig paddocks 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 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
- identifying practical controls that could reduce risk
- re-evaluating the risk level with the new controls in place.

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

20 Monitoring and assessment of sustainability

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.

Environmental monitoring, which includes using productivity and sustainability indicators to interpret results, is critical to the overall environmental management of a piggery. It provides a mechanism to assess the effectiveness of strategies chosen to minimise environmental impacts. This section provides guidance on monitoring, with detailed sampling guidance provided in Appendix C.

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 and may also conflict with land productivity. Sometimes 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 helpful for day-to-day management. Alerts for power, electric fence and water supply system failures can help in managing the piggery and mitigating environmental harm. Automatic weather stations can assist in monitoring weather conditions.

20.1 Complaints

Ideally, a piggery will operate in harmony with the community. Where issues arise, it is best to address these quickly and effectively.

20.1.1 Community liaison

Open communication lines between neighbours, piggery operators and regulators can help to quickly identify and rectify issues to minimise the impact of a piggery on community amenity. Establishing and maintaining lines of communication from the beginning is better than dealing with complaints as they occur. Once an operation commences, on-going two-way communication between the piggery operator and nearby land holders reduces the likelihood of complaints, can help in identifying when nuisance occurs and can assist in issue resolution.

Good community liaison may include:

- informing neighbours in advance of any events or problems that may cause an unavoidable increase in odour, dust or noise, including practices to mitigate the problem and the expected duration of the problem
- participation and cooperation in dispute resolution
- gathering relevant evidence, and identifying and implementing strategies to remedy the problem
- informing the complainant of the outcome of any investigations and any actions taken to resolve the issue and prevent future problems, and seeking feedBack to ascertain if the problem has been resolved.

20.1.2 Handling complaints

The number 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. Full details of the complaints received, results of investigations into complaints and corrective actions taken should be recorded in a complaints register as this can help in assessing future issues and demonstrates a commitment to resolving issues. An example of a complaints register form is provided in Appendix B.

Many amenity impacts are closely related to weather conditions, so consider daily weather monitoring if complaints are ongoing. This can also help in assessing the validity of complaints. Large enterprises, or those with a history of complaints, may find that investment in an on-site automatic weather station that continuously monitors wind direction and speed, along with other climatic conditions, is worthwhile.

20.2 Soils

Soil monitoring is necessary to effectively manage nutrients to avoid adverse impacts to soil properties, crop growth and the potential for impacts to surface waters and groundwater.

20.2.1 Soil Sampling Frequency

There are many guides available for interpreting soil tests, but they mainly focus on the quantities of nutrients needed to grow good crops. Using land for a rotational outdoor piggery changes the properties of soils and can result in an excess or imbalance of nutrients or concerns like sodicity. For rotational outdoor piggeries, it is best practice to test the soil of paddocks before the pigs move onto an area and also when the pigs leave an area. However, this should occur at least every 2 years for longer pig phases. This helps in understanding and managing soil nutrients. Soil nutrient levels may determine when pigs need to be moved from a land area. An understanding of total and **available nutrient** levels is important in optimising plant growth during the crop-forage-pasture phase and is also a determinant of the length of this phase. Where a risk assessment shows high risk, annual monitoring may be warranted.

In summary, soil testing should occur:

- before pigs move onto a new area of land (start of pig phase)
- at the end of any 2 year period in which pigs are stocked on a land area for any length of time or annually if there is a high risk
- in accordance with any approval conditions.

The **APIQ✓**® standards manual specifies soil monitoring requirements for certification as a FR or OB farm. Refer to the current standards manual for details at www.australianpork.com.au/apiq

20.2.2 Soil sampling and analysis

Samples should be collected from random locations in the areas between the shelters and the feeding, watering and wallowing facilities as these areas are likely to have the highest soil nutrient levels and pose the greatest risk to the environment. Recommended methods for soil sampling are provided in Appendix C.

The minimum recommended soil analysis parameters are given in Table 20.1. Analysis results should be compared with the sustainability indicator limits given in Section 20.2.3. Where soil analysis results exceed these limits, further investigation is triggered to identify whether changes need to be made to the system to ensure it is sustainable.

Table 20.1 Recommended soil analysis parameters

Soil test parameter	Depth (down profile)	Justification
pH	0-0.1 m 0.3-0.6 m OR bottom 0.3 m of soil profile/base of root zone	Influences nutrient availability
ECse (Can measure EC1:5 and convert to ECse)[a]	0-0.1 m 0.3-0.6 m OR bottom 0.3 m of soil profile/base of root zone	Measure of soil salinity
Nitrate-nitrogen	0-0.1 m 0.3-0.6 m OR bottom 0.3 m of soil profile/base of root zone	Measure of nitrogen available for plant uptake
Colwell phosphorus and phosphorus buffering index (PBI)	0-0.1 m 0.3-0.6 m OR bottom 0.3 m of soil profile/base of root zone	Measure of phosphorus available for plant uptake
Potassium	0-0.1 m 0.3-0.6 m OR bottom 0.3 m of soil profile/base of root zone	Measure of potassium available for plant uptake
Sulfur	0-0.1 m	Necessary nutrient for plant growth
Organic carbon	0-0.1 m	Influences soil stability and consequently soil erosion
Exchangeable cations and CEC (calcium, sodium, potassium, magnesium).	0-0.1 m 0.3-0.6 m OR bottom 0.3 m of soil profile/base of root zone	Needed to calculate ESP, exchangeable potassium percentage and Ca:Mg, which have important implications for soil structure

[a] ECse levels in the top soil layers are not intended to be a direct sustainability indicator, but will provide useful agronomic information and provide a guide to soil salt movements.

Note: Measuring chloride at 0.3-0.6m (or base of root zone) may also be warranted if further investigations or actions for salinity are triggered.

20.2.3 Evaluating soil monitoring results

Most soil nutrient recommendations understandably focus on the 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. Agronomic recommendations are different from environmental indicators. From an agronomic perspective, nutrients would ideally be applied at rates that optimise plant growth but do not provide excess nutrients. For rotational outdoor piggeries, there will likely be a surplus of some nutrients at the end of the pig phase that needs to be managed through the crop-forage-pasture phase. From an environmental perspective, it is important to recognise that any nutrients in excess of crop needs may pose environmental risk through leaching or removal in runoff.

This section and Tables 20.2-20.3 provide suggested trigger values to assist in deciding if pigs need to move from a land area, but also for management of the crop-forage-pasture phase. 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.

It is also important to note that nutrients may move more quickly through lighter soils. For most soils, subsoil nutrient levels may provide an early indication of the risk of nutrient leaching to groundwater, allowing mitigation before this occurs. However, for very sandy soils nutrient leaching after rain may remove these nutrients before they can be measured in the soil.

Soil properties vary widely and these suggested trigger values are not always the most appropriate measures of sustainability. For this reason, they should be regarded as a prompt for further investigation, such as comparison with data from a representative background plot. The ideal background plot would be close to the area of interest and have a similar soil type, but would not have been recently used to run pigs or spread with spent bedding or fertiliser. Refer to Appendix C for details on sampling background plots. Comparison with historical data and trend analysis may also be useful. Agronomists or soil scientists can assist with interpretation.

NITROGEN

Nitrate-nitrogen is extremely mobile and readily leached. Consequently, high nitrate-nitrogen levels in the subsoil may pose a risk to groundwater. 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 NO_3N/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 rotational outdoor piggery system based on nitrogen levels, consider a number of factors, including:

- the value or use of surrounding groundwater resources (human consumption, animal consumption, irrigation etc). Water containing less than 90 mg NO_3N/L is generally suitable for livestock consumption (ANZECC 2018)
- the depth to groundwater and aquifer type. The risk is greater for shallow or unconfined aquifers
- the soil types overlying the groundwater (e.g. clay versus sand) and how quickly leaching is likely to occur
- 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). Thus, 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 (or the bottom 0.3 m of the soil profile), although deeper sampling (to the base of the root zone) may be required if there are concerns about nitrate-nitrogen leaching.

For different soil types, Skerman (2000) calculated nitrate-nitrogen concentrations equivalent to 10 mg/L of nitrate-N in soil solution (see Table 20.2). This trigger value applies at a depth of 0.6 cm, or at the base of the root zone. it does not apply to the topsoil. Soil nitrate-nitrogen concentrations in conventional cropping systems using inorganic fertiliser often exceed those shown in Table 20.2. A nitrate-nitrogen rootzone concentration of 20-50 mg/kg generally provides enough nitrogen for cereal cropping and intensive grazing. The highest nitrate-nitrogen concentration given in Table 20.2 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 prompt 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 20.2 Nitrate-nitrogen concentrations corresponding to a soil solution concentration of 10 mg NO_3N/L at field capacity

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

Nitrate-nitrogen levels throughout the soil profile provide an indication of nitrogen availability for crop growth and sustainability. Once nitrate-nitrogen moves below the plant root zone, it is no longer available for plant uptake, but can leach to groundwater. Compare the results from the pig paddocks with those for background plots. 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 paddock management.

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

PHOSPHORUS

The main pathways for 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) can also cause phosphorus loss below the plant root zone. Leaching and runoff can occur when the soil is heavily overloaded with phosphorus or when available phosphorus is not being removed by growing and harvesting plants.

Table 20.3 give acceptable values for phosphorus concentrations in surface soil for various extracTable phosphorus tests. These values can provide guidance on concentrations that will meet plant requirements without resulting in significant leaching. It should be noted that these limits are commonly exceeded in normal agricultural soils. Thus, they should be used as triggers for further investigation (such as comparison against results from **background sites**) if there are doubts about sustainability. Alternatively, comparison with historical data and trend analysis may also be useful.

Moody (2011) reviewed the literature and concluded that there is no universally accepted environmental risk indicator for soil phosphorus status. He identified that the widely used Olsen-P, Colwell-P and phosphorus buffering index (PBI tests were useful for assessing the phosphorus status of the soil and the risk of off-site movement of dissolved and particulate phosphorus. He noted that the phosphorus soil levels needed to ensure optimal agronomic outcomes were well established, providing a link between the phosphorus levels needed for production and environmental risk. However, he also observed 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. It is suggested that the upper values for soils with a medium soil phosphorus status for crops with a low and moderate demand for phosphorus could serve as preliminary triggers for further investigation for soil tested post-harvest or at the end of the main pasture growth period. Values based on the work of Moody and Bolland (1999) are presented in Table 20.3.

Table 20.3 Suggested trigger levels for investigation for phosphorus in topsoil

PBP	P sorption category	Colwell phosphorus (mg/kg) by crop type	
		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 level would be expected during the crop production phase.

To investigate any possibility of phosphorus leaching through lighter 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 during the crop-forage-pasture phase is recommended.

POTASSIUM

Potassium generally causes few environmental problems. 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.

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.

Pig paddocks should not show increases in soil salinity that will adversely impact on the productivity of the land over the long term. In most cases, salinity is unlikely to be a problem for rotational outdoor piggeries. However, increases in soil salinity may occur in manure hot spots. The salt load needs 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 a saturated extract electrical conductivity (ECse) of up to 1.9 dS/m fall into the 'very low' to 'low' salinity rating. Thereafter, any ECse increase exceeding 2.5 dS/m shifts the soil salinity rating by less than one salinity class. Consequently, a trigger for further investigation or action is considered to be 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 also be useful.

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.

Sodium chloride is the main salt of interest from a soil degradation perspective. If further investigation or actions are warranted, the soil sodium (Na+) and chloride (Cl-) concentrations throughout the profile should be measured in both the pig paddocks and background sites. The Na+ and Cl- concentrations of the soil should be less than 150% of background levels.

20.2.4 Sodicity

Sodicity is important because it adversely affects soil structure and increases the associated risk of erosion.

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). A trigger for further investigation or action is a soil ESP exceeding 6%, in which case comparison with the soils of a background plot is suggested. Alternatively, comparison with historical data and trend analysis may also be appropriate. An ESP level exceeding 150% of background (e.g. from 6% to more than 9%) in any soil layer is considered unsustainable. Soil with an ESP exceeding 6% is not necessarily dispersive, particularly if it is saline. However, non-dispersive saline soils with a high ESP can become dispersive if the soil salinity declines. For example, following high rainfall, salinity may fall more rapidly than sodicity through increased drainage of the more soluble salts. This can lead to soil dispersion. Consequently, calcium application to displace sodium is recommended where the topsoil ESP exceeds 6%, and strongly recommended where it exceeds 9%.

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, or 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.

20.3 Surface water

Eutrophication (excessive nutrients) in surface waters may result in algal blooms and impacts to water quality that affect habitats and potential uses.

20.3.1 Surface water monitoring requirements

Surface water quality monitoring is rarely relevant because rotational outdoor piggeries do not directly discharge to watercourses providing the nutrients are managed as part of an overall farming system approach. In specific high-risk situations where there is a possibility of organic matter and nutrients entering watercourses, a risk assessment may identify the need for surface water monitoring. This may involve sampling and analysis of watercourses, other water bodies or stormwater runoff. This type of monitoring requires sophisticated equipment and trained operators to achieve meaningful results.

Piggery operators should also regularly inspect nearby surface waters for algal blooms (such as blue green algae) that are associated with elevated phosphorus and nitrogen levels. Affected water should not be used as a pig drinking water source until tested and deemed safe.

Monitor the usage of surface water to ensure any allocations are not exceeded.

Appendix C provides suggested sampling methods for surface waters. Environmental regulators may also have sampling methodologies and analysis requirements.

20.3.2 Surface water analysis parameters

If environmental monitoring is warranted, typical analysis parameters include:

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

20.3.3 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* (National Health and Medical Research Council and National Resource Management Ministerial Council 2011)

Comparison of nutrient, BOD and *E. coli* levels between upstream and downstream results can help to identify whether watercourse contamination could be occurring, although it is important to consider other possible inflows. Any changes in water quality downstream of the piggery should be evaluated.

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 welfare standards of the piggery.

20.4 Groundwater

Nutrient leaching into groundwater may reduce its quality and limit its potential uses. At many sites, groundwater monitoring is not warranted because the particular hydrogeology of the site and the design and management of the piggery provide confidence that the water is well protected. Subsoil monitoring usually provides for earlier problem detection and remediation than direct groundwater monitoring. However, groundwater monitoring may be warranted for sites with sandy soils and vulnerable groundwater due to the higher leaching risk (nutrients may move more quickly through light soil and into groundwater).

20.4.1 Groundwater sampling

Ideally, groundwater is monitored by comparing analysis results for water sampled from immediately up-gradient and down-gradient of the pig paddocks. The appropriate siting of the monitoring bores (**piezometers**) depends on the formation, depth, flow direction and connectivity of aquifers to other aquifers and surface waterbodies. Consultation with a hydrogeologist during the planning stage is recommended.

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

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

Groundwater usage should also be monitored.

20.4.2 Groundwater analysis parameters

Typical groundwater monitoring parameters include:

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

20.4.3 Evaluating groundwater analysis 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.

20.5 Manure and compost

Some large rotational outdoor piggeries, particularly those with grower pigs kept indoors on bedding, may need to manage large amounts of spent bedding. Spent bedding may contain high levels of copper and zinc (Wiedemann and Gould 2018). For piggeries collecting large quantities of spent bedding, it may be worth testing for these metals along with manganese and boron, particularly if the spent bedding is being sold.

Refer to the PMEMRG and the NEGIP for management and monitoring recommendations.

21 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 impacts can be detected and resolved. Proactive and genuine handling of complaints is an integral component of the monitoring and feedback loops.

21.1 EMP contents

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 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
- piggery design and operation including nutrient management plan and mortalities management
- environmental risks and any required mitigation or management strategies
- proposed environmental monitoring
- chemical storage and monitoring
- 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 reviews of the EMP to ensure that any changes in regulatory requirements, the environment and surrounds (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 1 of these guidelines provides a risk assessment process.

21.2 Piggery description

It is useful to describe the size, type and history of the operation. An example is given below.

EXAMPLE

The piggery operates as a 1,000 sow breeder unit. It is a rotational outdoor system with a rotation including 2 years of pigs followed by 3 years of barley crops (grain only, 3 t DM/ha) then one year of pasture hay (baled, 5 t DM/ha). Dry sows are kept in paddocks set out in a radial with bedded group shelters. The average stocking density is 15 sows/ha. Farrowing sows are kept in rectangular paddocks with individual bedded shelters. The average stocking density of these paddocks is 10 sows/ha. Piglets are weaned at 28 days and leave the site for rearing in deep litter shelters. The typical herd composition is:

- 830 dry sows
- 170 farrowing sows
- 50 boars
- 55 **gilts**
- 1725 suckers.

The pig phase commences with good ground cover levels.

21.3 Description of natural features and surrounding land uses

This section describes the surrounding land uses and also the land, native vegetation, groundwater and surface water resources.

The description of the surrounding land uses should cover:

- planning overlays
- 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.

An example of the description of natural resources follows.

EXAMPLE

The site has a gentle slope of about 2% to the north. It is fully cleared for farming. The soil across the site is a clay loam suitable for crop production. Groundwater is at a depth of about 30 m. It is the water source for the piggery. Crystal Creek forms the northern boundary of the property. Buffers 50 m wide are maintained between the pig paddocks and the creek. This buffer zone is kept well vegetated. There are no other significant watercourses or dams on the farm.

21.4 Nutrient management plan

A nutrient management plan (NMP) is needed to:

- provide a nutrient budget for the farm including manure nutrient application rates and nutrient removal rates by plant harvest
- evaluate how evenly manure nutrients are spread
- identify potential nutrient loss pathways
- develop and implement an action plan for managing the risk.

During the pig phase, there is a net accumulation of nutrients since nutrients imported as pigs, feed and bedding are not matched by removals through pig grazing and gaseous losses. For rotational outdoor piggeries the nutrients are spread over the paddocks as manure and spent bedding (unless this is removed from the paddocks). Surplus nutrients can be removed by growing and harvesting crops, forage or pastures after the pig phase. To optimise the growth of these crops it may be necessary to apply some fertiliser since pig manure is not a balanced fertiliser and some nutrients may not be available for plant uptake in sufficient quantities.

21.4.1 Preparing a nutrient budget

Understanding the rate at which nutrients are added during the pig phase and removed during the crop-forage-pasture phase is the first step to their management. Section 12 provides the steps for preparing a nutrient budget for a rotational outdoor piggery.

21.4.2 Promoting even spreading of manure nutrients

Without active management, manure nutrients will concentrate in the area between the shelter, feeder, water trough and wallow. The nutrient rich hot spots that result pose an increased risk of nutrient leaching and runoff during both the pig phase and the early part of the crop-forage-pasture phase that follows.

Active site management is needed to promote more even manure excretion. This involves regularly relocating movable infrastructure around the paddock (e.g. shelters and feeding points). See Section 13 for more details.

The NMP should include a statement about how evenly manure nutrients are spread in rotational outdoor piggeries.

EXAMPLE

In the dry sow paddocks, huts and feeders are relocated every 3-4 months. Wallows are replaced if they become too deep. Water troughs are static. Spent bedding is spread evenly over the paddocks after shelters are moved.

In the farrowing paddocks, farrowing huts move down the paddock to fresh ground after each litter is weaned (about every 4 weeks). As sows are individually fed near the hut, this means that the feeding point also moves frequently. The spent bedding is left in the paddock. Water troughs are static. Wallows are replaced if they become too deep.

Moving the huts and feeders regularly helps to spread the nutrients more evenly over the paddock area.

21.5 Potential nutrient loss pathways

This section should evaluate the detail contained in the previous sections, along with any soil analysis results, and identify areas where there is a significant risk of nutrient losses. For example:

EXAMPLE

In both the dry sow and the farrowing paddocks there is a significant surplus of nutrients after 2 years, particularly in the farrowing paddocks. There is the potential for nutrient runoff and leaching during both the pig and the crop-forage-pasture phases unless suitable mitigations are in place.

The paddocks are largely denuded by about 6 months into the pig phase. This increases the erosion risk. Any eroded soil is likely to have a high nutrient content.

21.6 Action plan for managing the risks

This section needs to provide targeted action aimed at reducing the likelihood of nutrient losses.

When planning rotations, it is important to aim for sustainable soil nutrient levels. Nutrient concentrations need to be at manageable levels at the end of the pig phase. When planning this phase, there may be a need to reduce nutrient inputs (e.g. by reducing the stocking density or shortening the length of the pig phase) or increase nutrient removals (e.g. by growing crops that remove more nutrients when harvested like hay or silage crops or by lengthening the crop-forage-pasture phase). Generally, the length of the pig phase should not exceed 2 years. In situations where higher stocking densities are used, or the paddocks have light or shallow soils, shorter pig phases will be needed to effectively manage nutrients.

There is also a need to promote even nutrient distribution over the paddocks to minimise the risk of nutrient hot-spots as these may pose a significant risk even if the overall nutrient balance is manageable.

Reducing the stocking density or the length of the pig phase in a rotational outdoor piggery may also help to retain groundcover, which helps to protect against soil erosion.

Soil monitoring can confirm nutrient status. This should occur before a pig phase commences to ensure that the soil has suitable properties and provide benchmark data. Thereafter soil monitoring should be undertaken at a frequency determined from a risk assessment but generally at least every 2 years. Samples should be collected from areas that are expected to be nutrient rich (i.e. between the shelters and the feeding area, water troughs and wallows). If interpretation of the results confirms that soil nutrients are at suitable levels, the area can be used for ongoing or subsequent pig phases. If they do not, action must be taken to reduce soil nutrients to acceptable levels. This will generally involve destocking the land and growing and harvesting plant material from the area.

An Action Plan for the example used in this section follows:

EXAMPLE

By 1 Mar 20:
A vegetated filter strip will be installed between the paddocks and the creek. This will filter the runoff and slow the rate of runoff increasing infiltration, which reduces the risk.

By 1 Mar 20:
Implement twice-yearly soil monitoring across the farm. Undertake baseline soil monitoring for new areas and sampling of the nutrient rich areas of the existing pig paddocks.

By 1 July 20:
Engage an agronomist to assist in interpreting soil results and planning the crop-forage-pasture phase.

22 Chemical use, storage and handling

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

Each Australian state and territory 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 used and stored
- 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 absorbent 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
- disposal of empty chemical drums and vaccine and other 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 safe storage and handling of agricultural and veterinary chemicals, see *The Storage and Handling of Agricultural and Veterinary Chemicals* (Standards Australia 1998).

23 Gaseous emissions: National Pollutant Inventory

Under the *Emission Estimation Technique Manual for Intensive Livestock – Pig Farming* (Department of the Environment and Water Resources 2007) outdoor piggeries do not need to report ammonia emissions. However, the manual does require reporting of emissions from indoor piggeries, such as the shelters typically used with OB production systems. Deep litter piggeries that stockpile spent bedding on-farm (the grower component of some piggeries) trigger reporting responsibilities if they have a capacity of about 2,000 SPU. For deep litter piggeries that do not stockpile spent bedding on-farm, the threshold increases to about 7,100 SPU.

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Appendix A

Environmental risk assessment - methods for assessing the likelihood that the piggery will have an impact on the environment

Appendix A: Environmental risk assessment

A1 Introduction

An environmental risk assessment identifies any potential impacts that a proposed or operating rotational outdoor piggery 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 ISO 31000:2018 *Risk Management – Guidelines* provide further guidance.

A2 Environmental risk assessment process

The steps in the environmental risk assessment process are described below.

A2.1 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 A1 Summary of risk assessment process

Identify hazards	• Identify hazards.
Consequences	• Identify the consequence of the hazard occuring considering siting, design and management, i.e. low to severe.
Likelihood	• Identify the likelihood of occurence, i.e. rare to certain.
Risk rating	• Determine the level of risk to the environment, i.e. low to extreme.
Identify practical controls	• If acceptable risk, manage and monitor to ensure risk remain acceptable • If unacceptable, identify new controls.
Re-evaluate risk	• Re-evaluate risk with new controls.

A2.2 Hazards

Hazards are the ways in which a rotational outdoor piggery may pose a risk to the environment or public health. For example, excessive nutrient accumulation in soil might pose a risk to groundwater.

Common hazard categories could include the potential for risks from:

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

A2.3 Consequences

The consequences are 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. Table A1 provides information to allocate consequence levels.

Table A1 Consequence levels

Low	No or minimal environmental or public health impact.
Minor	Low environmental impact or potential for public health impacts. Examples include: • elevated nutrients levels in the soil (no nearby waterways) • hard pan developed at 20 cm depth due to sodicity (no offsite implications) • pigs damage unprotected native trees (no trees killed).
Moderate	Medium level of harm to the environment or public health over an extended period of time. Examples include: • eroded soil from pig paddocks regularly entering a waterway following rainfall events • nitrate-nitrogen in groundwater beneath pig paddocks exceeds 10 mg/L • pigs damage unprotected native trees (a small number of trees killed, none of them vulnerable or endangered species).
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: • running pigs on protected native grasses significantly damages that habitat • nutrients leaching into a perched water table move laterally downslope into an important wetland.
Severe	Something that causes permanent or long term serious environmental harm, life-threatening or long-term harm to public health. Examples include: • *E. coli* from pig paddocks enters groundwater used as a drinking water supply • worker death resulting from untrained staff working in a confined space or hitting overhead power lines with machinery.

A2.4 Risk likelihood

Next, evaluate the likelihood of the hazard eventuating. Use the information in Table A2 as a guide.

Table A1 Consequence Levels

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 trees within a pig paddock are not fenced off, damage to those trees is expected to happen due to pig chewing and rooting. It is "certain" to happen as it is expected this would happen regularly under normal circumstances.

A2.5 Evaluating the risks

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

Figure A.2 Risk 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

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 additional controls should be considered to try to reduce the risk to low.
- High (orange) – the risk is unacceptable. Risk will need to be mitigated through 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.

For example, moderate consequence x possible likelihood = medium risk.

EXAMPLE 2

If pigs damage native trees (no vulnerable species) killing a small number, the consequence is "moderate". If trees within a pig paddock are not fenced off, this is "certain" to happen. The risk is "high" (moderate x certain).

A2.6 Action plan

The level of risk from the risk rating matrix identifies whether corrective or preventative actions are needed to reduce or mitigate risk. Use the information in Table A3 to decide on risk actions.

Table A3 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.

A2.7 Identifying practical controls

Where a risk needs to be addressed, consider the causes of the risk and use these to identify options to minimise the risk to the extent that is reasonably practicable taking into account effectiveness, feasibility and cost. This could be achieved by eliminating or reducing the hazard or consequence and the likelihood. Controls could involve changes to siting, design or management. For example, a risk to a watercourse could be reduced by relocating pig paddocks further away. A nutrient risk to surface water due to runoff from pig paddocks could be mitigated by installing a VFS or a bund, diversion bank or terminal pond.

EXAMPLE 3

In the previous example, there was a high risk to biodiversity from pigs damaging native trees. Fencing the trees below the drip line is expected to significantly reduce the risk.

A2.8 Re-evaluate risk

This step involves re-assessing the risks using the risk matrix to determine if the new controls will eliminate or lower it to an acceptable level. If not, the process should be repeated.

EXAMPLE 4

In the previous example there was a high risk to biodiversity from pigs damaging native trees. If the trees were fenced below the drip line to prevent pig access, the likelihood of harm would reduce to “rare”. The risk is now low (moderate x rare).

A3 Guidance to assist in risk assessment

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

A3.1 Amenity and natural resources vulnerability

The purpose of this section is to identify sensitive land uses and natural resources that might be at greater risk from hazards. It provides a way to assess the vulnerability of the:

- soils of pig paddocks
- 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 the tables below. Since it is not possible to represent all situations that will occur on all farms, discretion should be used when evaluating site vulnerability. To use the vulnerability assessment, read the statements in the individual rating criteria and select the most appropriate category for the site. The options are ordered from lowest to highest risk. Using the vulnerability templates will help to pinpoint areas where better design and management may be needed to minimise risks to the environment.

Table A4 Vulnerability rating — soils of pig paddocks

Criteria
Paddocks used to run pigs are:
• suited to growing a broad range of broadacre crops and pastures • suited to growing crops or pastures that can be cut and carted • unsuited to growing or harvesting crops or pastures that can be cut and carted.
Paddocks used to run pigs have a soil depth of:
• at least 1 m • at least 0.75 m • at least 0.5 m • less than 0.5 m.
Paddocks used to run pigs have soils that are:
• well structured, non-rocky, non-saline and non-sodic • non-rocky, non-saline and non-sodic • rocky or saline or sodic.

Paddocks used to run pigs have soils that are:
• loam to light clay in texture • sandy loam to medium clay in texture • heavy clay (>50% clay) in texture • sandy in texture (<10% clay).
Paddocks used to run pigs are:
• not prone to waterlogging • prone to waterlogging.
Paddocks used to run pigs are:
• above the one-in-100-year flood line • above the one-in-50-year flood line • above the one-in-20-year flood line • lower than the one-in-20-year flood line.
Paddocks used to run pigs have slopes of:
• 2-4% • 0-2% or 4-6% • >6%.

Table A5 Vulnerability rating — groundwater and availability

Criteria
The depth to groundwater is:
• always at least 20 m below the ground surface of paddocks used to run pigs OR always at least 10 m beneath the surface and protected by a significant rock or clay band • always at least 10 m below the ground surface of paddocks used to run pigs OR always at least 5 m beneath the ground surface and protected by a significant rock or clay band • always at least 2 m below the ground surface of paddocks used to run pigs • sometimes present at a depth of less than 2 m below the ground surface of paddocks used to run pigs.
Water for potable use is:
• not sourced from bores located within 1 km of the piggery • sourced from bores located within 1 km of the piggery.
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.

Table A6 Vulnerability rating — surface water quality and availability

Criteria
Paddocks used to run pigs are located:
• at least 200 m from the closest watercourse • at least 100 m from the closest watercourse • within 100 m from the closest watercourse.

Paddocks used to run pigs are located:
• at least 800 m from the closest major water supply • within 800 m from the closest major water supply.
Paddocks used to run pigs and other on-farm reuse areas:
• comply with the buffer distances in Table 9.3 of the NEGROP and there are also vegetative filter strips or terminal ponds between these areas and all watercourses • comply with the buffer distances in Table 9.3 of the NEGROP • don't comply with the buffer distances in Table 9.3 of the NEGROP but there are effective VFS (designed as per Section 9.3 of the NEGROP) or terminal ponds between these areas and all watercourses • don't comply with the buffer distances in Table 9.3 of the NEGROP and there are not effective VFS (designed as per Section 9.3 of the NEGROP) or terminal ponds between these areas and all watercourses
Paddocks used to run pigs are 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.
On-farm 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.

Table A7 Vulnerability rating — 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 • four or more complaints per year (on average) over the past 5 years.
The pig paddocks:
• always meet all the minimum fixed separation distances specified in Table 9.1 of the NEGROP • always meet the minimum fixed separation distances to a town, rural residential area, rural dwelling specified in Table 9.1 of the NEGROP • always meet the minimum fixed separation distances to a town, rural residential area and rural dwelling specified in Table 9.1 of the NEGROP • don't always meet the minimum fixed separation distances to a town, rural residential area or rural dwelling specified in Table 9.1 of the NEGROP.
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.

A3.2 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:

- nutrient budgeting and monitoring
- the distribution of manure nutrients
- nutrient loss prevention
- mortalities
- paddock rehabilitation
- odour, dust and noise.

Not all the factors will be applicable to all enterprises. For example, not all rotational outdoor piggeries will have a VFS. To evaluate the protection afforded by each element of design and management, read the statements and select the most appropriate one for the farm. The guidance in these design and management templates can also be used to identify options to further reduce environmental risks.

Table A8 Risk assessment — nutrient budget and monitoring

Criteria
The quantity of nutrients deposited over the paddocks as pig manure is:
• estimated before or within the first 12 months of the pigs moving onto an area and a pig and crop-forage-pasture rotation able to remove the added nitrogen, phosphorus and potassium or achieve sustainable soil nutrient levels over a maximum of 4 years is planned • estimated before or within the first 12 months of the pigs moving onto an area and a pig and crop-forage-pasture rotation able to remove the added nitrogen, phosphorus and potassium or achieve sustainable soil nutrient levels over a maximum of 6 years is planned • estimated before or within the first 24 months of the pigs moving onto an area and a pig and crop-forage-pasture rotation able to remove the added nitrogen, phosphorus and potassium or achieve sustainable soil nutrient levels over a maximum of 8 years is planned • either not estimated within the first 24 months of the pigs moving onto an area or a plan for a pig and crop-forage-pasture rotation able to achieve sustainable soil nutrient levels or achieve sustainable soil nutrient levels over a maximum of 8 years is not developed.
Soil sampling:
• occurs before the commencement of each pig phase expected to exceed 24 months in length, at the end of any 24-month period during which pigs are stocked on an area for any length of time, and at the end of any subsequent 24-month period that includes a pig phase • occurs at the end of any 24-month period during which pigs are stocked on an area for any length of time, and at the end of any subsequent 24-month period that includes a pig phase • occurs at the end of any 36-month period during which pigs are stocked on an area for any length of time, and at the end of any subsequent 36-month period that includes a pig phase • does not occur regularly.
Soil sampling:
• produces a set of samples representative of the expected nutrient-rich area of each **block of paddocks** • produces a set of samples representing the average of the whole block of paddocks (i.e. soil collected from the expected nutrient-rich area of each block is combined with soil from other areas) • does not occur regularly.

Table A8 Risk assessment - nutrient budgeting and monitoring (continued)

Criteria
Soil sampling depths and analysis parameters:
• are in accordance with Table 20.1 of the NEGROP or the requirements of a planning or development consent, approval, permit, or licence • include topsoil monitoring of pH, EC, ESP, nitrate-nitrogen, available phosphorus, PBI, and potassium, as well as subsoil monitoring of EC, ESP, and nitrate-nitrogen • include topsoil monitoring of pH, EC, ESP, nitrate-nitrogen, available phosphorus, PBI, and potassium, and subsoil monitoring of nitrate-nitrogen • are not in accordance with any of the above.
Before the commencement of a pig phase expected to exceed 24 months in length:
• the results of soil testing show that the soil properties are either below the trigger values suggested as indicators of sustainability in Section 20.2.3 of the NEGROP, similar to those of a background plot, or satisfactory to the licensing authority, an independent soil scientist or an independent agronomist • either no soil testing results are available, or the results do not meet the criteria above.

Table A9 Risk assessment — distribution of manure nutrient

Criteria
In breeder paddocks:
• shelters and feeding points are moved at least every 3 months to promote more even nutrient deposition over the land, or, if the pig phase is less than 3 months, shelters and feeding points are relocated before the pigs return to the area • shelters and feeding points are moved at least every 6 months to promote more even nutrient deposition over the land, or, if the pig phase is less than 6 months, shelters and feeding points are relocated before the pigs return to the area. Alternatively, feed is distributed along the length of a paddock perimeter fenceline or dispersed across a significant part of the paddock, ensuring feeding areas are well-separated from shelters • waterers, wallows, or cooling facilities are moved at least every 6 months to promote more even nutrient deposition over the land, or, if the pig phase is less than 6 months, waterers, wallows, or cooling facilities are relocated before the pigs return to the area • the above criteria are not met.
In grower paddocks:
• shelters and feeding points are moved at least every 6 weeks to promote more even nutrient deposition over the land. If the pig phase is less than 6 weeks, shelters or feeding points are relocated before the pigs return to the area • shelters or feeding points are moved at least every 3 months to promote more even nutrient deposition over the land. If the pig phase is less than 3 months, shelters or feeding points are relocated before the pigs return to the area. Feed is always delivered along most of the paddock perimeter fence line or dispersed over a significant part of the paddock area, and feeding areas are well separated from shelters • waterers, wallows or cooling facilities are moved at least every 3 months to promote more even nutrient deposition over the land. If the pig phase is less than 3 months, waterers, wallows or cooling facilities are relocated before the pigs return to the area • the above criteria are not met.
If significant quantities of spent bedding are produced from the shelters, this material is:
• dispersed over land within the pig paddocks that is not in the expected nutrient-rich areas bounded by shelters, shade, feeding points, waterers, wallows and spray or drip coolers • removed from the pig paddocks and spread on other parts of the farm that meet the fixed buffer criteria in Tables 9.2 or 9.3 of the NEGROP • dispersed over land within the piggery that includes the expected nutrient-rich areas • spread on land on-farm that does not comply with the fixed buffer criteria in Table 9.2 or 9.3 of the NEGROP.

Table A10 Risk assessment - nutrient loss prevention

Criteria
Potential nutrient loss pathways:
• are identified in a nutrient management plan or environmental management plan, which includes an action plan to address these concerns • have been identified, and there is a written action plan to address these concerns • have been identified, but there is no formal action plan • have not been specifically identified.
Nutrient export from pig paddocks is:
• minimised by selecting sites with a flat to gentle slope and maintaining good groundcover over the paddocks • minimised by selecting sites with a flat to gentle slope and installing structures that effectively limit erosion and nutrient transfer to surface waters, such as contour banks or minimised by selecting sites with a flat to gentle slope and maintaining good groundcover over the paddocks • minimised by selecting sites with a flat to gentle slope and installing structures that effectively limit erosion and nutrient transfer to surface waters, such as contour banks or VFS • minimised by selecting sites with a moderate slope and either maintaining groundcover over the paddocks or installing structures that effectively limit erosion and nutrient transfer to surface waters, such as contour banks or VFS • not minimised because the land has excessive slope, there is insufficient groundcover, or there are no structures that effectively limit erosion and runoff • minimised by selecting sites with a moderate slope and either maintaining groundcover over the paddocks or installing structures that effectively limit erosion and nutrient transfer to surface waters, such as contour banks or VFS • not minimised because the land has excessive slope, there is insufficient groundcover, or there are no structures that effectively limit erosion and runoff.
Nutrients in runoff or soil eroded from the pig paddocks are:
• controlled by meeting the recommended buffer distances specified in Table 9.3 of the NEGROP and using appropriately designed VFS at least 10 m wide or terminal ponds that catch the first 12 mm of runoff • controlled by meeting the recommended buffer distances specified in Table 9.3 of the NEGROP • not specifically prevented.
Wallows:
• are lined with clay soil • are lined with loam soils • are not lined with loam to clay soils.

Table A11 Risk assessment — mortalities management

Criteria
Dead pigs are:
• always removed from the paddocks daily • left in the paddocks for more than 24 hours

Mortality 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.

Mortality management is undertaken by:

- rendering or composting
- burial or proper incineration
- burning or dumping.

Mortalities composting areas, burial pits and areas used to store mortalities prior to collection:

- always provide at least 2 m depth between base level and groundwater, and are 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
- 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 straw, sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered
- generally promptly covered with at least 300 mm of straw, 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 straw, sawdust or alternative carbon source (if composting) or soil (if burying) or not continuously kept covered.

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 area.

To be prepared for a mass mortalities event, there is:

- a suitable site selected and a detailed plan for managing mass mortalities
- a suitable site selected and a plan for managing mass mortalities
- a suitable site selected but no real plan for managing mass mortalities
- no site selected or plan for managing mass mortalities.

Table A12 Risk assessment — paddock rehabilitation

Criteria

Inspection of each block of paddocks to identify soil erosion or structural issues:

- occurs on completion of the pig phase or at least every 24 months, any issues that need addressing are identified, and a plan to address the issues is developed and implemented within one month of the inspection
- occurs on completion of the pig phase or at least every 24 months, any issues that need addressing are identified and a plan to address the issues is developed and implemented within 3 months of the inspection
- does not occur in accordance with the above.

Where significant soil erosion has resulted from the pig phase:

- the site is remediated by back-filling the eroded area with soil and incorporating a pasture ley crop into the crop-forage-pasture phase
- the site is remediated by back-filling the eroded area with soil before growing a crop
- the site is not remediated.

Where significant soil compaction has resulted from the pig phase:
• the site is remediated by applying ameliorants, cultivating the soil only when the moisture content is between wilting point and field capacity, and incorporating a ley crop into the crop-forage-pasture phase • the site is remediated by cultivating the soil only when the moisture content is between wilting point and field capacity, and by deep ripping the soil or applying ameliorants • the site is not remediated.
Wallows are:
• remediated when they are replaced, and if needed within 3 months of completion of the pig phase, by deep ripping the soil, applying ameliorants, filling with soil, and levelling to match the slope of the land • remediated when they are replaced, and if needed within 3 months of completion of the pig phase, by deep ripping the soil, filling with soil, and levelling to match the slope of the land • remediated when they are replaced, and if needed within 3 months of completion of the pig phase, by filling with soil • not remediated.
Before a new pig phase commences:
• pasture or a forage crop is well established over the whole paddock area • pasture or a forage crop is not well established over the whole paddock area

Table A13 Risk assessment — odour, dust and noise

Criteria
Odour, dust and noise are:
• minimised by maintaining clean, dry bedding in shelters, promptly remediating or replacing wallows and other wet areas if they become odorous, scheduling truck movements during the day except under exceptional circumstances, fitting manufacturer-specified exhaust systems to all mechanical equipment and vehicles used on-farm, and ensuring dust does not reach nuisance levels off-farm • managed by maintaining clean, dry bedding in shelters, remediating or replacing wallows and other wet areas if they become odorous, scheduling truck movements to occur during the day, and fitting manufacturer-specified exhaust systems to all vehicles used on-farm • not actively managed.
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 and corrective action.
Mediation is:
• used to try to settle disputes with neighbours (or would be if there were issues) • generally used to try to settle disputes with neighbours (or would be if there were issues) • not generally used to try to settle disputes with neighbours.

Appendix B

Complaints register – shows an example of a complaints register that can be used to record and manage complaints received

Appendix B: Complaints register

The rate of complaints received cannot be used as a sustainability indicator as it is an imprecise measure of community amenity impact. However, any complaint should be taken seriously by the piggery operator and should be recorded and properly investigated. Full details of complaints received, results of investigations into complaints, and corrective actions should be recorded in a 'complaints register'. An example of a complaints register form is below.

Complaint register

Investigation 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):	

Complaint details
Temperature at time of complaint:
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 C

Sample collection and analysis – describes methods for collecting samples (e.g. spent bedding and compost, soil, surface waters and groundwater) for analysis

Appendix C: Sample collection

C1 Introduction

This appendix details methods for collecting, storing, handling and treating samples of soils, spent bedding, **compost**, surface water and groundwater in order to monitor quality and quantity. For details on plant testing refer to the latest edition of the NEGIP.

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, that 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 in 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.

C2 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 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.

C3 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 necessary preservatives. Obtaining sample containers or advice from the laboratory reduces the chance of sample **contamination** and ensures that the sample size is adequate. For soil, manure or compost, ziplock plastic bags are generally suitable
- personal protection equipment (e.g. rubber gloves and face mask)
- a sampling rod if sampling surface waters directly from the source. A rod with a large clamp for holding the sampling container allows greater reach when sampling liquids. If a rod is not used, the sample should be taken from upstream of the feet, to ensure that disturbed sediment is not collected
- a sampling bailer or pump if sampling from bores or piezometers, along with a tape measure and plopper or fox whistle to determine groundwater depth. A bailer is inexpensive but time-consuming and impractical for deep bores. It is also important to ensure the bailer is clean before use. A pump is more convenient
- equipment for sampling manure, compost, or soils, including a shovel, auger, post hole digger, hydraulic soil sampling rig, trowel, clean plastic sheet, ruler or tape measure, and 3 clean buckets for soil sampling
- 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.

C4 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
- any method used to preserve samples (e.g. sample immediately put on ice in cooler)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

C5 Sampling soils

C5.1 Sampling location

Samples should be collected from the expected nutrient-rich areas of each block of paddocks. These are generally the parts of the paddock bounded by the shelter, the feeding area and other installations (see Figure C1).

Figure C1 Soil Sampling Locations

C5.2 Sampling procedure

1. Identify and record details of the block/s of paddocks and any representative background plots[1] that will be sampled.
2. For each sample, allocate a unique sample name including the name of the block of paddocks or background plot and the sample depth. Unless the conditions of a planning or development consent, approval, permit or licence state otherwise, for each block of paddocks and background plot a single sample will be needed for each of the following depth ranges:
   - 0 to 0.1 m
   - 0.3 to 0.6 m or 0.3 m to the base of the root zone or the base of the soil profile
   - whole soil profile from surface to a depth of 0.6 m or to the base of the root zone or the base of the soil profile.

An example of appropriate sample names for all the soil samples for a block of paddocks is:

- Road Paddock Radial 0-0.1 m
- Road Paddock Radial 0.3-0.6 m
- Road Paddock Radial 0-0.6 m.

3. Label one sample bag and one laboratory analysis request form for each sample. Include the enterprise name, telephone number, unique sample name, sampling location, sampling depth and sampling date.
4. For each block of paddocks, drill at least 10 test holes in dispersed locations between the shelters and the feeding and watering points. Record the location of each test hole on the piggery map, paddock plan, or using GPS coordinates. For each background plot, drill at least 10 test holes in dispersed locations within the plot. Record the location of the representative background plot on the piggery map, paddock plan, or using GPS coordinates.
5. For each block of paddocks or representative background plot, make a single composite soil sample for each sampling depth by:
   - placing approximately 2 cups of soil from each relevant depth from test hole into the bucket with the corresponding depth label
   - repeating this procedure by adding soil to the buckets from subsequent test holes until sampling from all test holes for a block of paddocks or a representative background plot is completed.
6. For each sampling depth, thoroughly mix the collected soil on the plastic groundsheet. Fill the labelled sample bags with soil from the matching sampling depth. Repeat for each block of paddocks or representative background plot.
7. Place the bags of samples in an cooler. Place the completed analysis request forms in an envelope and tape firmly to the top of the cooler.
8. Arrange for sample delivery to the laboratory. Confirm that the samples have been received.

[1] A representative background plot is an area of land that has a similar soil type and is physically close to the land being monitored that is sampled and analysed at the same time to provide a basis for comparison when interpreting soil test results. It should not have been used for outdoor pig production, spread with spent bedding or manure, or recently had fertiliser applied. Each background plot should be a circle with a diameter of 20 m. The location of the centre of each representative background plot should be carefully noted as samples should be collected from the same location each time.

C6 Sampling spent bedding and compost

C6.1 Sampling location

For piggeries that collect spent bedding, separate samples are needed for each type of manure product. This could include spent bedding and compost. If spent bedding is stored or composted before reuse, then only the stored or composted product would generally need to be analysed.

C6.2 Sampling procedure

1. Assemble the sample containers or bags and with a waterproof pen, label the sample containers (not lids) or bags with the enterprise name and telephone number, a unique sample number, the sampling location (e.g. compost area 1) and the date of sampling.
2. Complete as many details of the analysis request forms as possible. This should include contact details, sample numbers (matching those recorded on the sample containers), 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 and carry out standard hygiene practices.
4. Use a clean shovel to collect at least 10 one-cup grab samples. Put each sample in the bucket and thoroughly mix with the trowel. Place about 4 cups of the mixed sample into a bag and seal. Put the bag inside another bag and seal well.
5. 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. If the sample will be frozen, leave room in the sample bag to allow for expansion. Do not keep samples in a freezer used for food storage.
6. Immediately place the sample in an 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.
7. Arrange for sample delivery to the laboratory. Confirm that they have been received.

C7 Sampling surface water

C7.1 Sampling location

Sampling sites must provide representative samples and be accessible. Discuss selected sampling locations with the relevant approved authority before sampling to ensure that the results will be acceptable.

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.

C7.2 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 steps can be followed:

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name and telephone number, a unique sample number, the sampling location (e.g. Deep Creek upstream of piggery) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.
2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.

3. Organise bottles and rods for sample collection. Grab samples should be collected directly into sample containers. 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. Ideally 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 plunging it 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 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. Consult the laboratory for details.
5. Immediately place the samples 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. If samples will be frozen, leave space at the top of the sample bottle to allow for expansion. Do not freeze 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 contaminated water 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 samples to be delivered to the laboratory. Confirm that they have been received.

C8 Groundwater sampling

C8.1 Sampling location

If groundwater monitoring is to be undertaken, suitable monitoring bores or piezometers must be identified or installed. A piezometer is a non-pumping well, generally of small diameter with a short screen through which groundwater can enter. These must be installed correctly with depth and casing particularly important. Monitoring bores or piezometers may also need to be registered before construction. The approved authority should be consulted.

As groundwater may move extremely slowly, bores or piezometers should be located in close proximity and downstream of the area being monitored. It is also advisable to locate a bore or piezometer above the area of interest, to allow for comparison. Both bores should access water from the same aquifer. While a network of bores provides better information, this can become expensive. Hence, it is worth consulting a hydro-geologist or specialist consultant for advice on the location, installation and sampling of bores.

C8.2 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 and telephone number, a unique sample number, the sampling location (e.g. Bore 1 north of pig paddocks) 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. 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 one to 2 days before sampling to allow time for it to refill. Allow bore to recharge with groundwater before sampling. If it is not possible to purge the bore before sampling, the sampling process should not disturb the water within the bore.
4. Measure the depth to groundwater.
5. Collect a grab sample using a bailer or pump.
6. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Rinse the sample bottle with the water to be collected. Fill the bottle directly from the bailer or pump. Remove the bottle from the flow as soon as it completely fills. 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. Consult the laboratory for advice.
7. Immediately place the sample in an cooler, pack crushed ice completely around it and replace the cooler lid.
8. 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. If samples will be frozen, leave space at the top of the sample bottle to allow for expansion. Do not freeze samples in a freezer used for food storage.
9. When all other surface water or groundwater samples have been added to the cooler, seal it with the waterproof tape. Do not put contaminated water 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.
10. Arrange for the samples to be delivered to the laboratory. Confirm that they have been received.

Appendix D

Useful conversions – lists conversions that may be used in implementing the National Environmental Guidelines for Outdoor Piggeries

Appendix D: Useful conversions

D1 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
1t	1000 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)	1 m^2 = 0.0001 ha

Volume		
1 cubic inch (in^3)	16.4 cubic cm (cc, cm^3)	1 cc = 0.06 in^3
1 cubic foot (ft^3)	28.3 litres (L)	1 L = 0.035 ft^3
1 ft^3 = 6.2 gallon (gal) 1 gal = 0.16 ft^3		
1 cubic yard (yd^3)	0.8 cubic metres (m^3)	1 m^3 = 1.3 yd^3
1 acre foot (ac-ft)	1.23 ML	1 ML = 0.8 ac-ft
1 gallon (gal)	4.5 L	1 L = 0.22 gal

Pressure		
1 gallon/hour (gph)	0.00125 litres per second (L/s)	1 L/s = 800 gph
1 pound/inch^2 (psi)	6.9 kilopascals (kPa)	1 kPa = 0.145 psi
1 pound/foot^2	47.9 pascals (Pa)(lb/ft^2)	1 Pa = 0.02 lb/ft^2
1 pascal (Pa)	1 newton/m^2 (N/m^2) (pressure units)	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

D2 Other conversions

1 ML	1 000 000 L = 1000 m^3
1 m^3	1000 L = 0.001 ML
1 ML/ha	100 mm depth over 1 ha
ppm	mg/kg, mg/L
1 mg/kg	1 kg/t
1 mg/L	1 kg/ML

D3 SI units

D3.1 SI units

Quantity	SI unit	Other units
Length	metre (m)	inch (in), foot (ft), yard (yd)
Mass	kilogram (kg)	ounce (oz), pound mass (lbm)
Volume	metre^3 (m^3)	inch^3 (in^3), foot^3 (ft^3)
Time	second (s)	
Velocity	metre/second (m/s)	foot/second (ft/s), miles/hour (mph)
Acceleration	metre/second^2 (m/s^2)	inch/second^2 (in/s^2), foot/second^2 (ft/s^2)
Area	metre^2 (m^2)	inch2 (in^2), foot^2 (ft^2)
Density	kilogram/metre^3 (kg/m^3)	pound mass/in^3 (lbm/in^3), pound mass/ft^3 (lbm/ft^3)
Force	newton (N [= kg-m/s^2])	pound force (lb)
Pressure	pascal (Pa [= N/m^2])	pound force/inch^2 (psi), pound force/foot^2 (lb/ft^2)
Power	watt (W [= J/s = N-m/s])	foot-pound/minute (ft-lb/min), horsepower (hp)

D3.2 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

D4 Water quality conversions

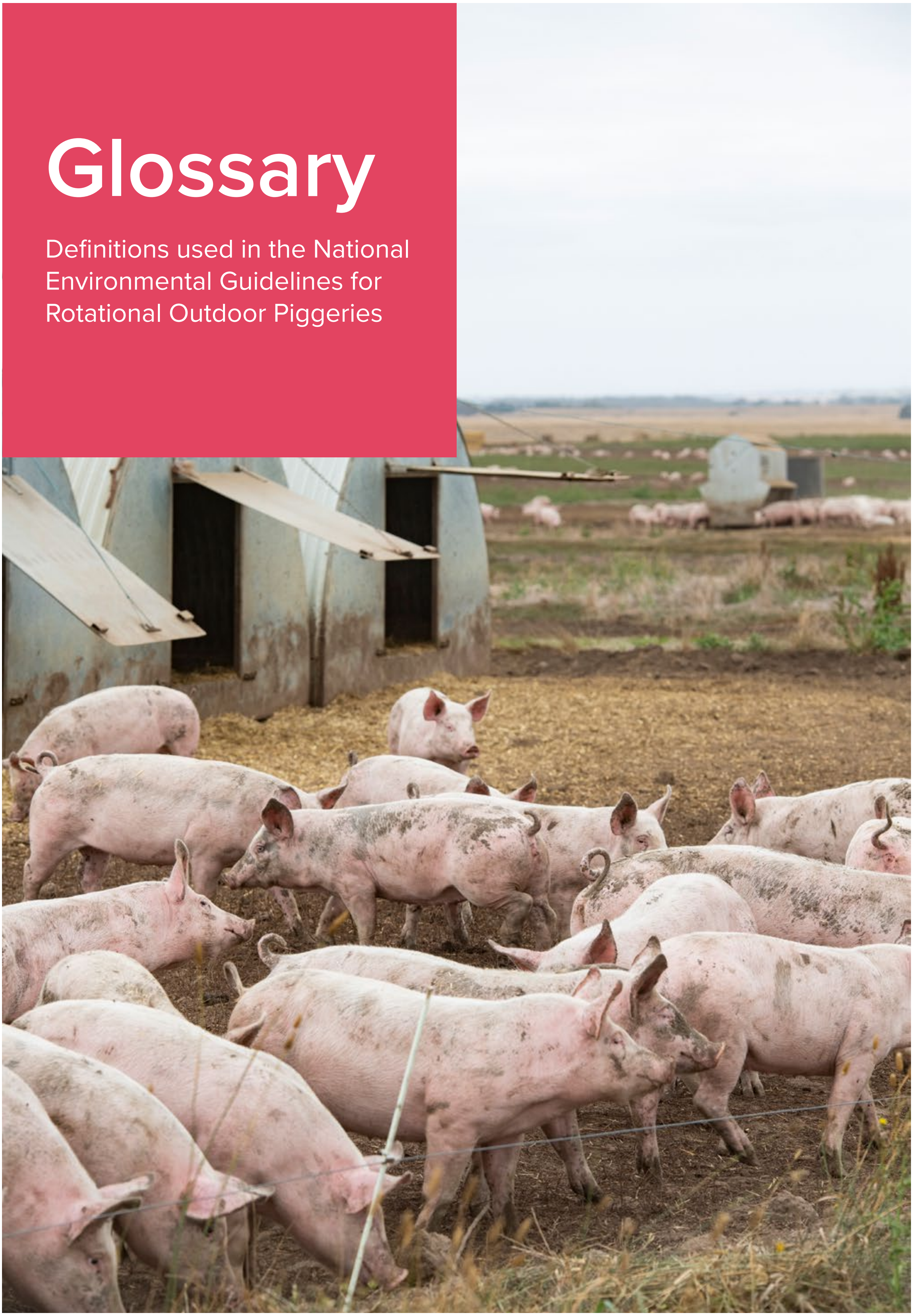
TDS to EC	multiply TDS in mg/L by 640 to convert EC to dS/m
Nitrate-nitrogen	multiply nitrate-N (mg/L) by 4.427 to convert to nitrate
Nitrite-nitrogen	multiply nitrite-N (mg/L) by 3.284 to convert to nitrite
Phosphate-phosphorus	multiply phosphate-P (mg/L) by 3.066 to convert to phosphate
Sulphate-sulphur	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
Pressure	pascal (Pa [= N/m^2])
Power	watt (W [= J/s = N-m/s])

D5 Salinity conversions

To / From	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

Definitions used in the National Environmental Guidelines for Rotational Outdoor Piggeries



Appendix E: Glossary

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

Approved authority local or state/territory government entity with relevant statutory authority

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

Available nutrient that 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 to the pig paddocks, but should not have recently been used for outdoor pig paddocks or been spread with spent bedding or fertiliser

Best practice environmental management a collection of exemplary and recommended practices at a farm level that piggery operators should strive to achieve in the long term to ensure that their operation is environmentally sustainable

Block of paddocks a group of adjacent paddocks used simultaneously to run pigs. For piggeries that operate with a radial paddock system, one radial would constitute a block of paddocks. Similarly, if a piggery uses eight adjacent rectangular paddocks at a time, this would constitute a block of paddocks

Boar an uncastrated male pig over nine months of age

Breeder paddock a unit where breeding stock are kept, along with sucker pigs

Buffer/buffer distance the distances provided between the piggery complex or reuse areas and sensitive natural resources (e.g. bores, watercourses, major water storages and native vegetation) 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 adsorb

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 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 preformed 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 and water, urine and faeces fall through the slats into the underfloor channels or pits. These are regularly flushed or drained to remove effluent from the sheds. Sheds without slatted flooring usually include an open channel dunging area which is cleaned by flushing or hosing

Crop-forage-pasture phase nutrient removal phase/non-pig phase of the land use rotation when crops, forage crops or pastures are grown and harvested to remove the nutrients added during the pig phase

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

Dry sow a female pig that has been mated and has not yet farrowed

Electrical conductivity (EC) the generally accepted measure of salinity – usually expressed as deciSiemens per metre (dS/m) or its equivalent, miliSiemens per centimetre (mS/cm)

Environmental management plan (EMP) an EMP focuses on the general management of the whole farm taking into account the environment and associated risks. It documents design features and management practices, identifies risks and mitigation strategies and includes ongoing monitoring to ensure 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 occupied by sodium

Farrow give birth to piglets

Farrow-to-finish a production system incorporating a breeding herd plus progeny through to finished bacon weight (usually 100-110 kg)

Feedlot/feedlot outdoor piggery a piggery where the pigs are continuously accommodated in permanent outdoor enclosures that are not rotated. This includes fixed shelters or sheds with verandas or small pens that are not rotated

Feeder equipment from which feed is dispensed

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

Free range APIQ✓® free range (FR) is based on the Australian Pork Limited (APL) free range (FR) definition which is:

Free range means that pigs are kept permanently outdoors for their entire life with shelter from the elements provided, furnished with bedding. Free range pork production consists of outdoor paddocks, which include rooting and foraging areas, wallows (where state/territory regulations and seasonal climates permit) and kennels/huts for shelter. The huts allow the animals to seek shelter from environmental extremes. They also provide additional protection for the piglets when very young.

The weaners, growers, and sows, from which they have been bred, have access to paddocks at all times for their entire life. Shelter, food and water must be provided and all pigs must be able to move freely in and out of the shelter and move freely around the paddocks, unless required to be confined for short amounts of time for routine husbandry or diagnostic procedures to be conducted.

All pigs raised under free range conditions must comply with the latest edition of the Model Code of Practice for the Welfare of Animals – Pigs to show compliance with state/territory animal welfare regulations and use good land management practices as per the latest edition of National Environmental Guidelines for Indoor Piggeries (NEGIP).

Note: Shelters or Sheds with verandas or small pens attached – are NOT considered free range as they do not comply with the APIQ✓® Standards. They are considered to be a "feedlot outdoor piggery".

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

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

Grower pigs generally with liveweights of 20-60 kg

Growing pigs weaners, growers and finishers

Grower/grow-out unit a production system where pigs are grown from weaner or grower weight through to pork or bacon weight

Hut a weatherproof structure designed for providing shelter for pigs in outdoor production systems

Indoor piggery piggery system in which the pigs are accommodated indoors in either conventional or deep litter sheds

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

Manure faeces plus urine

Nutrient a food essential for 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

Organic carbon a major component of 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 bred APIQ✓® outdoor bred production is based on the APL outdoor bred (OB) definition, which is:

Outdoor bred pork production means that adult breeding sows live in open spaces with free access to paddocks for their entire adult life; with rooting and foraging areas, wallows where conditions and local regulations allow, bedded shelter and adequate feed and water provided. Piglets are born and raised under these conditions until weaning.

At weaning piglets move to bedded grow-out housing with adequate feed and water provided where they remain until sale or slaughter. Housing can be permanent or portable structures or outdoor pens with shelter. The shelters must have an impermeable base or be located and moved regularly to minimise nutrient leaching and runoff.

Pigs may be temporarily confined to pens for routine health treatments and husbandry practices, or when directed by a veterinarian.

Paddocks and soils are managed to meet the APIQ✓® environmental free range standards and performance indicators including soil monitoring, nutrient management, promoting even nutrient distribution and land and water protection.

Outdoor piggery system in which the pigs are kept outdoors but 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

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

Phase feeding the use of multiple diets that match the pig's requirements for optimal growth

PigBal 4 the nutrient mass balance model for piggeries developed by the Department of Primary industries and Fisheries– Queensland. It is a Microsoft Excel® spreadsheet model that was developed to estimate the waste production of piggeries, and to assist in the design of effluent treatment facilities and in assessing the environmental sustainability of associated land reuse practices

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 facilities where pigs are kept, 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 separate reuse areas

Pig phase the portion of a land use rotation when pigs are using a particular land area

Piglet a young 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

Receptor person or site that receives and is sensitive to community amenity impacts, including a residential dwelling, school, hospital, office or public recreational area

Reuse the act of spreading spent bedding, compost or water collected in terminal ponds on land for the purpose of utilising the nutrients and water they contain for crop or pasture growth

Reuse area an area where spent bedding, compost or terminal pond water is spread for the purpose of utilising the nutrients and water they contain for crop or pasture growth

Rotational outdoor piggery an outdoor piggery where the pigs are kept in small paddocks that are used in rotation with a pasture or cropping phase. During the stocked phase, the pigs are supplied with prepared feed, but can also forage

Runoff all surface water flow, both over the ground surface as overland flow and in streams as channel flow. It may originate from excess precipitation that can't infiltrate the soil or as the outflow of groundwater along lines where the water table intersects the earth's surface

Salinity the salt content of soil or water. 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. Total dissolved solids (TDS) is another measure of salinity

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. Separation distances are measured as the shortest distance measured from the piggery complex to the nearest part of a building associated with the sensitive land use

Shelter see "hut"

Sodicity an excess of exchangeable sodium causing dispersion to occur

Sow an adult female pig, which has had one or more litters

Standard pig unit (SPU) pig equivalent to a grower pig (average weight 40 kg) based on volatile solids production in manure

Stocking Density the number of pigs an area of land (SPU/ha) during the pig phase

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. an 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 solids (TS) dry matter content of a compound

Total dissolved solids (TDS) the inorganic salts (major ions) and organic matter/nutrients that are dissolved in water, used as a measure of salinity.

Vegetated filter strips (VFS) grassed areas beneath the pig paddocks or reuse areas designed to reduce the nutrient concentration of runoff through particle trapping, and reduce runoff volumes by increasing infiltration

Volatile solids (VS) the quantity of total solids burnt or driven off when a material is heated to 600°C for one 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

Wallow a mud-filled depression in the ground that the pigs can roll in. This allows them to cover themselves with mud which cools their bodies and helps to protect against sunburn

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 up until approximately 30 kg in liveweight

Weaning the act of permanently separating piglets from the sow

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National Environmental Guidelines for Rotational
Outdoor Piggeries - Siting and Design (NEGROP-SD)