DAIRY FEEDPADS AND CONTAINED HOUSING

NATIONAL GUIDELINES

SECOND EDITION

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FOREWORD

The Australian dairy industry is historically recognised and remains today grazing based production whereby producers have relied predominantly on home-grown feed, with the support of supplementary feeding. Over time dairy producers have adopted and incorporated innovative feeding and housing solutions utilising a range of feeding infrastructure such as short-term use of earthen areas with troughs through to permanent concreted flood washed feedpads (with or without roofing). This has enabled an extensive range of feedstock and by-products to be fed throughout the year with the ability to accommodate herds during periods of adverse weather, seasonal variability, and emergency events.

In more recent years the Australian dairy industry has seen some farms transition to contained housing facilities with zero grazing to address a range of farming and regional specific challenges including climate adaptation, water availability, workforce efficiencies, improvement in environmental management, and enhanced animal health and production outcomes. These more significant investments change land use to intensive farming and therefore require more complex decision making, planning and a longer term vision for the farm.

The establishment of any feeding infrastructure or contained housing should not be a quick fix solution to address issues of feed utilisation and wastage or a reactive response to a poor season. Choosing the most appropriate feeding infrastructure and contained housing for the farm, and its locality, requires understanding the range of potential feeding and housing solutions commonly used in the industry and determining which development will best suit the farms future growth or proposed change.

These National Guidelines, written by 21 Subject Matter Experts from Australia and the United States, are intended to provide referral agencies, service providers and dairy producers across Australia with a clear and concise overview of all the elements that require consideration when undertaking the initial development and longer-term management of these feeding and housing facilities.

The information in these National Guidelines is a collation of current planning and technical information compiled to:

- assist the dairy industry to make informed decisions with respect to dairy feedpads and contained housing
- raise awareness of industry, government, and community expectations to minimise any adverse impact on the environment
- establish a key reference enabling new proposals to progress smoothly through the various development and planning stages relevant for each state
- demonstrate that the dairy industry has an ongoing commitment to support producers undertake farming system changes.

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GLOSSARY

Term	Definition
Amenity	The comfortable enjoyment of life and property, particularly with regard to visual appearance, odour, dust, noise and light spill.
Basic feed-out area	A type of feedpad. Contains an area with a permanent compacted earthen feeding infrastructure shared by cows and vehicles which may be dry scraped. Can be relocated to another site on the farm (with effort) if necessary.
Batter	The uniform side slope of an excavation such as a pond, track, road or ditch.
Bedded pack	Deep layers of organic material (i.e. woodchips, straw, sawdust etc.) that form a bed and pack down over time.
Bedding	Organic or inorganic material or manufactured products used to provide a comfortable laying space to improve animal health and welfare. Bedding materials include sand, composted manure, woodchips, sawdust, straw and rubber mats.
Behavioural enrichment	The practice of providing animals under managed care with environmental stimuli to improve quality of life.
Brisket locator	A device at the front of stalls to assist the position of the cow when lying, preventing her from lying too far forward in the stall.
Buffer	The distance between the dairy complex or reuse areas and a sensitive natural resource (e.g. waterway, bore and water storage) to reduce the risk of potential environmental impacts. Buffers are measured from the outer perimeter of the dairy complex, or reuse areas unless otherwise indicated.
Bun stack	An above ground storage option for silage where the harvested feed is heaped on the ground, rolled and covered completely with plastic.
Bund	Watertight wall or embankment designed to prevent liquid entering and/or exiting an area.
Capital cost	One off investment cost - in this case, the costs associated with construction of feeding/ housing facilities and the purchase of any associated equipment.
Commodity shed	A row of flat-bottom, usually concrete, storage bays or bunkers that are covered with a high roof for storage of wet and dry feedstuff materials such as by-products, grains and meals etc.
Compost	A humus-rich soil conditioner produced by composting manure.
Compost bedded pack	A bedding system where an active composting process is maintained in the base of the bedding pack to promote a clean, dry, comfortable bedding surface.
Composting	A natural biological decomposition process that takes place under controlled self-heating and aerobic condition.
Contained	Where dairy cattle are contained for the purpose of access to water and feed e.g. hay, silage, grain or total mixed ration.
Contained housing	An integrated facility for feeding and housing cattle with zero grazing such as a freestall, loose housing or dairy dry lot.
Controlled drainage area	An area that collects and contains runoff from the dairy complex while excluding stormwater inflows.
Cow barrier	Structures used to prevent cows from standing in or on the feeding table. Common structures include elevated troughs, fences, hot wires, steel cables, head locks, neck rails and stanchions.
Cow brush	Rotating cylinder with hard bristles that cows can scratch themselves against.
Cross over	In a freestall, a walkway that joins two alleys.

Term	Definition
Cross ventilation	A negative pressure mechanical exhaust system that provides forced air movement laterally across the housing from side to side.
Curtain baffles	Curtain style structures that hang vertically from the ceiling to trap and force air down at fast-moving speeds to promote cooling to the space below.
Deep litter pack	A bedding system where new bedding material is continuously piled on top of the old bedding material to keep the surface clean and dry.
Dairy complex	Land where dairy cattle are milked, contained, loaded or unloaded; manure and effluent are stored and treated, cattle feed is prepared, handled or stored. The dairy complex does not include manure and effluent reuse areas.
Drain	A conduit for conveying stormwater water or effluent.
Drive alley	The area adjacent to the feeding table along which vehicles and machinery drive to deliver and push up feed. Cattle are not allowed access to the drive alley.
Dairy dry lot	An open, well-drained area with an earthen surface and a shade structure over part of the area, to protect animals from the sun and rain. A bedded area may be provided under the shade structure.
Effluent	*See manure*
Effluent reuse	The application of manure and recycled effluent onto land.
Erosion	The wearing away of the land surface by rainwater, water-flow or wind, removing soil from one point to another e.g. gully, rill or sheet erosion.
Far off dry period	The period from dry-off to 21 days before calving.
Feed alley	The alleys occupied by cattle when they are accessing feed. These alleys are located parallel to the feeding table.
Feed conversion efficiency (FCE)	The amount of feed required or consumed per unit of milk solids production.
Feeding table	The surface on which feed is placed when feeding cows on feedpads and in contained housing facilities.
Feedpad	Used for supplementary feeding cattle where the surface is either formed, laid with a durable material or stocked at a rate that precludes vegetation. Examples of feedpad facilities include temporary feed-out area, basic feed-out area, formed earthen feedpad and concrete feedpad.
Five domains welfare model	A model for animal welfare that considers both the positive and negative aspects of nutrition, environment, health, behaviour and mental state and embraces the provision of positive experiences and desirable outcomes to determine the overall welfare state, rather than simply focusing upon limiting animal exposure to negative experiences.
Flexible feeding system	A feeding system that allows feeding on a feedpad as well as in paddocks. Useful in drought or wet conditions.
Flood	An overflow of water that submerges land that is usually dry. A 1% annual exceedance probability (AEP) flood is a large flood with an average recurrence interval (ARI) of 100 years.
Formed earthen feedpad	A type of feedpad. Has a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall or cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures.
Freeboard	The elevation difference between the full pond and the crest of the bank. Freeboard protects the bank from wave action, riling, by-wash flows and overtopping under high-intensity rainfall and fast filling.
Freestall	These can be open-air, partially or fully enclosed structures in which dairy cattle are housed. They can be used to house dairy cattle long term and include a bedding area for cattle to lie down, and possibly a loafing area for cattle to stand. The term 'freestall' refers to the bedding area where cattle are allocated specific cubicles (stalls), which they may enter to lie down.
Geosythentic material	A thin flexible and permeable sheet of synthetic material used to stabilise soils.
Groundwater	All water below the land surface that is free to move under the influence of gravity.
Impermeable	Materials with a permeability no less than 1x10-9m/s. For design purposes this includes concrete, synthetic pond liners or suitable compacted clay liners.

Term	Definition
Landscaping	The use of plants, earthen banks or other features to provide visual amenity.
Leeching	The process whereby soluble nutrients (e.g. nitrogen) are carried by water down through the soil profile.
Levee bank	An earthen bank designed to confine or direct liquids and solids to or away from designated areas.
Loafing area	A formed surface adjacent to a feedpad, or within the contained housing facility. Its primary purpose is to provide a separate section away from the feeding table for cattle to stand, lie, ruminate or idle.
Longitudinal slope	The slope along the length of the feedpad, or contained housing facility, to facilitate drainage particularly for flushing alleys.
Loose housing	The key difference to a freestall is that the stalls and stall alleys are replaced with a bedded area of absorbent organic bedding including straw, wood chips or composted manure. These facilities are typically categorised by their management of the bedded area as a: • *Compost bedded pack* that is mechanically tilled at least twice daily; or • *Deep litter pack* where absorbent organic bedding is added regularly to the bedded area, but there is no mechanical tilling.
Manure	Livestock faecal and urinary excreta in a liquid, slurry, semi-solid and solid form. It can also include waste feed, bedding and soil. Liquid manure is typically referred to as *effluent*. *Effluent* is produced by cleaning the dairy shed and holding yards with water. Effluent may also include stormwater, residual milk and chemicals from cleaning dairy plant and equipment. Effluent may be recycled (i.e. recycled effluent) and used for washing manure from areas such as holding yards, alleys and housing facilities, or applied to land.
Manure management system	Integrated system designed to manage the manure stream from its point of generation through to its reuse onto land, or off-site export. It typically includes components to contain, treat, store and/or reuse manure.
Milking platform	This is the total hectares of land directly contributing to milk production and includes grazed and harvested forage (pasture and crops) and designated feeding and sacrifice areas. The milking platform is where the greatest nutrient inputs, manure deposition, nutrient cycling, pasture, crop and milk production and potential for nutrient losses, is occurring.
Natural ventilation	The provision of fresh air into a building space using natural air flow movements.
Neck rail	A rail to assist the position of cows in a stall so they have enough forward lunging space when they lie down.
Nib wall	A small concrete wall constructed along the perimeter of alleys to prevent manure from leaving the feedpad or contained housing facility or entering the feeding table.
Partial budget	A budget used to calculate the effect on profits of a proposed change in a portion of the operation by including only the costs and returns that change as a result of the proposed change in the operation. Because only a portion of the costs and returns are included, the partial budget only provides an estimate of the profitability of an alternative relative to current operations. It does not provide an estimate of the absolute profitability.
Partial mixed ration (PMR)	A method of feeding where feedstuffs, supplementary to what the cows will graze, are combined as a single mixed ration and fed in between bouts of grazing, so the mixed ration makes up only part of the cows' diet.
Photoperiodic manipulation	Subjecting cows to specific light and dark exposure periods to increase milk production.
Principle productivity area	*See milking platform*
Recirculation fans	Fans used to create fast air movement above cow resting places to promote cooling.
Regrouping	The mixing or comingling of cows that were not previously in the same group.
Sedimentation basin or pond	A pond structure that allows the settling out and storage of solid material from the effluent stream.
Sensitive use	Sensitive use is a use that may be impacted by including odour, dust, and noise. It includes a dwelling, a dependant persons unit, a residential building, a hospital, a school, childcare centre, a caravan park and other uses involving the presence of people for an extended period. Sensitive use does not include recreational areas such as parks and sporting facilities.

Term	Definition
Separation distance	The distance between a dairy complex and a sensitive use. Separation distances are measured from the edge of the dairy complex to the nearest wall of a building associated with a sensitive use.
Shrink	The loss of feed that occurs during storage, handling and consumption, often due to unavoidable processes. Examples are trampling and soiling of pasture during grazing, silage effluent and volatiles, spoilage, contamination, handling losses, rejections/refusal to eat.
Side slope	The slope in the feed alley that directs manure and runoff away from the feeding table. The slope direction runs perpendicular to the feeding table. This is usually only associated with earthen feedpads.
Social licence	Refers to the acceptance granted to a company or organisation by the community and is based on trust and confidence.
Stall alley	In a freestall, these are walkways to enable the cows to access the stalls.
Stall divider	A looped rail that defines the width of the freestall and facilitates the lying direction of the cow.
Stall kerb	A small concrete barrier at the back of a stall used to prevent slurry manure from the alley contaminating the bedding.
Stalls	Individual resting spaces or beds in a freestall which cows are free to enter and leave as they please.
Stocking density	Feedpad: space per cow. Freestall: number of cows per stall. Loose housing: cows per square metre of bedded area.
Stockpile area	A bunded area with an impermeable base used for the temporary storage of manure or compost.
Stormwater	Rainfall runoff from building roofs, other hard surfaces and land.
Struvite	A crystalline mineral made up of magnesium, ammonium and phosphate that can precipitate out of wastewater and build up on the inside of pipes, pumps and other wastewater treatment equipment causing clogging and damage.
Surface waters	A waterway, any body of water above the ground, including streams, rivers, lakes, wetlands, reservoirs and creeks.
Temporary feed-out area	Located in a pastured or bare cropping paddock, a designated sacrifice paddock or along a laneway without a prepared surface where feed is delivered to cows either on the ground, in hay rings or in tractor tyres. Can be readily relocated to other sites on the farm.
Thermoneutral zone	The ambient temperature range across which an animal is comfortable and doesn't need to expend energy to maintain its normal body temperature. For healthy cattle this is generally 0°C to 25°C.
Topography	The shape of the ground surface as defined by the presence of hills, mountains or plains, both natural and artificial, of an area, such as are required for a topographic map.
Total dissolved solids (TDS)	A measure of the inorganic salts and small amounts of organic matter dissolved in water. The main constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions.
Total mixed ration (TMR)	A method of feeding which involves mixing all diet ingredients together into a single ration so that, in theory, each mouthful the animal eats is nutritionally balanced.
Transition period	The period from four weeks pre-calving to four weeks post-calving, which is characterised by an increased risk of metabolic disease for the cow due to the physiological changes that are happening at this time.
Tunnel ventilation	A negative pressure mechanical exhaust system that provides forced air movement longitudinally through the housing from end to end.
Vegetated filter strip (VFS)	A vegetated area (typically grassed) separating a waterway from an area where organic matter is deposited. It is designed to reduce the nutrient concentration of runoff through particle trapping and by increasing infiltration into the soil.
Vegetative environmental buffer (VEB)	A dense multiple-row planting of trees or shrubs etc. for the purpose of improving air quality, to filter dust, noise and mitigate odour, along with providing a shelter belt and wind break.

ABBREVIATIONS

EIS	Environmental Impact Statement
DBYD	Dial Before You Dig – **byda.com.au**
DM	dry matter
DMI	dry matter intake
kg	kilogram
kL	kilolitre
KWe	Kilowatt-electric – One thousand watts of electric capacity
KWh	kilowatt hours
kPa	kilopascals
m	metres
mm	millimetres
ML	megalitres
TS	total solids
Wh	watt-hours
1100	dial before you dig

INTRODUCTION

The *Second Edition National Guidelines for Dairy Feedpads and Contained Housing* were first conceptualised in 2019. At that time, the intent was to create a compete revamp of the first edition, created in 2010, but widen their footprint to be nationally relevant in addition to incorporating the best science and design from around the world. This has been achieved. The authorship for this edition is truly international and the information contained in these chapters is a distillation of current global best thinking and practice.

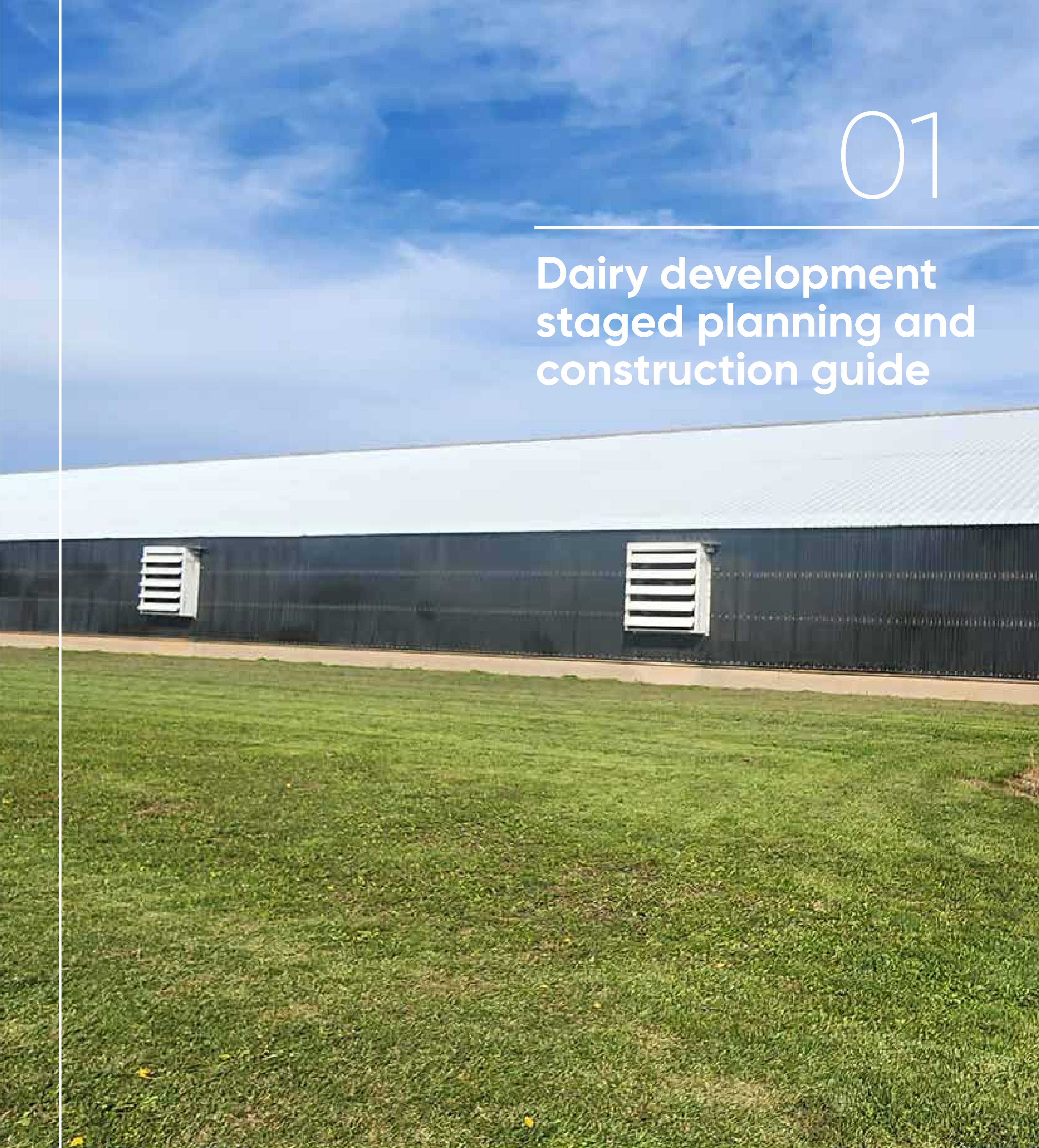
Across 245 pages of content, the Guidelines are arranged into 14 Chapters. This resource is not intended to be solely read cover to cover and from the beginning. Rather, it is deliberately designed to be accessed, by relevant topic, depending on the present need of the farm team or their advisers. It is designed to be "dipped in and out of" depending on the task at hand. Further, the Guidelines make extensive use of figures, photographs and tables to assist the reader in clear understanding of the content. Technical terms commonly used in this topic area are explained in the Glossary.

The intended audience for the Guidelines is anyone with an interest or role in the decision making around establishing, modifying or using some type of feedpad or dairy cattle housing. It is equally relevant to farm owners, farm workforce members and advisers.

A look over the contents description reveals the breadth of topics covered. The Guidelines are designed to comprehensively cover optimising animal welfare through good facilities design, maximising cow comfort through the various ventilation options, efficient energy use and generation plus feed delivery systems to maximise efficiency and productivity. The second edition contains expansive sections on amenity, environmental considerations and management of manure. Readers will also note the inclusion of a chapter on using automatic milking systems within cattle housing where an alternative to conventional milking is an option.

For farmers involved in the early stages of planning for a new piece of feeding or housing infrastructure, the Guidelines offers them, along with their advisory team, the opportunity to significantly reduce the risk of poor planning and design decisions. People using this resource are really encouraged to read the relevant chapters, consider their plans, and then review their designs and approach based on a comparison against the information contained within the Guidelines. The authors and review team for this resource have gone to extensive lengths to present design and use information which not only represents state of the art thinking, but also reflects optimised Australian and international facilities currently in use. Much of the usefulness of this publication lies within the time prior to the first concrete being poured on a building project.

The *Second Edition National Guidelines for Dairy Feedpads and Contained Housing* are a truly world class publication and resource for the Australian dairy industry and should be highly applicable and relevant for many years into the future.



01

Dairy development staged planning and construction guide

1.1 FARM SYSTEM AND INFRASTRUCTURE SELECTION

ANALYSE DRIVERS FOR CHANGE

The first step before purchasing or constructing infrastructure or making a farm system change is clearly understanding and being able to articulate the key motivators for change, the desired objectives, and anticipated outcomes. It is critical at this stage to consider the long term vision for the property.

Farm System Evaluator – an on-line decision tool to support infrastructure selection

Making the best decisions around infrastructure investment requires sound analysis of available options. A farming system decision support tool has been developed to help inform decision making when considering feeding and housing infrastructure investments. The on-line tool identifies the main motivations driving a farm system change and through a logical framework gauges readiness for change to a new farm system involving feeding and contained housing infrastructure. Use this link to access the **Farm System Evaluator on-line tool**.

Testing the concept

Significant investments and operation change should not be made hastily to mitigate an immediate or short-term issue. Testing concepts and options with business partners and trusted advisors is very important. This is also an opportunity to delve deeper by travelling and visiting other businesses who have already transitioned and are operating the system being contemplated. This first-hand experience will confirm and test the thinking before commitment.

Consult specialists

Discuss the concept ideas with trusted and professional consultants, industry bodies and government agencies specialising in agriculture. This will test the thinking and raise matters that may not have been considered. Seek a range of opinions and weigh up the pros and cons.

Where specialists will be engaged to assist, the relationship between various parties needs to be clearly and formally recorded in a contract to provides legal protection for all those involved. Typically including scope of work, activity schedule, associated costs and payments, accountabilities for all parties, dispute mediation, insurance, warranties, OH&S and sign off at completion.

Consult a financial adviser

Once the operation's potential future direction has been firmed up, consult a financial adviser, lender and/or potential investors outlining the economic rationales for the investment. A Benefit Cost Analysis (BCA) provides reassurance that due diligence has been undertaken and the cost of the development is outweighed by the longer-term gains. This is a critical step before getting too advanced with design and planning. Discussions with others will inform the potential scale of the investment. Key triggers for the release of finance should also be discussed at this point e.g. approval stage, equipment order, construction etc to understand the cash flow requirements through the process.

Infrastructure design and siting

In this early stage of planning, it is recommended to consult with system designers and specialists to review various options, configurations and stages of development best suited to the property. This should include the integration of the proposed infrastructure complex with existing infrastructure and consider, connection to laneways, water access, milking facilities, commodity areas, paddocks, and relationship to surrounding areas (sensitive receivers, planning overlays). The infrastructure complex involves all the associated works including feeding and housing facilities, effluent system, commodity, and feed preparation area overlayed on a property footprint.

Develop timeline schedules

An aspect of project management that is often under-estimated is timelines, given the amount of work required to take the proposed concept through construction to operation. Complexities can arise depending on the development type, chosen site, planning requirements and assessments, locality complexities and separation distances from sensitive land uses such as neighbours and waterways, and the coordination of multiple professional services, timelines for larger investments can take a minimum of ten months and even longer should the development attract objectors. Typically, larger scale developments (contained housing, dairies) can take well over twelve months to reach operations.

1.2 PROJECT PLANNING AND DEVELOPMENT

ASSEMBLING THE PROJECT TEAM

Quite often several professional services will need to be engaged to support and guide the development from planning consultants, engineers, surveyors, earthmovers to various trades services, builders and equipment suppliers. Larger scale developments (i.e. multiple freestall facilities) often appoint a project manager to oversee and coordinate works, enabling the business to focus on farming.

Preliminary property data collection and planning

To prepare the relevant approval documents, the appointed environmental planner must have a better understanding of the business, the proposed developments and property and operational specific information. Property specific reports including identification of land use and development controls is an important aspect to determine the information that will be required to support the development or identify constraints which may require review.

It is at this stage, the original proposed site for development may need refinement or if not considered in the initial siting, reconsideration, taking into account various planning overlays and relevant conditions that will be imposed by government agencies.

Liaison with local councils and agencies

Early communication with approval authorities which in many cases will be local government councils will help inform the assessment criteria and expectations along with identifying other government agencies that may be involved in the approval process and their requirements and or further consent. This is often best undertaken in a Focus Planning Meeting (see below).

Development consent

Depending on the type and size of development and the investment being proposed, the planning pathway in different states will vary. Some states, depending on how the development is classified (i.e. a state significant development, a designated development, or a scheduled premise), will need to seek consent from the relevant planning authority before an approval or planning permit can be granted. It is important to understand these triggers at a very early stage to enable the planning for and meeting these requirements in a timely and cost-effective manner. If not recognised and addressed correctly, this can add significant, cost, delays and frustration to the process.

Often development consent approvals will identify further actions that must be undertaken prior to commencement of construction (e.g. Building Permit/Construction Certificates, road access connections) and operation (e.g. EPA licensing, Fire Safety Certificates). These are important requirements to meet as they may have implications on the release of finance and insurance cover.

Preliminary desktop environmental planning

No development, including initial site preparation and/or earthworks should be undertaken until a comprehensive planning desktop assessment and relevant site investigations have been completed.

All proposed development requires the preparation of relevant documents and reports to ensure approval agencies that due diligence has been undertaken to mitigate potential risks and meet the conditions outlined in the states and local planning provisions. Site inspections by relevant authorities are undertaken as part of this assessment during the approval process. When proposing contained housing developments, Environmental Impact Statements and professionally designed Effluent Management Plans must be developed to support the application. These overarching documents can also be supported by a range of other plans such as: Land Capability Assessment and Soil Management Plan, Salinity Management Plans, Traffic Management Plans, Aboriginal Cultural Heritage Management Plan, Storm Water Management Plans, Flora and Fauna Assessment, Floodplains Management Plans, and Irrigation Whole Farm Plans etc. Quite often, developments can be delayed if plans are not properly prepared and planning agencies seek further information.

Site investigations

These investigations should commence with the environmental planning aspect covering both the construction site, any site for borrowing earth and those proposed for disturbance (roads etc). These investigations involve: site surveying, site plans (in addition to infrastructure plans), drainage, location of ground water, geotechnical assessments, soil classification and suitability. It is the combination of the infrastructure development plans, environmental planning considerations and site investigation results that confirm the proposed development site is proposed in the best location.

Focus planning meeting (pre-lodgement meeting)

Usually associated with larger scale investments, the pre-application meeting may involve a proponent and the project management team conducting an on-site presentation to approval authority and other relevant government agencies. This will involve outlining the broad proposal to identify any specific areas of focus that agency might raise during the application/approval phase together with the assessments and detailed considerations required to be presented as part of the application. This provides an opportunity to finetune and strengthen relevant information before lodging the application. It also assists agencies to better understand the proposed development and future operation proposed at the site.

Community planning meeting

A public meeting may be conducted by the proponent or required by the approval authority pre-application to involve neighbours and the communities to better understand the proposal and provide an opportunity to raise any areas of concern. This has the benefit of informing the preparation of application documentation to address any concerns and seek to minimise any potential future complaints, as well as any requirements for mediation once the application has been lodged.

Submitting the application

This is the final checking stage to ensure all relevant documents and supporting plans have been finalised and are ready for submission. Completion of the generic approval authority application form and payment of the permit application fee. Some authorities may require a pre-lodgement meeting requirement to check that all documentation has been prepared to the satisfaction of the approval authority (local council).

Application lodgement

The approval authority (local council) will review and determine if all required information has been submitted. If incomplete, the authority may formally request further information with timeframes for response.

Referral to relevant government agencies

The approval process may require the referral of the proposal to relevant government agencies. The various agencies are required to assess the proposal, may apply conditions to any approval, require further information and or object to the proposal.

Public notice

If it is deemed a notice of application is required, a letter to adjoining neighbours, notice on the site or local media will be instigated. The approval authority will consider any submissions received within a nominated timeframe.

Council processing

The Council planner will review and determine if all required information has been submitted (if not, the officer will either return the application or will formally request outstanding information is supplied through a *Request for Further Information* before referring to statutory referral or non-statutory referral agencies. These referrals will depend on the development type, related works, and their location. The various agencies will then undertake their assessment and respond with specific conditions to apply to the approval.

In most cases, the application will be publicly advertised via the local or state related system, notice on website and sometimes social media. This will likely also include notification to adjoining and surrounding residents.

Mediation

In the event the proposed development attracts objections to the proposal (individuals or community groups), the approval authority council will organise a public meeting council for submissions to be heard and the proponent to address those concerns. The aim of this process is to resolve concerns and reach a satisfactory outcome by amending the proposal or providing further information to address the concerns raised. Planning consultants may need to be re-engaged.

Approval issued (conditions)

The approval authority will collectively weigh up all information presented and will make their final determination to grant a permit and/or approve subject to conditions, give notice of a decision subject to review or a refusal. If required appeals can then be made through the relevant body either by the proponent or objectors depending on the outcome.

It is important to carefully review these conditions and their required timing to ensure that the Construction Phase is undertaken in adequate timeframes and without delays. Conditions of consent – particularly those that relate to construction activities should be provided to all contractors.

1.3 PROJECT CONSTRUCTION

Project management

Effective project management is a critical aspect once planning approval has been granted ensuring the scheduling of works and associated activities to support construction and installation are closely monitored and managed. Arising issues and unforeseen circumstances can be addressed quickly to minimise disruptions to the numerous personnel on-site undertaking various works. Experienced project managers with expertise in specific works can save time and cost during this phase.

Site preparation and earthworks

The results obtained from site assessments, various planning documents and any relevant amended conditions informs the construction requirements and determines how the site must be prepared, which will include stages for inspection and supervision.

Shed construction and infrastructure installation

During construction, the project manager will be required to observe and manage onsite activities and confirm all specified requirements are being met, with the construction monitoring typically undertaken by the design engineer (or representative) to ensure "key elements" of the design have been interpreted and constructed. This will be in line with relevant documents including drawings, specifications, consent conditions and required inspections.

1.4 PROJECT COMMISSIONING AND TRANSITION

System commissioning and completion review

At the completion of the project construction, it is important to undertake a final check and assessment of the facilities and installed equipment to ensure they are fully functional and operating to specifications. Training should be received in the installed systems and future reviews of the system should be established.

Transitioning

It is common to hear the transitioning process to new facilities takes time as the herd and staffing adjust to the farm operation changes. The transition from a grazing business to contained housing takes longer and requires a lot of pre-planning particularly right from the very start at the concept idea. The transition should consider the potential to manage short term reduced production, staff training and seasonal change where possible.

02

Planning requirements – development applications and approvals

OVERVIEW

When considering a new development or the expansion to an existing dairy complex, it is important to consider the regulatory requirements that might apply, including:

- Whether the development is an allowable use under the land use controls for the site and any other relevant controls.
- Whether a development approval is required for the works.
- Whether an Environment Protection Authority approval or Licence is required, and
- Any local or state government authorities may be involved in the assessment of any development approval application and the information they might require.

The successful outcome of the process may be called a development approval, consent, or planning permission.

Typically, the local government authority will decide on any development approval and refer the application to relevant authorities, such as water and environment protection authorities. This process may include a requirement for public notice and consideration of any submissions received.

A development approval may provide that the proposal can take place on the subject land and there may be requirement for other permits, licences, and approvals prior to commencing the use and development. Prior to construction commencing further approvals such as building permits or construction certificates may be required.

The following illustrates the typical approval process across most states and territories (*see 3 State and Territory Planning Resources*).

2.1 THE APPROVAL PROCESS – PROJECT CONCEPTION AND PLANNING

This section sets out areas for consideration prior to submitting a development proposal application. The detail and steps required will vary dependent on the scale and scope of the development proposal.

The planning phase will assist in gathering information on:

- The opportunities and constraints of the proposed site and activity.
- The relevant authorities, their assessment criteria and the information required to satisfy those criteria.
- The expertise required to develop components of the development application.
- The flow and timeline for the approval process.
- Costs associated with the approval process.
- The likelihood of a successful approval process.

A well-considered and prepared application will reduce the likelihood of unnecessary delays due to a requirement for decision makers having to request further information.

Planning steps

- Consider potential sites and operational production level requirements.
- Prepare draft layouts of the proposal to achieve a concept design as an overview which provides for the desired production and environmental performance.
- Seek formal advice from the approval authority and relevant authorities, typically through a pre-application meeting etc. to inform the final design and consider any requirement for community engagement for larger/ more complex developments.
- Prepare a proposal report which identifies:
  - the proponent
  - the owner
  - the site
  - specifics of the proposal e.g. animal numbers, production system, site layout plans, manure management plan, nutrient management plan
  - details on land use or environmental requirements including property overlays
  - potential environmental impacts
  - potential community amenity and receptor impacts
  - management of potential impacts
  - proposed monitoring and intervention.
- Complete the relevant application forms, checklists and other supporting documentation.
- Submit the application in the format and method identified by the determine authority.

Lodging the development application

The lodgement of the development application initiates the formal stages of the approval process. The process is generally regulated through statutory timeframes for the decision maker who generally coordinates the referral of the proposal/application to relevant authorities and public notice, responses, and the formal decision process.

Typically, the local government authority or equivalent acts as the decision maker and will determine any development approval but in some cases, where the proposal/application is of regional significance, this may be determined by a regional planning committee or in the case of State significance, the relevant state government minister may be responsible for approvals.

Information and referral stage

After lodgement, the decision making authority will go through a number of steps. The first step will determine if all of the relevant and required information has been provided. If this is prepared to the receiving authorities satisfaction, fees will be requested and the application will progress to the next stage. The following stages are generally prescribed timeframes for referrals, responses, requests for further information and modifications to the proposal that provide basis for a final decision. The application is:

- Checked as complete, accepted and application fees paid.
- Lodgement date established.
- Referred under a statutory process that sets out the relevant authorities who have specific regulatory functions over public resources, water, and the environment, of which the proposal may impact.
- Advertised generally by public notice to the relevant authorities website, in a locally distributed newspaper and/or through letters addressed to neighbouring properties inviting submissions to review or comment on the proposal.

A referral authority may respond through no objection to the proposal, no objection subject to conditions or object to the proposal.

A referral authority may require further information to enable it to fully consider the proposal and make a formal request for further information. The applicant will be advised in writing as to the extent of information required, the timeframe available to provide this response and if the assessment timeframe period will be paused – termed 'stop the clock'. On receipt of the information requested, the decision maker will forward to the referral authority to consider and respond.

The decision making authority then considers the referral authority responses, any public submissions, and the recommendations of staff.

Pathway to a decision

The decision making process may take several pathways. Having considered all the referral responses and public submissions the decision making authority may decide to approve or refuse the application. This may involve presenting the application, responses and the assessment to the Council or joint regional planning panel.

In the case of an application being approved, and the applicant accepts the conditions of the approval, the applicant:

- If issued as a notice of determination/decision, awaits any statutory period applied to third party appeal rights (where they are available)
- If issued as approved:
  - undertakes any further requirements for applications for any building approvals, construction certificates, licences or permits; and then
  - commences the development and use, subject to the conditions of all approvals.

In the case of an application being approved, and the applicant seeks a review of the conditions of the approval, the applicant:

- May seek a review of conditions.

In the case of an application being refused, the applicant:

- May seek to appeal the decision.

NOTE

The formal decision will generally set out the terms of rights to appeal or review.

Disclaimer

It should be emphasised that the guidelines do not override or replace applicable federal, state, or local government legislation, regulation, plans or policies.

Developers need to be aware that development applications may be assessed in a manner or scope outside that provided in the guidelines.

Dairy farm operators must also observe their responsibilities under current workplace health and safety, animal welfare, biosecurity, environmental protection, and other relevant legislation.

2.2 SITE SELECTION, DESIGN AND MANAGEMENT

The following objectives detail what should be achieved in relation to site selection, design and management. Information under the standard headings are ways to meet the objectives – there may be others.

OBJECTIVE 1 SITE SELECTION

Standard 1.1 Local, regional and state planning policy

The dairy farm is sited on land to enable efficient production and is compatible with the relevant local, regional and state planning policies.

Standard 1.2 Catchment management areas

An application to use land within a designated catchment management area must comply with controls as required by the relevant water board, water supply authority or catchment management authority.

Standard 1.3 Land subject to flooding and inundation

An application to construct a building or to construct or carry out works within areas designated as land subject to flooding and inundation must comply with the controls as required by the relevant water board, water supply authority or catchment management authority.

OBJECTIVE 2 SURFACE WATERS

The dairy complex and reuse areas are sited and designed to prevent contamination of surface waters.

Standard 2.1 Dairy complex siting

The dairy complex is separated from surface waters to protect them from contamination or inundation.

Standard 2.2 Dairy complex design

Runoff from within the dairy complex is controlled to prevent contamination of surface waters.

Standard 2.3 Reuse areas

The design of reuse areas includes measures that prevent sediment and nutrients from contaminating surface waters.

OBJECTIVE 3 GROUNDWATER

The dairy complex and reuse areas are sited and designed to prevent contamination of groundwater.

Standard 3.1 Dairy complex siting

The dairy complex is physically separated from groundwater.

Standard 3.2 Dairy complex design

Areas within the dairy complex are designed to be impermeable.

Standard 3.3 Reuse areas

There is a plan that demonstrates that reuse areas are sited and designed to manage the manure that will be applied.

OBJECTIVE 4 SOILS

The dairy complex and reuse areas are sited and designed to prevent contamination or degradation of soils.

Standard 4.1 Erosion

There are plans that provide measures to minimise erosion for the construction of the dairy complex, internal roads and vehicle access points.

Standard 4.2 Reuse areas

There is a plan that demonstrates that reuse areas are sited and designed to manage the manure that will be applied.

OBJECTIVE 5 COMMUNITY AMENITY

The dairy complex is sited and designed to prevent or minimise the potential for off-site impacts to community amenity.

Standard 5.1 Separation distances to sensitive uses

The dairy complex provides a suitable separation distance from sensitive uses based on local or state requirements to prevent potential adverse off-site impacts to community amenity. *See notes below – Methods to determine a suitable separation distance.*

Standard 5.2 Manure management system

Manure management systems are sited and designed to manage the expected organic matter load and prevent potential adverse off-site impacts to community amenity.

Standard 5.3 Feeding and watering systems

The feeding and watering systems are sited and designed to minimise the potential risk to community amenity.

OBJECTIVE 6 VISUAL AMENITY

The dairy complex siting and design considers its integration into the surrounding landscape.

Standard 6.1 Visual amenity

The dairy complex is sited and designed to prevent or minimise the potential for impacts to the visual amenity of the surrounding land uses.

OBJECTIVE 7 AREAS OF NATURAL, CULTURAL OR INDIGENOUS HERITAGE AND NATIVE VEGETATION

To ensure areas of natural, cultural or indigenous heritage; and native vegetation are protected.

Standard 7.1 Areas of heritage sensitivity

The siting of the dairy complex complies with all relevant archaeological, natural, cultural and or indigenous heritage legislation and regulations.

Standard 7.2 Native vegetation

Where possible, site the dairy complex to avoid and or minimise the removal, destruction or lopping of native vegetation or provide an offset to compensate for the biodiversity impact if a permit is granted to remove, destroy, or lop native vegetation. Each State differs on these requirements and they should be carefully considered during the planning stage.

OBJECTIVE 8 DRAINAGE, ACCESS AND UTILITY EASEMENTS

Standard 8.1 Drainage, access and utility easements

The dairy complex and any other infrastructure are sited with consideration of any crown land, parcel or closed roads, actual or implied easements for public drainage, access, or utilities on the land.

OBJECTIVE 9 VEHICLE ACCESS, INTERNAL ROADS AND PARKING

Vehicle access points, internal roads, loading and unloading areas and on-site parking areas are sited, designed and constructed to provide all-weather access and minimise the potential for impacts to community amenity, traffic flow and road safety.

Standard 9.1 Access points

Access points are sited, designed and constructed to provide safe and all-weather entry and exit for the anticipated number and type of vehicles with consideration of road and traffic conditions.

This should include required standing sizes to match the size of vehicles and type of entrances.

Standard 9.2 Internal farm roads, loading and unloading areas and parking

Internal roads, and hardstand areas, including loading and unloading areas and parking areas are sited, designed and constructed to provide safe and efficient all-weather site access and turning areas for the proposed number and type of vehicles.

OBJECTIVE 10 ENVIRONMENTAL MANAGEMENT

To apply best practice operation and management of the dairy farm to prevent or minimise the potential for adverse impacts on the environment and community amenity.

Standard 10.1 Environmental management plan

A dairy farm specific Environmental Management Plan (EMP) is developed that includes strategies, measures and contingency actions to avoid, minimise or address the potential for impacts to the environment and community amenity.

Methods to determine a suitable separation distance
(see above Standard 5.1 Separation distances to sensitive uses)

Traditionally with new developments, the regulatory approach to minimise odour impacts was the imposition of fixed separation distances allowing odour to disperse before reaching any potential sensitive use. These separation distances are still commonly used in state based dairy guidelines, however, only provide a guide depending on the particular development being undertaken.

Typically, dairy farms utilising temporary feeding systems, under a predominant grazing production, would commence with a fixed distance to provide adequate separation from sensitive uses such as neighbouring houses.

If there are site limitations such as steep topography, a cluster of nearby houses, limited vegetation, and likelihood the feedpad or contained housing facility will become more regular in use, the recommendation would be to consider more advanced methods of determining appropriate separation distances to mitigate potential risks and impacts to community amenity.

More advanced methods to determine appropriate separation distances include:

- Empirical calculations commonly referred to in livestock sectors as “S factors” which consider the number of animals, facility design and management practices, receptor type, local terrain, vegetation, and wind factors assessing the fate of odour emissions under synthetic or “worst case” climate data.
- Dispersion modelling provides a representation of impacts and includes key factors such as understanding odour emissions of current farms, odour emission rate data for new developments, meteorological data, with the ability to select and set up a dispersion model and assess predicted impacts.

Reliable odour modelling will supersede any prior results from fixed or S-factor methods and may identify some areas with smaller separation distances.

Other siting and design considerations

Climate

Climate and climatic events can impact on a diverse range of issues associated with developments. These can include:

- Heat and cold stress and animal welfare
- Stock water requirements
- Animal productivity and feed conversion
- Odour
- Dust
- Noise
- Stormwater and drainage systems
- Manure management and utilisation.

With careful planning, siting, and design, it is possible to avoid or minimise the potential impacts of climate and climatic events. The ongoing management of the site should include contingencies to address likely site-specific scenarios including proximity to floodplains and or wind corridors etc.

Topography

The land slope must be able to accommodate the fall required within the drainage system. Sites with a low gradient can be more difficult (and expensive) to drain.

There should be sufficient depth of soil to accommodate the cut-and-fill and borrowing requirements needed to undertake earthworks during construction. This applies particularly to areas where sedimentation basins and holding ponds might be located.

NOTE

Sites with a natural slope of 2–4% will help minimise the cost of earthworks.

Soil – geotechnical qualities

Soil materials for construction purposes may be available on site or borrowed from near-by sites. This applies particularly to clay that might be used as an impermeable lining material in pens, the drainage system, ponds, manure and compost stockpiles.

The suitability of soil for earthworks must be assessed based on its geotechnical qualities. These qualities are generally assessed through site sampling and laboratory testing.

Authorities assessing development applications are likely to request copies of geotechnical laboratory reports confirming the suitability of the materials, construction requirements along with compaction reports. *See 5 Site investigation and earthworks.*

Water supply requirements

Dairy farm developments require a secure water supply. That security must be in both a legal (i.e. a legal right to the required volume) and a physical sense (i.e. the physical ability to pump, store and deliver the required volume of water). In areas where water usage is regulated, this usually requires a commercial water licence, allocation or entitlement.

In addition to water for stock, this estimate includes water for the following purposes:

- Dust suppression
- Feed processing
- Wash down areas
- General cleaning
- Staff and office amenities.

Additional consideration should be given to water requirements for peripheral activities such as irrigation of cropping and reuse areas, along with the establishment and maintenance of screening plantings and any vegetated filter strips.

Water supplies for fire services

Water supply planning should consider fire services requirements under the National Construction Code and its impact on building permit approval at the construction phase of the project.

Part H3 of the National Construction Code contains concessions for buildings used for farming. Concessions from certain requirements are provided because these buildings are considered to pose a lower risk to occupants.

Specific requirements relating to the provision of a fire services water supply are found in *Part H3.9 Fire Hydrants and Water Supplies* as per the summary below:

A farm building:

- With a total floor area greater than 500m^2; and
- Located where a fire brigade is available to attend a building fire, must be located on the same allotment as an access point to a water supply which:
  - has a minimum total capacity of 144,000 litres
  - is situated to enable emergency services vehicles access to within 4m
  - is located within 60m of the building and not more than 90m from any part of the building.

For the purposes of Part H3.9, a water supply for a farm building must consist of one or any number of the following: A water storage tank, a dam, a reservoir, a river, a lake, a bore, or a sea.

For more detailed information on building requirements please refer to the Australian Building Codes Board (ABCB) resources available at **abcb.gov.au**

2.3 CONSTRUCTION

Complying with approval conditions

Design modifications

At the construction phase it is important to ensure that any modification to the approved design or management does not result in non-compliance with any development consent. Prior to any works being carried out consult with the relevant authority and seek written consent. This may be in the form a formal amendment to the development approval or the endorsement of an amended plan.

Staging

If the development approval includes staged development, it is important to ensure compliance with the prescribed start and completion conditions. If there are anticipated delays to the completion of a stage it is recommended to seek a formal extension to the timeframes from the relevant authority prior to the expiry date. This will avoid unnecessary delays due to the potential lapsing of the approval.

Notification of authorities

It is advisable to formally advise the relevant authority on the completion of construction, stages, and or milestone conditions. This should be done in the format identified in the approval documents and may include inspections and or certifications e.g. compaction test results.

Managing construction-related environmental and amenity impacts

Erosion and sedimentation control

Ensure construction activities comply with the appropriate erosion and sedimentation control requirements of the relevant authority.

Traffic

Construction activities may lead to increased amounts of traffic. The transport of materials to and from the site should not impact on traffic flow, road safety or community amenity. Ensure that no waste, soil, mud etc is carried from the site and deposited on the surrounding public roads by vehicles leaving the site.

Dangerous and hazardous goods

During construction, the storage and handling of dangerous and hazardous goods on the site. Fuels, oils, explosives, and similar materials must be safely and securely stored and managed to comply with relevant Australian Standards, regulations, guidelines, and codes.

Biosecurity

Ensure the construction activities do not contribute to the transport of contaminated material to or off the site. Vehicles and machinery should be washed and maintained to reduce the potential for the transport of weed seeds etc.

Other permits, approvals and licences

Ensure that any development approval conditions requiring additional and or secondary approvals prior to the commencement of construction and operation are met.

2.4 FARM PLANNING FOR THE LONG TERM

A key aspect of any farm development with respect to upgrading or incorporating additional infrastructure, requires a longer-term understanding of the intended purpose, the potential footprint within the property, potential impacts associated with the change and forecasted management strategies, to deliver the desired outcomes.

This longer-term vision is critical when contemplating a permanent feedpad or cattle shelter development to support a grazing business, as the potential site selected for these types of facilities, may not be appropriate for transitioning into a contained housing development. The environmental considerations outlined above will be amplified as an increased herd capacity and accommodation within a contained housing option increases manure and nutrient generation, potential odour emissions and farm activity, which may cause impacts to neighbouring residences and communities.

The transition from a grazing dairy business to an intensive operation is a change in land use and therefore will trigger more planning accountability.

With respect to dairy contained housing such as freestalls, loose housing facilities and dairy dry lots, and transition to intensive farming, it is important to understand and document a range of information, which may be requested from various government agencies during the planning process. The documentation of this information specific to the type of development and locality, clearly outlines thorough planning and environmental consideration reassuring communities, potential risks are mitigated with robust management and contingency plans.

The fundamental plans to support the planning application should include:

Environment Impact Statement (EIS)

Other common names include Review of Environmental Factors, Statement of Environmental Effects or Environmental Effects Assessment.

This document is prepared by a proponent and planning consultant to accompany the development application as a formal evaluation of the effect or likely effect of the development, connecting works e.g. roads and utilisation areas on the environment or community amenities. The level of detail required in this document is related to the size and scope of the development and its potential impacts.

The various planning objectives as outlined above in section 2.2 provide the foundation information that will be sought by a range of government agencies throughout the planning process specifically working through each objective as it relates to the entire dairy complex. That being all the relevant infrastructure associated with the development of feedpads and contained housing such as the milking facility, commodity bunkers, feed preparation area and effluent management systems.

Environmental Management Plan (EMP) – Other common names include Operation Plan, Site Management Plan

This document is an operational document that provides a framework for monitoring and recording the activities necessary to mitigate environmental impacts. An EMP is a living document and should detail all operation, maintenance and monitoring procedures, including the frequency of each activity and the person responsible for completing it.

Typically, they contain:

- Proposed monitoring program
- Operation and maintenance procedures checklist
- Record keeping (fertiliser management, manure testing results, manure application areas)
- Emergency action plan including mass mortality management
- Complaint response form
- Review and revision timeframe
- Any other requirements identified in permits or licences held.

Effluent Management Plans (EfMP)

An EfMP is a document that provides information on effluent and manure system design, engineering, and management. They are developed by qualified professionals in consultation with the property owner and site operators to ensure an effective system is implemented that suits the locality, physical characteristics of the property, farm management strategies and provides the maximum opportunity to reuse effluent and manure to achieve production gains whilst minimising the risk to the environment. A key component of these plans are adequate sizing of systems and nutrient budgeting and management, which is a significant focus of several government planning agencies.

The Australian Dairy Industry has access to a list of accredited Effluent System Designers who have completed Agriculture Victoria's national Design Livestock Effluent Systems training and therefore have access to relevant design toolkits and technical information.

agriculture.vic.gov.au/livestock-and-animals/dairy/managing-effluent/effluent-system-designers

The Effluent and Manure Management Database for the Australian Dairy Industry is a repository of reliable and scientifically validated technical information on dairy effluent management adaptable to all dairying regions in Australia. The database outlines the principles for effective effluent management, performance-based design criteria for components of effluent containment and reuse systems, and appropriate management principles for optimal operation of each design. The database not only provides the technical information required for on farm effluent management designs but also the technical base to support National, State and Regional regulations on dairy effluent management, technical and farmer-based extension programs, and educational material on dairy effluent management.

03

State and territory planning resources

3.1 STATE AND TERRITORY PLANNING RESOURCES

Farms contemplating any type of development should utilise relevant state-based dairy guidelines or codes of practices, which should provide the information to assist in the documentation required to support the application.

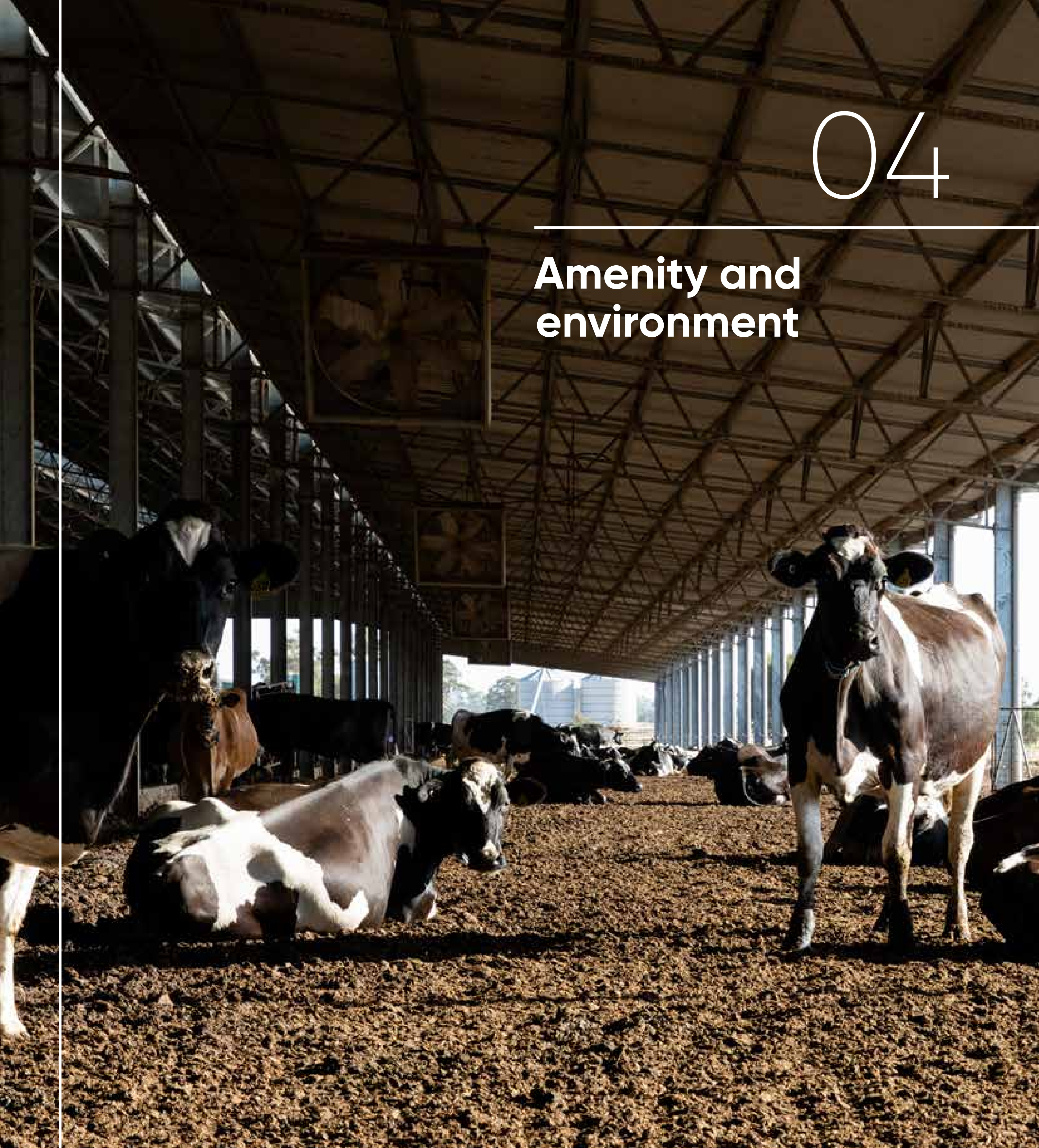
State	Government Department responsible for planning	Planning scheme
Australian Capital Territory	Environment, Planning and Sustainable Development Directorate **environment.act.gov.au**	**planning.act.gov.au/planning-our-city/territory_plan/zones-and-overlays**
New South Wales	NSW Department of Planning and Environment **planning.nsw.gov.au** **Planning Guidelines Intensive Livestock Agriculture Development** is a guide intended to assist applicants and planning authorities to understand the assessment requirements for intensive livestock developments **dpi.nsw.gov.au/__data/assets/pdf_file/0008/194399/planning-guidelines-intensive-livestock-agricultural-development.pdf** **New South Wales Environmental Management Guidelines for the Dairy Industry (2008)** is a key document which outlines the key requirements for farms planning a new dairy development and/or a major re-development of an existing operation. **dpi.nsw.gov.au/__data/assets/pdf_file/0003/249033/Environmental-management-guidelines-for-the-dairy-industry.pdf** **SIX Maps** is an NSW property planning tool providing relevant land and parcel data **maps.six.nsw.gov.au/**	**planning.nsw.gov.au/Plans-for-your-area/Local-Planning-and-Zoning**
Northern Territory	Northern Territory Planning Commission **planningcommission.nt.gov.au**	**nt.gov.au/property/land-planning-and-development/our-planning-system/nt-planning-scheme**
Queensland	Queensland State Development – Planning **planning.statedevelopment.qld.gov.au** **Queensland dairy farming environmental code of practice** is a key document which outlines the key requirements for farms planning a new dairy development and/or a major re-development of an existing operation. **catalogue.nla.gov.au/Record/1439888**	**planning.statedevelopment.qld.gov.au/planning-framework/plan-making/local-planning/local-planning-schemes**

State	Government Department responsible for planning	Planning scheme
South Australia	Planning and Land Services – PlanSA **plan.sa.gov.au** South Australia Property and Planning Atlas (SAPPA) is a property planning tool providing relevant land and parcel data **sappa.plan.sa.gov.au/** **Code of Practice for Milking Shed Effluent** (2003) represents a translation of the Environment Protection (Milking Shed Effluent Management) Policy 1997 into a code of practice linked to the Environment Protection (Water Quality) Policy 2015 (the Water Quality Policy). **epa.sa.gov.au/files/4771456_milking_shed.pdf** **A development referral checklist** has been prepared by the EPA to assist applicants and relevant authorities identify information that should be included with an EPA referral. **epa.sa.gov.au/files/13082_devt_checklist.pdf** The EPA has a range of information to assist with understanding the EPA position on how environmental issues should be addressed through the South Australian planning system **epa.sa.gov.au/environmental_info/environmental_planning/advice-and-assistance**	**code.plan.sa.gov.au**
Tasmania	Tasmanian Planning Commission **planning.tas.gov.au** **Farm Dairy Premises Effluent Management Code of Practice – Tasmania** represents one step towards ensuring that appropriate farm dairy premises effluent management is undertaken in the state. **tdia.tas.gov.au/Documents/Final%20Approved%20Code%20May%2010.pdf**	**planning.tas.gov.au/other-resources/effective-planning-schemes**
Victoria	Department of Environment, Land, Water and Planning **delwp.vic.gov.au** **Navigating Farm Development (NFD)** is an online tool designed to identify the statutory planning requirements and relevant property overlays to streamline the farm development projects. **developments.agriculture.vic.gov.au/NFD/index** **Management of Dairy Effluent Victorian Guidelines (DairyGains 2008)** provides a clear and concise overview of the environmental management requirements and industry expectations with respect to dairy effluent management. **dairyingfortomorrow.com.au/wp-content/uploads/2008-DairyGains-Victorian-Effluent-Guidelines.pdf** **VicPlan** is a tool that you can use to view, query, and create your own property reports. More than a mapping tool, it's a gateway to a whole range of planning information. **mapshare.vic.gov.au/vicplan/**	**planning.vic.gov.au**

State	Government Department responsible for planning	Planning scheme
Western Australia	Department of Planning, Lands and Heritage **wa.gov.au/organisation/department-of-planning-lands-and-heritage** **Code of Practice for Dairy Farm Effluent Management WA 2021** features clear standards that are aligned with industry, government and community expectations. **dairyaustralia.com.au/western-dairy/resources-repository/2020/07/09/code-of-practice-for-dairy-farm-effluent-in-wa#.Y372dfdBxaQ**	**wa.gov.au/organisation/department-of-planning-lands-and-heritage/state-planning-framework**

04

Amenity and environment



4.1 ENVIRONMENTAL CONSIDERATIONS

The main environmental issues relating to dairy farms are associated with:

- Runoff or leaching of nutrients and/or manure to surface water or groundwater.
- Management of nutrient and salt levels in soils where solid manure or recycled effluent has been spread.

Surface water protection relies on the provision of:

- Adequate buffers to waterways, channels, dams, and other surface waters.
- Effective manure containment, handling, and reuse practices.
- Effective containment and handling of runoff from the storage of high moisture feedstuffs (e.g. orange pulp, silage).

Dairy farms can prevent adverse impacts to surface waters by:

- Frequently and thoroughly cleaning the dairy complex to ensure that manure does not accumulate to excessive levels.
- Installing physical barriers (e.g. earthen bunds or banks) as required to minimise the amount of stormwater that can enter the dairy complex.
- Ensuring that manure and runoff from the dairy complex is collected and stored using an appropriately designed system.
- Ensuring solid manure and recycled effluent is applied at sustainable rates. Solid manure and recycled effluent must be spread at rates and at times when off-site movement of nutrients is unlikely to occur (e.g. not when the soil is very wet, or rainfall is imminent). The nutrients, salts and water in manure must be spread on land at rates that are balanced by plant growth and evapotranspiration.

Groundwater protection relies on:

- The provision of effective design and construction of the dairy complex where manure concentrates or recycled effluent is stored.
- Ensuring solid manure and recycled effluent is applied at sustainable rates. Solid manure and recycled effluent must be spread at rates and at times when leaching of nutrients is unlikely to occur (e.g. not when the soil is very wet). The nutrients, salts and water in manure must be spread on land at rates that are balanced by plant growth and evapotranspiration.

Dairy farms can prevent adverse impacts to groundwater by:

- Ensuring the dairy complex is constructed to a suitable standard to minimise leaching.
- Maintaining adequate buffer distances from groundwater access points.
- Ensuring the base of ponds are impermeable.
- Ensuring solid manure and recycled effluent is applied at sustainable rates. Application of manure at excessive levels, either as a once-off application or over time, can result in nutrient or salt leaching to groundwater.

4.2 AMENITY CONSIDERATIONS

Amenity refers to the comfortable enjoyment of life and property, particularly regarding odour, dust, noise, light, and visual appearance.

4.3 ODOUR

Dairy complex siting and design needs to consider the potential for generating odour. In general, dairy farms should have some understanding of odour generation and dispersion so they can implement effective odour control strategies.

Odour is generated during the anaerobic decomposition of organic matter in manure and spilt feed. Emissions can become an issue when manure remains wet for several days (above approximately 70 per cent moisture content), allowing anaerobic conditions to prevail. Common odour sources at dairy farms include solids separation systems, ponds, manure or compost stockpiles, feedpads, contained housing systems, laneways, application system type and high moisture content feeds.

Factors that influence odour generation by dairy farms include:

- The number of cattle
- Farm management and operation
- Feed types
- Moisture content of the manure
- Type of feedpad, contained housing facility and the manure handling equipment
- Manure management practices. For example:
  - Cleaning frequency: farms that remove manure infrequently (e.g. monthly scraping of an earthen pad) generate more odour than those that either scrape or flush frequently (e.g. daily). Fresh manure does not generally emit offensive odours. However, if there is a significant depth of manure on the pad surface and this becomes wet after rain, significant levels of offensive odour will be generated for several days.
  - Manure accumulation: small areas of accumulated manure and wet patches within these areas can produce significant amounts of odour. Hence, attention to detail is important when cleaning around fences, fence posts, feed troughs and laneways. Similarly, potholes need repairing as water pooling in these areas promote anaerobic breakdown of manure.
  - Handling and distribution of manure, compost and recycled effluent. i.e. disturbance of material exacerbates odour release.
  - Desludging of ponds (i.e. removal of accumulated slurry manure).

The likelihood of odour causing a nuisance at nearby sensitive uses depends upon:

- Local meteorological conditions (i.e. in particular prevailing wind direction and strength)
- Topographical features that affect transport and dispersion of odorous air (e.g. terrain, height and density of vegetative cover)
- Distance between the odour source and sensitive uses
- The type of sensitive use (e.g. house, town).

Generally, the greater the frequency, intensity, duration, and offensiveness of an odour, the greater the likelihood of annoyance and complaints. Where the timing of odorous activities can be controlled, these should be scheduled to occur when dispersion will be enhanced through favourable meteorological conditions. Unstable atmospheric conditions (e.g. a hot windy day) result in faster dispersion of odours than stable atmospheric conditions (e.g. an overcast, cool day with no wind).

NOTE

Producers undertaking developments should consider their own state's preferred method to support the planning application.

4.4 DUST

Dust can be a physical irritant and may also pose a respiratory or allergenic risk. Dust from dairy farms may originate from traffic movements, cattle laneways, earthen feedpads, manure handling and distribution equipment and manure reuse. Like odours, dust dispersion is enhanced under unstable atmospheric conditions. However, dry, windy conditions also promote dust generation from outdoor areas.

4.5 NOISE

The dairy shed; contained housing facility; feed preparation areas; and manure handling and management areas may generate some noise. However, truck and traffic movements are most likely to cause nuisance. The potential for noisy activities to cause nuisance depends primarily on the level of noise created and the time of day it occurs. However, it also depends upon atmospheric conditions, local topography, and natural and artificial barriers. Surrounding sensitive uses (e.g. neighbouring houses) are more susceptible to noise during the early morning or night, when there is greater potential to interrupt sleep.

4.6 LIGHT SPILL

Light spill from roadways, parking areas, dairy sheds and contained housing facilities can impact nearby residences. Most dairy farms will use artificial lighting as milking generally occurs in the early morning and late afternoon (during the winter months milking often occurs before and/or after dawn and dusk). Strategically locating lights or providing shields to prevent light spill onto surrounding sensitive land uses prevents nuisance from occurring.

4.7 VISUAL AMENITY

While dairy farms, like other agricultural enterprises are a normal part of the rural landscape, the construction of a feedpad or contained housing facility may significantly alter the landscape character. Careful siting including the use of topographic or vegetative buffers, or landscaping can minimise the impact.

4.8 AVOIDING ADVERSE AMENITY

Most amenity issues can be managed through:

- Providing an adequate separation distance to nearby sensitive uses.
  - The dairy complex and reuse systems should be adequately separated from sensitive land uses. This minimises the risk of the dairy farm causing offensive odour and dust levels at sensitive uses, under both usual and abnormal conditions. Where practicable, the greater the separation distance to sensitive uses, the lower the likelihood of nuisance from odour and dust. The location of on-farm roadways and property access should also be considered.
- Best practice siting, design, construction, and management.
  - Where practicable, sites that offer topographic or vegetative screening should be selected (additional vegetation may also be proposed as part of the planning permission process). Facilities should be designed and constructed to promote ease of cleaning and management. Regular cleaning reduces the odour generation rate. Timing odorous activities to occur under conditions that are unlikely to promote odour dispersion reduces the odour levels at sensitive land uses. Alerting neighbours before odorous activities occur (e.g. pond solids removal) and not undertaking these on weekends reduces the likelihood of complaints.

05

Site investigation and earthworks

INTRODUCTION

Site investigation and earthworks for dairy feedpads and contained housing facilities should consider the following:

- Site and soil attributes are assessed at a desktop and visual inspection level before any ground disturbance.
- Soil materials are suitable for the purpose, meeting appropriate engineering standards.
- Site plans and designs inform any proposed earthworks.
- Construction methods and requirements are identified before earthworks are undertaken.
- Design and construction protect environmental features such as surface waters and groundwater, and nearby sensitive uses.

5.1 PRELIMINARY DESKTOP INVESTIGATION

For information related to the development application and approval process see *2 Planning Requirements – Development Applications and Approvals*.

Any potential development site should not be disturbed until desktop due diligence is carried out in full, covering overlays, services and environmental site conditions. Some of these factors include, but are not limited to, the following:

Local and state planning zones and overlays: flooding, heritage (natural, cultural or indigenous), natural resources (surface water, groundwater, soil) and native vegetation. See *2 Planning Requirements – Development Applications and Approvals*.

Site levels, slope, drainage and stormwater: should be reviewed with available electronic information. Contours may be obtained from state databases while other more detailed information including Light Detection and Ranging (LiDAR) may be accessible. Levels, slopes and drainage should be understood to determine:

- Stormwater from neighbouring land flowing onto or across a proposed development site.
- The direction and discharge point for stormwater from the proposed development site, specifically noting where drainage water passes across site boundaries.

Where detail is not available electronically, site survey for levels should be carried out in the outset of field investigations.

Surface waters: sites must consider any area where waterways, watercourses, drainage paths or passive flow paths occur within or in close proximity to proposed development areas. Infrastructure must be positioned with adequate buffer distances or protection measures from these features.

Groundwater: conditions for most states are available via electronic databases or hydrogeological map sheets including Australian Geological Survey Organisation Mapping, Waterconnect, WaterNSW Real-time data and Visualising Victoria's Groundwater.

All groundwater information collected at a desktop level should be verified from field measurement of stock and domestic bores, irrigation bores or state monitoring bores. Geotechnical investigation pits or boreholes should be used for detection of shallow or perched groundwater. Groundwater considerations:

- Areas with high water tables, where groundwater is found within 1.0 metre of the finished floor level of proposed ponds or from the base of foundations. Standing water and capillary rise will impact pond lining and foundations, regardless of salinity quality.
- Beneficial use groundwater, where adequate protection measures are required, regardless of depth. This is particularly important landscapes with permeable soil and rock.

Geology: information available electronically and in hard copy should be accessed and reviewed from state database information or from geological map series data. Where proposed development sites are located in areas of permeable geological formations such as deep sands or fractured rock, special design considerations will be required for construction of effluent ponds, manure stockpiles and freshwater storage dams to achieve an impervious standard.

Soil management overlays specific to sites can be obtained from state databases or local council. Examples of soil management overlays include, but are not limited to the following:

- Salinity (natural soil salinity, irrigation induced or from high water tables).
- Potential acid sulphate soils should not be uncovered, avoiding impacts to surface waters and groundwater.
- Sodic or dispersive soils where soil exchangeable sodium percentages are 6.0% or greater, or where soils disperse upon immersing in fresh water.
- Potentially contaminated land.

Dial Before You Dig (DBYD) and engagement of a Services Locator: Note: DBYD is limited to public land. The location of services within property boundaries is the responsibility of the landowner.

Some local council areas require permits before proceeding with site investigations. Inquiries should be made with local councils before commencing any earthworks.

It is also critical to ensure that national and state guidelines are consulted for the geotechnical investigation, erosion, soil management and sediment control, effluent pond and farm dam construction and operation. These guidelines will form part of the approval process from your local council prior to issuing a works approval for construction.

5.2 SITE INVESTIGATION

Site investigations must consider both the construction site and the site for borrowing earth.

Underground services locators

Where there is any known occurrence of underground services, an underground service locator is required to peg the alignment of these features and provide guidance on the safe working distance from these features. Clearance for any works should not proceed until all known services are located.

Site survey and site plan

A qualified and experienced land surveyor should carry out a feature survey with levels. A site survey is critical to confirm slopes, drainage flow paths, speed of drainage and likelihood of inundation as well as supporting the design stage that must detail options for manure management. A site survey sets the basis for development of a site plan required by authorities to assess planning applications and for earthworks and construction contractors for quoting works.

Engineers will base their designs on the topographic data collected by the site surveyor. The site survey data will be provided to the engineers and other professional service providers in digital format for computer aided design and drafting (CADD).

Following the approval of the site development proposal, the surveyor will again be required for the set-out and confirmation of the positioning of features. Plans are required to ensure authorities assessing applications and contractors providing quotations understand:

- Site boundaries
- Existing buildings
- Location of neighbouring residences and neighbouring land use
- Waterways, watercourses, depressions, low areas and natural drainage lines
- Native vegetation
- Markers indicating the presence of underground services
- Easements, including council, water authority or other
- Cross sections, including earthworks volumes and schedules, allowing borrow material volume from sumps or ponds to be matched with requirements for pad or embankment construction
- Stormwater drainage away from the site under high rainfall design intensity scenarios (e.g. 1 in 100-year rainfall).

Site drainage

Poor drainage and uncontrolled soil moisture ingress can impact on earthen structures and facilities causing excessive ground movement and failures in structures and concrete. This is important in fine-textured, clay-dominant soils or where high-water tables and capillary rise of groundwater impact foundations. All areas of poor drainage should be avoided or engineered to prevent drainage impacts.

Location of effluent ponds and borrow pits

Sites for effluent ponds and borrow pits should be defined early in the planning process by targeting preferred soil types, or by identifying the logical location of the storage site from the facility. In most cases, the most common location for accessing suitable borrow material for construction of earthen pads is by excavating soil from proposed effluent pond sites.

Additional borrow material may need to be sourced for flat sites, poorly drained sites, sites impacted by inundation, flooding, high water tables or sites requiring elevation above natural surface level.

5.3 GEOTECHNICAL INVESTIGATION AND MATERIALS SUITABILITY

Depth of geotechnical investigation and equipment

Geotechnical investigations are well supported with use of Electromagnetic Mapping (EM) which measures apparent conductivity of a soil to variable depths, reflecting changes in texture, moisture, salts and rock. EM31 should be used for deep investigation to 3.0–4.0 metres. EM38 vertical dipole can be used for shallow investigations to 1.0 metre.

Depth of investigation should extend to at least 1.0 metre below the proposed base of an effluent pond or foundation depth, allowing for characterisation of deeper materials. For example, if an effluent pond or sump has a proposed depth of 3.0 metres, investigations should extend to at least 4.0 metres.

Geotechnical investigations should be carried out with the aid of equipment including an excavator, backhoe or drilling rig. Excavators and backhoes provide greater accuracy and clarity to determine soil horizons and accuracy in sampling, particularly where in-situ lining and horizon thickness is critical to determine. Further reasoning includes:

- A reduction in smearing and mixing of soil during investigation
- Ability to collect clean, uncontaminated samples from set depths by hand in shallow pits or by machine retrieval from deep pits
- Measurements of shallow or perched groundwater which are timely and accurate
- Ease in collection of large samples for geotechnical testing
- Exposure of soil layers for in-situ permeability testing.

Figure 1. Layers of soil extracted from investigation sites using an excavator

Figure 2. Layers of soil extracted from investigation using a drill rig

Soil classification and suitability

Materials should be classified using the Unified Soil Classification in accordance with AS 1726:2017 Geotechnical Site Investigation. Different soil types are needed for different purposes and types of construction activities.

Constructing earthen feedpads, manure stockpiles or composting areas: construction may occur using coarse or fine-grained soils. Materials should be compacted to 98–100% of standard Maximum Dry Density for coarse grained soils and 95–98% for fine textured soils. All material types should have provisions for external and internal drainage to control moisture ingress and prevent fluctuations in moisture content. Fine grained soils may suffer ground movement with changes in moisture content from seasonal variation, perimeter plant growth, groundwater and capillary rise. Moisture content may also change if pads develop cracks allowing moisture to enter or if there are failures in plumbing.

Use of highly organic soils of any type are not recommended for use in pads. The organic fraction is subject to decay causing soil consolidation and pad movement. Furthermore, organic materials may promote excessive moisture ingress and retention which must be prevented.

Lining effluent ponds: fine-grained soils including clays and some silts are preferred for impervious soil lining. The suitability of materials generally increases with an increasing clay percentage. Materials suitability is summarised as follows:

- Preferred – fine grained soils:
  - CH, CI and CL: Clays of high, moderate or low plasticity
- Marginal – silts, low plasticity clays with high sand percentages and some clayey sands.

Materials may require soil treatment or amendment by importation and mixing clay, bentonite or sodium tripolyphosphate.

  - MH: Silt of high plasticity
  - CL: Clay, low plasticity with high sand percentages
  - SC: Sand, clay.
- Not suitable – coarse grained soils including sands and gravels, or silts with excessive rates of permeability:
  - ML: Silt of low plasticity
  - GW, GP, GM and GC: Gravels of all types
  - SW, SP, SM and SC: Sands of all types.

Marginal soil materials and options for reducing permeability to achieve minimum permeability standards:

1 Clay spreading and mixing, including dispersive clay which may seal from dispersion when in contact with fresh water.

NOTE

- **Care is required in use of dispersive clays around pipes and structures through banks. Soils around pipes and structures should be stabilised with hydrated lime.**
- **Dispersive clays may not disperse under elevated electrical conductivity (EC) levels from flocculation.**

2 Bentonite, spread and mixed into surface layers of lining, rates of 7–10kg per m^2 are used as a guide on marginal soils.

3 Sodium tripolyphosphate (STPP), spread and mixed into surface layers of lining. Rates of 0.5kg per m^2 are used as a guide on marginal soils. STPP can also be incorporated into water supplies at 0.5g per litre to reduce permeability.

Gypsum (Calcium Sulphate) should not be used for sealing embankments. Gypsum is a salt which flocculates clay, reduces or eliminates soil dispersion and enhances the structure and permeability of clay. Gypsum is suitable for reducing or eliminating dispersion and rill erosion on the finished surface of embankments, enhancing prospects for achieving pasture cover.

Laboratory assessment

Geotechnical testing of soil materials should be carried out by a NATA accredited laboratory. Laboratory testing should be in accordance with procedures outlined in AS 1289 (2000) *'Methods of testing soils for engineering purposes'*. Minimum testing requirements for understanding material characteristics and suitability include:

- Moisture Density Relationship (MDR):
  - Optimum Moisture Content (OMC)
  - Maximum Dry Density (MDD).
- Particle Size Distribution:
  - Sieve analysis – all coarse fractions to 75 microns
  - Hydrometer analysis – percentage sand, silt and clay.
- Atterberg Limits, including:
  - Liquid Limit (LL)
  - Linear Shrinkage (LS)
  - Plastic Limit (PL)
  - Plastic Index (PI).
- Moisture Content (MC).
- Permeability (Constant Head) carried out using a saline brine reflective of the electrical conductivity (EC) of effluent.

Agricultural soil testing to compliment geotechnical testing: parameters which are beneficial include:

- EC 1:5 (salinity): measure of salts in the soil
- pH (water): measure of soil acidity
- Slaking Class: measure of aggregate stability and breakdown upon wetting
- Exchangeable cations, including calcium, magnesium, potassium, sodium and aluminium: Measure of the cation balance of a soil and likely stability. Required for calculating Exchangeable Sodium Percentage (ESP)
- Exchangeable Sodium Percentage (ESP) (calculated). Measure of the likely soil dispersion that may occur.

Groundwater assessment and measurement: the presence of groundwater should be recorded along with the depth. Where possible, groundwater should be sampled and tested for EC (salinity) and pH. Evidence of groundwater should also be recorded. Pit or borehole smearing by equipment is expected. Groundwater is best checked several hours or the following day after digging pits or drilling boreholes, allowing standing water levels to stabilise.

5.4 CONSTRUCTION REQUIREMENTS FOR EARTHEN FEEDPADS, EMBANKMENTS AND LINERS

Topsoil removal and management

Topsoil including all soil material with organic matter and tree roots should be removed from all areas for construction of feedpads, contained housing facilities and effluent ponds and infrastructure supporting where earthen pads, banks and lining is required. Topsoil should be stockpiled for embankment shrouding, paddock renovation or construction of aesthetic banks.

Borrow areas

Guidelines for extracting borrow soil as potential sites for effluent ponds or freshwater storages are:

- **Batter slopes:** should permit machinery access and maintenance, with grades of 3:1 horizontal to vertical (H:V)
- **Soil stripping:** materials should be stripped in layers of uniformity, reflecting horizons. Each layer should be individually or composite tested for laboratory assay
- **Depth of borrow:** depth based on geotechnical investigation results. In clay-dominant soils, ideally a minimum of 600mm of impervious clay should be retained for lining
- **Inspection:** all borrow areas should be inspected on completion of excavation, confirming materials are suitable for impervious lining.

Embankment construction for effluent ponds and small fresh water storages

- **Embankments:** zoned, ensuring a core section which provides security of water impoundment and intercept of any horizontal water flow or preferential pathway for water transmission.
- **Core construction:** common core construction methods are shown in Figure 3 and Figure 4. Configuration and thickness are listed as follows:
  - Extend from the base of the key trench or borrow pit to the crest
  - Minimum thickness of 0.6 metre.
- **Batter slopes:** minimum of 3:1 horizontal to vertical (H:V) grade or flatter for safety, access for maintenance and minimal erosion. Steeper grades can be applied however trafficability is limited, safety risks for machinery increase and erosion of banks is more likely. Where less than 5:1, erosion control measures will be required.
- Freeboard:
  - Refer to relevant state or territory guidelines or code.
- Crest:
  - Width: minimum of 3.0 metres, allowing a 5:1 phreatic line to be maintained from full supply level on the inner batter without reaching the outer toe.
  - Slope: 1 in 25 to 1 in 40 H:V grade sloping towards the dam.

Figure 3. Common embankment core construction method – central clay core

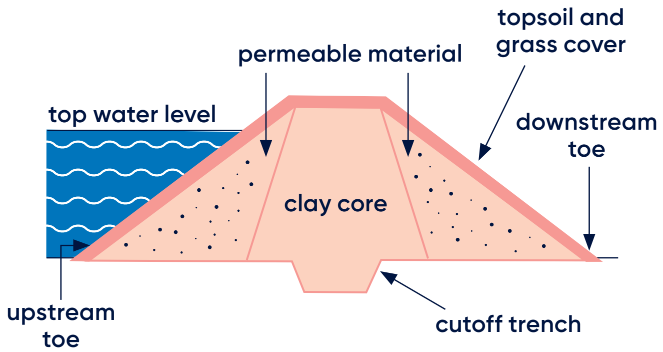
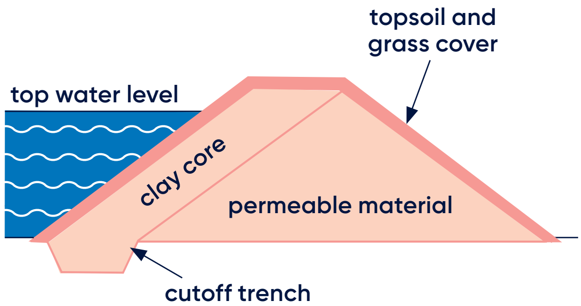


Figure 4. Common embankment core construction method – typical upstream clay core



- **Core section**: 98% of the standard maximum laboratory dry density determined in accordance with Method 5.4.1 of AS 1289, at the optimum moisture content (OMC).
- **Non-core section/non-liner material compaction:** 95–98% of the standard maximum laboratory dry density determined in accordance with Method 5.4.1 of AS 1289, at the OMC.
- **Construction technique:** lifts of approximately 150mm, wetted to the OMC and compacted to the MDD for specific material type.
- **Protective shroud (topsoiling) over liners and embankment:** minimum of 100mm of topsoil or any available material to protect embankments and liners from drying and desiccation.
- **Pipes through embankments:** minimum of two cut off collars installed, extending at least 0.6m in all directions around the pipe, affixed and sealed to the pipe.
- **Stabilisation of soil around pipes and cut off collars:** incorporate hydrated lime mixed through the soil at 1% w/v, wetted and compacted to the specifications for soil core construction.
- Track walk the banks to reduce rill erosion, enhance stability and promote the lodgement of seed for establishment.
- Gypsum treatment of finished embankments after topsoiling is recommended at 1% w/v to control dispersion.
- Seeding of embankments is recommended using grass species such as Kikuyu. Trees should not be planted on embankments.
- **Overflow systems:**
  - Effluent ponds should be contained with no overflow. Alarm systems should be installed for monitoring pond levels.
  - Fresh water storages should have overflow systems installed at full supply level to prevent overtopping. Overflow discharge areas should be rock armoured or stabilised by grass cover or geosynthetic options.

Construction of internal farm roads and laneways

Construction of earthen pads should follow guidelines and procedures for earthen lining, outlined in the previous section on embankment construction for effluent ponds and small fresh water storages above. This includes topsoil stripping and compaction of selected materials.

For internal farm roads and laneways, coarse-grained materials including gravels and sands are preferred as sub-grade or sub-base material. These materials have low shrinkage values and less propensity for soil movement. In accordance with AS1726:2017, these materials are classified as gravels (GW, GP, GM, GC) and sands (SW, SP, SM). Clays and silts (CH, CI, CL, MH and ML) can be used if well-drained with minimal risk of moisture ingress. Imported materials may need to be imported to achieve elevated tracks, laneways and roads that are well-drained with minimal ground movement.

Safe bearing pressures should be based on engineer specification, set based on axle loads, frequency of use and material type.

5.5 EARTHWORKS QUALITY ASSURANCE ASSESSMENT

Quality assurance (QA) assessments should be carried out on all earthworks supporting dairy feedpads and contained housing facilities. Earthworks should be supervised or be periodically checked at various stages by qualified or experienced personnel.

Supervision during earthworks is essential to ensure:

- Topsoil are adequately stripped from all borrow areas, from under embankments, earthen pad sites and any other area including tracks and laneways prior to construction.
- Placement of clay on pads or embankment areas occurs in a 'like-on-like' fashion, ensuring compacted clay is placed on the same material and adequately bonded. Topsoil, manure and other foreign material must not be mixed into any earthen pad or liner.
- Clays excavated from borrow areas are uniform in condition. Where variable, compaction specifications will need to be adjusted for differing material types.
- Sand and other unfavourable material is not uncovered in any borrow area or used for construction of embankments or pads. Where uncovered, in-situ liners are not suitable, and an engineered clay liner is required for construction to an impervious standard.

For large projects, QA checks covering site plans and specifications should occur constantly throughout the project. AS 3798 (2007) provides guidelines around earthworks testing for commercial development sites.

Embankments, liners and pads must be checked for compaction as layers of material are placed. Testing should occur in accordance with differing material types and the contractors requirements, ensuring they achieve the recommended specifications for moisture and density. Samples that fail will require ripping, rewetting to the OMC and compaction.

Permeability testing is required on all in-situ liners to ensure a minimum coefficient of permeability of 1×10^{-9} metres per second is achieved, reflecting an impermeable condition.

Borrow areas should be inspected upon completion for pervious materials. EM38 mapping may be beneficial across the borrow area to define any pattern of subsurface conductivity that defines sand lenses.

Erosion control measures should be constructed within and around construction sites to ensure rainfall does not cause excessive erosion.

Clay-dominant soils, particularly those that are dispersive should be covered with topsoil or have a layer of gypsum spread on the surface to reduce dispersion and turbidity of stormwater emanating from construction sites. Sites should be left in a condition that allows for drainage without site ponding.

5.6 ENGINEERED LINING OPTIONS FOR PONDS AND SUMPS

Several dairying areas of Australia contain soils and geology not suitable for impervious lining. Regions with pervious limestone rock such as the south-east of South Australia, widespread sandy soils in Western Australia or dairying regions on alluvial soils in old river valleys of Victoria, Tasmania and New South Wales often reveal no clay for use in lining ponds. Under these conditions, geosynthetic lining, concrete lining or other engineered lining options are required to achieve impervious conditions.

Two of the most common geosynthetic lining options include Geosynthetic Clay Lining (GSL) and High-Density Polyethylene (HDPE) (Figure 5). Liners of this type should be constructed to the following criteria and considerations:

- Suitable for effluent or use as an impervious barrier for effluent or leachate.
- Installed to manufacturers requirements, including site preparation.
- Adequate ultra-violet (UV) rating for the proposed lifespan of the material.
- Drainage and seepage detection beneath the liner.

Where small structures or sumps are required, concrete is the most common option for providing an impervious barrier which is not subject to movement. Concrete can also withstand trafficking and cleaning with machinery. Sulphate resisting concrete should be used where concrete will be subject to liquid with an elevated salt loading, where soils are saline or where groundwater impacting foundations is saline.

Above-ground tanks are used in landscapes where pond construction is difficult based on landscape characteristics.

Figure 5. HDPE lining installed for impervious ponds in northern Victoria

5.7 FINALISE PLANS AND SUPPORTING DOCUMENTATION

Final plans

All site plans must be finalised prior to submitting development applications to council for approval.

Earthworks plans, schedules and machine control

Earthworks plans and schedules quantities should be prepared for any site subject to earthworks of a reasonable scale. Earthworks plans and quantities allow for:

- Developers to gain a real appreciation of the size and scale of works to be undertaken along with anticipated costs of earthworks and maintain works to set budgets
- Authorities to have quantified the exact amounts of earth to be shifted during each stage
- Contractors to provide accurate quotations for works.

An equal earthworks balance should be calculated, ensuring that the required volume of earth (compacted) for all earthen structures including embankments, liners and pads equals the amount available and designated for excavation. A compaction factor of 10–15% should always be allowed for in calculations for earth.

Where possible, machine files should be created for contractors carrying out works. Machine files allow all finished levels to be matched to plans without continual need for supervision. Regular checks of levels against benchmarks should occur.

Figure 6. Construction of a an earthen feedpad and ponds – long view

Figure 7. Construction of a an earthen feedpad and ponds

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06

Water supply

INTRODUCTION

The purpose of any water supply system is to support production and ensure appropriate standards of animal health, welfare and hygiene are maintained by:

- providing sufficient volumes of good quality water
- designing the system to manage periods of increased demand
- designing and locating water troughs that are easily accessible, easily cleaned and positioned to minimise contamination by feed.

It is also important to ensure water requirements to operate a dairy farm are readily available by:

- understanding potential water consumption and frequency of use
- identifying opportunities to capture and utilise rainwater sustainably.

6.1 STOCK WATER QUANTITY AND QUALITY REQUIREMENTS

When planning temporary containment or longer-term contained housing facilities where cattle are concentrated to a designated area, it is essential to determine stock water requirements, both from a quantity and quality perspective, while providing adequate access for all stock.

Dairy cows need access to clean, fresh water supplies, with the potential to consume 30–50 per cent of their daily water intake within one hour following milking. It has been reported that lactating cows can consume water at rates of up to 20 litres per minute.

The amount of water a cow drinks depends on several variables such as: size and milk yield, quantity of dry matter consumed, temperature and relative humidity of the environment, water temperature, quality and volume of water on offer, and amount of moisture in the feed ration (Table 1).

Table 1. Estimations of dairy cow water requirements

Dairy cow	Daily water requirement
Non-pregnant cows in cool environment (less than 15ºC)	Estimated 3.5 litres of water per kg of dry matter consumed
Pregnant cows in warm environment (around 21-25ºC)	Up to 7.1 litres of water per kg of dry matter consumed
Lactating cows	5 litres of water per kg of dry matter consumed plus • additional allowance of 1 litre of water per litre of milk produced • additional requirement during hot weather

On average throughout the year, dairy cows typically drink somewhere in the range of 120–150 litres of water per day when producing about 20 litres of milk. Approximately 25–35 per cent is obtained from the various feed rations consumed and the rest from drinking.

Water is an important source of nutrients during periods of heat stress. Dairy cows drinking intake can increase by as much as 80 per cent on days over 35ºC. Therefore, on hot days, allow 200–250 litres per cow each day.

Signs that indicate the water delivery system is inadequate are cows queuing up to drink, regularly empty troughs or cattle damaging float valves.

Optimal drinking water temperature is between 15–20ºC. However, water temperature only has a slight effect on drinking behaviour and animal performance, therefore responses to chilling water under most circumstances would not warrant the costs of cooling the water.

It is good practice to routinely test the water supply to ensure water quality parameters are within an acceptable range to maintain animal performance. Testing should include levels of total dissolved salts (TDS), pH, hardness, specific minerals/compounds, heavy metals, other toxic compounds, and microbes.

If results of water analysis indicate water quality problems, seek an alternate water source, or water treatment system that can improve the specific parameters.

Excess concentrations of minerals above recommended stock tolerance will not only limit the amount of water consumed, due to palatability issues, but also affect the animal's digestive and physiological functions.

Table 2 shows the upper limits for stock water quality and the likely effects on animal health if these limits are reached or exceeded.

Table 2. Stock water quality – upper limits of mineral/metal levels for livestock

Element	Upper limit milligrams per litre (mg/L)	Effect
Calcium	greater than 1000 mg/L	Phosphorous deficiency
Magnesium	greater than 1000 mg/L	Scouring and diarrhoea
Nitrate	greater than 1500 mg/L nitrate, greater than 30 mg/L	Vomiting, convulsions, death
Sulphate	greater than 1000–2000 mg/L	Diarrhoea
Aluminium	5 mg/L	Phosphorous deficiency
Arsenic	0.5 mg/L	Diarrhoea, anaemia, poor coordination
Copper	0.5 mg/L	Liver damage and jaundice, copper accumulation in the liver
Fluoride	greater than 2 mg/L	Tooth damage and bone lesions
Iron	Low toxicity	
Lead	0.1 mg/L	Respiratory diseases, anorexia, poor co-ordination
Molybdenum (related to copper)	0.15 mg/L	Scouring and loss of condition. Infertility, skeletal disorders, testicular damage.
pH	greater than 9 less than 5	Other mineral become available such as copper and aluminium
Total dissolved solids	Variable generally greater than 5000 mg/L	Poor production, diarrhoea, higher mortality rates

6.2 WATER TROUGH TYPES AND DESIGN REQUIREMENTS

Dairy cattle water troughs can be constructed from a range of materials including concrete, heavy duty plastic, polyethylene, stainless steel, galvanised steel, and fibreglass, all with lifespans over 10 years.

- Over time, the inside surface of concrete troughs may become more difficult to clean.
- Surfaces deteriorate due to hardness of the water, cattle saliva, enzymes in feed stuffs and general cleaning processes.
- Concrete surfaces can be protected by a fibreglass or polyethylene insert.
- An epoxy resin can also be used to coat the interior of the tank preferably when the trough is new, like the way concrete feed alleys are coated to eliminate deterioration.

Water trough volume and receival flow rates:

- At least 200 litre trough volume for receival flow rates of up to 10 litres per minute.
- At least 100 litre trough volume for receival flow rates of up to 20 litres per minute or greater.

Water trough spacing:

- At least 80–100mm of linear water trough space should be provided per cow in systems where cattle are contained for 24 hours per day.
- The upper edge of the trough should be located 610–810mm above the cow standing surface for mature Holstein cows and 530–740mm for Jerseys.
- Ensure a water depth of 150–200mm to maintain a cool water temperature and reduce debris accumulation.

Figure 8. Well designed tippable trough with reinforced protection around the float and ball valves

At least two troughs should be present per group of 15-20 cows to prevent dominant cows from monopolising a single water trough and allowing for 10-15 per cent of a herd drinking at the same time.

Troughs with closed external vertical walls to protect piping and fittings and that eliminate spilt feed and manure building up under the trough are recommended. These types of troughs enable any manure and spilt feed to be removed regularly and this reduces odour production and habitat for flies. Sturdy reinforced protection around the float and ball values is essential to prevent cows from damaging troughs if the inflow of water is slow (Figure 8).

Troughs should have drainage bungs or be tippable to enable complete and easy cleaning. Drained water should be directed towards the manure management system by dumping into the flushed alleys.

A further recommendation for troughs on non-concreted surfaces is installing a 3 metre concrete apron along or around the trough due to the heavy trafficking and regular damage caused by cows accessing water.

6.3 WATER TROUGH LOCATION

Locating and positioning water troughs throughout the dairy complex is just as important as an ample supply of quality water and requires careful consideration to minimise:

- Unnecessary congestion of cows around the feed alley and water troughs
- Restrictions and bottle necks in cow flow entering and leaving feeding areas
- Pugging and surface water pooling if located in low lying areas
- Contamination from overhanging trees and dust from nearby tracks.

Water troughs should be surrounded by plenty of passage space for cows to move freely, preferably on the outside of the traffic curve and be easily accessible for cleaning. Various studies indicate that during the summer months, 10 per cent of the herds total daily consumption is consumed at the dairy.

Preferred location on earthen and concreted feedpads:

- Place water troughs within about 15m of the feeding table, but not next to the feeding table to minimise feed spillage from cow mouths directly into water troughs.
- For earthen feedpads: on the downslope side of an earthen pad, so that water can drain directly into the site drainage.
- For concrete feedpads: to enable water from the trough to be drained or piped directly into the manure management system.

Preferred location in a freestall:

- At the crossovers to prevent feed contaminating the water and to reduce the incidence of cattle blocking each other in the alleys.

Preferred location at the dairy:

- On the exit side of the dairy shed. Locate in a wide passage, preferably on the outside of cow traffic curve.

Figure 9. Well positioned and guarded water trough – can be tipped into the cow alley

Water troughs can be readily contaminated with cud, manure, bird faeces, rodents, pesticides, dust, feed, bedding material, and microbes entering through water systems. These contaminants can provide a nutrient rich substrate for bacterial growth and survival at the bottom of a trough. Troughs management should include regular inspection and cleaning (at least weekly but more frequently if possible).

6.4 DETERMINING WATER REQUIREMENTS TO OPERATE THE FACILITY

Dry seasonal conditions invariably put stress on farm water supplies. Properties that have access to reliable groundwater are fortunate, whereas those using dams reliant on runoff will require more planning to ensure their water supplies are ample to meet demand.

A key step before constructing a dairy complex, is understanding the volumes of water beyond typical stock drinking water, that are required to operate the facility. Water is required for:

- The flushing and removal of effluent from cow alleys
- Supplying cooling systems such as sprinklers
- Servicing any automatic milking systems housed within the facility
- Cleaning manure build up around facility entry and exits points
- Cleaning manure from around troughs in raised crossover sections
- Pressure spraying mechanical stationary screens used in the solid separation process.

The amount of water required to operate cooling systems, remove manure, bedding material and flush cow alleys can be significant for various facilities depending on herd capacity and occupation times and should not be under-estimated.

These volumes are in addition to any water requirements to milking areas where they are separate from the housing system.

For example, concrete feedpads using flush systems have recorded consumption rates of more than 61,000 litres of water per cleaning cycle for a 500-cow herd.

In contained housing facilities, water volumes to flush cow alleys several times throughout the day has been recorded at more than 400,000 litres per day. Some facilities catering for much larger herds, (i.e. more than 3,000 cows) budget on a total water use of 780,000 litres per day.

From a site planning perspective there are critical decisions to be made. These include:

- Where will this water be sourced from and is it a reliable all year-round?
- How will this water be stored and delivered to the facility to match volume and peak demand?
- How will the quality of the water be monitored and maintained?
- How many times throughout the day should cow alleys be flushed?
- How will this water be captured and collected at the end of the facility?
- How will it be stored, reused or irrigated to fodder crops and pastures?
- What options are available to utilise recycled effluent from the effluent storage pond?

There are several factors, from a design perspective, which influence the overall water consumption required to operate these facilities and the frequency in which cleaning processes are used.

It is critical in the planning phase of the development to estimate expected water consumption.

Typically, water requirements for cow alleys will depend on the width and length of area being cleaned, the roughness co-efficient of the concrete and slope, with a recommended minimum depth of wave height of 50mm and a recommended velocity of 1 metre per second to adequately remove deposited manure or 1.5 metres per second for sand bedding deposited in the cow alley.

For example, a concrete alley of 5m width and length of 160m would require an estimated 24,400 litres per flush for cleaning at a 1% slope, compared to 14,300 litres per flush, should the slope be set at 2%.

Dry scraping prior to flushing can reduce the volume of water required for wash down.

A key starting point in understanding potential water consumption is commencing with the existing dairy complex and conducting a full water audit to determine if overall water use is compatible with industry water use data for a similar herd size and dairy type. Agriculture Victoria has collected and analysed this information, following over 1,500 dairy facilities water use audits throughout Australia, with clear strategies for water saving measures. Once the dairy complex consumption has been determined, available tools such as effluent design calculators can be used to estimate potential water use. Combining this information will not only assist with reviewing the manure system requirements, but also assist in identify options for recycling effluent to reduce freshwater consumption.

It is also important to consider evaporation rates from farm dams, particularly if used to supply the facility with freshwater, as volumes and supplies may be compromised during the summer months.

6.5 RECYCLED EFFLUENT

Recycling effluent from appropriately designed pond systems is a long-established practice within the Australian dairy industry and has successfully been applied in many situations to reduce freshwater usage when cleaning manure from dairy holding yards and alleys from within contained housing facilities.

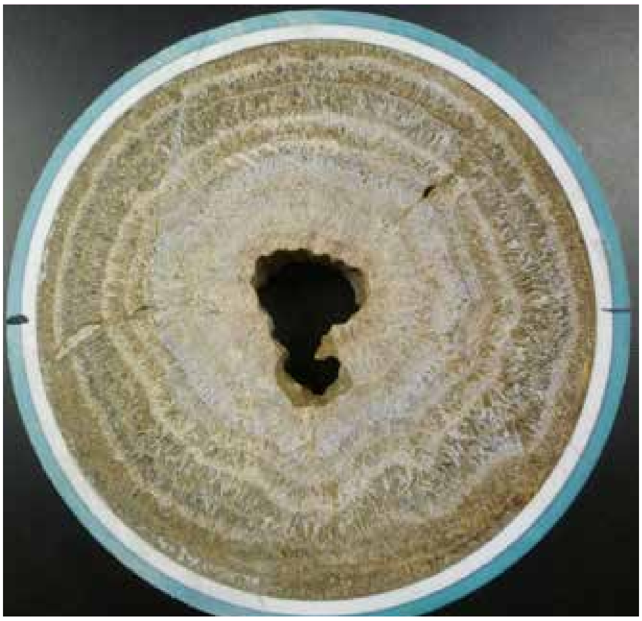
Recycled effluent is typically extracted from the final pond in multiple pond systems (or as a lesser option, larger single storage ponds) because at this stage effluent has undergone settling and some treatment, providing a better option for recycling for flushing or irrigation to land.

Even though recycling effluent has many benefits, it is important to monitor the effluent ponds to ensure quality doesn't deteriorate and impact the facilities. Irrigated farms may mix freshwater with recycled effluent during the summer months to improve the quality, prior to irrigating pastures or crops. Dairy farms will need to monitor the pond performance and quality of recycled effluent prior to reuse.

Farm indicators that recycled effluent has deteriorated in quality may include:

- Heavy crusting
- Slime deposits and growth on surfaces around the facilities impacting cow traction
- Increased odour emissions
- Struvite (salt crystallisation) build up in pumps and piping.

Figure 10. A pipe clogged by struvite (salt crystallisation) build up



Struvite management

The continuous use of recycled effluent without freshwater dilution can lead to the build-up of struvite; a crystalline build-up of magnesium ammonium phosphate resulting in blockages in piping and poor pump performance. Struvite accumulates where there is turbulence in the water flow particularly around valves, joins, bends, and in the pump (Figure 10).

Key management practices to reduce issues could include:

- Dilute the effluent to reduce the chances of salt accumulation.
- Ensure ponds are emptied each year.
- Check salt levels in the pond and try not to exceed 3,000–5,000 uS/cm. This can be difficult to achieve when groundwater is used for washing around the dairy complex.
- Have an irrigation technician check the system hydraulics to reduce turbulence ensuring pumps and pipes are compatible.
- Minimise suction lift by locating pumps near water level. Make sure suction pipes are large enough to prevent cavitation. Have gentle bends rather than sharp turns in pipes.
- Replace pipes and fittings. This may be easier than trying to dislodge the built-up crystals which need a hammer and chisel to break them off fittings.
- Dissolve crystals with acid cleaning solutions. A recirculating system is best, but care is needed if metal components are involved because the acid is corrosive.

Make sure any pump is well grounded to earth to ensure no stray voltage or electrostatic charges can contribute to crystal build-up.

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07

Manure management

INTRODUCTION

The Effluent and Manure Management Database for the Australian Dairy Industry is a repository of reliable and scientifically validated technical information on dairy manure management. It provides design and engineering criteria adaptable to all dairying regions in Australia.

Understanding how dairy manure can be contained, handled and managed then enables value to be extracted from reusing it on farm as a fertiliser or for renewable energy generation.

7.1 WHAT IS MANURE?

Manure is the faecal and urinary excretion of livestock. It may be mixed with bedding, spilled feed, water, soil and sediment, fibrous material as well as other components not associated with excreta such as dairy plant wash water, detergents, milk residue and hair.

Liquid manure is typically referred to as effluent. Effluent is produced by cleaning the dairy shed and holding yards with water. Effluent may also include stormwater, residual milk and chemicals from cleaning dairy plant and equipment. Effluent may be recycled (i.e. recycled effluent) and used for washing manure from areas such as holding yards, alleys and housing facilities, or applied to land.

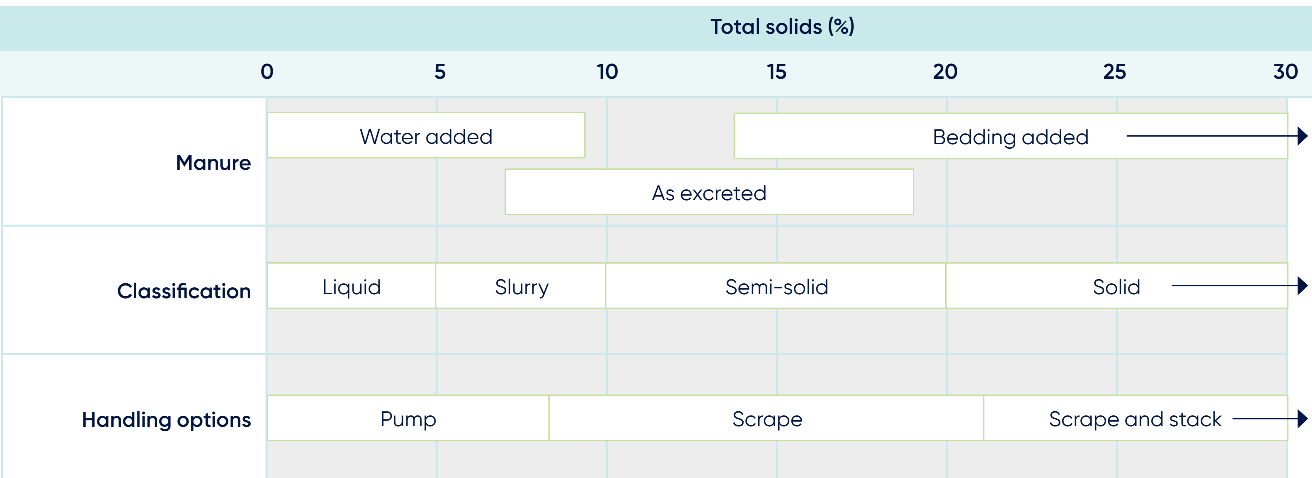
The manure stream can be classified in different ways depending on its solid and moisture content, which ultimately influences handling, storage, and application methods on farm (Figure 11). Manure guidelines often use a common terminology of Total Solids (TS) to classify manure such as:

- Liquid effluent (less than 5% TS)
- Slurry manure (5–10% TS)
- Semi-solid manure (10–20% TS)
- Solid manure (greater than 20% TS).

To simplify terminology throughout this chapter the generic term "manure" will be used as a representation of all forms covering liquid, slurry and solid materials. However, understanding the composition of the manure stream and the volumes generated will be important to ensure the most suitable manure system design, appropriate components and farm management is implemented to ensure manure is managed productively.

This is particularly important for any contained housing facilities such as freestalls or loose housing which utilise a range of bedding material such as sand or organic materials, as the extraction and recovery of this material from the manure stream requires specialised consideration. The overall volumes of manure generated from these facilities where cows spend a significant proportion of their time is considerably higher than for a grazing operation typically collecting manure just from the dairy shed, therefore requiring a greater focus on design and management.

Figure 11. Moisture content, manure classification and manure handling



Source: ***www.nrcs.usda.gov***

7.2 INDUSTRY GUIDELINES AND STANDARDS

Every state within Australia has established dairy guidelines or codes of practice, which clearly outline the expectations for the management of manure, closely aligned to the state Environment Protection Acts and any subsequent regulations.

Irrespective of the size of the dairy farm, the number of cows or type of feeding infrastructure used, the objectives for manure management at a farm are similar. In that:

- All manure generated from the dairy complex, underpasses and contained housing (point sources) must be contained, managed, and reused sustainably to aid production and mitigate risks.
- Manure must not enter surface waters such as streams, rivers, lakes, wetlands, reservoirs, and creeks, with each state having a clear definition of waterways.
- Manure must not enter groundwaters either directly or through infiltration from poorly constructed ponds via seepage.
- Manure must not contaminate land by the continuous discharge onto the same area of land causing a nutrient overload and higher risks of leaching and runoff to groundwater and surface waters.
- Regular offensive odours must not impact beyond property boundaries.

State based environmental legislation, which covers all sectors including residential, commercial, industrial, and agricultural, often classifies manure as a by-product or waste stream generated from livestock production.

Australian livestock industries will continue to focus on manure as a valuable nutrient resource, that if managed correctly not only mitigates environmental risks, but provides significant productivity benefits to farms through its agronomic application to fodder crops and pastures.

7.3 MANURE MANAGEMENT SYSTEMS AND COMPONENTS

The Australian Dairy Industry has been proactive over a long period in designing and developing manure management systems to manage both liquid and solid streams generated from farm point sources where cows congregate for longer periods, particularly the dairy shed, feedpad and contained housing facilities.

State based legislation does not provide prescriptive and technical information on how to design and construct manure management systems. It sets clear standards on expected outcomes for the protection of the environment and amenity. These expectations focus the dairy farm's attention to contain, manage and recycle manure into the farm's production.

It is the responsibility of the dairy farm owner, lessee and operators to identify the most appropriate manure management system and the relevant components of that system best suited to the farm's circumstances, locality, and overall management. Decision makers are strongly encouraged to source information from experienced system designers.

Removing and cleaning manure from feeding areas

Broadly there are three fundamental approaches to removing deposited manure from dairy sheds, feedpads and contained housing facilities:

1. Dry scraping is the most practical method when dealing with manure as a semi-solid or solid. It is commonly used on earthen feedpads utilising compacted earth, rubber matting, a geohex modular foundation or concreted aprons around feed troughs and modular hay rings. Occasionally farms with concrete feedpads during periods of lower use, will opt for a temporary dry scrape approach to conserve flushing water. It is important that scrapers use a "sacrificial edge" such as rubber that contacts with the surface to reduce damage and not compromise the feedpad foundations.

Scraping works well during the drier months of the year, when manure has an opportunity to air-dry, but is more problematic during the wetter months when manure tends to become a slurry, hence the requirement to consider slope and adequate drainage.

Typical equipment used for dry scraping includes rubber tyres (cut in half), front-end loader buckets, skid steer loaders, quad-bike mounted scrapers (Figure 12), tractor mounted blades or automated cow alley scrapers (more common in contained housing).

2. Vacuum tankers provide a more effective approach for slurry and semi-solid manure particularly for larger concrete feedpads as the manure can be collected and transported directly from the feedpad and applied to land, without the need for stockpiling and double handling.

Note that avoidance of double handling is only an option during those periods when the paddock is not too wet.

3. Flushing with fresh water or recycled effluent of concrete surfaces. Tanks may be located at the higher end of feedpads either mounted on the ground or raised on platforms to generate sufficient head. Alternatively, it is common for a buried pipe main and riser or hydrant systems to flush the manure down the alley using clean water or recycled effluent pumped directly from storage ponds (Figure 13).

The most effective volume and desired flow rate is dependent on several key factors such as: slope, width and length of area being cleaned, surface texture, amount of manure deposited and type of bedding material present. Freshly deposited manure will require more energy to break up and entrain the material in the slurry manure compared to hay and straw bedding. Removing sand requires more energy than any other bedding option. Any attempt to scrape, break up manure or pre-wet prior to cleaning will reduce the amount of energy and water required.

It is important to keep in mind, that this approach has the potential to use significant volumes of water, with a 500 cow feedpad having the potential to use 70,000 litres per day or 480,000 litres per day for a 1000 cow freestall, typically flushed a minimum of three times each day.

Feedpads are often cleaned during milking or while the herd is grazing, while contained housing, due to the higher occupation of herds, are sometimes cleaned with cattle present.

Figure 12. ATV mounted manure scraper

Figure 13. Buried main and riser

Liquid – solid separation components

There is a trend towards larger herds spending more hours contained for milking, feeding or loafing. This makes it increasingly important to focus on separating and removing larger particles and organic material.

The advantage being to:

- Reduce the rate of sludge accumulation and volatile solids loading on primary ponds, which reduces the pond footprint or the frequency of de-sludging
- Remove spilt feed and fibrous material to prevent blocking of conveyance pipes and pumps
- Collect and establish sufficient composted material to reuse as bedding material or as organic fertilisers easily applied around the farm
- Allow more conventional irrigation equipment to distribute recycled effluent from adequately sized single ponds.

Solid separation systems are broadly associated with two categories:

1. Gravity-separation components such as: trafficable solids traps (Figure 14), concrete basins, shallow sedimentation ditches and sand recovery lanes. During the cleaning process manure from feedpads, holding yards or contained housing facilities is conveyed to an appropriately sized structure that utilises weeping walls, weirs, sieves or other settling methods to allow solids to settle out of the manure stream.

These systems can consistently remove more solids and nutrients from liquid manure than mechanical methods when the TS content is low. It remains the preferred approach for many farms utilising feedpads washed on a regular basis. Earthen sedimentation basins – designed for ease of desludging, are a suitable option where the catchment area around a feedpad generates a significant volume of runoff during a rainfall event.

2. Mechanical separation devices such as: inclined or elevated stationary screens (Figure 15), vibrating or rotating screens, centrifugal decanters, roller press, belt press or screw press. Manure directed from cow alleys and holding areas is collected in large sumps and agitated to keep solids in suspension before being pumped to the mechanical device. Separated liquid is directed to the ponds, while the separated solids are deposited on a bunded stockpile area.

These systems are suited to larger contained housing facilities, which have more significant manure volumes to manage and rely on the need to capture and recover adequate bedding material for reuse.

Separation technologies can be supplemented by chemical treatment to improve separation efficiency. While chemical separation is rarely used on dairy farms in Australia, it is based on coagulants and flocculants used to treat municipal and industrial wastewater. The chemicals (including alum, ferric sulphate and ferric chloride, and polymers such as various polyacrylamides) cause sedimentation of particulate matter, resulting in the precipitation, usually of soluble P, and the flocculation and aggregation of suspended material. The result is liquid fractions with lower turbidity and greater clarity, and solids with a higher nutrient content. This technology is usually applied to wastewater with low TS.

Figure 14. Trafficable solids trap with offset sump

Figure 15. Mechanical stationary screen – screw press combination

Manure management systems and risk mitigation

Producers have two broad options when choosing an appropriate manure management system.

1. Direct application with buffer storage – manure is pumped directly from the collection point to pasture or crop, and a small sump or pond provides buffer storage.

This system is mainly used for small herds that operate low water use dairy sheds and minimal use of stock containment or feedpads. Direct application is generally less likely to suit feedpads or contained housing due to the larger volumes of manure being generated. Direct application systems do not cope with large catchment areas or large and regular rainfall events. For example, an earthen catchment area of $500m^2$ would be large enough to overwhelm a pump with a capacity of 10 litres per second during a 15mm, 10 minute storm event.

Contingency or buffer storage would need to be included in any direct application system to contain storm runoff, allow the dairy farm to avoid application during extremely wet conditions and allow time for equipment to be fixed or replace as a result of a breakdown.

This option is regarded as potentially high risk and would require stringent management and monitoring. Significant separation distances are likely to be required for this application method.

2. Deferred application - manure is stored in one or more ponds or tanks for a period before it is reused on pasture or crops.

- This option suits feedpads and contained housing as larger volumes of manure being generated make direct application hard to manage. It is important that deferred application systems have sufficient storage and are sized to manage the risk during the wettest year in ten.
- Retention of effluent in ponds or tanks results in reduced organic, nutrient and pathogen loads, thus producing a product more suitable for reuse than raw effluent. Ponds enable storage during the wetter months and allows for strategic use and application of nutrients.

Pond systems

Ponds have been successfully used in the Australian dairy industry for many decades to:

- Provide storage for effluent during the typical wetter periods of the year
- Reduce the nutrient and pathogen loadings
- Provide recycled effluent for cleaning cow alleys and holding yards
- Minimise blockages in conventional pumping and irrigation components
- Recover and recycle accumulating solids
- Provide an opportunity for biogas production.

Understanding the fundamental difference between the type of ponds is important due to the different design functions, potential configurations, and positioning within the overall manure management system as well as the expected management requirements. Australian dairy farms commonly use a range of ponds depending on the intention for solid deposition and/or storage. Single ponds are usually constructed for smaller herds seeking a storage option given the pond can become too large for effective solids management with larger herds. Dual or multiple ponds separate the functions of solid deposition and liquid storage and support more effective management of the system. Effluent quality from dual pond systems is substantially better than for single pond systems and so reuse can occur via a broader range of irrigation systems.

Ponds can be constructed either above or below ground depending on the site chosen and integrated management equipment. Pond dimensions are subject to specific farm variables including storage requirement, depth to groundwater and soil type.

Primary or solids ponds: designed to allow solids to drop out of suspension and be managed separately to the liquid fraction. Primary ponds operate with a fixed water level (via a transfer pipe fitted with a 'T' inlet for excluding floating solids) which allows for the higher quality liquid fraction to pass through to the effluent storage pond. Surface crusting is common.

Desludging must occur at regular intervals whereby settled solids are removed and land applied or alternatively, stockpiled and/or composted. If the system and equipment requirements allow, desludging on an annual basis supports more effective nutrient recovery.

Desludging must be completed well before the primary pond is full of sludge. That is, an absolute minimum of 600mm (preferably 1000mm or more) of liquid above the sludge level is required for solids deposition processes to occur. If the sludge layer reaches the level of the transfer pipe, significant transfer of solids into the effluent storage pond will have occur and effluent quality will deteriorate.

Anaerobic ponds are also designed as the primary pond in multiple pond systems, retaining the manure for processing, allowing the liquid component of the manure to transfer into a storage pond ready for land application or recycling to cow alley flush systems.

Effluent storage ponds: provide storage of effluent during those periods when land application would potentially result in runoff and loss of nutrients. The required volume is calculated on dairy complex water use, 90th percentile rainfall contributions (yard, roof, and pond surfaces) over those periods when land application is not possible based on local climatic data. All ponds should maintain a minimum 600mm freeboard to accommodate wave actions and provide bank stability. These ponds are commonly used when effluent storage over the wetter months of the year is the preference to allow a strategic application of nutrients to paddocks during the irrigation season or when pastures are actively growing. Typically, the final storage pond, if managed correctly, also provides the opportunity for recycling to cow alley flush systems.

The design and construction of ponds require professional knowledge, not only in the type of ponds, best suited to the situation and required capacity, but just as importantly the siting and construction phase which requires appropriate investigations.

The importance of pond management

Ponds are not designed to be managed with a "construct and forget" mentality. Pond maintenance and monitoring programs are critical to optimise performance, reduce failures and minimise unnecessary environmental risks.

Primary ponds are designed with a specified desludging frequency, which is the trigger point at which sludge or solids need to be removed. Failing to do so will compromise available capacity, performance and where applicable consent conditions. Monitoring sludge accumulation is vital to ensure pond performance is not compromised.

For effluent storage ponds to work effectively, they need to have sufficient storage capacity at the onset of the wetter months (retaining 0.3m to prevent liners and pond surfaces from cracking) so that all effluent generated from the various cow facilities can be contained.

In the event of extended wet periods and increased effluent and stormwater entering the pond, dairy system managers should seek to draw down the pond volume, to eliminate the risk of overtopping, by strategic application of low rates of effluent to areas of the farms that are less likely to cause environmental or amenity impacts.

Emergency disposal of milk

Even though suitably sized ponds can handle several milk dumps (in the event milk cannot be collected from farm), the practice is generally discouraged due to the potential to compromise microbial activity within the pond resulting in poor functioning, performance, and risks of odour.

Alternative approaches such as diluting milk with water (7-parts water to 1-part milk) and irrigated onto pasture with a 10–12mm application. Under no circumstances can milk enter waterways.

Strategic reuse of manure

The land application of manure and effluent should be strategically linked to the dairy farm's soil fertility targets, ongoing fertiliser applications and ability to specifically target less productive areas of the farm (Figure 16).

Figure 16. The final stage of the effluent system returning nutrients to enhance pasture and crop production

7.4 INTENSIFYING – IMPACT ON CURRENT MANURE AND FARM MANAGEMENT

It is common for existing ponds and manure management systems servicing the dairy shed to be significantly compromised when connecting additional manure streams from new feedpads or contained housing developments. Depending on the current system and opportunity for expansion or modification, it is usual to have to construct either a new or separate manure management system.

Planning a new or upgraded manure management system needs to consider collection, conveyance, solids separation, storage, application, monitoring and management.

Before undertaking any significant development on farm, it is important to understand the current capacity and performance of existing sumps, traps and ponds, along with the current volume of manure being generated from the dairy. The expected increase in manure volume due to farm developments can be estimated using industry data and will guide an upgrade of the system.

The amount of manure deposited in any location is often proportional to the time the cows spend on the area, with traditionally 10-15 per cent of the daily manure output occurring at the dairy shed. The inclusion of a feedpad or contained housing facility may increase the time cows spend contained to 8-12 hours per day, which significantly increases the volume of manure that needs to be managed.

Any increase in herd number should also be factored into each of these calculations.

Farm changes influencing manure management system design

The following dairy farm variables are significant considerations when it comes to designing manure management systems, hence the need to be mindful when incorporating feedpads and contained housing.

- **Rainfall contributions:** Large hard catchment areas such as roofing, cattle handling yards, concrete feedpads, manure drying pads and cow access laneways all have the potential to contribute stormwater into the manure stream. This rainfall input needs to be calculated as it will influence the required size of the storage pond.
- **Total water used at the facilities**: The water used to clean yards, concrete feedpads, cow alleys, dairy platforms, milking plant and equipment produces a large volume of manure that needs managing. This volume influences the size of the storage pond, hence the need to be water conscious and use recycled effluent where possible on yards and alleys. Water used in cow cooling systems generally does not coincide with winter storage periods and therefore are not typically included in the design criteria.
- **Cow occupation times on concrete:** The more time cows spend on concrete surfaces, the more manure being collected. Understanding the amount of manure being deposited is an important consideration which directly influences solid separation components and the primary pond in dual or multiple pond systems.
- **Cow production:** Production is a good indicator of the amount of manure generated with a direct link between dietary intake and manure production. Higher producing cows have larger dry matter intake and consequently excrete more manure than lower producing cows.
- **Cow flow and facility design:** This is often underestimated but plays an important part in the manure management system, with restricted flow and congestion of the herd causing stress which results in increased manure deposition at the facility.
- **Recycling effluent:** Recycling from the storage pond for yard and alley cleaning will reduce the overall water consumption, and capacity of the effluent storage ponds. Recycled effluent needs to be from sufficiently sized ponds (preferably in a dual or multiple pond system) to ensure an adequate quality.
- **Solid separation before ponds:** Solid separation components (traps, screens, screw presses, ditches) reduces the required footprint of the primary pond.

On average a cow will produce about 11 per cent of her body weight in manure. So, for a 500kg cow that is 55kg of manure every day.

7.5 ODOUR MITIGATION

While it is unrealistic to expect no odour from a dairy farm, it is the combination of appropriate siting, design and on-going management that reduces odour problems.

Odour emissions are generated during the incomplete anaerobic decomposition of organic matter in manure. Likely sources of odour around the dairy complex include ponds, solids separation systems, manure stockpiles, silage, commodity and feed preparation areas, feedpads, contained housing and loafing areas.

The following siting recommendations and management practices will reduce the frequency and intensity of odour production within containment areas, feedpads and contained housing facilities.

- Appropriate siting to provide a suitable separation distance to sensitive uses. Most complaints derive from poorly sited infrastructure and cows in pugged paddocks close to roadways.
- Odours can build up over 4–5 days particularly after rainfall events.
- If the manure stockpile is large or emitting odours, it may need to be windrowed and turned regularly until it dries enough to maintain aerobic conditions required for composting. However, such turning is likely to release significant odours and must be timed to avoid worsening the situation.
- Manure solids and sludge extracted from trap cleaning and pond desludging processes should be stored in appropriate locations to promote the drying and composting process if they cannot be spread immediately. Stockpiling and double handling may increase the risk of odour production. Once drying is complete, solids should be strategically applied to pasture and crops based on manure analysis results and known soil fertility.
- Placing a cover over the disturbed face of the silage bunker may be necessary where neighbours experience effects.
- Spoiled grain and silage can be a source of offensive odour, and spills should be removed promptly. Any feed accumulating behind feed bunks or around feedpads must be removed, as it can also discourage cows from accessing the area.
- Feed storage areas should be constructed so that feed is kept dry. Purchased feedstuff should be stored for a short time before use. Ideally, these feedstuffs should be stored on an impervious surface, in a covered area or shed.
- Attention to minor details such as cleaning under fences and around troughs to maintain drainage and removing accumulated manure or spilt feed.

For larger scale dairy farms maintaining an activity logbook is recommended to record critical management events such as:

- Pond desludging
- Manure and compost spreading
- Effluent irrigation
- Removal of stockpiled manure
- Dry scraping loafing areas or removal of bedding from contained facilities.

These activities should consider weather forecasts (i.e. rainfall, prevailing winds, humidity) to minimise neighbour complaints. A complaints log should be available to record any complaints and to action investigation and mitigation.

7.6 MANURE STOCKPILING AND COMPOSTING

Stockpiling and composting are not the same thing; a common misconception is that piling manure into a mound and letting it decompose is composting.

Composting requires a carefully managed process to control temperature (40-60 degrees), moisture (50-60 per cent), effective carbon:nitrogen ratio and aeration over an extended period. It involves adding straw, sawdust, or hay to manure to balance the carbon requirement and regular turning of the pile. Manure stockpiling should be short-term or temporary storage of manure, waiting for the right opportunity to spread on land.

The advantages of composting include:

- More biologically stable and does not generate noxious odours during land application and can be stored without being a nuisance or forming a water repellent crust.
- Does not provide a medium for the breeding of flies.
- Destruction of pathogens and common weed seeds during the process.
- More concentrated plant nutrients with removal of biodegradable carbon compounds reducing the manure volume.
- A more viable option for bedding material readily extracted from the manure stream, as opposed to alternatives such as sand, wood chips and straw.

Key considerations for siting and management of stockpiled manure and composted rows include:

- Machinery access, manure volume, access to carbon source, distance to neighbours and waterways and other sensitive uses.
- Locating on an area of impermeable ground such as a compacted earthen or concrete pad that will provide all weather trafficability for machinery.
- Diverting stormwater away from the area and transferring runoff from within the composting area to the manure management system.
- Ensuring the compost is analysed and regularly utilised for production purposes.

7.7 WARNING SIGNS AND CONTINGENCY PLANNING

The first indication that something has gone wrong with the manure management system should not be notification from a regulatory authority. Dairy producers should understand the warning signs that can flag an urgent need to address potential risks.

These may include:

- Reduced pond freeboard indicating risk of ponds overtopping.
- Heavy crusting and silting of primary pond indicating urgent need to de-sludge before blockage in piping or compromising the function of the secondary pond(s).
- Recycled effluent creating odour or slime deposits at the dairy indicating quality has deteriorated and requires freshwater injection and mixing of the pond.
- Soil analysis results from recently conducted soil testing indicating imbalances in nutrients.
- Structural integrity of ponds being compromised with erosion, cracking, wall breaches or damage following machinery use on or near the ponds.
- Regular pump failures leading to effluent conveyance issues and manure build-ups in solid separation components.
- Conveyance pipe blockages indicating damage, solid build-up, and presence of struvite (crystalised salts) restricting or preventing effluent conveyance to ponds or irrigation equipment.
- Effluent pond liner floats to surface indicating liner integrity compromised.
- Continuous cleaning of solid separation components and primary ponds indicating the effluent system may need upgrading following significant farm changes such as increased cows, longer time on concrete.
- Increased incidences of mastitis, higher bulk milk cell counts, milk fever, salmonella or grass tetany indicating the need to test paddocks and discuss with local vet.
- Increased presence of birds indicating large quantities of spilt and unmanaged feed.

Irrespective of the feeding infrastructure utilised on farm or manure management system in place, a regular maintenance program and contingency planning is critical as these two aspects of the farm have the potential to create impacts if left unchecked and not monitored regularly.

A contingency plan should enable procedures to be put in place immediately once issues arise, before the actual failure, to minimise impact to farm operations, community amenity and the environment. All farm staff members should be familiar with contingency plans and procedures.

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08

Feeding infrastructure to support grazing and intensive dairy production

OVERVIEW

The Australian dairy industry is historically recognised as predominantly grazing-based production system.

Producers have successfully adopted an extensive range of innovative feeding and containment solutions from temporary and basic feed-out areas to more complex integrated housing facilities. The fundamental aim being to feed, shelter and sustain production during periods of adverse weather, seasonal variability and emergency events. This minimised production losses, animal health issues and protected paddocks from pugging and damage to laneways.

In most recent years, the dairy industry has seen an increase in cattle shelters. These shelters have been used for extended loafing to combat months of the year, which routinely impact production i.e. wet winters or hot summers. Some producers are selecting more contained housing options when undertaking complex decision making to change their farming system away from grazing to more intensive, zero grazing contained housing systems such as freestalls, loose housing and dairy dry lots. These contained housing facilities provide improved management flexibility for livestock and improve opportunities to explore technologies and significantly mitigate farming risks.

A fundamental step when contemplating farm developments, particularly with contained housing and feeding infrastructure, is determining if the changes to the farm will alter land use with each state having different planning requirements depending on whether the infrastructure supports grazing animal production or changes to intensive animal production.

Grazing animal production applies to farms where grazing is a key component of the farming system.

Grazing Animal Production is land used for animal production where the animals' food is obtained by directly grazing, browsing or foraging plants growing on the land. It includes:

- emergency, seasonal and supplementary feeding
- the incidental penning, feeding and housing of animals for weaning or other husbandry purposes.

In this definition:

- **emergency feeding** means providing feed to animals when an emergency event such as a flood, bushfire or biosecurity event restricts or prevents the animals from grazing, browsing or foraging plants growing on the land;
- **seasonal feeding** means providing feed to animals when seasonal conditions, including drought, restrict or prevent the animals from grazing, browsing or foraging plants growing on the land;
- **supplementary feeding** means providing feed to animals to supplement the food the animals obtain by directly grazing, browsing or foraging plants growing on the land.

Dairy (pasture-based) means a dairy that is conducted on a commercial basis where the only restriction facilities present are milking sheds and holding yards and where cattle are constrained for no more than 10 hours in any 24-hour period (excluding during any period of drought or similar emergency relief).

If there is little intention for the animals to meaningfully obtain food by directly grazing/browsing/foraging (e.g. eating grass growing in the paddock), then the use would likely be Intensive Animal Production.

Intensive Animal Production is land used for animal production where the animals' food is imported from outside the immediate building, enclosure, paddock or pen. The provision or availability of nominal, incidental or minimal grazing is not sufficient for a farm to be considered grazing animal production.

Dairy (restricted) means a dairy that is conducted on a commercial basis where restriction facilities (in addition to milking sheds and holding yards) are present and where cattle have access to grazing for less than 10 hours in any 24-hour period (excluding during any period of drought or similar emergency relief). It may comprise the whole or part of a restriction facility.

Throughout Australia the development of contained housing facilities (i.e. dairy dry lot, loose housing or freestalls) should be considered intensive animal production as these facilities are designed to house animals 24 hours per day supported by a total mixed ration diet (i.e. zero grazing).

Understanding the difference between grazing production and intensive production is critical from a statutory planning perspective as restrictions and consent will apply with changes in land use and the documentation required to support the proposal will be different.

8.1 FEED DELIVERY INFRASTRUCTURE

A diverse range of alternative feed delivery methods and feeding and housing infrastructure are used on Australian dairy farms. Determining the most appropriate feed delivery infrastructure depending on whether the farm is seeking a temporary short-term solution, or a more permanent frequently used solution requires careful planning and longer-term thinking. This is a personal choice that producers should not need to justify or defend to others, as the decision will be influenced by many factors including:

- Farm's natural resources: land area, topography, soil type and climate
- Stocking rate and calving patterns
- Type and range of supplements being fed
- Frequency of use for the infrastructure throughout the day and over the year
- Milk supply company and pricing system
- Labour constraints and employment preferences
- Life stage and/or business cycle stage
- Longer term vision for the property and stages of development.

Fundamentally in the Australian Dairy Industry, there are five main types of feed delivery infrastructure. Infrastructure 1 to 4 are typically used for partial mixed ration feeding to support farms focused on grazing and infrastructure 5 (contained housing) are typically used in intensive operations supported by total mixed ration feeding and zero grazing.

1 Temporary feed-out area
2 Basic feed-out area
3 Formed earthen feedpad
4 Concrete feedpad (may have shelter i.e. roofed feedpad or cattle shelter)
5 Contained housing facility (freestall, loose housing or dairy dry lot)

The rationale for these five types of feed delivery infrastructure follows:

- A classification system should be based on a facility's design and its pattern of use. It is de-coupled from the type of ration fed.
- A classification system is best limited to five main types of feed delivery infrastructure as more would be difficult for producers and advisers to grasp.

A detailed description of each type of delivery infrastructure is presented in Table 3.

Table 3. Five main types of feed delivery infrastructure

Type	Description	Concerns	Typical patterns of use
1. Temporary feed-out area	• Area located in a pastured paddock, sacrifice paddock or along a laneway • No prepared surface • Feed on ground, in hay rings or tractor tyres • Can be readily relocated to other sites on the farm • Very basic feed storage facilities and machinery • Use front-end loader (FEL) or silage cart • Capital cost for feed-out facility: Low cost per cow	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade not available • Difficulty accessing area with tractor if wet conditions and poor drainage • Pugging • Very high feed wastage • Manure build-up if over-used • Nutrient runoff • Odour, flies	• Feed out hay/silage before/ after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Hold, feed, and water cows between am and pm milkings on very hot days if tree shade is plentiful • Hold, feed, and water cows during emergency event such as bushfire or flood • *If use for 3-4 hours/day: require >3.5 m²/cow* • *If use for 8-12 hours/day: require >6 m²/cow* • *If use for 24 hours/day: require >10 m²/cow*
2. Basic feed-out area	• Contains an area with a compacted surface shared by cows and vehicles which may be able to be scraped • Can be relocated to another site on the farm (with effort) if necessary • Low-cost modular concrete troughs or conveyor belting under cable or hot wire +/- loafing areas • Very basic feed storage +/- mixing facilities and machinery, effluent system • Use silage cart or mixer wagon • Capital cost for feed-out facility: Low cost per cow	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade not available • Pugging of loafing area • High feed wastage • Manure build-up/stockpiles contaminated with rubble, making it difficult to spread on paddocks • Nutrient runoff • Odour, flies	• Feed out hay/silage before/ after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Hold, feed, and water cows between am and pm milkings on very hot days if tree shade is plentiful • Hold, feed, and water cows during emergency event such as bushfire or flood • *If use for 3-4 hours/day: require >3.5 m²/cow* • *If use for 8-12 hours/day: require >6 m²/cow* • *If use for 24 hours/day: require >10 m²/cow*
3. Formed earthen feedpad	• Formed earthen pad with a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall under cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures • Basic to more developed feed storage and mixing facilities and machinery, effluent system • Use mixer wagon • Capital cost for feed-out facility: Moderate cost per cow	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade not available • Pugging of loafing area • Moderate feed wastage • Manure build-up/stockpiles contaminated with rubble, making it difficult to spread on paddocks	• Feed out hay/silage before/ after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Practice 'on-off grazing' of day paddock to protect pastures from pugging damage during prolonged wet weather • Hold, feed, and water cows between am and pm milkings on very hot days • Cool cows on hot days if feedpad is fitted with shade structures and/or sprinklers over feeding table fitted with concrete apron • *If use for 3-4 hours/day: require >3.5 m²/cow* • *If use for 8-12 hours/day: require >6 m²/cow* • *If use for 24 hours/day: require >10 m²/cow*

Type	Description	Concerns	Typical patterns of use
4. Concrete feedpad, Roofed feedpad and Cattle shelters	• Concrete areas for cows and feed (usually separated) which can be scraped, or flood washed • +/- loafing areas, shade structures, sprinklers and fans for cow cooling • Well-developed feed storage and mixing facilities and machinery, effluent system • Usually use mixer wagon • Capital cost for feed-out facility: High • When combined with shade structures over large loafing areas, may use facility to hold, feed and water cows for extended periods when there is no standing pasture e.g. summer	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade +/- evaporative cooling not available • Pugging of loafing area • Low-moderate feed wastage • Manure build-up/stockpiles contaminated with rubble, making it difficult to spread on paddocks	• Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Practice 'on-off grazing' of day paddock to protect pastures from pugging damage during prolonged wet weather • Hold, feed, and water cows between am and pm milkings on very hot days • Cool cows on hot days if feedpad is fitted with shade structures and/or sprinklers over feeding table fitted with concrete apron • *If use for 3-4 hours/day: require >3.5 m^2/cow* • *If use for 8-12 hours/day: require >6 m^2/cow* • *If use for 24 hours/day: require >10 m^2/cow*
5. Contained Housing Dairy dry lot Loose housing Freestall	• Many fixed structures including shade structures • Well-developed feed storage and mixing facilities and machinery, effluent system +/- sprinklers and fans for cow cooling • Use mixer wagon • Capital cost for feed-out facility: - Freestall: Very high - Loose housing facility: Very high cost per cow - Dairy dry lot: Moderate cost per cow	**Dairy dry lot:** • Cow comfort • Risk of heat stress if shade or cooling systems are not adequate • Weather variability and wet conditions **Loose housing** • Cow comfort • Risk of heat stress if ventilation and cooling systems not adequate • Ability of cows to move around barn and access feed and water **Freestall:** • Cow comfort • Risk of heat stress if ventilation and cooling systems not adequate • Ability of cows to move around barn and access feed and water	**Freestall or Loose housing or Dairy dry lots:** • Hold, feed, and water cows permanently with zero grazing

8.2 THE FIVE TYPES OF FEED DELIVERY INFRASTRUCTURE

1. TEMPORARY FEED-OUT AREA

Description

Area located in a pastured or bare cropping paddock, a designated sacrifice paddock or along a laneway without a prepared surface where feed is delivered to cows either on the ground, in hay rings or in tractor tyres. Can be readily relocated to other sites on the farm.

Generic types

Grazing or cropping paddock, sacrifice paddock, laneway

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage pasture residual mass on each rotation (prevent over-grazing)

Characteristics

Frequency of use	Before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited or during an emergency event (i.e. fire/flood)
Typical hours per day	3-4 hours per day
Surface	Pasture, bare earth, or roadway
Feeding table	On the ground, in hay rings or tractor tyres
Loafing areas	Nil
Shade/cooling	Nearby trees if available
Effluent management	Dry scraping manure and stockpiling
Feed prep. and delivery	Front-end loader, side winder round bale feeder, silage cart or mixer wagon
Feed storage	Silage pits/bunkers and hay sheds +/- commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up	✓				
Weather durability		✓			
Permanency		✓			
Capital cost	✓				
Feed wastage					✓
Potential production benefits	✓				
Improved farm efficiencies		✓			

Costs

Capital cost: Very low/cow (not including silage cart, mixer wagon and feed storage and mixing facilities)

Operating costs: Very low

Lifespan

Depends on how firm the area's surface is and how quickly it deteriorates with use by cow and vehicles in dry and particularly wet conditions.

Examples of temporary feed-out areas

Hay/silage fed out under wire along a laneway and along an irrigation check bank

Hay fed out in rings in sacrifice paddock. Note high level of wastage

Old tractor tyres cut in half and used as feeders on a sacrifice paddock

Hay fed out in a line on a grazing paddock

Skill level/training required to operate

- Low if feeding out forage mixes with a silage cart
- Need to ensure silage or hay is placed correctly on the feed-out area and not wasted
- Moderate if preparing and feeding out a mixed ration

Wastage after feeding out lucerne and cereal hay on this grazing paddock was measured at 18%

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Temporary feed-out area may be used to deliver hay, silage or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milking instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feed-out area immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, and the feed-out area provides plentiful tree shade, then its use may help to reduce heat stress on cows in hot weather, resulting in more milk.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• A sacrifice paddock may be used to some extent to reduce pugging damage in grazing paddocks in wet conditions. However, feed wastage will be high, and the area may become unusable in a short period of time, requiring another site on the farm to be set up as a temporary feed-out area.

Limitations/concerns

Limitation	Comment
Maintenance	• Very difficult to maintain feed-out area as it does not have a prepared, well drained surface and effluent cannot be captured. It will therefore need relocating regularly to maintain an adequate level of hygiene for cows.
Feed wastage	• Feed wastage is high (5–25% on a grazing paddock under dry conditions, 5–35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line). • Feed refusals cannot be collected and fed to other cattle. They are wasted. • Feed wastage can be very high in wet conditions.
Cow health risks	• Environmental mastitis and lameness if feed-out area deteriorates. • Increased spread of disease if cows spend time in a confined area.
Environment issues	• Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feed-out area in which cows and vehicles share the same area is never ideal. • In wet weather, the area may become slippery for cows and vehicles.

2. BASIC FEED-OUT AREA

Description

Contains an area with a permanent compacted earthen feeding infrastructure shared by cows and vehicles which may be able to be dry scraped. Can be relocated to another site on the farm (with effort) if necessary.

Generic types

Compacted earthen feed-out area +/- loafing areas

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather

Characteristics

Frequency of use	Before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited or during an emergency event (i.e. fire/flood)
Typical hours per day	3-4 hours per day
Surface	Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel, with or without geosynthetic sheets
Feeding table	Low-cost, modular concrete troughs or conveyor belting under cable or hot wire
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Nearby trees if available
Effluent management	Dry scraping off feedpad regularly, may require site drainage to control nutrient runoff
Feed prep. and delivery	Front-end loader, side winder round bale feeder, silage cart or mixer wagon
Feed storage	Silage pits/bunkers and hay sheds +/- commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up		✓			
Weather durability			✓		
Permanency			✓		
Capital cost		✓			
Feed wastage				✓	
Potential production benefits		✓			
Improved farm efficiencies		✓			

Examples of basic feed-out areas

Large square hay bales fed out with front-end loader into low-cost troughs with steel frame and conveyor belting

Silage fed out with silage cart into low-cost troughs ('Waste-Not Fair Go Dairy Feedpad' panels)

PMR fed out with mixer wagon into very low-cost troughs made of conveyor belting with/without timber sides

PMR fed out with mixer wagon into 2 types of modular concrete troughs (3-sided profile and 'J' profile). On trough with J profile, note strip of timber added to low side

Costs

Capital cost: Low/cow (not including silage cart, mixer wagon and feed storage and mixing facilities)

Operating costs: Low (may be increased if manure needs to be stockpiled and spread)

Lifespan

Depends on how well the area's compacted surface (rock or clay) stands up to use. Surfaces of suitable rock base material or clay compacted with a heavy roller and water may last up to 20 years. Poorly prepared areas may only last a few years before requiring re-surfacing. Lifespan depends on:

- How well the area was formed with drainage and the surface compacted when first set up, and
- How intensely the area is used by cows (number x time) and vehicles in dry and particularly wet conditions.

Skill level/training required to operate

- Low if feeding out forage mixes with a silage cart
- Need to ensure silage or hay is placed correctly on the feed-out area and not wasted
- Moderate if preparing and feeding out a mixed ration

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Basic feed-out area may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feed-out area immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, and the feed-out area provides plentiful tree shade, then its use may help to reduce heat stress on cows in hot weather, resulting in more milk.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out may be reduced by up to 15% when conserved forages and mixed rations are fed out on a basic feed-out area rather than in a sacrifice paddock, on bare ground, in hay rings or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to 15%. • A basic feed-out area may be used to some extent to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.

Limitations/concerns

Limitation	Comment
Maintenance	• Repairs may be required if surface or feeding table is damaged by cows or vehicles. • Feed-out area's surface may be difficult to regularly dry scrape. • Feed troughs are generally difficult to clean. Spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. Troughs may hold water during rain events.
Feed wastage	• Feed wastage is moderate to high (5–20% under dry conditions). • Feed refusals cannot be collected and fed to other cattle. They are wasted. • Feed wastage can be very high in wet conditions. • Wastage will be increased if troughs used and their height and width are not compatible with front end loader, feed cart or mixer wagon used.
Cow health risks	• Environmental mastitis and lameness if feed-out area deteriorates because it is not well prepared and/or regularly scraped. • Increased spread of disease as cows spend time in a confined area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environment issues	• If gravel is scraped up with manure, it is unsuitable for spreading on pastures, leading to manure build-up/stockpiles. • Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

3. FORMED EARTHEN FEEDPAD

Description

Formed earthen pad with a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall under cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures.

Generic types

Compacted earthen feedpad +/- loafing areas +/- shade structures

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather

Characteristics

Frequency of use	Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited. Practice 'on-off grazing' of day paddocks to protect pastures from pugging damage during prolonged wet weather. Cool cows on hot days if feedpad fitted with shade structures and/or sprinklers
Typical hours per day	3-4 hours per day
Surface	Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel, with or without geosynthetic sheets
Feeding table	Purpose-built concrete troughs or nib wall. Feed barrier usually hot wire or cables, but may be post and rail +/- narrow cement strip for cows to stand on while eating
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Shade cloth or solid roofed structures possible over feeding table and/or loafing areas
Effluent management	Dry scraping off feedpad regularly. Basic to well-developed effluent system
Feed prep. and delivery	Usually a mixer wagon, but may be a side winder round bale feeder or silage cart
Feed storage	Basic to well-developed storage and mixing facilities including silage pits/bunkers, hay sheds +/- commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up			✓		
Weather durability			✓		
Permanency				✓	
Capital cost			✓		
Feed wastage			✓		
Potential production benefits			✓		
Improved farm efficiencies			✓		

Costs

Capital cost: Moderate/cow (not including silage cart, mixer wagon and feed storage and mixing facilities)

Operating costs: Low-moderate (may be increased if manure needs to be stockpiled and spread)

Lifespan

Depends on how well the feedpad's compacted surface (rock or clay) and fixed structures stand up to use. Surfaces of suitable rock base material or clay compacted with a heavy roller and water may last up to 20 years. Poorly prepared areas may only last a few years before requiring re-surfacing. Lifespan depends on:

- How well the area was formed with drainage and the surface compacted when first set up, and
- How intensely the area is used by cows (number x time) and vehicles in dry and particularly wet conditions.

Examples of formed earthen feedpad

PMR fed out in two reversed J troughs on an earthen feedpad

Narrow square-profiled trough being overfilled by mixer wagon, resulting in excess

Wider square-profiled trough on earthen pad under solid roof

PMR fed out in one trough on earthen pad. Note vertical bars defining each cow space and frame for shade cloth yet to be installed above feeding table

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Low if feeding out forage mixes
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Permanent feedpad may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feedpad immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ litres milk/day in hot weather.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 2-10% when conserved forages and mixed rations are fed out. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • A feedpad may be used to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.

Limitations/concerns

Limitation	Comment
Maintenance	• Feedpad surface needs to be regularly dry scraped. • Feed troughs may be difficult to clean. If so, spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. Troughs may hold water during rain events.
Feed wastage	• Feed wastage is moderate (2–10% under dry conditions. Higher under wet conditions). • Feed refusals should be able to be collected and fed to other cattle. • Wastage will be increased if trough height and width is not compatible with FEL, feed cart or mixer wagon used. Other factors related to feedpad design and construction, feed ingredients/rations offered and feeding management may influence % feed wasted.
Cow health risks	• Environmental mastitis and lameness if feedpad is not well designed, constructed and regularly scraped. • Increased spread of disease as cows spend time in a confined area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environment issues	• If gravel is scraped up with manure, it is unsuitable for spreading on pastures. • Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

4. CONCRETE FEEDPAD

Description

Concrete areas for cows and feed (usually separated) which can be scraped, or flood washed +/- earthen surfaced loafing areas, shade structures, sprinklers, and fans for cow cooling.

Generic types

Concrete feedpad +/- earthen surfaced loafing areas +/- shade structures

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather

Characteristics

Frequency of use	Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited. Practice 'on-off grazing' of day paddocks to protect pastures from pugging damage during prolonged wet weather. Cool cows on hot days if feedpad fitted with shade structures and/or sprinklers
Typical hours per day	3-4 hours per day
Surface	Concrete for cows and vehicles. Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel for loafing areas
Feeding table	Purpose-built concrete troughs or nib wall. Feed barrier may be cables, post and rail or headlocks
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Shade cloth or solid roofed structures possible over feeding table and/or loafing areas +/- sprinklers and fans
Effluent management	Dry scraping off feedpad regularly, may require site drainage to control nutrient runoff
Feed prep. and delivery	Usually a mixer wagon
Feed storage	Well-developed storage and mixing facilities including silage pits/bunkers, hay sheds and commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability				✓	
Permanency				✓	
Capital cost				✓	
Feed wastage		✓			
Potential production benefits				✓	
Improved farm efficiencies				✓	

Costs

Capital cost: High/cow (not including silage cart, mixer wagon and feed storage and mixing facilities)

Operating costs: Moderate (may be increased if manure needs to be stockpiled and spread)

Lifespan

If fully concreted, more than 30 years. Depends on how well the facility was designed and constructed.

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted
- Need to push feed up regularly if nib wall

Examples of concrete feedpad

PMR fed out on fully concreted feedpad with nib wall, central feed alley

Cows beginning to push PMR out of reach

Concrete bunkers for storing by-products

Fully concreted feedpad with nib wall, central feed alley, solid roof and flood wash system

Alternative feed barriers: Cables, post and rail, headlocks

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Permanent feedpad may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feedpad immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ L milk/day in hot weather.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 0-5% when conserved forages and mixed rations are fed out. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • A feedpad may be used to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.

Limitations/concerns

Limitation	Comment
Maintenance	• Feedpad surface needs to be regularly dry scraped or flood washed. • Some feed troughs may be difficult to clean. If so, spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. Troughs may hold water during rain events.
Feed wastage	• Feed wastage is low (0-5% under dry conditions. Higher under wet conditions). • Feed refusals should be able to be collected and fed to other cattle. • Wastage will be increased if a trough with height and width is not compatible with mixer wagon used. Other factors related to feedpad design and construction, feed ingredients/rations offered and feeding management may influence % feed wasted.
Cow health risks	• Environmental mastitis and lameness if feedpad is not well designed, constructed and regularly scraped or flood washed. • Increased spread of disease as cows spend time in a confined area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environment issues	• Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

4. ROOFED FEEDPAD

Description

Concrete areas for cows and feed (usually separated) which can be scraped or flood washed, with solid-roofed or shade sail structures over feeding table and/or loafing areas +/- sprinklers and fans for cow cooling.

Generic types

Fully concreted feedpad with a solid, corrugated iron roof. Typically a widespan structure comprising a pitched roof with a central, open ridge vent in the roof apex to let heat and humidity escape. Alternatively, a flat, angled roof.

Fully concreted feedpad with a series of steel poles holding large shade sails under tension.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Minimise heat stress
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited. Practice 'on-off grazing' of day paddocks to protect pastures from pugging damage during prolonged wet weather. Cool cows on hot days
Typical hours per day	3-4 hours per day. Longer on hot days if earthen surfaced loafing areas provided nearby
Surface	Concrete for cows and vehicles. Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel for loafing areas
Feeding table	Purpose-built concrete troughs or nib wall. Feed barrier may be cables, post and rail or headlocks
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Solid-roofed or shade sail structures over feeding table and/or loafing areas +/- sprinklers and fans
Effluent management	Dry scraping off feedpad regularly, may require site drainage to control nutrient runoff
Feed prep. and delivery	Usually a mixer wagon
Feed storage	Well-developed storage and mixing facilities including silage pits/bunkers, hay sheds and commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability				✓	
Permanency				✓	
Capital cost				✓	
Feed wastage		✓			
Potential production benefits				✓	
Improved farm efficiencies				✓	

Costs

Capital cost: High/cow (not including silage cart, mixer wagon and feed storage and mixing facilities)

Operating costs: Moderate (may be increased if manure needs to be stockpiled and spread)

Lifespan

Fully concreted feedpad: more than 30 years.

Solid-roofed shade structure: more than 25 years. Shade cloth shade structure, more than 10 years. Depends on how well the facility was designed and constructed.

Examples of roofed feedpads

Concrete roofed feedpad with multiple rows of feed troughs

Concreted overlapping roofed feedpad

Concrete roofed feedpad with extended eaves for cattle loafing

Concrete roofed feedpad with dry scrape feed alleys

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted
- Need to push feed up regularly if nib wall

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Permanent feedpad may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the roofed feedpad is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking and minimize heat stress. • If cows are fed a high level of concentrates in the bail at milking, using the feedpad immediately before or after milking may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ L milk/day in hot weather. • If solid-roofed shade structure is installed, key considerations for maximum effectiveness and useful life are: roofing material (aluminium or white galvanised steel increase solar reflection), roof height and pitch, ridge opening, eave overhang, guttering and downpipe design, and orientation (east-west works best for concrete floors). • If shade cloth shade structure is installed, key considerations for maximum effectiveness and useful life are: fabric material (green or black coloured material of minimum 300 grams per square metre is preferred), height, orientation, support posts and foundations, fastening of fabric to posts.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 0-5% when conserved forages and mixed rations are fed out. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • A feedpad may be used to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.
Public acceptance	• If designed and managed well, roofed feedpads will improve cow comfort and may be viewed positively as an addition to grazing-based dairy farm systems.

Limitations/concerns

Limitation	Comment
Maintenance	• Feedpad surface needs to be regularly dry scraped or flood washed. • Some feed troughs may be difficult to clean. If so, spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. • Shade cloth shade structure.
Feed wastage	• Feed wastage is low (0-5% under dry conditions. Higher under wet conditions). • Feed refusals should be able to be collected and fed to other cattle. • Wastage will be increased if a trough with height and width is not compatible with mixer wagon used. Other factors related to feedpad design and construction, feed ingredients/rations offered and feeding management may influence % feed wasted.
Cow health issues	• Environmental mastitis and lameness if feedpad is not well designed, constructed and regularly scraped or flood washed. • Increased spread of disease as cows spend time in a confined area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environmental issues	• Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

4. CATTLE SHELTER

Description

A permanent, engineered roofed structure, with or without walls, under which some or all cows in a milking herd, or dry cows or young stock can loaf and rest comfortably on loose bedding material. The shelter's roof may be solid, corrugated iron, a white or clear, plastic film, or a set of shade sails. Feed and water may be offered to animals inside the shelter, either in troughs, along nib walls either side of a drive-through central feed alley, or in troughs along the perimeters of the shelter. Alternatively, feed and water may be offered to animals on a new or existing feedpad located adjacent to the shelter. Cows are not confined in the shelter – they are free to move outside to access the feedpad (if present) or to return to paddocks. The shelters are suited to grazing farms in regions where wet, cold, windy winter conditions may stress cows and lead to mastitis and damage to paddocks and laneways, and where summer heat impacts milk production and cow welfare. On hot days, the shelter with its feeding and watering infrastructure may only be used by cows in the hours between am and pm milkings. However, in harsh winter weather it may be used 24 hours per day for up to 2-3 weeks.

Generic types

Engineered steel-framed structure comprising interconnecting, multiple spans, clad with a tensioned clear or white fabric (polypropylene, polyethylene or polyvinylchloride of varying thickness). May be referred to as an 'eco-shelter'.

Engineered steel-framed structure with a corrugated iron roof. Typically a widespan structure comprising a pitched roof with a central, open ridge vent in the roof apex to let heat and humidity escape. Alternatively, a flat, angled roof.

Engineered structure comprising a series of steel poles holding large shade sails under tension.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Provide cow comfort and reduce heat stress and cold stress
- Support supplementary feeding with a PMR or TMR
- Increase herd feed intake and milk production without increasing farm size
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Practice 'on-off grazing' of day paddocks to protect pastures and laneways from damage during prolonged wet weather. Cool cows on hot days if feedpad fitted with shade structures and/or sprinklers. Loaf and feed cows for extended periods (e.g. 1-2 weeks) during wet, cold winter conditions or during hot periods when little/no pasture available
Typical hours per day	System dependent, multiple hours up to 24 hours per day at times of the year
Surface	Deep litter (e.g. woodchips) on a compacted clay base
Feeding table	Purpose-built concrete troughs or nib walls installed along centre or perimeter of shelter or located in area adjacent to it. Feed barrier may be cables, post and rail or headlocks
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Cattle shelters may be fitted with manually or automatically controlled overhead shade screens, roof vents, fans, misters and roll-up wall blinds as optional extras Steel-framed structures with solid roof may be fitted with fans and misters
Effluent management	Removal of bedding material at regular intervals (may be spread on pastures, reducing fertiliser costs) Dry scraping or flood washing of feed alley (if fitted) at regular intervals
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up			✓	✓	
Weather durability			✓	✓	
Permanency			✓	✓	
Capital cost			✓	✓	
Feed wastage		✓			
Potential production benefits				✓	
Improved farm efficiencies				✓	

Costs

Capital cost: Moderate-high/cow (not including feeding and watering infrastructure inside or adjacent to shelter, silage cart, mixer wagon and feed storage and mixing facilities)

Operating costs: Moderate (may be increased if manure needs to be stockpiled and spread)

Lifespan

Ecoshelter: steel frame, more than 25 years, clear or white fabric cladding, more than 10 years. Solid-roofed structure: more than 25 years. Shade sail structure: more than 10 years. Depends on how well the facility was designed and constructed and prevailing weather conditions.

Examples of cattle shelters

Woodchips and manure bedding with external troughs for feeding

Stand alone cattle shelter with spouting and downpipes to remove rainfall

Woodchips and manure bedding in an eco-shelter

Straw bedding to accommodate the herd during wet winters to minimise pugging

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted
- Need to push feed up regularly if nib wall
- Need to manage bedding and top up / replace regularly

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Cows in shelter expend minimal energy walking. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ L milk/day in hot weather.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 0-5% when conserved forages and mixed rations are fed out in purpose-built troughs. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • Shelters may be used to manage paddock rotations • Shelters may be used in wet conditions to reduce pugging damage by cows in grazing paddocks, thereby improving pasture growth rates and annual pasture utilisation, and reducing pasture renovation costs.
Improved cow comfort and welfare	If well designed and managed, a cattle shelter provides cows with: • unlimited access to feed and drinking water. • freedom to lie down and rest, eat and move around and socialise each day. • close monitoring and assessment for production and health. • shade +/- evaporative cooling, so they are protected from heat stress. • protection from adverse weather events, muddy walking tracks and paddocks etc. • a comfortable environment during the transition period.
Public acceptance	Dairy shelters are relatively new to the Australian dairy landscape – if designed and managed well they will improve cow comfort and may be viewed positively as an addition to grazing-based dairy farm systems.

Limitations/concerns

Limitation	Comment
Climatic	• Careful choice of location and orientation of shelter on each farm is required (including rainfall, wind and heat considerations). • A solid roof may be more suitable for shelters on farms in regions with very high solar radiation loads than a clear fabric roof with optional overhead shade screens and roof vents.
Increased operating costs	When being operated, requires more specialised skills in staff management, animal management, ration balancing and environmental management: • PMR/TMR needs to be delivered to cows at each feed bunk at least once per day and pushed up regularly to maximise intake and reduce wastage. • Pack needs to be tillered at least once per day even when not in use and have unrestricted air flow over it. • Bedding material needs to be regularly topped up.
Availability of bedding material and pack maintenance to control mastitis	• Bedding material may be costly or in limited supply in local area. • If the pack is not managed well, the higher risk of exposure to environmental mastitis pathogens can add to costs. Temperatures reached in the compost bedded pack may not be high enough to eliminate mastitis-causing bacteria, especially if the shelter is not being used 24 hours per day.
Planning process	• Dairy shelters are classed as an integrated facility for feeding and housing cows system and hence trigger a change in land use requiring a planning permit. Obtaining necessary approvals and permits across a range of government departments can be very slow and involved.
Higher skill/training level and standard of management required	• Attention to detail and management skill are required to ensure the pack surface in the shelter remains dry, and to detect and mitigate issues early • If management of feed purchasing, storage, mixing and delivery to shelter, and of cow comfort are sub-optimal, milk production and milk income less feed costs will be sub-optimal.

5. CONTAINED HOUSING: DAIRY DRY LOT

Description

These systems typically have centralised roofed shelters over composted bedding packs, located in earthen pens that are adequately sloped for drainage to a centralised manure collection system. The dairy herd is grouped depending on production and stage of lactation and various management groups. Typically, feed troughs and water supply are located away from the shelters to improve cattle movement and reduce congestion. Alternatively, a centralised concreted feedpad (either sloped and flushed or flat and dry scraped) provides effective infrastructure for feeding. Manure from the pens is regularly dry scraped and stockpiled in a designated area for composting and reused as bedding or re-applied to land supporting fodder production. These systems are most suited in hot, arid climates with suitable soils that facilitate drainage.

Generic types

Concrete feedpad +/- earthen surfaced loafing areas +/- shade structures

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	**TMR feeding system**

Purposes

- Compacted and sloped earthen pens and cattle loafing areas support supplementary feeding with a PMR or TMR
- Increase feed intakes, feed conversion efficiency and milk yields/cow
- Provide cow comfort and minimize heat stress
- Control nutrient run-off

Characteristics

Frequency of use	Hold, feed and water cows permanently
Typical hours per day	System dependent, multiple hours up to 24 hours per day at times of the year
Surface	Earthen sloped pad
Feeding table	Concrete nib wall. Cow barrier either post and rail or head locks. If sprinklers are fitted at feeding table, it is important that the concrete cow feeding platform be constructed with a nib wall against the dry lot to prevent the runoff from the sprinklers reaching the earthen surface of the pen
Loafing areas	Large earthen sloped loafing areas to facilitate drainage
Shade structures	Shade structures constructed with a north-south orientation parallel to the feeding infrastructure. This allows the shade to move throughout the day, resulting in cows resting on different sections of the dry lot surface. Shade shelters are fitted with gutters removing rainfall away from the pen to allow the dry lot earthen surface to dry faster during wet weather and eliminating pugging around the shelters
Effluent management	Dry scraping or flood washing of cow alleys at regular intervals throughout the day Manure from the pens regularly dry scraped and stockpiled for composting and applied to land to support fodder production
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability			✓		
Permanency				✓	
Capital cost			✓		
Feed wastage	✓				
Potential production benefits					✓
Improved farm efficiencies					✓

Costs

Capital cost: Moderate/cow (not including mixer wagon, feed storage and mixing facilities or milking facilities). The advantage of dairy dry lot facilities lies in the lower capital investment per cow compared to CBP barns or freestalls.

Operating costs: Higher than a permanent feedpad due to extra labour, machinery, and material costs to till bedding material under skillion shelters and dry scrape manure from earthen pens for composting, handling, transport and application.

Lifespan

More than 5–10 years. Depends on how well the facility was designed and constructed and maintained with regional climate. Extended wet periods can cause pugging so developing systems with adequate slope to accommodate drainage, so water drains off pens is critical. The slope of pens will have a dramatic impact on how fast the earthen surface will dry.

Examples of dairy dry lots


Shade shelters at a dairy dry lot with a north-south orientation


Cows resting comfortably on compost bedded pack aerated daily


Cows feeding at concrete central feedpad


Concrete cow feeding alley ways constructed with a nib wall against the dry lot to prevent the runoff reaching the earthen surface of the pen


Cows resting on sloped earthen pen of dairy dry lot


Flood washing of concrete cow feeding alleyways


Water trough with concrete drinking apron to prevent runoff onto earthen pen and pugging damage around the trough

Skill level/training required to operate

High

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • Less walking • Reduced heat stress	• TMR enables cows' daily feed inputs to be more closely controlled. • Feeding cows a TMR 2+ times per day is optimal in terms of rumen stability and function. • Presenting the milker diet as a TMR has been shown to optimise daily feed intake. • Cows on dairy dry lots expend minimal energy walking. • Under hot weather conditions, a dairy dry lot with effective cooling systems such as sprinklers placed at cow feeding alleyways and adequate shade may result in a saving of up to 5L milk/day.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage	• Studies indicate that feed wastage at feed-out may be reduced to 1–2% when presented as a TMR and fed out at a feed bunk. • Annual average feed conversion efficiency of 1.5L/kg DM (ECM) is achievable in a dairy dry lot (Don Stewart, Pers. comm)
Improved cow comfort and welfare	If well designed and managed, a dairy dry lot provides cows with: • unlimited access to feed and drinking water • freedom to lie down and rest, eat and move around and socialise each day • close monitoring and assessment for production and health • opportunity to calve in a special maternity barn under supervision • no need to walk long distances or wait in a dairy holding yard to be milked in the hot sun • shade and evaporative cooling, so they are well protected from heat stress.
Public acceptance	• Dairy dry lots are relatively new to the Australian dairy landscape – if designed and managed well they will improve cow comfort and may be viewed as an alternative to freestall or CBP barns
Specialisation of labour and management	• If enterprise is large enough, can train and manage specialised operational teams for earthen pen management (scraping and tilling of bedding), fodder growing and harvesting, feed mixing and delivery to cow, herd management, milk harvesting, young stock management and improved monitoring during joining
Improved feed utilisation	• Shifting feedbase to forages which are mechanically harvested eases pugging and compaction which may occur during grazing in miserable weather

Limitations/concerns

Limitation	Comment
Climatic	• Careful choice of location is required (including rainfall and heat considerations) and design for satisfactory year-round dairy health. A dairy dry lot may work in a semi-arid environment. While earthen pens are sloped extensive rainfall events can challenge dairy dry lots – particularly if they are overstocked. • During severe windy, wet conditions skillion shelters provide little protection from wind-chill.
High operating costs	Requires more specialised skills in staff management, animal management, ration balancing and environmental management: • TMR needs to be delivered to cows at each feed bunk at least once per day. • TMR needs to be pushed up regularly to maximise intake and reduce wastage. • Pack needs to be tillered at least twice per day and bedding regularly topped up.
Availability of bedding material and pack maintenance to control mastitis	• If the pack under the skillion shelters is not managed well, there is a higher risk of exposure to environmental mastitis pathogens which can add to costs. • Temperatures reached in the compost bedded pack may not be high enough to eliminate mastitis-causing bacteria.
Planning process	• Dairy dry lots are classed as an integrated facility for feeding and housing cows system and hence trigger a change in land use requiring a planning permit. Obtaining necessary approvals and permits across a range of government departments can be very slow and involved.
Economies of scale with herd size	• The two major costs of barn systems (besides the cost of capital) are feed costs and labour costs. While major savings in labour and other overhead costs can be achieved with increased herd size, feed costs tend to be similar across herd size. Maximising utilisation of dairy parlour requires a larger herd size.
High skill/training level and standard of management required	• Attention to detail and management skill can be critical in the management of a dairy dry lot system to detect and mitigate issues early. Different management skills are required as labour units are increased – including delegating responsibility, providing access to training etc. Regular and open communication is essential. Workplace health and safety needs to be addressed.
More complex labour requirements	• As the size of the enterprise increases, several labour units – with specialised skills and different areas of expertise and responsibility – tend to be required in a large dairy dry lot.
Environmental pressures	• Under dry lot conditions – especially close to urban and non-farming areas – infrastructure and management needs to be sufficient to prevent odours, dust and increased fly population that are likely to attract negative attention. Nutrient movement needs to be controlled, captured, and re-applied within the farm boundary.

5. CONTAINED HOUSING: LOOSE HOUSING

Description

A large, permanent, engineered roofed structure in which cows are fed and housed 24 hours per day. Loose housing facilities comprise of a large open resting area, bedded with a range of different bedding materials to create a comfortable lying surface that encourages cows to lie down. Loose housing facilities do not include stalls and partitions and the cows' resting and exercise areas are combined. Ventilation is natural or mechanically assisted.

Generic types

These facilities are typically categorised by their management of the bedded area:

- **Deep litter pack** where absorbent organic bedding is added regularly to the bedded area, but there is no mechanical tilling, or
- **Compost bedded pack** that is mechanically tilled at least twice daily.

All bedding is usually removed at intervals of 6-12 months, then new absorbent organic bedding added back into the facility.

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	**TMR feeding system**

Purposes

- Have maximum control over feeding, with minimal wastage
- Achieve optimal feed intakes, feed conversion efficiency and milk yields/cow
- Have maximum control over climatic variability and extreme weather events
- Provide maximum cow comfort and minimize heat stress and cold stress
- Control nutrient run-off

Characteristics

Frequency of use	Hold, feed and water cows permanently – zero grazing
Typical hours per day	24 hour per day
Surface	Organic materials, such as sawdust, straw, woodchips, wood shavings, shredded paper, dried manure, bark, seed hulls (e.g. rice, almond etc) can be used effectively for deep bedding.
Feeding table	Concrete nib wall. Cow barrier either post and rail or head locks
Loafing areas	Large resting area without partitions with composted bedding surface
Shade structures	Solid roof over entire barn
Effluent management	Dry scraping or flood washing of feed alleyways at regular intervals Removal of composted bedding material at regular intervals
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability					✓
Permanency					✓
Capital cost					✓
Feed wastage	✓				
Potential production benefits					✓
Improved farm efficiencies					✓

Costs

Capital cost: Very high/cow (not including mixer wagon, feed storage and mixing facilities or milking facilities). Per cow construction costs are generally lower than for a freestall, despite more area being required per cow, as less concrete is used and there is no investment in freestall partitions and bases.

Operating costs: Higher than a freestall due to extra labour, machinery, and material costs to till bedding material and top up regularly.

Lifespan

More than 30 years. Depends on how well the facility was designed and constructed.

Examples of loose housing facilities

Deep litter pack – low bed retaining curb, water troughs, access from feed alley only

Cows resting comfortably on compost bedded pack

Cows in feed alley and on compost bedded pack

Tilling a compost bedded pack with harrows to help aeration and to break up clumps while the cows are off the pack being milked

Skill level/training required to operate

High

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • Less walking • Reduced heat stress	• TMR enables cows' daily feed inputs to be more closely controlled. • Feeding cows a TMR 2+ times per day is optimal in terms of rumen stability and function. • Presenting the milker diet as a TMR has been shown to optimise daily feed intake. • Cows in loose housing facilities expend minimal energy walking. • Under hot weather conditions, a well ventilated freestall with effective cooling systems may result in a saving of up to 5 L milk/day.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage	• Studies indicate that feed wastage at feed-out may be reduced to 1-2% when presented as a TMR and fed out at a feed bunk. • Annual average feed conversion efficiency of 1.6 L /kg DM (ECM) is achievable in a loose housing facility.
Improved cow comfort and welfare	If well designed and managed, a loose housing facility provides cows with: • unlimited access to feed and drinking water • freedom to lie down and rest, eat and move around and socialise each day • close monitoring and assessment for production and health • opportunity to calve in a special maternity barn under supervision • no need to walk long distances or wait in a dairy holding yard to be milked in the hot sun • shade and evaporative cooling, so they are well protected from heat stress • protection from adverse weather events, muddy walking tracks and paddocks etc.
Public acceptance	• Loose housing facilities are generally viewed by the public as better in terms of cow welfare than a freestall, and are likely to have less odours and flies if well managed
Specialisation of labour and management	• If enterprise is large enough, can train and manage specialised operational teams for fodder growing and harvesting, feed mixing and delivery to cow, herd management, milk harvesting, and young stock management.

Limitations/concerns

Limitation	Comment
High capital cost	• Engineered structures with steel and concrete fixtures. • Addition costs are required for barn ventilation and cooling systems, and effluent system
High operating costs	• TMR needs to be delivered to cows at each feed bunk at least once per day. • TMR needs to be pushed up regularly to maximise intake and reduce wastage. • Pack needs to be tillered at least twice per day and bedding regularly topped up.
Availability of bedding material and pack maintenance to control mastitis	• Bedding material may be costly or in limited supply in local area. • If the pack is not managed well, the higher risk of exposure to environmental mastitis pathogens can add to costs. Temperatures reached in the compost bedded pack may not be high enough to eliminate mastitis-causing bacteria
Planning process	• A planning permit for intensive animal husbandry is required, under the state and local planning policy frameworks. There are several additional state legislations and policies that may impose additional requirements on the development and operation of a loose housing facility. Objections to a planning permit application may be received from neighbours and other members of the local community (noise, odour etc.)
Economies of scale with herd size	• The two major costs of barn systems (besides the cost of capital) are feed costs and labour costs. While major savings in labour and other overhead costs can be achieved with increased herd size, feed costs tend to be similar across herd size. Maximising utilisation of dairy parlour requires a larger herd size.
High skill/training level and standard of management required	• If management of feed purchasing, storage, mixing and delivery to barns, herd numbers and composition (age, stage of lactation, milk yield), and cow comfort are sub-optimal, milk production and milk income less feed costs will be sub-optimal.

5. CONTAINED HOUSING: FREESTALL

Description

A large, permanent, engineered structure in which cows are fed and housed 24 hours per day. They may be open or partially or fully enclosed. The term 'freestall' refers to the bedding area (or cubicles) where cows lie down and rest. Additional loafing areas may also be provided. Cows are kept in pen groups and access a TMR at a feed bunk via alleyways. Cows leave the barn 2-3 times each day to be milked in an adjacent milking parlour. Alternatively, if it is a robotic freestall, milking stations are located within the barn. Ventilation in barn may be natural, crossflow or tunnel.

Generic types

Freestall with alternative layouts: 3-row, 4-row (head-to-head or tail-to-tail), 6-row, 6-row with perimeter feeding, 8-row wide-body, low profile, cross-ventilated barn (head-to-head or tail-to-tail)

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	**TMR feeding system**

Purposes

- Have maximum control over feeding, with minimal wastage
- Achieve optimal feed intakes, feed conversion efficiency and milk yields/cow
- Have maximum control over climatic variability and extreme weather events
- Provide maximum cow comfort and minimize heat stress and cold stress
- Control nutrient run-off

Characteristics

Frequency of use	Hold, feed and water cows permanently – zero grazing
Typical hours per day	24 hour per day
Surface	Concrete or rubber
Feeding table	Concrete nib wall. Cow barrier either post and rail or head locks
Loafing areas	Cubicles with bedding +/- additional loafing areas adjacent to barn
Shade/cooling	Solid roof over entire barn
Effluent management	Dry scraping or flood washing flushing of alleyways at regular intervals to remove manure to a professionally designed effluent system
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up					✓
Weather durability					✓
Permanency					✓
Capital cost					✓
Feed wastage	✓				
Potential production benefits					✓
Improved farm efficiencies					✓

Costs

Capital cost: Very high/cow (not including mixer wagon, feed storage and mixing facilities or milking facilities)

Operating costs: Moderate-high depending on whether bedding in cubicles is sand or mattresses

Lifespan

More than 30 years. Depends on how well the facility was designed and constructed.

Examples of freestalls

Sand bedded cubicles. Flood-washed cow alley

Feed push-up using tractor

Sand replenishment

Alternative cubicle bedding: Sand, mattresses top-dressed with wood shavings or bentonite

Skill level/training required to operate

High

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • Less walking • Reduced heat stress	• TMR enables cows' daily feed inputs to be more closely controlled. • Feeding cows a TMR 2+ times per day is optimal in terms of rumen stability and function. • Presenting the milker diet as a TMR has been shown to optimise daily feed intake. • Cows in freestall expend minimal energy walking. • Under hot weather conditions, a well ventilated freestall with effective cooling systems may result in a saving of up to 5 L milk/day.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage	• Studies indicate that feed wastage at feed-out may be reduced to 1-2% when presented as a TMR and fed out at a feed bunk. • Annual average feed conversion efficiency of 1.6 L/kg DM (ECM) is achievable in a freestall.
Improved cow comfort and welfare	If well designed and managed, a freestall provides cows with: • unlimited access to feed and drinking water • freedom to lie down and rest, eat and move around and socialise each day • close monitoring and assessment for production and health • opportunity to calve in a special maternity barn under supervision • no need to walk long distances or wait in a dairy holding yard to be milked in the hot sun • shade and evaporative cooling, so they are well protected from heat stress • protection from adverse weather events, muddy walking tracks and paddocks etc.
Specialisation of labour and management	• If enterprise is large enough, can train and manage specialised operational teams for fodder growing and harvesting, feed mixing and delivery to cow, herd management, milk harvesting, and young stock management.

Limitations/concerns

Limitation	Comment
High capital cost	• Engineered structures with steel and concrete fixtures. • Addition costs are required for barn ventilation and cooling systems, and effluent system
High operating costs	• TMR needs to be delivered to cows at each feed bunk at least once per day. • TMR needs to be pushed up regularly to maximise intake and reduce wastage. • Cubicles need to be regularly groomed and bedding topped up • Effluent management • Sand (if used) needs to be recovered from effluent system
Planning process	• A planning permit for intensive animal husbandry is required, under the state and local planning policy frameworks. There are several additional state legislations and policies that may impose additional requirements on the development and operation of a freestall. Objections to a planning permit application may be received from neighbours and other members of the local community (noise, odour etc.)
Economies of scale with herd size	• The two major costs of barn systems (besides the cost of capital) are feed costs and labour costs. While major savings in labour and other overhead costs can be achieved with increased herd size, feed costs tend to be similar across herd size. Maximising utilisation of dairy parlour requires a larger herd size.
High skill/training level and standard of management required	• If management of feed purchasing, storage, mixing and delivery to barns, herd numbers and composition (age, stage of lactation, milk yield), and cow comfort are sub-optimal, milk production and milk income less feed costs will be sub-optimal.

8.3 MOVING FROM ONE TYPE OF FEED DELIVERY INFRASTRUCTURE TO THE NEXT

It is common for a farm to set up a basic feed-out area or formed earthen feedpad, and then, over many years, develop it into a fully concreted permanent feedpad (or possibly even into an integrated facility for feeding and housing cows). This is only feasible if the factors in Table 6 are well considered at the outset. Otherwise, down the track, a new permanent feedpad may need to be constructed at another site on the farm (with many costs being incurred again) and another use found for the old feedpad (e.g. as a calving pad).

Feed delivery infrastructure for basic feed-out areas, formed earthen feedpads, concrete feedpads and integrated facilities for feeding and housing cows all enable mixed ration feeding systems to be used. These have advantages and disadvantages (Table 4).

Table 4. Factors to consider when moving from one type of feed delivery infrastructure to the next

Factor	
Area	Will the feedpad be large enough to cater for increased cow numbers and how long you intend cows to stay on the feedpad per day?
Site on farm	Consider weather and wind, proximity to the dairy, feed storage and mixing facilities, water points, drains, effluent ponds. Think about vehicle access, distance from boundaries and easements etc.
Orientation	Is it possible that the feedpad may evolve into a permanent, concrete-surfaced feedpad with a roof? If so, consider an east-west orientation.
Topography, soil type and slope	Consider the natural slope and drainage of the proposed site. What will happen to storm water? Will you need to undertake earthworks? Soil investigations and permeability tests establish load tolerance and likelihood of pad surface cracks, nutrient leaching, and seepage into effluent storage.
Impact on ground and surface water	Consider how siting and effluent runoff management will impact ground and surface water. Remember, runoff containing effluent must not leave the boundary of your property.
Odour, dust, noise	Cow numbers, climate, type of feed and feedpad management all affect feedpad odour. What buffer distance is planned? Fine particle dust can be managed by good laneway design and regular management. Buffer zones help reduce noise too – very important if you have neighbours close by.
Vehicle access to feedpad	Vehicles require a minimum of 3.7m for easy access – 4m for all weather access. Have you allocated enough room for the distribution of feed as well as access for cleaning? Large trucks need high clearance.
Cow access to dairy, loafing pad, feed areas	Routes for laneways should permit easy cow flow and allow for herd expansion.
Stock water	Stock need access to water close to where they will be feeding. You may need water for cleaning the feedpad. How will water be delivered to the site? If collecting off roofs, how will rainwater be diverted and stored?
Drainage	Effective drainage is important for all weather access. Can your proposed feedpad handle a flood or one-in-20-year-24-hour storm event? You may need diversion banks and catch drains to carry storm runoff and effluent.
Power	Will you need access to power at the feedpad site – now and in the future?



How one farm's feedpad evolved through 3 stages of development over 15 years

Table 5. Mixed ration feeding systems – advantages and disadvantages

Advantages	• More resilient in the face of drier, hotter weather conditions and extreme weather events, greater fluctuations in home-grown forage availability and quality due to greater climate variability, and greater volatility in milk, water, grain and fodder markets • Can further intensify their operation to increase productivity and remain profitable (increasing stocking rate and feeding more supplementary feeds per cow) • Increase flexibility, to access cost-effective by-products and cope with increased climate and market volatility • Can feed cows higher levels of grain/concentrates with less ruminal acidosis and better feed efficiency than possible using bail feeding in the milking shed • Can better control diets and reduce feed wastage associated with feeding out hay, silage and other supplements • Can better control monthly milk flows to suit their processor's requirements and payment scheme (particularly if supplying the domestic liquid milk market)
Disadvantages	• Increase complexity – diets, pasture and feeding management • More time pressures on staff and cows • Increase business overheads - finance and capital costs for new facilities and equipment • An increase in the cost structure of the farm business which necessitates achievement of higher levels of feed efficiency to remain viable • Fixed structures which cannot be moved or sold • Increased risk of cow health problems such as lameness and mastitis if not managed well • A need to manage manure and effluent well and avoid image and odour problems • Changes required in thinking re. feeding cows and in daily work routines

Before committing to a specific type of feed delivery infrastructure, consider these farm management questions:

- How will pasture management be adjusted to maximise efficiency?
- How will a feedpad impact the farm's profitability?
- What will the feedpad be used for?
- How will animal health and welfare on the feedpad be managed?
- How will the proposed system be operated long term, for example feed management?
- Will a change in system align with goals for the farm?
- Will the farm change to a higher input feeding system?
- Does the farm have sufficient staff to run a supplementary feed system?
- How will the increased effluent and stormwater generated from the pad be managed?

A feeding facility which enables mixed rations to be fed and perhaps also enables cows to be sheltered or housed for varying periods of time (from a few hours a day to a few days at a time to permanently) invariably involves:

- Increased capital
- A changed operating environment with increased operating costs
- Increased complexity, with impacts on labour and time management, and skills required, and
- A change in risk profile for the farm business

Future designs of permanent infrastructure for feeding and housing cows

The main factors shaping future designs for feeding and housing cows are:

- Animal welfare issues, especially less lameness and fewer hock lesions, and more natural behaviour
- Less emissions of ammonia and greenhouse gases
- Reuse of waste products
- Climate control
- Aesthetics of the building in the landscape
- Increased capital efficiency, and
- Increased manure quality.

Additional factors shaping future design to consider include:

- Farm production, larger higher production animals – US freestall designs and cubicle spacing is increasing
- Increased technologies (e.g. cattle monitoring, manure systems with advanced solid separation and anaerobic digestion), and
- Incorporation of robotic milking systems into housed complexes.

(Scott McDonald, Pers. Comm.)

8.4 BENEFITS OF FEED DELIVERY INFRASTRUCTURE

THROUGH USE OF FEED DELIVERY INFRASTRUCTURE, IT IS POSSIBLE TO ACHIEVE:

- More milk/cow/day from:
  - a) increased rumen stability and daily feed intake
  - b) reduced walking distance per day, and
  - c) Reduced heat stress
- Higher feed efficiency and reduced feed costs from:
  - a) reduced feed wastage, and
  - b) reduced pugging damage to soil in wet weather

More milk/cow/day from:

a) Increased rumen stability and feed intake

Milk yield increases seen from progressing from a system where grain and concentrates are fed in the bail and conserved forage in the paddock to a PMR system where all the forage and concentrates are included in the one ration and delivered on a feedpad are at least 3.5kg/day. Milk yield increases by progressing from a feedpad to a TMR contained housing system with no access to pasture may be in excess of an additional 6.0kg/day. These increases are achieved due to improved rumen stability, higher daily feed intakes and improved feed conversion efficiency.

Kolver and Muller (1998) were one of the first to quantify the difference in production of dairy cows fed either only high-quality pasture or a nutritionally balanced TMR. The increase in milk yield from 29.6–44.1kg/day was due largely to the increase in DMI from 19.0–23.4kg/day.

Bargo *et al.* (2002) demonstrated that feeding a TMR maximised DMI and milk production. They found that the dry matter intake of cows receiving pasture and up to 10kg/day concentrate in the bail consumed 21.6kg/day comprising 12.9kg DM pasture and 8.7kg DM concentrate, while TMR cows consumed 26.7kg DM/day. Cows on an intermediate treatment of grazing during the day, and then housed and fed a mixed ration overnight consumed a total of 25.2kg/day comprising 2.2kg DM concentrate, 7.5kg DM pasture and 15.5kg DM/day of the mixed ration. The respective milk yields were 28.5kg/day for pasture plus concentrate in the bail, 38.1kg/day for the TMR cows and 32.0kg/day for the intermediate system.

The research group at Ellinbank confirmed greater dry matter intakes were associated with a mixed ration being offered to dairy cows, in addition to grazing on pasture. At the higher daily supplement intakes of about 15.0kg DM total supplement, cows that were provided with their nutrients in a mixed ration form produced about 2.0kg ECM/day more than cows feed the same concentrate in the bail and silage in the paddock (Auldist *et al.*, 2013). In addition, the replacement of part of the wheat with canola meal in the mixed ration improved pasture intake and consequently, ECM milk yield by up to 5kg/day.

The results of a case study of dairy producers progressing from a system that involved grazed pasture, conserved forage fed with a mixer wagon under a hot wire and grain mix in the dairy, to grazed pasture and forage and grain mix from the mixer wagon fed to cows on a feedpad, have been described by Dairy Australia (2020). In this case study, milk yield increased by 3.5kg/day, which is similar to that observed by Bargo *et al.* (2002).

b) Reduced walking distance per day

Feed delivery infrastructure may also increase milk yield by reducing the amount of energy expended in activity if it enables cows' walking distances to be reduced. On relatively flat terrain as in the Murray Dairy region, each kilometre walked requires a conservative 2 MJ metabolisable energy (ME). Given that each litre of milk produced requires about 5.0 MJ ME, the milk yield loss for every km walked is approximately 0.4 litres.

Janna Heard used the equations from the Standing Committee on Agriculture (1991) to calculate the energy cost of walking from the paddock to the dairy (Heard *et al.*, 2004). Using the Standing Committee on Agriculture equations, Heard and co-workers calculated that the energy used in walking 1 km along the horizontal was 2.6 MJ/kg bodyweight, which is about 1.6 MJ for a 600kg cow. Assuming the efficiency of converting energy from feed into milk is 75% another 2.1 MJ ME is required for every km walked. Assuming 5.0 MJ ME required per litre of milk (Moe & Tyrell, 1975), this equates to 0.42kg milk/km walked on predominantly flat terrain.

Moran (2005) estimated that on flat terrain an additional 1 MJ ME will be required to provide the energy to walk to and from the dairy for every km covered. In hilly country this energy requirement increases up to 5 MJ ME/km. Assuming about 4.5 MJ ME are required to produce a litre of milk (Moran, 2005), the estimated loss in milk yield/km walked would be about 0.22kg/km on relatively flat terrain, but over 1kg/km travelled in hilly terrain. Later, Islam *et al.* (2015) provided an intermediate value when they estimated that milk yield decreased by 0.61kg for every 1 km increase in total walking distance between the dairy and paddock.

c) Reduced heat stress

Modifications to the infrastructure involved in housing cows, even for relatively short periods of time during summer, can have a marked effect on cow comfort and productivity. Physical modification has been the primary way of reducing these adverse effects of hot weather conditions. The use of shade and various forms of cooling that may include sprinklers, fans and ventilated buildings can been used to reduce heat stress exposure.

When cows are suffering heat stress, their maintenance energy requirement increases 20–30% due to efforts to defend their core body temperature to ensure it stays within the optimal range through panting. In addition, during hot weather, dry matter intake decreases. NRC (1981) estimated that dry matter intake can drop by about 8% as temperature increases from the thermoneutral level of about 20-35°C. Thus, the energy status of the cow receives a double hit, greater energy costs trying to maintain a stable internal body temperature as well as the lower energy intake. It is not surprising that milk production decreases. Again, NRC (1981) estimated that milk yield drops by over 30% when the temperature increases from 20–35°C. At these higher temperatures, dairy cows may also be more prone to ruminal acidosis and less able to digest and absorb nutrients.

The susceptibility of cows to heat stress is dependent on farm location, breed, the herd's age profile and level of milk production.

The best single descriptor of heat stress is the Temperature Humidity Index (THI), because this combines temperature and relative humidity into a single comfort index. The higher the index, the greater the discomfort, and this occurs at lower temperatures for higher humidity's. Many of the experiments that have examined the effect of heat stress have used maximum daily THI as the key measure of heat stress.

Although feed management may help in controlling the adverse effects of heat stress on intake and milk yield, physical modification of the environment has been the primary way of reducing these adverse effects of hot weather conditions. Shade and various forms of cooling that may include sprinklers, fans and ventilated buildings can be used to reduce heat stress exposure. Use of sprinklers and fans helps cows offload heat through evaporative cooling. These measures will decrease respiration rate and subsequently increase dry matter intake and milk yield. Provision of shade can lessen the intensity of the heat load of cows each day.

There has been little quantitative information on the impact of heat stress on dairy herd milk production in Australia. In their study of effectiveness of adaptations to heat stress to maintain dairy productivity in the Murray Dairy region Nidumolu *et al.* (2010) calculated estimates using conversion factors based on literature and expert knowledge for cows with different susceptibility to heat stress. They examined low susceptibility cows (i.e. a Brown Swiss Jersey producing less than 5,500 litres or milk per year), moderately susceptible cows (i.e. other European breeds or cross breeds producing 5,500–8,000 litres of milk per year) and highly susceptible cows (i.e. Large Holstein-Friesian producing more than 8,000 litres of milk per year) (Little & Campbell, 2008). In all three cases milk production losses were assumed to occur when daily THI values exceeded 75. When THI exceeded this threshold the amount of milk lost in litres per cow per day was calculated by subtracting 75 from the daily THI value and multiplying this difference by a scaling factor.

For the cows with low susceptibility to heat stress a scaling factor of 0.6 was used. For moderately susceptible cows a scaling factor of 0.8 was used and for highly susceptible cows a scaling factor of 1 was used. Maps of the Murray Dairy region were generated to show the impact of THI on milk production (litres/cow/year) using climate data for 1971–2000 as base years (Figure 17). Additional impacts of THI on milk production over and above those for the base years due to climate change by 2025 and 2050 were also projected using a climate model with 3 alternative emission scenarios. Figures 17a and 17b show impacts based on the most pessimistic emission scenario 'A1F1', which is how actual emissions are tracking.

Figure 17. Impact of THI on milk production for 'low susceptibility', 'moderate susceptibility' and 'high susceptibility herds in Murray region, based on climate data for 1971–2000

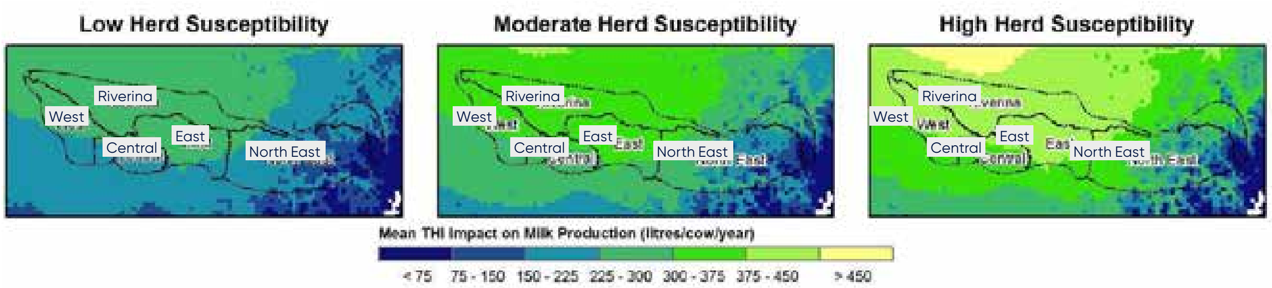


Figure 17a. Further changes in milk production for 'low susceptibility', 'moderate susceptibility' and 'high susceptibility herds for 2025 (based on A1FI emission scenario)

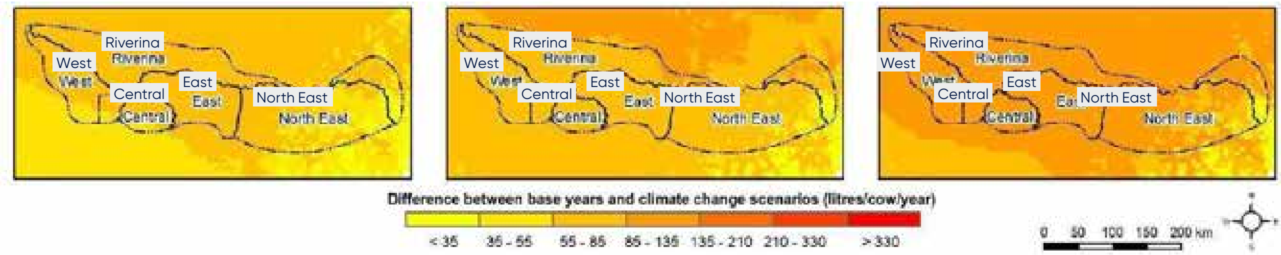
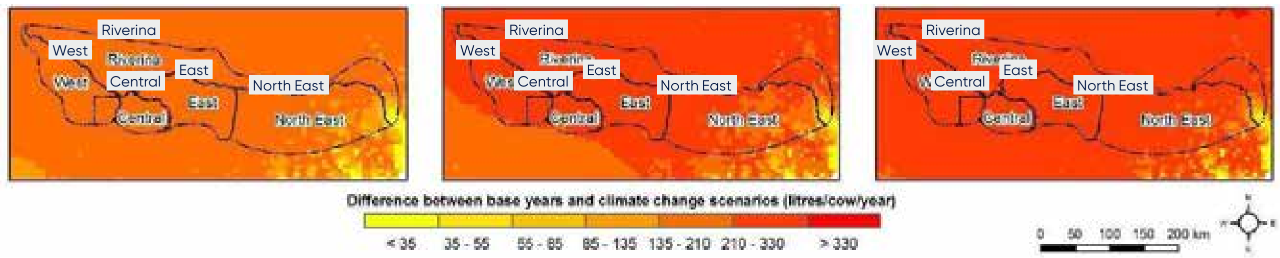


Figure 17b. Further changes in milk production for 'low susceptibility', 'moderate susceptibility' and 'high susceptibility herds for 2050 (based on A1FI emission scenario)



Providing shade and cooling to dairy cows limits their accumulation of heat load during long periods of hot days and warm nights and during heat wave events, thereby avoiding dramatic falls in daily feed intake, milk yield, protein test and cow health problems. There has also been little quantitative information on what are the benefits of providing shade and cooling to dairy cows that has been published in Australia. A few studies conducted in Australia confirm the beneficial effects of shade and cooling.

For example:

- The results of trials in Queensland have shown that 30 minutes of wetting cows with sprinklers at the dairy can produce an extra 1 litre of milk/cow/day, while 60 minutes has produced an extra 1.5 litres of milk/cow/day in hot weather (QDAF, 2013).
- Shade can reduce a cow's heat load from the environment by up to 50% (QDAF, 2013).
- Wildridge *et al.* (2017) found that providing shade in the yard for the short period before milking during summer in a pasture-based system can alleviate heat stress by decreasing respiration rate and improving milk yield by 0.5kg/day. Obviously providing shade for longer times in the more intensively housed dairy systems will have an even more beneficial effect on cow comfort and productivity.

Cost:benefit estimations provided towards the end of this section, assume that the provision of cooling infrastructure in paddocks and laneways, and on dairy holding yards and feedpads will reduce losses in milk production per year due to heat stress by differing percentages, as proposed in Table 6 (Pers. comm. S. Little). Note that the percent reduction in milk production losses per year due to heat stress in Table 6 are additive. For example, if a herd's annual milk yield drops by 350kg/cow due to heat stress, the addition of sprinklers and fans used with a shade structure over a feedpad to ensure good evaporative cooling, even on days with little/no wind, will reduce this annual milk yield loss by 50% to only 175kg/cow, or an improvement of 175kg milk/cow.

Table 6. Estimated reductions in milk production losses per year due to cooling infrastructure

Cooling infrastructure item	Estimated percent reduction in milk production losses per year due to heat stress
Trees provide every cow with 4m^2 shade at midday in paddocks on all warm/hot days.	45%
Additional water troughs enable cows to access cool drinking water in all paddocks and main laneways.	5%
Sprinklers in dairy holding yard used effectively on all cows before morning and afternoon milkings on all warm/hot days.	15%
Structure over dairy holding yard provides cows shade while waiting to be milked.	10%
Structure over dairy holding yard provides cows shade for longer periods before afternoon milking on warm/hot days.	15-20%
Fans used with sprinklers in holding yard to ensure good evaporative cooling, even on days with little/no wind.	5%
Trees in a sacrifice paddock provide cows 4m^2 shade each at midday on all warm/hot days	30%
Structure over feedpad (shade cloth or solid roof) provides cows 4m^2 shade each at midday on all warm/hot days.	35-45%
Sprinklers and fans used with shade structure over feedpad to ensure good evaporative cooling, even on days with little/no wind.	10–15%
Additional water troughs enable cows to access cool drinking water within 15m of feed while on feedpad.	5%

There have been many studies in the US that have studied the effects of environmental mitigation strategies on the physiology and productivity of dairy cows. For example, results of these types of studies have provided good quantitative information on the effects of sprinkler attributes such as flow rate, frequency of spray application and amount of water delivered on productivity and cow comfort.

In addition, there have been several extensive reviews on environmental strategies for alleviating heat stress of dairy cows. For example, Fournel *et al.* (2017) recently reviewed the effects of cooling in humid climates through shade, fans, and sprinklers on thermal stress and consequently on cow health and productivity.

Much of this information is transferable to Australian dairy farms, and good practical information and tools for managing heat stress in dairy cows have been provided by Dairy Australia (2019b) in their Cool Cows publication and website.

Higher feed efficiency and reduced feed costs from:

a) Reduced feed wastage

Feed wastage during feed-out can be significant and will vary depending upon the type of feed delivery infrastructure that is in place. Based upon feed wastage values measured on commercial dairy farms, reliable values for feed wastage are ascribed for each of the five feed delivery infrastructure systems that may be used on Australian dairy farms.

Feed wastage is reduced as one progresses to more developed feed delivery infrastructure. Although feed wastage can be significant and in some cases approach well over 20%, the amount of feed losses during feed-out has not been well documented. The amount of feed wastage was measured in a range of different feed-out methods on Australian dairy farms from feeding on pastures in the paddock through to a TMR type system (Dairy Australia, 2009). Six feed-out methods were assessed, and the average estimated feed wastage ranged from 8.8% (range 0.9–22.3%) for a temporary feed-out area to 1.8% (range 0–5.6%) in a permanent and well developed feedpad (Dairy Australia, 2009).

Based upon these observed feed wastage values measured in commercial dairy farms, the following values for feed wastage may be reliably used when comparing different feed delivery systems (Table 7). Applying these feed wastage values effectively reduces the cost per tonne of feeds fed out.

Table 7. Feed wastage rates for different feed delivery systems (dry conditions)

Feed delivery infrastructure	Feed wastage
Temporary feed-out area	Range: 5-35% Typical: 25%
Basic feed-out area	Range: 5-20% Typical: 10%
Formed earthen feedpad	Range: 2-10% Typical: 5%
Concrete feedpad	Range: 0-5% Typical: 3%
Integrated facility for feeding and housing cows	Range: 0-5% Typical: 3%

A key finding of the feed wastage study (Dairy Australia, 2009) was that there was substantial variation in the amount of feed refusal and wastage between and within feed-out methods on Australian dairy farms. With all feed-out methods, some producers achieved very low wastage. These variations may reflect variations in farm management with a particular feed-out method e.g. feed-out procedure, feed bunk management, forage quality, operator skill etc. There was no significant association between the amount of feed offered per cow and amount of feed wastage per cow across all feed-out methods.

Unlike temporary and basic feed-out infrastructure, formed earthen feedpads, concrete feedpads and integrated facilities for feeding and housing cows enable feed not consumed by cows after a certain period following feed-out (termed 'refusals') to be collected before it is contaminated and spoiled. It can then be fed to other cattle on the farm such as dry cows.

Three critical factors help to minimise waste during feed-out on feedpads and therefore help to optimise the return on investment in the feedpad. These include:

a. feedpad design and construction

b. feed ingredients/rations offered, and

c. feeding management.

These are discussed later in this review, in the section 'Keys to Success'.

There are emerging discussions from farms transitioning to permanent feeding infrastructure that supplementary feed wastage is significantly declining. However, on the other hand, pasture-grazing wastage is increasing with herds returning to paddocks already full of the feed.

b) Reduced pugging damage

Poorly drained soils are prone to treading or "pugging" damage and may occur on grazed pastures during the wetter months of the year. The results of research studies conducted in Australia and New Zealand have shown that if pugging in winter is significant, pasture yield in the following spring and pasture utilisation may be reduced by about 40%. One simple method of reducing pugging is removing the cows from pasture and housing them for various lengths of time on a feedpad. A feedpad with a large loafing area enables 'on-off' grazing management to be used, which reduces pasture wastage by cows and enhances re-growth. Under extremely wet conditions, a feedpad with an adequate area and surface may enable cows to be held on it continuously for several consecutive days.

Pugging is a form of compaction and is the term used for when cows damage both the soil structure and the pasture. Pugging seals the soil surface and exacerbates waterlogging of the topsoil by impeding infiltration and providing surface indentations for water storage, thereby reducing the efficiency of surface drainage from the paddock to many soil types in wet weather.

As pasture is the cheapest source of feed for most producers it is important to minimise the damage that cows can do to pastures through pugging up the paddocks. A grazing trial conducted in south-western Victoria found that medium to heavy pugging in winter reduced pasture yield in the following spring by 40–42%, pasture utilisation by 34–40% and perennial ryegrass tiller density by 39–54% (Nie *et al.*, 2000). DairyNZ research has shown similar results in that pasture seriously pugged in Spring will likely produce about 40% less DM than undamaged pasture through the following season, although pasture yield reductions of up to 80% have been recorded (DairyNZ, 2020a).

Cost:benefit calculations provided towards the end of this section, assume that pugging causes a 30% reduction in pasture utilisation rate. One simple method of reducing pugging is removing the cows from pasture and housing them for various lengths of time on a feedpad. A feedpad with a large loafing area enables 'on-off' grazing management to be used, which reduces pasture wastage by cows and enhances re-growth.

Cost:benefit estimations (typical examples)

More milk/cow/day from:

a) Increased rumen stability and feed intake

If use of a feedpad enabled an increase in feed intake of 3kg DM/day at a cost of $350/t DM, and this resulted in an increase in milk yield of 3.5kg/day at a milk price of $0.40/kg, this would give a milk income minus feed cost (MOFC) of $0.35/cow/day. For a herd of 300 cows, this equates to $105 extra MOFC per day or nearly $40,000 extra MOFC per year.

b) Reduced walking distance

If a typical 300 cow farm in the Murray Dairy region was to reduce the walking distance of each cow by 4 kilometres per day using a permanent feedpad near the dairy which meant that cows only had to walk to/from a paddock to graze once a day (instead of twice), this would equate to 1,200 km saved per day for the herd. Assuming, on an energy basis, 0.5 litres milk per km walked on flat terrain, this would equate to 600 litres extra milk per day.

At a milk price of $0.40/litre, this would equate to extra income per day of $240. If this pattern of use continued for 60 days over summer, when pasture was limited, this would equate to extra income of $14,400 during this period.

c) Reduced heat stress

The inherent level of susceptibility to heat stress of a herd of 300 moderate sized Holstein-Friesian cows on a farm at Tatura in the Murray dairy region producing 6,500kg milk/year is moderate. Nidumolu *et al.* (2010) estimated that this herd would incur an average annual milk production loss due to heat stress of 355kg/cow based on expected climatic conditions. At an average milk price of $0.40/kg, this would equate to a cost of approx. $142/cow/year or $42,600 for the herd per year.

If an investment of $70,000 was made in a shade cloth structure over an existing feedpad and installation of sprinklers, and this feeding and cooling facility was used effectively, this would reduce this annual milk production loss by 45% (35% for shade cloth structure plus 10% for sprinklers, as per Table 8) i.e. 160kg/cow, to 195kg/cow.

At an average milk price of $0.40/kg, this would equate to an annual benefit of approx. $19,200 per year due to a reduction in lost milk production. The represents a return on investment of 27% per annum, and a payback period of less than four years.

Note:

- Losses in milk income due to effect of heat stress on milk yield can often be doubled when you also account for losses from low milk protein and fat tests, reduced in-calf rates, more clinical mastitis cases and other cow health problems.
- Payback period assumes no debt funding. If debt funding is required, payback period will be longer.

Higher feed efficiency and reduced feed costs from:

a) Reduced feed wastage

If a typical 300 cow farm was feeding out 1,500kg DM of hay/silage per cow per year valued at $300/t DM in hay rings and wasting 20% using this method, this equates to a loss of $90/cow/year or $27,000 for the herd per year. If use of a well designed and constructed permanent feedpad enabled feed wastage to be reduced by 15% to 5%, this would represent a saving of $68/cow/year or $20,250 for the herd per year.

b) Reduced pugging damage to soils

If a paddock from which 9 t DM/ha/year would have been utilised was subjected to very wet weather, and a 30% reduction in utilisation rate was prevented through practising 'on-off grazing' using a feedpad, this would equate to a saving of 2,700kg DM/ha. Assuming a pasture growing cost of $0.15/kg DM, this would equate to a saving of $405/ha/year.

Additional benefits captured by industry:

The benefits outlined earlier focus on cow production, feed, and pastures. As farms transition to TMR feeding and housed systems producers are experiencing additional productivity gains. While the gains may be small in isolation, the cumulative effect may be greater than the sum of the parts. These include:

- Increased labour efficiencies
- Potentially greater ability to retain labour as some staff favour indoor environment compared to working outdoors in variable weather
- Optimal milking plant performance
- Improved conception and animal health detection with closer monitoring
- TMR/PMR systems help create an environment for high genetic cows the reach their genetic potential
- Improved farm WUE on higher yielding fodder crops under cut and carry as opposed to pasture-based systems
- Reduced laneway maintenance costs, particularly with a winter stand-off
- Decreased costs to renovate and recover pastures, pugging and compaction
- Reduced fertiliser costs associated with improved effluent and manure distribution
- Improved machinery efficiencies
- Opportunity to attract premium milk pricing
- New income opportunity to sell solids, bedding compost and energy anaerobic digestion, and
- Improved fodder production with less compaction.

The dairy transition economic and risk project was conducted by Agriculture Victoria, DPI NSW and Dairy Australia. It will attempt to identify and where possible estimate, the productivity gains producers are experiencing from their change to a TMR feeding system. While the gains may be small in isolation, the cumulative effect may be greater than the sum of the parts.

09

Facility design and management

INTRODUCTION

The design and construction of feedpads and contained housing facilities should:

- Achieve appropriate standards of animal health, welfare and hygiene by providing good access to feed and water, sufficient space and clean lying surfaces, solid surfaces for standing free from mud plus access to shade and shelter
- Minimise the risk of adverse amenity and environmental impacts and allow for regular manure removal
- Support the operational efficiency of the farm – easy cow movements around the system, easy access to the alleys for vehicles
- Provide a safe working environment for farm staff.

In addition, all housing designs should:

- Allow for multiple routes between bedding and feeding/watering areas to minimise 'boss' cows restricting the movement of less dominant cows
- Incorporate adequate cow access and egress to suit the milking system that is used on the farm – herringbone, swing-over, double up, rotary or robotic/automatic milking system (AMS) dairy.

9.1 FEEDPAD OVERVIEW

As noted in chapter 8, feedpads are typically used for partial mix ration feeding to support farm production focused on grazing. The surface of feedpads is either formed, laid with a durable material or stocked at a rate that precludes vegetation.

Examples of feedpad facilities include:

Temporary feed-out area: Located in a pastured or bare cropping paddock, a designated sacrifice paddock or along a laneway without a prepared surface where feed is delivered to cows wither on the ground, in hay rings or in tractor tyres. Can be readily relocated to other sites on the farm.

Temporary feed-out area using an electric fence along a laneway

Basic feed-out area: Contains an area with a permanent compacted earthen feeding infrastructure shared by cows and vehicles which may be dry scraped. Can be relocated to another site on the farm (with effort) if necessary.

Basic feed-out area with portable feed troughs

Formed earthen feedpad: Will have a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall or cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures.

Formed earthen feedpad with concrete troughs

Concrete feedpad: Will either have separate drive and feed alleys or a combined drive and feed alley. The advantage of individual alleys is that there is no direct interaction between machinery and cattle, which is obviously preferred. This allows feed to be delivered or feed to be pushed-up at any time during the day (cattle will push feed away from the feeding table as they eat which requires pushing back to the feeding table). It also reduces spoilage and waste due to mud and manure.

Concrete feedpad with separate drive and feed alleys

Roofed feedpad: A common expansion phase for farms with concreted feedpads where herds spend considerable time supplementary feeding and standing off paddocks is the inclusion of some type of shade structures over the feeding table and loafing area to mitigate adverse weather, particularly during the cooler and wetter seasons and the hotter days throughout the summer period.

A range of shade structures typically used in the dairy industry include widespan corrugated iron roof, comprising a pitched roof with a central, open ridge vent in the roof apex to allow heat and humidity to escape, flat angled roofs, overlapping roofs, heavy duty membranes and large Fabritecture (fabric) shade sails.

Keeping cows cool and comfortable is critical to maintaining high feed intakes and high milk production.

Feedpad design and the selection of appropriate roofing can have a major influence on cow performance.

Concrete roofed feedpad with dry scrape feed alley

Cattle shelters: Dairy cattle shelters and calving sheds are becoming increasingly popular within the dairy industry to provide management flexibility with the herd and to mitigate seasonal climatic events, which can dramatically impact production. Typically, these shelters are primarily cow loafing facilities used to compliment grazing farms in regions where summer heat impacts production and animal welfare, whilst providing a much cooler environment for loafing and resting between milking and feeding. Cows are generally not confined to these shelters, having freedom to move outdoors for feeding and watering, or return to paddocks for grazing.

Woodchips and manure bedding with external troughs for feeding

Woodchips and manure bedding in a Redpath shelter

9.2 CONTAINED HOUSING OVERVIEW

Contained housing is an integrated facility for feeding and housing cattle and are typically used in intensive operations supported by total mixed ration feeding and involve zero grazing.

The main contained housing facility types are:

Dairy dry lot: An open, well-drained area with an earthen surface and a shade structure over part of the area, to protect animals from the sun and rain. A bedded area may be provided under the shade structure. These systems are most applicable in hot, arid climates with suitable soils that facilitate drainage. Manure accumulates on the floor of the area and is regularly mechanically tilled, then all manure removed at intervals of 1-6 months.

Loose housing: The key difference to a freestall is that the stalls and stall alleys are replaced with a bedded area of absorbent organic bedding including straw, wood chips or composted manure. These facilities are typically categorised by their management of the bedded area as a:

- Deep litter pack where absorbent organic bedding is added regularly to the bedded area, but there is no mechanical tilling; or
- Compost bedded pack that is mechanically tilled at least twice daily.

All bedding is usually removed at intervals of 6-12 months, then new absorbent organic bedding added back into the facility.

Loose housing facility with a deep litter pack

Loose housing facility with a compost bedded pack

Freestall: These can be open-air, partially or fully enclosed structures in which dairy cattle are housed. They can be used to house dairy cattle long term and include a bedding area for cattle to lie down, and possibly a loafing area for cattle to stand. The term 'freestall' refers to the bedding area where cattle are allocated specific cubicles (stalls), which they may enter to lie down. Feed and cow alleys, and bedding areas are cleaned regularly (usually daily) to maintain cow comfort and health. Freestalls can be classified by the number of 'stall' rows they contain.

Freestall with sand bedding

9.3 BEDDING OVERVIEW

The bedding system and type of bedding materials used in contained housing facilities impacts the design and management and therefore should be considered in the early planning stages.

When choosing a bedding system and type of bedding material it is important to consider the local climate, availability and price of bedding material, how the bedding will be managed on a daily basis, what interaction it will have with the effluent management system and how the waste bedding will be handled once removed from the housing. Bedding options are compared in Table 8.

Table 8. Comparison of bedding options

	Mattress	Waterbed	Sand	Dry manure solids	Sawdust	Other organic
Advantages	Minimal bedding No extra water to pump	Minimal bedding No extra water to pump Some cushion effect	Conforms to cow's body Standing/ Lying cushion Increased resting time Milk quality	Availability Easier to handle down stream of housing area	Availability Easier to handle down stream of housing area	Availability Easier to handle down stream of housing area
Concerns	Leg and hock injury Milk quality	Leg and hock injury Milk quality	Manure handling challenges Poor sand quality	Stall compaction if not groomed Rewetting from urine, humidity, water Airflow velocity vs dust	Lack of bedding depth Airflow velocity vs particle movement Moisture absorbed by bedding Udder contact with wet surface	Lack of bedding depth Airflow velocity vs particle movement Moisture absorbed by bedding Udder contact with wet surface
Manure handling	Solid Separation + Liquids	Solid Separation + Liquids	Sand Separation + Solid Separation + Liquids	Solid Separation + Liquids	Solid Separation + Liquids	Solid Separation + Liquids
Cow welfare	Leg and hock injury Perching in stalls due hard surface	Leg and hock injury Perching in stalls due hard surface	Leg and hock injury Perching in stalls due hard surface	Resting time if stalls become hard Air borne particulate matter when fans operating	Leg and hock injury Perching in stalls due hard surface	Leg and hock injury Perching in stalls due hard surface
Daily volume	Manure production + feed line soaker water	Manure production + feed line soaker water	Manure production + sand bedding + feed line soaker water	Manure production + manure bedding + feed line soaker water	Manure production + organic bedding + feed line soaker water	Manure production + organic bedding + feed line soaker water
Flush velocity and minimum alley slope	≥ 1.2m per minute 0.75%	≥ 1.2m per minute 0.75%	≥ 1.8m per minute 2.0%	≥ 1.2m per minute 1.0%	≥ 1.2m per minute 1.0%	≥ 1.2m per minute 1.0%
Water total solids if flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally additional water has to be added to the system if the sand is reclaimed. The total solids in flush or cleaning water should be <= 3 %. The volume of extra water required is dependent on performance of solid separation equipment	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing

Source: Adapted by James Green (Greencon) from table originally developed by Joe Harner (Professor, Kansas State University), Jake Martin (Consultant, JGMiii Dairy Design) and Dennis Armstrong (Professor Emeritus, University of Arizona), 2017

9.4 FEEDPAD DESIGN AND MANAGEMENT

A feedpad can be installed for a wide range of different uses and a range of different types have been described earlier in section 9.1 of this chapter. The final option chosen will depend on each individual site, the proposed feeding system and farm management.

Feedpad design should:

- allow for easy cow movements around the facility (i.e. resting, eating, drinking, exercising and milking)
- allow for regular manure removal
- provide adequate feeding table space
- provide easy access to the drive and feed alleys for vehicles.

The following section provides guidance on the design and management of feedpad facilities.

Temporary feed-out area

A temporary feed-out area can be set up in several ways:

- Running an electric wire along a laneway or along an irrigation check-bank
- Placing hay rings or old tractor tyres in a designated sacrifice paddock
- Simply running hay/silage mixed ration along the ground in a grazing paddock or a bare cropping paddock.

Site selection and set-up

The following factors are important for ensuring that cows are comfortable while using the temporary feed-out area:

- If setting up a sacrifice paddock, select a paddock which needs to be renovated anyway, has good drainage and provides trees for shade.
- Avoid a paddock near a roadway or waterway.
- If using a grazed paddock, select one that has good pasture cover and is not wet.
- Provide ready access to water troughs.
- Feed-out area per cow (general guidelines):
  - If cows are only on the feed-out area for a few hours a day (i.e. < 4 hours), an area of 3.5m^2/cow is adequate
  - If the patten of use of the feed-out area involves cow resting on it for up to 12 hours (i.e. the entire period between consecutive milkings), then at least 6m^2/cow is required.
  - If cows are to remain on the feed-out area constantly for several consecutive days (e.g. when paddocks are very wet or during hot weather), an area of 10-12m^2/cow is required.
- Avoid using the temporary feed-out area for too long, especially in wet conditions.
- Relocate to another site on the farm as soon as necessary.
- Feed can be placed directly on the ground, on rubber matting or in modular steel or concrete troughs.
- If feeding on bare ground, in ring feeders, old tractor tyres or under a fence line, it is recommended that:
  - Feed-out in dry conditions
  - Feeders used are large and deep enough to easily hold quantity of feed to be fed without spillage
  - Feeders are not being over-filled
  - Feeders have minimal residual feed in them after each feeding event
  - Feed space of cow width + extra 10-30% is provided to each cow
  - If using hay rings, adequate rings are provided so that no more than 20 cows share each ring.

Basic feed-out area and formed earthen feedpad

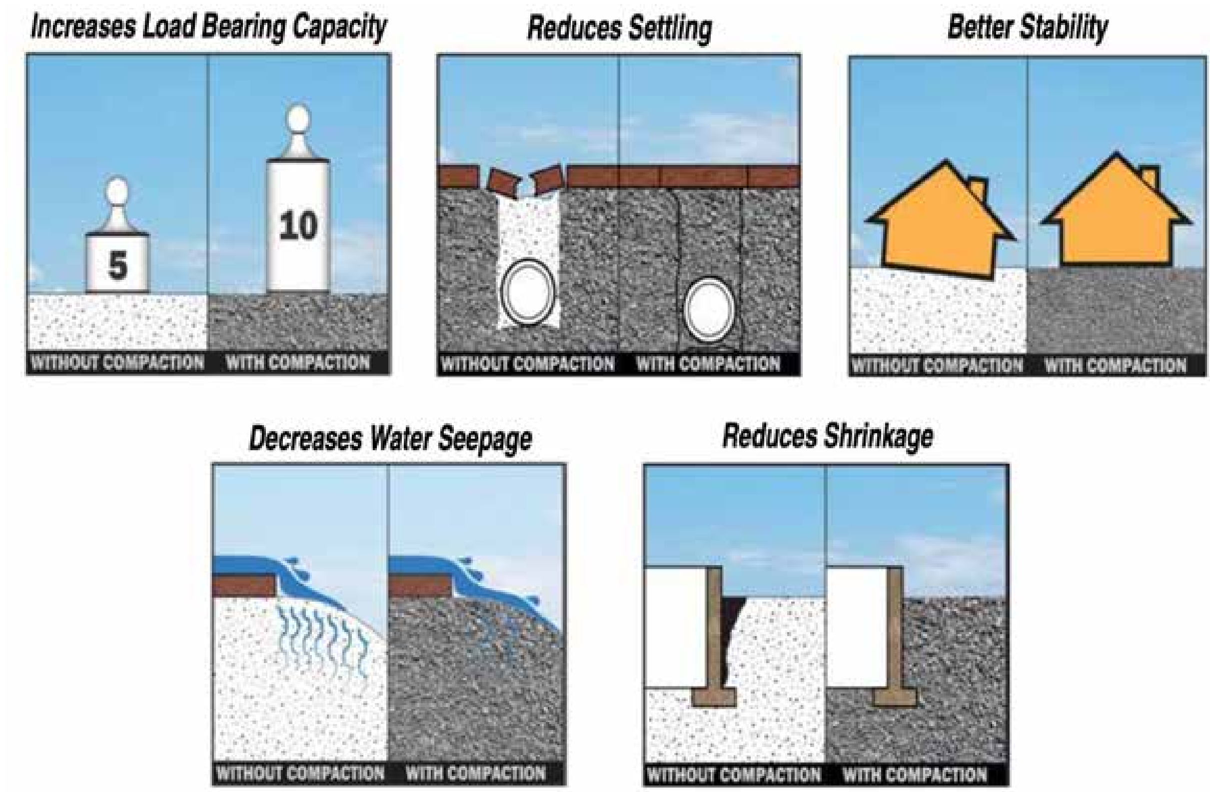
The lifespan of a basic feed-out area and formed earthen feedpad can be extended from just a few years to 20+ years if the following critical design factors are considered.

Surface material selected

The surface material for an earthen feedpad must be selected very carefully. It should be a uniformly blended mixture of coarse and fine aggregate (i.e. an evenly graded material) that is free from sharp stones, cobbles, stumps, roots, sticks etc. While gravel surfaces are more durable and can withstand higher loading, they are not as hoof friendly.

If the material on-site has low load-bearing strength because of an excess of clay, silt, or fine sand, adding a stabiliser such as hydrated lime or gypsum, or buying in a good quality material from a quarry, should be considered. Geosynthetics, which are thin, flexible, and permeable sheets of synthetic material used to stabilize soil, should also be considered. Cheap and resistant to moisture and bacteria, their filtration restricts movement of fine soil particles but allows some water to permeate. They also reinforce and stabilize soil to decrease compaction by stock.

Figure 18. Effects of compaction



Compaction of material

Compaction of the material is necessary to increase its dry density and therefore its load-bearing capacity, durability, and water permeability. This is achieved with a vibrating or compression roller (as used in road construction).

Figure 18 illustrates the importance of a well compacted surface in terms of loadbearing capacity, settling, stability, water seepage and shrinkage.

Each material has an optimal moisture content for maximising dry density with compaction (Figure 19). This is achieved with a water truck as used in road construction. The variation in optimal moisture contents between different materials (i.e. products CL, ML, SM etc.) is illustrated in Figure 20.

Figure 19. Optimal moisture content for dry density of a material

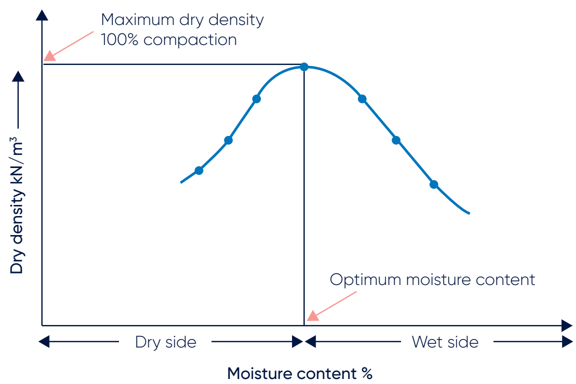
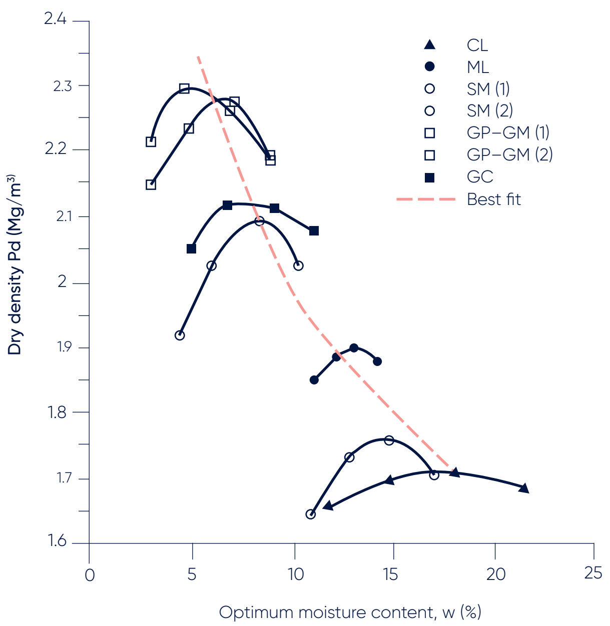


Figure 20. Optimal moisture contents of several materials



Thickness

Ensure that the surface layers of the feed pen and roadway are thick enough to spread the load of cow and vehicle traffic so that the underlying subgrade is not stressed. These thicknesses will depend on the load-bearing strength of the material used, the strength of the foundations, drainage and expected load of both cows and vehicles. A thickness of between 150–360mm may be required for feed pens and between 200–670mm for roadways (MLA, 2016).

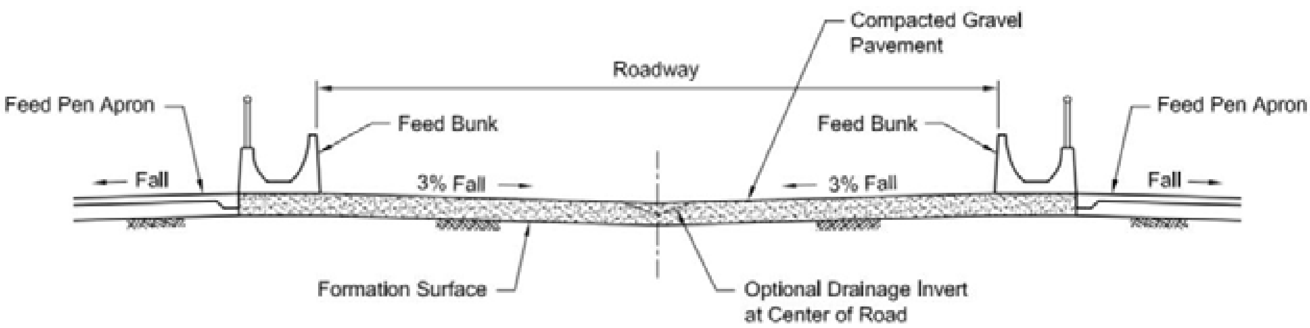
Contours

The pad needs to be contoured with sufficiently angled slopes (3–5%) to carry manure and run-off away from the feeding table. Sub-surface drainage using slotted drainage pipes 1.5–2.0m apart should be overlaid by 20cm gravel (Figure 21).

Gradient

A formed earthen surface needs a gradient of at least 1:500 (0.2 per cent). However, operating experience shows it is better to aim for slopes in the 2 to 4 per cent range.

Figure 21. Feedpad with contours for a central feed alley and pen aprons on either side



Concrete and roofed feedpad

The main design principles used for a concrete feedpad can be applied to contained housing facilities (i.e. freestalls and loose housing) and are therefore incorporated in section 9.10 of these guidelines.

A concrete feedpad usually consists of a concrete pad located adjacent to the dairy of the main farm laneway. The pad generally consists of a concrete feed alley that is used by vehicles for delivering feed (drive alley) and a separate alley that cattle stand on whilst feeding (feed alley).

The surface of the actual feedpad should be designed to provide sufficient slope to contribute to effective drainage and to prevent surface wastewater reaching the subsoil. The pad should be elevated to facilitate fall with a recommended longitudinal slope of 0.5-3 per cent (i.e. along the entire pad length. The pad should be sloped away from feed and drink facilities. Pad slope and surface must facilitate safe purchase of cow hooves.

Dairy producers are required to manage manure and recycled effluent to avoid adverse impacts from odour and dust, prevent the pollution of ground and surface waters and land, and to provide a safe working environment for staff and contractors. Accumulated manure can either be scraped or vacuumed from the alleys; or flood washed into a containment sump or pond.

A poorly designed and/or managed feedpad may result in potential issues such as:

- runoff from the site, which can lead to surface or subsurface water contamination
- muddy surfaces, especially in wet conditions, which can lead to increased incidence of mastitis
- dust, especially in dry conditions
- excessive odour and or noise
- spilt feed can result in increased bird numbers and unwanted defecation by the birds on nearby residences
- increased animal health issues such as pinkeye.

Key construction, cleaning and maintenance guidelines:

- Regularly monitor stock for animal health concerns, such as pinkeye and mastitis.
- Ensure safe and easy access for animals, vehicles and farm workers around the pad to meet with occupational health and safety needs.
- Provide adequate spacing for loafing, recommended 9m2/cow short term durations or 15m^2 long term.
- When constructing, use appropriate surface and subsurface materials which will increase the longevity of the pad and allow for effective drainage.
- Effective drainage is important to deal with wet conditions plus allow all weather access. Dairy feedpad surfaces should provide sufficient slope for effective drainage. A concrete surface can drain at a slope of 1:2000 (0.5 per cent) or even shallower if smooth. However, operating experience shows it is better to aim for slopes in the 2 to 4 per cent range.
- Good collection and harvesting of manure and spilt feed is important and should be scraped or removed from the pad, stockpiled and stored on an impervious surface and well bunded structure (e.g. concrete or a compacted earthen pad with drainage to the effluent system). It can then be applied appropriately to paddocks as a source of fertiliser.
- Use harvested manure and effluent on crops and pastures.
- The right design and proper maintenance will help to protect ground water from contamination from leaching down the soil profile, and from runoff of effluent.

Plan with the future in mind

When designing and building a feedpad, there are a number of important considerations to ensure it can be further developed in the future. If this is not done, a farm may find itself a few years down the track having to construct a new feedpad from scratch at another site on the farm to meet its needs (with many costs being incurred again). Planning with future expansion in mind will allow an effectively sited feedpad to be retrofitted into a contained housing facility using a process of a staged development.

Site the feedpad so that it can be expanded in the future. Select a site which provides:

- Scope to expand the feedpad's area and further develop the effluent system
- Easy vehicle access
- Easy cow access to the dairy and main laneways
- Easy access to feed storing and mixing facilities
- Good access to stock water and power
- Good drainage, and minimal risk of generating excessive odour, dust and noise.

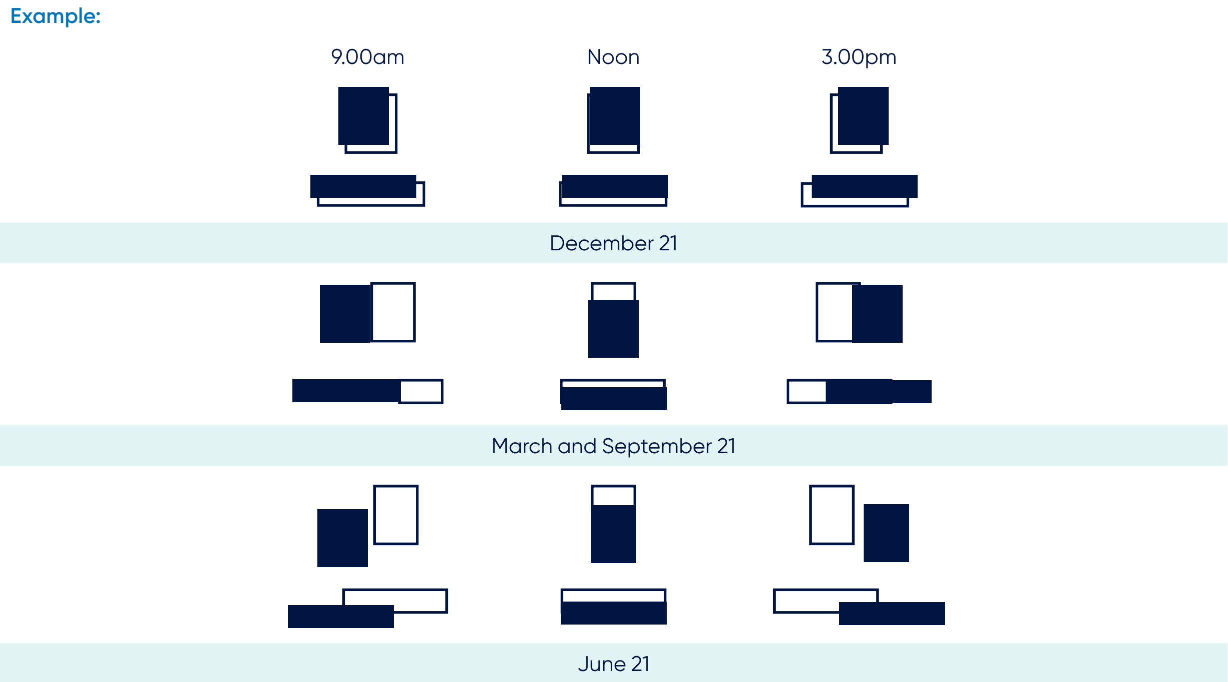
Consider feedpad orientation

Careful consideration should be paid to the orientation of a feedpad. Formed earthen feedpads with roof structures are well suited to a north-south orientation because the sun strikes every part of the floor area under and on either side of the roof at some time during the day. This helps keep the floored area dry and restricts pathogen build up.

However, with a concrete feedpad with a roof over it, an east-west orientation is ideal from a heat stress management, viewpoint, because provided the roof is wide enough, it will ensure that the feed table and water troughs are shaded at all times (Figure 22).

Given the effort and cost to re-orient a feedpad, whether a roof will be placed over the feedpad initially or at some later stage should be carefully considered, when deciding in which direction to orient the feedpad.

Figure 22. Shed profiles at 9am, noon and 3pm at four different times of the year



9.5 CATTLE SHELTER DESIGN AND MANAGEMENT

Farms with flatter low-lying topography, often have herd management issues over the wetter winter months maintaining milk quality and minimising damage to pastures and laneways. Moving away from the traditional earthen stock containment areas or sacrifice paddocks, these shelters provide a more sustainable environment to contain the herd temporarily until conditions improve enabling the herd to return to paddocks.

Similar to the contained housing options the type of bedding material used and the overall management is critical for cow comfort as well as consideration for rainfall collection off roofing to minimise water pooling and pugging of the areas around the facility.

Cattle shelters are often standalone facilities with just bedding material, allowing the herd to seek shelter and provide loafing and resting space, while feeding and watering infrastructure are sited a short distance away to encourage cows to disperse and prevent congregation around the shelter.

The other common approach is incorporating troughs and a concrete apron along the outer perimeter of the shedding to accommodate loafing on the inside and more convenient feeding with feed equipment not having to enter the facility. A more openly spaced bedding area allows easier management, without having to navigate posts and concrete alleys.

The type of cattle shelter can range from shade sails, plastic membranes (Figure 23) or corrugated roofing depending on the region's climatic conditions and the farm's requirements.

Figure 23. Redpath clear roofed deep litter shelter. Redpath shelters are steel framed with a flexible clear roof (polythene) membrane

9.6 DAIRY DRY LOT DESIGN AND MANAGEMENT

Dairy dry lots are generally more successful in dry climates. Constructed with the correct slope for drainage to a centralised manure system, a well-managed dairy dry lot provides cows with a comfortable, low stress environment. Feeding areas may be fitted with cooling infrastructure such as misters to make sure cows stay cool on hot days. Cows have freedom to lie down and rest and move around and socialise. Dairy dry lots are thought to be advantageous, in comparison to other intensive housed systems (e.g. freestall) because of lower disease prevalence (e.g. lameness and mastitis), better reproductive outcomes and lower capital costs.

Factors which impact on cows' lying time and general level of comfort are:

- Access to shade
- Bedding and management
- Dairy dry lot layout

Access to shade

Shade is important to protect cows from direct exposure to radiant heat and rain. Ideally, shade structures should be constructed parallel to the feed table and cow alleys in the centre of pens so that cattle can follow the shaded area as it moves across the pen during the day. The orientation of a shade structure should be north-south with the eastern side of the structure elevated to provide a 10–15° pitch (Figure 24). This allows better pen floor drying during the morning, provides more shade area during the afternoon and increases air flow under the shade structure.

Shade roofs should be steel clad with a minimum height of 3.6m from the ground. The installation of gutters is recommended on shades structures to remove water from the pens to allow the earthen surface to dry quicker after inclement weather. The total area of shade recommended is 4.6m^2 per cow. Cooling measures such as fans and water misters may be used beneath the shade.

Figure 24. Centralised shade shelters at a dairy dry lot with a north-south orientation

Bedding and management

The bedding in dairy dry lot shelters can be non-composting bedding packs, composting bedding packs, or packs that only actively compost occasionally. The pack needs to be managed to provide cows with a comfortable, dry bedding surface (Figure 25). The pack relies on an aerobic process to decompose cow waste (manure and urine) in the bedding. Tilling at least twice a day is generally recommended and can be timed when the cows are being milked. If possible, cows should be kept off the pack for at least an hour after tilling to enable the top layer to dry, especially during winter.

Regular mechanical tillering fluffs up the bedding and encourages the composting process drying the pack and killing some pathogens, viruses and fly larvae. A loose fluffy pack is a good indicator of a well-managed pack, especially if it feels warm below the surface, as it is aerated ad the microbes are active and generating heat. Conversely, a compacted, cool pack results in chunky bedding indicating the pack is not well composted (Figure 26).

Figure 25. A well-managed compost bedding pack provides cows with a comfortable, dry bedding surface

Figure 26. A compost bedding pack that is not well managed – over crowding results in a wet chunky, cold bedding surface

Dry lot layout

Sound design ensures optimum animal performance, good animal welfare and high standards of environmental performance (Figures 27 and 28).

Key considerations of well-designed pen layouts:

- Pens are constructed with 2-4% side slope and 0.5-1% down slope. Pens with a double slope are ideal with the shade located at the high point of the pen. Pen slopes less than 2% do not drain well and can emit odour at 50 to 100 times the rate of dry pen surfaces. Wet patches also lead to discomfort of cows.
- Proper site drainage design. Construction of dairy dry lot so water drains outside of the pens in ideal. The slope of the pen will have a dramatic impact on how fast the earthen surface will dry (Smith *et al.* 2006).
- There should be 45 to 50m^2 of net space per cow in the dry lot if feed lane manure is scraped or flushed out of the system. If feed lane manure is scraped into the lot, then net space per cow should be increased to 60m^2 or higher (Jake Martin, Pers. Comm.).
- Feed table and feed alley design is as for a freestall with a north-south orientation in parallel to the shade structures. If sprinklers are used at the feed table, it is important that a nib wall is installed, and the alley is sloped towards to the feed table to prevent runoff from the sprinklers reaching the earthen surface of the pen.
- Wind breaks can improve cow comfort where the potential for severe weather exists.
- Water troughs design and specification is as for a freestall. Water troughs should allow dairy cows access to an adequate supply of good quality water for their survival, welfare and performance without causing environmental impacts on the feedlot. The water trough system should:
  - Provide clean, cool, fresh water at an adequate volume of water to livestock
  - Provide sufficient access area to enable all cattle to drink regularly
  - Allow for easy and regular cleaning inside the trough
  - Not cause wet areas or drainage problems in pens or lead to pen maintenance issues.

Figure 27. Aerial image of a well-designed dairy dry lot with north-south shade structures and central feeding table

Figure 28. A leaking trough will cause drainage problems on the earthen dry lot pen

9.7 LOOSE HOUSING DESIGN AND MANAGEMENT

Deep litter pack

This type of loose housing facility requires less specialised operational knowledge or pack maintenance, when compared with a compost bedded pack loose housing facility. A deep litter pack, if managed well, generally achieves better cow comfort, in comparison to a freestall, with very high lying times. They can accommodate different sized animals, have higher oestrous detection rates, and have lower levels of lameness (with the exception of white line separation and heal ulcers in heifers reported in some studies) and have a lower capital cost.

The reduced capital cost to build a deep litter pack loose housing facility compared with a freestall can make this an attractive housing option however, the quantity and cost of bedding material and the cost of managing the bedding material on a daily basis also needs to be considered.

Design

Loose housing facilities with a deep litter pack are generally covered yards with bedding added daily to absorb urine and faeces. Sufficient bedding must be added to keep animals clean and dry. Fresh dry straw is added daily to a bed and this remains unturned. The straw accumulates in layers over a period before removal and replacement. The layers compact, become moist and decompose, removing oxygen from the bed, leading to an anaerobic fermentation. Sand bedded areas have also been used successfully, where wet contaminated sand is removed daily and fresh sand added weekly.

Loose housing facilities with a deep litter pack can be built with or without feed bunks and concrete alleyways, depending on their use and other facilities that are available. These systems become difficult to manage on a large scale (> 70 cows) and many converted sheds with low roofs may result in bedding becoming too deep inhibiting removal of soiled bedding with machinery. Poor ventilation can also be an issue in some facilities as well as mastitis, lameness and respiratory disease.

The preferred design for anaerobic packs is to allow drainage of moisture away from the surface. Concrete can be used, sloped to facilitate drainage to the feed alley to prevent liquid collecting low corners of the bed. A drainage pipe covered with single size aggregate gravel is an expensive option requiring annual or periodic maintenance, but these systems will use less bedding due to the lower moisture content.

Similar to other contained housing facilities, good ventilation is necessary to ensure cow health, aid in pack drying and reduce odour.

High eaves are necessary to facilitate natural ventilation in loose housing facilities. Loose housing facilities with a deep litter pack require a 4,500mm side eave in cool climates and 5,000 to 5,500mm side eaves in hot climates.

A bedding retainer (nib wall or plinth) in this type of loose housing facility should be typically a 250mm high and 200mm wide concrete kerb, rounded at the edges. The retainer allows access to the bed along the length, thereby reducing the damage caused by cow movement on and off the bedded area.

Bedded area management

A deep litter pack requires intensive management and large amounts of bedding material to be effective. An upper layer moisture content of <15 per cent is required in the pack to maintain cow cleanliness, low cell counts, cow health and to maximise cow comfort. To maintain this environment, with anaerobic fermentation, straw or similar organic bedding is added to the bedded area daily at a rate of approximately 12kg bedding per cow per day (Figure 29). Bedding use may be reduced through removal of manure from the pack area and feed alleys and water areas. After a period of 4-6 weeks all bedding is removed, and the process repeated.

Figure 29. Organic bedding added to a loose housing facility with a deep litter pack

Spacing

Space per cow is essential. Cows constantly add manure and urine to the deep litter pack (this is exasperated with higher yielding, larger cows). Greater cow density also increases pack compaction. More space per cow reduces the use and costs of bedding. A minimum of $12m^2$ of pack space per cow is recommended for lactating Holstein cows to achieve better cow comfort, with very high lying times.

Figure 30. Deep litter pack – low bed retaining curb, water troughs, access from feed alley only

Compost bedded pack

Loose housing facilities with a compost bedded pack do not include the stalls and partitions found in freestalls. These consist of a large, open resting area, usually bedded with sawdust or dry, fine wood shavings and manure composted into place and mechanically stirred on a regular basis to aerate the pack. This design however does require a larger overall footprint, expert pack management as well as more bedding requirements compared to loose housing facilities with a deep litter pack or freestall.

The difference between a compost bedded pack and a deep litter pack is that the composting process is an actively managed process adding oxygen to bedding materials by stirring 2-3 times daily using various types of cultivators or roto tillers. Composting creates heat that dries the bedding material, which provides the cows a clean, dry place to lie down. This keeps cows clean, with no increase in clinical mastitis levels (Figure 31).

Figure 31. Properly managed compost bedded packs providing a dry resting surface is important for herd health

Cows housed in loose housing facilities with a compost bedded pack benefit from increased area to rest and exercise compared to a freestall (Figure 32). When working effectively, these barns have the potential to improve cows' comfort, hoof health and milk yields. Heat detection is also easier in a compost bedded pack. Other benefits claimed by operators include increased longevity, less odour, fewer flies, less concern with cow size, ease of manure handling and improved manure value (Figure 33). Compost bedded packs also minimise the time cows stand on concrete.

Figure 33. Cows have more freedom of movement on a composted bedded pack being able to lie down and get up without restrictions

Facility design, ventilation, timely addition of fresh, dry bedding, frequent and deep stirring, and avoidance of overcrowding are the keys to a good working compost bedded pack. Loose housing facilities with a compost bedded pack are not for everyone. The risk for mismanagement is higher for a compost bedded pack than for a freestall. Ignoring the basic principles of compost management may lead to very undesirable compost bed conditions, dirty cows, elevated somatic cell counts, increased clinical mastitis incidence, and increased digital dermatitis.

Figure 32. Compared to freestall facilities compost bedded packs allow animals choice when resting

Design and layout

Most newly constructed loose housing facilities with a compost bedded pack are built by modifying existing designs for two-, three-, or four-row freestalls. This allows flexibility for converting to a freestall later by adding concrete alleys, freestall platforms, dividers, and waterers. These modifications allow flexibility in case the producers find the facility does not meet their needs or a changing market in bedding supply makes modifications necessary

While a number of different barn designs exist, a suggested layout is illustrated in (Figure 34). This single structure includes the open compost bedded area with a concrete feed alley for access to the feedbunk and waterers. The bedded pack is surrounded on all sides by bedding retainer walls, including a wall to separate the bedded pack from the feed alley. The layout has two access points to the bedded pack, a drive alley. Waterers are against the concrete wall, separating the bedded pack from the feed alley. They are accessed from the feed alley only.

- **Bedded area** should be rectangular, with the longest side adjacent to the feed alley, and divided lengthwise to create a 4-5m wide concrete apron next to the feeding table, and a bedding area typically no more than 9 to 11m wide. With flexibility in mind, the width of the bedded area should be designed to equal the width of two rows of freestalls and a stall alley, so it can be converted later if desired.
- **Bedding retaining walls** 0.6 to 0.75m surround the perimeter of the bedded pack to keep bedding material in the barn. These walls are usually precast or cast-in-place concrete, designed and specified to withstand the considerable forces that the compost pack puts on them as it builds up. The bedding must be contained so it does not drift into the feed alley by the use of a bedding retainer (Figures 35 and 36). The size and shape of this depends on the type of bedded area being constructed. To prevent cows from walking over the wall adjacent to the feed alley when bedding has built up over time, steel post and rail fence is recommended along the top of the wall (Figure 37).

Figure 34. Typical loose housing compost bedded pack facility layout (not drawn to scale)

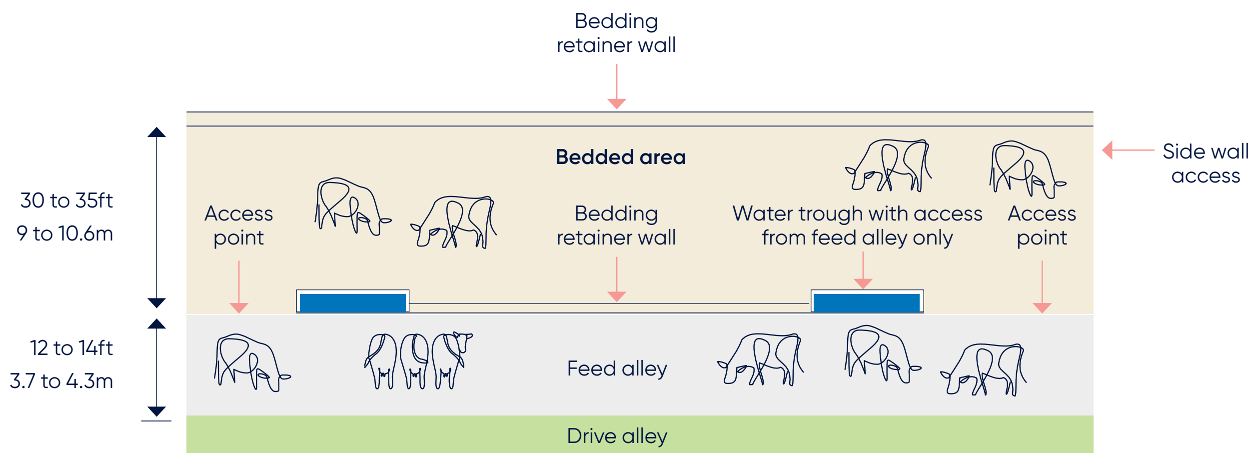


Figure 35. Concrete retaining walls provide separation between the feed alley and the bedded pack area which is helpful in managing pack moisture

Figure 36. A retaining wall separating the bedding pack and feed alley reduces bedding drift. Monitor the bedding pack height

Figure 37. Compost bedded pack – high retaining walls, barriers stop cows climbing over wall if bed is full

- **Access points** to the bedded pack should be located every 15 metres and at each end. Cows will generally use the resting space provided more efficiently when they have multiple entry access points along the long side of the rectangular bedded area. Limiting access points may result in the development of wet areas because of increased cow traffic. The effective resting area will be reduced because cows avoid this are of the pack when resting.
- The **floor** beneath the bedded area should be an impermeable material of at least 600mm in thickness (permeability must be less than 1×10^{-9} metres per second).
- **Water troughs** should only be accessible from the feed alley with a wall built around to limit access from the bedded pack side and to prevent splash from entering the bedded area. When cows can access waterers, the areas around the waterer are generally wet and bacteria-laden. The increased moisture from waterers and cow congregation impair compost success. Alley-only access minimises excess moisture in the pack and keeps water cleaner. It also eliminates the need to alter water trough height as the pack depth changes (Figure 38).

Figure 38. Adequate water access is critical without allowing access from the pack.

- **Feeding table** space, design and feed barrier (post and rail or head locks) as per in a freestall (see section 9.10) (see Figure 39).
- **Sidewall access** to machinery for pack filling, tilling and removal.
- **Wide eaves** to minimise rain reaching the pack and roof gutters to prevent water running off roof and blowing into the barn onto pack. A 900 to 1,800mm eave overhang is recommended (Figure 40).

Figure 39. Feeding table, feed barrier (post and rail) in a loose housing facility with a compost bedded pack

Figure 40. Eave overhangs can help minimise the amount of wind, precipitation, and sunlight entering the barn

- **Ventilation** is essential to remove heat and moisture created by cows and the composting process. Proper ventilation generally includes natural air movement through the barn, but mechanical ventilation (fans), can also be used to prevent stagnant areas (Figure 41). Fans must be hung high enough to avoid equipment operating in the bedding area. As a guide, use 3,600mm plus the expected bedding height for clearance. High open sidewalls maximise cross ventilation. A minimum 5,000mm opening should remain between the top of the retaining wall and the bottom of the barn eave. Refer to section 9.9 for additional ventilation and cooling requirements.
- **Barn orientation** has a significant impact on the natural light patterns.

A facility with a compost bedded pack should be oriented east-west as it allows the least sunlight penetration into a barn.

Figure 41. Mechanical ventilation (fans) – fans hung high enough to avoid equipment operating in bedding area

- With an east-west orientation, the sun moves over the top of the barn through the day. With a north-south orientation, the sun moves over the broader sides of the barn, which creates more light intensity in areas where the cows rest or eat. During heat stress conditions, cows will move away from areas with more light and move toward darker parts of the barn resulting in cow bunching behaviour. In extreme situations, cows may only use 10 to 20% of provided space.
- East-west barn orientation also takes advantage of prevailing southerly, summer winds. Prevailing winds can be regional or site specific due to the local terrain and barn position within the landscape. Under these situations, the barn should ideally be oriented so the prevailing summer wind is perpendicular to the longitudinal sidewall to allow for adequate ventilation. Under these circumstances an extension of the roof eave may be required to reduce afternoon sunlight from entering the facility.
- **Resting space per cow:** A guide for determining a size for a compost bedding pack barn is in Table 9. Additional space increases cows' lying time per day.

Typical mature Holstein cows require a minimum of 12m^2 of bedded space per cow, while Jerseys require a minimum of 10m^2.

Pack space per cow needs to be increased 1m^2 for each 11 kg/day of increased milk production above 22 kg/day because these cows will produce more urine and manure due to more food and water intake. In facilities for special needs cows including maternity areas, producers should provide 14m^2 of resting space.

Table 9. Calculating loose housing, compost bedded dimensions

Step	Calculation		Formula	Example inputs*		Example answer
1	Required Pack Area	=	RC x NC	12 x 100	=	1,200 sq m
2	Barn Length	=	(MC x NC)/100	(60 x 100)/100	=	60m
3	Pack Width	=	RPA/BL	1,200/60	=	20m
4	Total Barn Width	=	PW + FAW + EW	20 + 5 + 0.3	=	25.3m
5	Total Barn Area	=	TBW X BL	25.3 x 60	=	1,518 sq m

KEY:

BL = barn length	EW = exterior walls	FAW = feed alley width
MC = manger space/cow	NC = no. of cows	PW = pack width
RC = resting space/cow	RPA = required pack area	TBW =total barn width

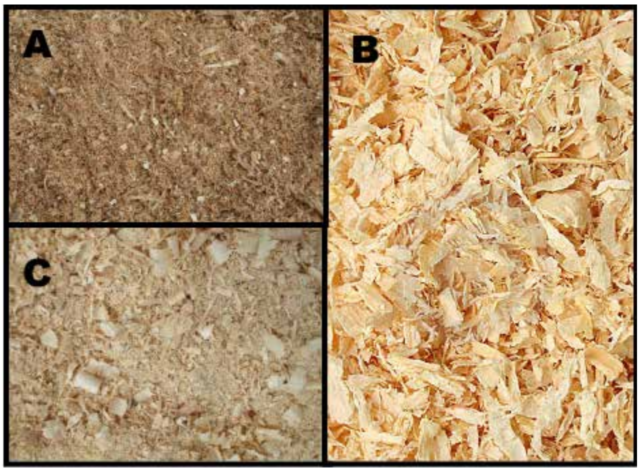
**Recommendations: RC = 12 sq m/cow, MC = 60cm/row, FAW = 5m, EW = 0.3m.*

The most common cause of compact bedded pack failure is overstocking. Providing less than 12m^2 of resting space per cow can lead to serious problems as the amount of moisture deposited through urine and manure is too much to overcome increasing the pack's moisture content and slowing the composting process. Increased pack moisture content causes the bedding to become more compacted, reducing airflow in the pack. The incidence of environmental mastitis may also increase because of the amount of faecal contamination.

Bedding material: Several bedding materials have been used in compost bedded packs. However, dry, fine wood shavings or sawdust are considered the gold standards for compost bedded pack barn bedding (Figure 42). Even when mixed with shavings, sawdust has enough structure to be able to be easily stirred and remain fluffy enough to ensure oxygen transfer within the bedding material. Sawdust provides a large surface area to volume ratio, is easier to till and absorbs liquids well.

Kiln-dried sawdust performs well as long as the dry matter is 88% or more. Green sawdust is generally wet and may harbour Klebsiella bacteria and more bedding is required to maintain the composting process.

Figure 42. Sawdust from (A) sawn wood, (B) planed wood, (C) mixture



Woodchips are less desirable than sawdust and wood shavings as they hold less water due to their lower surface area/volume ratio. If they have sharp edges, they may also injure cows.

Keys to management

As with any facility, the success of a compost bedded pack barn hinges largely on how well it is managed. Maintaining proper aeration and stocking density are fundamental. When the pack is stirred frequently and uniformly, the manure and urine from the surface are stirred into the pack while oxygen and moisture are incorporated. The result is better heating and aerobic decomposition of organic material.

The Compost Process: A composted bedded pack is managed very differently from a deep litter pack, requiring significant attention to bed management. A successfully managed compost bed will appear dry and fluffy (Figure 43), while one that is not, will appear wet and chunky (Figure 44).

REASONS TO COMPOST vs DEEP LITTER

- Use lees bedding/cost savings
- Less frequent cleanout
- Reduction in volume of material to remove
- More nutrient dense material for application to cropping areas
- Retains more nitrogen
- Odour reduction
- Fly reduction

Composting relies on aerobic microorganisms to break down organic matter and produce carbon dioxide, water, and heat. In a compost bedded pack barn, the manure and urine released by cattle and the added bedding provide the essential nutrients (carbon, nitrogen, moisture, and microorganisms) needed for the composting process.

Composting is an aerobic process. The continuous introduction of oxygen (air), carbon and nitrogen (through manure) and moisture control (new bedding) is required for success. In a compost bedded pack barn, the oxygen comes from stirring (aerating) the bedding and from the air that diffuses into the bedding surface, which should be fluffy to encourage the air infiltration. How well the compost bedded pack works depends on maintaining the appropriate balance of carbon, nitrogen, oxygen, moisture, temperature, and microbial activity populations. When the proportions of bedding, cow stocking density, oxygen, and moisture are optimally balanced, the microorganism population will thrive and produce sufficient heat to dry the pack and maintain active aerobic bacteria to continue the composting process. This may result in reduction of pathogens, fly larvae, and weed seeds. When the compost pack is working well, the pack surface will appear dry and fluffy (Figure 43). However, when the pack is not working well, the surface appears wet and chunky (Figure 44).

Figure 43. A well-managed compost bedded pack looks dry and fluffy

Figure 44. When the compost process is not working the pack surface will appear wet and chunky

The temperature of the pack provides a good indication of the level of microbial activity. Temperatures near the surface of the pack are closer to the air temperature because moisture, evaporation, and air movement dissipate heat. The bedding surface-temperature under a resting cow will rise, however. The ideal pack temperature goal, measured at approximately 15 to 30cm below the surface, is between 43 and 60°C (Figure 45). When temperatures exceed 66°C, surface temperatures may increase to the point where cows do not want to lie down on the pack. A temperature in that range indicates that organic materials are breaking down rapidly. When the temperature is lower, the composting process is too slow, often because inadequate oxygen from stirring, too high moisture, or high heat loss during the winter. When it is above this range, the beneficial aerobic bacteria are killed.

Figure 45. Frequent measurement of temperature with a long probe is important for monitoring compost success and understanding

A: Example of compost heating well with high temperature and dry material – forms loose ball

B: Example of compost that is too wet with insufficient temperature – forms firm ball with water drops

C: Example of compost that is too dry with insufficient temperature – will not form ball

Temperatures can be measured with a long cooking thermometer. If a thermometer is not available, you can feel the material (at 30cm beneath the surface) with your bare hands. If the pack is hot almost to the point that you do not want to touch it, the temperature is likely high enough (> 43°C). Above 55°C you will not be able hold at all. Particularly in the morning, compost that is heating properly may even produce steam. This is not always a good indicator – it just means that the temperature of the bed is warmer than ambient.

Manure, urine, and microbial activity produce a pack's source of moisture, which ideally should be between 45 to 55% but an operating range that can still have significant activity for success is 40 and 60%. When moisture is too low, the microbes will not have enough water, and the compost will be too cool, resulting in a compost rate that is too slow. If the moisture level is too high, the pack becomes anaerobic (lacking oxygen); the rate of microbial decomposition will slow; and again, composting and heat generation will be too slow.

As a simple moisture check, grab a handful of bedding and squeeze it. If you can squeeze water out or if water droplets drip from or appear on the surface of squeezed bedding, the pack is too wet. This is a sign that new dry bedding should be added to the pack. If you cannot form a loose ball that easily falls apart, the pack is too dry. This condition may actually occur when bedding is added too frequently. When the pack is working well, the bedding material will appear loose and fluffy, not compacted and chunky.

Generally, temperatures are higher when the pack is fluffy because air promotes microbial activity. When the pack is compacted and has excessive moisture, you will see reduced temperatures. Moreover, when moisture is excessive, the bedding and manure then will more readily stick to the cow's hide and udder then you will see temperatures falling out of the ideal temperature range.

Excessively high temperatures in the compost bed (more than 65°C) occur when there is high microbial activity due to the presence of easily digestible organic matter and moisture is near the low end of the optimal range. Under these conditions, the pack does not have enough water for evaporative cooling. Lack of water may occur when cow density is low, when air movement dries the pack more quickly, or in warm, dry weather.

Ideally, the Carbon:Nitrogen (C:N) ratio for a peak composting rate needs to be between 25:1 and 30:1. New bedding material, besides absorbing water, will also aid in achieving this ratio. If you can smell ammonia in the barn, the C:N ratio is likely below 25:1.

Compost bed start-up in a new barn or after barn cleanout requires 300 to 500mm of dry bedding to be applied to the barn floor. Depending upon barn size, cow numbers, and pack area, several semi-loads of sawdust may be required to start the pack. Make sure to add enough sawdust so that the mixing equipment does not encounter the barn floor. Starting a new bed should occur when 4 to 6 weeks of weather with highs generally above 10°C are expected. Ideally, the new compost should be started so that heat generation rate reaches a peak before the arrival of cooler temperatures. Not achieving an actively composting bed going into winter may result in low heat production that does not overcome the heat losses and poor bed performance results throughout the winter.

Compost cleanout: The pack depth may reach 1 m before cleaning depending on sawdust used and composting intensity. Most producers return 15 to 30 cm of old material to help start microbial activity in the new pack. If it is possible to conserve the top layer of the old compost bed, this is the most active, acclimated microorganisms to continue the composting process in the new bed.

It is possible to allow the composting process to continue and be completed by stockpiling material after the pack is cleaned out. This dry composted mater can then be mixed with new sawdust to stretch the sawdust supply for new bedding.

Bedding stirring/aeration: Uniform stirring and mixing provide a clean, soft, dry surface upon which the cows lie. The compost bedded pack should be aerated to at least 30cm at least twice daily during milking while the cows are out of the barn. This reduces the risk of respiratory disease from the dust created. Workers should also wear personal protective equipment (PPE). Some producers plow the pack twice during each stirring event, both lengthwise and crosswise, to further increase aeration. Periodic deep stirring, up to 45 cm, with a chisel plow reduces the amount of bedding you will need and increase pack temperatures.

If possible, cows should be kept off the pack for at least an hour after stirring to allow the top layer of bedding to dry (especially during the winter). Running fans after stirring helps dry the surface throughout the year, not just during warmer conditions. Packs should be stirred as soon as new bedding is added.

Equipment: A variety of methods is used to stir compost bedding. Most producers use a cultivator or tines attached to a skid steer or small tractor (Figures 46–47). The depth of tilling varies, depending on the operator and the equipment used, but 18-30cm is typical. Fixed tine tillers generally have a deeper penetration (25-30cm). However, best results are observed with specialized roto-tillers that reach at least 30-45cm deep (Figure 48). These types of equipment provide deep tillage but also break apart clumps of material, where there is no internal moisture, very well.

Figure 46. Most compost bedded packs are tilled twice daily with a field cultivator. Many different types of tillage implements have been used successfully

Figure 47. Sweeps or shovels may be added to tillage implement tines to provide more effective stirring. This is a cheap and effective addition to existing implements

Figure 48. Roto-tillers may be used and are helpful to break up clumps of bedding material and maximize oxygen/air infiltration into the pack providing a uniform mix of material

It is important to breakup tractor tracks by positioning mixing tools to follow the tires. If heavy equipment is used, wheel tracks will not be broken up; also, if the pack is too wet, the pack may become compacted, limiting oxygen and causing lower temperatures (Figure 49). Compaction prevents air infiltration into the pack, which is needed by composting bacteria. Compaction also leads to higher bed moisture and thus inadequate aeration.

Figure 49. Compaction of material may occur when heavy tractors are used to stir the pack or when implements are pushed rather than pulled

Addition of bedding material: To check pack moisture grab a handful of bedding and squeeze it. If you can form a tight ball, squeeze water out or if water droplets drip from or appear on the surface of squeezed bedding, the pack is too wet. New bedding (10 to 20 cm) is added to the pack before the moisture increases to the point where the tight ball is formed. Response of the bedding addition will be a higher temperature and lower moisture content within 24 to 48 hours, depending on how high the moisture content is above 60%. Waiting until bedding starts to stick may be too late.

The frequency of adding bedding depends on how much evaporation occurs, how much manure and urine are introduced, season, ambient temperature, and ambient humidity. Generally, the new bedding is added every one to six weeks (more frequently when humid and wet in winter). Some producers add smaller amounts of bedding more frequently. More bedding may be used during humid or wet weather or if the barn is overcrowded. When using green sawdust, more bedding will be used since it will not absorb as much moisture as kiln-dried sawdust.

Moisture control of bedding in the 40-60% range and twice-daily bed stirring are critical for success. The compost bed can get out of balance if management does not recognise poor moisture conditions before temperatures start falling, cow hygiene deteriorates, and the risk of environmental mastitis rises. Moisture control depends on recognising the moisture range by the hand squeeze test and responding with added bedding, lower cow numbers, and increasing stirring effort for improved drying and aeration.

Winter management of compost bedded packs is the most challenging and requires the most bedding. When pack moisture levels exceed acceptable levels in the winter resulting in dirty cows (Figure 50), many dairy producers alter their management toward more frequent addition of thin layers of fresh bedding to keep cows dry and clean. Bedding usage during winter is generally 2 to 3 times more than during summer. Because sawdust is generally more available in summer but needed in winter, building a facility for stockpiling bedding material can be helpful for sawdust supply management (Figure 51).

Figure 50. When conditions increase pack moisture, the wet resting surface creates conditions conducive for an increased incidence of dirty cows, mastitis, digital dermatitis, and elevated somatic cell counts

Figure 51. Dedicating a storage area for sawdust supplies helps keep bedding supplies dry and allows for stockpiling of bedding material for times of high demand or low supply

Mastitis pathogens: Surface bedding bacteria levels are high in compost bedded pack barns. Contrary to popular belief, composting heat doesn't reach a high enough temperature to kill mastitis causing bacteria. Producers must use recommended milking procedures and mastitis preventative practices to maintain low somatic cell count in herds in compost bedded pack loose housing facilities. Extra attention should be paid to cleaning teat ends during the milking process. Vaccination of cows with E. coli and Klebsiella vaccines have been beneficial in many cases.

9.8 FREESTALL DESIGN AND MANAGEMENT

The term freestall refers to a resting cubicle or 'bed' which dairy cows are free to enter and leave, as opposed to being contained in pens. Freestall housing carries the chief advantage that they reduce the volume and cost of required bedding material, while allowing cows freedom of movement. The typical features of a freestall are shown in Figure 55.

Design and layout

Freestall facilities with an east west orientation will provide greater protection from direct sunlight than north-south orientation. When freestall facilities are oriented north-south rather than the preferred east-west, there will be greater solar exposure along the west side of the barn during the afternoon hours, creating bunching issues and reducing the usage of the outside row of stalls.

Stall layouts and milking cow group sizes

Freestalls are built with feeding tables either located centrally or along one or both sides most commonly with between two and four rows of freestalls. Rows of stalls may be in:

- A single row or double row, oriented head-to-head (cows facing each other on a single double stall platform.
- Tail to tail (two single stall platforms with one row of cows facing the feeding table and the other row facing the opposite direction).
- Head to tail (two single stall platforms with cows each facing away from the feed bunk).

The number of rows of stalls significantly influences the space allowance per cow at the feed alley. A freestall 'pen' refers to self-contained groups of cows that are housed and managed together and milked as one group in the dairy.

Figure 52. A three-row pen with a single row of stalls along the side wall

Note the double head-to-head row of stalls adjacent to the feed alley.

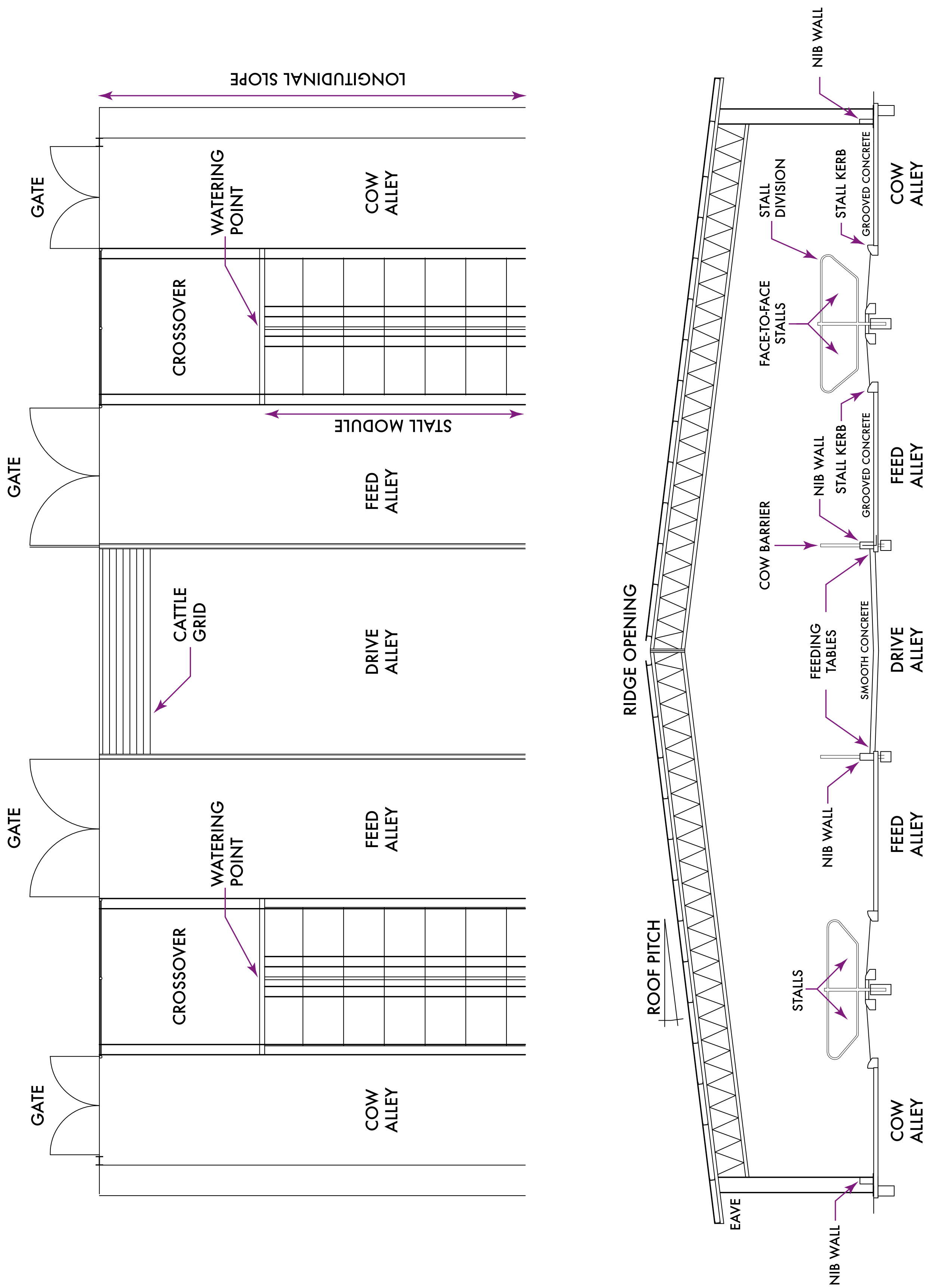
Figure 53. A two-row pen with double row of head-to-head stalls

Figure 54. Two-row tail to tail freestall pen

The total group size in the pen depends on the capacity of the dairy and milking throughput. The aim is to minimise the time out of the pen away from food, water and a place to rest. Current recommendations are to limit pen size so as not to exceed 3 to 3.5 hours per day total time out of the pen milking per day, and not to exceed one cow per stall stocking density, to maximize the opportunity for rest and minimise the risk for health problems such as lameness.

For example, a dairy with 20 milking places that milks at a rate of 4.5 rows (sides of the dairy) per hour would milk 4.5 x 20 = 90 cows per hour, which would be the target pen size.

Figure 55 Plan and cross section view of a typical 4-row freestall



Stall terminology and dimensions

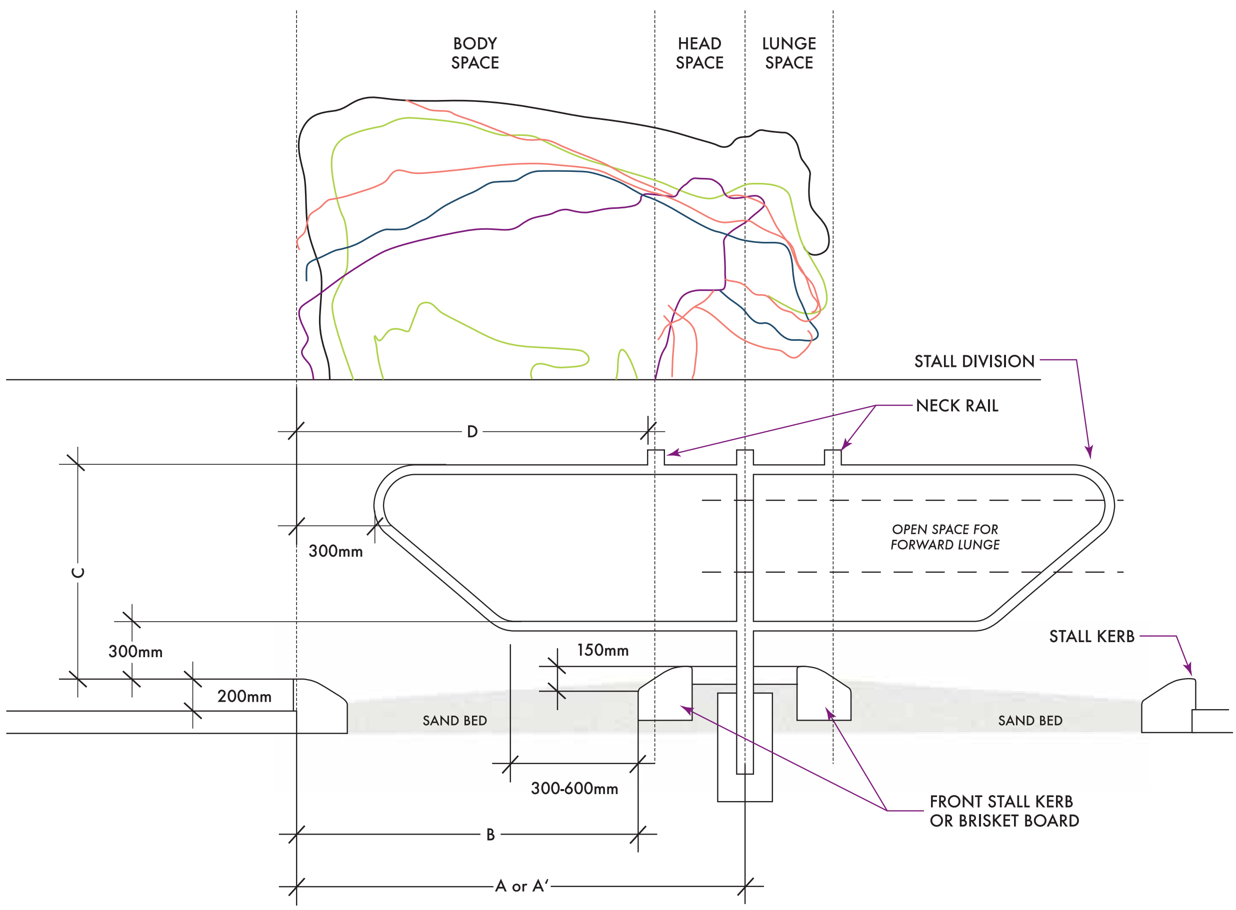
Freestalls consist of elements which serve to provide a bedded structure within which a cow may rest. Key elements to this structure include:

- **Stall kerb:** The barrier at the back of a freestall used to prevent slurry manure from the alley contaminating the bedding.
- **Brisket locator:** A device at the front of stalls that prevents cows from lying too far forward in the stall.
- **Neck rail:** A rail to assist the position of cows when they are standing in the stall so that they have enough forward lunging space when they lie down in a stall. They are also referred to as a 'training rail'.
- **Divider loop:** A metal loop that delineates the lateral borders of the stall resting area and assists in positioning the cow when lying down.

The stalls should be sized to accommodate the resting frame of the cattle using them and allow for easy lying and rising movements, including forward lunge space – *see Figure 57: Stall diagram*. Recommendations are provided based upon an estimate of body weight in Table 10.

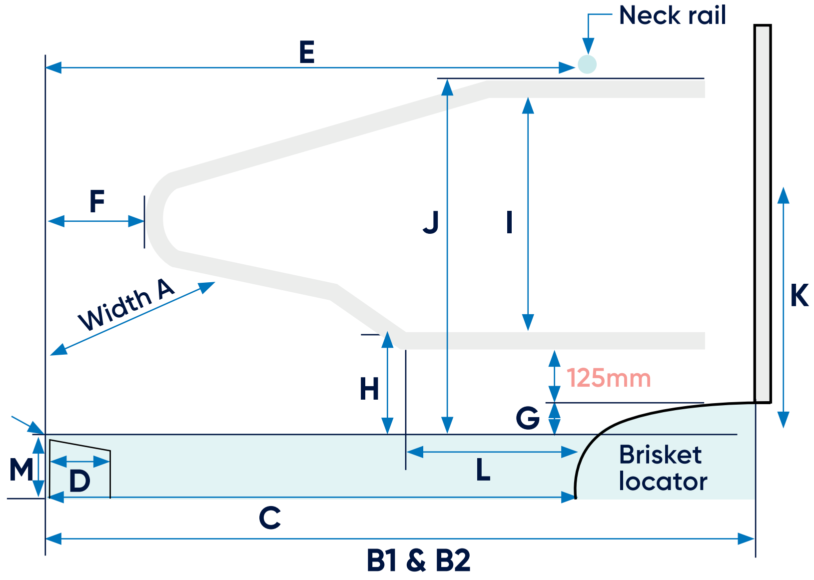
The resting space in front of the cow may be defined by a brisket locator, the purpose of which is to assist in the alignment of the cow when lying in the stall. When located too far from the rear edge of the stall kerb, cows will lie too far forward and soil the rear of the bed. If used, brisket locators (*see G in Figure 57*) must be no higher than 100mm above the stall surface so the cow can get her leg over the top of the locator as she rises. Some deep bedded stalls are designed without a brisket locator, where the bedding is used to form a mound in front to assist with cow placement, however when these mounds are large, they compromise the height of the divider rails and neck rail.

Figure 56 Side view of a typical stall



Source: O'Keefe et al, 2010

Figure 57 Stall diagram – parts labelled



Key: A = stall width, B = stall length, C = distance from rear point of kerb to brisket locator, D = width of the rear stall kerb, E = distance of neck rail from rear point of kerb, F = distance from the rear edge of the divider loop to a point vertically above the rear kerb, g = distance between bottom rail and top of brisket board, G = height of the brisket locator, H = height of lower divider rail, I = interior diameter of loop, J = height to the top of loop/underside of neck rail, K = height of any loop mounting rail in front of the stall, L = distance of the angle of the loop from the brisket locator. Distance from top of brisket locator to lower divider rail should be 125mm to avoid leg entrapment.

Note: The rear stall kerb should be high enough to limit manure contamination of the stall alley during manure scraping or flushing, but low enough to facilitate exit from the stall. Locate the stall kerb (M) 200mm high above the stall alley for mature cows in a deep bedded stall and no wider than 200mm (D).

Table 10. Target freestall dimensions (mm) based upon an estimate of a cow's body weight (kg)

	Body weight estimate							
Stall dimension (mm)	**270kg**	**360kg**	**450kg**	**550kg**	**650kg**	**750kg**	**820kg**	**900kg**
Centre-to-centre stall divider loop placement (stall width) (A)	860	960	1,070	1,140	1,220	1,270	1,370	1,450
Total stall length facing a wall (B1)	2,030	2,240	2,440	2,740	2,740	3,050	3,050	3,200
Outside stall kerb to outside stall kerb distance for head-to-head platform (B2)	3,960	4,270	4,570	4,880	4,880	5,180	5,180	5,490
Distance from rear stall kerb to rear of brisket locator (C)	None		1,630	1,680	1,730	1,780	1,830	1,910
Horizontal distance between rear edge of neck rail and rear edge of stall kerb for mattress stalls (E)	1,170	1400	1,630	1,680	1,730	1,780	1,830	1,910
Horizontal distance between rear edge of neck rail and rear edge of stall kerb for deep bedded stalls (E)	1,020	1250	1,470	1,520	1,570	1,630	1,680	1,750
Height of upper edge of bottom stall divider loop rail above top of stall kerb (loose bedded stall or mat/mattress surface) (H)	200	200	250	250	310	310	330	360
Interior diameter of the stall divider loop (I)	610	710	760	840	840	910	910	910
Height of neck rail above top of stall kerb (loose bedded stall or mat/mattress surface) (J)	860	970	1,070	1,140	1,220	1,270	1,320	1,370

Note: letters in brackets refer to Figure 57: Stall diagram. No table entry for K.

Stall divider loop design and placement

The freestall divider has a number of functions, including:

- Defining the lateral limits of the resting space
- Facilitating lying direction of the cow – straight rather than diagonal is preferred for cleanliness
- Permitting or preventing side lunge
- Determining the height of the neck rail

The most important part of the divider is the lower rail.

- The rail's purpose is to guide the cow where to lie down and it must allow her to rise without obstruction or risk of injury.
- The height of the lower rail must allow for at least a 125mm gap between the lower edge of the bar and the top of any brisket locator that is used. This will prevent front leg entrapment below the rail.
- Divider rails that are located too low allow cows to rise with their front legs over the lower rail – leading to entrapment, while divider rails that are too high do not prevent side lunge into the adjacent stall.
- The preferred height of the lower rail above the level stall surface (or rear point of the stall kerb in a deep loose bedded stall) is 250 to 330mm for most cows (*see H in Figure 57*).
- Locate the angle of the lower rail 500 to 550mm toward the rear stall kerb measured from a correctly located brisket locator (*see L Figure 57*).
- The rear limit of the divider loop should be (*see F Figure 57*) 230 to 300mm inside the rear stall kerb – close enough to the kerb to prevent cows from walking along the back of the stalls, but not so close that the loop may get damaged by machinery used for alley scraping.
- The open diameter of the loop determines the height of the neck rail. A distance of 840 to 910mm from the upper edge of the lower rail to the lower edge of the upper rail should locate the neck rail at the target height of 1,170 to 1,320mm – depending on the size of the cow.

Whatever design of loop is chosen, it should meet the criteria above to place the cow correctly in the stall and avoid injury.

The neck rail provides lateral stability to the stall dividers, while helping position the cow in the stall while she is standing. Proper standing position limits the amount of manure on the rear of the stall. For deep loose bedded stalls with a raised rear kerb, with the neck rail 1,170 to 1,270mm above the stall surface, locate the neck rail about 150mm closer to the rear stall kerb than a correctly located brisket locator. This will force cows to take a step back and perch in the stall when rising.

Figure 58. Well-designed freestalls – choice in resting position, optimises resting behaviour, keeps cows clean

Stall surface and bedding

A variety of freestall base surfaces and bedding materials have been employed. Cows bedded on mats and mattresses have been repeatedly shown to be at greater risk for hock injuries and lameness compared to deep sand bedding. For this reason, deep-loose bedding is recommended to provide a comfortable resting surface to optimise resting behaviour. Sand is often considered to be the 'gold-standard' for deep-loose bedding but other options such as recycled manure fibre have also been used successfully with good management.

Deep loose bedding is a challenge to maintain and requires the frequent removal of wet contaminated material each milking and the addition of fresh bedding at least once weekly. In addition, bedding material needs to be levelled flat with the rear stall kerb typically at least twice a week.

Figure 59. A comfortable freestall bedded with a deep layer of sand

Alleys and cross overs

In freestalls, there are three types of alleys:

1. **Feed alley** – the alleys occupied by cattle when they are accessing feed. These alleys are located parallel to the feeding table.
2. **Stall alley** – these alleys provide a walkway for cattle to access the stalls.
3. **Drive alley** – the area adjacent the feeding table. In a freestall the drive alley does not allow any cattle access, as its intended purpose is to only allow machinery to enter and deliver or push-up feed along the feeding table.

Alley width recommendations vary with their purpose and are shown below for conventional and robotic freestall pens. The recommendations in Table 11 should be viewed as minimum requirements given the cost of concrete. The wider recommendations for robotic facilities reflect the importance of cow flow around the pen to and from the milking robot, and the need to reduce congestion in the alleys.

Table 11. Freestall alley width recommendations by alley type

	Recommended alley width (mm)	
Alley type	**Standard facility**	**Robotic facility**
Stall alley	3,500	3,700
Feed alley	3,700	4,000
Feed and stall alley	4,000	4,600
Drive alley	6,000	6,000

The width of the alley depends on its purpose.

- For the feed alley in a tail to tail pen layout, 3,700mm is recommended so that a cow can stand at the feeding table eating, with sufficient space for two cows to pass behind the cow side by side.
- For a feed alley in a head to head or head to tail pen layout, where cows must also access a stall from the opposite side of the alley, the width recommendation is increased to 4,000mm.

The width of the drive alley in drive through freestalls, with feed access either side is determined by the width of the feed delivery equipment, but usually ranges between 5,500 to 6,000mm in order to avoid driving over feed.

All longitudinal alleys should be sloped along their length to facilitate drainage. The degree of slope depends on the length of the alley, the system used for manure removal (e.g. flushing compared with scraping) and the type of bedding. Typical slopes along the length of the alley vary from 0.5 to 3%. A slope of 0.5 to 1.0% is recommended for manually scraped alleys and 1.5 to 2.5% for flushed alleys. Flushed alleys should be level from the feed side to the stall side of the alley.

Figure 60. Drive alley in a freestall

Cross overs between the feed and stall alleys should be located at the ends of each pen to avoid dead ends which inhibit cow flow.

- Water troughs are usually positioned at these locations and it is preferable to place them along the outside concrete wall rather than up against the stalls to facilitate cow movement and to keep water from entering the stalls.
- If free movement of cows is to be maintained while cows drink at these locations, then the alley must provide a minimum of 3,700mm of available space for a cow to drink and two cows to pass behind.
- Taking account of space required for the water trough and typical stall dimensions, the total cross over alley width should be 4,800mm with a single water trough. In cross overs with two water troughs on both sides, the recommendation would be 6,000mm.
- Cross overs without water troughs may be 2,400 to 3,000mm wide.

Figure 61. A wide cross over with a water trough and cow brush

When cow brushes are used, they are commonly added to cross overs to facilitate grooming and enhance cattle welfare.

- When present, the cross over should be increased in width by a further 1,200 to 1,500mm and the water trough should be located on the opposite side.
- One brush per 60 cows is the current standard.

Cross overs in front of robotic milkers must be a minimum of 6,000mm to allow for cows waiting to be milked and adequate cow flow around this important area.

Each cross over is elevated above feed and stall alleys and should not be excessively crowned as these areas can become very slippery.

- A 50 to 100mm rise to the centre encourages quick drainage.
- Cross overs should be raised 100 to 150mm above the feed and stall alleys to prevent the spillage of manure into the area while scraping or flushing.

Cross overs between feed and stall alleys must be located frequently enough to maintain good cow flow and provide for sufficient access to water. The distance should be less in pen layouts with no direct stall access from the feed alley (i.e. tail-to-tail layouts).

- It is recommended that a cross over be provided every 20–25 stalls for tail to tail and 6-row stall arrangements and 25–32 stalls for other stall layouts.
- In transition cow pens, more frequent crossovers every 15–20 stalls are recommended to improve availability.

Water troughs are usually located in cross overs, and water access must be taken into account when determining the optimum number of cross overs. Often, the number of cross overs is governed by the number of water troughs and brushes required, especially in a 6-row freestall.

Figure 62. A double cross over with the trough located in the middle

The pens may be divided with gates or left open to give cows free access to both sides of the trough.

Figure 63. Water troughs located in the middle of alley

Building eave and ridge heights

High eaves are necessary to facilitate natural ventilation in freestalls. Freestalls may need a 4.5m side eave in cool climates and 5-5.5m side eaves in hot climates.

Circulation fans spaced over the bedded area facilitate air movement, but they must be hung high enough to avoid machinery operating in the bedded area.

- As a minimum, allow 3,000–3,600mm from the bottom of the fan to the floor – factor in bedding height.
- A 900 to 1,800mm eave overhang is recommended to minimise the chance of roof runoff and rain being blown onto the stalls.

The eave heights of tunnel and cross ventilated freestalls need to be designed to suit the design and the structure and the location of access doors to the feeding table and cow pens and as low as possible to accommodate equipment heights.

Keys to management

Freestall management is key to achieving optimum cow health and cow comfort. Following the best management practices will help producers maintain clean, dry bedding, comfortable freestalls and happy, healthy, high milk-producing cows.

Bedding management: A key to stall management is to keep the bedding clean and dry. Clean and dry bedding reduces the ability of mastitis pathogens and bacteria to survive. It also keeps the cows cleaner and drier by absorbing moisture from the cows' bodies.

Clean, dry stalls are more comfortable and encourages cows to have longer bouts of lying time which results in more milk production.

If bedding is being recycled, starting with clean, dry bedding is key. For sand bedding, sand separation systems can be used to remove the sand from the manure stream and wash away a majority of the organic matter in the recycled separated sand. For manure fibre bedding, manure separation systems and dryers can be used to remove the liquid from the manure fibres and dry to a moisture content suitable for bedding.

Bedding depth: Bedding depth influences lying time. Freestall maintenance research found that lying time decreased by 11 minutes per 24 hours for every 1cm decrease in sand depth.

Freestall bedding needs to be deep enough to cushion the cow but not deep enough to retain moisture that can allow bacteria to grow. Sand bedding should be 15 to 20cm deep and should cover the cows' feet as she enters the stall.

As cows naturally prefer to rest facing slightly uphill, bedding should be higher at the front of the stall and slope back towards the kerb. The height of the sand in the back of the stall should be higher than the kerb to maximise lying time.

Bedding frequency: Fresh bedding material needs to be added frequently to replace bedding kicked out of the stall and to maintain bedding depth.

Sand bedding requires replacement at least once a week while manure solids should be replaced more frequently (at least twice a week and sometimes daily). Regardless of bedding material, any soiled bedding should be removed from the stall prior to the addition of new bedding material.

Freestall grooming: Freestalls require regular grooming to improve cow comfort. Bedding can become compacted under the weight of the cows' as they lie down. Stall grooming equipment make it easy to rake and aerate the stalls between the addition of bedding material. Stall groomers attach to a skid-steer and fit neatly under the neck rails to access an entire row of stalls in once pass. Stall groomers help keep the stall bedding loose and comfortable to allow for better drainage, drier bedding and drier cows (Figure 64).

Figure 64. Machinery is used to add fresh bedding to stalls

9.9 ADDITIONAL CONTAINED HOUSING DESIGN AND MANAGEMENT CONSIDERATIONS

Feeding table

All contained housing facilities require the incorporation of a feeding table along which cattle may eat their ration. Feeding tables are most commonly designed with a single post and rail system with headlocks (head gates, stanchions etc) or with a double rail system. In youngstock facilities slant bar feeders are also common.

While post and rail feeding tables allow greater freedom of movement, there is more wasted feed and there are more aggressive displacements between dominant over subordinate cows at the table compared with headlocks. Headlocks have the advantage of facilitating animal handling in critical groups such as transition cows (within 21 days before and after calving), and the sick cow or hospital groups. However, headlocks are more costly and when used, they should not be introduced for the first time to inexperienced animals during the transition period as this may significantly impact dry matter intakes at this crucial stage.

The feeding table surface should be 900–1,000mm wide and smooth to encourage feeding activity. Suitable epoxy paint, ceramic tile or high-strength concrete performs well with silages and split feeds which tend to etch concrete over time.

Headlocks can be mounted on a 400 to 500mm high feed kerb for Holsteins (400mm for Jerseys). The height of the upper edge of the lower headlock rail should be approximately 50 to 100mm above the kerb. Some producers will angle the headlock toward the feed in an effort to increase the cow's reach. However, if headlocks are properly installed and the feeding table is properly managed this is not necessary. Note that different manufacturers of head stall sections have differing heights and length requirements.

- Headlocks are generally available in 3,000mm lengths providing 600 to 750mm wide spacing options. The latter is recommended for transition and sick cows.
- At peak utilisation of the feed alley with 600mm wide headlocks, it is typical for only 80% to be filled.
- When planning facilities, it is important to realise that one headlock does not necessarily equal one feed space.

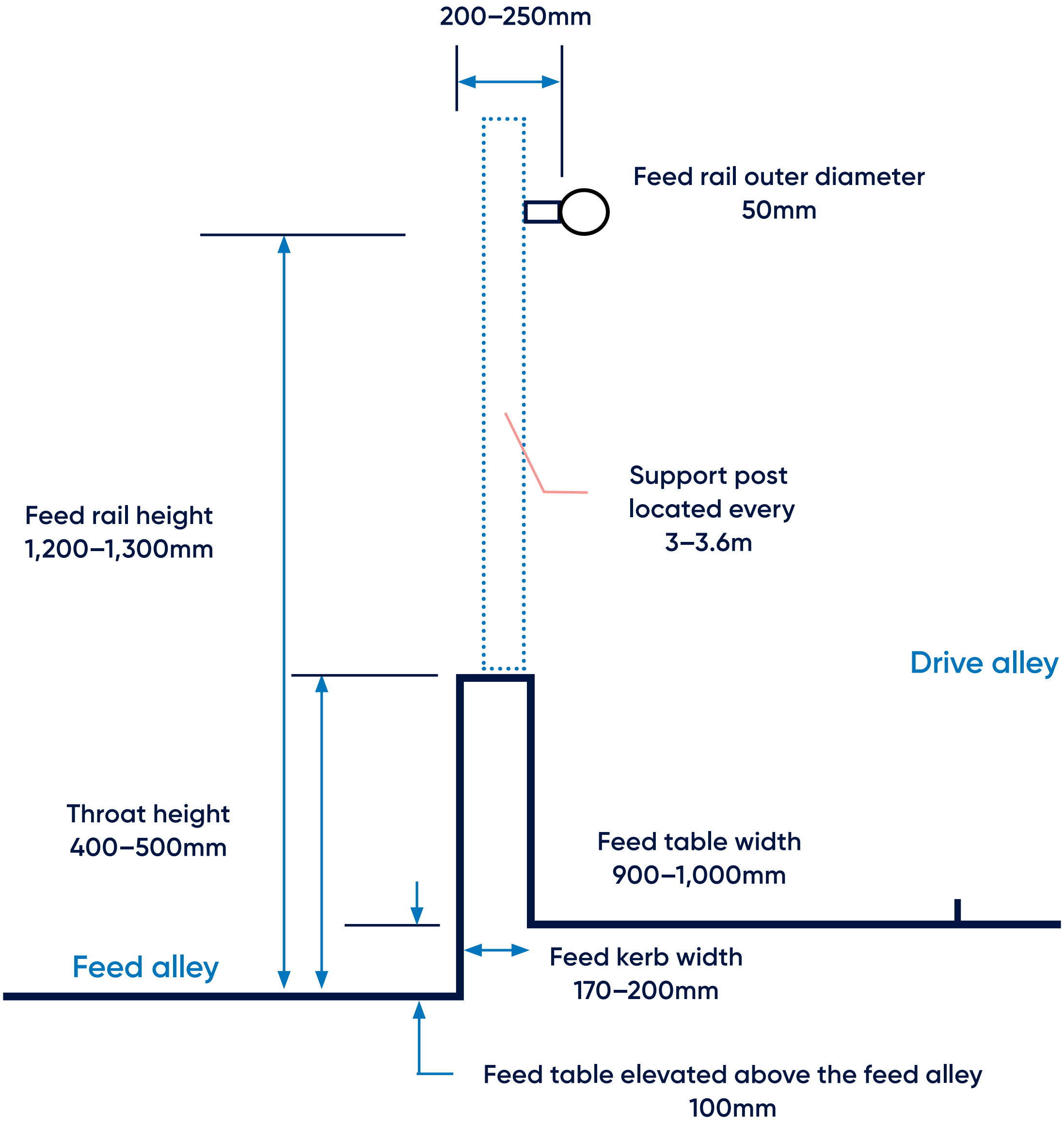
For post and rail type barriers, the feed alley kerb height is equivalent to the height of the upper edge of the lower horizontal rail of the headlock (Figure 65). The drive alley side should be elevated 100mm above the feed alley. T he kerb should be 170–200mm wide.

Feed rails are typically 50mm Nominal Bore med gal pipe and should be mounted 1,200 to 1,300mm above the cow-side feed alley depending on the size of the cow (Figure 66). The rear edge of the bar should be 200 to 250mm forward of the cow-side of the kerb, with the greater distance used for the wider kerb. The rail needs to be supported every 3,000–3,600mm with a post. Posts are typically 80mm Nominal Bore med gal pipe.

Personnel access points are typically located at intervals of 30m along the drive alley and are made 600mm wide, to allow one feeding space when not in use.

Figure 65. A feeding table along which cows may eat their ration with a single post and rail system

Figure 66. Diagram of feeding table dimensions for Holstein cows – metric



Feed troughs

Precast concrete troughs and modular steel troughs are commonly used as they provide a robust, sturdy feeding table that can be relocated if required but careful selection is required to minimise feed wastage.

- Due to the large module size of some troughs or feeders, cattle may not be able to reach the feed at the base, therefore spoilt feed will need to be removed periodically.
- Cleaning may require the modules to be partly dismantled or moved to allow access for a front-end or skid-steer loader to clean the area.
- Raised troughs facilitate the cows reaching the feed when appropriately sized and they can also reduce the ability of cattle to flick/toss feed out of the troughs.
- A cow barrier such as a metal rail may need to be installed above the centre line of the troughs to prevent cattle from standing in the troughs.

Precast concrete troughs

Precast concrete troughs volume is relatively small; therefore feed is delivered at least daily.

- The internal profile of a concrete trough can be an oval, semi-circle or square shape.
- A square internal profile may allow feed to accumulate in the front and back corners of the trough, but it also allows for easier cleaning with a skid steer or tractor fitted with a scraper attachment.
- Troughs should be cleaned at least weekly.

Modular steel troughs

Modular steel troughs sit on the ground or on concrete.

- Some modules provide a large volume to store feed.
- Large round or square hay bales to be placed directly into them.

Cow transfer lanes

Correctly designed and sized cow transfer lanes facilitate cow movement to and from the milking facility and movement of cattle between pens. In larger farms with high throughput rotary dairies, dual cow transfer lanes facilitate the simultaneous flow of cattle to and from the dairy.

Recommendations for cow transfer lane widths based on group size are shown in Table 12.

Table 12. Cow transfer lane widths based on pen size

Pen size (cows)	Cow transfer lane width (mm)
Up to 150	4,500
151-250	5,000
251-400	6,000
Greater than 400	7,500

Return lanes from the dairy would only have to be 2,500 to 3,500mm wide, since cattle will be returning in smaller groups. This transfer lane should be wide enough to accommodate manure scraping machinery or the aforementioned widths if machinery access not required.

Flooring types

Flood washed cow and feed alleys and high traffic areas are constructed of concrete, with a variety of finishes. Strategic use of rubber flooring is also important in the design of a freestall facility.

Special attention must be paid to concrete floor surfaces since they do not provide enough friction to allow natural locomotion behaviour. As a consequence, it is common to see cattle slip and injure themselves on concrete floors. Enhancing this friction will often involve a combination of surface finish and concrete grooving to avoid problems.

Grooving concrete floors is as much art as it is science, and experienced finishers are required to provide a proper finish to provide confident footing for cows. There are numerous grooving patterns, but the final product must strike a balance between providing enough grip to prevent slipping, while not being so rough that it promotes excessive wear of the sole of the hoof. The aim of any grooving pattern is for the cow's foot to make contact with the floor over a groove wherever the foot lands. This will force the manure from the floor into the groove and facilitate contact between the claw sole and the concrete surface. As the claw meets the sharp vertical edge of the groove, it slides to a stop providing traction.

When the walking surface is completely flat, with appropriate grooves going in the direction of the main traffic (i.e. in the direction of the alley) the best mobility in cows is observed (Figure 67). The "Deep Groove" pattern has provided the best overall results for adult cows: grooves are spaced 80 to 100mm on centre, 19mm wide and 13mm deep. This is the most used floor pattern worldwide with less animal slips reported and an increase in stride length (Figure 68). Deep grooves that are cut with diamond blades have a sharp 90 degree edge, which provides best traction. Grooves made with a bull float at the time of placing new concrete will never provide as sharp an edge in comparison and in the long term will result in more slips and an increase in lameness (Figure 69). V-shaped grooves should also be avoided as they allow the claw to slip which may cause trauma to the hoof wall. In Figure 70 it is obvious that the v-shaped grooves are not creating a 90 degree edge, in the long term this pattern will result in more slips and an increase in lameness.

Figure 67. Concrete grooves on flooring

Note: Grooves cut into the concrete in the direction of the alley.

Figure 68. A deep groove pattern provides the best traction for cows

Figure 69. Grooves made by a bull float will never provide as sharp of an edge

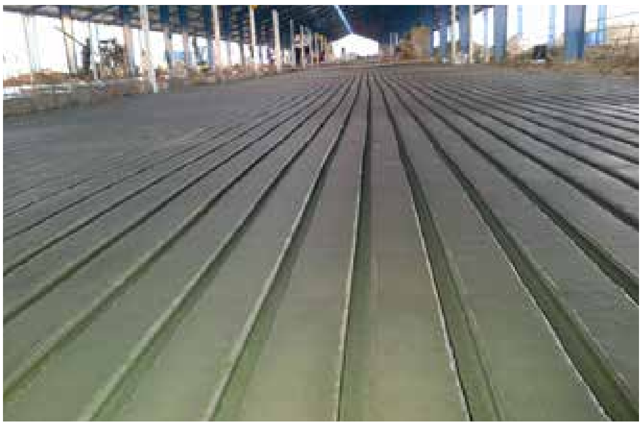


Figure 70. V-shaped groove patterns should be avoided as they result in more slips and an increase in lameness

A good quality finished floor is essential for the long term success of the facility and experienced dairy construction personnel should be employed to deliver it. The flooring surface must be flat rather than convex between the grooves, and the edges must be smooth, with little or no aggregate exposure. Floating and stamping are time sensitive and must be done when the concrete is not too wet (grooves tend to fill in, concrete sticks to stamp), or too dry (poor penetration and shallow grooves with aggregate exposure and bulging between grooves). Before the cows are exposed to the concrete, it may be necessary to grind the floor to smooth off the finished surface, removing all sharp and broken edges. While groove floating wet concrete is cheaper, some producers choose to cut grooves in formed dry concrete. This would be desirable when experienced concrete finishers are not available.

Figure 71. A typical float used to groove wet concrete

The compressibility of the floor, independent of roughness, reduces the risk for slippage. Animals walking on rubber have been shown to slip less, take longer fewer strides and increase the speed of walking, compared to walking on concrete. For this reason, it has been commonplace for grooved or textured rubber flooring to be used to facilitate the movement of cows between pens and the dairy.

Grooved or textured rubber floor surfaces could be provided in the following locations:

- Cow transfer lanes – especially where cows are walking significant distances to the dairy.
- Holding areas – where cows are forced to stand for an hour or more.
- Dairy exit or return lanes – where excessive slopes >2% may enhance wear.
- Dairy platforms and exit areas from rotary dairies – where cows make sharp turns.
- Cow and stall alleys – to provide the cow a comfortable surface for standing while eating and to facilitate cow flow from large pens or crossovers.

Sick cows

It is advantageous to provide a separate **'hospital or sick cow pen'** where cows can be hospitalised for treatment and recovery, ensuring that milk with antibiotic residues is diverted from the bulk tank.

Where sick cows are kept separate from fresh cows, the hospital pen should be sized to accommodate 1.5 to 2% of the herd size. The pen could be a loose housed deep litter pack or a freestall with a two-row design fitted with 750mm wide headlocks and:

1. Have a separate water trough used only by the sick cow group to reduce the risk of spreading faecal/oral pathogens, and must be cleaned out daily.
2. Be located on the end of the alley manure removal system to avoid moving sick cow manure through healthy cow pens.
3. Be adjacent to a storage area for easy access to medicines, and a handling chute for the easy administration of treatment.

It is becoming increasingly clear that herds need a separate management plan for lame cows and a lame cow recovery pen is recommended, in addition to the traditional hospital pen. The **lame cow pen** should have a deep litter pack where treated cows can be housed in a low stress environment in which they can recover – milked no more than twice a day. Ideally, this pen should be located immediately adjacent to the dairy to minimise the distance walked at milking time and sized to match the expected population of lame cows in the herd.

Transition cow and maternity area management

Successful housing and management of the cow during the transition period defined as the time from 21 days before to 21 days after calving is critical to the overall success of the dairy herd. The transition cow facility impacts the lactations of all of the cows in the herd, thus its design and layout warrant particular emphasis in overall facility planning.

The transition area should be designed around five basic design principles:

1. 750mm of feeding table space per cow for the period 21 days before and after calving to ensure that all cows can eat at the same time.
2. Deep litter packs sized to accommodate the size of the cows using them or a comfortable, dry bedded area to ensure that non-lame and lame cows have a comfortable place to rest and rise without hindrance.
3. At least one stall per cow (or at least 10m^2 of bedded area per cow) to ensure that transition cows do not have to compete for a place to rest.
4. Minimise regrouping stress within the critical period 2–7 days before calving to avoid any risk for a precipitous drop in dry matter intake during the crucial stage of gestation.
5. A quiet place to calve, with limited disturbance from humans and other cows, to ensure as natural a birth as possible with a lowered risk for difficult labour and stillbirth.

Cows should be provided with a dedicated area to calve – referred to as the calving or maternity pen. As cows managed outdoors enter the first stage of labour, they tend to seek isolation from the rest of the group, presumably as a defence against predators and to promote bonding between the dam and offspring, and this same type of behaviour has been observed in housed cattle. Efforts should be made to design calving accommodation to allow cows to express these natural behaviours.

Locate the maternity area in a quiet area of the farm, free from busy animal and human traffic, close to the dry cow housing or pasture area, and provide cows the ability to isolate themselves from their herd mates at the point of calving.

- Calving pens may be designed as individual pens or group pens, with the provision of sufficient bedded space (14m^2 per cow).
- Cows show a preference for straw bedding in the calving area.
- Isolation may be achieved by providing a solid wall within the pen to allow cows to rest against, or individual areas with solid partitions.

Depending on the herd size, there are a variety of approaches to managing the dry cow and maternity area.

Where herd size is less than 250 cows and where 24-hour monitoring of the maternity area cannot be assured, group maternity pen management is preferred.

- A duration of stay of around 7 days or more – avoid the stress of regrouping within the critical period 2–7 days before calving.
- Prior to being moved to the maternity pen in this system, cows maybe managed in one or two groups of dry cows.
- These dry cow groups are often referred to as the close-up group within 21–30 days of calving and far-off groups for cows between dry off and 21–30 days before calving.

The maternity pen should be sized to accommodate at least 1.4 times the average daily calving rate of cattle for the calving period, to ensure sufficient space is provided at peak calving rates. The area is designed as for all loose housing, with the addition of a handling area to manage cows requiring assistance.

The system described for smaller herds maybe used as herd size increases, but the bedded area tends to become too large and time consuming to manage effectively, and other options for management become available as the possibility of 24-hour monitoring of calving cows presents.

One approach is a switch to 'just-in-time' calving in larger herds; where cows are moved at the point of calving to an individual maternity pen to deliver the calf, and the duration of stay in the pen is reduced to a few hours.

- Each individual maternity pen typically measures at least 3,700 x 3,700mm, and the pens are designed for ease of cleaning, with folding gates.
- The required number of calving pens is 1.5 times the average daily rate of calving for the calving period.
- In order to reduce the risk for dystocia (a slow or difficult labour or birth), it is essential that the move to the maternity pen be short and stress free, for the cow and for the handler.

Cows should be moved when the calf is in the pelvis and the feet are showing at the vulva. Moving cows too early will result in a delay in parturition. This approach requires sufficient staffing for round the clock supervision of the calving area, which may not be possible when there are staff shortages and wage rates are high.

Prior to being moved into the maternity pen for calving, dry cows in larger herds are typically managed in two main groups: a close-up group and a far dry cow group.

In these larger herds, these groups are typically managed in dairy dry lots, loose-housing or freestalls and fed separate dedicated rations. Close-up pens maybe sub-divided by parity – housing the heifers separate from the older cows. Since the close-up pen is susceptible to overstocking during periods of intense calving, it is recommended that it be sized to 1.4 times the average daily calving rate of cattle for the calving period, while the far dry group is sized at 1.2 times the average daily calving rate of cattle for the calving period.

When freestall housing is used for the housing of close-up cows, 2-row pens are preferred to optimise feed accessibility, with the head to tail layout having the advantage that the cows can be checked for signs of calving from just the feed alley side of the pen, rather than having to walk around the entire pen. The maternity pens should be located immediately adjacent to the close-up pen to facilitate ease of movement between the pens.

One alternative approach to transition housing and management is the 'all-in, all-out' approach, which utilises a series of loose housing pens, sized to accommodate one week of calvings (Figure 72).

Figure 72. An all-in all-out facility for close up dry cow – three separate pens sized to fit one week of calvings

- Cows typically enter the pen 21–30 days before calving from the far dry group and remain in a socially stable group for the entire close-up period.
- Each week, a new group is formed in a separate pen. Eventually, the cows calve out and the pen is emptied and cleaned out ready for the next group of cows to enter.

Cows are moved from far off to close up pens once per week, to reduce the periods of regrouping stress. A drovers' lane facilitates movement between pens in transition cow facilities, with gates located in pens to facilitate single person movement.

Handling areas

Ease of handling cattle is an essential component of any contained dairy operation. Specific handling areas required include a dedicated treatment area, area for hoof-trimming and a truck loading area. Other routine tasks such as vaccination and routine veterinary checks may be performed at the feeding table if headlocks are used, or in a palpation rail.

Wherever cattle need to enter a narrow lane or chute system, a redirection pen or 'Bud Box' is ideal (Figure 73). This concept works on the basis that cows like to return from the direction that they came from, and this eases movement. The box is typically 3,700–4,300mm wide and 6,000mm long for around 5 cows to be handled at a time. Cows enter the box through a gate which is then closed, and the chute access lane is opened. A correctly positioned handler then turns the cows around and they willingly enter the lane.

Footbaths

The footbath is an essential component of infectious hoof disease control in herds at risk from digital dermatitis and foot rot.

Footbaths should be located:

- For use when cows exit the dairy or milking robot
- So cows can be diverted around it when it is not required.

Commonly, the bath is in the dairy exit lanes or on one side of a cow transfer lane. It is essential that the bath be in a long straight lane so that cows can follow each other through the bath.

Design footbaths so that each cow walks through the bath and that each limb is immersed at least twice – this ensures good contact with the chemical. Footbaths that are 3–4m long meet this recommendation, whatever the width chosen.

- To reduce bath volume to around 200 litres, one method would be to limit the width of the bath to 500–600mm at the base and the side walls slope outward to 1m wide to accommodate the girth of the cow at 1m height.
- The step-in kerb should be 250mm to retain solution and short stride the cow as she enters, and the bath should be filled to 100mm depth.

In larger farms with faster dairy throughputs, multiple long narrow baths can be built in parallel, or alternatively, a single wider footbath that can accommodate many cattle at a faster rate can be used (Figure 74).

Figure 73. Cow handling area with a footbath

Note: Footbath on the right, and a chute area adjacent to a redirection pen or 'Bud Box' on the left. Cows enter from the far end and the gate is closed behind them. The gate to the race is then opened and the cows are redirected.

Figure 74. Two long, narrow footbaths with high side walls in use on a large dairy herd

For easy emptying and mixing, ensure that the footbath has a drain point 75 to 100mm diameter.

Since footbath chemicals are dangerous to handle, staff must comply with Safety Data Sheets (SDS) when handling, mixing, emptying and disposal of footbath solution.

Ventilation and cooling

Ventilation is the provision of fresh air into a building space to displace heat, moisture, noxious gases and airborne dust and microorganisms. Good ventilation is essential for good respiratory health in cows. In a dairy complex, ventilation may be provided naturally or mechanically using positive or negative pressure fan systems.

In hot climates, dairy cows are impacted by heat stress through several pathophysiological and behavioural pathways, resulting in reduced milk production, infertility and poor health.

- The impact of heat stress becomes apparent at a Temperature Humidity Index of around 68, which under typical relative humidity occurs at an ambient temperature of 21–24°C.
- To combat heat stress, cooling measures are required in addition to ventilation to maintain health and productivity.
- These measures require the use of recirculation fans within the facilities and use of water, either to cool the air reaching the cow, or to soak the cow directly using soakers mounted along the feeding table.

Cows lie down less under conditions of heat stress and engage in bunching activity – where cattle group away from end and side walls of the facility in an effort to avoid direct sunlight. These behavioural changes occur despite the implementation of commonly available heat abatement measures such as feeding table water sprinklers. However, the loss in lying time can be lessened by the provision of fast-moving air, making the addition of fans over the resting areas of the facility a priority in both natural and mechanically ventilated systems.

The final choice for ventilation system will depend upon:

- The climate where the facility is situated
- The size of the facility, the available building space and aesthetics
- Management considerations unique to the farm's situation (i.e. birds, biting flies, dust, etc.)
- Producer comfort with fan maintenance requirements
- Build cost/economics.

It is prudent to consider the costs of installation and operating costs of any given contained housing facility with different systems for different locations under varied climatic conditions.

Figure 75. A naturally ventilated freestall with 2-row head-to-head stalls

Note: the high open side walls and fans located over the resting area.

To achieve the minimum cooling air speed required in the resting microenvironment where the cows are lying down.

- Locate fans over the resting surface.
- Position fans to create air moving at 1–2m per second measured at 0.5m above the resting surface.
- Locate panel fans with 900 to 1,400mm diameter at a height of 2.5m, spaced at intervals of 7.5 to 9.1m, angled to direct the air down below the adjacent fan.
- Larger fans may be spaced further apart provided that they achieve the target air speed.

High volume, low speed (HVLS) 'helicopter' fans move large volumes of air, but at lower speeds than desired, and they are generally not suitable for contained housing facilities.

Figure 76. Fans over freestalls and the feeding table

Based upon local climate and a desire for cost-effectiveness, natural ventilation continues to most commonly be adopted for contained housing facilities. Natural ventilation systems require:

- An open ridge or vented ridge
- Side wall openings that can be managed between seasons to optimise air flow into the facility
- An adequate interior roof slope to facilitate the flow of air toward the ridge opening.

Other design specifications are included in Table 13.

Air flows toward the ridge opening as a result of thermal buoyancy as the animals within the facility heat the air, and as a result of the negative pressure created at the ridge opening by the flow of air over the top of the ridge. This 'chimney effect' is sufficient to ventilate the facility in cold and moderate climates. In hot climates however, natural ventilation at higher air exchange rates is dependent upon orienting the facility favourably to prevailing winds, so that the longest axis of the facility captures the wind. There is a limit though as a significant departure from an east-west orientation would expose any west or even south-west facing row to the afternoon sun.

It is also essential that there are no physical obstructions to the wind within 30m or more of the facility.

Close proximity of nearby structures on the prevailing wind side of a natural ventilated barn are a potential problem for the optimisation of natural ventilation as they may cause a wind shadow effect (a phenomenon where airflow is disturbed downwind of an obstruction, such as a build, tree, silo or hill).

Even when these design parameters are met, the high air exchange rates required under hot weather conditions are not met in a naturally ventilated facility when the wind does not blow. Therefore, when the facility site is compromised (i.e. existing obstructions to wind, existing site slopes/elevation changes), and/or under climatic conditions of intense heat and high humidity, this may not be the preferred option and mechanical ventilation may provide a more effective solution.

Mechanically ventilated facilities employ fans to remove heat and humidity from the facility more effectively and reliably than can be done in naturally ventilated facilities. Aim for:

- Air exchange targets of 40 to 60 air changes per hour (ACH)
- At least 2,550m^3 per hour per adult cow

In hot humid regions this maximum ventilation rate may not be adequate due to the moisture holding capacity of the air. In hot humid regions, the ventilation system design must be adapted based on:

- Cow body weight
- Building type
- Inlet and exhaust area
- Local power availability
- Analysis of local climatic conditions.

Negative pressure mechanical exhaust systems can be configured in two ways:

- Tunnel design – where the air moves in the same direction as the feeding table
- Cross ventilated design – where the air moves perpendicular to the feeding table

Since air will always follow the path of least resistance and flow over the top and around the cow occupied area, these systems still require the use of fans over the resting area to achieve minimum cooling air speed of 1–2m per second in the resting microenvironment with one exception – fans over the lying area in a cross-ventilation design may be replaced with solid baffle curtains.

Baffles suspended from the ceiling force the air down into the resting space without the use of supplemental fans and are designed with cross-sectional air speeds of 2–3m per second beneath the baffle (Figure 77). The height of the baffle is dependent on the number of baffles used, airflow characteristics in the facility, and target static pressure, but they are usually located 2,400–3,500mm above the stall kerb. These baffle systems have an operating cost advantage since they use fewer fans. In cooler weather, the curtain baffles may be raised, thereby preventing them trapping air within the facility at low airspeeds.

Figure 77. Cross ventilation system with curtain baffles to direct fast-moving air into the resting area

In hot climates, water may be used to provide supplemental cooling. Consider:

- Water may be used to cool the air in low humidity conditions.
- Cross ventilated facilities are well suited to evaporative cooling pads.
- Position cooling pads along the inlet side of the facility.
- If water is hard or contains large concentrations of minerals, if left untreated, then evaporative pad's life is shortened – replace every 3 to 5 years.
- Pads are generally not used in a tunnel contained housing due to pad area along the sidewalls but still an option.
- High pressure fogging systems are an alternative method of cooling the air leaving a fan under conditions up to 60% relative humidity. Once relative humidity exceeds 70% for a significant proportion of the heat stress period, direct application of water to the cow through sprinkler systems above the feeding table is the predominant method used to help cool the cow.

Table 13. Main design characteristics for each of the main ventilation options

	Natural ventilation	Tunnel	Cross – baffle	Cross – fans
Basic description	Open ridge and eave/side walls with fans over the stalls or bedding	Negative pressure with air exhausted at one end of the facility and designed inlets at the opposite end with air movement parallel to the feed alley. Fans located over stalls or bedding	Negative pressure with air exhausted along one side of the facility with inlets along the opposite side with air movement perpendicular to the feed alley. Baffles over the stalls or bedding	Negative pressure with air exhausted along one side of the facility with inlets along the opposite side with air movement perpendicular to the feed alley. Fans located over stalls or bedding
Ridge	Open (target 50mm per 3m of building width)	Closed	Closed (optional cupola fan system for winter)	Closed (optional cupola fan system for winter)
Side wall height	3,000–5,000mm	3,000–4,000mm	4,000–5,000mm	4,000–5,000mm
Roof slope	14–19-degree slope	19-degree slope (may have a flat false ceiling internally)	2–5-degree slope	2–5-degree slope
Cold climate ventilation (less than 5.6°C)	Managed eave opening and open ridge with chimney effect	Fan exhaust set at 4-8 air changes per hour (ACH)	Fan exhaust set at 4-8 ACH	Fan exhaust set at 4-8 ACH
Hot climate ventilation (greater than 20°C)*	Open side walls exposed to wind	Fan exhaust set at around 40-50 ACH and a minimum of 2,500m³ per cow	Fan exhaust set at ~ 50-60 ACH , minimum 2,500m³ per cow and air speed below the baffle of 2-3m/s	Fan exhaust set at around 50–60 ACH , minimum 2,500m³ per cow
Achieving target air speed in the cow resting area	Fans over stalls or bedding	Fans over stalls or bedding	Baffle set at 2,400-3,500mm above stall platform or bedding	Fans over stalls or bedding
Side wall curtains	Yes	No	No	No
Additional cow cooling options	Sprinklers above feeding table or pen sprinklers, high pressure fogging	Sprinklers above feeding table or pen sprinklers, high pressure fogging	Evaporative cooling pads at inlet, sometimes sprinklers above feeding table	Evaporative cooling pads at inlet, sometimes sprinklers above feeding table
Main challenges	Low ventilation rates on still air days and wind shadows from adjacent obstructions to air flow	Air movement and distribution at low ventilation rates.	Air trapped by baffles and unpredictable air movement and distribution at low ventilation rates	Minimal

**Note: In very hot and humid regions, these exhaust specifications may need to be exceeded to ensure optimal ventilation.*

Sprinkler systems

Sprinklers have been installed in holding areas, milking facilities and exit lanes and above the feeding table or stalls because thoroughly wetting the cow improves evaporative heat loss. Controller units can be installed to change soaking times and intervals at different ambient temperatures.

Soaking in the stalls along the feeding table may be problematic. The additional water in the cow alley causes wet manure to be transferred to the freestall bedding, increasing the risk of mastitis. In sand bedded barns, the extra water leads to sand settling in transfer channels and collecting pits, which leads to pumping problems. Also, water is wasted when cows are not at the bunk (up to 19 hours per day in some instances).

Feeding table systems fitted with optic sensors can reduce water use with nozzles activated by the presence of a cow beneath them.

Low-pressure sprinklers (15 to 20 psi, 103 to 138 kPa, or 1 to 1.4 bar) may be used along the feeding table. These can be set to deliver 1.1 litres of water per square meter of wetted area per sprinkler per cycle above temperatures of 21 degrees celsius. The wetted area in stalls should be set to cover an area of 1.8 to 2.4 m behind the feed line, and the water supply should be sized to provide the necessary flow rate of water.

Wetting cycles with sprinklers on for 0.4 to 0.5 minutes every 12 to 15 minutes are recommended for temperatures between 21 and 24 degrees celsius. During periods of severe heat stress, sprinklers should be on for 0.4 to 0.5 minutes every 6 to 10 minutes.

The nozzles on the water line are typically suspended 15 to 30 cm above the top of the headlocks or post and rail type barrier, 1.5 to 1.8 m above the cow alley, and 30 to 46 cm behind the feeding table. The nozzles used should spray water in a 180-degree arc, and they should be spaced according to their spray diameter, which is usually 1.8 to 2.4 m. Avoid the use of nozzles that create fine mists. Droplets need to be large to penetrate the hair coat and cool the skin of the cow. Always check the alignment of the nozzles to make sure that the water is actually landing on the cows' backs, and use nozzles with check valves to prevent the distribution line from draining after each cycle.

Lighting requirements

Cows are susceptible to photoperiodic manipulation in contained housing facilities.

Long day lighting aims to deliver a constant, 16 to 18h period of light and 6 to 8h period of darkness (18L:6D) for lactating cows. Target light intensity for long day lighting is 160 to 215 lux of uniform illumination at a level of 0.9m above the resting surface. Lights should be cleaned on a routine basis to have maximum effect.

For low ceiling buildings, LED or fluorescent lighting is preferred while for higher ceilings, LED or metal halide lamps may be a better choice. Lighting design should be discussed with the electrician to ensure that the desired illumination is achieved.

For cow movement and observation during the 'dark' periods of the day, dim red lights (~15W) at 6 to 9m intervals may be used as this will not be perceived by the cow as 'light'.

In contrast to lactating cows, dry cows are responsive to short day lighting. Implementing a photoperiod of 6L:18D in practice has been difficult to achieve on farms.

Building materials and specifications (minimum suggested requirements)

Material suppliers should be able to provide certification of materials being used for a project. The materials should meet the applicable Australian Standards.

Concrete

Companies supplying concrete should comply and guarantee that the concrete product meets the required standards – refer to AS1379 – *Specification and Supply of Concrete.*

The actual concrete strength, type and thickness required will depend on the type and strength of the sub-base and base materials, and the proposed animal and vehicle loadings. Please keep in mind that larger farms use larger equipment for feed delivery, bedding delivery, manure removal, etc., so thicker concrete may be required. In some instances it may be advisable to have a structural engineer provide a design for concrete pavements.

RECOMMENDED MINIMUM CONCRETE DETAILS	
Concrete strengths	
N = normal class concrete, 20 is the amount of compressive strength measured in megapascal (Mpa).	
Footings	N20 concrete
Pedestrian traffic	N25 concrete
Cow and vehicle traffic	N32 concrete
Concrete thickness for alleys	
Feed and cow alley	100 to 125mm
Drive alley	150mm or greater
Reinforcement	
Footings	As per engineering design
Pedestrian areas	SL72 reinforcing mesh in the top (30mm cover)
Feed and cow alley	SL82 reinforcing mesh in the top (30mm cover)
Vehicle traffic/ Drive alleys	SL82 reinforcing mesh in the top (30mm cover)

Construction joints

Alley design should incorporate construction, expansion and contraction joints. Generally, they should be placed in regular grid intervals approximately matching the widths of the sections but suggest no more than 4,000 to 5,000mm apart.

All construction joint types should be designed in advance of construction.

- Joints to be placed to suit the layout.
- Joints to be designed and placed for movement, shrinkage, expansion and loadings on the concrete.
- Joints to be placed at the end of each pour or for any unplanned breaks in concrete pours.
- Joints are provided to minimise unplanned cracking of the concrete slab.

Many proprietary joint systems are available to form construction joints such as dowel bars, diamond dowels and plate or key joint systems. A structural engineer should provide joint details with the design for concrete pavements.

On concrete areas for cow traffic, care should be taken to seal all joints to prevent manure and recycled effluent from entering the joints and corroding the reinforcing steel. This material is highly corrosive and can quickly cause problems.

Steel

A structural engineer should be contacted for the design for any steel structures, including contained housing facilities and dairy buildings. Note that most councils will require structural certification and plans of all buildings to accompany planning permit applications.

Tube steel products used for structural applications should be fully compliant to AS1163 – *Structural Steel Hollow Sections*. All other structural steel should meet AS/NZS 3679 – *Hot Rolled Bars and Sections.*

It is recommended to install hot-dip galvanised steel wherever possible. Manure and water with high mineral content can cause corrosion issues very quickly.

The Australian steel market has non-structural steel sections available for non-structural, general purpose and light duty applications. These products may not meet the above standards for structural construction.

POST, RAIL AND CABLE MINIMUM SUGGESTED SPECIFICATIONS

**NB refers to 'nominal bore of the pipe', medium refers to the wall thickness of the pipe.*

Drive alley, stall or gate posts	80 *NB medium galvanised pipe
Intermediate posts	65 NB medium galvanised pipe
Post footings	N20, 300mm diameter x 600mm deep
Top rails	50 NB medium galvanised pipe
Intermediate rails	25 to 32 NB medium galvanised pipe
Cables	12–15mm galvanised cable (either fibre or steel core)

Reinforcement

All reinforcement products should comply with AS/NZS 4671 – *Steel Reinforcing Materials.* Reinforcing Products should be certified by the Australian Certification Authority for Reinforcing Steel.

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10

Health and welfare

INTRODUCTION

When dairy producers transition from a grazing system to fixed feeding infrastructure and/or contained housing, they face a wide variety of health and welfare-related challenges. However, high levels of performance can be achieved while maintaining excellent standards of welfare in housed dairy cattle systems. Management is the key to success in any system and poor animal welfare is not an inevitable consequence of housing. If poorly managed, any dairy production system can result in significant health and welfare issues.

10.1 DEFINING CATTLE WELFARE

The Five Domains Model of animal welfare was developed to provide clear guidance suitable for all members of the farm team – including producers, nutritionists, veterinarians, consultants, to foster the concept of 'a life worth living'.

The Five Domains Model considers both negative and positive aspects of:

- Nutrition
- Environment
- Health
- Behaviour
- Mental state.

The concept embraces the provision of positive experiences and desirable outcomes to determine the overall welfare state, rather than simply focusing upon limiting animal exposure to negative experiences.

Regulation of dairy cow welfare in Australia

In Australia, state and territory governments are responsible for regulating animal welfare.

Australian Animal Welfare Standards and Guidelines for Cattle (the Standards and Guidelines (AHA, 2016) are an important initiative intended to guide the development of nationally consistent welfare legislation to enhance animal welfare arrangements across Australia. They were developed at a national level under the Australian Animal Welfare Strategy by the relevant sector, state and federal governments, interest groups, animal welfare experts and researchers and included public consultation.

The Standards and Guidelines have been endorsed by Australian Dairy Farmers (ADF) and all state and territory governments and are being regulated into law by most state and territory governments. However, the degree to which they are implemented in legislation varies (*Australian Animal Welfare Standards and Guidelines, 2020*). Standards are intended as mandatory requirements, whereas guidelines are intended as voluntary, better practice recommendations.

The standard for facilities and equipment requires that:

S4.1 A person in charge must take reasonable actions in the construction, maintenance and operation of facilities and equipment to ensure the welfare of cattle.

Specific guidelines for housed cattle recommend that:

G4.7 Housed systems should have hospital pens with a comfortable lying surface for sick or injured cattle, and the means to move downer cows to the hospital pen.

G4.8 A normal diurnal pattern of lighting should be provided for indoor cattle.

G4.9 Cattle should have the opportunity for appropriate exercise each day.

G4.10 Air should be of acceptable quality with respect to dust, chemicals and smells. Continuous periods of detectable smoke should be avoided.

G4.11 Concrete flooring in rest areas should be covered by an appropriate depth of bedding material.

G4.12 Fire alarms and adequate firefighting equipment should be fitted and maintained in all indoor housing systems

Policy direction on animal health and welfare for the Australian dairy sector is set by the Australian Dairy Farmers' Animal Health and Welfare Policy Advisory Group (PAG), which has producer representatives from each state dairy producer organisation. Some recent policies directed by the PAG include:

- Phase-out of calving induction by 2022.
- Provision of pain relief for all calves during disbudding, which must occur under the age of 2 months.
- No euthanasia of calves by blunt force trauma.
- No tail docking.

The Australian Dairy Sustainability Framework, owned by the Australian Dairy Industry Council (producer and processor peak bodies), uses these policies to set targets for the sector, and reports on industry progress against the targets every year. These targets can change over time to reflect evolving practices and attitudes.

In addition, dairy processors often include animal welfare and biosecurity requirements in their quality assurance programs.

10.2 BENEFITS AND CHALLENGES OF HOUSING SYSTEMS

Cows do not always prefer to be outside, suggesting that there are elements of housing that are attractive to the cow, and not all aspects of natural living are desirable or 'missed' by the cow when they are housed. When dairy cattle are given a choice between grazing and contained housing facilities, they tend to choose pasture during the night time, and housing during the daytime.

Poor weather and higher levels of milk production lead cows to increase the use of housing and even when the housing facilities are made less desirable by overstocking, cows continue to exhibit the same preference for housing during the day, suggesting that the use of housing at this time is highly desirable.

Proper nutrition, health, shelter from the weather and protection from predation are important aspects of animal welfare, and these issues can all present as challenges in grazing systems. These challenges are lessened using containment. Housing provides additional benefits to cows and their care givers, which include:

- Provision of soft bedding to keep cattle clean and comfortable (Figure 78).
- Management of separate groups of cattle and manipulation of the nutrients in the feed delivered to those groups.
- Protection from inclement weather, providing shelter from heat stress as well as from wet, cold, windy conditions.
- A more convenient and comfortable environment to work in.
- Reduced walking distance, and therefore time off feed for cows that are contained close to the dairy, compared to some farms where there may be significant walking times to and from the dairy.

Figure 78. Cow on soft bedding

Specific welfare challenges of housing

Housing can be designed to allow cows to exhibit a broad repertoire of important natural behaviours, and tackle the specific risks faced by cows on feedpads or in containment housing systems.

Multiple features of housing may have the potential for negative impacts on welfare; impacts which are primarily seen as poorer outcomes for health and behaviour. These include:

- Increases in risk for lameness
- Mastitis
- Metabolic diseases such as ketosis
- Pneumonia
- Injury
- Some infectious agents that spread via faecal-oral contamination, such as salmonellosis Johne's Disease.

Behavioural impacts principally lead to a failure to permit cows to rest when they wish to, for as long as they need. However, it is also true that housing systems may be designed to mitigate the risk of these conditions. Very high standards of health and performance can be achieved, and resting behaviour optimised. Table 14 summarises these approaches which are covered in detail in Chapter 9.

Other aspects of welfare potentially impacted by housing are, most notably, the absence of outdoor access and lack of grazing. The ability to exhibit natural behaviour is an important component of animal welfare and, in many regions of the world, an important societal expectation. Despite evidence that cows find aspects of housing attractive, society may continue to hold a bias against containment housing management.

Finally, housing reduces the space available to the cow compared to a grazing system, creating more barriers to movement. This may elevate the risk for negative welfare consequences of poor animal handling in these situations, with greater potential for cows to experience fear, and to slip, fall and collide with fittings.

Training the farm team in low stress handling techniques and the provision of purpose-built handing areas for cow treatment is essential for the promotion of good animal welfare.

Table 14. Features of fixed feeding infrastructure – animal welfare risks

Feature	Risk	Potential consequence	Mitigation of risk
Lack of outside access and inability to perform normal grazing behaviour	May not meet societal expectations for grazing animals	Loss of social licence	Permitting managed periods of outside access in exercise lots
	Low roughage diets may not allow expression of an internal motivation to obtain feed	Thwarted motivation – consequences unknown	Proper ration formulation and adequate provision of fibre coupled with access to feed
Uncomfortable resting area due to poor design, hard bedding surface or insufficient space	Compromised resting behaviour and inappropriate lying behaviours (e.g. lying in alleyways)	Lameness, mastitis, injury (hocks, knees, neck, back, etc.)	Provision of an appropriately designed resting area with a soft bedded surface
Overstocking and inadequate access to a resting space	Reduction in lying time in subordinate cattle	Lameness (claw horn lesions)	Provision of one usable resting space per cow
Unsuitable flooring	Hoof damage from traumatic or abrasive concrete flooring	Lameness (claw horn lesions)	Proper flooring finishes and targeted use of soft rubber flooring, coupled with excellent animal handling
	Slips and falls on slippery flooring	Injury	
Poor hygiene	Close proximity to manure in alleyways and on resting surfaces	Lameness (infectious causes), mastitis (environmental causes)	Well-designed resting areas, appropriate bedding management and regular manure scraping of alleys
	Exposure to faecal-oral spread pathogens	Salmonella, Johne's disease	
Lack of access to feed	Lowered Dry Matter Intake (DMI) and altered feeding behaviour	Elevated risk for ketosis, sub-acute ruminal acidosis (SARA), retained placenta and metritis. Reduced fertility.	Provision of sufficient bunk space for all of the cows to eat simultaneously and adoption of strategies to optimise feed access such as targeted frequent feed push up
Regrouping (the act of mixing one or more cows together from different groups)	Reduced feeding and lying activity immediately after regrouping, increased social stress and fighting	Elevated risk for metabolic disease and injury	Minimise the frequency of movement of cattle between groups, especially during the transition period
Inadequate ventilation and cooling	Poor air quality and build-up of noxious gases and airborne pathogens	Respiratory disease	Ventilation design to ensure a minimum air exchange rate of 4 air changes per hour in cold weather
	Increase in core body temperature	Heat stress and associated impacts on immune function, gut health and fertility	Provision of shade and drinking water. Ventilation designs to ensure air exchange rates of 40-60 air changes per hour in hot weather coupled with air speeds of 1-2 m/s at resting height, with additional use of water to directly cool the cow or the air around the cow (Chapter 7 Facility Design and Management)
	Abnormal behaviours – increased standing and bunching in groups	Lameness (claw horn lesions)	Provision of adequate air speed and air exchange rates
Potential for increased milking frequency from two times a day to three or more times a day	Increased time spent milking may impact the time available for resting and feeding when prolonged	Lameness (claw horn lesions)	Ensure that time out of the housing facility during milking is no more than 3-3.5 h/d by correctly sizing milking facilities and group sizes
Poor animal handling	Injury and a negative mental state	Injury and gross animal abuse	Proper training of all farm personnel in appropriate handling methods and provision of correctly designed animal handling areas

10.3 MANAGING THE FIVE DOMAINS

Nutrition

Provide ready access to fresh water and a diet to maintain full health and vigour to minimise thirst and hunger and enable eating to be a pleasurable experience.

Appropriate nutrient delivery requires the preparation of a balanced ration, suitable for the production level or growth rate of the cattle receiving it, and the provision of sufficient space to consume it. Stale feed and refused feed (refusals) must be frequently removed before fresh feed is added.

At pasture, peak grazing activity occurs around dawn and dusk, but in containment housing systems, group feeding activity is more closely related to milking time, fresh feed delivery and feed push up times. These relatively short, but critical periods of time, place significant pressure on feed space and usage.

High standards of animal welfare dictate that animals be given the opportunity to exhibit natural behaviours.

- Dairy cattle naturally exhibit behavioural synchrony: a tendency when one animal in a group exhibits a behaviour, for the rest of the group to exhibit a similar behaviour.
- Sufficient feed space should be provided to permit the entire group to eat simultaneously during these critical periods of feeding activity – a feed space allowance of 0.6–0.75m per cow, depending on the size of cattle is appropriate.

Greater feed space allowance has been demonstrated to have numerous beneficial behavioural and health related effects including:

- Reduced ration sorting and less variable nutrient intakes across individuals within a group
- Less altered feeding and rumination behaviour in subordinate cattle
- Less risk for elevated non-esterified fatty acids (NEFA) and signs of insulin resistance during the transition period
- Less metritis and ketosis and improved fertility.

Freestall designs with three rows of stalls preclude the ability for all of the cows to eat at the same time, but nonetheless high milk production has been reported from herds in such facilities. Milk production alone cannot be used as a justification for this practice as it is a poor measure of animal welfare, but performance does indicate that perhaps for some groups of cattle, management approaches such as well-timed feed delivery and regular feed push-up can help to offset some of the disadvantages of a lack of bunk space.

These approaches do not appear to mitigate the risk for poor post-partum health and performance when bunk space is compromised during the critical transition period from 21 days before to 21 days after calving however. Provision of 0.75m of feed space throughout the transition period has become the industry standard recommendation in order to optimize health and productivity, and this space requirement necessitates use of freestall pens with two rows of stalls for these 'special needs' cows. Three-row pens are still in common use for other groups of cattle even though they lack sufficient feed space and excellent feed bunk management is required to mitigate the negative impacts of this design, as outlined above.

All cattle of all ages should be provided sufficient daily access to clean potable water to maintain hydration.

- Provide sufficient space for cattle to move freely around the alleyways within the pen to access feed and water
- Regular water trough cleaning is recommended to remove contamination as it has been shown that cattle avoid water contaminated with relatively little manure.

See 6 Water Supply for cow water requirements and *9 Facility Design and Management* for recommendations for waterer design and location.

Environment

Provide shade/shelter or suitable housing, good air quality and comfortable resting areas to minimise discomfort and exposure and promote thermal, physical and other comforts.

In addition to adequate feeding and drinking space, a well-designed freestall or loose housing pen provides a comfortable, clean and dry place to rest, and appropriately sized alleyways to navigate around the pen without risk for injury from trauma and slipping. In addition, ventilation and cooling systems should be in place to limit extremes in barn temperature and humidity and maintain good air quality. Failure to provide these key elements will result in elevated risk for lameness, injury, respiratory disease, mastitis, and abnormal resting behaviour.

Resting comfort

Dairy farm owners building a new facility must make choices about lying surface and bedding type. The surface, or base of the bed, may be earthen or concrete and, in freestalls they must choose between a deep loose bedded stall surface or a rubber mat or mattress

(typically constructed of rubber crumbs, foam, air or water) surface with minimal bedding to absorb moisture. In deep litter or compost barns, different bedding materials are accumulated over time to provide a comfortable resting area.

Some typical combinations of surface and bedding are:

- Dirt and dried manure – usually associated with formed earth feed pads or feedlots.
- Compost bedded pack – deep litter wood chips or dirt that is raked at least daily. A true compost bedded pack generates heat and requires a high degree of maintenance.
- Deep litter pack – a formed base constructed for drainage and covered with deep bedding usually with wood chips or dried manure that is topped up at intervals and may be raked but is not composted.
- Freestalls with deep, loose bedding, typically with sand, sawdust or recycled manure solid bedding.
- Freestalls with a concrete base overlaid with a mat or mattress and a shallow layer of sawdust or dried recycled manure solids to absorb moisture.

Deep bedding that 'gives' around the bony prominences of the hock region reduces pressure and friction and provides traction and support when the cow rises and lies down. While deep bedding has been shown to promote longer lying times in some studies, this has not been the case in every study, indicating that other aspects of stall design and bedding management are also important. Most importantly, deep bedding may make it easier for lame cows to rise and lie down and maintain a normal pattern of resting behaviour – avoiding the abnormally short and abnormally long lying times which may inhibit recovery.

The size of the stall, the divider design and the presence and position of neck rails also influence behaviour and health outcomes. Stalls should be appropriately sized to the animal using them, providing sufficient lying area and room to lunge while rising and lying.

In freestall, deep, loose sand bedding is considered the gold standard for optimal animal welfare.

- Herds utilising mats or mattresses have been repeatedly shown to have a greater risk for hock injury and a higher prevalence of lameness compared to deep loose bedding with sand.
- Herds using sand report better udder health than those with organic bedding types.

It is more challenging to design and manage a deep bedded sand stall compared to a mattress stall. It is important to maintain clean dry uncontaminated sand in the beds, so that it supports a lower bacterial population than organic types of bedding. Bedding material over mats and mattresses should ideally be removed and replaced daily to minimise bacterial growth and mastitis risk, while fresh bedding is typically added once or preferably twice weekly to deep loose bedded freestalls. Wet contaminated bedding material is removed each milking and the beds levelled frequently in order to avoid the cows making dug out 'nests' which negatively impact lying times.

Bedding management for compost barns is complex with fresh bedding added at a frequency that keeps cattle clean and maintains a healthy composting process (*see 9 Facility Design and Management*).

Thermal comfort

There is general agreement that the upper critical limit of the thermoneutral zone, at which cows begin to exhibit the signs and effects of heat stress, occurs around a Temperature Humidity Index (THI) of around 68. Under typical levels of relative humidity (20–90%) this limit can occur at ambient temperatures of 21–24ºC.

During periods of heat stress, when cattle experience conditions outside their thermoneutral zone:

- Cows may stand in a group bunched together at one end of the pen.
- Bunching behaviour appears to be an innate shade seeking response.
- When contained indoors they will move to darker areas of the barn, away from the bright light entering the end and side walls, even if the darker area is not cooler.

Bunching can be prevented by improving cooling and maintaining an even light intensity across the whole pen. Similar behaviour may also result from fly worry and responds favourably to fly control if there are large stable fly populations. Heat stress also results in a significant reduction in daily lying time of around 3–4 hours per day and physiological effects on milk production, gut health and immune function.

Providing shade and sufficient access to drinking water is imperative for the mitigation of heat stress. In feed pad and feed lot systems this requires the construction of shade structures under which cows may shelter. In containment housed systems, shade is provided by the roof of the facility, but additional cooling measures are required. While many herds employ feed line water soakers to lessen the negative behavioural effects of heat stress, there is no evidence to suggest that soakers impact the reduction in lying time, but they do reduce the negative impacts on dry matter intake and milk production. Current approaches to lessen the behavioural changes observed involve the delivery of fast moving air directly into the resting microenvironment, with air speeds of 1–2m/s at 0.5m above the lying surface, through the use of fans directly over the stalls and providing sufficient exhaust of air to remove the heat and humidity that accumulates within the barn.

Predictable exhaust is difficult to achieve in naturally ventilated barns that rely on wind vectors for air turnover in hot climates. This has led to growing interest in the adoption of mechanically ventilated facilities typically configured in tunnel or wide-body cross ventilated floor-plans with the negative pressure generated by fan exhaust drawing fresh air into the barn through designed inlets. However, these barns tend to be more enclosed and their perception is a challenge for the industry to overcome.

An even light intensity across the pen can be achieved by considering barn orientation to the sun at the planning stage and by using sidewall curtains, closed to 80% or shade blinds on the sunlit side of the barn – *see 9 Facility design and management.*

Dairy Australia's manual, *'Cool Cows: Strategies for managing heat stress in dairy cows'* provides practical advice on planning for and managing heat stress (Dairy Australia, 2019).

Walking and standing surface comfort

In contrast to grazing cattle, who stand on a soft dirt surface for most of the day, housed cattle must stand on concrete when they are not resting in a stall, which likely contributes to an increased risk for lameness. Cattle in loose housing facilities have the advantage that they may stand on a deep bedded surface rather than concrete between lying bouts. Walking surfaces should not be excessively abrasive, slippery or continuously heavily contaminated with mud or manure. Surfaces may be compacted earth, gravel, concrete or artificial compounds (e.g. rubber coated concrete). Feedpad and laneway surfaces should be designed to shed water and not become excessively muddy or have sharp exposed gravel. Wood shavings or sawdust can be used on laneways to provide softer surfaces in frequently trafficked areas.

Non-slip rubber matting may prove useful in reducing hoof wear in frequently trafficked areas, where cattle may jostle for position (e.g. from the dairy yard to the feedpad). Stones on concrete floors may cause bruising and efforts should be made to remove them on a regular basis. New concrete and grooving are often very abrasive and may need to be abraded and cleaned prior to use.

Alleys and concrete yards need to be cleaned regularly so that cows are not continuously walking in slurry manure (urine and faeces) and mud. This predisposes to excessive hoof hydration, heel horn erosion, wear, infection and lameness. It is preferable for hooves to be able to dry out on a daily basis. Cows' hooves that are wet for extended periods of time become soft and more prone to wear and lameness.

Health

Prevent or rapidly diagnose and treat disease and injury, and foster good muscle tone, posture and cardiorespiratory function to minimise breathlessness, nausea, pain and other aversive experiences and promote the pleasures of robustness, vigour, strength and well co-ordinated physical activity.

Housing systems elevate the risk for certain health conditions that producers must work to mitigate through design decisions and changes to management when transitioning from a grazing system. This section deals with the specific challenges of lameness and mastitis.

Lameness

Lameness is a significant animal welfare concern and affects the ability of the cow to eat, rest, reproduce, and remain in the herd. The majority of lameness in dairy cattle results from lesions of the foot with genetic, nutritional, hormonal, mechanical, infectious, and environmental factors contributing to their causation. Factors that are associated with lower lameness risk in housed systems include:

- Less time standing on concrete
- Provision of a comfortable place to rest
- Stalls with less restrictive neck rail locations and absence of stall lunge obstructions
- Access to pasture or an outside exercise lot
- Use of non-slip, non-traumatic flooring scraped of manure when the cows are outside the pen
- Use of a divided feed barrier and wider feed alleys
- Prompt recognition and treatment of lameness
- Preventive hoof-trimming and frequent foot bathing.

In addition to the resting area and flooring features and management already discussed, it is recommended that hoof trimming be practised to a high standard, with each cow being trimmed at around dry off and again 2–4 months after calving, and that an effective footbath program be implemented to control infectious hoof disease. Locomotion should be routinely evaluated so that lame cows may be separated and effectively treated as soon as possible. This task should be performed at least monthly and whenever cows may be observed moving between pens and the dairy.

Mastitis

The risk for clinical mastitis in housed systems is potentially elevated. The presence of a mastitis infection can create a painful udder which impacts welfare. Good udder health depends on a number of factors, including:

- Udder and teat-end conformation
- Genetics, environmental conditions
- Milking machine function
- Hygienic milking practices.

Housing may increase exposure of the teat end to environmental organisms between milkings, and efforts must be made to mitigate this risk.

The Australian Dairy industry best practice, mastitis prevention, monitoring and treatment approach 'Countdown' program is recommended to prevent new infections and control the spread of existing infections with contagious and environmental organisms. Prevention of infection with environmental pathogens such as coliforms (e.g. *E. coli*) and *Streptococcus uberis* requires the maintenance of excellent standards of hygiene, both in the housing environment and in the dairy at milking time.

A clean dry and comfortable place to rest must be always maintained through excellent design and good bedding management. In the dairy, in addition to pre-milking cleaning prior to milking unit attachment, the use of pre-milking teat disinfection may be necessary to reduce the bacterial load at the teat end.

Biosecurity

Farm biosecurity is a set of measures to protect a property from the entry and spread of pests and diseases which can pose a financial risk to the farm business and animal welfare risk.

All dairy producers should have an active biosecurity plan to help protect their own farm and the broader dairy industry from the spread of pests and diseases on and between farms. Biosecurity plans need to be tailored to the specific risks faced by the farm enterprise and region.

Containment systems have different biosecurity risks to grazed pasture systems, so biosecurity plans need to be updated when a housing/feeding system changes. For example:

- When silage is put through a mixer wagon the risk of botulism increases as cows are unable to avoid eating source material.
- Cows are in closer contact with their manure, increasing the risk of infections such as *Streptococcus uberis* mastitis and digital dermatitis.
- Closer containment of groups of cows may simplify the management of some diseases, such as Johne's disease which is spread when youngstock are exposed to the faeces of infected older animals.

There are a wide variety of tools available to assist with developing a biosecurity plan, including Dairy Australia and Agriculture Victoria's online dairy biosecurity tool, available at **biosecurity.dairyaustralia.com.au**.

Behaviour

Provide sufficient space, proper facilities, congenial company and appropriately varied conditions to minimise threats and unpleasant restrictions on behaviour and promote engagement in rewarding activities.

Since cattle are social creatures operating within a complex social hierarchy, their natural behaviours need to be taken into consideration in developing approaches to housing and management at critical periods in their life and lactation cycle.

Management at the point of calving is one such period. As they enter the first stage of labour all cows, whether grazing or housed, seek isolation from the rest of the group, presumably as a defence against predators, and to promote bonding between the dam and offspring. Efforts should be made to accommodate these natural behaviours in calving pen design. The calving area should avoid busy animal and human traffic and be close to the dry cow housing area. Individual or group pens may be used, and cows should be given the ability to isolate themselves from their herd mates.

Similarly, sick cows tend to lie down more and seek isolation from other cows within a group, leading to the conclusion that these animals should be provided a separate area with plentiful space to avoid having to compete for feed, water and a place to rest.

Grazing herds are commonly managed in one lactating cow group, but this is rare in housed dairy herds. It is common as herds increase in size for dairy producers to manage multiple groups, frequently separating breeding or early lactation cows from pregnant or late lactation cows, necessitating a move between these groups once the cow becomes pregnant or passed peak milk production. Moving cows between groups creates a stressor on those that are moved as they must re-establish their social rank within the new group. For approximately 48 hours, elevated frequencies of agonistic interactions between the transferred cow and the other cows in the group are observed, which reduce feeding and lying times, and reduce milk production by around 3-5%. Lactating dairy cows can be managed in a stable pen for the majority of their lactation, but this approach necessitates adaptations to work routines, such as the requirement to breed cows in multiple pens rather than one or a few pens of cows. In housed dairy herds, it is commonplace to see first lactation cows housed in a separate pen from older cows, with the potential for benefits in health and performance as a result.

Regrouping stress, which occurs when cows from different groups are mixed together, may be of particular significance during the transition period. It is essential to optimize dry matter intake in early lactation, to minimise the negative energy balance that drives ketosis and other immune function related conditions such as metritis. A comfortable environment with adequate access to feed is essential. In addition, and especially as herds increase in size and start to group cattle separately, regrouping within the critical period 2-7 days prior to calving should be avoided.

Agonistic interactions between cows are apparent when they desire access to a resource that is limited. Access to a stall for rest is a common example in freestall housed herds. While the synchronisation of resting behaviour is less apparent in housed dairy cattle compared to grazing cattle, multiple studies confirm that stocking rates in excess of one cow per stall negatively impact lying times.

Mental state

Provide safe, congenial and species-appropriate opportunities to have pleasurable experiences to promote various forms of comfort, pleasure, interest, confidence and a sense of control.

Numerous studies demonstrate that cattle experience pain and also have emotions such as happiness, frustration, fear and distress. As described in the introduction to this chapter, good welfare goes beyond the prevention of negative experiences and emphasises the provision of opportunities for positive experiences.

Positive mental experience

Behavioural enrichment is the practice of providing animals under managed care with environmental stimuli to improve quality of life. Generally, cows need little behavioural enrichment as feeding, ruminating and resting occupy most of their time and other cows in the herd provide social stimulation.

However, cow brushes may be provided to allow cows to groom and scratch themselves (Figure 79). Grooming is a natural behaviour, and it is common to see grazing cattle rub against a substrate, such as the bark of a tree, in order to remove dirt and external parasites. Grooming appears to be something cows enjoy, since otherwise clean and healthy cattle are highly motivated to access a grooming brush, as much as they are motivated to access fresh feed. It may also reduce frustration and stress due to boredom. The installation of grooming brushes in contained housing facilities is recommended and has been embraced by the dairy industry in new constructions with apparent positive behavioural effects.

Cows can be very vigorous in their use of brushes so these need to be robust. Some brushes automatically start to rotate when an approaching cow is detected, which may encourage their use. Cows particularly use brushes to scratch their backs, rather than their heads, so brushes which allow this behaviour are preferred.

Figure 79. Cow brushes allow cows to groom and scratch themselves - a natural behaviour

Negative mental experience

In contained housing facilities most negative mental experiences develop from fear and frustration.

Overstocking leads to competition for important resources; feed, water access and a place to rest as previously discussed, leading to bullying and frustration in subordinate cows, emphasising the need to follow recommendations for design and stocking rates (*see 9 Facility design and management*).

Poor animal handling and overt animal abuse involving the hitting of animals, and excessive use of electric prodders and force can arise when the training of personnel is inadequate and in facilities lacking well-designed areas for handling and restraint. A specific knowledge and use of the point of balance and flight and pressure zones is required for all employees coming into contact with cattle and is now a requirement of many global animal welfare audits. Use of triangle and redirection pens can ease the stress of handling on the animals and the humans alike and the use of these designs is recommended for a variety of activities, such as loading cattle into a chute or loading them for transport.


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10.4 MONITORING OUTCOMES

Management is critical to the success of all contained housing facilities, and it is important to monitor the cows' health and well-being to assess the success of management strategies. It is recommended that all farm team members be well trained in observing normal behaviour and recognising and reporting abnormal or unusual behaviour, and other signs that may indicate emerging health and welfare issues.

Visibly comfortable cows will:

- Ruminate well and produce milk
- Be in appropriate body condition for their stage of lactation
- Stand, lie down and walk easily
- Be free of injuries and have a low incidence of disease.

Cows will not normally lie in alleyways, or backwards in freestalls, and they should be able to lie down and stand-up without hindrance or hesitation.

However, more objective evaluations of animal welfare and physical well-being outcomes are now commonly used in animal welfare programs for dairy cattle (Table 15). These outcomes include:

- lameness/mobility
- hygiene/cleanliness
- injury.

Injuries can affect the hock, knee and other body regions – such as the neck, back, tail and wounds over the hook bones. The emphasis is on the avoidance of animals with severe scores which represent a failure of prevention coupled with a failure to identify and treat conditions effectively. The aim would be to achieve levels of severe scores less than 1% of the at-risk population using an appropriate sample size that varies based upon the risk group size, the relative frequency of the outcome being scored and statistical confidence.

Note: These scoring systems may also be used to identify cattle with mild to moderate (score 2) lameness and injury requiring attention and treatment. Note that the hygiene score described herein, adapted from Cook and Reinemann (2007), focuses on areas of the body which reflect the cleanliness of the lying surface that the cattle have access to, rather than approaches that are used to assess udder health (Schreiner and Ruegg, 2003).

Proper nutrition may be assessed visually through body condition scoring – a commonly used management tool with details available in the *Dairy Australia Handbook 2013*. Target body condition score varies with stage of lactation, but the emphasis from a welfare perspective is the avoidance of cows that are too thin.

During periods of hot weather, thermal comfort can be monitored by measuring respiratory rates within a group of cattle. Cattle are considered heat stressed when the group mean respiratory rate exceeds 60 breaths per minute.

Table 15. Suggested 3-point scoring systems for locomotion, injuries and for hygiene

Outcome	Score description			Suggested target
	1	2	3	
Locomotion score	Walks without obvious gait asymmetry or weight transfer between limbs and cannot discern which leg is lame after a few strides. Steps may be slightly uneven and may have a flat or subtle arch to the back.	Asymmetric gait with obvious weight transfer and shortening of the stride of the affected limb altering cadence of movement. May also show a head bob, back arch and joint stiffness leading to abduction of the limb.	Able to walk only with extreme difficulty, almost unable to bear weight on the affected limb. Pronounced back arch with rear limb lameness. These animals are frequently in poor body condition and in obvious pain.	Less than 1% score 3 severe lameness and less than 10% score 2 mild to moderate lameness
Lesion score (hock, knee, neck etc)	No or minimal hair loss (≤2.5cm in diameter), no or minimal swelling (less than 1.0cm in diameter), no abrasion.	Hair loss area greater than 2.5cm in length or width or mild swelling (1.1–2.5 cm). May have a small open wound or dried scab.	Swelling greater than 2.5cm in height over the joint regardless of hair loss or skin abrasion.	Less than 1% score 3 severe injury and less than 10% score 2 mild to moderate injury
Hygiene score *(adapted from Cook & Reinemann (2007)*	Clean or manure or mud (may be dried) on flank or upper hind limb less than 25cm diameter.	Manure or mud (may be dried) greater than 25cm diameter in one of the two regions scored; flank or upper hind limb on the same side.	Manure or mud (may be dried) greater than 25cm diameter in both of the two regions scored; flank or upper hind limb on the same side.	Less than 5% score 3 and less than 20% score 2

Source: Nigel Cook


Dairy Australia

Transition program review

WORKSHEET

In addition to regular scoring of physical well-being, herds should keep accurate records of all health events and treatments so that rates of disease can be monitored over time. Dairy Australia's transition program review worksheet has targets for a range of fresh cow health problems, including clinical mastitis (Dairy Australia, 2020). All deaths and herd removals (culls) should be recorded along with a description of the reason for culling.

In the future, new technology will provide other metrics to consider for routine monitoring such as daily rumination and lying times. Rumination monitoring is currently being used to assist in the identification of sick cows and may have some merit as a monitor of welfare when available. The use of activity and lying behaviour is also actively being researched. However while short lying times are detrimental to the health and welfare of dairy cattle, very long lying times may also be reflective of sickness and lameness, making use of an absolute target for daily lying time.

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11

Feeding cows for efficiency

11.1 EFFICIENT FEED CONVERSION

The key to all dairy production systems is the efficient production of milk from feed. Two measures that provide an indication of this are:

- **Feed conversion efficiency = kg of feed dry matter/ milk solids produced**
- **Income over feed costs = income in $ of milk solids per day – costs of feeds and feeding per day.**

In the case of more intensive dairies, it is critical that feed conversion is efficient. The most basic version of this concept is conversion of feed dry matter to milk solids. Feed conversion efficiency is influenced by factors such as nutrients fed versus nutrients required, quality of feed and how the feed is offered to the cows including mixing, processing, feed surface and frequency of pushing up. Feed wastage is clearly important in reducing income over feed costs. Income over feed costs is a key financial measure that indicates likely success or failure.

It is critical in any dairy production systems to consider the true costs of feed, including loss of feed in storage and handling. This loss is often called 'shrink'. In pasture-based grazing systems shrink could be considered to include trampling and soiling loss of pasture. In silage systems it includes silage loss in effluent, volatiles, storage and removal of silage. In total mixed ration (TMR) systems it may include commodity wastage and feed rejections. When transitioning from a pasture-based system to contained systems there are a lot of factors that need to be considered in terms of feed storage and handling.

11.2 NUTRITIONAL REQUIREMENTS

Knowledge of the nutritional requirements of your herd, and what feeds you will supply to meet this will inform the design of the feed storage facility. Nutritional targets for cows do not vary with production system but do for stage of lactation.

Table 16 provides information on the nutritional targets for diets for cows in the far-off dry period, during the transition period from 21 days to calving and once in lactation.

Cows in the dry period will eat approximately 2% of body weight, around 2.5% in the transition period before calving and high producing herds 3.5 to 4% of body weight in lactation.

A key goal of any dairy production system is to tempt milking cows to eat extra high-quality feeds, as this strategy is most likely to increase efficiency and income over feed costs; provided the ratio of increased feed cost to milk value is profitable.

In intensively managed herds there are more opportunities to allocate different feeds to different groups of lactating cattle in order to utilise by-product feeds that may have limited availability or feed value.

Some nutritional advisors also use several different lactation diets, perhaps one for very early lactation (e.g. days 0 to 28) and sometimes to reduce the energy and protein density and cost of late lactation diets (e.g. from day 240 to dry-off).

Requirements by replacement heifers

Achieving a suitable liveweight at herd entry is an important component of successful management of dairy herds. Heifers should reach 85% of mature adult weight before calving. A number of studies addressing calf rearing have shown that an increased calf weight at weaning is substantially associated with increased future milk production.

Table 16. Nutrient composition targets for far-off, transition and fresh cows

Nutrient	Far-off dry cows	Transition	Fresh cows
Neutral Detergent Fibre (NDF; %)	greater than 36%	greater than 36%	greater than 32%
Physically effective NDF (%)	30%	25–30%	greater than 19%
Crude protein (CP; %)	greater than 12%	14–16%	16–19%
Degradability of CP	80%	65–70%	65–70%
Estimated metabolisable energy (ME; MJ/kg)	10 (9)*	11	11.5–12
Starch (%)	12–14%	16–18%	22–24%
Sugar (%)	6%	6–8%	6–8%
Ether extract (%)	3%	4–5%	4-5%
Calcium (%)	0.4%	0.4 to 0.5%	0.8 to 1%
Phosphorous (%)	0.25%	0.25%	0.4%
Magnesium (%)	0.3%	0.45%	0.3%
Dietary cation anion difference (DCAD; Meq/kg)	less than 150	less than 0	greater than 250

Note – on a dry matter basis, fresh cows – first 40 days, optimal transition period 21 days.

Source: Lean et al., 2020

**Energy content that is desirable will vary with body condition.*

11.3 FEED STORAGE OPTIONS

To manage feed inventories and minimise feed losses a well-planned feed management system must be in place. Reducing feed losses by improving management practices during handling and storage can have substantial beneficial economic impact. Good storage helps to preserve quality of the feed and to reduce spoilage from soil, manure, wind, rain and attack by vermin. Dedicated feed sheds will minimise losses of expensive feeds such as protein meals.

Silage

The most common silage storage methods include hillside pits, above ground bunkers, in ground pits and stack and bale silage. The system used will depend on cost, area available, topography, equipment available, expertise and personal preference.

Whatever the method used, the main functions are to exclude air during the ensiling process, prevent air from entering the silage during storage and minimise losses and quality problems during feeding out. Modern technologies, such as inoculants, preservatives and oxygen impermeable covers, can greatly reduce surface losses – irrespective of storage method.

Above ground stack (bun)

Silage stacks are for short-term storage. The silage is placed on top of the ground, then compacted and covered (Figure 80). Large dairies will often use a concrete pad as a base. As there are no side walls, the height of the stack is limited and the surface area to volume ratio is higher. The greater surface area increases potential spoilage. Stacks should be located in an area with a slight slope for drainage and away from trees to minimise potential damage from falling limbs and birds. The stack width should fit the size of the plastic cover to be used.

Figure 80. An above ground silage stack with no side walls

Advantages of above ground stack:

- No material construction costs.
- Easily sealed using a grader blade or front-end loader bucket.
- Removing silage from the face minimises loose silage, reducing air penetration into the bun.
- Size of bun can be adjusted to suit rate of feeding.
- Multiple separate buns can promote quality and better inventory control.

Disadvantages of above ground stack:

- High surface area to volume ratio, thus larger area to cover and greater chance of surface spoilage.
- Can be a workplace health and safety issue for tractor operators during stack formation and compaction.
- Stacks are not suitable for long term storage unless the cover is protected from sunlight exposure (UV degradation).

These stacks are better placed on concrete as there is better control of effluent, less wastage, a better base for machinery and reduced generation of odour from mud and silage mixtures (Figure 81).

Figure 81. An above ground large stack on a concrete base

Hillside pits

Hillside pits are usually dug into the sides or tops of hills, or high embankments, with the 'down hill' end open for drainage and pit access (Figure 82). The surrounding earth provides the side walls of the storage. Earth walls should be sloped to prevent caving in and to enable adequate silage packing. Where soil is unstable, the walls may need to be lined with concrete or untreated timber.

Figure 82. Hillside pits excavated into gently sloping site

Advantages of hillside pits:

- Suitable for long- and short-term storage.
- Lower risk of water entry compared to in ground pits.
- Reduced area to cover compared to above ground storage with no walls.
- Can be replicated by sharing a common wall on either side.

Disadvantages of hillside pits:

- Earth walls may become unstable if rocks or loose soil are encountered.
- Location must be planned to avoid problems with surface water run-off.
- Direct contact with soil generates risks of clostridia and mycotoxins.
- During unloading, any rocks picked up will damage feed mixing equipment.

Bunker storage

Bunker storages are permanent structures constructed above ground and are commonly used in flat areas. Above ground walls are constructed using concrete, earth, steel or timber and braced with timber or concrete buttresses. Bunker storages are rectangular in shape and are open at one or both ends. Most have earth floors, but concrete flooring provides all weather access and is strongly recommended (Figure 83).

Bunker storages must have adequate drainage. The height and width of the structure will depend on the daily silage usage, based on the removal of the required amount of silage per day from the silage face.

Figure 83. Large concrete silage bunker storage

Advantages of bunker storage:

- Can be built in areas where the soil type is rocky or has a high-water table.
- Is reasonably inexpensive to construct (with earth floors – not recommended).
- Can be replicated by sharing a common wall on either side.

Disadvantages of bunker storage:

- Concrete floor bunkers are expensive to construct.
- Poor compaction, or an uneven surface, can lead to water pooling where the cover meets the side walls.
- Earth walls must have stable slopes – ideally they are concreted.
- Requires regular maintenance (e.g. cleaning walls, weed control and re-surfacing the base).
- Losses or wastage from silage can be caught on walls.

Bale storage

Bale storage systems are typically temporary and used for making haylage – wilted forage that is stored at higher dry matter (Figure 84).

Figure 84. Silage bale storage

Advantages of bale storage:

- Greatest flexibility with the storage location.
- Low capital requirement.
- Low labour requirement.
- Stronger wrapping achieved, as the bales can be wrapped multiple times.
- Relatively small face is exposed when a bale(s) is retrieved, which reduces aerobic spoilage.

Disadvantages of bale storage:

- Specialised wrapping machine is required.
- Spoilage can be large if care is not taken to adequately seal out oxygen during the wrapping process and during storage.
- Not suitable for long term storage unless the cover is protected from sunlight exposure (UV degradation) and predator and pest damage.
- Disposal of used plastic may present problems.
- Preparation costs are high due to the cost of the plastic required to seal the forage.

Hay

If possible, aim to stack hay in a shed (Figure 85). Sheds should have good gutters and drainage so that water does not gather around the bottom bales when it rains. Aim to have two to three sides on the shed to protect the stack from weather. Good airflow is also important to prevent moisture build up. Whether the hay is being stored in a shed or outside it is important to have a raised storage pad to stack the hay on. This helps water drain away from the bales during rain events which in turn decrease the chance of mould and rot forming in wet hay.

Figure 85. Good hay storage

Disadvantage of hay:

- Hay fires are reasonably common.
- Special care should be taken to ensure air flow and appropriate dryness of hay to reduce the risk of fire.

Dry and wet commodities

Dry and wet feed commodities may include dry grains, processed grains, oilseed meals such as canola and soybean meal and by products from feed or food processing operations such as wheat mill run, brewers' grain and distillers' grains. Another class of feed commodity includes industrial food wastes such as potato waste, bakery waste (e.g. bread) and fruit and vegetable cannery waste.

For storage and handling of these feed commodities, factors that should be considered include volume, shelf life of product and delivery and loading system. Commodities have varying physical characteristics. Therefore, the volume needed for storage should be calculated according to bulk density. Other physical characteristics such as high moisture content, increase the likelihood of feed quality losses and spoilage.

Storage options include silos, covered flat bottom storage bays and uncovered concrete bunkers for wet feed commodities such as brewers' grain and citrus pulp.

Flat bottom storages are usually concrete bottom bays with timber, steel or concrete walls. Without a concrete floor, commodities can be contaminated with dirt and stones. Several bays may be located next to each other to form a commodity shed. The number of bays will depend on the number of different ingredients, or commodities, likely to be used in the ration mixes.

Flat storage commodity sheds are especially useful for by-product ingredients that do not flow, cannot be moved with augers or cannot be stored in conventional silos where gravity flow is required. Front end or articulated loaders are generally used for both loading and unloading feed from the storage bays to the feed truck or mixer and need convenient access.

For single-row, open-front buildings, a concrete apron in front of the bays allows manoeuvring by delivery vehicles and equipment. The bays should be designed and located to allow the delivery vehicle to unload the material directly into the appropriate bay to minimise double handling.

A high roof clearance and ability to back straight into the bay is needed if feed commodities are unloaded from tipping trailers directly into the bay. The base of the bays and any concrete apron should be sloped away from the storage bay to prevent water flowing into the bay. The orientation of the commodity shed should ensure adequate protection against the prevailing wind so that commodities are not exposed to blowing rainfall during storms.

Figure 86. Commodity shed

Figure 87. Design individual bays to cater for typical delivery truck volumes – store feed undercover

Figure 88. Brewers' grain in bunker storage

As seen in Figure 88, wet commodities are often stored without a roof. This can mean that environmental factors such as rain and sun can reduce feed quality. Heavy rainfall can mean that the feed commodity leaches out some of the valuable nutrients such as sugars, starches and protein.

11.4 PLANNING FEED STORAGE

Commodity storage facilities should be designed to:

- Provide enough storage to meet the demands of the dairy.
- Provide sufficient storage space for a given volume of each commodity.
- Minimise wastage and spoilage.
- Provide moisture protection for dry commodities.

The physical characteristics of feed commodities vary. Knowing the bulk density (weight per unit of volume) of a feed commodity can be used to determine the volume and area needed for storage (Table 17).

Table 17. Bulk density of common feed commodities

Feed commodity	Bulk density (kg/m³)
Wet brewers' grain	800
Canola meal	620
Cottonseed meal	593
White whole cottonseed	401
Soymeal	650
Lupins	770
Mill run	350
Wheat grain	730
Dry distillers' grain	480
Almond hulls (whole)	450

Table 18. Dry matter density of common silages

Feed commodity	Dry matter %	Dry matter density (kg/m³)
Maize silage	33–38	170–250 (average 200)
Ryegrass silage	28–35	160-–180 (average 170)
Lucerne haylage/silage	45–55	200–220 (average 210)
Whole crop cereal silage	40–50	180–220 (average 200)

STORAGE REQUIREMENT EXAMPLE FOR 1,000 COW DAIRY TMR SYSTEM

Assuming the following scenarios:

1,000 milking cows with followers and a fully fed in TMR system 365 days with average 24kg dry matter intake (DMI) including dry stock and followers – with the following diet composition:

- 6kg dry matter (DM) Maize Silage
- 6kg DM Ryegrass Silage
- 7kg DM Grain
- 3kg DM Canola Meal
- 1.5kg DM Oaten Hay
- 0.5kg DM Additives

Maize silage storage:

6kg DM x 1,000 cows x 365 days = 2190 t DM + 5% for shrink and wastage = 2,300 t DM

Dry matter density: ***220kg DM per cubic metre***

Area required: 2,300 t DM/220kg DM/m³= 10,455m³

Wall height of bunkers are 4 m and removing 6,000kg DM each day (approximately 18,000kg Wet) will allow for bunker width of 30m which means the silage face will be well managed.

Bunker size required: 30m wide x 4m high x 87m long (= 10,440m³ approximate total volume)

Ryegrass silage storage:

6kg DM x 1,000 cows x 365 days = 2,190 t DM + 5% for shrink and wastage = 2,300 t DM

Dry matter density: ***170 kg DM per cubic metre***

Area required: 2300 t DM/170kg DM/m³ = 13,529m³

Wall height of bunkers are 4m and removing 6,000 kg DM each day (approximately 18,000kg Wet) will allow for bunker width of 30m which means the silage face will be well managed.

Bunker size required: 30m wide x 4m high x 112m long (= 13,400m³ approximate total volume)

Hay storage:

Daily hay usage is 1.5kg DM x 1,000 cows = 1.5 t DM. Ideally a farm should store enough hay for 30 days in a designated hay shed.

Monthly hay storage: 1.5 t DM x 30 days = 45 t DM = 50 t of hay (wet of ~ 90% DM).

Large square bales (2.4 x 1.2 x 0.9m) weigh on average 500kg/bale so there needs to be room for 100 bales.

Shed space required: 2.7m³/bale x 100 bales = 270m³ (assuming a new load every month).

11.5 EFFICIENT STORAGE AND HANDLING

Storage bunkers and commodity sheds need to be close to the feedpad area to minimise time and labour taken for mixing and delivery.

Most large herd feedpad operations and contained system will be using pit silages such as corn silage, ryegrass silage or cereal silages. To maintain a good silage face and to reduce losses and spoilage, additional equipment such as silage grabs, silage shear grabs and shavers are required. The shear grab allows a block of silage to be removed whilst leaving a clean-cut face. The shaver may reduce dry matter losses over front end loader use by approximately 3% (Figure 89). The shear-grab and the shavers have the advantage of reducing oxidative loss, water penetration and dangers of overhanging silage collapse (Figure 90).

Figure 89. Silage shaver creating a good silage face

Silage grab design can play apart in maintaining silage quality by preventing aeration of the silage face and cleaning up silage that has fallen to the ground. The type of forage ensiled will also impact the cleanness of the silage face and the design of the silage grab that is used. Length of forage ensiled will also determine the efficiency in maintaining a clean silage face i.e. corn silage is easier to achieve a clean face compared to rye grass silage due to the length of cut of the forage.

Figure 90. A clean face on ryegrass silage with use of a shear grab

Other handling equipment required can be hay forks and front-end loader of a suitable size to allow for efficient loading of feed commodities into the mixing and feed out equipment. Many enterprises use a telehandler to good effect for managing commodities.

11.6 OPTIONS FOR FEED DELIVERY

An optimal feeding system must meet the following goals:

- Deliver the needed nutrients.
- Provide these nutrients to each cow.
- Support the optimal amount of milk and milk components.
- Provide needed nutrients at the correct time of the lactation and gestation cycle.
- Feeds need to be fresh and palatable.
- Feed should not be contaminated by soil, manure of other contaminants.

Frequency of feed outs should be proportional to the time spent on feed-pads or in housed systems.

- Feed must be pushed up regularly to allow for optimal feed intake.
- The mixed feed must be uniformly blended. Samples taken from the beginning, middle and end of loading should show no significant differences in ration composition. Over-mixing can be as detrimental as under-mixing in achieving optimum uniformity.
- Feed out chutes and speed of mixing wagon travel must be calibrated which is particularly important if narrow troughs are used.

Type of mixers

Mixers can be categorised into stationary or mobile mixers, with either horizontal or vertical mixing actions. Selection of the mixer will depend on a wide range of factors:

- Rations with a large percentage of roughage will require larger capacity mixing equipment.
- The mixer size must be selected on budget, ration density, feed intake, herd size and number of feed deliveries per day.

Most mixers have a width of approximately 2.5-3.0m (depending on model and size), so it is important that feed alleys are designed to be wide enough to make sure that the feed it not being run over.

Vertical mixer

The vertical mixer consists of a large tub with one or more vertical screws centred in the tub. The screws elevate the ingredients to the top of the mixer, where they fall by gravity to the bottom to be mixed and re-elevated. The continuous lifting and falling action creates a blended mixture of ingredients. Knife sections may be attached to the screw flighting to cut material, such as hay or straw. Vertical mixers are the most common type found in small trailer mounted mixers but they are now also available in larger sizes for truck mounting.

Figure 91. A tractor drawn vertical mixer

Figure 92. Vertical mixer augers

Horizontal screw

Horizontal screw mixers consist of a series of augers mounted on a horizontal rotor in a hopper. Auger mixers use one to four augers to churn the feed in a hopper. The flighting of the auger(s) moves the feed towards the middle of the mixer where it bubbles to the top, toward the sides and back down to the augers. The mixers have one or two counter rotating auger(s) and/or flighting, moving feed in the opposite direction to the other augers. Feed moves from end to end and from bottom to top. In many mixer designs, notched auger flighting and/or knife sections are attached to the auger flighting to process roughage and improve its incorporation into the ration. Horizontal screw mixers are more efficient than vertical types in mixing ingredients with different particle sizes.

Figure 93. Four auger horizontal screw

Figure 94. T-tractor drawn horizontal mixer

Horizontal paddle mixer

The horizontal paddle type mixer combines a set of augers and a paddle in a hopper. The feed is lifted and tumbled by the paddle, moving it upwards to the upper and lower side augers. The augers provide a mixing action and move the feed from end-to-end. The rotor can be configured with three or more paddles (i.e. up to five or six). The tumbling action mixes the lighter roughage and high moisture ingredients without grinding or high-pressure feed movement.

Stationary mixers

These mixers are permanently positioned and so require other equipment for feeding out the mixed ingredients to the feed bunks. The vertical feed mixer is often less efficient than the horizontal mixer because of its smaller size, restricting the level of liquid addition and requiring a longer mixing time.

Mobile feed mixer

The mobile feed mixer can either be trailed behind a tractor or permanently mounted on a truck. These allow the feed to be mixed on the go before the feed is delivered, avoiding the need for double handling and giving faster turnaround times. Tractor drawn feed mixers are the most commonly used in intensive dairy systems. Mobile mixers can be vertical or horizontal types.

Pre-processing of forages

Pre-processing forages with a long forage length can be beneficial for improving the consistency of the mixed feed and to reduce mixing time in the mixing wagon. Various machinery options are available such as having a pre-chopper on a baler, tub grinder or a hay processor prior to forage getting added into the mixer.

11.7 FEEDING FOR HEALTH AND REPRODUCTION

There is a comprehensive review of the nutritional strategies that most influence the risks of disease in the period around calving (Lean *et al.*, 2020). Most of the disease in adult cattle occurs within 20 days of calving and management of the transition period is critical to establishing healthy, productive and successful lactations. These disease conditions include:

- Hypocalcaemia (milk fever)
- Hypomagnesaemia (grass tetany)
- Ketosis or acetonaemia and fatty liver
- Udder oedema
- Abomasal displacement
- Mastitis
- Ruminal acidosis
- Retained foetal membranes/retained placenta and metritis
- Poor fertility and poor milk production.

Table 19 outlines the targets for health performance in early lactation and these can be used to identify whether your herd is performing at an acceptable level. In Table 20 the effects of not meeting or exceeding nutritional targets on health and production indicators are outlined. The targets and measures in these two tables are highly relevant to achieving good health and performance through sound nutritional strategies.

Two related conditions are also of substantial importance to the health and productivity of cattle. Ruminal acidosis and lameness are important disorders of cattle in all production systems.

Ruminal acidosis is not simply one disorder, but rather a continuum of conditions that reflect the degree of generation and safe sequestration of hydrogen in the rumen. The severity of acidosis reflects the substrates available to cattle e.g. sugar and starch that predispose cattle to acidosis and the balance of the diet including fibre that reduces risk. The risk of acidosis is present in all milk production systems, but especially when concentrates are fed.

Studies in Australia have found that 10% of dairy cows less than 100 days in milk had acidosis, as defined by assessment of ruminal volatile fatty acids (VFA), ammonia, lactic acid and pH, when sampled. Studies in the US found that 20.1 and 23% of cows had acidosis. It is likely that many cows will experience some level of acidosis during lactation and, indeed, some may be affected many times.

Table 19. Health performance indicators – target and alarm levels

Indicator	Target performance	Alarm level
Clinical hypocalcaemia (Milk fever)	1% cows older than 8 years – 2%	3%
Pregnancy toxaemia	0%	1 case
Clinical ketosis	less than 1%	2%
Abomasal displacements (left or right)	less than 1%	2%
Mastitis	1.8 cases per 100 cows per 30 days	2.5 cases per 100 cows per 30 days
Lameness [Sprecher, Hostetler *et al.* (1997) scale 1–5]	less than 2% greater than score 2	greater than 4% greater than score 2
Hypomagnesaemia (Grass tetany)	0%	1 case
Retained foetal membranes more than 12 hrs after calving	less than 3%	greater than 6%
Metritis % infected after 21 days	less than 5%	greater than 10%
Calving difficulty	less than 2%	greater than 3%
Clinical ruminal acidosis	0%	1%

Note – expressed as percentage of cases of calving cows within 14 days of calving.

Acidosis is a continuum of conditions of varying severity that reflect the challenge of safely sequestering hydrogen that accumulates from carbohydrate fermentation. Safe pools to 'hide hydrogen' include starch engulfment by protozoa, bacterial glycogen formation, growth of bacteria, methane, and weak organic acids (VFA). Less safe pools include lactic acid. Alternatively, decreasing the hydrogen supply by increasing the more slowly fermenting fibre content of the diet and enhancing rumination can also reduce risk.

Signs of acidosis

Cattle with rumen perturbations consistent with subacute acidosis may present with a range of clinical and subclinical signs that include diarrhoea, poor body condition, a dull and lethargic demeanour, dehydration, a lack of rumen fill, lameness, weak rumen contractions, depression in milk fat, and inappetence.

For acute acidosis: Ruminal distension, diarrhoea (often with grain in the faeces and a sickly, sweet smell), abdominal pain, tachycardia, tachypnoea, staggering, recumbency, coma, a marked decline in milk yield, and death may occur.

Herd diagnosis: acidosis

While access to fermentable feeds is important to the diagnosis of subacute cases, the focus must be on the herd examination, as clinical signs of acidosis can be relatively subtle in the individual animal.

Check the latest herd test results. Milk fat to protein ratios less 1.02 to 1 for cows in the first 100 days in milk provide a weak, but useful, indication of acidosis. It is not true that all cows with a low test are likely to have acidosis, but cows with acidosis are very likely to have low fat test. Unsaturated fatty acids have also been implicated in milk fat depression without relationship to ruminal acidosis. The sensitivity and specificity for using a fat : protein ratio as a predictor of acidosis is 0.54 and 0.81, respectively. The sensitivity indicates that only 54% of acidosis cases were detected by use of a low fat : protein as a test, but the specificity indicates that 81% of acidotic cows had a low fat test. This indicates that there are other causes of a low fat to protein ratio apart from acidosis.

The following examinations of the herd should be made:

Dung check: If a high percentage of cattle are scouring, especially if the dung bubbles and contains grain – the risk of acidosis is high (Figure 95). The dung can contain undigested fibre, particles greater than 1.5 cm. Differential diagnoses include very lush grass and parasites.

Lameness check: Only swelling of the coronary band occurs at the same time as ruminal acidosis, but herds that have had acidosis causing other typical foot problems that arise with acidosis often have active acidosis, especially if there has been no effort to control it. Changes observed in hooves such as 'poverty lines' and paint brush haemorrhage indicate acidosis, but the acidosis occurred some-time before examination.

Check the bulk vat: A low fat: protein test on a herd basis is similar to that in a cow. Again, it is only a rough guide, but a low herd fat : protein test is a cause to consider the possibility of acidosis or concerns with excessive intake of dietary unsaturated fatty acids.

History: Have cattle bled from the mouth (or nose) or have liver abscesses been reported for the farm? Both of these indicate that it is very likely the cows have had acidosis in the past. Some acidotic herds have history of increased respiratory disease, but there are many other causes of respiratory disease apart from acidosis.

Ration: An essential step is to check the ration and feeding systems to see whether the following problems are present: Highly fermentable diets e.g. non-structural carbohydrates (NSC) greater than 36% and Neutral Detergent Fibre (NDF) less than 32% of the total diet. These need not be enough alone to provide a problem and acidosis can be present with less NSC and more NDF. Chemical analysis should be performed on individual feed components and residual TMR after feeding to obtain the percentage of dry matter, NDF, acid detergent fibre (ADF), crude protein (CP), starch, sugar, and NSC content - this will allow estimation of the overall chemical composition of diet and for comparison with recommended requirements. This information, combined with the evaluation of the physical characteristics of the feed will indicate possible sub-optimum rumen function and ruminal acidosis. It is often the way that the diet is fed. For example, short chop or sorting in partial mixed ration (PMR) or TMR herds, cows can access extra grain in the milking parlour, and very lush pastures or young grass. Feeding behaviour will be the best indicator of adequacy of dietary fibre and physical form.

Figure 95. Acidotic dung from poorly designed diets with contained housing facility

Feeding behaviour: Feeding behaviour of the herd including the following should be observed: percentage of cows cud-chewing at rest should exceed 50%, sorting behaviour of a TMR, and DMI and whether cows are allowed to go straight to pasture after milking or are held to provide even access. Cows that have a low rumination time, are sorting their feed, have a cyclic feeding pattern, or low DMI may be at risk of ruminal acidosis. Cows that are low in the social order, which are frequently first lactation cows, often eat last and therefore can be exposed to feed with a different effective fibre content or chemical composition resulting from sorting from the previous cows and may increase their risk of ruminal acidosis. The animal's increased risk of ruminal acidosis will be dictated by what they sort for: concentrate (increased risk) or forage (typically decreased risk). All feed sources should be assessed for forage or chop length or particle size if applicable, and quality using relevant characteristics i.e. stage of maturity of pasture, type of pasture or forage.

Table 20. Diet composition targets for early lactation cows – deficiency/excess indicators, production effects

Diet composition (dry matter basis)	Fresh cow targets	Effect of deficiency	Deficiency key indicators*	Effect of excess	Excess – key indicators*
Dry Matter Intake (DMI; kg)	≥ 3.5 to 4% body weight	Weight and Body Condition Score (BCS) loss	Weight loss greater than 75kg and BCS loss greater than 0.75 (calving to nadir), high blood Non-Esterified Fatty Acids (NEFA) and high ketones (urine, blood, milk)	Reduced feed conversion efficiency (FCE); suggests diet is imbalanced. Targets for FCE (Energy corrected milk/DMI) for Day 150 of lactation: TMR greater than 1.3 – ideally greater than 1.4 Pasture and PMR greater than 1.2 – ideally greater than 1.4 Pasture and concentrate greater than 1.2 – ideally greater than 1.3	High residuals: in bunk greater than 2% or pasture greater than 1600kg (ryegrass). Marked increase in body weight or body condition in herds with adequate weight and BCS. Target BCS: 3 to 3.25 peak and 3.25 to 3.5 at calving.
Neutral Detergent Fibre (NDF; %)	28–32	Increased risk of acidosis; reduced feed efficiency	Low NDF in diet. Loose, low fibre content of faeces, fibre greater than 1cm long, undigested feed observed in faeces, low fat test: less than 3.5% (Holstein-Friesian), low rumen fill, decreased rumination: less than 50% chewing cud at rest, lameness prevalence may be high: greater than 25% of cows 2+	Body weight loss, lower milk, production, higher butterfat percentage, lower protein production	High NDF in diet. Low or declining BCS or weight, High fat, low protein test, high rumen fill, large firm faeces, high faecal fibre, high blood NEFA and high ketones (urine, blood, milk)
Physically effective NDF (%)	19–21	Increased risk of acidosis; reduced feed efficiency	Low fibre content of faeces, low fat test, low rumen fill, decreased rumination: less than 50% chewing cud at rest, lameness prevalence may be high (depends on the environment)	Lower production, higher butterfat percentage, lower protein production	Firm faeces, high fibre content of faeces, high rumen fill, unlikely to be excessively high without high NDF%, increased rumination: greater than 50% chewing cud at rest

Diet composition (dry matter basis)	Fresh cow targets	Effect of deficiency	Deficiency key indicators*	Effect of excess	Excess – key indicators*
Crude Protein (CP; %)	15.5 – 19	Lower milk production, body protein mobilisation, increased acidosis risk	Pale green faeces, slow passage rates, can have high rumen fill, lower fibre digestion, low Milk Urea Nitrogen (MUN), low milk protein production, low milk protein content	Lower pregnancy rates with high soluble protein intake	Dark green loose faeces, however, colour can be variable, variable passage rates, high MUN, low production, possible weight loss
Degradability of CP (%)	65–70% of CP i.e. 13% rumen degradable protein of diet DM	Lower production depending on the amino acid composition of the rumen undegradable protein fraction of CP	Lower fibre digestion, can have high rumen fill, low blood urea nitrogen (BUN) or MUN, low milk protein production, low milk protein %	Lower production, Lower pregnancy rates with high soluble protein intake, can increase BCS mobilisation	High BUN or MUN
Estimated Metabolisable Protein (g/Day)	11–13, depending on size and production	Lower production depending on the amino acid composition	Poor production with increase in weight gain and BCS over lactation, poor feed efficiency	Loss of income, inefficient use of protein	
Estimated Metabolisable Energy (MJ ME/ kg DM)	11.5–12	Weight and BCS loss	Weight and BCS loss, high blood NEFA and high ketones (urine, blood, milk)	Weight and BCS gain if imbalanced	Low MUN (if high non-structural carbohydrates)
Estimated net energy required for lactation (NEl; MJ/day/ kg milk)	2.9–3.5	Weight and BCS loss	High blood NEFA and high ketones (urine, blood, milk)	Weight and BCS gain if imbalanced	
Starch (%)	20–26, depending on NDF and forage NDF content of diet	Low production (is not an absolute, but often the case)	Low milk protein, can test fecal starch	Increased risk of acidosis and lameness	Loose, bitter sweet smelling faeces (may be low MUN depending on protein in the diet), often contain bubbles of trapped gas, a high prevalence of cattle with pH less than 6.5 on stomach tube or 6.0 on ruminocentesis indicates presence of acidosis
Sugar (%)	6–8	Low production	Low milk protein	Increased risk of acidosis and lameness	Loose, bitter sweet smelling faeces, a high prevalence of cattle with pH less than 6.5 on stomach tube or 6.0 on ruminocentesis indicates presence of acidosis
Ether extract (%)	4–5	Lower efficiency of production		Decreased fibre digestion, lower fat percentage especially rumen degradable	Faeces less well digested and turn white after drying
Dietary Cation-Anion Difference (DCAD; Meq/kg)	25–40	Lower production	Urinary pH in lactation low (less than 7)	Decreases milk production	Urinary pH in lactation high (greater than 8.5), high K & Na and low Cl & S in feed

Source: Lean et al., 2014

11.8 TRANSITIONING FROM PARTIAL MIXED RATIONS AND GRAZING

The following compares the key criteria that are required to achieve high-level performance on total mixed rations and pastures. Subsequently, the core skills and challenges of moving between grazing and total or partial mixed rations are explored.

Keys to achieving high intake on total mixed rations

Increase feeding frequency in early lactation for diets of moderate to high energy density especially when feeding management is not optimal.

- The better the other aspects of feeding management, the less the benefit of increased frequency of feeding.
- Pushing up feeds between feedings is important to ensure that cattle get access to the feed and to stimulate feeding behaviour.
- A reasonable target might be to feed twice a day and push up feed twice in between each feeding.

Ensuring adequate access time to feed:

- Feed bunks should not be empty of feed nor time off pasture excessive - ideally cows should have access to feed for 21–22 hours per day, allowing for milking time.
- Grouping by parity and production level. Primiparous cows and multiparous differ in feed intake and feeding behaviour.

It is important to provide cows with palatable feeds. This means:

- Cleaning the bunks at least once a day to ensure clean feed.
- Avoiding spoiled feeds.

Providing palatable feeds is important as the impact on individual cattle and the herd in general can be substantial.

Bolsen *et al*. (1999) demonstrated significant decreases in DMI as well as apparent digestibility of dry matter, organic matter and neutral detergent fibre (NDF) in cattle fed silage that consisted of 25% aerobically surface-spoiled silage. In addition, the authors noted that rumen fibre mats in treated cattle were either partially or totally destroyed.

Also important to consider:

- Providing adequate feed bunk space – between 0.6 to 0.7 linear metres per adult cow – *see 9 Facility design and management.*
- Ensuring that cows are comfortable (i.e. relaxed, are not heat stressed, socially adapted). Rapid changes in cow groupings are not advisable, especially during the transition period.
- Feed should not be hot either in the bunk or in the silage stacks or commodity bunks (indicates the deleterious action of yeasts and moulds).
- Monitor moisture in the feed – excessively wet feeds can sour and reduce DMI.
- Cows need adequate time to rest (more than 8 hours per day). Water access and quality need to be high. Cows will drink 40 to 70L of water per day but may require up to 200L of water per day. Cows will go to water from 6 up to even 40 times a day and water sources should be made readily available for cows. Access should be approximately 0.1 to 0.2 linear metres/head and not with a solitary trough or source.
- *See 6 Water supply.*

Indicators of spoiled silage include:

- Spoilage (mould or blackening, foul smell) in the stack or on the face with slow feeding.
- Dropped, black cud in bunks or near silage.
- Spoiled orts (remainder of food from a meal).
- Changes to faeces – often scant, slow passage, undigested or 'slimy', sometimes liquid diarrhoea.
- Low rumen scores – variable across the group. Rumen scores are a useful tool but need to be assessed with some caution.

Keys for achieving high intake for grazing cattle supported by feeding infrastructure

With grazing cows, availability of feed is influenced by varying the stocking rate, stocking intensity (grazing pressure – which is a function of appetite of cattle and supplementary feeding rates), herbage height or time available for grazing. Changes in digestibility and composition which occur at different stages of the growing cycle must be understood if optimum use of grass is to be made.

Critically, more DMI can be achieved by offering more pasture – feed intake increases in a curvilinear manner, but pasture residuals then also increase.

The residuals that are left influence the rate of grass production in the future and the quality of grass. Simply, leaving too much residual (typically greater than 1,600kg DM/ha for temperate pastures e.g. ryegrass, fescues) can reduce pasture quality for the next grazing; leaving less than 1,300kg/DM/ha for temperate grasses will reduce pasture growth rates. Consequently, ideal residuals for ryegrass are between 1,300 and 1,500kg DM/ha.

In order to achieve high production from pasture and supplement – forage is provided to appetite, the forage is of high digestibility, highly palatable, free of anti-nutritional factors (e.g. toxic endophyte alkaloids, high levels of nitrates) and the ration is balanced by use of supplements (or complementary feeds). Intake of forage is determined by selection, physical form and substitution rates when forage is fed ad libitum.

Keeping production up and rumen function stable on pasture

If pasture residuals are too short, some cattle are not achieving optimal DMI (and grass growth is depressed)

- Grazing short pasture or pasture high in legume may not provide sufficient physically effective fibre for rumen stability.
- If pasture residuals are too long, pasture quality will decline in the future.
- Provide simultaneous access of the herd to the pasture (releasing cattle to pasture as they are milked disadvantages less dominant cattle and heifers).
- Provide ample water access at pasture.
- Meet mineral requirements.

Increase DMI at pasture by:

- Increasing pasture available (stocking rate change, rotation change, fertiliser use).
- Increasing time of access to pasture.
- Improved pasture quality (cultivar selection, fertiliser use).
- Moving hot wires (electric fences) to provide fresh pasture.
- When weather is hot and humid, providing access to pasture in the cooler parts of the day.

Management to achieve high DMI is critical and additional detail can be found in the key reviews listed in the reference list.

Transitioning between systems

As noted above, the nutritional targets for the cow do not differ with production systems. Indeed, the energy density of many good pasture-based diets exceeds that of TMR, but exercise and difficulty achieving high dry matter intakes can reduce milk solids production.

Perhaps the most challenging production system is the partial mixed ration system in which managers and workers need to have high level skills with pasture feeding and mixed rations. The skills required to manage the two systems are often very different, but skilled observation of the cattle is critical to success in both.

Table 21 highlights the critical areas of attention to detail and management observations required in TMR or PMR systems and on pasture.

Achieving consistency of diet and a steady rate of change is vital to the success of changing from one system to another. Ration changes should be made over a period of 2 to 3 weeks.

Options such as provision of green-chop pasture over the first 2 to 3 weeks when changing from pasture to TMR help maintain rumen stability. Similarly, provision of silages and concentrates when adapting from TMR to pasture can be used to manage the change in substrates in feed. In the latter case, consideration of the increased exercise component can be important; feed dense pastures and, by preference, those that do not require considerable walking.

Table 21. Key observations for total, partial mixed ration and pasture-based systems

Key questions for managers	Observation – TMR or PMR	Observation – Grazing
Are cows are being fed to appetite?	A small residue of palatable feed remains in the feed bunk. Feed is pushed up to stimulate appetite. Milk production is high and as expected.	Pasture residuals are optimal. Milk production is high and as expected.
Do cows have enough time to eat?	Access to feed other than when milking.	Access to feed other than when milking.
Do cows have enough time to rest?	Able to rest greater than 8 hours per day.	Able to rest greater than 8 hours per day.
Does exercise and discomfort depress milk production?	No significant mud in 'dairy dry lots'. Compost barns are dry. Freestall cows are using their stalls well.	Cows get considerably more pasture energy than the exercise required to walk to pasture.
Are cows disrupted moving between diets i) Pasture to TMR	The main dangers are in abrupt changes in diet. Highest risks are with acidosis, if the increase in starch and sugar is too abrupt. Loose faeces. Poor appetite.	Not applicable.
Are cows disrupted moving between diets i) TMR to Pasture		The main dangers are in abrupt changes in diet. However, cows do take a little time to adapt to the increased exercise components and tend to be 'lax in grazing'. Unless the total available dry matter and energy density is similar, cows can markedly drop body condition as they continue to milk and have increased energy loss in exercise, but do not receive sufficient nutrients to support production.

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12

On-farm nutrient management

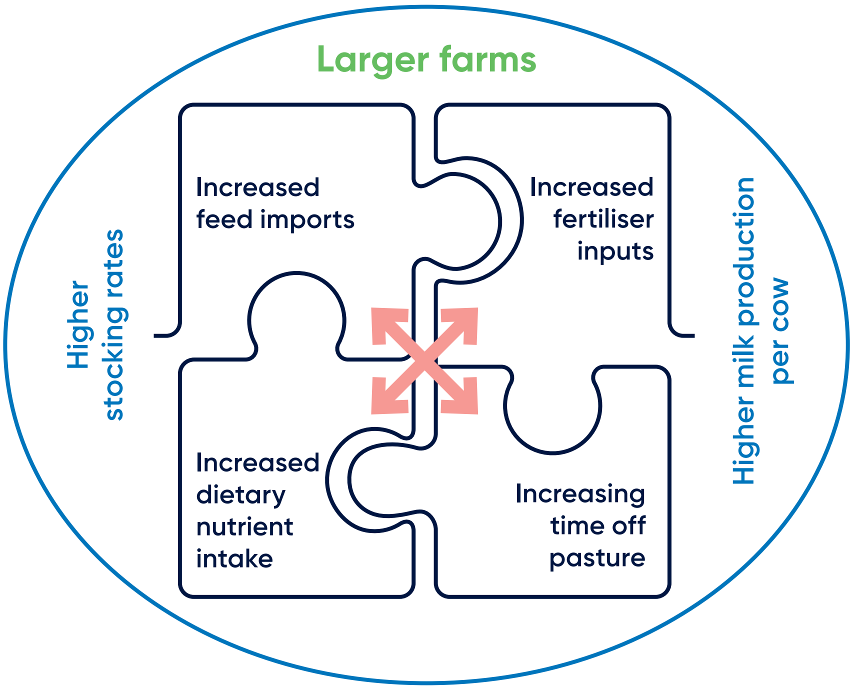
12.1 NUTRIENT MANAGEMENT CHALLENGE

As dairy production systems continue to intensify, increased cow numbers usually result in a greater reliance on imported feed and fertiliser (Figure 96). Increased stocking density can also lead to excessive nutrient loads from manure directly deposited in concentrated areas including feedpads and contained housing facilities (Table 22).

Higher nutrient loads increase the risk of environmental impacts including nutrient, greenhouse gas (GHG) and odour emissions. Consequently, global markets are now expecting evidence of reduced environmental harm, and science-based industry and government policy responses to deal with excess nutrients and a farm-based nutrient management planning approach.

- Manure nutrient management requires greater emphasis when dairy farms import a large proportion of feed and animals are contained.
- Fertiliser nutrient management will require greater emphasis when dairy farms grow most of their own feed.

Figure 96. Implications of intensifying dairy production systems on nutrient load



Source: Cameron Gourley

Table 22. Differing dairy production systems and nutrient management priorities

Importance of fertiliser nutrients → Importance of manure nutrients	Grazing-based	Grazing + bail feeding	Grazed + contained feeding	Contained feeding + grazing	Containment-based
Reliance on imported feed	<20%	20–30%	30–50%	50–70%	>70%
Stocking rate	<1 cow/ha	>2 cows/ha	>3 cows/ha	>4 cows/ha	>5 cows/ha
Time-off pasture	5%	5–15%	15–30%	30–60%	>60%

Source: Fertilizer Australia

To achieve the goals of improving nutrient use efficiency and reducing environmental emissions, nutrient management planning needs to be consistent, comparable, complete, accurate and transparent.

12.2 IMPLICATIONS OF INTENSIFICATION DAIRY FARM NUTRIENTS

Increasing nutrient inputs and load

Increasing land area and milk production per animal often leads to an increase in feed intake, increases in total feed grown, greater inputs of water and nutrients, in particular nitrogen, and increased nutrient inputs.

Dairy farms like this, need improved nutrient management practices (monitoring, application rates, timing, placement) and fit for purpose manure management systems. This is because there is a greater potential loss of nutrients to the environment, notably reactive nitrogen and phosphorus, with various transformations and loss pathways causing if not well managed.

- Increased feed and fertiliser inputs will increase overall farm-gate nutrient surplus
- Whole-farm nitrogen budgets are an important tool in managing risks
- Total nutrient inputs and outputs are estimated, and the difference (surplus or deficit) and ratio (nutrient use efficiency) are quantified.
- The whole-farm nutrient budget approach is relatively simple to calculate using generally available farm-scale data.

Increased nutrient intakes and manure nutrient concentrations

Dairy cows inefficiently utilise the nutrients they consume, with only about 20% of nitrogen, 24% of phosphorus and 8% of potassium consumed by lactating dairy cows being secreted in milk.

An average producing Australian dairy herd of about 300 cows per farm and a lactation period of 305 days, would excrete around 35,000kg nitrogen, 5,000kg phosphorus, and 27,000kg potassium in dung and urine.

As total feed intake and milk yield increases per cow, so does the amount of nutrients excreted by cows (Table 23).

Increased nutrient loads and challenges with nutrient distribution

When animals spend more time contained in feedpads and housing facilities there is a greater need for improved capture, storage and sustainable reuse of manure. Ineffective management within any one component can have a cascading negative effect on the others.

A characteristic of dairy intensification is a transition from traditional grazing-based systems to pasture – feedpad hybrid or contained housing facilities such as freestall, loose housing and dry lot. This transition has the potential to increase milk production per cow but also increases the amount of manure that needs to be managed.

For an equivalent herd size, moving from a pasture-based grazing system (with supplements supplied during the milk harvesting process) to contained housing potentially results in a sixteen-fold increase in the volume of manure to be managed (Table 24). The actual mass of fresh manure requiring collection, storage and land application will vary, but can be substantial. For example, it is estimated that 2400 lactating cows in a freestall will produce 187 tonnes of wet manure each day.

In both grazing and contained systems, there can also be other high stocking density parts of the farm where cows are held for feeding, calving, for welfare, or for exercise, but where excessive deposition of manure can be largely uncollected. Even in grazing-based production systems, where most excreted manure is directly deposited onto pasture soils, there will be varied or uneven distribution of manure across the farm landscape. Paddocks regularly receiving solid manure or effluent or where animals were held for long periods typically have had highest soil phosphorus and potassium levels.

Table 23. Minimum, median and maximum annual nutrient excretion

	Cow live weight (kg)	Total Dry Matter Intake (tonne per cow)	Milk yield (litres per cow)	Excreted nutrients (kg per cow)		
				Nitrogen (N)	Phosphorus (P)	Potassium (K)
Minimum	430	3.8	2,628	73	7	51
Median	500	6.5	6,741	157	22	122
Maximum	680	10.4	11,285	289	48	245

Note: for lactating dairy cows with a range of liveweights, dry matter intake and milk production in Australia.

Source: modified from Aarons et al. 2020

Table 24. Increasing herd size – estimated tonnes of wet manure[1] requiring collection

Herd size	150	300	600	1200	2400
% time contained	Manure captured (tonne per day)				
6	0.4	1	2	5	11
12	1	2	4	10	22
25	2	4	9	21	47
50	3	8	18	42	94
75	5	12	28	63	141
100	7	16	37	84	187

1 Calculations based on 3 litres of wet manure per litre of milk produced (Nennich et al. 2005) and annual milk production increasing from 5,500 to 9,500 litres per cow with increasing herd size.

12.3 NUTRIENT CONCENTRATIONS IN MANURE STORAGE SYSTEMS

Nutrient content of manure sources

Nutrient content of manure sources on dairy farms can vary widely (Table 25), influenced by the feed types and nutrient intakes of dairy cows, dry matter content, methods of manure collection and gravity or mechanical separation processes. Additionally, collection and storage practices can greatly influence nutrient losses and remaining nutrient contents, most notably for nitrogen.

The different types of dairy manure (freshly flushed or scraped manure, first pond sludge, second pond effluent) will contain varying amounts of organic and inorganic nitrogen and phosphorus fractions.

Directly collected and applied dairy manure generally has 50% of nitrogen as ammonia-nitrogen and 50% in organic nitrogen forms. However, these proportions of nitrogen forms vary depending on the dairy cow diet, how much time cows spend on areas draining to the manure management system or frequency of manure collection.

Sludge from the first pond has a high proportion of organic nitrogen forms, which may potentially mineralize over several years after land application. Sludge will also contain a smaller proportion of ammonium nitrogen which is readily available nitrogen to crops or pastures.

Liquid effluent from second and subsequent ponds typically has a low total solids content. Depending on the storage time, liquid effluent will have a higher proportion of ammonia-nitrogen (50% to 90% of total nitrogen) and a comparatively lower proportion as organic nitrogen. Therefore, a high proportion of the total-nitrogen is readily plant available, with added nitrogen supply comparatively short lived.

Semi-solid manure resulting from a screw press (mechanical separation) will have a higher phosphorus to nitrogen ratio, with a higher proportion of nitrogen in an organic form, and so will be more slowly plant available. Composted manure will also have a higher phosphorus to nitrogen ratio, with remaining nitrogen in largely stable forms, resistant to microbial degradation and poorly plant available.

Table 25. Nutrient values for differing manure sources – average and range

Manure Source n=number of farms	Nitrogen (N) (kg/ML or % DM)	Phosphorus (P) (kg/ML or % DM)	Potassium (K) (kg/ML or % DM)	Sulphur (S) (kg/ML or % DM)
Yard wash (directly applied) n=14	419[2] 87-1,334[3]	77 19-237	573 99-1,900	51 9-143
Single pond effluent n=46	323 56-1,800	75 9-622	432 27-3,130	38 7-476
First pond effluent n=50	524 62-2,290	118 22-654	556 150-1,300	87 6-484
Second pond (green water) n=88	211 5-1,080	53 6-250	462 79-1,320	17 2-60
Third/forth pond (green water) n=14	161 7-828	26 6-156	369 70-1,110	16 4-59
Single pond Sludge n=24	0.60 0.26–2.13	0.23 0.05–0.37	0.36 0.12–1.01	0.39 0.07–0.71
Stockpiled Solids n=23	1.2 0.11–3.02	0.32 0.20–0.87	0.62 0.12–3.01	0.26 0.07–2.59

Note: Collected between 2016 and 2019 on commercial dairy farms.[1]

1 *Agriculture Victoria Dairy effluent data base (Biosecurity and Agriculture Services, or R Campbell pers comm..*
2 *Average.*
3 *Range.*

12.4 MANURE NUTRIENT LOSSES

Manure is a valuable source of organic matter and nutrients which can enrich soil and enhance pasture and crop production. However, many physical, chemical, and biological processes can alter manure characteristics after excretion and deposition by cows, and during the process of collection and storage. This results in losses in fertiliser value and increasing environmental emissions.

- Rapid transformation of urea nitrogen to ammonium occurs when urine is mixed with faeces on hard surfaces, resulting in immediate and significant ammonia emissions to the atmosphere.
- Ammonia (NH3) gaseous loss is usually rapid, and higher in material with higher nitrogen concentration.

The management and treatment of manure also influences nutrient losses in gas or leaching.

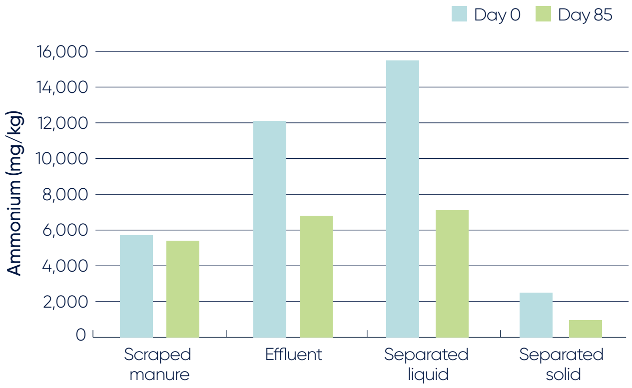
- Nitrogen concentrations continue to decrease during manure storage.
- Ammonia concentrations decrease in stored scraped manure (liquid-solids) after solid-liquid separation.

More soluble elements such as ammonium and potassium will remain in liquid fractions, while phosphorus and organic nitrogen stratify and concentrate in more solid fractions, contributing to variations in nutrient concentrations of manure in different storage systems (Figure 97).

Composting and medium to long term storage of solid manure in stockpiles will further reduce nutrient concentrations and nutrient availability via gaseous and leaching losses, therefore reducing the fertiliser value to crops and pasture (Figure 98).

Manure stockpiles may also produce nutrient rich leachate, with considerably more lost from screen or screw press separated manure solids compared with an equivalent weight of scraped manure (Table 26). Both leachate and atmospheric losses were greater for separated solids manure. Additionally, stored manure can be a significant source of odour (*see 4.3 Odour*).

Figure 97. Ammonium concentration in scraped manure, effluent, liquid and solid fractions



Note: Ammonium concentration after solid-liquid separation at the start (Day 0) and end (Day 85) of storage.

Source: Kitching, Shelley, Aarons, Heaven and Gourley – unpublished data

Figure 98. Windrows and composting of manure prior to land application

Windrows and composting will reduce moisture content and overall volume, but also decrease nutrient availability.

Table 26. Degradation of manure

	Scraped yard manure (i.e. total solids 50%)		Screw-press solids (i.e. total solids 50%)	
Loss pathway	**Uncovered**	**Covered**	**Uncovered**	**Covered**
Leachate (% initial weight)	0.2%	0.2%	12%	19%
Atmospheric (% initial weight)	27%	6%	36%	7%
Nitrogen loss to atmospheric (%)	25%	20%	12%	11%
Carbon loss to atmospheric (%)	30%	22%	49%	53%

Note: Scraped from dairy yards or solids separated through a screw press of yard-wash after 318 days

Source: Gourley, Aarons, Shelley, and Heaven; unpublished data

12.5 DEVELOPING A DAIRY FARM NUTRIENT MANAGEMENT PLAN

A dairy farm nutrient management plan is a strategy for obtaining the optimal return from on-farm and commercial nutrient resources in a manner that minimise nutrient losses to the environment. In many regions around the world such as Europe, United States of America and New Zealand, developing and utilising a nutrient management plan is recommended for the operation of a dairy farm.

Nutrient management plans aim to integrate system level information such as milk production, feed, manure and fertiliser management practices, such as described in the Australian dairy industry Fert$mart program to optimize nutrient use efficiency, and better manage nutrient load at the farm- and within-farm scale, to assist nutrient management decisions for improved productivity and environmental outcomes.

A nutrient management plan should be tailored to an individual farm and should efficiently utilise all sources of nutrients to meet pasture/crop needs and minimise nutrient losses to groundwater, surface waters and the atmosphere.

A dairy farm nutrient management plan should rely on readily available and producer accessible information, should be easily understandable, provide clear guidance, and enable benchmarking of nutrient management performance.

Key components of a dairy farm nutrient management plan

The key information sources required to develop a nutrient management plan are provided below. All components of a dairy nutrient management plan are basic farm and nutrient management practices, with required information readily available from a successful dairy farm business.

a) Meeting regulatory requirements.
b) Defined dairy farm system boundaries.
c) Determining whole-farm nutrient balance and nutrient use efficiency.
d) Determining a manure, effluent and nutrient inventory.
e) Identifying nutrient deficiencies and excesses through soil testing.
f) Developing specific management-zone nutrient recommendations.
g) Targeted manure and fertiliser applications
h) Incorporating management strategies to reduce nutrient losses.
i) Opportunities and strategies to export excess nutrients.
j) Planning and record keeping.

a) Meeting regulatory requirements

Advisors and agronomists offering dairy specific nutrient management advice should be aware and understand all the relevant industry guidelines and codes of practice for manure and effluent management.

b) Defined dairy system boundaries

Australian dairy farms generally have land where dairy cows are located during the lactation for grazing and supplementary feeding, and which directly contributes to milk production and nutrient cycling. There are often other land uses within a dairy farm boundary such as native vegetation, wetland and riparian areas, that do not contribute to milk production. Many dairy farms may also have separate land areas (i.e. dairy support areas), where young and dry cows are contained and where additional pasture and forage will be grown and conserved.

- The dairy farm area most relevant to nutrient management planning is the milking platform – this is the principal productivity area.
- The milking platform is the total hectares of land directly contributing to milk production and includes grazed and harvested forage (pasture and crops) and designated feeding and sacrifice areas.
- The greatest nutrient inputs, manure deposition, nutrient cycling, pasture, crop and milk production and potential for nutrient losses occurs on the milking platform.

The milking platform is therefore used as the land area for determining nutrient inputs, outputs and net nutrient balance, reported on a per hectare basis. Whole-farm nutrient use efficiency measures, being a ratio, is not affected by assumptions about the land base.

- An aerial photograph or detailed farm map is useful for determining milking platform. In addition to detailed property and paddock boundaries and dimensions, infrastructure such as buildings, roads and laneways, gates and watering points should be identified.
- The farm map should also categorise bushland, hydrological characteristics such as waterways and gullies, flood plains, soaks and wetlands, and topographic characteristics (i.e. step-rises, sandy ridges.).

Aerial photography, satellite imagery and other coverages such as farm and paddock boundaries are often accessible both online and offline to assist with this task.

c) Determining whole-farm nutrient balance and nutrient use efficiency

A whole-farm nutrient budget considers the quantity of nutrients coming onto the dairy farm milking platform as inputs and the quantity of nutrients leaving in products, usually determined over a 12-month period (Figure 99).

The sum of nutrient inputs and outputs enable the determination of nutrient surpluses and deficits, while the ratio of the sum of nutrient exports to nutrient imports provides an estimate of nutrient use efficiency at the farm scale.

A nutrient budget calculation for nitrogen, phosphorus, potassium and sulphur therefore requires information about the nutrients imported and exported for an individual dairy farm, as determined by their mass and corresponding nutrient concentration.

Key nutrient imports generally include feed (forage and grain-based), fertiliser and nitrogen from biological nitrogen fixation. However, there can also be a wide range of additional nutrient imports such as by-product feeds, bedding, alternative fertiliser products, atmospheric deposition and irrigation of reuse water.

Key exports largely involve milk and animal sales. Additionally, manure may be an important source of nutrient exports on some farms.

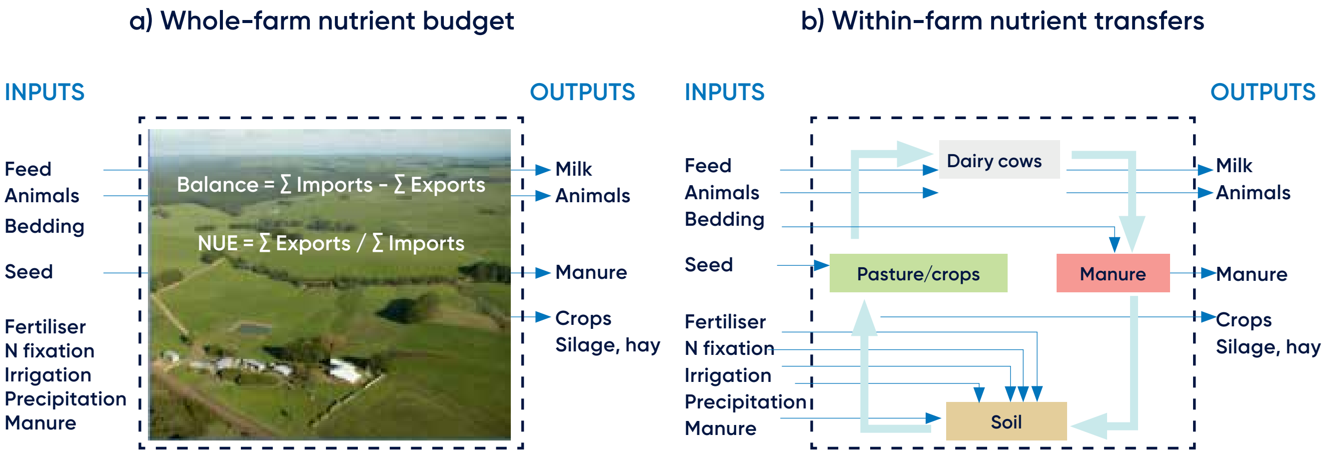
While the mass or volume of imported and exported nutrient sources can usually be determined, nutrient budget calculations usually rely on nutrient concentrations sourced from lookup tables provided by commercial suppliers as well as published and scientifically credible industry standards.

A national dairy farm nutrient budget calculator (Ellinbank Dairy Farm Nutrient Budget calculator) which provides Australian dairy industry standard nutrient concentrations, is accessible from the Dairy Australia Fert$mart website.

Whole-farm nutrient surplus and use efficiency estimates provide a simple and largely standardised way to quantify and differentiate the utilisation of imported nutrients, and when combined with information on key components of nutrient load on dairy farms can greatly assist in targeting improvements in management (Table 27).

- A higher nutrient use efficiency indicates a greater utilisation of nutrients in exported animal products, and/or reduced inputs.
- Note, very high nutrient use efficiency, sometimes greater than 100%, indicates more nutrients are being removed than replaced, mining the soil of nutrients. For farms with excess reserves of soil phosphorus and potassium, this may be appropriate.
- High nitrogen use efficiency may however be decreasing soil nitrogen supply and degrading soil carbon.
- It is unreasonable to expect a farm to be 100% efficient as there are natural losses of nutrients in any ecological system, and agricultural systems are inherently inefficient.
- Whole-farm nutrient budget information is increasingly required by national and international food manufacturers and retailers as part of the demonstration of sustainable nutrient management practices.

Figure 99. Key nutrient load and cycling of nutrients within the farm boundary



Source: Adapted from Fertilizer Australia, 2020

Table 27. Whole-farm nutrient use efficiencies from a range of dairy farms

Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)
Median value: 26%	Median value: 28%	Median value: 20%	Median value: 21%
Range: 14–50%	Range: 6–158%	Range: 9–48%	Range: 6–110%
Target range: 35–45%	Target range: 60–90%	Target range: 30–50%	Target range: 30–50%

Source: Gourley et al. 2012

While whole-farm nutrient balance and nutrient use efficiency are used as broad environmental indicators, the diverse climatic and soil conditions experienced in Australia, makes it difficult to make general predictions about the forms and amounts of nutrient losses from dairy farms. To quantify actual environmental losses, or even to determine relative losses, more detailed measures or predictive modelling is required that includes the partitioning of nutrient losses between various loss pathways.

d) Determining an effluent, manure and nutrient inventory

Nutrients available for land application from manure storage facilities are determined from the dry mass and nutrient concentration of each manure source. Information required include pond or stockpile volume and density, moisture and nutrient content.

Pond volumes are determined using the surface area and depth and adjusting for batter wall angles. However, it is difficult to arrive at an accurate gauge of pond depth and batter wall angles and so the calculated volume needs to be recognised as informed estimates.

Manure stockpile volumes can be determined by collecting length, height and shape data either manually or using software packages that use photogrammetry to capture a detailed 3-D image. Density of manure can be estimated or calculated from the weight of manure in a known container volume (i.e. bucket).

Average nutrient content values are available for different manure types (see Table 25). However, it is important to note that the actual nutrient content of manure sources on any farm can vary widely from published values, so laboratory analysis of farm-specific manure stores is recommended.

Collecting a representative sample of manure sources is important. This is particularly challenging in single or primary ponds where stratification occurs. Sampling methods for different manure and effluent sources are provided in the Australian dairy effluent and manure management database.

The minimum recommended laboratory analysis of manure should include moisture content, total and mineral nitrogen, total phosphorus, potassium and sulphur.

Collecting effluent and sludge samples from manure ponds can be dangerous. Ponds can be deep and viscous, with organic matter crusts and vegetation concealing the pond surface and edges. A safety assessment is essential prior to sampling.

e) Identifying nutrient deficiencies and excesses through soil testing

Soil testing and plant analysis are invaluable tools to diagnose constraints to crop and pasture production and may also assist to identify nutrient loss risk areas. Fertiliser recommendations for agriculture require supporting soil and plant chemical analysis and interpretation, underpinned by samples that represent the relevant soil environment.

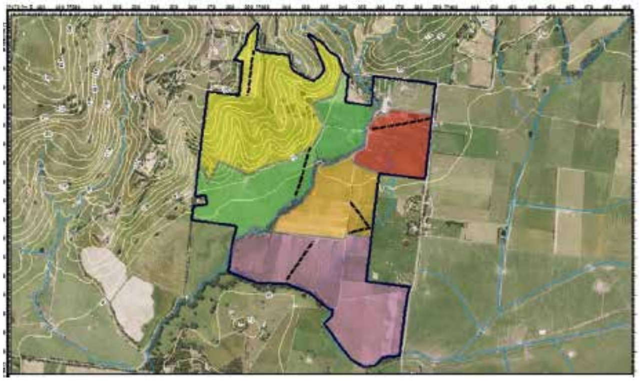
An on-farm soil testing program should adhere to the Australian Fertcare® Soil Sampling standard (Fertilizer Australia 2019) and be conducted at a time that allows for analysis of the sample and its interpretation in advance of the recommended fertiliser treatment.

It is important that a farm specific soil sampling map be developed. Paddocks or blocks that have differing management regimes and different soil types that need to be identified and categorised. In grazed dairy pasture systems, these regimes may include day and night paddocks, regular fodder harvesting, high feeding areas, regular effluent application areas and extensively managed out-paddocks. Areas that may be prone to greater nutrient loss should also be identified.

- The most comprehensive strategy is to sample every paddock (or even sub-paddock areas) every year to support an evidence-based approach to fertiliser decision making.
- Other options include cycling around the farm over a 3-4-year period until the whole farm is completed or selecting 'typical or representative' paddocks with similar characteristics.

The number of areas selected to be sampled should recognise the diversity of groups identified. Setting up a simple matrix based on paddock ID and matched against defined management practices (i.e. production potential, grazing practices, manure and effluent applications, previous fertiliser inputs, etc.) can assist in grouping paddocks and identifying representative areas to sample. For paddocks or blocks with the same soil types, and that have a similar management regime, an individual or group of paddocks with an average productivity can be selected to represent the rest of the paddocks or blocks in that group (Figure 100).

Figure 100. Example – five identified dairy farm management zones showing soil sampling transects



Note: The paddocks and transect paths used to collect representative soil samples.

Source: Fertilizer Australia 2020

The number of areas to sample should consider the cost of soil testing against the potential production benefits, savings in fertiliser, and costs to implement alternative approaches to fertiliser management.

It is important to record the specific location sampled (i.e. using GPS or recording/marking the transect on fence posts) within each representative paddock, block or management zone, so that you can return to the location and identify trends in fertility status site over time.

The sampling approach adopted should have an organized and systematic pattern to ensure that a collected bulk paddock sample is repeatable, labour efficient, adequately addresses the variability within the paddock and minimised bias. For information on sampling techniques, see *Fert$mart Chapter 8 – Assessing soil nutrients*.

Within-paddock variability in nutrient or other soil parameters can be significant. Some atypical paddock areas may be easily identified (i.e., current fence lines, gates, troughs, stock camps, feed-out areas, stock tracks), while others may not (previous fence lines, fertiliser or lime dumps, timber burns).

- Collecting an adequate number of cores to account for within-paddock variability is critical to achieving a representative sample.
- Paddocks with high variability require more cores to achieve the same error estimate than paddocks with low variability.
- At a minimum, the number of bulked soil cores should be 30–40 for 19mm diameter cores and 20–30 for 25mm diameter cores (accepting a ±15% error), irrespective of paddock size.

Soil sampling depth should reflect the zone of root activity and align with nationally accepted soil test calibration experiments for relevant pastures and crops. The required soil sampling depth is 10cm for pastures and forage crops in all States and Territories.

Soil analysis and interpretation

The quality of analytical services is critical in determining fertiliser and soil amendment advice provided to producers. In selecting a laboratory service provider, the following factors need to be considered and confirmed:

1 Participation in independent laboratory proficiency testing programs, whereby common homogeneous samples are sent for analysis to laboratories. The Australasian Soil and Plant Analysis Council (ASPAC) conducts the Proficiency Testing Programs for Australian laboratories. Laboratories are certified for particular test analytes if their results meet the qualifying criteria, with their annual certification status updated on the ASPAC website.

2 The use of recognised analytical methods which generate results that can be interpreted for Australian conditions, published interpretation data and/or historical records,

3 Presence of a quality control system, by way of internally-driven procedures or by verification to the AS/ISO 17025 standard through an authority such as the National Association of Testing Authorities (NATA).

Interpretation of soil test results must be underpinned by the national and soil specific soil test – pasture yield response functions and the derived critical soil test values for near-maximum growth of improved pastures across Australia.

Soil testing will also identify potential soil constraints (e.g. soil acidity, soil sodicity, soil salinity and soil dispersion) that will impact on pasture nutrient uptake and that soil amendment requirements will also be identified.

Derived relationships for phosphorus, potassium and sulphur form the basis of national standards for soil test interpretation and fertiliser recommendations for Australian pastures (Gourley *et al.* 2019) and are incorporated within the major Australian fertiliser company decision support systems. The most common tests are Olsen P (Victoria and Tasmania), Colwell P (NSW, SA, WA, ACT), Colwell K and exchangeable potassium (nationally), and MCP S or KCl40 S (nationally). Colwell P also requires the phosphorus buffering index measure for interpretation (Table 28). Soil testing for nitrogen in dairy pastures may be useful in determining residual mineral nitrogen in the soil profile but is generally poorly related to responses to applied nitrogen fertiliser.

Optimum nutrient status will be in the lower ranges on farms where pasture utilisation is low or when pastures contain poorer producing species. Whist 95% of pasture production potential is regarded as ideal in grazing-based dairy systems, optimum soil nutrient status is often regarded as 95–98% of pasture production potential (Table 28). It is a business decision where a producer chooses to operate, but it is not economically or environmentally sensible to operate above the 95% pasture performance level.

It is important to recognise that with increasing soil nutrient levels comes diminishing economic, and ultimately negative financial returns, as well as an increased risk of nutrient losses and offsite impacts.

Table 28. National interpretation guidelines for common soil tests for dairy soils

Soil test targets for 0–10cm samples accounting for pasture performance goals					
			Critical value range		
Pasture yield performance compared with potential	80–89%	90–94%	95–97%	98–99%	>99%
			Olsen P (mg/kg)		
All soils	8–10	11–14	15–20	21 –26	>26
PBI value			**Colwell P (mg/kg)**		
<5	7 - 8	9–11	12–15	16–19	>19
10	9–12	13–16	17–22	23–27	>27
20	13–17	18–23	24–30	31–37	>37
50	16–21	22–28	29–37	38–44	>44
100	18–24	25–32	33–42	43–51	>51
200	21–29	30–38	39–50	51–60	>60
350	25–35	36–46	47–60	61–72	>72
600	32–45	46–59	60–77	78–92	>92
1,000	45–64	65–83	84–109	110–129	>129
			Colwell K (mg/kg)		
Sand	85–94	95–125	126–155	156–200	>200
Sandy/Silty loam	94-104	105–138	139–175	176–210	>210
Sandy/Silty clay loam	99–109	110–142	143–185	186–220	>220
Clay loam and clay	110–119	120-160	161–210	211–270	>270
			Exch K (meq/100g)		
Sand	0.19–0.23	0.24–0.31	0.32–0.39	0.40–0.51	>0.51
Sandy/Silty loam	0.21–0.26	0.27–0.34	0.35–0.44	0.45–0.54	>0.54
Sandy/Silty clay loam	0.22–0.27	0.28–0.35	0.36–0.46	0.47–0.56	>0.56
Clay loam and clay	0.24–0.30	0.31–0.40	0.41–0.53	0.54–0.68	>0.68
			Sulfur (KCl-40) (mg/kg)		
All soils	4.5–5.5	6.0–7.5	8.0–10.0	10.5–12.0	>12.0
			Sulfur (CPC S) (mg/kg)		
All soils	1.6-2.2	2.0–3.0	3.1–3.8	3.9–4.5	>4.5

1. Critical value defined as 95% of potential maximum yield for grass – legume pastures.

2. Production goals defined by management.

f) Developing specific management-zone nutrient recommendations

Soil fertility and chemical condition mapping allows translation of soil test results into a visual representation of fertility and chemical conditions across the farm and highlights between-paddock or block variability (Figure 101). Mapping of soil test results across the farm is also useful in defining nutrient transfers such as regular forage harvesting, animal feeding areas and application of manure and effluent, or identifying the risk of metabolic problems in livestock. This approach can also identify areas close to dairy sheds that often have high or excessive nutrient levels, and those further from the dairy that may have nutrient levels below critical values which can accept effluent.

Different colours, depending on the context, may be used to correspond to soil nutrient status and targets (i.e. very high, high, adequate, marginal and deficient). Paddocks or blocks are then colour coded based on soil test results. Soil pH and salinity maps similarly determined are useful for targeted soil amendment decisions such as lime and gypsum.

g) Targeted manure and fertiliser applications

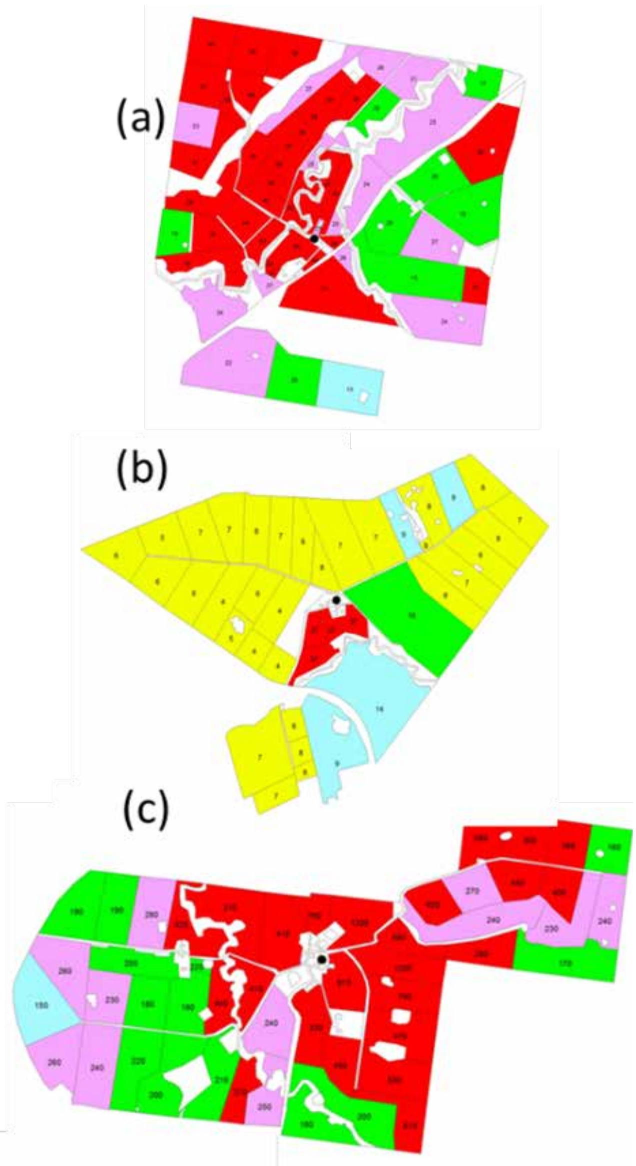
The 4R nutrient stewardship principles (IPNI 2020) are globally recognised, but how they are used locally varies depending on site-specific characteristics such as pasture and cropping system, soil and topography, climate and management techniques. The scientific principles of the 4R framework include:

- **RIGHT SOURCE –** Ensure a balanced supply of essential nutrients, considering both available sources and characteristics of specific fertiliser products, in plant available forms.
- **RIGHT RATE –** Assess and make decisions based on soil nutrient supply and plant demand.
- **RIGHT TIME –** Assess and make decisions based on the dynamics of plant uptake, soil supply, nutrient loss risks, and field operation logistics.
- **RIGHT PLACE –** Ensure that spatial variability within the paddock is addressed to meet site-specific plant needs and limit potential losses from the paddock.

Manure nutrient applications

The manure inventory enables an estimate of the total nutrients currently available for land application from stored manure and effluent. Matching this nutrient supply with estimated nutrient requirements across the farm is an important part of a dairy farm nutrient management plan.

Figure 101. Nutrient distribution map of Australian dairy farms



a) Olsen P levels on a conventional farm, (b) Olsen P on an Organic farm, (c) Colwell K on a conventional farm. Red indicates very high, purple is high, green is adequate, light blue is marginal and yellow is deficient nutrient phosphorus or potassium availability. The dot represents the location of the dairy shed.

The nutrient requirements of pastures and crops on a dairy farm may be totally, partially or only marginally met by the generated and stored manure. This will be influenced by the intensity of the dairy operation, informed by the whole-farm nutrient balance for nitrogen, phosphorus, potassium and sulphur, but also depend on the efficacy of manure collection, storage and land application.

Manure applications to deliver phosphorus, potassium and sulphur should be based on soil testing of identified farm management zones. Nitrogen inputs should be applied to optimize pasture and crop yields and use efficiency.

The 'fertiliser value' of nutrients in manure should be discounted depending on the manure source (LPELC 2019). Nutrients in manure are present in inorganic and organic forms, and hence are often not all immediately available to plants. Organic sources of nutrients must be mineralised into inorganic forms. For example, proteins need to be mineralised to ammonium, where it can be directly adsorbed or further transformed to nitrate. Organic forms of nitrogen will continue to mineralise and become available to crops in subsequent years after the initial application. In contrast, potassium remains in an inorganic form and is immediately plant available.

The rate of mineralisation will depend on the manure composition and load applied as well as the soil conditions such as clay content, biological activity, moisture content and temperature.

Most manure nutrient availability tables and decision support calculators will provide discounting factors to use when calculating nutrient availability.

Dairy manure sources rarely provide the correct balance of nitrogen, phosphorus, potassium and sulphur when manure is applied to land. Manure applications to meet nitrogen requirements will generally result in an oversupply of phosphorus and potassium, above pasture or crop requirements, with potential environmental and animal health impacts. If potassium application rates are optimised, then nitrogen and potentially phosphorus rates are likely to be sub-optimal and require additional commercial fertiliser.

It is important to calculate the required manure application to land, based on the target nutrient application rate (kg/ha).

This may require the calibration of manure application equipment. For irrigation systems the volume of effluent applied will be required (i.e. ML or mm applied per ha). For more solid material, this requires the mass or volume of manure applied (i.e. ton or cubic metres/ha). In both cases the mass or volume is multiplied by the nutrient concentrations (volumes need to be adjusted for density).

Figure 102. A trailing hose tanker spreading effluent from an agitated first pond

Preferred timing of manure applications must balance multiple factors including timing of pasture and crop uptake of nutrients and probability of rainfall events following manure application. The location of manure applications must consider site specific characteristics that influence environmental risks, such as existing soil test values, soil phosphorus buffering, slope, erosion potential and proximity to waterways. Effluent and sludge should not be applied to waterlogged or excessively wet soils.

CALCULATING EFFLUENT/MANURE LAND APPLICATION RATES:

Effluent/sludge

Target nutrient application (kg/ha) ÷ ((Nutrient concentration (kg/ML) x availability factor)) = Effluent application rate (ML/ha).

Example for potassium:	60kg/ha ÷ (462kg/ML x 1) = 0.13ML/ha or 13mm
Example for nitrogen:	50 kg/ha ÷ (211kg/ML x 1) = 0.24ML/ha or 24mm

Solid stockpiled manure

Target nutrient application (kg/ha) ÷ ((Nutrient conc. (%) x availability factor x DM content = Solid material application rate (tonne/ha).

Example for phosphorus:	30kg/ha ÷ (0.2% x 0.75 x 50%) ÷ 1000 = 40 tonne/ha wet weight
Example for nitrogen:	60kg/ha ÷ (1.2% x 0.50 x 50%) ÷ 1000 = 20 tonne/ha wet weight

Note: Targeting the land limiting constituent avoids environmental impacts, so select the lowest of the two application rates.

Inorganic fertiliser nutrient applications

Nutrients contained in manure should be used first. After that, inorganic fertilisers can be used to plug any gaps.

- Fertiliser applications to meet phosphorus, potassium and sulphur requirements should be based on existing soil test results of the identified farm management zones as well as nutrient budget calculations.
- Fertiliser applications need to also account for nutrient removal and soil retention or losses (soil phosphorus fixation, potassium leaching) when determining 'maintenance fertiliser rates', and surplus nutrient inputs ('capital fertiliser applications') when the build-up of soil nutrient reserves is justified.

The rate of phosphorus, potassium and sulphur should be determined with the use of an accredited nutrient decision support system (i.e. Fertilizer Australia, Fertcare accredited), or alternatively a transparent calculation process which clearly identifies the scientific justification for the recommended fertiliser application.

Nitrogen fertiliser applications, often dominated by urea, is increasingly being used on dairy farms to increase pasture yields. Nitrogen fertiliser can substantially increase pasture yield and feed on offer when conditions are optimal for plant growth (i.e. adequate soil moisture and temperature, appropriate pasture species composition and maturity, and adequate supply of other nutrients). In contrast, yield responses can be low or negligible if soil, season and climate conditions are restricting plant growth, grazing pressure is too harsh or too little, or soil nitrogen supply from legumes, manure or mineralisation is meeting or exceeding plant demand.

National nitrogen management guidelines (Dairy Australia 2020) aim to improving nitrogen use efficiency and reducing avoidable environmental nitrogen losses. Best practice should also include determining the economic optimum nitrogen fertiliser rate.

- Optimum nitrogen fertiliser rates usually range between 30 and 60kg nitrogen per hectare per application.
- Total nitrogen applications for most pastures should not exceed 250kg nitrogen per hectare per year.

Ready reckoners such as 'Dairy N Fertiliser Advisor', based on a database of national nitrogen fertiliser response experiments, enables paddock specific nitrogen fertiliser recommendations for pastures based on regional, pasture production, season and cost-benefit analysis.

h) Incorporating management strategies to reduce nutrient losses

The main environmental issues which relate to nutrients include phosphorus and nitrogen losses to surface waters - leading to excessive growth of aquatic plants and algae and reduced oxygen availability (anoxia), and excess nitrogen leading to nitrate leaching to groundwater. The loss of ammonia, nitrous oxide and methane from the storage and land application of manure, is of increasing importance due to their contribution to greenhouse gas emissions.

On-farm nutrient use is highly regulated in many regions of the world. Some regulations are now evident in Australia, with controls on fertiliser use being introduced to protect the Great Barrier Reef (Qld). In other regions there are 'softer' options occurring, with combinations of research, extension, incentives and regulation, supported by Federal and State governments, industry organisations, producers, processors and retailers. Wise use of nutrients, and demonstration of nutrient management planning, will reduce the risk of increased regulation of farming activities.

Beyond the economic benefits of reducing expenditure on fertilisers, there are potential positive water quality outcomes using soil testing and adherence to agronomic critical values.

- Water quality risks will be reduced by allowing current soil phosphorus levels to rundown to the critical values.
- The Phosphorus Buffering Index (PBI) soil test provides an estimate of the potential phosphorus retention of a soil.
- Soils which have a low to very low phosphorus retention may be prone to leaching of stored and applied phosphorus (fertiliser or manure) through the soil profile and increased horizontal phosphorus losses through surface water movement.

Use of tools such as the Farm Nutrient Loss Index (FNLI) can assist in determining the risk of phosphorus and nitrogen losses at the landscape and paddock scale.

Minimising direct losses from fertiliser applications

- Know the soil fertility levels and do not fertilise or apply manure and effluent to soils with levels above-optimum soil fertility targets.
- Ensure fertiliser applications do not directly impact surface waters such as waterways, drainage lines and water storages – maintain the appropriate buffer distance when spreading.
- Avoid spreading fertiliser on critical source areas with connectivity to waterways, such as excessively wet paddocks adjacent to streams.
- Avoid areas with potentially above optimum nutrient levels (i.e. around gateways, feed pads, etc).
- Do not apply fertilisers to buffer strips or the end of irrigation bays.
- Do not apply nitrogen and phosphorus within 5 days of an anticipated rainfall runoff event.
- Ensure adequate ground cover and minimise soil erosion potential.
- Minimise urea applications to warm, wet soils and excessively short pasture to reduce ammonia volatilisation.

Minimising losses from storing and mechanically spreading manure

- Designing, maintaining and correctly sizing pre-treatment systems, ponds and manure stockpiles is critical to the effective capture and storage of dairy manure and minimising greenhouse gas losses.
- Ensure no direct overflow or leaching losses from ponds or stockpiled manure. Earthen or concrete bunding, drainage lines and ponds to contain leakage may be required.
- Dairy effluent and manure applications should be directed to areas in need of nutrient applications and applied at the required nutrient rates, accounting for slope, soil moisture content, leaching potential and ground cover.
- Ensure appropriate setbacks from waterways, buffer strips and native vegetation.
- Breakdown alerts and automatic shut-off systems should be used to address effluent irrigation system blockages, disconnections and overflows.
- Minimise the use of splash-plates and muck-spreaders. Concentrating effluent and slurry applications using trickle, trailing hose, or injection applicators will reduce nitrogen losses.

Minimising losses from animal deposited manure

- Manure deposited on hard stand areas (i.e. holding yards, feedpads, loafing areas etc) should be contained and managed within the manure management system.
- Keep stock out of waterways. Fence creek crossings and provide alternative watering points.
- Remove grazing animals from excessively wet soils and poor pasture cover. Restricting grazing to 8 hours a day over the autumn/winter period, and use of 'off-paddock' facilities, such as feed and stand-off pads can reduce nitrogen leaching losses.
- Ensure laneway runoff does not concentrate and drain direct to waterways. Construct drainage diversion humps to direct laneway runoff to grassed areas.
- Designated feeding areas, troughs and gateways should also be carefully sited.

i) Opportunities and strategies to export excess nutrients

The distribution of nitrogen, phosphorus, potassium and sulphur across a dairy farm is related to the intensity of the dairy farm system, paddock use (e.g. feeding areas, routinely grazed pastures, routinely cut and carry forage), and distance of grazed pastures from the dairy shed. A key influence of nutrient loads in particular areas, depends on how a dairy farm manages stocking density and the distribution of collected manure and effluent. Paddocks closer to the dairy shed are likely to be grazed more frequently, or used as holding or feeding paddocks, and hence will have a higher animal density and nutrient load. Those same paddocks are also more likely to receive mechanically applied effluent as they are more conveniently located to ponds. Be aware that:

- The nutrient concentrations of harvested forage are low relative to inorganic fertilisers, and manure and effluent application rates are generally much higher than the forage yields removed.
- Running down excessive nutrient levels such as phosphorus and potassium in soils is therefore a much slower process than the accumulation due to excess fertiliser, manure or effluent applications.

Nutrient accumulation within paddocks should be managed by monitoring the nutrient inputs and outputs associated with management decisions, assisted with soil test information about nutrient status. Forage harvesting may result in some significant net removal of nutrients but will depend on forage type, DM yield and nutrient concentrations (Table 29). For example, a good quality pasture silage will remove nearly twice the nitrogen, phosphorus, potassium and sulphur of an average pasture hay, while corn silage may produce higher yields, but a lower proportion of nutrients removed. It should also be noted that while legume crops such as lucerne may result in a net removal of phosphorus, potassium and sulphur, there is likely to be a net input of nitrogen through nitrogen fixation.

j) Planning and record keeping

Record keeping improves the planning and reviewing process. It is beneficial to keep structured annual records which include details of farm layout and identifies the principal productivity area, paddock uses, management zones, as well as any setback areas. Information on farm maps should also include soil sampling pathways and be linked to current and previous soil test results.

Manure, effluent and fertiliser applications to individual paddocks or at least management zones, should include the type, timing and rate of application and associated nutrient rates applied. Other useful information may include weather conditions and observed or measured pasture or crop yield responses to applied nutrients.

Table 29. Typical nutrient removal[1] when forage is exported

	Crop removal (tonne/ha)	Nutrient removal (kg/ha)			
		Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)
Pasture hay	2	34	5	35	4
	4	68	10	70	9
Pasture silage	2	74	9	55	7
	4	147	18	111	14
	6	221	27	166	20
Lucerne silage	2	60[2]	8	43	6
	4	120	17	86	11
	6	180	25	129	17
Maize silage	4	67	10	41	4
	6	101	16	62	7
	8	134	21	82	9

1 Forage nutrient concentrations based on average farm data from Rugoho *et al.* 2016.

2 Lucerne cropping will increase nitrogen inputs through nitrogen fixation.

DAIRY FARM NUTRIENT MANAGEMENT PLANNING CHECKLIST

- ☐ Farm area defined, paddocks identified and grouped into farm management zones.
- ☐ Regulatory requirements and environmentally sensitive areas identified.
- ☐ Whole-farm nutrient budgets and nutrient use efficiencies determined.
- ☐ Soil sampling areas and sampling routes identified according to Fertcare® soil sampling guidelines.
- ☐ Soil analysis and interpretation according to accepted science in Australia e.g. Making Better Fertiliser Decisions for Grazed Pastures in Australia.
- ☐ On-farm manure nutrient sources quantified and use optimised.
- ☐ Pasture and crop composition and growth performance assessed and considered.
- ☐ Basic soil health indicators have been assessed and considered e.g. waterlogging, pugging, sodicity and soil structure.
- ☐ A manure and fertiliser application strategy incorporating the 4Rs for each farm management zones have been developed.
- ☐ Environmental risks associated with nutrient applications have been identified and documented, and measures to minimise environmental risks implemented
- ☐ Adequate records are created and retained.

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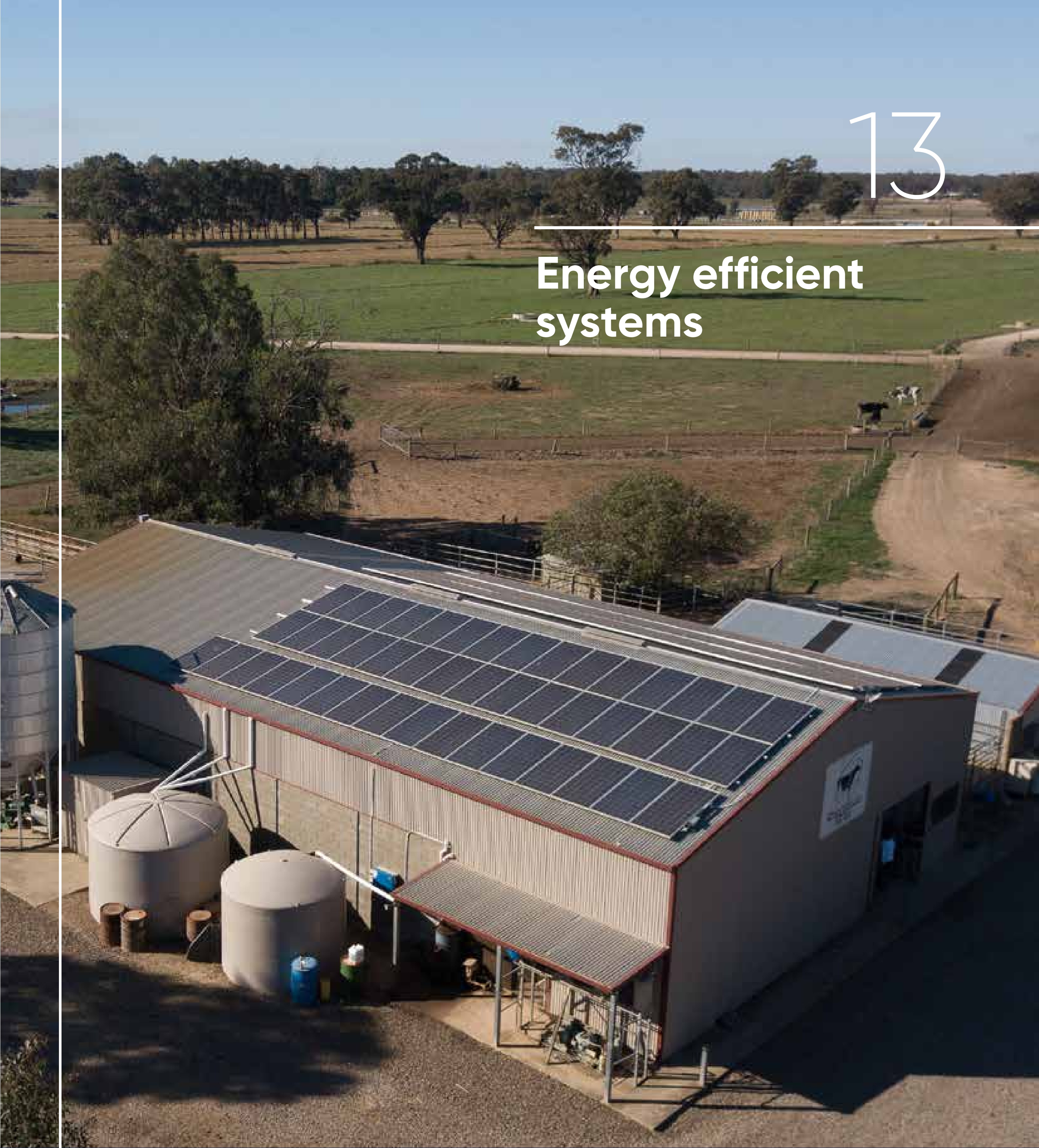


13

Energy efficient systems

INTRODUCTION

The development of a feedpad or contained housing facility may increase total energy requirements for the dairy operation leading to increased energy costs and greenhouse gas emissions. Upgrades to electricity grid connection including transformer upgrades may be required when electricity demand increases or if excess on-site renewable electricity generated is feed into the grid.

Steps can be taken in the design, development and operational phases to improve the site's energy efficiency through:

- Equipment selection
- Regular maintenance
- Renewable energy generation.

Energy consumption and costs will change over time and will vary from farm to farm. Understanding the energy requirements and site operational issues can assist to identify where efficiency gains can be made.

13.1 REVIEWS OF ENERGY USE ON DAIRY FARMS

Energy audits completed on 1,400 Australian dairy farms between 2012 and 2015, by the Smart Energy Use project, identified milk cooling, milk harvesting and water heating as the top three uses of electricity, totalling 81% of a dairy's electricity usage on average.

- Average electricity usage was 48 kilowatt hours (kWh) per kilolitre (kL) of milk.
- There was a range with two thirds of the farms falling into the range of 31 to 66 kWh per kL milk.
- These audits were completed for a range of dairy types and herd sizes in predominately grazing systems as there were limited contained housing systems in Australia at the time.

Mohsenimanesh *et al.* (2021) reviewed 37 international electricity studies from across five continents from both grazing and contained housing systems reported that the average energy use of:

- The confined systems were 92 watt-hours (Wh) per kg milk and 769 kW per cow per year
- The pasture systems had an average energy use of 66 Wh per kg milk and 475 kWh per cow per year.

Table 30. Electrical energy consumption breakdown statistics of studies found in literature

Study	Total Wh/kg	Milk cooling Wh/kg	Milk harvesting Wh/kg	Water heating Wh/kg	Water pumping Wh/kg
Mean AMS – Contained	n/a	17.45 (13.20–21.90) N=2	14.54 (11.13–29.30) N=3	10.67 (2.2–5.05) N=2	n/a
Mean Conventional – Contained and Grazing	48.91 (38.68–73.00) N=4	15.32 (9.85–21.7) N=7	13.97 (6.91–23.01) N=7	9.45 (3.43–16.30) N=7	3.28 (1.51–6.57) N=5
Mean Conventional – Contained	57.92 (42.84–73.00) N=2	16.68 (9.85–21.7) N=5	16.54 (8.14–23.01) N=5	9.80 (3.43–16.30) N=5	4.27 (1.51–6.57) N=3
Mean Conventional – Grazing	39.89 (38.68–41.11) N=2	11.94 (11.24–12.64) N=2	7.55 (6.91–8.19) N=2	8.60 (7.66–9.54) N=2	1.79 (1.51–2.07) N=2

Note: Brackets is range of averages in the studies, N=number of studies, Wh/kg = watt-hours per kg milk, AMS = Automatic Milking System, Conventional = Conventional milking system

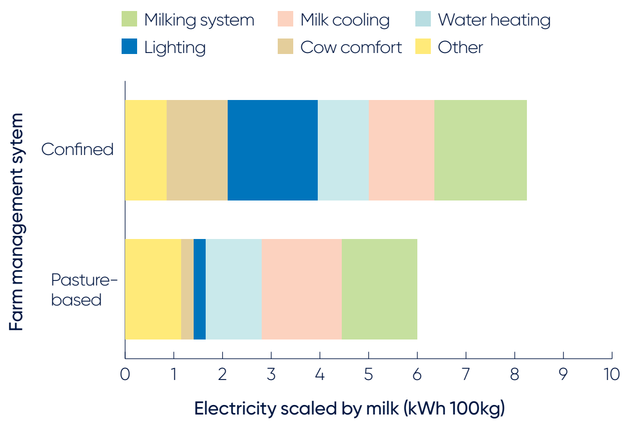
Source: Adapted from: Shine et al (2020)

Shine *et al.* (2020) also reviewed a number of international studies looking at electricity consumption in both grazing and contained housing systems, excluding automatic milking systems (AMS), showed the mean electricity usage was 48.9 watt-hours per kg of milk. The three top uses were milk cooling (15.3 Wh/kg), milk harvesting (14.0 Wh/kg) and water heating (9.5 Wh/kg) (Shine *et al.*, 2020). Table 30 shows the mean and range of electricity consumption of the studies identified by Shine *et al.* (2020).

The findings from Shine *et al.* (2020) are consistent with the energy assessments completed on Australian dairy farms (RMCG, 2015) while the average electricity use figures for grazing systems from the study by Mohsenimanesh *et al.* (2021) are at the higher end of the Australian dataset range.

Figure 103 shows the energy use profile for contained housing systems compared to grazing systems. The studies reviewed by Mohsenimanesh *et al.* (2021) show the main area where there is an increase in electricity use is fans for cow comfort and lighting, with these accounting for 15% and 20% respectively in the studies available. This study noted there is a gap in data available in electricity consumption of fans and lighting.

Figure 103. Electricity use in contained housing vs grazing systems (pasture-based)



Note: Confined = Contained. Electricity use in kWh per 100kg milk broken down into the component of the dairy operation the energy is used in.

Adapted from: Mohsenimanesh et al (2021)

Energy audits completed in New York State, United States of America indicate that ventilation and lighting may be two areas where energy requirements increase in contained housing systems. These audits, completed on 32 contained housing systems, saw milk cooling (25%), lighting (25%), ventilation (22%) and milk harvesting (17%) being the largest uses of electrical energy with a combined usage of 88%.

These studies show the electricity consumption per kilogram of milk tended to be higher in contained housing systems than grazing systems. This indicates there may be an increase in electricity use per unit of milk produced when moving to a contained housing dairy system.

13.2 IDENTIFYING ENERGY OPPORTUNITIES ON FARM

While energy surveys in the United States of America have shown that newer facilities are more energy efficient due to the implementation of newer energy efficient technology, that data, and others, also shows that there is a large variation in energy use between dairy operations. Therefore, it is important to understand the energy use of the dairy operation you are working with.

In Australia, the Energy Efficiency Council and National Farmers Federation have identified four steps that assist farm businesses through the process of identifying and implementing energy management upgrades.

FOUR STEPS TO IDENTIFY ENERGY EFFICIENCY ON-FARM - ENERGY EFFICIENCY COUNCIL, 2021

1 Reach out

Contact farm groups, industry associations and governments for ideas and resources. This support provides farms with confidence and information to start their energy management journey.

2 Walk the farm

Scan the farm for visible issues and opportunities, review habits and routines. Diving into existing data leverages the knowledge of the team on the ground to identify quick wins.

3 Work with an external expert

Find the right auditor for your farm, specify the audit you need and prepare a post-audit action plan that gives you a detailed understanding of energy performance and upgrade opportunities. This builds the case for more significant investments.

4 Integrate energy management into farm management

Establish processes for continuous improvement in energy performance to ensure that smart energy management becomes a part of farm management, and is a way to make farms more productive, especially in peak season.

Energy audits can identify how efficiently energy is being used and identify energy and cost saving measures as well as process and productivity improvements. National standards are available for energy audits. There isn't a specific standard for agriculture, however, AS/NZS 3598.2:2014 Industrial and related activities is most commonly used for agricultural operations (Energy Efficiency Council, 2021).

There are three audit types set out by the standard which should be selected based on the dairy operation's needs:

- Type 1: Basic energy audit
- Type 2: Standard energy audit
- Type 3: Precision subsystem energy audit.

More information on energy Audits can be found at: **energybriefing.org.au/energy-audits-101**

Figure 104. A Gekko Systems biodigester on a dairy farm at Bungaree

13.3 ELECTRICITY SUPPLY

If total energy use and demand of the dairy operation increases, there may be a need to:

- Ensure the grid and connection can meet future electricity demand.
- Review electricity tariff structures.
- Consider back-up power requirements.

Grid connection

Electricity supply should be considered in the planning stages. Connecting to the grid or altering grid connection, due to increased electricity demand or to enable energy to be fed into the grid, can take several months. The time taken will vary based on the type and complexity of the connection. Work with your electrician, electricity retailer and electricity distributor through the process.

During the dairy design stage an assessment of current and future energy requirements should be completed.

- The electricity distributor should be contacted to ensure there is capacity in the local grid and existing connection to supply the required electricity.
- If a new grid connection is required, the existing connection requires alteration to increase capacity or renewable electricity is to be generated on site, for use on site or to be fed into the grid, it is the distributor who is responsible for these upgrades.

The electricity distributor may require a contribution for a new connection or connection upgrades.

- Where a contribution is required, a formal connection offer, setting out the cost of the works and the terms and conditions, must be provided.
- The Australian Energy Regulator preapproves most costs and publishes them on their website (Australian Energy Regulator, 2013).
- Distributors cannot charge more than the approved amount.

If unsure of the energy distributor for the area contact the existing electricity retailer or a list of distributors can be found on the Australian Energy Regulators website: **aer.gov.au/consumers/who-is-my-distributor**

More information on supplying energy into the grid can be found in *Energy generation and storage*.

Electricity tariffs

The electricity tariff structure determines how a dairy operation is charged for electricity usage. Transitioning to new or upgraded feeding and/or contained housing facilities may increase the operation's electricity demand, alter time of use and/or the daily peak electricity demand. These changes in electricity usage may affect which tariff structure is most cost effective for the site and should be reviewed periodically.

Tariff components

Energy tariffs vary between electricity providers, from state to state and over time. They are typically made up of three basic charges: supply, electricity consumption and demand.

Supply charge

The supply charge is a cost per day for providing electricity to the farm and covers costs associated with operation and maintenance of the grid infrastructure.

Electricity consumption tariff

This charge is based on the amount of electricity consumed with a rate charged for each kWh consumed. Consumption charges depend on the tariff structure. The most common consumption charge arrangements are single rate pricing and time of use pricing.

Single rate tariffs

Single rate tariffs apply the same rate for all electricity consumed, regardless of the time of day this occurs. This arrangement is also referred to as 'anytime' or 'flat rate'.

Time of use tariffs

Time of use tariffs apply different rates depending on the time of day and day of the week the electricity is used. There are generally three periods: peak, off-peak and shoulder.

- **Peak:** This is the highest cost period. Peak period is typically during the evenings of weekdays when there is a high demand for electricity.
- **Off-peak:** This is the cheapest cost period. Off-peak is typically overnight and on the weekend when there is low electricity demand.
- **Shoulder:** This is charged at a rate lower than peak. Shoulder periods are typically between peak and off-peak periods when there is moderate demand for electricity.

Controlled or dedicated loads

A controlled or dedicated load tariff option may be available in conjunction with flat rate or time of use tariffs. This tariff provides a lower rate for a dedicated circuit supplying a single large load such as a hot water service, irrigation pump or ice banks. The dedicated load is charged at a lower rate or at off-peak rates. This option is not available in all locations. It will need to be confirmed with electricity retailers if this option is available for the situation.

Demand tariff

Some tariff structures include a demand tariff. For large customers this is often a mandatory tariff. Demand is a measure of how intensely electricity is used at a point in time. The demand tariff is a charge based on the peak energy use during the billing period and charged for the entire billing period. Demand tariffs encourage electricity use to be spread out over time.

Demand charges are based on the peak load of the system regardless of how many hours the system operates at the peak load. A demand charge is incurred even if the high load occurs for just one 30-minute interval during the entire billing period. Depending on the retailer this may relate to any time during the day or may only be within the peak demand hours.

Demand tariffs do differ, so it is important to understand:

- How the retailer calculates demand charge
- The demand charge threshold
- The peak and off-peak periods and the rates associated with these
- If the demand charge is applied to the maximum demand or average demand.

Reducing peak demand may reduce the demand tariff charged.

Loss factors

Loss factors allow retailers to account for the losses that occur in distribution and transmission between the electricity generators and the site. This factor is applied to various charges on the electricity bill.

Power factor

Power factor is a measure of how efficiently electricity is used at customer's premises. It is the ratio of real power (the power actually consumed, measured in kW) to apparent power (the power delivered by the network, measured in kVA). Some electrical items such as motors and fluorescent lighting can require large currents to operate, giving them a poor power factor and often high demand charges. Power-factor correction equipment can stabilise the load for these items, which improves energy efficiency and reduces demand charges.

Feed-in tariff

Feed-in tariffs are determined by each state with each having a different feed-in tariff structure. In general, these rates have been reducing over time.

In Victoria the Essential Services Commission sets the minimum feed-in tariff that energy companies pay for power exported to the grid. Retailers can offer solar system owners above this price but not below. These rates change each year.

As the minimum feed in tariff is much lower than the price paid for electricity consumed from the grid, the best value for energy is gained when renewable energy is used on-farm to displace energy consumed from the electricity grid.

For more information including the current Victorian feed-in tariff visit: **esc.vic.gov.au/electricity-and-gas/electricity-and-gas-tariffs-and-benchmarks/minimum-feed-tariff**

Finding a plan or energy provider

There are a range of plan types depending on energy consumption with differing tariff structures for residential, small business, and large business accounts.

Each state and electricity retailer have varying criteria for large business accounts. Large business accounts usually have bills in excess of $30,000 per year, or greater than 40,000–100,000kWh per year power consumption, depending on the retailer. Bills for large energy users are more complex with different charge rates than those described in this document and may include additional items such as Loss Factors which is broken into marginal loss factor (MLF) and distribution loss factor (DLF).

Each retailer has different cost and tariff structures. Contact several retailers to get the best deal for the operation's energy needs. Provide actual or predicted energy data to compare different plans. Energy consumption data at 30-minute intervals or less can be obtained online from the electricity distributor using the electricity meter's national metering identifier (NMI).

Private energy brokers and comparison sites operate for small and large electricity customers. Using these may assist in finding an offer that suits the site. There are also government comparison sites available including the two below:

- Energy Made Easy (National): **energymadeeasy.gov.au**
- Victorian Energy Compare (Victoria): **compare.energy.vic.gov.au**

Business Energy Advice, a federal government initiative, facilitated by the NSW business chamber, provide a free energy advice service to small businesses including agricultural businesses: **businessenergyadvice.com.au/agriculture**

Understanding electricity bills

Each electricity retailer structure bills differently. Information on understanding energy bills can be found on the electricity retailer's website. Useful links to a range of retailer's bill structures can be found here: **businessenergyadvice.com.au/retail-market-advice**

Back-up power

A generator or another form of back-up power is essential to be able to continue operation of the dairy operation when a power outage occurs. If generators or other forms of back-up power already exist on site, the size of these should be reviewed and may require upgrading due to increased energy requirements.

Power outages can have immediate and ongoing impacts on the site and may affect many aspects of the system including, but not limited to:

- Milk harvesting - delayed milking may result in production loses with the cow's udder beginning to shut down after 36 hours not being milked and increase the risk of mastitis, impacting on milk quality.
- Inadequate milk cooling.
- Water and feed supply – electric pumps and machinery may impact on the ability to supply water and feed to the herd.
- Ventilation and cooling systems - it is important in mechanically ventilated sheds to have appropriately sized back-up systems and/or an evacuation plan to remove cows as a closed up shed becomes warm quickly due to the heat the cows generate and air quality declines when fans are not operating. An alarm or other warning system may be required to alert staff. Loss of cooling system operation may impact cow comfort and welfare, particularly during warm days.
- Alley cleaning and the effluent management system.

Ensure the site electrical system is capable of being isolated from the grid to allow generator and other back up power sources to function when there is a power outage.

Other forms of back-up power may include batteries or biogas generators powered by on site anaerobic digestion. The suitability and limitations of the technology as back-up power supply for the operation should be considered when selecting.

More information on preparing for power outages c an be found on the Dairy Australia website: **dairyaustralia.com.au/resource-repository/2020/09/01/preparing-for-power-outages-factsheet**

13.4 ENERGY EFFICIENT DESIGN AND OPERATION

The energy required to operate the site can be reduced through energy efficient design, equipment selection and regular maintenance.

Selection of energy efficient equipment

Selecting energy efficient and fit-for-purpose equipment can lead to energy savings. Energy efficient equipment may have a higher upfront cost but will save in energy consumption which can outweigh the higher capital investment. The cost of the equipment and operating costs should be considered over the working life of the equipment.

Energy surveys in the United States of America have shown that newer facilities are more energy efficient due to the implementation of newer energy efficient technology (Capareda et al., 2010).

There are many areas in the system where energy efficiency measures can be implemented including:

- Upgrading lighting to LED.
- Reviewing the performance of milk harvesting and milk cooling equipment as changes in herd production and numbers occur.
- Preheating of water using heat recovery, heat pump or solar hot water systems.
- Have an experienced technician select the appropriate type and sized pump for the task with variable speed drives used in situations where there are varying pressures or flow rates (multiple duty points).

More information on these energy efficiency measures, including a checklist for dairy shed energy savings, can be found in Dairy Australia's *Saving energy on dairy farms booklet* (2018).

In Australia energy efficiency of equipment is regulated through the Equipment Energy Efficiency program. The program is underpinned by the Greenhouse and Energy Minimum Standards (GEMS) Act 2012. The program provides energy efficiency standards and energy labelling for equipment and appliances. Limited agricultural equipment is currently regulated under the program with minimum energy performance standards for three phase motors and standards for incandescent and fluorescent lighting. For more information visit **energyrating.gov.au**

Layout and operation

Layout of the infrastructure and day to day activities can impact on energy use and efficiency as well as impacting on other areas including labour and machinery maintenance. Aspects of layout and operation to consider:

- Create flow and minimise the distances between areas which are frequently used. This may impact on operation and driver behaviour. For example, locate feed storage areas in close proximity to the feed out area.
- Use of electric vehicles, such as side by side vehicles, that can be charged utilising solar or other renewable energy generated on farm.
- Utilise gravity, where possible, within the effluent system reducing the requirement for pumps and hence energy.
- Have an experienced technician size pumps and pipes while minimising distances effluent needs to be pumped. Consider the location of storage ponds to minimise the distance recycled effluent needs to be pumped for washdown.
- Effective alley slope reduces the volume of water required to be pumped for alley wash down reducing energy for pumping. The concentration of effluent may also affect the viability or processing required for the end use of the manure e.g. anaerobic digestion, manure bedding, application on pastures or crops.

Fans and ventilation

Ventilation and cooling systems limit extremes in temperature and humidity and maintain good air quality to ensure cattle welfare (Chapter 8). While the ultimate goal of the fans is to provide an ideal environment for cattle welfare, energy efficiency should still be considered when designing the system and selecting fans.

Understanding the purpose of the fans in the contained housing system, the difference between ventilation fans and cooling fans, the location within the system and the operation is important. The effectiveness of fans will vary depending on the climate. Shed design will also interact with natural air flow and fan function and can have a big impact on fan efficiency and effectiveness. *See 9 Facility design and management for more information on fans.*

Mondaca and Cook (2019) modelled the costs of operating a range of ventilation systems including natural, tunnel, hybrid and cross-ventilation across various climates in the United States of America. The key findings of the study were:

- Select high energy efficiency fans, although typically more expensive upfront, over the lifetime of the fans there will likely be higher savings. Regardless of regional

variations, the cost of ventilation lies mainly in the operating costs of the fans. The modelling showed on average the capital cost of the ventilation system was 11% to 26% of the operating cost depending on climate.
- Ensure fan layout is configured for maximum efficiency.
- Fans can be automated to turn on at set temperatures. This can ensure fans are used when required and turned off when not. Variable speed drives or ventilation ramping functions may be suitable to increase air flow as temperatures increases to cool the cows.
- Maintenance is required for effective fan function. Fans can lose as much as 30% to 50% efficiency due to poor maintenance e.g. dust and dirt build up on blades and shutters. A 3 mm build up can reduce efficiency by 30%. Fan maintenance is often overlooked and should be considered in the design stages to ensure maintenance processes are thought out. For example, being able to lower fans for cleaning rather than having to climb up and clean them will make fan maintenance easier and more likely to be carried out regularly.

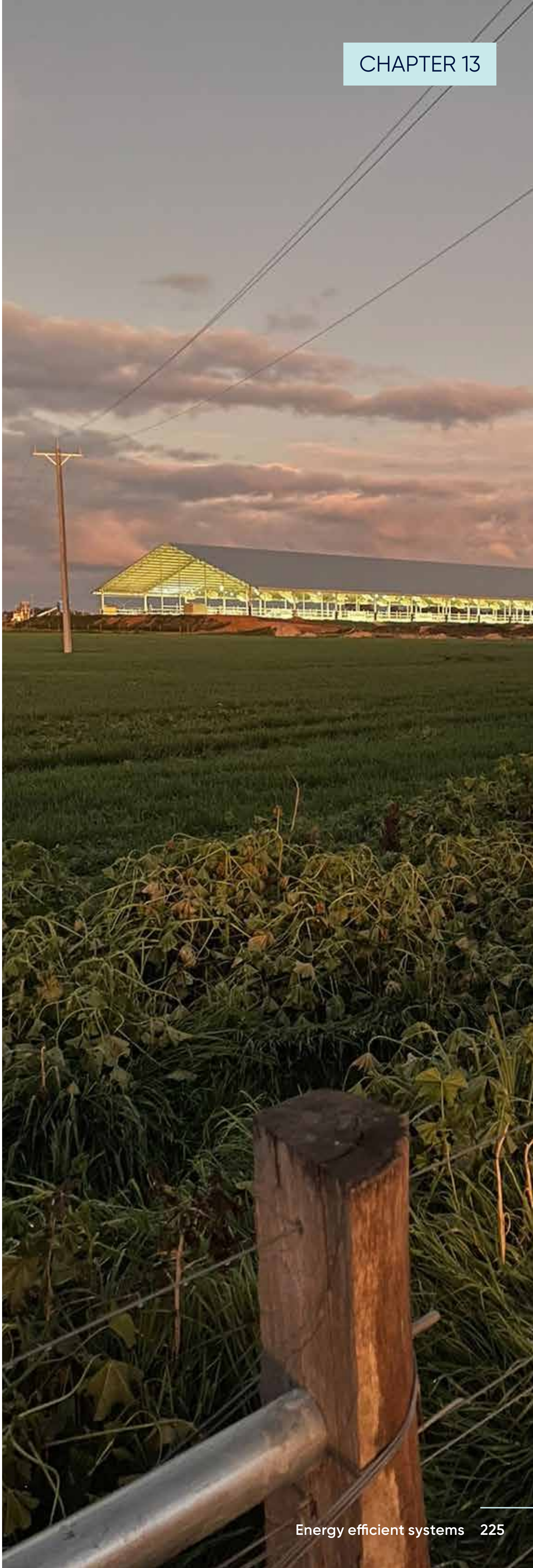
If a contained housing system is to be mechanically ventilated a back-up power supply, for example a generator or other alternate power source, is required to ensure ventilation can occur when there is a power outage. The sizing of the generator or other alternate power source should account for the ventilation energy requirements as well as the other energy requirements of the site.

Regular maintenance and monitoring

Maintenance is a low-cost way to maintain energy efficiency. Regular maintenance on equipment including milking plant, ventilation, lighting, pumps, vehicles and machinery, can assist to ensure efficient operation of equipment. Follow manufacturer recommendations for maintenance. Factor equipment maintenance into the design of the system to make it easier.

Monitoring energy use is important in managing energy use and can provide indication of how equipment and behavioural practices are contributing to energy efficiency. Monitoring electricity and fuel usage via bills is one way to monitor over all energy usage. Some technology has integrated monitoring systems, such as inverters for solar systems, or relatively cheap monitoring devices which allow for monitoring of individual equipment or systems. An asset register can assist in monitoring energy. Corelating data from the assets register with energy bills can assist to better understand energy use. It can assist to track planned maintenance and replacement of equipment.

A checklist including maintenance for dairy shed energy savings, can be found in Dairy Australia's *Saving energy on dairy farms* booklet (2018).



13.5 ENERGY GENERATION AND STORAGE

Renewable energy generation on farm is an option to reduce energy costs and reduce greenhouse gas emissions. The greatest return on investment is achieved when the energy is utilised on farm to reduce the electricity use from the grid or other forms of energy.

Before investing in renewable energy review the energy efficiency of the dairy operation. There may be major energy savings that can be made reducing the overall energy required and therefore the level of investment required for renewable energies.

When selecting a technology consider the time of day the energy generation occurs and the operation's time of demand. Matching the generation and use enables maximum utilisation of the energy generated, ensuring a shorter payback period. It is generally more cost effective to utilise energy generated directly on farm where possible due to the high costs of storage options and the low feed in tariffs available. There may also be limits to the amount of electricity that may be able to be fed into the grid.

Some forms of energy can be more cost effectively stored than others. Electrical energy generated from solar panels requires batteries for storage while the same energy converted to heat can be cost effectively stored as hot or cold water in insulated tanks.

Connection agreements for electricity feed-in

Before considering feeding electricity into the grid, work with the equipment installer to consult with the electricity distribution network service provider. There are technical requirements for connection to the electricity grid which vary depending on the size of the system, the local electricity grid infrastructure and exporting excess energy into the grid. The distributor has an obligation to ensure grid stability and reliability and if there is a sound technical basis may refuse connection. There may be costs associated with meeting the technical requirements of grid connection.

An export agreement will need to be negotiated with the distributor to export energy into the grid.

There will be a cost for connection. This cost generally covers:

- Network connection application fee
- Connection feasibility study
- Network stability study (if required)
- Cost of network extensions or augmentations specific to connection
- Metering charges.

A new meter may be required to be installed if there is not already a smart meter or interval meter in place. Refer to *section 2.1 Grid Connection*.

Solar photovoltaic (PV)

Solar is an established and widely used technology which generates electricity by capturing the energy of light. The generation curve for solar and the time of energy use needs to be considered. The majority of the energy is generated during the middle of the day, when the sun is highest in the sky and the solar energy intensity hitting the earth is highest. However, in a typical dairy system the energy demand is greatest in the morning and late afternoon, during milking, when solar energy generation is lower. There may be opportunities to alter the time of use of other equipment e.g. hot water service or water cooling which generally operate during the night to maximise off peak rates, to better match the time of energy generation.

Orientation

In Australia a northern solar panel orientation generates the greatest electricity production as it maximises solar interception. The optimum angle for maximum year-round solar interception is the same as the latitude of the location in which the panels are installed. However, if the installation is on a roof the additional cost of frames to achieve a small change in tilt may not exceed the benefit of additional energy generation. The cost benefit should be assessed and looked at over the lifetime of the system. The ideal angle can vary for the system depending on the aims of the system. For example, a system which aims to minimise seasonal variation, which is common for off-grid systems, may set the angle to maximise the solar capture of the winter sun which sits lower in the sky. Solar panels should be at a minimum angle of 10 degrees to allow rain to wash them clean.

However, the orientation of the shed may not be north facing or energy generation in the morning or evening may be more highly valued due to the dairy operation's electricity use profile. Typically, dairy systems have higher demand for electricity during the morning and evening when milking occurs. This may mean there may be a benefit from orientating panels in a north east or north west direction or even east and west. This orientation will decrease generation by up to 15% however it will extend the solar exposure time to increasing generation in the morning and evening when milking is occurring and there is a demand for energy.

It is best to investigate the options for each unique situation using actual or predicted energy use data. Work with your accredited solar installer to determine the best system size and orientation for your energy demands on site.

Renew Australia (2017) have a free solar calculator which can be used to look at the potential feasibility of different scenarios including different sizes of solar array or panel orientations, or different amounts of battery storage to meet the site's energy requirements. See 'Sunulator' **renew.org.au/resources/sunulator/**

If intending to put on roof top solar ensure the proposed shed structure is rated to take the load of the panels and any required mounting structures. The decision for solar may also impact on design features including:

- Orientation of the shed
- Locations for equipment such as inverters and batteries
- Potential shading from surround tress or infrastructure which would reduce the efficiency of the panels.

Renewable Energy Certificates

The Small-scale Renewable Energy Scheme and Large-scale Renewable Energy Target provide financial incentive for investment in solar. Renewable Energy Certificates are used as a measure of renewable energy that can be traded or sold.

Systems less than 100kW may be entitled to small-scale technology certificates under the Small-scale renewable Energy Scheme which can be sold to recoup a portion of the cost of purchasing and installing the system (Clean Energy Regulator, 2018a). To be eligible these systems must meet the eligibility criteria including being installed by a Clean Energy Council accredited designer and installer and meet the Clean Energy Council design and install guidelines. Systems over 100 kW are classified as renewable energy power stations and may be eligible to be accredited to create Large-scale Generation Certificates (LGC) under the Large-scale Renewable Energy Target (Clean Energy Regulator, 2018b).

Accredited Solar Installer and Approved Solar Retailers Program

The Clean Energy Council operate the Accredited Installer and Approved Solar Retailer programs. The Accredited Installer program certifies and trains individuals in the design and installation of solar and battery energy storage systems and ensures systems installed meet industry best practice and the relevant Australian Standards (Clean Energy Council, 2018a). Approved solar and battery retailers have been approved by the Clean Energy Council as showing a commitment to responsible sales and marketing activities and solar industry best practice and committed to complying with the program's Code of Conduct (Clean Energy Council, 2018b). A list of accredited installers and approved retailers can be found here: **cleanenergycouncil.org.au**

Batteries

Storage batteries provide the opportunity to store excess generated energy for use at another time when electricity generation doesn't meet requirements or is not able to be generated. Over the last decade the price of batteries has significantly reduced making them a potential option. There are several situations where batteries may be applicable including:

- Store excess energy for utilisation at another time when electricity is not being generated or generation is limited.
- Off grid sites where large grid connection costs inhibit grid connection.
- Replacement for diesel generators which also has the additional benefit of reduced maintenance cost.
- In situations where equipment needs a stable supply and to provide an uninterruptable power supply (UPS) before a generator can be started.
- Managing energy demand during peak charge periods and to reduce peak demand therefore reducing electricity costs.
- Offsetting upgrades to mains supply.

An economic feasibility should be completed to ensure batteries are a suitable option for the situation.

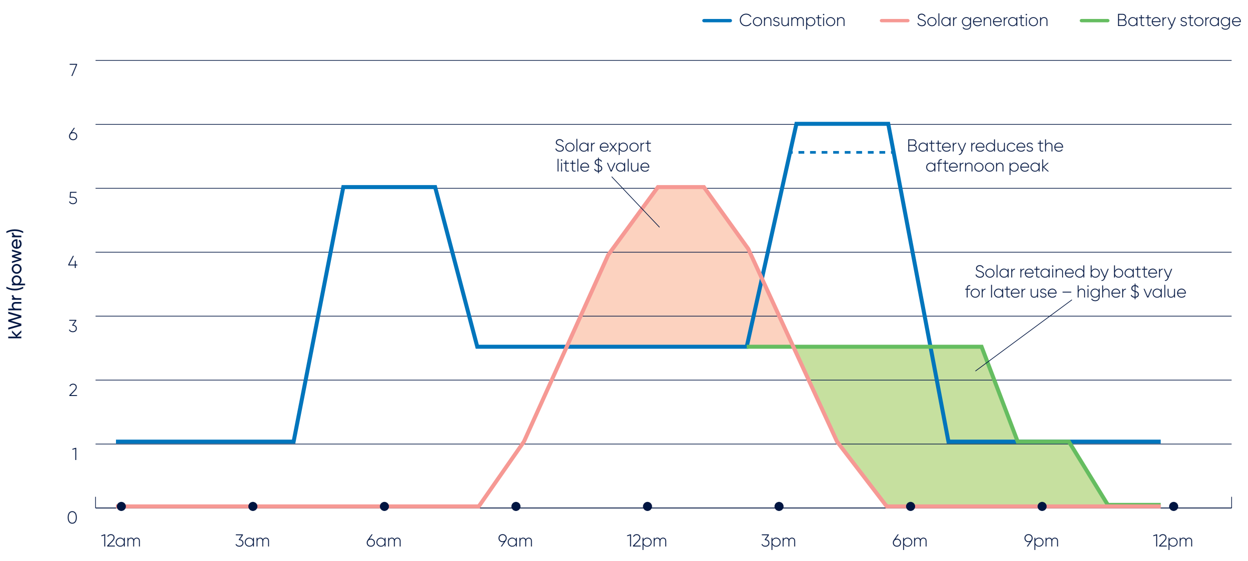
There are a number of different types of battery chemistries commercially available including, but not limited to:

- Lead-acid
- Lithium-ion
- Flow
- Flywheels.

Each type of chemistry can perform a variety of applications. The system design should take into account the application and be able to identify the chemistry which will provide the best performance.

The Accredited Solar Installer and Approved Solar Retailer program also covers the retail and installation of battery storage. See section on Solar photovoltaic (PV).

Figure 105. Graph of energy consumption and solar generation in a typical dairy



Note: Graph demonstrating how batteries can be utilised to capture energy for utilisation when there is increased demand.

Source: Dairy Australia Feasibility of stand-alone renewable energy systems

13.6 ANAEROBIC DIGESTION

Installing an anaerobic digester is another option for reducing energy costs involving the capture of biogas, containing methane, associated with the decomposition of manure under anaerobic conditions. It is a commercially proven method for reducing greenhouse gas emissions.

- The biogas can be ignited (flared), converted to electricity, used to generate heat or upgraded to biomethane and stored as an alternative fuel.
- The most popular option is conversion to electricity and heat recovery to offset energy requirements, which is a major and growing cost on dairy farms.

In addition to reducing energy costs and supplementing income through emissions reduction funds, other benefits of anaerobic digestion include:

- Improved management of manure
- Decreased odour
- Reductions in animal, human and plant pathogens as well as weed seeds
- Improvement in air quality where biogas is used to replace traditional fuels that generate particulates.

Feedpads and contained housing systems increase the potential feasibility of an anaerobic digester, due to the greater amount of manure that is collected in the effluent system when compared to grazed dairy systems. Cows in contained housing spend more time on areas where effluent is collected resulting in a greater volume of feedstock being available for anaerobic digestion. Contained housing systems often also have higher numbers of cows and production per cow than grazing systems.

The product of anaerobic digestion, biogas, contains 50–70% methane and 30–50% carbon dioxide along with other minor components including water vapour, nitrogen and hydrogen. Biogas can be used to fuel a boiler for heat generation or an engine for electricity and heat generation. Biogas may be upgraded to increase the methane percentage for use in vehicles or injection into the gas grid. This can increase the energy security of the dairy operation. The capture and burning of the biogas provide the additional benefit of reducing farm odour and greenhouse gas emissions. The digestion process also increases the amount of nutrients in a form biologically available for crop or pasture uptake.

Anaerobic digestion processes

In anaerobic digesters, organic material such as dairy manure undergoes a four-stage chemical transformation in the absence of oxygen, producing biogas mostly consisting of methane (Figure 106).

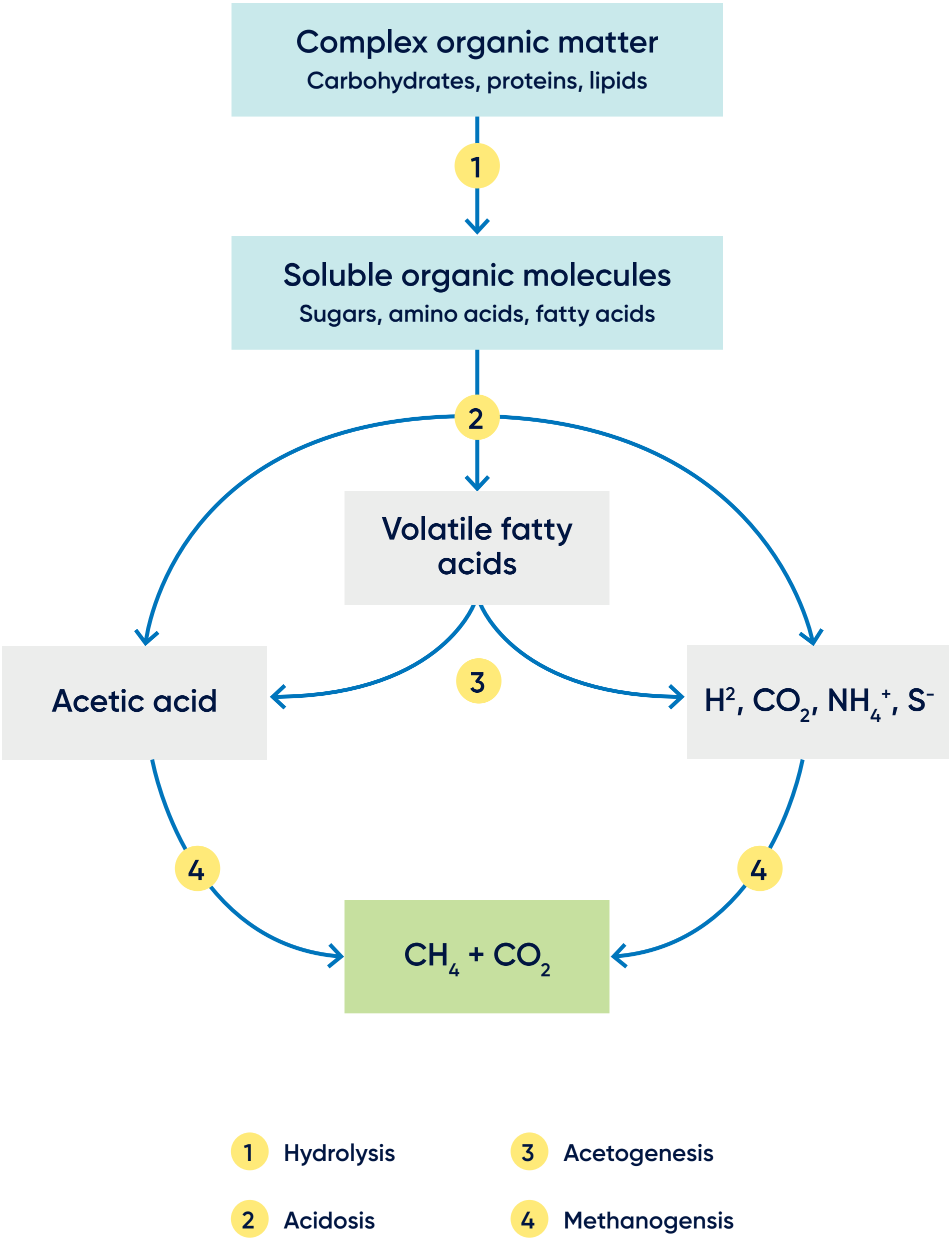
- The first step in anaerobic digestion is hydrolysis where complex materials such as proteins and fats are broken down into smaller molecules.
- In the second stage fermentation (acidogenesis) products include volatile fatty acids, carbon dioxide, and hydrogen.
- The volatile fatty acids are converted during the acetogenesis stage to acetate which the methanogens use in the final stage to produce biogas consisting of methane (45 to 75%), carbon dioxide (20 to 50%) and small amounts of other gases.

The type of methanogens will depend on whether they primarily use hydrogen or acetate to produce methane.

Factors such as the chemical and physical characteristics of the organic material to be degraded, pH, temperature, and the length of time the organic material is retained, also known as, hydraulic retention time (HRT), can all affect digestion and therefore, the volume and composition of the biogas produced. Typical inhibitory substances that can occur in dairy manure include antibiotics, sanitisers, cleaners, disinfectants, salts, ammonia and sulphide; with the latter two influenced by pH.

Temperature is one of the most important factors that influence aspects of anaerobic digestion, which is particularly relevant for digesters in temperate climates. Dairy Australia (2008) suggests that at temperatures 10°C lower than the optimum for mesophilic microorganisms, hydraulic retention times need to be increased which could mean a larger digester, although a variety of other factors, such as reduced ammonia inhibition at lower temperatures as well as mixing, could reduce the effects of lower temperatures.

Figure 106. Four stages of anaerobic digestion



Note: Hydrogen = H^2, Carbon Dioxide = CO_2, Ammonium = NH_4^+, Sulphide = S^-, Methane = CH_4

Source: Adapted from Hamilton, 2017

Anaerobic digestion substrates

Organic materials used in anaerobic digestion are often referred to as feedstocks or substrates. In addition to dairy manure, other organic materials can be included in the anaerobic digester to increase biogas production. These additional feedstocks are called co-digestion substrates, and the process of digestion two or more feedstocks is called co-digestion.

- Dairy producers will often have on-farm waste/spoiled feeds such as silage, hay, feed concentrates, or other plant-based organic materials.
- Off-farm sources include organic by-products and waste streams from processors, other primary producers and even urban wastes such as food or garden cuttings.
- Co-digesting dead animals can increase the risk of pathogens and is not advised.
- In Europe and other countries, crops grown specifically for biogas production (energy crops) are another feedstock for digesters, although these crops divert land from food production.

Organic materials vary in their potential to produce biogas. Three tests can be used to indicate the how effectively manure or other organic material will produce biogas. These measure the volatile solids content, the chemical oxygen demand and biochemical methane potential.

- Ideally material to be digested should have a volatile solids content greater than 60%.
- Chemical oxygen demand is relatively easy to perform and gives the maximum methane that a material could produce. However, the test may over or underestimate oxygen demand, due to inherent toxicities in the material, unrepresentative sampling and laboratory analyst's method.
- Biochemical methane potential is likewise a relatively simple test of the amount of methane produced from a material under anaerobic conditions, usually at 35°C, the optimum temperature for most methanogenesis. The total methane produced over a specified time is called methane yield (Table 31).

If materials other than manure are available on farm, or will be obtained from off-farm, it is also important to measure their chemical characteristics to determine if they could enhance biogas production of dairy manure. However, potential to increase biogas production from manure based on laboratory tests of co-digestion substrates needs to be confirmed at a bigger scale to ensure that the additional feedstock does not inhibit digestion in larger amounts.

Table 31. Theoretical methane yield of different anaerobic digestion substrates

Substrate	Methane yield (m^3/t VS)
Manure (pigs, cattle, chickens)	100–300
Food waste	400–600
Fruit waste	200–500
Grass	200–400
Straw	100–320
Municipal sludge	160–350
Protein wastes	496
Slaughterhouse waste	700
Cereals	300–400

Note: VS=volatile solids

Source: Adapted from Patinvoh, Osadolor et al. 2017

Anaerobic digestion pre-treatment

Manure and co-digestion substrates may need pre-treatment for anaerobic digestion. Pre-treatment aims to remove debris and unwanted material, to increase the dry matter content of the material by reducing the liquid content, to breakdown complex chemical components that are difficult for microorganisms to degrade such as ligning in the cell walls of straw and woody materials, to reduce the size of material that will be digested (e.g. bulky or long), or to remove inhibitory constituents. For instance, while some materials are easily digested, others, such as straw, have molecular structures that anaerobic digestion microorganisms are unable to breakdown. Extra energy may need to be expended to mix materials where large clumps are present. The aim of pre-treatment is to enhance biogas production, speed anaerobic digestion and create a more homogeneous material that does not stratify and therefore does not require agitation. Mechanical screens are generally used for the removal of debris and poorly-degradable materials.

Types of digesters

There are a number of types of anaerobic digesters with covered anaerobic ponds, continuously stirred or complete mix tank digesters and plug flow digesters being the most commonly utilised to capture biogas on dairy farms. In recent times there have been on-farm trials and pilots of modular container systems employing complete mix tank digesters.

Covered anaerobic lagoons or ponds require the least management of the digestion process, although the removal of sludge and sedimented material that accumulates at the base of ponds remains a challenge. In temperate regions gas production from covered anaerobic lagoons is likely to be limited during cold weather when temperatures fall below 20ºC.

Complete mix or continuously stirred tank digesters comprise one or more tanks with a residence time between 20 and 30 days. As the name implies the contents are mixed; continuously (Continuously Stirred Tank) or intermittently, and as these systems are usually heated, are best suited to effluent with a solids content of more than 4%.

Plug flow digesters use material of 12 to 15% solids content to allow the material to move as a 'plug' through the digester over a 15 to 20-day period. These digesters are heated and are designed with a specific length to width ratio to maintain plug flow conditions.

The suitability and type of anaerobic digester implemented is specific to the individual dairy operation and needs to meet the characteristics and needs of the farm. The advantages and disadvantages of each digester type are outlined in Table 26. On an annual basis, the quantity and quality of biogas produced by these technologies is similar. However, the rate of biogas production will vary with temperature, and feedstock retention times are higher in unheated systems. Rule of thumb values for production can be found in Table 32 below.

While there are high-rate digestion systems that offer a reduction in hydraulic residence time to as little as five days. These systems are not generally found on farms due to more intensive management and maintenance requirements.

Table 32. Parameters for completely stirred tank digesters and covered anaerobic ponds anaerobic digestion systems

	Passive system	Low rate systems		
		Covered anaerobic ponds	**Continuously stirred/ complete mix tank digester**	**Plug flow digester**
Description		In-ground earthen or lined lagoon with impermeable gas-collecting cover. Contents can be heated or mixed but are not typically due to volume. Covered lagoons work best with manure handled via flush or pit recharge collection systems in warmer climates.	Above- or below ground heated or unheated tank with impermeable gas-collecting cover. Contents mixed by motor or pump. Complete mix digesters work best when there is some dilution of the excreted manure with water (e.g., milking centre wastewater); manure should be handled via slurry	Long, narrow tank, typically heated and below ground, with impermeable gas-collecting cover. Contents move through the digester as new manure is added. Modified plug-flow systems can use vertical mixing techniques. These systems work best with dairy manure, handled by scraping, with minimal bedding.
Substrate dry matter (DM) concentration		Less than 5%	4-12%	12-15%
Operating temperature		Varies with ambient temperature (5–25°C)	Heated: 35–39°C or 50-60°C	Typically heated: 35–39°C
Hydraulic retention time (HRT)	40 to 60 days	15+ days	15+ days	
Co-digestion	Not optimal	Yes	Not optimal	
Advantages		Lower cost construction using local resources, lower operation and maintenance requirement, no heat demand, tolerant of shock loads, cover also provides biogas storage, easier to get through planning regulation.	Applicable to a wide range of materials, shorter treatment time, small size, standard designs, applicable for use in all climates.	Mid-range construction cost, shorter treatment time, lower operation and maintenance requirement, applicable for use in all climates, reduced water volume to manage.
Disadvantages		Large size, suitable only for liquid organic materials and temperate to warm climates lower yield rates.	Higher construction and operation costs including heat demand, requires skilled operation.	Not suitable for dilute effluent, bedding material or co-digestion, prone to build up of solids on bottom requiring clean out.

Adapted from: Is Biogas Technology right for Australian Dairy Farms? (Dairy Australia, 2015) and AgSTAR Project Development Handbook (US EPA, 2020)

Table 33. Rule of thumb values of dairy manure production

No. of cows	Farm system intensity (manure collection location/s)	Organic load per cow (kg VS/cow/d)	Total daily organic load (kg VS/d)	Waste concentration (%VS)	Daily methane yield (m^3 CH_4/d)	GHG emission/ abatement (t CO_2e/d)
400	All pasture fed (milking shed only)	0.25	100	0.7–1.0	20	0.35
600	With feedpad (milking shed and feedpad)	0.6	360	1.0–1.5	70	1.3
1,000	Fully housed (milking shed and housing)	5.0	5,000	3.0–7.0	1,000	18

Note: kilograms of volatile solids per cow per day (kg VS/cow/d), and biogas yield, cubic metres methane per day (m^3 CH_4/d), for hypothetical dairy farms of increasing size and system intensity, from grazing to freestall.

Source: Adapted from: Is Biogas Technology right for Australian Dairy Farms? (Dairy Australia)

For dairy farms the common end use of biogas is combustion to produce hot water or as a fuel for combined heat and power generators (CHP generators). A combined heat and power generator can generate electricity and capture the heat for use for thermal (heating and cooling) processes. To utilise biogas in a combined heat and power generator the gas may require cleaning to remove water vapour and to reduce hydrogen sulphide as these can be corrosive to the engines. If biogas production levels are sufficient the biogas generator may be able to be utilised as a back-up power source, complementing periods when solar or wind is unproductive.

For larger farms or co-digestion systems there may be opportunity for electricity or methane export. The gas may be utilised to generate electricity and feed into the electricity grid. For electricity export, like with solar connection, the distributor should be consulted in the design stages of the project. Excess methane may be able to be exported into the gas network. This would require the farm to be located close to the gas network and upgrading of the gas to meet the required minimum quality standard.

- Before implementing, an anaerobic digester a feasibility study should be completed to understand the economic feasibility and operational impacts of implementation of an anaerobic digester to the business.
- The decision of anaerobic digestion should take into account the additional benefits mentioned above as well as the additional costs including labour and safety requirements.

An anaerobic digester may provide the opportunity to diversify the business with co-digestion substrates such as horticultural waste or municipal food waste may be able to be fed into the digester to increase biogas yield.

A consistent supply of feedstock is required as not to upset the pH of the anaerobic digester while potentially decreasing payback time. Feeding an anaerobic digester is much like feeding a cow's rumen – any changes must be gradual.

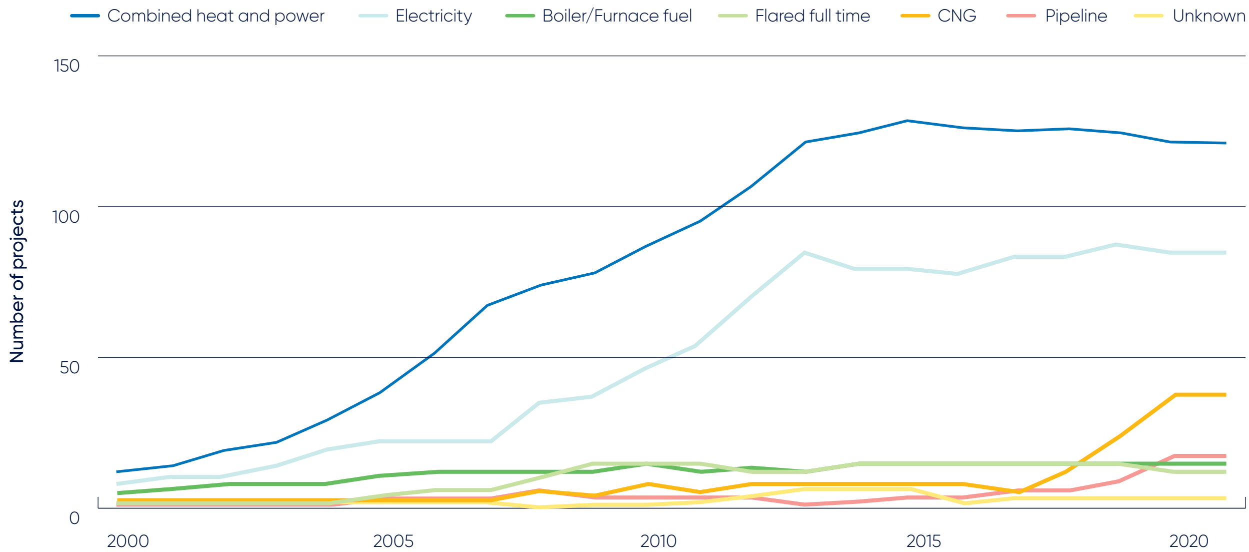
Feasibility

Feedstock from about 1,000 dairy cows that are fully housed are required for traditional biodigesters with an output of 100 kilowatt equivalent (kWe) combined heat and power (CHP), noting that manure has low energy value due to pre-digestion that occurs in the rumen.

Producers are encouraged to consider all options and to include heating and cooling of the whole farm rather than just the dairy shed. Policy instruments, such as feed-in tariffs and the Emissions Reduction Fund for Animal Effluent can also contribute to reducing costs and providing income. Increasing the productivity and value of on-farm manure and improving its management should be considered valid justification for adoption of small-scale anaerobic digestion, in contrast to the focus on electricity generation of many larger farms or commercial anaerobic digestion systems. Associated environmental benefits to support small-scale anaerobic digestion can include reduced GHG emissions, decreased odour as well as plant and animal pathogens and weed post-digestion treatment of biogas and digestate.

The outputs of anaerobic digestion are biogas and digestate. Biogas uses include flaring, electricity generation, combined heat and power, boiler fuel, upgrading for injection in natural gas pipelines or upgrading and compressing for use in vehicles and other uses. Data from the United States of America show changes in use over the past 20 years, with electricity and combined heat and power the major uses (Figure 107).

Figure 107. Uses for biogas produced from manure-based anaerobic digesters in the USA



Note: CNG = Compressed natural gas

Source: Biogas facts and trends in US EPA 2021a

In Australia, flaring and generating electricity or heat are emissions destruction activities supported by the Emissions Reduction Fund.

- The proposed use of the biogas will determine how the gas should be treated and the equipment that will be required.
- Both water vapour and corrosive hydrogen sulphide (H2S) are some of the impurities that need to be removed from raw biogas prior to use.
- The digestate produced is often mechanically separated to produce solids that are easier to handle and a liquid fraction that can be readily land applied or reused.

Digestate has similar nutrient concentrations to the feedstock (i.e. manure and any co-digestion substrates) and requires careful management to ensure that nutrient losses to air (ammonia), and to waterways are minimised.

Potential manure collection for biogas production

Grazing based Australian dairy farms generate smaller manure volumes and when flush wash systems are used in dairy sheds and yards, the DM content of effluent is usually less than 5%. This dilution of manure will generally reduce biogas production, requiring pre-treatment to reduce water content (e.g. solid-liquid separation) and/or larger infrastructure and longer retention times during digestion.

Summary of factors to consider before installing an anaerobic digester

A variety of anaerobic digestion systems have been installed on dairy farms with various herd sizes worldwide. A detailed assessment for each dairy farm is required to identify the most appropriate anaerobic digestion system. Factors to consider include:

- The volumes of manure that will be deposited in areas where manure can be collected
- The method of manure collection, including wash water used
- Manure solids content
- Methane potential of the collected manure.

If considering co-digestion, other feedstocks will be required and identified i.e. whether they will be sourced on-farm (e.g. spoilt silage and unused feed supplements) or brought from off farm. Appropriate storage facilities may also be needed.

The dairy farm will need to identify if pre-treatment of manure is required before digestion and post-treatment of digestate, as well as storage requirements of digestate fractions. Consideration must also be given to how the biogas will be used and any cleaning that is required. Likewise post-treatment and management of digestate will need to be accommodated to minimise environmental impact.

13.7 GREENHOUSE EMISSIONS

The methane, carbon dioxide and nitrous oxide emitted from manure sources on dairy farms contribute to global greenhouse gases in the earth's atmosphere, warming of the earth and the changing climatic conditions experienced (i.e. more frequent and longer droughts, more intense weather events).

Both methane and nitrous oxide are considered more 'potent' GHG because their warming effect are 28 and 265 times, respectively, greater than carbon dioxide.

Greenhouse gas emissions from manure are estimated to be about 17% of the total GHG emissions from Australian dairy farms, with methane emissions contributing 10%. This proportion tends to increase for more intensive dairy farm systems.

The Australian Dairy Industry Sustainability Framework Goal 10 is to Reduce greenhouse gas emissions intensity. This target is for a 30% reduction in greenhouse gas emissions intensity across the whole industry by 2030 (from a baseline of 2015). The emissions intensity in 2015 was 1.03kg carbon dioxide equivalent per kg of fat and protein corrected milk (CO_2-e/kg FPCM) (Christie, 2019).

Arnott *et al.* (2015) reviewed six studies which compared the carbon emissions of contained housing and grazing systems from a number of countries with the emissions per kilogram of milk in Figure 108. Two studies found carbon emissions were similar, three studies found carbon emissions were higher in contained housing systems and while one study found carbon emissions to be higher in grazing systems. The review of the studies indicates that it is not the system which determines the carbon emissions but the efficiency of the dairy operation.

Energy efficiency and renewable energy generation not only reduce energy costs of the dairy operation but are a quick win in reducing greenhouse gas emissions.

Figure 108. Sources of dairy farm greenhouse gas emissions

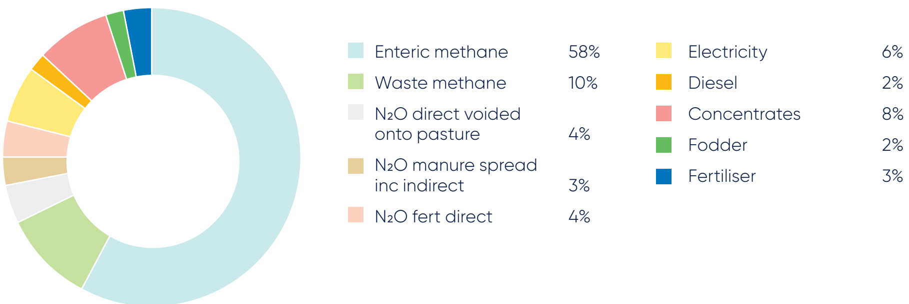
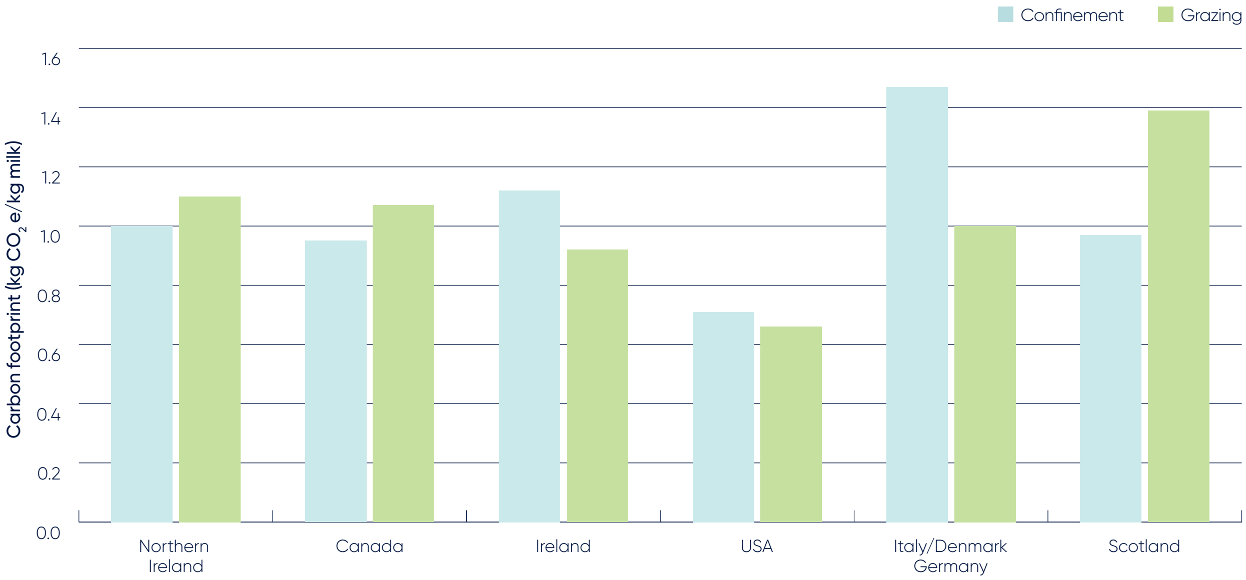


Figure 109. Result summary – studies comparing carbon footprint of contained housing and grazing systems



Note - kg of carbon dioxide equivalent (CO2-e) per litre of milk.

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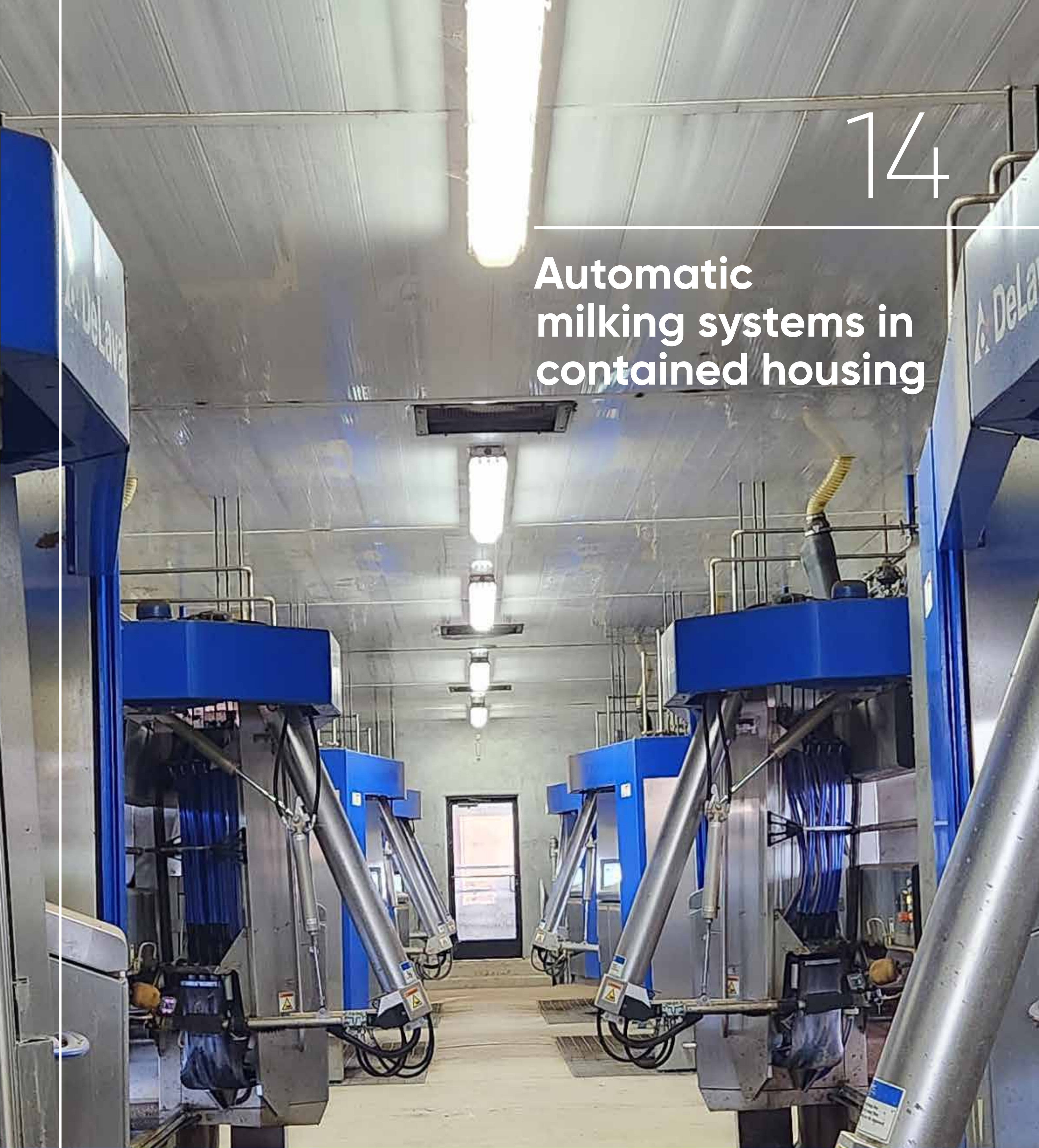
14

Automatic milking systems in contained housing



INTRODUCTION

The first commercial automatic milking system (AMS) installation took place in The Netherlands in 1992. In 2001, the first Australian, pasture-based AMS was installed in Gippsland on a commercial farm. To date:

- Over 38,000 farms globally have adopted this technology.
- Most operate in indoor-housed systems – often grazing occurs during certain periods of the year.
- Around 35% of current AMS producers have already increased the number of robots since they originally commissioned and about 50% expect to continue to expand in the future.

In Australia there is a strong interest for contained housing systems, and many producers considering changing to these systems, often consider incorporating AMS.

14.1 OVERVIEW OF AMS

The main characteristic of AMS is that milking-related tasks are automated.

- A robotic arm cleans, attaches, and sprays teats of each cow individually.
- Cows' traffic voluntarily and unassisted through the farm system – feed acts as the main incentive to encourage cow traffic and gain access to the milking unit.
- Milking events are distributed throughout the day and night - there are no set defined milking sessions.

Anecdotal evidence from AMS operators suggests that consistency in cow body type, size and teat placement may be important to reduce the time required to train a robot to an individual cow's teat placement when first introduced to the robot and subsequently reducing the proportion of incomplete attachments per day.

The most common type of automatic milking unit configuration to date is known as 'single box' (such as DeLaval VMS™, GEA DairyRobot R9500™, Lely Astronaut A5™ and BouMatic Robots MR-S2™). These units:

- Milk one cow at a time via a dedicated robotic arm that performs all milk harvesting tasks for the cow present in the milking crate.
- Normally cater for a cow group of around 50 to 80 cows milked between 2 and 3 times per day (per unit).
- Can handle an average of 150 to 180 milking events per day and harvest up to 2,500–3,000kg milk per day.

Other options available in Australia include 'multi box' robots (such as BouMatic Robots MR-D2™) or robotic 'rotaries' (such as DeLaval Automatic Milking Rotary™ or GEA DairyProQ™).

14.2 IMPACT ON FARM WORKFORCE

There are many reasons why producers consider moving from a conventional milking system to AMS including expectations around milk production, animal health, better control of the business due to the available data, or workforce availability. For many producers this is based on perceptions of workforce savings (more cows per full-time equivalent or FTE) or the ability to have a more flexible on-farm workforce. The assumption is that less people will be needed to operate the farm given milk harvesting will be automated. However, recent research indicates that this may not be the case.

An Australian study (Gargiulo et al., 2020) compared 3-years of physical and economic performance of 100 conventionally milked herds with 14 AMS herds - all AMS herds had pasture-based feeding systems milking between 130 and 395 cows.

- No significant differences were found in cows per FTE or milk solids harvested per FTE.
- A large-scale Dutch study (Steeneveld *et al.*, 2012) compared 63 AMS milked herds with 337 conventionally milked herds over one year.
- No differences were observed in the number of farm workforce members between the two groups.
- There was no evidence that an investment in capital (through AMS) led to a decrease in workforce size.
- This study assessed technical efficiency which is a comparison measure of capital inputs per milk output vs labour inputs per milk output.
- No differences in technical efficiency using this method were observed.

Note that neither the Dutch nor Australian study reported on any changes in workforce flexibility as it was not measured as part of the study design.

The inference from both studies is that an increase in capital investment in the AMS farms, to establish this milking system, did not lead to an immediate or obvious decrease in workforce size by default. Rather, the existing farm workforce was re-deployed to other tasks once the robots were installed. It has also been assumed that the farm workforce were then able to operate with a higher degree of flexibility around start and finishing times.

14.3 BOX EFFICIENCY METRICS AND UTILISATION

Feed is the main incentive to motivate cow traffic through the AMS, and consequently cows presenting themselves at the dairy facility to get milked.

- Cows prioritise feeding rather than milking when given the option.
- Feed management is a strategic tool to encourage cow traffic through the system.
- Utilisation is defined as the amount of time each robotic arm or AMS unit operates per 24 hours, or as a proportion of 24 h.
- Allowing time to perform system washes and technical maintenance usually means that robots are available to milk cows for approximately 21 h per day.
- This means that the greatest sustainable and achievable utilisation targets of AMS units are generally between 85 and 90% of total time available for milking.

For example, a large observational study of 635 North American AMS farms found there were relatively few units that recorded greater than 15% robot free time (or more than 85% milking utilisation).

Utilisation of milking units is related to box occupancy time per milking (which is in turn influenced predominantly by milk volume, attachment speed and milking speed) and is commonly termed milking duration (minutes per cow). Additionally, milking frequency (or the related reverse metric: milking interval), the number of non-milking visits, completeness of milking events and number of cows per robot also affect utilisation percentage.

Milk harvested per milking unit has been previously identified as the primary variable associated with AMS profitability). While there are many factors that influence profit, there are two main considerations in maximising milk production per AMS unit per day:

- Milk more animals at a lower milking frequency, or
- Milk less animals more frequently.

Observational study estimates of milk harvested per box per day include:

- 1,626kg – standard deviation 397kg (Tremblay *et al.*, 2016)
- 1,506kg – range 650–2,182kg (Castro *et al.*, 2012)
- 1,073kg – range 597–1,367kg (Gargiulo *et al.*, 2020) – this Australian study involved AMS herds in pasture-based systems only.

14.4 LAYOUT AND DESIGN

Layout is important on every dairy farm as it will have an impact on cost as well as on the day to day management activities of both cows and people. In order to achieve high utilisation of robots, the first important step is for producers to spend adequate time and thinking in the planning and design phase.

Layout is particularly important in AMS because:

- Layout has an impact on cow willingness to move around the system voluntarily - people will not always be around cows to encourage them to move.
- Cow traffic has an impact on the visitation pattern to the dairy, regularity of milking interval and milking frequency, as well as machine utilisation.
- Poor cow flow can reduce milking frequency, increase adaptation periods for new or inexperienced cows and have a negative impact on labour.
- Areas to hold cows that require the farm team's attention need to be included in the layout design and are critical to successful operation.

In every case, good layout design should then be followed by best management practice to ensure cows visit the robotic units the desired amount of times in a day, spread throughout the whole day.

14.5 FETCHING ROUTINE

Besides AMS maintenance tasks, routine cow fetching is one of the main activities involving the farm workforce related to milk harvesting on a daily basis.

In housed systems it is a common routine to fetch selected cows between two to five times per day, the focus is on any cow that has not presented for milking in the last 12 to 14 hours.

This is possible given that on average these herds have less than 100 milking cows close to the milking robot and to housed areas associated with one or multiple AMS units.

14.6 COW TRAFFIC SYSTEMS FOR CONTAINED HOUSING SYSTEMS WITH AMS

A contained housing system with AMS will have three key distinct areas:

- Feeding area: where cows have access to either forages or a partial/total mixed ration.
- Resting or lying area: multiple options but some of the most common ones include compost bedded pack and freestall, with different configurations and bedding material.
- Milking area: where the robots will be located.

The type of cow traffic system will depend on whether these areas being separated or not.

In 'free traffic systems' cows have unrestricted access from feeding to lying areas and the main motivation to attract cows to the milking unit is the provision of concentrate feed during milking.

Free cow traffic systems achieve greater and regular feeding frequency, yet milking frequency is usually lower.

Free cow traffic often also results in increased fetching but possibly improved cow welfare, in comparison to controlled or guided traffic systems, given that lying and standing times are not compromised.

Figure 110. Free cow traffic

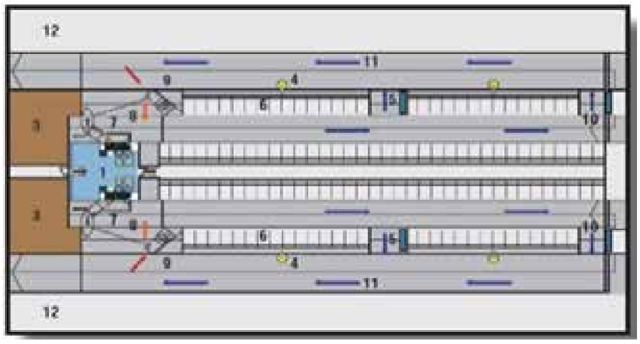
Source: Lely

In controlled or guided traffic systems, cows are required to visit the milking unit when trafficking from lying to feeding areas.

The decision for a cow to be milked or not is made at the milking unit.

Although a greater milking frequency (and lower milking interval) has been reported for cows managed under a controlled traffic system they also report a greater proportion of non-milking visits that use effective available robot time.

Figure 111. Diagram of guided cow traffic



Source: DeLaval

With semi-controlled or guided traffic management, cows are required to present themselves at selection gates when trafficking between feeding and lying areas. At these gates each cow is identified and only cows with milking permission are routed towards the milking units.

- Cows without milking permission are directed to other areas of the farm (such as feeding or lying areas).
- This minimises non-milking visits and maximises utilisation of the milking units.

Some producers might decide to install a pre milking waiting yard that commits cows to walk through the robotic units before accessing another area on the farm. Normally one of the following type of gates would be placed at the entrance to the yard:

- **Smart gates:** only cows with milking permission will enter the yard, you can also control the number of cows inside the yard and/or send cows to a specific robot or area within the yard, if its divided (this is the most common design in Australia currently).
- **One-way gates:** all cows will be able to enter the yard. Milking permission will be granted or refused at the robot.

Longer than desired pre-milking waiting area times, in which cows remain standing for extended periods of time, can be observed under controlled or semi-controlled cow traffic managements, which could particularly affect less dominant cows.

Observations across 635 North American AMS herds indicated that free traffic systems were associated with an extra 67 kg milk harvested/box/day (approximately 67 litres) compared with forced traffic systems.

A 12-month study conducted on a single farm utilising 20 individual AMS units with one pen per box found a significantly higher cow milk production rate in pens using semi-guided traffic versus a guided traffic system.

14.7 MILKING FREQUENCY

Overseas, AMS in contained housing systems have on average, smaller herd sizes (96 versus 159 cows) and fewer robotic units (1.7 and 2.6 AMS units per farm) than pasture-based AMS. It should be noted that there are likely marked increases in average herd size and robotic units per farms for more recent Australian AMS installations.

Farms with contained housing systems have a higher milking frequency (2.7 and 2.4 milkings per cow per day) but similar cows per robot than pasture-based AMS (55 and 57 cows per AMS unit).

The greater milk harvested for AMS in contained housing systems is mainly explained by the higher milk yield per cow (28 and 21 kg per cow per d), possibly associated with the greater dry matter intake typically achieved in those systems.

14.8 MILK TRANSPORT AND GENERAL LAYOUT IN MULTI-BOX DESIGNS

Normally in a housed AMS it can be common to split the herd in smaller groups, depending on herd size, shed design and setup. These groups can be based on attributes such as age, days in milk, lactation number or production level. Groups are kept separate and have access to a dedicated number of robots (usually 2 or 3 at maximum per cow grouping).

The largest study to examine differences in milk harvesting efficiency between a configuration (either one unit per pen or 2 or more units per pen), accounting for traffic system, found that two or more robots per pen was associated with an increased milk harvested per box per day compared with only one robot per pen although the difference was not significant for all years of the study.

- Some housing designs may require significant engineering to facilitate milk transport to a central vat location and the associated daily plant cleaning. This is due to the total length of milk transport piping involved.
- Producers and advisers should discuss design information the AMS manufacturer.

14.9 WHICH DESIGN TO CONSIDER?

When deciding on a design for your housed AMS, it is important to consider these factors:

- Management preferences
- Layout constraints
- Future growth or expansion
- Feeding strategy
- Labour requirements
- Investment
- Cow behaviour preference

When managed well, both free or guided cow traffic systems work and can be efficient. It is up to the producer to apply the right management tools to make the system work.

The recommendation is to visit established AMS farms wherever possible, discuss with your farm team (including employees and consultants) and work with your equipment supplier to ensure that an appropriate solution is developed for your own farm. Most suppliers should be able to advise you on dairy layout and provide plans that fit particular constraints or specifications on-farm. It is in their best interest to have well designed systems that work well for cows and people!

Information on the design, management and operation decision making in AMS are available on the Dairy Australia learning and development platform: Enlight (search on **dairyaustralia.com.au**). These modules were developed by the Miking Edge project (2018–2022) under the leadership of NSW Department of Primary Industries. The Milking Edge project was supported and funded by NSW Department of Primary Industries, DeLaval and Dairy Australia.

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