Guideline

Environmental Protection Act 1994

Landfill siting, design, operation and closure

This guideline provides guidance on siting, design, operation and closure of waste disposal activities in Queensland, specifically for environmentally relevant activity (ERA) 60 as defined in Schedule 2 of the Environmental Protection Regulation 2019 (EP Regulation). The purpose of this guideline is to assist industry and the administering authority in understanding application requirements and ongoing environmental management expectations for waste disposal activities.

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1 Introduction

Waste disposal sites, or landfill sites, form an important part of waste and resource management infrastructure throughout Queensland. They are currently the primary destination for residual waste. As part of a transition to a more circular economy and underpinned by the *Queensland Waste Management and Resource Recovery Strategy* targets for 2050, preferable methods of waste management in alignment with the waste and resource management hierarchy (waste hierarchy) will continue to gain prevalence (including recovery of energy from waste and recycling or composting). However, landfills will remain a vital part of the waste hierarchy for some regulated and harder to manage residual waste, particularly where there are no or limited alternative forms of safe and effective management.

Waste disposal activities are associated with many short- and long-term environmental and social risks. As such, landfills should be appropriately sited and designed with effective management of operations, emissions and closure processes to minimise environmental harm and promote intergenerational equity.

This guideline provides an overview of key considerations, suggested risk mitigation measures and minimum expectations to be implemented across the following elements:

- Landfill classification
- Siting
- Environmental baseline and risk assessment
- Community engagement
- Design and Construction Quality Assurance
- Emissions management, monitoring and treatment
- Landfill operations
- Closure, rehabilitation and post closure management

The terms ‘waste disposal site’, ‘waste disposal facility’, and ‘landfill site or facility’ are used interchangeably throughout this guideline.

1.1 Purpose

The purpose of this guideline is to:

- Assist industry and the administering authority in understanding application requirements and ongoing environmental management expectations for waste disposal activities.
- Minimise the risk of environmental harm from waste disposal activities by encouraging mitigation measures and incorporating transparent minimum expectations for siting, design, operations, monitoring, and closure of waste disposal sites.

1.2 Approach of this Guideline

This guideline has been developed to align with the following management frameworks (available on the Queensland Government website):

- Regulatory Strategy 2022-2027, Queensland’s Environmental Regulator,
- Queensland Waste Management and Resource Recovery Strategy, and
- Queensland Organics Strategy 2022–2032.

Under the *Environmental Protection Act 1994 (*EP Act) all persons have a general environmental duty (GED) to not carry out any activity that causes, or is likely to cause, environmental harm unless the person has an authority to do so or has taken all reasonable and practicable measures to prevent or minimise the harm.

Environmental harm is an impact, or potential impact, on an environmental value defined under the EP Act and includes environmental nuisance (e.g., odour, some types of noise, etc.). Environmental harm may be caused directly, or indirectly, by an activity or from the combined effects of the activity and other activities or factors. Environmental harm may be authorised under the conditions of an Environmental Authority (EA).

This non-statutory guideline details the risk management approaches for mitigating and managing the environmental and social risks associated with landfill activities[1]. The general approach of this guideline is to:

1. Set objectives and outcomes for key elements of waste disposal activities.
2. Identify key environmental and social risks of waste disposal activities and considerations for applicants when developing an EA application for a landfill activity.
3. Provide suggested measures that can be implemented to mitigate environmental and social risks, minimise environmental harm, and comply with GED.
4. Provide minimum expectations of applicants and operators where the department perceives a greater environmental risk. In alignment with the *Regulatory Strategy 2022 to 2027* and its principle of regulating proportionate-to-risk, the department may implement a more prescriptive approach to minimise or mitigate high environmental risks.

It is recognised that both existing and proposed landfill facilities are subject to a range of site-specific circumstances. The administering authority will assess each application on a site-specific basis when applying the suggested measures and minimum expectations provided in this guideline. Alternatives to the suggested measures and minimum expectations may be appropriate and will be considered on a case-by-case basis, subject to risk assessment and their alignment with the objectives and outcomes of this guideline. This may also be subject to independent verification.

Waste Disposal Activities (ERA 60)

Under the EP Act, a person must not carry out an environmentally relevant activity (ERA) unless the person holds, or is acting under, an EA for the activity. ERAs are activities with the potential to release emissions which may impact the environment and surrounding land uses.

Waste disposal is prescribed under Schedule 2 of the *Environmental Protection Regulation 2019 (EP Regulation)* as an ERA (ERA 60) and consists of only one of the following:

a) operating a facility for disposing of—
   i) only regulated waste; or
   ii) regulated waste and any, or any combination, of the following—
      A. general waste;
      B. limited regulated waste;
      C. if the facility is in a scheduled area—no more than 5t of untreated clinical waste in a year;

b) operating a facility for disposing of—

[1]This guideline is not an exhaustive guide to other risks of landfill siting, design, operation and closure. It focuses on mitigating and managing the environmental and social risks of landfill activities.

i) only general waste; or

ii) general waste and either, or a combination, of the following—

A. a quantity of limited regulated waste that is no more than 10% of the total amount of waste received at the facility in a year;

B. if the facility is in a scheduled area—no more than 5t of untreated clinical waste;

c) operating a facility for disposing of only inert waste;

d) maintaining a decommissioned waste disposal facility.

Waste disposal does not include using clean earth as fill.

1.3 Application requirements

Pre-lodgement service

The department offers a free pre-lodgement service to all applicants seeking direction and advice regarding their EA application. The pre-lodgement service provides an opportunity for the department to provide advice on the feasibility of approvals for a project based on early concepts, the application process, expected timeframes, and the information to be included in an application to meet the relevant legislative requirements. Pre-lodgement meetings are strongly encouraged to ensure a complete application is provided and a more efficient assessment of an EA application.

The department's *Application for pre-lodgement services for an environmental authority (ESR/2015/1664*) form is available on the Queensland Government website and may be used to request a pre-lodgement meeting or submit a draft application for written advice.

ERA 60 EA application

Waste disposal activities are a prescribed ERA (ERA 60) under the EP Regulation and will generally be assessed as a site-specific EA application.

A site-specific EA application must describe the land on which each activity will be carried out and include an assessment of the likely impact of the activity on the environmental values, including:

- A description of the environmental values likely to be affected by each relevant activity,
- Details of any emissions or releases likely to be generated by each relevant activity,
- A description of the risk and likely magnitude of impacts on the environmental values,
- Details of the management practices proposed to be implemented to prevent or minimise adverse impacts, and
- Details of how the land subject of the application will be rehabilitated after each relevant activity ceases.

Many prescribed ERAs require concurrence assessment by the State. Where a concurrence ERA is a material change of use, a development application is referred to the state for assessment. A development application for a concurrence ERA is also an application for an EA. Further details on how to prepare and lodge development applications can be found on the Queensland Government Planning website.

There are a number of relevant department guidelines that provide guidance pertaining to the ERA application process and application requirements, including:

- *Application requirements for activities with waste impacts (ESR/2015/1836)*

- *Application requirements for activities with water impacts (ESR/2015/1837)*
- *Application requirements for activities with noise impacts (ESR/2015/1838)*
- *Application requirements for activities with impacts to land (ESR/2015/1839)*
- *Application requirements for activities with impacts to air (ESR/2015/1840)*

These guidelines should be referred to as part of the application process for an ERA 60 activity. They also contain useful information that can be referred to in preparation of assessments that may be required as part of this guideline (see Section 3).

Where an activity will result in significantly disturbed land, the department may place a condition on an EA requiring the payment of a financial assurance (FA). For further information on FA, including when FA may be required and how it is calculated, refer to the guideline *Financial assurance under the Environmental Protection Act 1994 (ESR/2015/1758).*

Supporting information checklist

Table 1 summarises the supporting information to be provided at the pre-lodgement and, application and amendment stages for an ERA 60 application.

Table 1: Application checklist for ERA 60 EA applications

Supporting Information	EA pre-lodgement	New EA application	EA amendment[2]
Landfill classification, target waste types and quantity	✓	✓	✓
Proposed landfill method and staging plan	✓	✓	✓
Shortlist of alternative site locations	✓(for new applications only)	✓	
Conceptual Site Model (CSM)		✓	✓
Site water balance assessment		✓	✓
Hydrogeological risk assessment		✓	✓
Geotechnical slope stability risk assessment		✓	✓
Other assessments as determined by the landfill classification and CSM		✓	✓
Stakeholder engagement plan		✓	✓
Design report		✓	✓
Construction Quality Assurance (CQA) plan		✓	✓

[2] If the proposed EA amendment does not concern changes to landfill cells or associated infrastructure, not all the supporting information may be relevant. This can be discussed with the administering authority.

Supporting Information	EA pre-lodgement	New EA application	EA amendment[2]
Landfill environmental management plan (LEMP)		✓	✓
Closure, rehabilitation and post closure plans		✓	✓

Disaster management waste and Temporary Emissions License (TEL)

In the event of a disaster or event, operators may access a variety of tools to assist in managing the impacts of a disaster or event on the waste disposal activity.

For example, an operator who holds an EA may apply for a Temporary Emissions Licence (TEL) to seek authorisation of a temporary contaminant release into the environment in response to an event. Further information on the criteria for a TEL and the TEL application process is available on the department's website.

Further, disaster management waste may be exempt from the waste levy. Further information on clarifying what is disaster management waste and the associated waste levy exemption process is available on the department's website.

1.4 Key roles and responsibilities

Table 2 summarises the ongoing roles of Registered Professional Engineers of Queensland (RPEQs), and Appropriately Qualified Persons (AQPs) through key stages of design, construction, operation, and closure of a landfill facility.

The *Professional Engineers Act 2002* requires that anyone carrying out a professional engineering service in Queensland, or for Queensland, must meet the standards of and be carried out only by RPEQs, or by persons under the direct supervision of RPEQs. Landfill design (construction and closure), some elements of environmental management plans and preparation of a CQA plan or CQA report constitute provision of a professional engineering service and not an engineering service carried out in accordance with a prescriptive standard (where this requirement does not apply).

AQP means a person or persons who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis to performance relative to the subject matter using the relevant protocols, standards, methods or literature.

RPEQs and AQPs are responsible for ensuring that they undertake their roles in accordance with the relevant statutory requirements governing the provision of their services.

The CQA engineer should be independent of the construction contractor and landfill owner.

Table 2: Key roles and responsibilities checklist.

Stage	Item	Appropriately qualified person (AQP)	Registered Professional Engineer (RPEQ)	
			Design engineer	CQA engineer (Independent)
Environmental baseline and assessment	Conceptual Site Model (CSM)	✓		
	Individual assessments as determined by the CSM	✓		
Design	Design report, technical specifications & drawings	✓	✓	
Construction Quality Assurance	CQA plan		✓	
	Variations or amendments to design during construction		✓	
	CQA report		✓	✓
Landfill environmental management plan	Landfill environmental management plan	✓		
	Environmental monitoring, assessment and reporting	✓		
Closure, rehabilitation and post-closure	Closure plan	✓	✓	
	Rehabilitation plan	✓	✓	
	Post closure plan	✓	✓	
	Certified statement of completion	✓	✓	

1.5 Scope

This guideline is applicable to:

- New or amendment site-specific EA applications for waste disposal activities (ERA 60).
- Current waste disposal activities (ERA 60) where operation, closure and post-closure information may be relevant.

New or amendment applications may comprise of individual landfill cells or landfill facilities comprising of one or more landfill cells; this guideline applies to both.

The following are out of scope for this guideline:

- The design, operation or management of any non-waste disposal activities (e.g., quarries and mines).

- The contaminated land framework in relation to containment cells on sites listed on the CLR or EMR.
- Other waste ERAs such as:
    - Organic material processing (ERA 53),
    - Mechanical waste reprocessing (ERA 54),
    - Other waste reprocessing or treatment (ERA 55),
    - Regulated waste transport (ERA 57),
    - Thermal waste reprocessing and treatment (ERA 61),
    - Resource recovery and transfer facility operation (ERA 62), and
    - Crushing, milling, grinding or screening (ERA 33).
- Protocols, procedures, or management of the following aspects of waste management:
    - Financial assurance,
    - Operational compliance with the landfill levy,
    - Waste tracking,
    - End of waste,
    - The contaminated land framework and containment cells,
    - Management of disaster management waste, and
    - Definition of clean earth.

Further information on the above is available on the department's website.

2 Landfill classification

Objective

- To categorise landfill activities based on the type of waste being disposed of.

Outcomes

- Applicants can identify the landfill classification applicable to their proposed waste disposal activity and the requisite considerations, suggested measures and minimum expectations.
- To facilitate consistent regulatory outcomes in the design and construction of landfill facilities.

For the purpose of this guideline, the thresholds for ERA 60 as defined in Schedule 2 Section 30(3) of the EP Regulation are further categorised into landfill classifications based on the type of waste disposed. These are provided in Table 3 and are used to determine some of the minimum expectations applicable to a landfill facility throughout this guideline. Waste disposal (ERA 60) is as defined in Schedule 2 of the EP Regulation.

Table 3: Landfill classification[3]

Landfill classification	WASTE CATEGORY		THRESHOLD
	When operating a waste disposal facility disposing of:	**ERA 60 threshold**	**Disposing of the following quantity (tonnes) per annum**
Regulated	a) only **regulated waste**; or b) **regulated waste and any**, or any **combination**, of the following — i) general waste; ii) limited regulated waste; iii) if the facility is in a scheduled area—no more than 5t of untreated clinical waste in a year.	ERA 60 (1) (a) ERA 60 (1) (b) ERA 60 (1) (c) ERA 60 (1) (d)	Any quantity
General	a) only **general waste**; or b) **general waste** and either, or a **combination**, of the following— i) a quantity of limited regulated waste that is no more than 10% of the total amount of waste received at the facility in a year; ii) if the facility is in a scheduled area—no more than 5t of untreated clinical waste.	ERA 60 (2) (a) ERA 60 (2) (b) ERA 60 (2) (c) ERA 60 (2) (d) ERA 60 (2) (e) ERA 60 (2) (f) ERA 60 (2) (g) ERA 60 (2) (h)	Any quantity

[3] Regulated waste, limited regulated waste, general waste and inert waste are defined in Section 12 of this guideline as per Schedule 2 and Schedule 19 of the EP regulation.

Landfill classification	WASTE CATEGORY		THRESHOLD
	When operating a waste disposal facility disposing of:	ERA 60 threshold	Disposing of the following quantity (tonnes) per annum
Inert	only **inert waste**	ERA 60 (3) (a) ERA 60 (3) (b) ERA 60 (3) (c) ERA 60 (3) (d)	Any quantity

Landfill classifications do not account for site specific conditions. As such, depending on the outcomes of the conceptual site model, corresponding assessments (see Section 4) as well as the risk posed by the landfilling activity, additional requirements may be needed. These requirements may be additional to the considerations, suggested measures and minimum expectations outlined in this guideline. Conversely, in specific circumstances (e.g., local government areas applying for small, regional landfills in areas where there are low risks to environmental and social receptors) more flexible requirements may be possible, pending discussion and agreement with the administering authority. It is strongly recommended that all applicants arrange a pre-lodgement meeting with the administering authority prior to submitting any applications.

3 Siting

Objective

- Minimise negative environmental and social impacts from the waste disposal activity through appropriate site selection for new applications.

Outcomes

- Applicants assess the suitability of potential sites by adequately considering risk to environmental and social values when selecting an appropriate site.
- Discuss a shortlist of alternative site locations with the administering authority to ensure the most appropriate site is selected.

The siting of a new landfill is a critically important exercise, being the first and principal stage at which risk of environmental harm can be minimised. In selecting a site for a new landfill, the aim is to maximise the advantageous use of natural barriers (e.g., hydrogeological barriers) and buffers, with engineering and management controls being considered as secondary measures.

Consider the following when determining the location for a new landfill:

- A shortlist of alternative site locations, overlain with scaled preliminary site layouts and topography, including the following for each alternative site location:
  - Information about environmental and social receptors and the receiving environment as shown in Table 4.
  - Initial assessment of potential impacts to environmental values such as shown in Table 5.
- The proposed landfill method and filling plan (see Section 6.2 for more information).

Table 4: Receiving environment considerations.

Receiving environment	Considerations
Geological setting	Locate landfills in areas where the landform is stable to ensure long-term stability of the landfill structures (including the liner and capping). Geological issues for consideration include: • Seismic zones, • Voids or settlement that may be associated with mines, shafts, bores or quarrying that may not be suitable for siting landfill, • Fractured geology, • Acid sulfate soils, • Porous soils or geology that facilitate ground gas migration, • Potential for landslides or other ground movements, and • Excessive differential or total settlement from uncontrolled fill, collapse of low-density soils or consolidation of compressible soils.
Climate and precipitation	Precipitation, high temperatures and wind can impact the management of landfill sites and affect leachate and landfill gas generation, the site water balance,

Receiving environment	Considerations
	drainage, flooding, dust, erosion and land stability as well as dispersion of litter. Consider the impact of climate change which may lead to more frequent and intense extreme weather events.
Biodiversity	Consider impacts to biodiversity and any protected areas. Landfilling should not be conducted in category A and category B environmentally sensitive areas, as defined under the Environmental Protection Regulation 2019.
Encroachment	Consider potential encroachment issues over the landfill lifecycle. Conduct an analysis of the anticipated changes in the zoning or land use of the area surrounding the site during its projected lifespan, including consideration of planned developments. Guidance on future land use intentions may be found in the strategic planning statement prepared by the relevant local government.
Community engagement and social license	Consider the concerns of the local community as landfills can be particularly contentious. This includes consideration of planning issues including site access, land zoning, acceptable land uses for selected sites and adjacent areas.

Table 5: Environmental value considerations.

Environmental value	Considerations
Air	Identify potential impacts to air for each location including landfill gas emissions, dust, odour, and windblown litter.
Land	Identify any potential impacts associated with the migration of ground gas though the subsurface, the release of contaminants to land, disposal of waste to land, land disturbance and erosion.
Water	Identify potential impacts to surface water and groundwater through stormwater and leachate. Where landfills are within the 1% annual exceedance probability (AEP) floodplain, consider additional engineering and management controls to ensure that the facility will be protected from flooding, erosion by floodwaters and infiltration from perched water tables. The controls should not cause adverse increases to upstream flood levels. A major risk to groundwater is the potential for leachate or landfill gas contamination to occur because of a liner failure. Landfills should not be located where waste is proposed to be deposited below the permanent groundwater table. A minimum separation of 2m from waste to the permanent ground water table should be maintained. It is imperative to consider groundwater protection across all phases of a landfill.
Noise	Identify potential noise impacts associated with activity including from earthworks equipment and any systems for deterring birds.
Ecological health	Identify potential impacts to terrestrial and aquatic ecological values and receptors, including wetlands.

Minimum expectations for site selection are detailed in Appendix 1. These primarily focus on incorporating appropriate separation distances between the waste disposal activity and environmental and social receptors.

4 Environmental baseline and assessment

Objective

- Gain a thorough understanding of the current environment where the landfill will be located and key risks to environmental values as well as environmental and social receptors.

Outcomes

- Contamination linkages are understood and defined in a Conceptual Site Model (CSM).
- Representative environmental baseline data is collected to reflect the characteristics of the site and surrounding environment, understand background contamination levels and inform ongoing monitoring.
- Appropriate risk assessments are undertaken, and suitable management strategies are put in place to safeguard environmental values.

Once a site has been selected, and prior to operation and approval, establish a comprehensive baseline environmental assessment. This is important to inform the level of risk to environmental values as well as environmental and social receptors and determine appropriate landfill design, monitoring, operational and closure requirements.

Sufficient detail is required in the environmental baseline assessment to demonstrate that the selected site is suitable for development of the proposed landfill. The following builds upon the site information prepared during the siting phase (see Section 3).

Conceptual Site Model

A CSM is a representation of site-related information regarding contamination sources, receptors and exposure pathways between those sources and receptors. The development of a CSM is an essential part of all site assessments and provides the framework for identifying how the site may became contaminated and how potential receptors may be exposed to contamination either in the present or in the future[4]. For a contamination risk to exist, there needs to be a viable source, pathway and receptor. These are defined as:

- **Source,** the origin of contamination (e.g., leachate)
- **Pathway,** the route through which contamination can travel from the source to the receptor (e.g., groundwater, or stormwater runoff)
- **Receptor,** the environmental value or entity that can be affected by the contamination (e.g., suitability of surface water for irrigation, ecological receptors in the creek)

When all three of these are viable, it is known as a contamination linkage. Note that suitability for present and future uses should be considered in the CSM where such environmental values are prescribed to be protected.

A CSM should be prepared for the site by an AQP to determine the potential contamination linkages the landfill will present during all stages of its lifecycle. It is important the CSM considers not just current receptors and proposed operation of the landfill, but also likely foreseen changes to the operation of the landfill including its future use and potential new contamination linkages to receptors and environmental values.

[4] As per the National Environment Protection (assessment of site contamination) Measure April 2011, schedule B2

All landfill applications should prepare a CSM. Appendix 2 outlines the minimum expectations for a CSM.

The findings of the CSM should clearly demonstrate the viable contamination linkages. Viable contamination linkages will require a corresponding assessment. Non-viable linkages require robust justification as part of the CSM.

Environmental baseline data

Environmental baseline data assists in characterising the site and the surrounding environment (including accounting for seasonality, natural variability, and extreme events) prior to conducting an activity. Using this data, appropriate trigger values for ongoing monitoring throughout all stages of a landfill activity can be derived. A range of data may be collected to form the environmental baseline, including but not limited to:

- Groundwater characteristics and levels,
- Surface and receiving water characteristics,
- Air quality data,
- Presence or absence of subsurface gas,
- Background bore installation, and
- Noise and vibration data.

Assessment

All landfill applications should undertake the following key assessments:

- A site water balance assessment (including leachate generation and disposal, and operational water usage),
- A hydrogeological risk assessment, and
- A geotechnical slope stability risk assessment.

All landfill classification applications, except for inert landfills, should also undertake a landfill gas risk assessment.

Minimum expectations for the above assessments are detailed in Appendix 3.

Depending on the location, site specific conditions, initial environmental assessment and the findings of the CSM, further assessments may be necessary to quantify the risks and demonstrate they can be appropriately mitigated. These may include:

- An environmental amenity assessment (which may include odour, noise, visual, dust and air quality),
- A biodiversity impact assessment,
- A fire risk impact assessment, and
- A security risk assessment.

Minimum expectations for the above assessments are detailed in Appendix 3.

A CSM and the resultant assessments are all dynamic tools and should be periodically reviewed and updated if site conditions change.

5 Community engagement

Objective

- Engage with the local community to identify and consider potential community issues concerning the proposed landfill project.

Outcomes

- Appropriate ongoing engagement with communities that may potentially be impacted by the proposed landfill project.
- Community input is obtained early in the planning phase of the project so potential concerns can be mitigated as part of onward planning, design and operation of the proposed landfill project.

It is important that communities which may be affected by a landfill development are engaged early in project decision-making and provided with appropriate avenues for ongoing engagement. Effective engagement practices help identify potential issues, impacts, opportunities, options and solutions for improvement, and facilitate more effective and efficient decision-making.

The concept of obtaining a Social Licence to Operate (SLO) is becoming increasingly important for the waste disposal industry. SLO broadly refers to the informal licence or approval granted by a local community and project stakeholders for a project. Once earned, the SLO has to be maintained. Landfill operators should demonstrate they have an SLO in the impacted communities and subsequently maintain this SLO over the expected life of the facility.

Engagement with the community should adhere to the principles outlined in Table 6.

Table 6: Community engagement principles.

Principle	What this means in practice
Community engagement is authentic and transparent.	Community engagement is an integral part of project planning and is planned and undertaken in the early stages of project development. Clearly identify and communicate which decisions can and cannot be influenced by community input. The results of community engagement are communicated back to the community – engagement will 'close the loop'. Information is shared transparently with the community in a manner that encourages mutual trust.
Community engagement is inclusive.	Engagement and information sharing activities are as inclusive and accessible as possible and consider any specific requirements of community groups (e.g., cultural and linguistic diversity, First Nations values and traditions, restricted mobility, etc.). First Nations stakeholders should be consulted by an appropriately qualified indigenous engagement practitioner, with an acknowledgement that First Nations peoples and communities have cultural responsibilities to care for Country and play an important role in the conservation and sustainable use of Australia’s environment and heritage.

Principle	What this means in practice
Community engagement is respectful.	Stakeholders and the community can expect to have their concerns actively listened to. Engagement acknowledges the expertise, perspective and needs of the community and stakeholders. Stakeholders are open, trustworthy, and respectful when taking part in engagement.
Community engagement is responsive.	Engagement activities and information sharing are done in a timely manner that allows appropriate time for informed consideration and contributions by those potentially impacted.
People have a right to participate in decisions on matters that affect them.	If a project has the potential (real or perceived) to impact the community, the community has a right to be informed about the project and for their opinions and feedback to be included in decision-making.
Good neighbour principle.	Taking reasonable care to avoid acts or omissions that are reasonably likely to negatively impact one's neighbours.

Considerations for appropriate community engagement include:

- Any statutory requirements (e.g., under Queensland's planning framework as well as environmental harm and nuisance under the EP act),
- The size, location and type of proposed landfill,
- Environmental and social receptors nearby the proposed landfill,
- Cultural values and rights, needs, and interests of the communities and stakeholders,
- Environmental risks of the proposed landfill, and
- The intended post-closure land use.

Landfill operators have a key role in helping to ensure that communities are appropriately engaged in line with the principles in Table 6. Minimum expectations for community engagement are detailed in Appendix 4.

5.1 Guidance materials

A range of guidance materials are available to assist applicants in building trust and an understanding with the community, and to assist developing and implementing an effective engagement approach. These are outlined in Table 7.

Table 7: Community engagement guidance materials

Guidance or tool	Description
Quality assurance standard for community and stakeholder engagement, IAP2	Describes 11 steps of any engagement process that can be applied in a variety of contexts and with diverse stakeholders. It also assists evaluators in assessing the quality of a community engagement project.

Guidance or tool	Description
Community engagement toolkit for planning, Queensland Government	This toolkit supports local governments to meet their community engagement requirements with plan-making and supports communities and stakeholders in their interactions with the plan-making process.
Community engagement guidelines for the Australian wind industry, Clean Energy Council	Outlines a framework for applying engagement principles and provides a set of ideas, practices and tools to help industry earn and maintain an SLO through strong community engagement. While it is intended for wind and other renewable energy projects, the fundamental approaches can be translated to the waste disposal industry.
Stakeholder engagement guide – business case development framework, Queensland Government	Provides guidance on developing and implementing stakeholder engagement activities during the development of infrastructure proposals in Queensland.
Online community engagement guideline, Queensland Government Enterprise Architecture	Provides guidance on how online technology can be used to support community engagement.

6 Landfill design

Landfill activities incorporate containment and control measures into the landfill design to minimise the risk of contamination linkages. Mitigation measures are integrated into the design of landfill through:

- The site layout (Section 6.2)
- The lining system (Section 6.3),
- Stormwater management (Section 7.3),
- Landfill gas management (Section 7.1),
- Leachate management (Section 7.2), and
- The final capping at the end of a cell's life (Section 6.5).

A design report (Section 6.1) and the construction quality assurance (CQA) plan and reports (Section 6.6) are key components to ensuring a landfill is appropriately designed and constructed in alignment with the proposal.

The design of a landfill should complement and integrate with the proposed ongoing emissions management and monitoring (Section 7) of leachate, landfill gas, surface/receiving waters as well as groundwater.

Design of a landfill should consider the environmental factors listed in Table 8, this will help inform appropriate design of cell liners, leachate and landfill gas management systems, stormwater management and final capping. Note, additional environmental factors may need to be considered depending on the site selected for the landfill activity.

Table 8: Environmental factors for consideration during design.

Factors	Consideration
Groundwater	Landfill activities pose significant risks to groundwater through the release of leachate to groundwater, and landfill gas migration through the landfill liner to groundwater. Building upon the hydrogeological assessment (Section 4) prepared for the siting of the landfill, consider including the following engineering components in the landfill design: • Leachate detection and recovery (Section 6.4), • Cell liner (Section 6.3), • Groundwater monitoring network and program (Section 7.4), and • Groundwater depressurisation (Section 6.3.2). It is important to consider other influences on groundwater levels which may impact how a landfill is designed, such as: • Whether the historic land use of the area has artificially or temporarily changed groundwater levels (e.g., is there a possibility of groundwater recharge), • The change in wet and dry seasons, and • Other climatic factors (e.g., the El Niño Southern Oscillation). Use of site-specific data to validate any groundwater infrastructure and monitoring programs proposed at the landfill site. The department's *Using monitoring data to assess groundwater quality and potential environmental impacts* guideline describes approaches for selecting site and bore characteristics and analysing site-specific water quality monitoring data.

Factors	Consideration
Surface water	A significant risk of landfill activities is the direct and indirect release of leachate and contaminated stormwater to surface waters in the receiving environment (receiving waters). As receiving waters are influenced by the change in wet and dry seasons and other climatic factors, the design of landfill cells should consider: • Leachate detection and recovery (e.g., where a liner failure may result in release of leachate to groundwater and/or surface water) (Section 6.4), • Cell liner (e.g., where a liner failure may result in release of leachate to groundwater and/or surface water) (Section 6.3), and • Groundwater depressurisation (e.g., typically discharging to surface waters) (Section 6.3.2). Additional design considerations include: • Surface water monitoring (Section 7.4), • The stormwater management system (Section 7.3), and • The capping design (Section 6.5).
Airborne and ground borne emissions	Airborne emissions from landfill activities can impact far beyond the boundary of the site through landfill gas emissions (Section 7.1), dust, odour, and windblown litter (Section 8.1).
Geotechnical slope stability assessment	Landfill lining and capping systems may be impacted by unstable slopes and geotechnical conditions. Refer to the geotechnical slope stability assessment minimum expectations in Appendix 3 to inform the design of the lining system (Section 6.3) and capping system (Section 6.5) so failures are prevented.
Climate change	Landfill sites may be affected by the impacts of climate change. Consider adaptation strategies to deal with the increased frequency of extreme weather events including high rainfall and sea-levels, storms, bushfires and heatwaves. These events may impact groundwater levels, surface water flooding, leachate generation, landfill gas generation and the likelihood of fires. Landfill sites may also contribute to climate change through the release of greenhouse gases. Consider ways to reduce greenhouse gas emissions in the design of the landfill.

6.1 Design report

Objective

- Ensure the design of the landfill, or landfill cell, and its containment and management systems are documented and communicable to relevant stakeholders (e.g., administering authority, waste disposal operator, contractors, etc.).

Outcomes

- A design report is developed and endorsed by a design engineer (a RPEQ), identifying:
    - How the design of the landfill meets the objectives, outcomes, and minimum expectations of this guideline, and
    - How the ongoing operation and closure phases of the landfill will meet the objectives, outcomes, and minimum expectations of this guideline.

A design report demonstrates how the objectives, outcomes, and minimum expectations of this guideline are met in the design of the landfill site, as well as how identified risks are mitigated (as determined in the assessments as part of the CSM, see Section 4). This may include, but is not limited to:

- Landfill classification (Section 2),
- Siting (Section 3),
- Landfill design considerations (Section 6),
- Minimum expectations for:
    - Liner design (see Appendix 5),
    - Capping design (see Appendix 6),
    - The leachate management system (see Appendix 9)
    - The landfill gas management system (see Appendix 8),
    - The stormwater management system (see Appendix 10), and
    - The groundwater monitoring wells (see Appendix 12).
- Reference to prepared technical specifications and drawings,
- Emissions management, monitoring and treatment (Section 7) measures, required capacities and their timing, and
- Interface details and connections to existing cells and potential considerations for future landfill cells.

The design report should accompany the design drawings and technical specifications and be developed and approved by a design engineer (a RPEQ). The design report is accompanied by a declaration by the design engineer that the minimum expectations of this guideline are met by the design report.

Containment systems should be constructed in accordance with the design report, design drawings, and technical specifications, and verified by a CQA report (see Section 6.6) upon completion of construction.

The design report may be referred to onsite by the waste disposal operator and construction contractors. It should be provided to the administering authority with the EA application and during site inspections.

Construction should not commence prior to receiving the approved EA.

6.2 Site layout

Objective

- The layout of the landfill site considers environmental and site-specific conditions.

Outcomes

The landfill facility site is designed to:

- Minimise the risk of environmental harm,
- Encourage recycling in accordance with the waste management hierarchy,
- Make the most efficient use of resources on site, and
- Secure entry to the site to ensure that waste can be inspected and weighed before disposal or diversion to a resource recovery area.

Consider the following in the design of the site layout:

- Layout of all proposed disposal cells including location, size, depth and shape as well as the staged filling and capping plan. The staged filling and capping plan should include:
  - The filling and capping sequences,
  - Site material balance,
  - Progressive stockpile locations, and
  - Progressive cell access including roads and ramps,
- The proposed final landform and use once capping is complete (see Section 7 and Section 10),
- Layout of stormwater collection and management systems including storage ponds,
- Layout of leachate collection and treatment systems including storage ponds, if required,
- Layout of landfill gas collection system, if required,
- Internal access roads, direction of movement and site access including all ingress and egress roads,
- Weighbridge location and layout,
- Layout and details of any resource recovery areas declared under the *Waste Reduction and Recycling Act 2011* (WRR Act),
- Location of any transfer station areas,
- Location of ancillary buildings and other key features of the site (e.g., offices, welfare facilities, etc.), and
- Location of gatehouse, incoming load inspection areas, and site entrance.

6.3 Lining system

Objective

- Minimise impacts on surrounding environmental and social values through an appropriate lining system that contains and manages leachate and landfill gas.

Outcomes

- Ensure an adequate lining system is designed and installed on-site to mitigate the risk of leachate and landfill gas contamination to groundwater, surface water and air.
- Ensure cell liners and leachate collection systems are located above the permanent groundwater level.
- Implement design measures consistent with the CSM and any applicable risk assessments.

The complexity of a landfill liner will depend on the risks associated with the landfill based on the chosen site, the CSM, landfill classification and surrounding environmental values. As shown in Figure 1, an example landfill lining system consists of (from bottom to top):

- **Liner sub-base,** (preparation of the underlying foundation for the landfill area),
- **Groundwater depressurisation**, if required (to manage potential groundwater intersecting the landfill base),
- **Landfill liner,** (liner layers comprising a combination of natural soil materials and geosynthetic materials), and
- **Leachate drainage**, (to manage leachate).

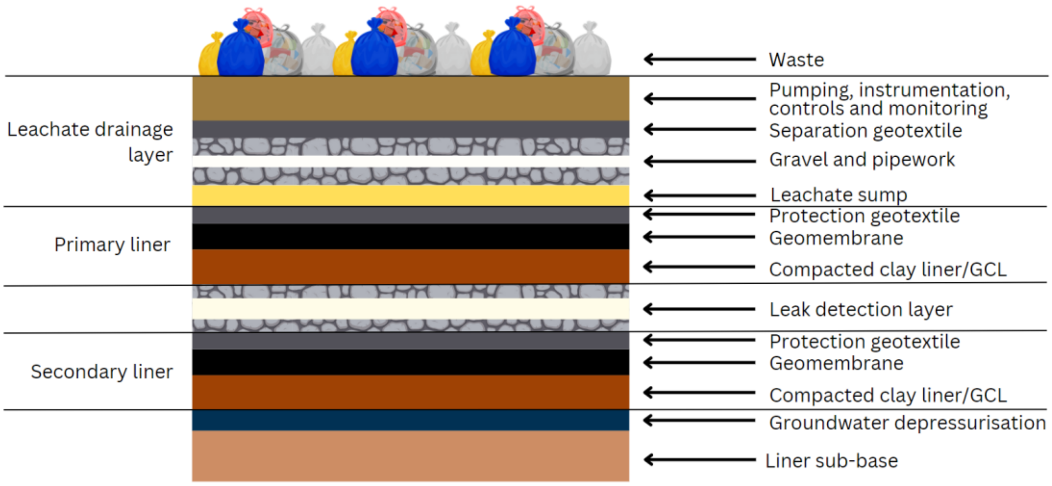

Figure 1: Example of landfill liner system (double composite type).

The design of a lining system should consider:

- The landfill classification.
- The CSM.

- The outcomes of the risk assessments, including the site water balance assessment, hydrogeological risk assessment, geotechnical slope stability risk assessment and landfill gas risk assessment (if required).
- The proposed base and sidewall grading. In particular, detailed slope stability analysis should be undertaken for lining systems on sidewalls with grading steeper than 25%, either as part of the geotechnical slope stability risk assessment or as part of the lining system design.
- The design of other relevant components of the landfill, including the leachate collection system and landfill capping.
- Compatibility with proposed waste to be received and associated byproducts (e.g., leachate).
- Waste filling method. This should consider whether a “fluffy” or “softer” layer of waste can be placed in the initial waste lift to mitigate damage to the liner, or if additional protection measures are required.
- Staging of the landfill, including potential long term UV exposure to the lining system prior to overlying waste placement.
- Cell geometry and:
    - Separation from groundwater.
    - Stability.
    - Access for both excavation, liner construction, future stages, operational access and closure.
    - Provision of sumps for the removal of leachate.

6.3.1 Liner sub-base

The liner sub-base provides the foundation for the landfill, including the liner system. It is typically formed from the natural ground surface after bulk earthworks, and has been suitably compacted, rolled and finished to support the overlying landfill, including the liner system. The sub-base preparation requirements should consider the characteristics of the sub-base materials, the expected loading over the life of the landfill, and the components of the liner and leachate collection system (such that it does not compromise these components). It should be appropriately graded in line with the leachate collection system, such that this grading carries through from the sub-base to this overlying system.

The sub-base on cell sidewalls may have different requirements from the cell floor, due to the grading and considerations such as slope stability.

6.3.2 Groundwater depressurisation

While landfills should not intersect with groundwater, it may be still be necessary to install a groundwater depressurisation system, depending on the geological and hydrogeological setting. For instance, a groundwater depressurisation system may be particularly important in metamorphic lithologies, areas prone to flooding, or spring fed areas.

A groundwater depressurisation system would typically consist of gravel filled trenches containing slotted or perforated pipework, adequately graded to drain to an extraction point (such as a sump or similar). A suitably designed drainage geocomposite may also form part of this system. The quality of groundwater should be effectively characterised and compared to water quality objectives and flow regimes relevant to any receiving waters to ascertain whether treatment and other mitigation measures are necessary to avoid environmental harm.

The need for and design of the groundwater depressurisation system should be based on the outcomes of the hydrogeological risk assessment.

6.3.3 Landfill liner

The landfill liner comprises a combination of natural soil materials and geosynthetic materials. The following arrangements should be considered:

- Single liner: Consisting of a compacted clay sealing layer.
- Composite liner: Consisting of a compacted clay sealing layer and geomembrane sealing layer placed adjacent to each other to work in composite. The compacted clay sealing layer may be substituted with a suitably designed geosynthetic clay liner (GCL) and compatible engineered subgrade.
- Double-composite liner: Consisting of two composite liners (as described above) – a primary composite liner underlain by a secondary composite liner. A secondary leachate collection system that also acts to provide a leak detection system is placed between the two composite liners.

The liner system should be appropriately graded in line with the leachate collection system, such that this grading carries through from the sub-base to this overlying system.

The liner should be protected from damage from the overlying drainage system and placement landfilling activities.

Design considerations for the liner vary for the sidewalls which are steeper than the floor.

Appendix 5 details the minimum expectations for the landfill liner type (e.g., single, composite or double), for each landfill classification as well as guidance on specifications for the relevant materials. Based on the outcomes of relevant assessments (see Section 4), a more robust liner system may be required beyond these minimum expectations.

6.3.4 Piggybacking

Where adequately justified, applications to construct a new landfill cell partly or wholly over an existing closed landfill cell may be considered by the administering authority (a practice known as 'piggybacking'). For a piggyback landfill cell, site-specific conditions need careful examination and the history of the original landfill cell and the conceptual site model need to be well defined and understood.

A piggyback lining system may be appropriate where:

- The original cell has an appropriate lining system, environmental controls and containment systems suitable for the deposited waste types and applicable landfill classification. The original cell can operate independently from the new cell and ongoing leachate and landfill gas management are not affected.
- The original cells are able to withstand the extra loading over time and increased settlement without geotechnical issues occurring.
- The piggyback cell liner has adequate slope stability and does not comprise the stability of existing slopes. A slope stability analysis should demonstrate this for all stages of construction and the final landform.
- The integrity of the piggyback cell liner is not compromised by:
    - Differential settlement of the underlying waste in the previous landfill cell, and
    - Landfill gas emissions or leachate seepage from the underlying waste in the previous landfill cell

- The environmental monitoring program for the piggyback cell can differentiate impacts occurring from the piggyback cell and the original cell.
- Long-term performance of the piggy back cell and the original cell can be assured,

Sites with existing contamination issues are unlikely to be suitable for piggyback systems. Consideration should be given to development approvals that may have height restrictions, as well as potential additional impact on amenity particularly visual impact.

Proposals for piggybacking will require engineering assessment and endorsement by a RPEQ engineer as part of the Design report.

6.4 Leachate collection system

Objective

- The leachate collection system minimises the hydraulic pressure on the lining system.

Outcomes

- An appropriately designed:
    - Leachate collection, extraction and level-control layer is implemented in cell liners.
    - Leachate detection and recovery system is implemented for higher risk activities.
- All leachate is collected by the leachate collection system and effectively transported to a storage facility until treatment, collection or disposal.
- The leachate collection system is robust and still able to function adequately in the event of several components of the system failing.
- The leachate collection system can withstand chemical attack and physical, chemical and biological closing, whilst also being able to withstand the weight of waste and compaction equipment.
- The leachate collection system can be inspected (where possible), cleaned and maintained and that it will function for the duration of the life of the landfill.
- Inspection, cleaning and maintenance of the leachate collection system should not introduce excess air into the system to avoid increasing the risk of a subsurface fire.
- The drainage layer, collection system and leachate sumps do not compromise liner integrity during installation and operation of the landfill.
- Leachate sumps do not compromise liner integrity under long-term down drag forces imposed on vertical risers or in the event of structural failure of the sump riser or base.

The leachate collection system forms part of the leachate management system implemented at the landfill (see Section 7.2), and consists of:

- **Leachate drainage layer** (system to collect and extract leachate from the landfill area),

- **Leak detection layer**, if required (system to detect leaks through a primary liner[5] and allow emergency extraction),
- **Leachate sump(s)** located at low points from which leachate is pumped from the layers above, and
- **Pumping, instrumentation, controls and monitoring** (measures to extract leachate and manage this process).

The design of a leachate collection system should consider the same items for consideration in Section 6.3. It should also consider the potential for clogging over time and be compatible with the proposed lining system and overall leachate management system at the landfill. In particular, it should consider the outcomes of the site water balance assessment in design and sizing of the system.

Appendix 5 details which landfill classifications require leachate collection, extraction and level-control and associated minimum expectations.

6.4.1 Leachate drainage layer

The leachate drainage layer is used to collect leachate above the lining system for extraction, to minimise the head of leachate on the lining system. It consists of a gravel drainage blanket containing perforated pipework and overlain by a separation geotextile, adequately graded to drain to an extraction point (such as a sump or similar).

6.4.2 Leak detection layer

A leak detection layer is used in a double liner to identify leachate leaks through the primary liner and provide a method for emergency leachate extraction as part of a secondary system. The layer should have identical requirements to the leachate drainage layer, however given its purpose for leak detection and emergency extraction, a suitably designed drainage geocomposite may also be utilised.

6.4.3 Leachate sump(s)

Leachate sumps are created in the landfill floor geometry to facilitate installation of sumps and pumps for the removal of leachate. Care should be taken to preserve the liner integrity at sumps and prevent transfer of loads that damage the liner.

Leachate sumps and risers are subject to significant loads induced by waste placement and settlement and require careful placement and design to ensure their survival during landfill operation and, closure and during the landfill aftercare period.

6.4.4 Pumping, instrumentation, controls and monitoring

Ancillary to the above, the leachate collection system should also include:

- Leachate pump/s to extract leachate from the leachate drainage/detection layers and transfer the leachate to the relevant leachate management infrastructure.
- Instrumentation and controls to direct the pump to turn on/off when the leachate builds up to a specified level, as well as other environmental controls such as turning off the pump if a rupture is detected in the transfer pipework, or turning off the pump if the leachate storage infrastructure is at capacity.

[5] A leak detection layer should be underlain by a liner equivalent to the overlying liner to have sufficient sensitivity to detect a leak, this is provided by constructing a double composite liner.

- Monitoring measures for leachate levels across the base of the landfill, as well as the quantity of leachate extracted from the landfill.

6.5 Capping

Objective

- Protection of social and environmental receptors by providing a stable, long-term separation layer between the waste and the final landfill surface.
- Minimise the potential of social and environmental harm occurring post-capping from:
    - Leachate contamination, where required,
    - Landfill gas migration, where required, and
    - Suspended sediment and contaminated runoff.

Outcomes

- Appropriately design and install a capping system that:
    - Is compatible with the future use of the area post closure,
    - Manages accumulation and migration of landfill gas, where required,
    - Minimises the infiltration of water from rainfall or flooding into the waste and the generation of leachate,
    - Minimises odour emissions, dust, litter, vermin, and the risk of fire, and
    - Is geotechnically stable and presents a sustainable landform suitable for its intended future use.
- Materials, construction methods and completed works comply with the requirements of the design drawings, technical specification, and design report.
- Capped landfill cells rehabilitated as soon as reasonable and practicable to control leachate contamination and suspended sediment and contaminated runoff from stormwater.

The capping system of a landfill cell is an important component of closure of a landfill activity. It is the final barrier that separates waste from the surrounding environment and provides a stable landform to support the designated end-use post-closure.

The design of the capping system should be compatible with the final landform for the landfill. The final landform should consider:

- Compatibility with surrounding topography and land uses,
- Promotion of positive visual amenity,
- Alignment with the end use of the site,
- Settlement as the waste decomposes, compacts and consolidates, and
- Maintenance of surface drainage and proposed vegetation.

As shown in Figure 2, a landfill capping system consists of (from bottom to top):

- **Capping sub-base** (preparation of the underlying foundation for the capping system),
- **Landfill gas collection**, if required (system to collect landfill gas migrating upwards from the underlying waste), and
- **Landfill capping** (capping layers of each cell).

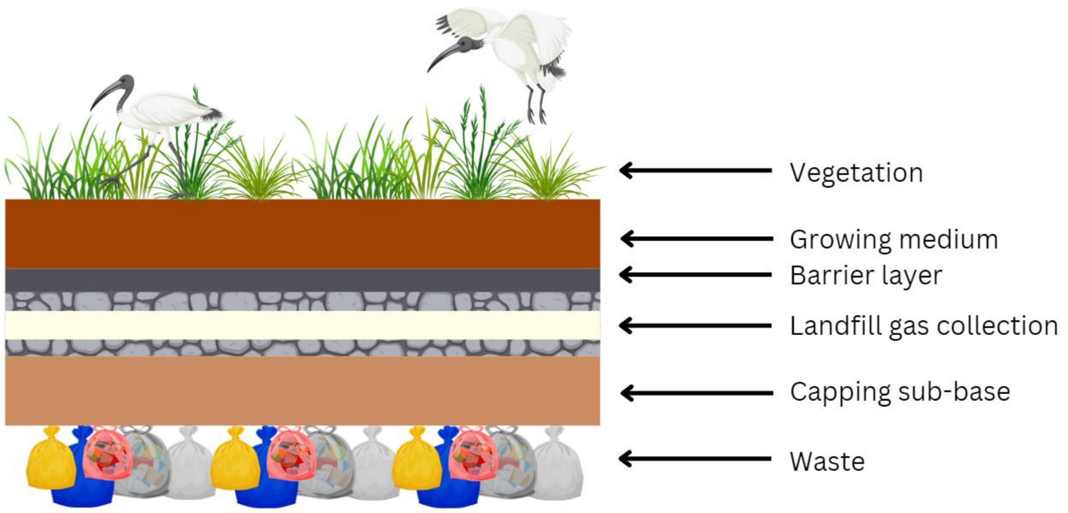

Figure 2: Example of landfill capping system.

The design of a capping system should consider:

- The landfill classification.
- The conceptual site model.
- Outcomes of the risk assessments, including the site water balance assessment, hydrogeological risk assessment, geotechnical slope stability risk assessment and landfill gas risk assessment (if required).
- Compatibility with the proposed end-use for the landfill post-closure.
- Proposed final landform grading. In particular, detailed slope stability analysis should be undertaken for capping systems on landforms with grading steeper than 20%.
- The design of other relevant components of the landfill, including the lining and leachate collection system.
- Compatibility with the landfill infrastructure to be retained following closure, including the proposed post-closure management of leachate, landfill gas and stormwater.
- Ability to manage ongoing settlement of the underlying waste, such that it does not compromise the integrity of the landfill capping through excessive strain or similar.
- Ability to manage potential landfill gas emissions from the underlying waste, such that it does not compromise the integrity of the landfill capping through capping uplift or similar.

Providing a copy of the CQA Report (see Section 6.6) to the administering authority upon completion of installation of the final capping system may be conditioned on the approved EA.

6.5.1 Capping sub-base

The capping sub-base provides the foundation for the capping system and future end-use infrastructure. It is typically formed from the interim cover layer placed over the waste after final levels are reached. Prior to capping, the sub-base should be suitably compacted, rolled and finished to support the overlying capping system.

6.5.2 Landfill gas collection

A landfill gas collection system in the capping system may be required to manage landfill gas migrating upwards and/or outwards from the underlying waste if there is sufficient landfill gas and/or it cannot be adequately managed by the landfill gas management system installed during operations. The landfill gas risk assessment should assess the need for this.

Landfill gas collection within a capping system typically consists of gravel filled trenches containing slotted or perforated pipework draining to an extraction point (such as venting or flaring infrastructure). A suitably designed drainage geocomposite may also form part of this system.

The landfill gas collection system should not introduce excess oxygen into the landfill to avoid increasing the risk of a subsurface fire.

6.5.3 Landfill capping

The landfill capping comprises a combination of natural soil materials and geosynthetic materials. The landfill capping should be designed to achieve a capping infiltration rate that does not exceed the liner leakage rate. It may include the following components (bottom to top):

- A barrier layer comprising of a single or composite liner similar to those described in Section 6.3.3.
- A growing medium that is suitably thick to protect the underlying liner and have suitable characteristics to support the proposed vegetation. Subsoil drainage may be included either within or directly below the growing medium to reduce build-up of water within this layer and subsequently reduce rainfall infiltration through the landfill capping.
- Vegetation to stabilise the capping surface, in line with the future end-use and that does not compromise the effectiveness of the capping system. Use of invasive plant species should be avoided.

Appendix 6 describes the minimum expectations for the landfill capping for each landfill classification, as well as guidance on specifications for the relevant materials. Based on the outcomes of relevant assessments for the landfill (see Section 4), a more robust capping system may be required beyond these minimum expectations.

6.5.4 Phytocapping

Phytocapping is an alternative capping system that involves the use of site-specific growing media and planting to store and release rainfall infiltration using evapotranspiration.

The performance of phytocapping is primarily determined by the type of vegetation and soil used as well as the climate. A detailed understanding of these elements is required to inform their design and provide assurance that the rate of infiltration will be sufficiently reduced. Field trials ranging from three to five years should be undertaken to verify the proposed phytocapping achieves the infiltration requirements.

Further guidance on phytocaps can be obtained in the *Guidelines for the Assessment, Design, Construction and Maintenance of Phytocaps as Final Covers for Landfills (Waste Management Association of Australia, 2010).*

6.6 Construction quality assurance (CQA) plan and report

Objective

- The construction of the landfill and its containment and management systems comply with the requirements of the design drawings, technical specifications, and design report.

Outcomes

- Develop and implement a CQA plan to ensure the liner, leachate management system, landfill gas management system, capping system and monitoring infrastructure (such as groundwater wells) meet the minimum expectations.
- Variations to the design and construction of a landfill, including for new landfill cells, are assessed and approved as per the process detailed in Appendix 7.
- A copy of the CQA report should be provided to the administering authority upon installation of:
    - The liner
    - The leachate management system, as required,
    - The landfill gas management system, as required,
    - Monitoring infrastructure, as required, and
    - The final capping system.

For each landfill cell:

- The CQA plan is developed and implemented prior to construction to outline how construction of the landfill cell will be in accordance with the approved design and will comply with the specified quality standards. The CQA plan will align with the design report, design drawings and technical specifications. The CQA plan is prepared by the design engineer (a RPEQ).
- The CQA report is prepared during construction of the landfill cell and provided prior to operation, demonstrating that the works were constructed in accordance with the CQA plan and that they meet the required quality standards and align with the approved design. The CQA report is prepared by a CQA engineer (a RPEQ) who is independent of the contractor, EA holder and the design engineer.

CQA plans and reports should be developed and implemented across all stages of the landfill lifecycle, including rehabilitation and closure, for each individual landfill cell, for all key components including:

- the liner,
- the leachate management system,
- the landfill gas management system,
- monitoring infrastructure including groundwater wells, and
- the final capping system.

Minimum expectations for CQA plans and reports are provided in Appendix 7.

The CQA plan should be provided to the administering authority with the EA application and during site inspections.

The CQA report provides assurance that the landfill has been constructed in compliance with the approved design and may be provided to the administering authority during site inspections and upon request.

6.7 Alternatives and continuous improvement

Industry practice for landfill design is continuing to evolve as new research and literature is made available on emerging issues such as emerging contaminants and the performance and suitability of new materials, products and techniques. There are also other evolving issues to consider such as changes to the waste streams received at landfills as they are utilised more and more for residual waste disposal following other waste management measures and the impact this has on the behaviour and emissions from changes to the physical and chemical composition landfilled residual waste

Whilst this guideline provides minimum expectations for the items such as lining, leachate collection and capping systems, the designer should be aware of these emerging issues and apply continuous improvement to their design, including going beyond the minimum expectations as required by industry practice.

Use of alternatives including new materials, products or techniques require careful risk-based consideration to ensure the objectives, outcomes and minimum expectations continue to be met or exceeded.

7 Emissions management, monitoring and treatment

When designing and operating a landfill activity, consideration needs to be given to the management of emissions from ongoing operations, particularly, landfill gas, leachate, and stormwater runoff. Landfill emissions are associated with an array of environmental risks which need to be sufficiently managed and/or treated to minimise and mitigate these risks. Emissions management commonly involves a monitoring program to measure the impacts of the emissions and ensure that mitigation methods are effective.

This section includes objectives and outcomes for:

- Landfill gas management (Section 7.1),
- Leachate management and disposal (Section 7.2),
- Stormwater and runoff management (Section 7.3), and
- Monitoring (Section 7.4).

7.1 Landfill gas management

Objective

- Minimise the risk to and impacts on groundwater, surface water, air quality, odour, global warming, as well as asphyxiation and explosion potential as a result of landfill gas emissions.

Outcomes

- Conduct a landfill gas risk assessment to inform the design and operation of the landfill gas system.
- Appropriately design, install and manage a landfill gas system to prevent impacts from on- and offsite landfill gas emissions and migration.
- Continue to update the CSM as onsite activities change.
- The landfill gas system is designed to:
    - Prevent fugitive emissions from landfill gas,
    - Prevent accumulation of landfill gas and it presenting an explosive or asphyxiant risk,
    - Minimise odour impacts at off-site environmental and social receptors,
    - Utilise barriers and preferential flow paths to effectively capture landfill gas,
    - Identify the infrastructure requirements for extraction of landfill gas (e.g., vacuum pumps),
    - Allow for monitoring of landfill gas,
    - Incorporate provisions for landfill gas treatment,
    - Establish a piping network to transport landfill gas, and
    - Provide infrastructure for utilisation or destruction of landfill gas.
- Ongoing monitoring of landfill gas migration and emissions are incorporated into operational management including closure and post-closure. Emission mitigation measures are implemented as necessary.

Landfill gas comprises methane, carbon dioxide and other trace gases such as hydrogen sulfide that result from the anaerobic degradation of organic waste within the landfill. It poses significant environmental risks and can contribute significantly to global warming if not managed. Landfill gas also poses a health risk as an asphyxiate and an explosive. The CSM should identify site-specific linkages and receptors for landfill gas (see Section 4).

A landfill gas management system will be required at most sites and will depend on the type of waste (e.g., wastes subject to anerobic decomposition such as food waste and green waste) and volume of waste (e.g., the greater the percentage of food waste and green waste in the total waste) disposed of at the facility.

Landfill activities should implement appropriate measures to minimise the risks from landfill gas emissions. Implementation generally involves:

- Conducting a landfill gas assessment,
- Appropriately designing the landfill gas system, and
- The ongoing management, monitoring, and treatment of landfill gas.

Landfill gas assessment

Landfill gas assessments assist in identifying the risks from quantities of landfill gas likely to be generated and the required management and mitigation options. A landfill gas assessment should be undertaken to assess the requirements of the management system and to identify migration pathways and risks to on-site and offsite receptors as well as identify any further monitoring and mitigation necessary (see Section 4 and Appendix 3).

Landfill gas management system

The landfill gas management system should be based on outputs from the landfill gas assessment and will inform the location of extraction wells, the reticulation network and interception systems.

Landfill gas management systems should be designed to manage fugitive emissions and odour, and associated migration risks by utilising barriers, preferential flow paths, extraction and flaring, or as energy generation.

The main control measures for landfill gas are the landfill gas system (as described in this Section) as well as the lining system (Section 6.3) and the capping system (Section 6.5). As such, these components should be considered holistically when designing the landfill gas system.

The design of the landfill gas system should consider the:

- Types of waste,
- Leachate generation and management,
- Operational life of the facility (including closure and post-closure),
- Final waste volume,
- Landfill gas generation potential, during and after placement of waste,
- Monitoring results,
- Collection systems,
- Flow rates and calorific value,
- Odour emissions, and
- Landfill gas utilisation or destruction systems (e.g., gas engines or enclosed flares).

The landfill gas system should actively extract landfill gas from the waste to either be utilised for energy, recovery or combustion in an enclosed flare. Figure 3 shows, in preferential order, the options for utilisation or destruction: energy recovery, enclosed flare system, microbiological gas treatment, and passive ventilation.

Microbiological gas treatment directs the landfill gas through a biofilter where the methane is oxidised to carbon dioxide. This kind of treatment may also be used at sites with higher gas generation to treat residual emissions from enclosed flare systems.

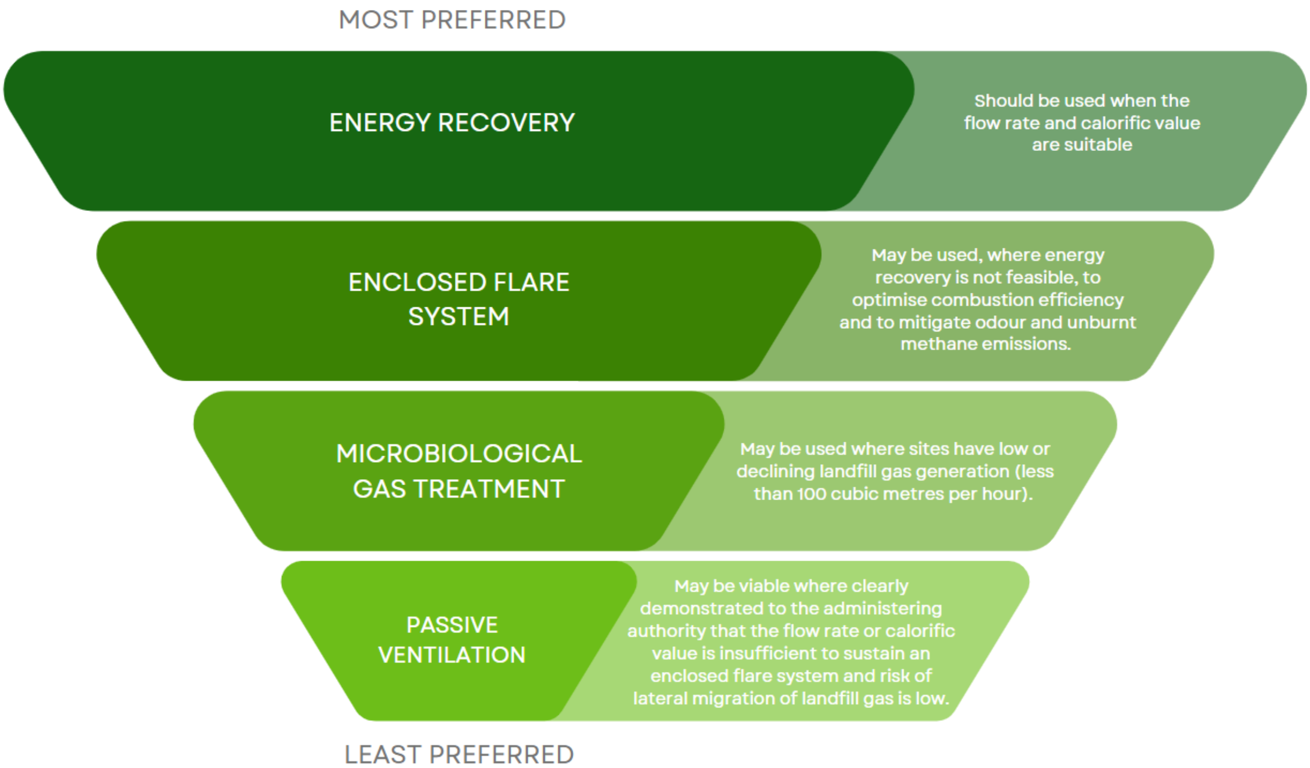

Figure 3: Preferential options for landfill gas utilisation or destruction.

Appendix 8 provides minimum expectations of a landfill gas system and an enclosed flare.

The landfill gas system should be installed progressively during the life of the landfill activity. Landfill gas extraction and utilisation (or combustion) should be used:

- no later than the completion stage of each landfill cell
- during operation where the cell remains open for than 2 years, and
- as required for odour and fugitive emission control.

7.2 Leachate management

Objective

- Minimise the risk of environmental harm occurring from leachate contamination by appropriately designing and implementing a leachate management system to minimise, collect, treat, and dispose of leachate.

Outcomes

- Design and implement leachate management such that:
    - Leachate storage areas do not intersect the permanent groundwater table,
    - Leachate storage areas are not prone to inundation, or damage, from flooding or rainfall events,
    - Leachate storage areas do not overflow into the surrounding land or water environments,
    - Leachate storage areas have an adequate liner achieving the same level of protection as the landfill cell liner,
    - Leachate storage areas have an appropriate leak detection and recovery method.
    - Untreated leachate is contained and managed.
    - Untreated leachate is not Intentionally, or unintentionally, released to surface water or groundwater.
    - Any thermal treatment of leachate removes hazardous contaminants in releases to air. Thermal treatment should not be used to disperse contaminants.
    - Leachate is not used for on-site operational purposes (e.g., as dust suppression or irrigation) unless it can be demonstrated the leachate has been treated to a sufficient standard such that it does not contaminate stormwater and/or cause odour nuisance.

Leachate is the product withdrawn from the leachate collection system after water passes through decomposing waste. Contact water (i.e., rainfall running off exposed waste or that has come in contact with exposed waste) is also to be managed through the leachate management system. As such, any liquid that encounters waste at a landfill (irrespective of the duration of contact) including waste disposed of in a landfill cell and waste stockpiled at the facility should be managed as leachate through the leachate system for reprocessing or treatment. All leachate should be collected and stored onsite where it is subsequently treated and/or disposed of appropriately. Selecting the appropriate leachate management system will be informed by the site water balance (Section 4). Leachate management systems may include:

- Implementing measures to minimise the generation of leachate.
- Designing and constructing a leachate collection system (Section 6.4).
- Where necessary, designing and constructing a leachate detection and recovery system (Section 6.4) in case of a cell liner failure.
- Designing and implementing a leachate treatment method, and
- Designing and implementing a leachate disposal method.

When designing an appropriate leachate management system, it is important to consider designing for wet and extreme weather events (e.g., flood events, wet seasons). A leachate treatment system should provide sufficient capacity to accommodate wet weather and provide robust and resilient performance under a wide range of operating conditions. It is important that the following are undertaken and well understood:

- assessment of leachate flow and quality variability.
- estimation of peak flows and total flows over extended wet weather periods.
- provisioning of sufficient buffer storage prior to secondary or more advanced treatment, to balance leachate flow and composition variability and allow stable operation.
- assessment of process performance and resilience, and contingency measures.

Leachate storage contingency should not be relied upon during normal operations.

Measures to minimise the generation of leachate include appropriate siting considerations, landfill design, and operational controls. It is important the measures are considered and implemented on a scale that can adequately minimise the leachate expected to be generated over the life of the landfill facility.

Leachate should be stored until it is treated and/or disposed of using one of the following methods in Table 9.

Table 9: Leachate disposal and treatment methods.

Disposal / treatment method	Considerations
Sewer discharge	Discharging leachate to a sewer system is generally managed under an agreement with the local water utility authority and may require pre-treatment prior to release. Requirements may be imposed on the quality of leachate that can be discharged, so a degree of treatment may be required. This method may not be suitable in rural areas or at remote landfill facilities where there are no sewer connections.
Removal by tanker	Leachate can be removed from the site by a tanker and transported to a site that can lawfully accept the leachate. Consideration is to be given to the expected volume of leachate to be generated over the life of the facility and seasonal impacts. When implementing this method, the operational process should ensure the rate of leachate removal offsite can keep pace with the amount of leachate being generated. A contingency plan should be developed if this leachate disposal method is selected.
Evaporation	Passive leachate evaporation can be a viable disposal method in areas where evaporation exceeds precipitation. Lined leachate ponds can be used to collect and store leachate and also dispose of leachate via evaporation. Leachate ponds should be designed and constructed to achieve the same performance as the landfill cell liner. The design should consider environmental factors (e.g., wind and sun exposure) and operational factors (e.g., access for inspections, monitoring, maintenance, repair, etc.). Consideration should be given to minimising and mitigating odours and other impacts to surrounding environmental and social receptors. This method is appropriate for periods of the year with high evaporation rates. Areas with increased seasonal humidity and rainfall can significantly decrease the evaporation rate and may increase the volume of leachate being generated. A

Disposal / treatment method	Considerations
	contingency plan should be developed for periods of the year when evaporation may not be an effective disposal method.
Treatment	A range of treatment technologies are available that use physical, chemical, biological and thermal processes. Examples include: • Aerobic treatment, where aerobic microorganisms break down organic contaminants. • Anaerobic treatment, where anaerobic bacteria break down organic matter and contaminants and produce biogas. • Reverse osmosis, where leachate is directed at pressure through a synthetic semi-permeable membrane to remove contaminants. • Physical-chemical treatment, where various techniques including coagulation, flocculation and sedimentation are used to remove contaminants. • Thermal treatment, where leachate is incinerated or evaporated (sometimes using combustion of landfill gas) leaving behind a reduced volume of concentrated contaminants for appropriate disposal. Using thermal treatment processes to ensure forced evaporation can entail a high risk of releasing odours, volatile organic compounds, ammonia and persistent organic pollutants such as PFAS into the atmosphere. Forced evaporation should incorporate best practice emission controls to remove such contaminants prior to releases and incorporate periodic emissions monitoring. Such treatment technologies require case by case basis consideration, and justification of the leachate treatment system includes provision of the following: • Applicable limits that may apply for any onward discharge or disposal of treated leachate • A functional description of the overall proposed treatment system as well as each element in the system • Demonstrated commercial scale performance of the proposed treatment system • Compatibility with the landfill classification, CSM and requisite assessments • Key risks in adopting the proposed treatment system and any required mitigation measures

Untreated leachate should not be used for on-site operational purposes, such as dust suppression or irrigation. Treated leachate may be used onsite where it is demonstrated the leachate can be treated to a sufficient standard. This will require discussion with the administering authority and may be conditioned in the EA.

Appendix 9 provides minimum expectations for leachate management systems including the monitoring network, collection system and ponds.

Leachate re-injection

Leachate reinjection is typically adopted as part of the leachate management system to maximise gas generation and should not be relied upon as the primary disposal method of leachate. The use of leachate reinjection needs to be carefully considered and ensure that associated waste placement methods is suitable (e.g., the filling sequence avoids issues with batter seeps), reinjection occurs at a sustainable rate and environmental risk mitigation techniques are implemented.

Appendix 9 details the minimum standards for leachate re-injection.

7.3 Stormwater and runoff management

Objective

- Minimise the contamination of stormwater through appropriate design and operation of the landfill activity.
- Minimise erosion and sediment runoff on- and offsite from stormwater discharges.

Outcomes

- Implement erosion and sediment control measures to mitigate adverse environmental impacts on- and off-site.
- Implement a stormwater management system to ensure clean water is not contaminated by waste (stockpiled or in a landfill cell), leachate, or other landfill operational activities.

Stormwater management at landfill sites is integral to ensure excess water does not drain or flood into landfill cells increasing the strain on the leachate management system or come into contact with exposed waste. For the purpose of this guideline:

- Contaminated stormwater is the runoff from intermediate (clean) cover, rehabilitated areas and other disturbed areas of the site.
- Uncontaminated stormwater is the runoff from undisturbed areas of the site.
- Leachate is withdrawn from the leachate drainage system after water passes through decomposing waste.
- Contact water is rainfall running off exposed waste or that has come in contact with exposed waste (e.g., runoff from stockpiles, etc.).

A stormwater management system is to be designed and constructed so that stormwater is managed by intercepting and diverting uncontaminated stormwater away from both disturbed areas and from where the landfill activity is conducted. Contaminated stormwater should be captured and directed to a stormwater management system, such as treatment ponds, and treated prior to any release.

Contact water and leachate should be managed through the leachate management system. All efforts should be taken to prevent uncontaminated or contaminated stormwater from becoming leachate and thus increasing the stress on the leachate management system.

Stormwater management is necessary at landfill sites to:

- Minimise the amount of receiving water contamination,
- Minimise leachate generation by preventing ponding and water from entering the landfill cell,
- Mitigate the risk of contaminated discharge from other landfill activities (e.g., from refuelling, sedimentation, etc.), and
- Mitigate erosion and sediment runoff.

A stormwater management plan is to be developed and provided as part of the application materials for an EA. Appendix 10 details the minimum expectations for a stormwater management plan.

Further considerations for the stormwater management plan can be found in the department's *Stormwater and environmentally relevant activities guideline (ESR/2015/1653).*

7.4 Monitoring

Objective

- Minimise the risk of contaminating the surrounding environment by developing and implementing a monitoring program, in alignment with the CSM, to detect and allow for timely interventions.

Outcomes

- Using appropriate sampling and monitoring methods, an emissions monitoring program is developed for the entire landfill lifecycle (including operation, closure and rehabilitation) which includes:
    - Landfill gas monitoring,
    - Leachate monitoring,
    - Stormwater monitoring,
    - Groundwater monitoring,
    - Storm water monitoring, and
    - Surface water monitoring.
- Where activities or site surroundings make it necessary or desirable, or EA conditions require, a monitoring program is developed and implemented for air, odour, noise, litter, and dust emissions, including assessment of potential nuisance impacts.
- The monitoring program is used to:
    - Characterise quality and quantity of emissions, in comparison with baseline data,
    - Detect potential contamination on- and off-site,
    - Rectify the causes of contamination, and
    - Notify, investigate, and remediate areas where the data has indicated potential contamination.

In alignment with the CSM, a site-specific emissions monitoring program should be developed and implemented at landfill sites using the baseline assessments (see Section 4). An emissions monitoring program will allow facilities to identify if the design, operations, or management processes need to be modified due to a change in the activity's risks. The emissions monitoring program should include:

- Landfill gas emissions and migration monitoring,
- Leachate head, quality, and volume monitoring,
- Groundwater monitoring,
- Stormwater monitoring, and
- Surface water monitoring.

An emissions monitoring program will allow for the early detection and intervention to minimise, or prevent, potentially adverse environmental impacts from occurring.

A nuisance monitoring program may be required to undertake routine odour, dust and noise monitoring both onsite and at surrounding environmental and social receptors. The frequency of this monitoring may depend on the site proximity to receptors. The monitoring programs should consider the environmental values and water quality objectives (WQOs) outlined in the *Environmental Protection Policy (Water and Wetland Biodiversity) 2019 (EPP Water)* as well as the air quality objectives outlined in the *Environmental Protection Policy (Air) 2019 (EPP Air).*

Landfill gas

Landfill gas includes methane, carbon dioxide, and small amounts of hydrogen which need to be monitored for odour and flammability. The landfill gas monitoring program should identify an appropriate number and locations of monitoring points which will depend on the landfill gas risk assessment.

The landfill gas monitoring program should be designed so that corrective actions or interventions can easily be implemented to mitigate or prevent environmental risks. The program should consider:

- Surface emissions monitoring,
- Subsurface emissions monitoring,
- Off-site migration monitoring, and
- Enclosed structure monitoring.

Appendix 11 details minimum expected landfill gas monitoring parameters and trigger levels for further investigation.

Leachate

The leachate monitoring program should include monitoring:

- Leachate head (using the leachate head monitoring wells),
- The volume of leachate (by recording the daily pump hours at each sump),
- The volume of leachate in leachate ponds, and
- The quality characteristics of leachate.

The leachate head monitoring wells will help identify the depth of leachate head across the base of the leachate collection layer and sumps.

Monitoring leachate volume assists in identifying any increase in leachate generation.

Leachate quality characteristics and analytes required to be monitored will depend on the types of waste being disposed of at the landfill. Leachate quality may change over time due to the progressive degradation of the waste.

Interpreting leachate volume, quality and head will assist in understanding the effectiveness of the leachate management system.

Electrical conductivity should be monitored in the leachate detection and recovery layer of the sub-base to provide real time data in case of a liner failure and leachate potentially contaminating groundwater or soil.

Appendix 11 details the minimum expected parameters for leachate monitoring.

Groundwater

The groundwater monitoring program assists in detecting any changes to groundwater characteristics and identifying if it is associated with the activity. The department's *Using monitoring data to assess groundwater* *quality and potential environmental impacts* guideline provides monitoring guidance using the baseline assessment of groundwater quality, the guideline:

- Details considerations that should be addressed in the program, and
- Identifies the approach to derive site-specific groundwater quality trigger and limit values. For PFAS contamination of groundwater, refer to the latest version of the PFAS National Environmental Management Plan and the EPP Water.

Appendix 11 details the minimum expected parameters for groundwater monitoring.

Groundwater monitoring wells should be appropriately designed, constructed and located at representative locations. Appendix 12 details the minimum expectations for locating and designing groundwater monitoring wells.

Stormwater

The stormwater monitoring program should monitor parameters in preparation for discharges. Some water quality limits are provided in the department's *Stormwater and environmentally relevant activities guideline* (ESR/2015/1653), other parameters will be determined on a site-specific basis and should be in alignment with the WQOs in the EPP Water.

Stormwater treatment ponds and stormwater management infrastructure should be routinely monitored, including the time, duration and estimated volume of all controlled and uncontrolled discharges, as well as the rainfall event preceding each overflow or discharge. This data should also be used to validate and refine the site water balance for the landfill site.

Appendix 11 details the minimum expected parameters for storm water monitoring.

Surface water

Surface waters in the receiving environment (receiving water) should be included within the monitoring program to detect any changes in the surrounding environment and identifying if it is associated with the landfill activity. The department's *Water Quality Sampling Manual* details considerations that should be incorporated into the monitoring program, such as:

- Sampling scope and design;
- Preparation for sampling;
- Quality control for water and sediment sampling;
- Record keeping, including taking field photographs and videos;
- Control and reference sites;
- Choosing a laboratory and analytical method, holding times and preservation

Suggested measures for the surface water monitoring program include:

- Monitoring for impacts or changes to sedimentation, aquatic flora, fauna and habitats.
- Monitoring locations upstream and downstream of the landfill activity to identify any impacts the landfill activity may have on nearby waterways.

A receiving environment monitoring program (REMP) may be included as a requirement of the EA. A REMP may be required where there are actual or potential releases of contaminants to waters (including groundwater), and the need for a REMP is usually determined during the assessment stage of the EA application. The aim of a

REMP is to monitor and assess the potential impacts of controlled or uncontrolled releases of wastewater and associated contaminants to the environment. A REMP provides a basis for evaluating whether the discharge limits or other conditions of the EA are successful in maintaining or protecting receiving environment values over time. The department's *Receiving environment monitoring program guideline (ESR/2016/2399)* provides further guidance on REMPs.

Appendix 11 details the minimum expected parameters for surface water monitoring.

8 Landfill operation

Objective

- Implement efficient management and operational processes to minimise offsite nuisance and amenity impacts (e.g., odour, dust, fire, litter, and noise) and the potential for environmental harm.

Outcomes

- Ensure that only allowable waste is accepted and disposed of in the landfill.
- Allowable waste should only be disposed of into suitably engineered landfill cells in a planned and methodical way to minimise the active disposal face within a landfill cell.

Landfill operations have the potential to give rise to both short- and long-term environmental pollution and nuisance issues. The key landfill operational management areas covered in this section are:

- Maintaining amenity
- Allowable waste for disposal and waste placement, and
- Daily and interim waste cover.

Emissions management, monitoring and treatment is covered in Section 7.

8.1 Amenity

Landfill facilities can have a variety of amenity impacts. Table 10 provides suggested measures to manage and mitigate these impacts.

Table 10 suggested measures to manage amenity impacts of landfill facilities

Potential amenity impact		**Suggested measures**
Odour	Odours associated with landfill activities can potentially cause environmental nuisance and impact surrounding areas. Odour is usually generated from: • The active tipping face, or waste awaiting tipping, • Highly malodorous wastes (e.g., biosolids), • Landfill gas (Section 7.1), and • Leachate collection and storage ponds.	A landfill should implement measures to manage and prevent odours travelling beyond the site boundaries. Suggested odour mitigation measures include: • Minimising the area of the active tipping face, • Applying daily and interim cover (Section 8.3), • Controlling and minimising fugitive landfill gas emissions (Section 7.1), • Managing leachate, surface water and condensate to ensure the proper functioning of any landfill gas collection system, • Preventing surface water and leachate pooling, • Covering incoming odorous wastes or wastes as soon as they are tipped on-site, • Minimising waste storage on-site, • Installing a meteorological station on-site to identify climatic conditions (e.g., windy conditions) and subsequently restricting odorous wastes from being tipped during these conditions, • Using deodorising or masking agents, • Ensuring adequate management and treatment of leachate and leachate ponds are implemented, and • Investigate all odour complaints as soon as practicable. General and regulated landfill classifications may be required to implement a monitoring program (prepared by an AQP) to undertake routine odour monitoring both onsite and at surrounding environmental and social receptors. The frequency of this monitoring may depend on the site proximity to receptors. This would be conditioned in the EA.

Potential amenity impact		Suggested measures
Dust	Landfill activities generate dust (e.g., through traffic movements, construction and earthworks, stockpiles of earth, exposed areas of soils and unsealed roads, etc.) which can cause an environmental nuisance offsite, decreasing air quality and increasing dust deposition. When identifying the potential impacts from dust, important elements to consider are: • The type and size of the operation, • Prevailing wind speed and direction, • Adjacent land use, and • The occurrence of natural and/or constructed wind breaks, and other wind-abatement buffers.	Suggested dust suppression measures include: • Wheel washing all vehicles on site, • Using vibration grids for all vehicles on site, • Minimising the area of exposed soils, • Using water, or other dust suppressants, on unsealed roads or stockpiles, • Regularly maintaining all roads (particularly unsealed), • Sealing regularly used roads, • Installing signage and enforcing appropriate site speed limits on site, • Vegetating or mulching exposed areas, • Modifying activities during periods of particularly high wind, • Covering of waste loads, and • Installing wind barriers and enclosures (where practicable) to deflect wind from erodible areas. All landfill classifications may be required to implement a monitoring program (prepared by an AQP) to undertake routine dust monitoring both onsite and at surrounding environmental and social receptors. The frequency of this monitoring may depend on the site proximity to receptors. This would be conditioned in the EA.
Noise	Operation of heavy machinery and vehicle movements across the site will generate noise, with typical noise sources at landfills including: • Vehicles delivering waste to site, • External telephone bells and public announcements, • Vehicle and plant reversing alarms, • Waste compaction equipment, • Operation of gas guns to deter birds and vermin, • Operating the leachate treatment system,	Suggested measures to mitigate noise include: • Locating operational areas, particularly those that feature noise generating activities, to be the maximum possible distance from environmental and social receptors, • Scheduling noise generating activities to occur during daylight hours, • Keeping equipment well maintained, • Using natural and constructed features to attenuate noise (e.g., noise attenuation barriers and earthen bunds), and • Where possible, placing loud machinery, plant and equipment within an enclosed building. Noise limits may be conditioned in an EA. All landfill classifications may be required to implement a monitoring program (prepared by an AQP) to undertake routine noise monitoring both onsite and at surrounding environmental and social receptors.

Potential amenity impact		Suggested measures
	• Crushing, mulching and screening activities, and • Operating the landfill gas system.	The frequency of this monitoring may depend on the site proximity to receptors. This would be conditioned in the EA.
Litter	Windblown litter (e.g., soft plastics) can be distributed over large areas. Amenity impacts from litter may include poor visual amenity, drain and waterway blockages, and impacts to neighbouring activities. Litter control measures at landfills may vary throughout the year depending on wind strength and the orientation and elevation of the active tipping area. As such, a combination of measures and controls should be implemented and may include both engineering solutions and management options.	Suggested measures for managing litter include: • Install portable litter screens to follow the tipping area that can withstand wind loads when loaded with litter, • Install perimeter fencing to contain litter, • Minimise the size of exposed tipping areas, • Implement a daily litter programme to collect and remove litter from screens, fences and other areas, • Avoid shredding waste, • Use wheel washing facilities and/or vibration grids for all vehicles on site, and • Develop and implement a process for collecting litter that may be blown or washed from site. Develop and implement a contingency plan in the event of extreme weather conditions.
Fire	Landfill fires can severely impact local air quality, damage to onsite infrastructure and containment systems, and damage the surrounding environment if the fire spreads. Fires associated with landfill activities can occur: • In incoming waste, • In stockpiled waste or materials, or • At or near the surface during landfilling subsurface (or subterranean).	Suggested measures to prevent fires within landfill facilities include: • Maintaining a controlled active tipping face (so that the exposed area of waste is minimised). • Ensuring all ignition sources (e.g., smouldering waste) are removed from the waste tipping area and extinguished. • Ensuring highly flammable or explosive waste materials are screened and are not disposed of in the landfill. • No burning of waste or materials on site. • Maintaining access to firefighting water of suitable pressure and volume at any point within the landfill facility (leachate should not be used as firefighting water). • Maintaining access to sufficient volume of inert landfill cover and suitable earthmoving plant and equipment to apply cover to fire affected areas when required. • Installing firefighting equipment. • Appropriately storing flammable materials and stockpiles ensuring they are segregated from any potential sources of ignition. • Plant and equipment, including built dozers and compactors, are fitted with heat guards and spark arrestors to prevent contact with hot vehicle components. • Regularly practicing fire management drills.

Potential amenity impact		Suggested measures

		• Use of a firebreak around the landfill site boundary.
		• Talk to the relevant fire authority (e.g. QFES) to ensure adequate measures are in place.
		• Not operating the active landfill gas extraction system in such a manner to introduce air into the landfilled waste.
		• Increasing the alertness level for relevant site staff during days of high and extreme fire danger.
		• Training staff as first responders to small fires (where it is safe to respond).
		
		Suggested measures to detect and respond to fires within landfill facilities include:
		
		• Routine monitoring of carbon monoxide levels and temperatures within landfill gas.
		• Vigilant monitoring for signs of flames, smoke, steam and hotspots. This may include the application of infrared monitoring and notification technology.
		• Developing and implementing a plan and process for responding to signs of fire or subsurface subterranean fires and consider where appropriate:
		  ○ Initial response actions and notifications,
		  ○ Application of soil to seal and smother,
		  ○ Use of water to smother and extinguish,
		  ○ Use of excavation to expose to access and extinguish,
		  ○ Use of water or leachate to flood, smother and cool subsurface fire or hotspot,
		  ○ Response to fire affecting the landfill gas infrastructure,
		  ○ Changing or ceasing operation of any landfill gas extraction system to control air ingress and temperature increases,
		  ○ Compaction of waste and the application of cover material to reduce air ingress through absent, poorly compacted or permeable cover soil layers (especially on batters), and
		  ○ Investigating and repairing any damage to landfill infrastructure (e.g., liner, collection pipes, etc.) after a fire event.

Light	Light pollution can cause a nuisance for surrounding environmental and social receptors especially where sites are visually prominent or overlooked by a receptor.	While lighting is beneficial for site security, the placement of lights should consider: • Light intensity, and • Light orientation (e.g., to manage light spillage, placed in a downward orientation facing the centre of the site to be less obtrusive, etc.).

Potential amenity impact		**Suggested measures**
Visual	Visual amenity of the surrounding area can be significantly impacted especially where a landfill is overlooked by environmental and social receptors. As such, the landfill operation design and operation should minimise the visual impact.	Suggested measures include: • Managing light at night, • Constructing visual screens (e.g., bunds and vegetation), • Managing the timing and phasing of operations to minimise visual impact, and • Managing other amenity issues (e.g., dust, day cover, birds, and litter as discussed above) to reduce the visual footprint of the site and improve visual aesthetic.
Vermin and disease vector control	Landfills attract various types of pest and vermin (e.g., birds, mosquitos, rodents, kangaroos, flies, feral cats, etc.) by providing a source of food and standing water. These vermin can be disease vectors and if left unmanaged can represent a risk to the health of site employees, the public and surrounding ecosystems. Operational controls should be applied to minimise vermin at the site.	Suggested measures include: • Appropriate use of daily and interim cover (Section 8.3), • Storing standing water for fire, sediment, or leachate control only (i.e., no more than necessary) and cover standing water where possible, • Using scare devices (e.g., gas cannons to deter birds), • Using insecticide spray bars (e.g., on compaction equipment), • Installing anti-perch strips on buildings and other areas where birds may congregate, • Installing nets or monofilament wires over glide-paths and bodies of water to deter birds, and • Using professional exterminators and traps. Note, the application and use of controlled chemicals should be appropriately monitored and be in accordance with relevant regulations. Implementing a variety of measures may be necessary as vermin can become accustomed to one management measure.
Site security	Active landfill sites can present a safety risk to the public and livestock.	Suggested measures for site security include: • Conducting a security risk assessment to determine the level of security suitable for the site, • Installing a physical barrier (e.g., wire mesh fencing and lockable security gates) around the perimeter of the site, and • Installing a security system at key site locations (e.g., video monitoring on access roads, at the site entrance and at key storage areas) to deter illegal access, illegal waste dumping, and theft.

8.2 Waste disposal and placement

8.2.1 Allowable waste for disposal

An EA application will identify the proposed type of waste and ERA 60 thresholds (i.e., quantity of waste received annually) to be disposed of on-site. The administering authority will assess the proposal and subsequently specify the types of waste and thresholds authorised to be disposed of at the landfill site on the EA.

Additionally, the conditions on an EA may specify wastes that are not permitted to be received or disposed of on-site. For example, waste streams not to be disposed of at waste disposal (ERA 60) sites include liquid waste, hot ash, explosives, ammunition containing explosives, and smouldering or highly flammable materials. Some ignitable, corrosive, reactive or toxic material may be allowed to be disposed of, however this will be conditioned as necessary on the EA.

Landfill operators should implement measures to ensure that only authorised waste is received and disposed of on-site. Suggested measures include:

- Installing signs advising which wastes may and may not be deposited at the landfill,
- Installing screening mechanisms (e.g., elevated mirrors, viewing platforms or video cameras) to allow all waste entering the site to be inspected,
- Developing and implementing procedures to manage non-conforming wastes that may be left at the facility (e.g., procedures for identifying the offender, isolating the waste, and notifying relevant authorities), and
- Random inspections and sampling of waste loads.

Where a site may be authorised to accept and dispose of regulated waste, ensure the waste is lawfully delivered to the facility (i.e., by a regulated waste transporter, with consignment notes, etc.) and the approved processes are followed.

8.2.2 Waste placement and compaction

Implementing appropriate waste placement and compaction methods for the active tipping face are important for maximising design and operational efficiencies and to prevent overfilling of landfill cells.

Suggested measures for waste placement methods include:

- Using ‘softer waste’ (e.g., kerbside domestic collection) as the first and final layer of waste on top of the liner to limit the risk of perforation.
- Placing waste at the base of the tipping face with a compactor pushing waste up the face compacting it in thin layers.
- Minimising the size of the active tipping area.
- Complying with the end geotechnical design.
- Terracing the unconfined face to enhance the stability of the waste and cover material.

Landfill facilities that are permitted to dispose of up to 10% limited regulated waste in conjunction with general waste should have a specific management method for special burial (i.e., to be placed in a specific order) ensuring the risk from these types of limited regulated waste do not complicate future operations of the facility.

Suggested measures for waste requiring special burial include:

- Designating a separate area of the landfill for special disposal. Records, including the location and depth of the special disposal area within the cell and in relation to the overall landfill, should be kept.
- Digging trenches into the existing waste to receive special wastes.
- Aligning the trench perpendicular to prevailing winds to minimise the potential wind blow impacts.
- Carefully placing the contained waste to avoid compromising its containment.
- Immediately burying and covering special wastes as they are deposited. Excavations should be made prior to the arrival of the load.
- Not locating special burial waste near the batters and upper surface of the final landform to minimise the potential for re-exposure of the waste.

Minimum expectations for waste placement and compaction are detailed in Appendix 13.

Regulated wastes that are not permitted under the waste acceptance criteria in the EA for a landfill facility will require disposal at a separate appropriately licensed landfill cell (e.g., a containment cell or monocell).

8.3 Landfill cover (daily and interim)

An essential part of landfill operations is the placement of daily landfill cover over deposited waste. The purpose of cover at a landfill is to:

- Minimise landfill odours,
- Minimise dust,
- Prevent wind-blown litter,
- Prevent the spread of fire,
- Minimise disease vectors (e.g., birds, flies, mosquitoes, and rodents),
- Minimise rainwater infiltration (and associated leachate and contact water generation),
- Ensure the landfill is trafficable, and
- Improve visual appearance.

When designing the operational method for daily covering of waste, the following should be considered:

- Site specific circumstances (e.g., location, waste types, past performance, etc.) to identify when, where and how cover should be applied.
- When using soil as cover, it should contain organic matter to attenuate landfill odours. Other materials (e.g., foams, mulch, papier-mâché, gravel or cover mats) may also achieve these purposes, however where combustible cover materials are utilised additional fire monitoring and mitigation should be implemented.
- Regardless of the material used as cover, sufficient material should be available at the tipping face.
- The permeability of the cover should eventually allow leachate to pass through and gas to be extracted. Particularly where low permeability cover is used, it should be partially removed prior to waste placement to avoid waste containment perching leachate, batter seepages of leachate and to facilitate the more efficient extraction of landfill gas.

- Conduct regular monitoring and record on the performance of the chosen cover material to ensure there are no gaps or cracks, especially in the case of interim cover.

As the active working face advances across the landfill cell a more robust interim cover may be required. The following should be considered for interim covers:

- Operators should ensure the characteristics of the interim cover meets its environmental objectives.
- Where landfill activities recommence in areas with an interim cover, the interim cover should be scraped back or punctured before waste is disposed to prevent leachate perching, batter seepages of leachate and facilitate the more efficient extraction of landfill gas.
- An area where interim cover will be placed for more than six months should consider installing a temporary capping system.

Minimum expectations for daily and interim cover are detailed in Appendix 14.

Acid sulfate soils and material with a high moisture content (e.g., slimes from sand mining operations) are not appropriate for daily or interim cover. Acid sulfate soils oxidise and produce acid run-off when exposed to the atmosphere. Material with a high moisture content may release water into the waste mass and are not appropriate unless dewatered.

Contaminated soils may be used as interim cover material in some circumstances, if the hazardous contaminants in the soil are relatively low in concentration and results using the Australian Standard Leaching Procedure using an unbuffered leach solution (pH 7) demonstrate very low leachability. If such soils are used for this purpose, stormwater monitoring programs should incorporate water quality parameters relevant to the hazardous contaminants. Use of such soils would be subject to approval from the administering authority. Contaminated soils with contaminant high leachability should not be used as cover material.

9 Landfill environmental management plan

Objective

- A landfill environmental management plan (LEMP) is implemented to prevent and minimise environmental harm by effectively managing all the environmental risks during the operation of a landfill site.

Outcomes

- The LEMP is a dynamic tool that is reviewed and updated regularly to reflect changes to the site and operational procedures.

A landfill environmental management plan (LEMP) details the strategies, procedures and processes to effectively manage and mitigate the environmental impacts of the landfill site. The LEMP is a dynamic document that serves as a single source of information for environmental management.

A preliminary LEMP should be submitted as part of an EA application and updated on a regular basis or at a minimum 12-month intervals.

Annual monitoring reports should be provided to the administering authority with the annual return for the EA.

The LEMP should cover key elements from this guideline and be approved by an AQP. Minimum expectations are provided in Appendix 15.

10 Closure, rehabilitation and post-closure

Objective

- Prevent and minimise environmental harm by effectively managing all the environmental risks (e.g., leachate contamination or landfill gas migration) that may persist following the closure of the landfill site.
- Promote responsible land management and ensure the site is compatible with a beneficial final post-closure use.

Outcomes

- Provide preliminary information outlining the approach for site closure to the administering authority in an EA application.
- Closure, rehabilitation and post-closure are considered and planned early in the landfill lifecycle.
- Develop and implement a closure plan to ensure the landfill site does not cause environmental harm after closure.
- Plan and implement a program of post-closure management until evidence can be provided that it is no longer required to prevent environmental harm.
- Upon completion of implementation of post-closure works, as detailed in the post-closure plan, provide a copy of the certified statement of completion to the administering authority.

Closure, rehabilitation and post-closure of a landfill comprises of the following key stages:

1. Closure of individual landfill cells once they cease accepting waste for disposal. This primarily involves capping of the cell within 12 months of the cessation of waste receival in accordance with the EA.
2. Closure of the entire landfill facility once the facility ceases disposing of waste onsite and all cells have been capped and closed.
3. Rehabilitation of the landfill facility and the final landform which may include additional cover, reprofiling, vegetation, ecological and amenity enhancements to better enable post-closure management and provide for the beneficial final land use.
4. Post-closure management including ongoing operation and maintenance of management and monitoring systems to ensure effective management of environmental risks.

Closure and rehabilitation activities should be progressive, such that closure of cells and their rehabilitation can be undertaken whilst other cells are still accepting waste. When applying for an EA to undertake a landfill activity (ERA 60), provide preliminary concept plans demonstrating how closure, rehabilitation and post-closure activities will be conducted. This should include:

- The design and operation of final capping and revegetation of cells (Section 6),
- The approach for future community engagement to identify a suitable and beneficial final land use for the area (Section 5), and
- The closure plan,
- The rehabilitation plan, and
- The post-closure plan.

Minimum expectations for the closure plan, rehabilitation plan and post-closure are provided in Appendix 16.

Further guidance on risks of post-closure management and application requirements for maintaining a decommissioned landfill (ERA 60(4)) are available in the department's *Information sheet - ERA 60 (4) – Maintaining a Decommissioned Landfill* (ESR/2020/5499).

10.1 Certified statement of completion

Once sufficient evidence can be provided that the post-closure plan has been fully implemented and that further on-going environmental management is not required in order to prevent environmental harm, a copy of the certified statement of completion should be provided to the administering authority. This will be conditioned in the EA.

Minimum expectations for the certified statement of completion are provided in Appendix 17.

11 References

ACIGS. (2020). RECOMMENDATIONS FOR THE MINIMUM QUALIFICATIONS OF ON-SITE CONSTRUCTION QUALITY ASSURANCE (CQA) PERSONNEL SUPERVISING CONSTRUCTION USING GEOSYNTHETIC MATERIALS.

American Society for Testing and Materials. (2018). ASTM D5514 Standard Test Method for Large-Scale Hydrostatic Puncture Testing of Geosynthetics.

American Society for Testing and Materials. (2023). ASTM D 8265 : 2023 Standard Practices for Electrical Methods for Mapping Leaks in Installed Geomembranes.

Clean Energy Council. (2018). Community Engagement Guidelines for the Australian Wind Industry.

Environment Agency. (2014). Cylinder testing geomembranes and their protective materials: LFE2.

EPA South Australia. (2019). Environmental management of landfill facilties solid waste disposal.

Geosynthetic Institute. (2016). GRI- GT12(b) - ISO version standard specification Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

Geosynthetic Research Institute . (2021). GRI GM13 Standard Specificaiton, Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

Geosynthetic Research Institute. (2016). GRI -GT12(a) ATSM version Standard Specification Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

Geosynthetic Research Institute. (2019). GRI-GCL3 Standard Specification, Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs).

Geosynthetic Research Institute. (2020). GRI-GN4 Standard Test Methods, Required Properties and Testing Frequency for Biplanar Geonets and Biplanar Geonet Composites.

Geosynthetic Research Institute. (2021). GRI-GM17 Standard Specification Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethrlene (LLDPE) Smooth and Textured Geomembranes.

IAP2 (International association for public participation). (2023). Quality Assurance Standard for Community and Stakeholder Engagement.

International Association of Geosynthetic Installers. (2015). Guidelines for installation of: HDPE and LLDPE Geomembrane Installation Specification.

National Uniform Drillers Licensing Committee. (2020). MINIMUM CONSTRUCTION REQUIREMENTS FOR WATER BORES IN AUSTRALIA FOURTH EDITION.

NGER. (2022). Solid waste calculator 2022-23.

NSW Government. (2023). Guideline for landscape character and visual impact assessment.

Queensland Government. (2017). Community engagement toolkit for planning.

Queensland Government. (2019). Waste Management and Resource Recovery Strategy.

Queensland Government. (2021). Stakeholder Engagement Guide, Business Case Development Framework, Release 3.

Queensland Government. (2021). Using monitoring data to assess groundwater quality and potential environmental impacts.

Queensland Government. (2022). Queensland Organics Strategy 2022-2023.

Queensland Government. (2023). Regulatory Strategy 2022-2027 Queensland's Environmental Regulator.

Queensland Government Enterprise Architecture. (2010). Online community engagement guideline.

Standards Australia. (2001). AS 1289.6.7.1-2001 Methods of testing soils for engineering purposes Soil strength and consolidation tests - Determination of permeability of a soil - Constant head method for a remoulded specimen.

Standards Australia. (2008). AS 1289.3.4.1-2008 Methods of testing soils for engineering purposes, Method 3.4.1: Soil classification tests — Determination of the linear shrinkage of a soil — Standard method.

Standards Australia. (2009). AS 1289.3.2.1-2009 Methods of testing soils for engineering purposes, Method 3.2.1: Soil classification tests — Determination of the plastic limit of a soil — Standard method.

Standards Australia. (2009). AS 1289.3.3.1-2009 Methods of testing soils for engineering purposes, Method 3.3.1: Soil classification tests — Calculation of the plasticity index of a soil.

Standards Australia. (2009). AS1289.3.1.1-2009 Methods of testing soils for engineering purposes, Method 3.1.1: Soil classification tests — Determination of the liquid limit of a soil — Four point Casagrande method.

Standards Australia. (2009). AS1289.3.6.1-2009 Methods of testing soils for engineering purposes, Method 3.6.1: Soil classification tests — Determination of the particle size distribution of a soil — Standard method of analysis by sieving.

Standards Australia. (2016). AS1289.6.7.3:2016 Methods of testing soils for engineering purposes, Method 6.7.3: Soil strength and consolidation tests-Determination of permeability of a soil-Constant head method using a flexible wall permeameter.

Standards Australia. (2017). AS 1289.3.8.1:2017 Methods of testing soils for engineering purposes, Method 3.8.1: Soil classification tests — Dispersion — Determination of Emerson class number of a soil.

Standards Australia. (2017). AS 1289.5.1.1:2017 Methods of testing soils for engineering purposes, Method 5.1.1: Soil compaction and density tests — Determination of the dry density/moisture content relation of a soil using standard compactive effort.

The Department of Environment and Science. (2014). Stormwater and environmentally relevant activities (ESR/2015/1653).

The Department of Environment and Science. (2018). Odour Impact Assessment from Developments.

The Department of Environment and Science. (2020). Noise measurement manual (ESR/2016/2195).

The Department of Environment and Science. (2021). Application requirements for activities with impacts to land (ESR/2015/1839).

The Department of Environment and Science. (2021). Application requirements for activities with water impacts (ESR/2015/1837).

The Department of Environment and Science. (2022). Application requirements of activities with noise impacts (ESR/2015/1838).

The Department of Environment and Science. (2022). Receiving environment monitoring program guideline (ESR/2016/2399).

The Department of Environment and Science. (2023). Application requirements for activities with impacts to air (ESR/2015/1840).

The Department of Environment and Science. (2023). Application requirements for activities with waste impacts (ESR/2015/1836).

The Department of Environment and Science. (2023). ERA 60 (4) Maintaining a Decommissioned Landfill (ESR/2020/5499).

The Department of Environment and Science. (2023). Financial assurance under the Environmental Protection Act 1994 (ESR/2015/1758).

The Department of Environment and Science. (n.d.). *Application for pre-lodgement services ESR/2015/1664*. Retrieved from https://www.qld.gov.au/environment/management/licences-permits/application-for-pre-lodgement-services

The Environment Agency. (2010). Guidance on monitoring landfill gas.

Victoria State Government. (2022). Landfill buffer guideline Publication 1950.

Waste Management Association of Australia. (2010). Guidelines for the Assessment, Design, Construction and Maintenance of Phytocaps as Final Covers for Landfills.

12 Definitions

Where a word or phrase in this document is defined in this section or within the document, it has its corresponding meaning.

Some definitions have been copied across from legislation. Where there is an inconsistency between the legislation and this document, the legislation definition will prevail.

Defined words or phrases in the singular include the plural and vice versa.

Administering authority is as defined in the EP Act, it means—

a) for a matter, the administration and enforcement of which has been devolved to a local government under section 514 of the EP Act—the local government; or
b) for another matter—the chief executive.

Where for the purposes of this guideline, the chief executive means the Department of Environment and Science, its successors or its predecessors.

Annual exceedance probability (AEP) means the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

Appropriately qualified person (AQP) means a person or persons who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis to performance relative to the subject matter using the relevant protocols, standards, methods or literature

Aquifer is a zone within the underlying geology of an area that is saturated with groundwater.

Clean earth is as defined in the EP Act, it means any natural substance found in the earth that is not contaminated with waste or a hazardous contaminant. Examples – clay, gravel, loam, rock, sand, soil.

Clinical waste is as defined in schedule 19 the EP Act, it means waste that has the potential to cause disease, including, for example, the following:

a) animal waste;
b) discarded sharps;
c) human tissue waste;
d) laboratory waste.

A **contaminant** is as defined in section 11 of the EP Act, it can be:

a) a gas, liquid or solid; or
b) an odour; or
c) an organism (whether alive or dead), including a virus; or
d) energy, including noise, heat, radioactivity and electromagnetic radiation; or
e) a combination of contaminants.

Confined aquifer means an aquifer that is contained entirely within impermeable strata.

Disaster management waste is as defined in section 26 of the WRR Act, it means waste generated by or because of a disaster that is or has been the subject of a declaration of a disaster situation under the *Disaster Management Act 2003*, but only within the limits, if any, declared by the chief executive, by publication on the department's website, for a particular disaster.

Financial assurance is as defined in the EP Act, financial assurance for an environmental authority for a prescribed ERA, means a financial assurance given for the authority under chapter 5, part 14, division 2 of the EP Act.

Enclosed flare means a device where the residual gas is burned in a cylindrical or rectilinear enclosure that includes a burning system and a damper where air for the combustion reaction is admitted.

Environmental and social receptors means specific entities or elements within the environment or society that may be affected by impacts or potential impacts from contaminants.

Environmental harm is as defined in section 14 of the EP Act, it means any adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value, and includes environmental nuisance. Environmental harm may be caused by an activity:

a) whether the harm is a direct or indirect result of the activity; or
b) whether the harm results from the activity alone or from the combined effects of the activity and other activities or factors.

Environmental value is as defined in section 9 of the EP Act, it means:

a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or
b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

General environmental duty is as defined in section 319 of the EP Act, it means a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.

General waste is as defined in schedule 19 of the EP Regulation, it means waste other than regulated waste.

Groundwater is as defined in the EPP Water, it means water that occurs naturally in, or is introduced artificially into, an aquifer.

Inert waste is as defined in schedule 2 of the EP Regulation, it means—

a) bricks, pavers, ceramics, concrete, glass or steel; or
b) similar general waste that does not biodegrade or decompose.

Invasive plant means a plant species that has, or is likely to have, an adverse impact on a biosecurity consideration because of the introduction, spread or increase in population size of the species in an area; and includes a plant species that is prohibited matter or restricted matter.

Landfill gas is the gaseous byproduct of the decomposition of organic material within landfills

Landfill lifecycle means all the phases involved across siting, design, operation, closure and post-closure of a landfill

Leachate means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the licensed place that contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

Limited regulated waste is as defined in Schedule 2 of the EP Regulation, it means any of the following types of regulated waste—

a) animal effluent and residues, including abattoir effluent and poultry and fish processing waste;
b) asbestos;
c) biosecurity waste that has been rendered non-infectious;
d) food processing waste;
e) sewage sludge or residue produced in carrying out an activity to which section 63 applies;
f) tyres.

Lower explosive limit means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25 degrees Celsius and atmospheric pressure.
Permanent groundwater level the depth at which the groundwater saturated zone begins in the subsurface, that remains relatively constant unless acted upon by artificial means or severe weather conditions.
Regulated waste is as defined in section 42 of the EP Regulation, it is waste that— a) is commercial waste or industrial waste; and b) is of a type, or contains a constituent of a type, mentioned in schedule 9, part 1, column 1 of the EP Regulation.
A **sensitive place** is any part of the following: a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or b) a motel, hotel or hostel; or c) a kindergarten, school, university or other educational institution; or d) a medical centre or hospital; or e) a protected area under the Nature Conservation Act 1992, the Marine Parks Act 2004 or a World Heritage Area; or f) a public park or garden; or g) for noise, a place defined as a sensitive receptor for the purposes of the Environmental Protection (Noise) Policy 2019.
Sensitive receptor means a sensitive receptor under any relevant environmental protection policies.
Stormwater is as defined in the EP Act, it includes a run-off of rainwater from an urban or rural source.
Surface water is as defined in the EP Regulation, it means water other than groundwater.
Waste and resource management hierarchy (waste hierarchy) is as defined in section 9 of the WRR Act, it is the following precepts, listed in the preferred order in which waste and resource management options should be considered: a) AVOID unnecessary resource consumption; b) REDUCE waste generation and disposal; c) RE-USE waste resources without further manufacturing; d) RECYCLE waste resources to make the same or different products; e) RECOVER waste resources, including the recovery of energy; f) TREAT waste before disposal, including reducing the hazardous nature of waste; g) DISPOSE of waste only if there is no viable alternative.
Waste is as defined in section 8AA of the WRR Act, it includes any thing that— a) is left over, or is an unwanted by-product, from an industrial, commercial, domestic or other activity; or b) is surplus to the industrial, commercial, domestic or other activity generating the waste.
Waste facility is as defined in the EP Act, it means a facility for the recycling, reprocessing, treatment, storage, incineration, conversion to energy or disposal of waste.
Waste disposal site is as defined in section 8A of the WRR Act, it is a waste facility to which both of the following apply— a) the operator of the facility is required to hold an environmental authority for the disposal of waste at the facility; b) waste delivered to the facility sometimes includes waste that is subsequently disposed of to landfill at the facility.

Approved:

11 December 2023

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Version history

Version	Date	Description of changes
1.00	9 June 2004 11 December 2012	Original publication. Document rebranded.
2.00	11 December 2013	Major document update.
2.01	15 August 2016	Minor reformatting and rebranding.
3.00	6 March 2017	Included details of submitting applications electronically to DES in Connect.
3.01	3 July 2017	Updated references from *Sustainable Planning Act 2009* to *Planning Act 2016*.
3.02	15 June 2018	Document rebranded to align with machinery of government changes.
3.03	30 July 2018	Deleted sentence in section 6.4.8 about floc as it is not appropriate cover material.
4.00	23 November 2018	Updated for the Environmental Protection (Waste ERA Framework) Amendment Regulation 2018.
4.01	8 October 2019	Updated for the Environmental Protection Regulation 2019 remake.
5.00	12 August 2021	Updated section 3 to reflect Connect being renamed Online Services and provide details of how to obtain the form to apply to be a registered suitable operator as applications can no longer be made electronically to DES.
6.00	11 December 2023	DRAFT: major document update.

13 Appendices

Appendix 1 – Minimum expectations for site selection

Landfill sites should be appropriately separated from environmental and social receptors, to protect against impacts resulting from a failure in the landfill design, containment systems or equipment, inadequate operation and management of the landfill or adverse weather conditions. Environmental and social receptors include environmental values and sensitive places. All environmental and social receptors within a minimum 2km radius of the site boundary should be identified and mapped to inform site selection, and the minimum separation distances in Table 11 mapped against these.

Table 11: Details the minimum expectations for separation distances based on landfill classifications[6].

	Landfill classification		
	Inert	**General**	**Regulated**
Minimum separation distance **to a sensitive place** not associated with the facility.	>500m	>1.5km	>1.5km

Where a **sensitive place** is any part of the following:

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or
b) a motel, hotel or hostel; or
c) a kindergarten, school, university or other educational institution; or
d) a medical centre or hospital; or
e) a protected area under the Nature Conservation Act 1992, the Marine Parks Act 2004 or a World Heritage Area; or
a public park or garden; or
f) for noise, a place defined as a sensitive receptor for the purposes of the Environmental Protection (Noise) Policy 2019.

All applications, for all landfill classifications, should not:

- Overlay an unconfined aquifer with high beneficial use or risk of migration off-site.
- Overlay an aquifer used for human drinking water.
- Be within 100m of surface waters.
- Dispose of waste below the permanent groundwater table. A minimum separation of 2m from waste to the permanent groundwater table should be maintained.
- Overlay or be within 100m of a geotechnically unstable area (e.g., limestone karsts, dispersive soils, underground mine workings etc.).
- Be within 1.5 km of a runway used by piston-engine propeller-driven aircraft.
- Be within 3 km of a runway used by jet aircraft.

Separation distances are measured from the sensitive land use or impacted environmental value, to the edge of the closest cell. All cells, including closed cells, need to be considered in calculating separation distances. For

[6] Based on the *Draft Victoria State Government Landfill buffer guideline Publication 1950, Dec 2022*

sites where there is uncertainty in the location of landfill cells, the boundary of the landfill site is the point of measurement.

Separation distance measurement should also consider other activities and site infrastructure capable of causing a nuisance, such as the leachate storage and treatment ponds and facilities and landfill gas management systems (i.e., active extraction and enclosed flare systems) and their proximity to the nearest sensitive land use.

Any new site-specific applications for a landfill activity should not impinge the separation distances in Table 11 and detailed above.

Where it is not feasible to meet the separation distances for:

- A new application for a waste disposal activity – the application needs to demonstrate the circumstances as to why the separation distances cannot be met, and why alternate site locations are unfeasible (i.e., after undertaking the full siting process and appropriately considering all alternative sites as described in Section 3); or
- An amendment application for an existing landfill site – the application needs to demonstrate the circumstances as to why the separation distances cannot be met.

Additionally, both scenarios above should also undertake a risk assessment and describe the additional design and/or operational measures that will be implemented to sufficiently minimise the risk of impacting the environmental and social receptors within the separation distances. These requirements may be additional to the considerations and minimum expectations outlined in this guideline, and will be conditioned in the EA.

Appendix 2 – Minimum expectations for a Conceptual Site Model (CSM)

A key aspect in the planning and design of a landfill is to conceptualise the site and surrounds to guide works such as site investigations, assessments, design, and monitoring. A landfill is a system and it should be considered as such, and the various components should not be developed in isolation.

For a landfill site, the CSM should include:

- Site specific scaled plans and cross-sections (a textual tabular or generic CSM is not appropriate).
- Geotechnical and hydrogeological features relevant to the engineering and environmental performance of the containment system.
- Landfill staging and construction interfaces.
- Operational and permanent controls.
- Interaction of surface water, groundwater, leachate and landfill gas under all operating and worst-case environmental conditions.
- Assessment of any source-pathway-receptor linkages and how these are considered and addressed by the assessment/design.
- Potential exposure for all contaminants associated with the proposed activities for the site taking into consideration the geology, buffer and climate of the site.

Applicants are expected to consider each of the linkage components in Table 12, noting that not all components may be applicable to some landfill classifications, particularly lower risk activities. For these sources the same approach should be followed, providing detailed information on each element of the CSM to provide a comprehensive understanding of these aspects to ultimately demonstrate how environmental values will be protected.

Table 12: Minimum expectations for a CSM.

Linkage component	Minimum expectations including details and information sources
Source: Historical land use	A summary of historical land use to date, including all activities that may have caused the site to be contaminated, drawing on: • Available historical and current mapping. • Available historical and current aerial/satellite photography. • EA and other relevant permitting or government records including the land registers (EMR/CLR). • Any known prior or current unlicensed prior activities or pollution incidents that may have caused contamination. • Local information and knowledge. • Compliance actions recoded in the public register.
Source: Proposed land use	Details of: • The proposed types of waste to be disposed of, including their volumes, quantities, and chemical characteristics. • The phasing of the proposed landfill cells, including locations, size, depth, shape and sequence of tipping. • The proposed final landform and use.
Source: Leachate	Details of: • Current (if applicable) and future volumes of leachate generation. • Volumes of leachate that may be stored on site (within cells or storage ponds). • Projected chemical characteristics of leachate and presence of hazardous substances and non-hazardous pollutants.

Linkage component	**Minimum expectations including details and information sources**
	• Expected short- and long-term changes in leachate characteristics over time.
Source: Landfill gas	Details of: • Current (if applicable) and future gas production rates and volumes. • Projected composition of landfill gas.
Source: Contaminated stormwater	Details of: • Current (if appliable) and future volumes and sources of contaminated stormwater. • Volumes of contaminated stormwater that may be stored on site. • Projected chemical characteristics of contaminated stormwater and presence of hazardous substances and non-hazardous pollutants. • Expected short- and long-term changes in contaminated stormwater characteristics over time.
Source: Dust	Details of: • Sources of dust, current (if applicable) and future concentrations of dust. • Projected chemical characteristics of dust and presence of hazardous substances and non-hazardous pollutants. • Expected short- and long-term changes in dust characteristics over time.
Pathway: Landfill	Details of (for all emissions): • Containment system and controls • Control effectiveness and leakage / emission rates • Sensitivity of the assessment to containment performance and service life.
Pathway and receptor: Geology	Local and regional geology, including: • Soil types. • Rock formations. • Surface elevation and topography. • Geophysical data. • Borehole records. • Environmental monitoring records. • Site investigations.
Pathway and receptor: Aquifer	Details of: • Site location in relation to aquifers. • Vulnerability and aquifer status. • Prescribed environmental values outlined in the EPP Water. • Spatial distribution of aquifers, aquicludes and aquitards. • Relevant hydrogeological parameters (such as transmissivity, permeability, and porosity). • Location of licensed abstractions, private water supplies and springs. • Significance of geological heterogeneity.
Pathway and receptor: Groundwater flow	Details of: • Pre-operational groundwater monitoring that considers seasonal variation. • Groundwater levels (metres above ordnance datum and on what dates). • Hydraulic gradients in all relevant deep, shallow, or perched groundwater.

Linkage component	Minimum expectations including details and information sources
	• Lateral flow directions, interconnections, and confining layers. • The thickness and nature of the unsaturated zone, e.g., fissured or inter-granular. • Local and regional groundwater flow regimes. • Regional groundwater contours for each groundwater body, where available. • Groundwater flow to discharge points. • Groundwater movement, including groundwater and surface water interactions and surface recharge and discharge. • Potential or known medium- or long-term influences on hydraulic balance from future groundwater rebound or changes in abstraction. • The relationship between the site base and sides and groundwater. • Groundwater levels for each groundwater body, and relevant surface water features. • Predicted final groundwater recovery levels (permanent groundwater level). Include drawings and cross sections of: • Local and regional hydrogeology. • Locations of groundwater monitoring boreholes.
Pathway and receptor: Groundwater quality	Details of: • Regional groundwater quality and its significance to existing and potential uses of ground or surface water. • Local groundwater quality and factors that might impact the proposed site (e.g., other existing landfills or industrial uses). • The nature and effectiveness of any remediation works that have been carried out. • Groundwater quality at licensed and private abstractions from ground and surface water springs, where available. • Groundwater quality at off-site groundwater monitoring points. • Interactions between groundwater and surface water, including any groundwater dependent ecosystems.
Pathway and receptor: Surface water	Details of: • Local average rainfall data. • Description of any water courses that may influence or be affected by activities at the site, including their key characteristics and environmental values, where applicable. • Description of any watercourses that may be affected by discharges from the site, including the WQOs mentioned in the EPP Water, where applicable. • Summary of surface water flows, including average, low and storm flows. • Flood risk and the presence of indicative flood plains. • Water quality, any existing sources of contamination, and the ecological importance of the watercourses. Include a drawing of all the relevant local surface water features.
Pathway and receptor: Air	Details of: • Local air quality and factors that might impact the proposed site (e.g., other existing landfills or industrial uses).

Linkage component	Minimum expectations including details and information sources
	• Meteorological conditions. • Prescribed environmental values and air quality objectives outlined in the EPP Air.
Receptor: underground Infrastructure	Details of: • Nearby infrastructure including pathways such as field drains, buried services, mine workings or boreholes.
Receptor: people and Buildings	Identify all the receptors that could be affected by activities at the site, for example from landfill gas, odour, noise, dust or vermin and disease vectors. Include: • The location and distribution of sensitive features in relation to the site and possible pathways. • An assessment of whether the receptors are sensitive to the potential hazards arising from the site. • Safeguarded aerodromes. • Local prevailing wind direction. Include a drawing that includes all the relevant receptors.
Receptor: Habitats and natural heritage	Identify any habitat and natural heritage sites included in local government, state, and national mapping. For example: • Protected areas. • Vegetation management. • Regional ecosystems. • Acid sulphate soils. • Matter of State Environmental Significance (MSES). • Wetlands areas of high ecological significance. • Koala habitat. • Groundwater dependant ecosystems.

Appendix 3 – Minimum expectations for assessments

Table 13 details minimum expectations for assessments that may be required based on landfill classification and site-specific conditions. All assessments should be undertaken by a AQP.

Table 13: Minimum expectations for assessments (listed alphabetically).

Assessment	Minimum expectations including details and information sources
Biodiversity assessment	A biodiversity assessment for a landfill facility should include: 1. Identification of the environmental values: • Physical description of the land including identification of the terrain, geology, shallow groundwater systems, floodplains, springs, soil descriptions and the presence of distinct or unique features. • Soil health and function, and the ability for soil to sustain growth of native vegetation, crops and other flora (i.e., soil suitability). • Bioregions and regional ecosystems including their health and biodiversity. • The natural interaction of the relevant land with other ecosystems, including wetlands, faults connecting groundwater systems, surface waters, etc. • Flora including vegetation communities, endangered, vulnerable, rare or near threatened species and pest species. • Fauna including fauna present, protected animal breeding places, endangered, vulnerable, rare or near threatened species, pest species, plants or animals and their habitats, including threatened wildlife, near threatened wildlife and rare wildlife under the relevant legislation including *Nature Conservation Act 1992*. • Prescribed environmental matters as defined in the *Environmental Offsets Act 2014*. 2. Identification of the impacts: • Provide a drawing/site plan showing the impacts to biodiversity as a result of the landfill activity. • Describe in detail any land disturbance and/or potential discharges over the life of the project that may impact onsite and surrounding biodiversity. 3. Assessment of the impacts: • Assess the environmental risk of impacts to biodiversity from the activity. • Assess the likely effect of any discharges to land on the environment including results of water/nutrient balance calculations. • A risk assessment should also consider the indirect risks to biodiversity as a result of operating the landfill. • If acid sulfate soils are likely to be present at the site and may potentially be disturbed as a result of the activity, an acid sulfate soils investigation should be provided with the application. 4. Identification of the proposed mitigation strategies to address the risks and impacts identified above.
Environmental amenity assessment	**Noise assessment** A noise assessment for a landfill facility should include: 1. Identification of the environmental values:

Assessment	Minimum expectations including details and information sources
	• Accurately identify the environmental values on and offsite which may be impacted by noise emissions. • Identify the location of sensitive places surrounding the proposed site location which may be impacted by noise emissions. • Provide a description of the site topography and structures, including features that may affect the way noise is dispersed. • Describe general climate and prevailing wind speed and direction. • Describe background noise levels within the vicinity of the site. 2. Identification of the impacts: • Identify noise and vibration sources, both mobile and stationary, associated with the landfill activity. • Describe the characteristics of noise emissions produced throughout the life of the landfill project. • Describe how any of the noise emission will be mitigated throughout the life of the project. 3. Assessment of the impacts: • Conduct a noise impact assessment where noise emissions cannot be mitigated. • Provide noise modelling contour maps to show predicted noise levels at all potential noise source locations. • Analyse whether noise emissions associated with the landfill activity will affect the environmental values of the receiving environment (including noise sensitive places). • A vibration risk assessment for blasting activities, if applicable. 4. Identification of proposed mitigation strategies of controls (e.g., noise emission limits or operational controls such as operating hours) to address the risks and impacts identified above which are appropriate to protect environmental values. Noise impact assessment should be in accordance with the latest version of the *Noise measurement manual (ESR/2016/2195).* **Air assessment** An air (dust and/or odour) assessment for a landfill facility should include: 1. Identification of the environmental values: • Accurately identify the environmental values of the site which may be impacted by air emissions. • Identify the location of sensitive places surrounding the proposed site location which may be impacted by air emissions. • Provide a description of the site topography and structures, including features that may affect air dispersion. • Identify general climate, ambient temperature, prevailing wind speed and direction. • Describe ambient air quality at the location of the proposed landfill site. • A description of the existing airshed environment should be provided having regard for particulates and gaseous and odorous compounds. The assessment should discuss the background levels and sources of suspended

Assessment	Minimum expectations including details and information sources
	particulates, PM10 and any other relevant air pollutants, whether major or minor, of the air environment that may be affected by the landfill facility. 2. Identification of the impacts: • Identify all sources of air emissions (e.g. dust and odour including VOCs and fine particles as well as hydrogen sulfide) associated with the activity and describe the situations under which the contaminants may be released. • Describe the characteristics (i.e., chemical and physical properties) of air emissions (i.e., dust and odour) produced throughout the life of the landfill project. • Describe the impacts of air emissions the landfill activity may have on the identified environmental values. • Sufficient data on local meteorology and ambient levels of pollutants should be gathered to provide a baseline for the studies or for the modelling of air quality environmental impacts within the airshed. Meteorological parameters should include air temperature, wind speed and direction, atmospheric stability, mixing depth and other parameters necessary for input to the models. 3. Assessment of the impacts: • Analyse whether air (i.e., dust and odour) emissions associated with the activity will affect the environmental values of the receiving environment. • The odour impact assessment should be in accordance with the department's *Guidelines: Odour Impact Assessment from developments.* • The dust impact assessment should be in accordance with the department's *Guidelines: Application requirements for activities with impacts to air.* 4. Identification of proposed mitigation strategies and controls to address the risks and impacts identified above which are appropriate to protect environmental values. **Visual assessment** A Visual Impact Assessment (VIA) should determine the likely visual impact of the proposed development on the existing views from the surrounding landscape. The assessment process should be able to provide broad design advice to the applicant in best managing any visual impact and how it can be minimised. The visual impact assessment can be conducted based on the guidance provided in the *NSW Guideline for landscape character and visual impact assessment.*
Fire assessment	A fire risk assessment should include: 1. Identification of the hazards. A hazard is something that has the potential to cause harm to the environment or people. 2. Assessment of the risks. A risk is the possibility of harm occurring. The level of risk is determined by considering both the consequence of the harm and the likelihood of the harm. 3. Implementation of controls. A control is something that eliminates or reduces a hazard or a risk. 4. Check of controls. The risk associated with each identified hazard should be assessed to inform decisions about the most appropriate controls. The risk assessment should include consideration of

Assessment	Minimum expectations including details and information sources
	the consequence and likelihood of a hazard causing a fire. Once hazards are assessed appropriate controls can be implemented.
Geotechnical slope stability risk assessment	The assessment may include, but is not limited to: • Any temporary and permanent slopes. • Drainage. • Interface strength. • Parameters of lining system. • Factors of safety. • Subsidence. • Final landform stability. The assessment should clearly outline all assumptions and boundaries. To lower the probability of failure to an acceptable level, a factor of safety should be used to quantify any analytical or numerical calculation methods. Many probabilistic methods have been developed using Monte Carlo simulations that quantify and assess risks of failures and consequences. The modelling package should demonstrate that sufficient factors of safety are delivered to ensure the structural stability of the residual landform and to prevent environmental harm occurring.
Hydrogeological risk assessment	It should include consideration of the following: • Miscibility/solubility of leachate components in water. • Potential for sorption onto strata within the unsaturated and saturated zones. • Nature, thickness and depth of the soil and drift. • Presence or absence of mineral workings. • Presence of preferential flow paths. • Hydraulic conductivity/effective porosity/storage characteristics of the aquifer. • Predominant flow mechanism. • Location, orientation, and density of any joints/fractures/fault zones. • Variability in the hydraulic gradient. • Groundwater levels, including seasonal and other variations. • Rebounding groundwaters and any other predicted future changes in the hydrogeological system. • Direction of groundwater flow. • Groundwater quality, including possibility of historic contamination. • Groundwater dependant receptors, such as abstractions or surface waters. • Impacts to groundwater level (e.g., from historic land uses) and the risk of drawdown or recharge. • Attenuation capability, e.g., cation exchange. • Assessment of groundwater head and flow rates. • Minimum and maximum transmission rates. • Direction and speed of subsurface water flow. • Location of downgradient receptors and groundwater discharge. • Identifying sensitive receiving environments associated with subsurface water flow (e.g., aquatic, marine, wetlands or groundwater dependent ecosystems).

Assessment	Minimum expectations including details and information sources
	• Potential for liner uplift and basal heave. • Clearly identify any assumptions and boundaries applied. The level of complexity for the risk assessment will depend on the potential environmental impacts at the proposed site. For instance: • For lower risk impacts such as lower risk inert landfill, a simple risk assessment using quantitative calculations solved in a deterministic fashion using conservative parameters may be sufficient. • For higher risk impacts such as medium and higher risk landfill, a more complex risk assessment may be more appropriate using quantitative, stochastic (probabilistic) techniques (e.g., using computer modelling packages such as LandSim).
Landfill gas risk assessment	A landfill gas assessment should identify: • All assumptions and boundaries used. • Characteristics (e.g., quantity, rate, and composition) of the landfill gas emitted by the landfill. • Potential landfill gas emission pathways as informed by the CSM. • It's expected duration. • Its ability to be used for power generation, combusted in an enclosed flare systems or passively vented in limited circumstances. • The mitigation measures required to minimise landfill gas migration risks. There are a variety of models that can be used to estimate landfill methane generation and emissions such as USEPA's LandGem model, the England and Wales Environment Agency GasSim model and the Commonwealth of Australia's Department of Climate Change NGER Solid Waste Calculator. Probabilistic models should be generated for sites that have a more complex CSM and contamination linkages. The Monte Carlo simulation technique should be applied (e.g., GasSim) using random selection for parameter values from a user-defined range of potential inputs. Modelling should include: • The Proposed Assessment Scenario. • Landfill Lifecycle Phases. • Gases to be Modelled. • Justification for Modelling Approach and Software. • Risks to the Environment and Human Health. • Landfill Gas Emissions. • Atmospheric Dispersion and Odour. • Greenhouse Gas Emissions and Global Warming Potential. • Landfill Gas Management System Completion Criteria. • Control Measures. • Monitoring and Sampling Plan.
Security risk assessment	A site security assessment for a landfill facility should include:

Assessment	Minimum expectations including details and information sources
	• Identification of key features, infrastructure, physical structures, and assets within the landfill site. • Identification of potential security threats including illegal access, illegal dumping, theft, vandalism, and arson. • Assess the risk to the key features resulting from potential threats and prioritise these based on severity. • Specify control measures for risks as required, including consideration of fencing, surveillance, visitor control, lighting, remote monitoring, security staff and secure storage.
Site water balance assessment	A water balance model should include the following: • All predicted inputs and outputs, including rainfall infiltration, groundwater ingress, incident rainfall into leachate storage dams, surface runoff, evapotranspiration, leachate generation/disposal/treatment, dust suppression, irrigation, operational water usage and recirculation. • Consideration of climatic conditions, landfill geometry, waste composition, the leachate collection system, final cover, absorption of leachate by waste and surface vegetation. • All cells at the landfill (including active cells, cells with intermediate cover and capped cells). • Use of probabilistic modelling, applying Monte Carlo simulation (such as the latest version of the Hydrologic Evaluation of Landfill Performance (HELP) model or equivalent) to assess liner and capping performance as part of the overall water balance. • Where site data is not available, use of Bureau of Meteorology (SILO) data for rainfall, evaporation and other climate data needed to populate the model. • Consideration of uncertainties and limitations involved with the input data and model, as well as justification of assumptions and data inputs. • Comparison of modelling results to site records from leachate monitoring. If no historic site records exist, a program should be developed for calibration of the model over time.

Appendix 4 – Minimum expectations for community engagement

At a minimum, the department expects the following to demonstrate adequate community engagement:

- Work with local government to identify appropriate community stakeholder groups.
- Prepare and implement a stakeholder engagement plan during the design phase which:
    - Demonstrates how the principles of community engagement (in Table 6) have been implemented, and are proposed to be implemented over the life of the proposed facility, and
    - Documents the outcomes of the community engagement undertaken up to the point of making the application.
- Plan and undertake consultation activities in line with the stakeholder engagement plan.
- Ensure local and state government are regularly informed throughout the engagement planning and implementation process.
- An AQP community engagement practitioner develops and implements the community engagement process for the project and a skilled indigenous engagement practitioner undertakes First Nations people engagement.

Appendix 5 – Minimum expectations for a lining system

Table 14 details minimum expectations for a lining and leachate collection system based on landfill classification.

Table 14: Minimum expectations for lining and leachate collection system based on landfill classification (ascending from bottom to top)

Lining and leachate collection system component		Inert landfill	General landfill	Regulated landfill
Liner type		*Single*	*Composite*	*Double composite*
Leachate drainage layer	Pumping, instrumentation, controls and monitoring	Not required	Required	Required
	Separation geotextile	Not required	Required	Required
	Gravel and pipework[7]	Not required	Required	Required
	Leachate sump	Not required	Required	Required
Primary liner	Protection geotextile	Not required	Required	Required
	Geomembrane	Not required	Required	Required
	Compacted clay	Required		
Leak detection layer		Not required	Not required	Required
Secondary liner	Protection geotextile	Not required	Not required	Required[8]
	Geomembrane	Not required	Not required	Required
	Compacted clay	Not required	Not required	Required[9]
Groundwater depressurisation		Based on the outcomes of the hydrogeological risk assessment		
Liner sub-base		Required		

Lining system design and specifications

Table 15 details minimum expectations for the design and specification of each of the lining system components described in Table 14.

[7] A suitably designed drainage geocomposite may be used as an alternative on sidewalls exceeding 25% grade.
[8] May potentially be omitted if the leak detection layer is a suitably designed drainage geocomposite.
[9] A suitably designed GCL may be used as an alternative.

Table 15: Minimum expectations for lining system design and specification

Component	Minimum expectations
Liner sub-base	Refer to Section 6.3.1
Groundwater depressurisation	Refer to Section 6.3.2

Compacted clay	The compacted clay should have a total thickness of 1 m and a permeability of less than 1x10^{-9} m/s when tested in accordance with *AS1289 6.7.3*. In addition, the clay should:
	• Not contain any oversize particles greater than 50 mm when tested in accordance with *AS1289 3.6.1.*
	• Have a liquid limit less than 50% and plasticity index greater than 10% when tested in accordance with *AS1289 3.1.1, 3.2.1, 3.3.1*, and *3.4.1.*
	• Have low susceptibility to undergoing dispersion when tested in accordance with *AS1289 3.8.1.*
	• Have a calcium carbonate content of less than 15%.
	The design of the compacted clay layer should:
	• Assess seepage based on the materials selected, thickness, seepage management, installation control and geometry of the base and sidewall.
	• Incorporate measures to reduce seepage include composite lining, low permeability of the underlying layers, thicker liner and/or low hydraulic head over the liner.
	• Include provisions for future tie-in, including access, limitations to filling extent, liner protection, erosion and landfill gas and leachate management.
	• Consider tie-in methods with existing clay liners, including stepping/benching into the existing liner over a minimum of 3-6 m and surface scarification over 1 m (minimum) of the existing liner.
	• Include specific details for construction joins, staging, edge effects at the landfill cell perimeter and joining of sidewall lining to the capping.
	• Account for loading impacts of the overlying leachate collection sumps.
	The installation of the compacted clay layer should:
	• Ensure appropriate moisture content and compactive effort to achieve the required permeability – typically 0-3% wet of the optimum moisture content at a dry density ratio of greater than 95% relative to standard compactive effort (in accordance with *AS1289 5.1.1*). The line of optimums method may be considered as an alternative method on a case-by-case basis.
	• Undertake processing and moisture conditioning prior to placement to remove clods greater than 50 mm.
	• Undertake installation in thin compacted layers of 150 mm or less.
	• Maximise effective bonding between each layer to avoid preferential flow paths via:
	  ○ Compaction using a sheepsfoot roller that fully penetrates each layer.
	  ○ Surface scarification and moisture conditioning between each layer.
	• Undertake surface maintenance to avoid issues such as erosion, cracking and/or desiccation.

Component	Minimum expectations
	• Limit any trafficking of the clay once placed. • Use trial pads to verify the proposed construction method will achieve the required moisture content, compaction and permeability requirements.
Geosynthetic clay liner (GCL)	GCL may be used as an alternative to compacted clay in certain circumstances. The GCL should consist of a thin layer of bentonite between an upper and lower layer of geotextiles with a hydraulic conductivity less than 5 x 10^{-11} metres/second. In addition, the GCL should: • Be reinforced (i.e., the geotextile layers are bonded by needle punching or stitching to enhance the internal shear strength of the geosynthetic clay liner). • Have adequate strength, flexibility and durability to maintain performance over the entire life of the landfill (including the operating and post-closure periods). • Meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications; see *GRI-GCL3 test methods, required properties and testing frequencies of GCLs*. • Be made from bentonite that has been formulated for landfill applications. • Where additives such as polymers and pH modifiers are added to the bentonite to improve their performance, the manufacturer should provide details of the additives and demonstrate their nature, suitability and long term durability in the application. • Be compatible with the proposed cover soils and expected leachate from the waste received at the landfill. In addition to the below, the general geosynthetic requirements in Table 17 should be considered. The design of the GCL should: • Include justification of the equivalency of the GCL by comparison of contaminant transport to that of a compacted clay. • Specify suitable overlaps across GCL panels (typically 300 mm on side overlaps and 1,500 mm on end overlaps, treated with bentonite paste or powder). • Include anchoring to achieve stability required by the design. • Ensure particles in contact with the GCL should be less than 15 mm in any dimension, with protrusions limited to less than 10 mm (in both the subgrade and overlying layer). • Avoid or appropriately manage the risk of internal erosion and panel separation. • Ensure compatibility for applications where GCL is exposed to cations (e.g., Ca+) for Na+ exchange reactions (I.e., during hydration, from cover soils or leachate), and the design hydraulic conductivity is supported by testing. • Detailed slope stability analysis demonstrating adequate interface friction between the GCL and other adjacent materials, in particular on sidewalls. This should consider self-weight, down drag (during and after waste placement), anchorage, loading from overlying materials such as leachate gravel and other geosynthetics, and interface with underlying materials such as clay or GCL.

Component	Minimum expectations
	• Include design and material specification acceptable for exposure to UV, thermal gradients and wind loads during construction and in service. • Specify details for anchoring, interfaces with adjacent materials and structures, temporary works, staging and changes in loading or subgrade. The installation of the GCL should: • Adopt procedures to ensure hydration once confined, prevent premature hydration and provide confinement to the GCL. • Adopt procedures to prevent opening of the overlaps due to placement of overlaying layers of wet-dry cycle(s). • Limit trafficking of the GCL once placed. • Adopt procedures to deal with and manage wrinkles (waves). • Adopt procedures to deal with installation around protrusions and penetrations • Adopt procedures to prevent desiccation of geosynthetic clay liner and/or any underlying subgrade material. • Adopt procedures to install a geomembrane on top of the GCL.
Geomembrane	The geomembrane should be a minimum of 2 mm thick and manufactured from high density polyethylene (Other geomembrane type materials may be considered on a case-by-case basis if shown to have been used elsewhere in landfill lining systems and have been demonstrated over an extended period to possess equivalent performance, strength and durability. In addition, the geomembrane should: • Have adequate tear resistance, puncture resistance, and resistance to installation damage. • Resist degradation caused by factors such as chemical attack, temperature, oxidation and stress cracking over the life of the landfill (including post-closure and aftercare) and not be chemically reactive with the leachate or waste contained within the lined system. • Meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications; see *GRI Test Method GM 13* for high density polyethylene geomembranes and *GRI Test Method GM 17* linear low density polyethylene geomembranes. In addition to the below, the general geosynthetic requirements in Table 17 should be considered. The design of the geomembrane should: • Significantly limit stress in the geomembrane, keeping the material unstressed wherever possible, including: o Potential stresses on the geomembrane for all relevant scenarios. This includes at anchor trenches, on sidewalls, from subgrade settlement and from overlying materials/infrastructure such as leachate gravel and leachate sumps.

Component	Minimum expectations
	◦ Thermal stresses during installation, construction, and operation. ◦ Installation and construction stresses, and state limits on equipment and traffic during installation if necessary. • Ensure protection from damage or strains that might result in stress cracking from adjacent materials, installation methods, and ongoing loading (including sump loading). • Ensure the geomembrane is covered as soon as practicable. • Avoid penetrations where possible. If required, penetrations should be designed to maintain geomembrane integrity and eliminate stresses. • Ensure chemical compatibility of the geomembrane liner and the leachate, such that it is shown to retain the required strength and performance after exposure. • Incorporate detailed slope stability analysis demonstrating adequate interface friction between the geomembrane and other adjacent materials, in particular on sidewalls. This should consider self-weight, down drag (during and after waste placement), anchorage, loading from overlying materials such as leachate gravel and other geosynthetics, and interface with underlying materials such as clay or GCL. • Provide clear detail for each configuration of the geomembrane showing its location, extent, layers and elements. The installation of the geomembrane should: • Be undertaken in line with the *Guidelines for Installation of HDPE and LLDPE Geomembrane Installation Specification (International Association of Geosynthetic Installers 2015*). • Include procedures to protect the underlying materials (from issues such as desiccation and shrinkage) before and after geomembrane placement. Mitigate potential key issues including thermal effects on geomembrane surfaces on rolls, spotting of deployed geomembranes, thermal expansion and contraction, wind effects and ballasting to prevent uplift. • Include the following with respect to seaming: ◦ Provide a continuous layer with minimised seaming needed. ◦ Ensure panels overlap at a minimum of 125 mm and are orientated so that the lap is in the down sloping direction and across the flat base. All welds should run down a slope or be on the flat base. ◦ Ensure weld surfaces are clean immediately prior to welding. The weld area should be free of moisture, dust, dirt, debris, markings and foreign material. ◦ Ensure welding of all main joints between adjacent geomembrane panels (primary welds) is conducted using hot-wedge welding, producing two parallel seams with an air channel in between (dual-track fusion welding). The hot wedge welding is conducted using the split head wedge fusion weld method which will fuse the upper and lower overlapped geomembrane sheets.

Component	Minimum expectations
	○ Ensure extrusion welding is used primarily for detailed work and repair work (secondary weld) or where approved in areas that would be inaccessible to the dual track fusion weld (such as around structures, pipes and other penetrations). The extruded granulate for surface extrusion welding is manufactured from the same resin type used in the manufacture of the geomembrane. All physical properties shall be identical to those possessed by the geomembrane raw material. The manufacturer should provide certified test data with each batch of welding granulate. ○ Ensure oxidation byproducts-are removed from the surface to be welded by grinding/buffing prior to extrusion fillet welding. Grind marks should not be deeper than 10% of the geomembrane thickness. Welding should be performed shortly after grinding so that surface oxide formation does not reform. ○ Ensure all geomembrane panels subject to hot wedge welding shall be overlapped by a minimum of 125 mm and a minimum of 75 mm for extrusion welding to allow for proper construction quality assurance testing. ○ Ensure that all primary welds used to connect panel ends to sheets form T-joins (tees). These T-connections should have a distance of at least 0.5 m. The welding seams of the geomembrane cannot cross (no cruciform connections). ○ Ensure that on slopes, the seams shall to a large extent run parallel to the line of maximum slope. ○ Not undertake patching of geomembrane panels using transverse joints on slopes. The connecting seam between geomembranes on the slope and the base should be located in the base at a distance of at least 1 m from the slope toe. ○ Adopt procedures to deal with damages and defects. • Adopt criteria, testing and action on test failure which include the following requirements: ○ Rejection criteria of the geomembrane sheets and details of actions to be taken if geomembrane fails a conformance test. ○ Details of actions to take after cutting of each destructive test sample from the production seam. ○ Details of actions to take in the event of a defective weld, including retesting procedures. ○ Details of criteria and actions in the event of damage during welding. ○ Rejection criteria of the laid geomembrane if test results indicated failure. ○ Details of actions to take in case of defects and/or damages to the surface of the laid geomembrane are identified (by any means) and corrective measures. ○ Details of actions to take if geomembranes have been damaged due to shifting by wind.

Component	Minimum expectations
	o Weather and temperature conditions during geomembrane deployment and seaming. o Details of actions to take to minimise geomembrane wrinkles and bridging. o Verification process of the geomembrane installation around areas of protrusions and penetrations is made according to specifications. • Ensure geomembranes installed on slopes are fixed in anchor trenches. • Define detail actions to take to protect the geomembrane following installation. • Consider methods of placement of the overlying protective layer and/or leachate collection layer. • Adopt methods of dealing with or managing wrinkles (waves), including: o The geomembrane should be installed without undergoing substantial buckling or wrinkling which result in tensioning/bridging at changes of grade or depressions due to thermal effects or otherwise. o Particular care taken during installation of the geomembrane to ensure that the surface of the geomembrane after installation is substantially free from buckles, wrinkles, ripples, creases and folds, and is flat and conforms to the underlying surface before the cover material is placed above it. o At the time the geomembrane is covered with soil (e.g. leachate gravel), the growth or movement of wrinkles should be minimised. Any remaining wrinkles should be sufficiently small that they are flattened without creasing, and not 'locked' or preserved within the placed drainage layer. o Removal of wrinkles by cutting out and patching where necessary. • Include leak location surveys in accordance with *ASTM D8265-2023*, including bare geomembrane survey and survey following placement of the leak detection and leachate drainage layers.
Protection geotextile	The protection geotextile should consist of a non-woven, needle-punched geotextile, typically made of polyester or polypropylene (with the exception of inhibitors and/or carbon black added for UV resistance), formulated to meet landfill conditions and not contain recycled materials. In addition, the protection geotextile should: • Be of sufficient mass, strength and thickness to protect the underlying geomembrane from puncture and from excess stresses and strains due to indentations from the overlying gravel. This can be assessed via compression testing in accordance with *LFE 2 or ASTM D5514* compared to the requirements in the table below. • Meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications. *See GRI Test Method GT12(a) and GRI Test Method GT12(b)*.

<table>
<tr><th>Component</th><th>Minimum expectations</th></tr>
<tr><td></td><td>
Maximum allowable strains for various geomembrane materials
<table>
<tr><th>Geomembrane type</th><th>Maximum allowable strain</th></tr>
<tr><td>HDPE smooth</td><td>6%</td></tr>
<tr><td>HDPE randomly textured</td><td>4%</td></tr>
<tr><td>HDPE structured profile</td><td>6%</td></tr>
<tr><td>LLDPE density <0.935 g/cm³</td><td>12%</td></tr>
<tr><td>LLDPE density >0.935 g/cm³</td><td>10%</td></tr>
<tr><td>LLDPE randomly textured</td><td>8%</td></tr>
<tr><td>LLDPE structured profile</td><td>10%</td></tr>
</table>
In addition to the below, the general geosynthetic requirements in Table 17 should be considered.
The design of the protection geotextile should::

Consider site-specific conditions.
Make appropriate allowance for construction, service and after use conditions, and any uncertainty in assumptions made.
Undertake sampling and testing that is representative of the materials, protection and site-specific service conditions selected.
Factor in measured strains account for creep in protection materials, geomembrane bending, uncertainty in the strain measurement technique and actual field conditions and evaluated against appropriate criteria.

</td></tr>
</table>

Leachate collection system design and specifications

Table 16 details minimum expectations for the design and specification of each of the leachate collection system components described in Table 14.

Table 16: Minimum expectations for leachate collection system design and specification

Component	Minimum expectations
Leachate sump	The design of a leachate collection sump should: • Include resistance to chemical attack, and physical, chemical and biological clogging. • Account for loads due to the placement, compaction and settlement of waste without crushing. • Ensure accessibility for future inspection and maintenance (such as flushing / clean out). • Allow for redundancy and robustness to allow continued function in the event of several components of the system failing. • Ensure the sump and associated infrastructure do not compromise liner integrity during installation and landfilling.

	• Ensure the sump does not compromise liner integrity under long-term down drag forces imposed on vertical risers or in the event of structural failure of the sump riser or base. • Protect the liner from impacts of the pump, its installation, operation and maintenance. • Ensure the depth of leachate in each sump can be measured and removed. • Ensure leachate pump operation is automated and alarmed. Leachate sumps should be designed to allow for the increased heads that are required to allow for the pumping and removal of leachate. Where sumps are located such that they reduce the minimum required separation to groundwater, additional measures to improve the performance are required.
Gravel	The gravel should have a total thickness of 300 mm and a permeability of greater than 1 x 10^{-3} metres/second when tested in accordance with *AS 1289.6.7.1*. In addition, the gravel should: • Be clean, durable, hard and sound. • Not contain any oversize particles greater than 50 mm. • Not contain more than 10% particles smaller than 20 mm and 3% smaller than 0.075 mm (by weight). • Have a suitable shape an angularity such that it does not compromise the underlying geomembrane (in combination with the protection geotextile). • Be compatible with the leachate generated by the proposed waste to be received. The installation of the gravel should: • Install gravel in one 300 mm thick layer. • Ensure minimum grading of 1% along the main leachate drainage pathway and 3% transverse to this pathway. • Use trial pads to verify the proposed construction method will not compromise the underlying geomembrane or break down the gravel and generate excessive fines.
Pipework	The leachate collection pipework should have a minimum internal diameter of 150 mm and be manufactured from polyethylene. In addition, the pipework should: • Be strong enough to cater for expected loading during construction, landfilling operations, closure and post-closure. • Be perforated to allow for leachate inflow. • Be compatible with the leachate generated by the proposed waste to be received. • Consider the impacts of clogging in the sizing calculations. The installation of the pipework should: • Adopt maximum spacing limits to allow leachate to be maintained within the gravel layer. • Ensure minimum grading of 1% along the main leachate drainage pathway and 3% transverse to this pathway. • Ensure accessibility for future inspection and maintenance (such as flushing or cleaning), including appropriate bends and fittings. • Include sealing to prevent release of landfill gas and air being drawn into the landfill (and reduce the associated subsurface landfill fire risk).

Separation geotextile	The separation geotextile should consist of a non-woven, needle-punched geotextile, typically made of polyester or polypropylene (with the exception of inhibitors and/or carbon black added for UV resistance), formulated to meet landfill conditions and not contain recycled materials. In addition, the separation geotextile should: • Have appropriate filtration characteristics to limit the effects of clogging, while at the same time limiting excessive migration of fines into the underlying drainage layer. • Allow flow of water into the leachate collection layer without significant flow impedance. • Have sufficient strength to resist installation damage and the weight of the overlying waste mass. • Have appropriate UV resistance properties based on the estimated exposure of the material before covering. • Be able to resist degradation caused by factors such as chemical attack, temperature and oxidation over the entire life of the landfill (this includes chemical resistance of the geotextile polymers to the site leachate). • Meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications. *See GRI Test Method GT12(a) and GRI Test Method GT12(b).* In addition to the below, the general geosynthetic requirements in Table 17 should be considered. The design of the separation geotextile should: • Consider site-specific conditions. • Ensure puncture resistance during installation and when covered with waste.
Drainage geocomposite	Drainage geocomposite may be used as an alternative to gravel and pipework in certain circumstances such for sidewalls that exceed a 25% grade. The drainage geocomposite should consist of: • An internal geonet drainage core manufactured from high-density polyethylene (plus anti-oxidants) and consisting of layers of parallel ribs creating drainage channels through which liquid can flow. • Geotextile fabric bonded to the upper surface of the geonet to prevent fines from entering the drainage channels, and geotextile bonded to the lower surface to prevent damage to adjacent geosynthetic layers from the ribbing, edges and ties of the geonet. In addition, the drainage geocomposite should: • Be able to resist degradation caused by factors such as chemical attack, temperature, oxidation and stress cracking over the entire life of the landfill (this includes chemical resistance of the geotextile polymers to the site leachate). • Have adequate long-term flow capacity for the estimated leachate flow rate. • If relevant, meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research

	Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications. See *GRI Test Method GN4.* • Have a minimum hydraulic transmissivity of $0.3x10^{-3}$ m^2/sec under design considerations. • Maintain a maximum leachate head of less than 300 mm above the liner. In addition to the below, the general geosynthetic requirements in Table 17 should be considered. The design of the drainage geocomposite should: • Account for an allowable flow rate determined from a standard 100-hour test simulating field conditions (adjacent layers, waste loads and hydraulic gradient). This should account for decreases in flow capacity due to intrusion of the geotextile into the geonet core. • Account for reduction factors that will further reduce the thickness and capacity of the drainage core under long-term field conditions, including long-term creep deformation, and chemical and biological clogging. In addition to these specific reduction factors, adequate general safety factors should be applied to account for overall design uncertainties. • Include measures to prevent development of hydrostatic pressure equivalent to greater than 300 mm head above the liner. The installation of the drainage geocomposite should: • Adopt procedures to be adopted to prevent soil intrusion. • Include measures to prevent bentonite intrusion from GCL. • Include measures to prevent separation of adjacent panels and slope instability. • Include measures to prevent damage to the geocomposite due to the loads imposed by construction and operational plant. • Include measures to prevent damage due to UV exposure of the material before covering. • Include measures to prevent entry of surface runoff. • Include measures to prevent uncontrolled release of LFG.
Pumping, instrumentation, controls and monitoring	The pumping, instrumentation, controls and monitoring should: • Include at least one leachate collection sump and leachate riser for each cell to facilitate extraction of leachate. They should be stable under the load of the surrounding waste mass and withstand stresses due to settling of the surrounding waste. They should be accessible for future inspection and maintenance (such as flushing or cleaning), including appropriate bends and fitting. • Include controls to ensure that the leachate level does not exceed 300 mm above the upper surface of the lining system. This should include an alarm system that is activated if the leachate level rises above this level. • Be automated and equipped with telemetry for remote data access. • Include interlocks or water level sensors to prevent leachate from being pumped out of the cell at least 24 hours before the capacity of any receiving storage is reached (additional storage or disposal capacity may be required when this occurs).

	• Include non return valves and pump interlocks on the leachate transfer pipework to prevent the backflow or pumping of leachate should the pipework rupture. • Include instrumentation with real time monitoring of electrical conductivity used in conjunction with an alarm system to identify any breakthrough of leachate for the leak detection layer. • Include remote collection of level and extraction volume data for record keeping and future assessment (such as water balance calibration). • Allow for redundancy and robustness to allow continued function in the event of several components of the system failing

Geosynthetic materials

Table 17 details general minimum expectations for all geosynthetic materials.

Table 17: Minimum expectations for geosynthetic materials in landfill applications

Phase	Minimum expectations
Design	The design of geosynthetic materials should: • The interface friction of geosynthetic materials is typically very low, resulting in a preferential sliding plane. Hence, detailed stability analysis is required when using geosynthetic materials in lining and capping systems under the range of potential loading scenarios across the landfill life (both temporary and permanent). Where appropriate, laboratory testing of geosynthetics in conjunction with the proposed construction materials should be considered to determine the interface friction over the likely confining stress range. • Consider stresses and strains resulting from imposed loads on the liner system are applied to the geosynthetics both from waste placed over the liner (to the full height including future capping) and from construction loads. Loading from settlement of the waste adjacent to a sidewall, as well as settlement of the subgrade soils should also be considered. Static and seismic conditions should be considered. • Specify requirements to maintain integrity, strength and stability of seams and constructing joints. • Ensure redundancy and robustness, given that elements such as liner systems cannot easily be accessed for repair and maintenance without significant cost and operational impacts (due to overlying waste placement). • Account for seepage based on materials selected, thickness, seepage management, installation control and geometry of the base and sidewall. Measures to reduce seepage include composite lining, low permeability of the underlying layers, thicker liner and/or low hydraulic head over the liner. • Account for chemical and temperature impacts on the geosynthetics based on the landfill type and proposed wastes to be received. • Limit any trafficking of the geosynthetics once placed. • Include specific details for construction joins (with similar or other materials), staging, anchoring, edge effects at the landfill cell perimeter and joining of sidewall lining to the capping. Penetrations should be avoided, but also be considered if required. • Account for loading impacts of the overlying leachate collection sumps.

	• Ensure provision for future tie-in, including access, limitations to filling extent, liner protection, erosion and LFG and leachate management. • Demonstrate equivalence of the geosynthetics taking into consideration issues such as flow rate and concentration gradients with respect to time, related to the point of compliance for the site (e.g. monitoring locations).
Installation	The installation of the geosynthetic materials should: • Implement an effective quality control and quality assurance program. • Include material testing in accordance with Appendix 7 • Ensure labelling for ease of material identification and roll number/identification. • Ensure the geosynthetic is protected during shipping, storage, handling and installation. • Ensure preparation of a suitable sub-base that is sufficiently firm and free of defects (such as voids and/or foreign objects) that may compromise the geosythetic. • Include a panel placement plan, and requirements for panel identification, placement method (including appropriate weather conditions), seaming (including preparation, orientation and overlap), damage and defects. • Include quality control and assurance measures for geosynthetic materials as it is delivered to the site. • Include quality control and assurance measures for joins and seaming. • Include quality control and assurance measures for handling, storage and installation, taking into account weather conditions. • Ensure intimate contact between the geosynthetic and underlying materials, including removal of wrinkles prior to covering. • Adopt procedures to prevent damage during deployment and UV exposure prior to covering. • Adopt procedures to identify and deal with damage and defects. • Adopt methods of dealing with installation around protrusions and penetrations • Consider stormwater management as many geosynthetics are significantly impacted by water impacts. This is crucial on sidewalls to prevent infiltration under the lining system. • Consider access, including for appropriate installation on sidewalls. • Consider safe work methods. • Undertake quality control/assurance measures to prevent damage from placement of overlying materials. • Account for presence or risk of groundwater or hydrostatic pressures under the liner system.
Durability	Durability issues are related to the environment of the geosynthetic liner. The durability considerations for various geosynthetics are different and hence are captured in Table 15. Given the critical nature of the performance of geosynthetics in landfill applications over long periods of time, the risks associated with failures and the lack of data regarding the impact of using post-consumer resins and materials in their manufacture on performance, current recognised minimum specifications exclude their use in manufacture and limit the proportion of reworked materials within the manufacturing facility. Peer reviewed, evidence based, scientific justification is required to support variation of these specifications for critical lining, protection and drainage applications.

Appendix 6 – Minimum expectations for the capping system

Table 18 details minimum expectations for a capping system based on landfill classification.

Table 18: Minimum expectations for the capping system based on landfill classification (top to bottom)

Capping system component		Inert landfill	General landfill	Regulated landfill
Landfill capping	Vegetation	Required	Required	Required
	Growing medium	Required	Required	Required
	Barrier layer	Not required	Required	Required
Landfill gas collection		Based on the outcomes of the landfill gas risk assessment (see Appendix 3) and assessment of use of landfill gas (see Appendix 8)		
Capping sub-base		Required		

Table 19 details minimum expectations for the design and specification of each of the lining system items described in Table 18.

Table 19: Minimum expectations for capping system design and specification

Component	Minimum expectations
Capping sub-base	Refer Section 6.5.1
Landfill gas collection	Refer Section 6.5.2
Barrier layer	A single or composite liner comprising compacted clay, GCL and/or geomembrane may be used for the capping liner, such that the overall capping system achieves a capping infiltration rate that does not exceed the liner leakage rate. Alternative capping systems such as those incorporating phytocaps or biocover should also demonstrate this. For comparison, liner leakage rates can be estimated as follows: • Single liner: 1000 L/ha/day • Composite liner: 10 L/ha/day • Double liner: 1 L/ha/day Protective layers should also be considered (such as protection geotextile) based on the design and construction method for the overlying layers. Specifically: • A compacted clay layer should be a minimum of 600 mm thick if used. • A GCL should not be used in a single liner scenario unless it includes polyethylene coating.

Component	Minimum expectations
	• If a geomembrane is used, a liner low density polyethylene should be used to account for the ongoing and differential settlement of the underlying waste. Refer to Table 15 for minimum expectations for the design and specification of these materials.

Growing medium	The growing medium should provide a substrate for vegetative growth, erosion protection and protects elements of the capping system (e.g., from root penetration). It typically comprises (from bottom to top):
	
	• A subsoil that protects the underlying barrier layer, allows for store and release of moisture, and assists in supporting plant root growth.
	
	• A topsoil with organic matter. This organic matter may be from augmentation (e.g., mulch, biosolids, etc.).
	
	The growing medium should be compatible with the proposed vegetation for the capping system.
	
	Consideration given to:
	
	• The sustainability of the soil or growth medium as the organic material decomposes overtime,
	• The soil structure (e.g., aeration, moisture and nutrient retention) to promote vegetation growth,
	• Thickness or root depth, including:
	    o The location and amount of subsidence,
	    o Minimising the loading placed on other components of the capping system, and
	    o Minimising the risk of root penetration,
	• Rainfall distribution,
	• Stability, and
	• Drainage characteristics.

Subsoil drainage	If required, a subsoil drainage system would typically consist of gravel and/or slotted or perforated pipework draining to an extraction point (such as into the above ground stormwater management system). A suitably designed drainage geocomposite may also form part of this system, refer Table 15 for minimum expectations for the design and specification of this material.
Vegetation	Vegetation should be planted on the surface of the capping system to stabilise the capping surface. The chosen vegetation should be compatible with future end-use and local climate. Native species should be used, and use of invasive species should be avoided. Vegetation planted should not compromise the effectiveness of the capping system.

Appendix 7 – Minimum expectations for a CQA plan, a CQA report and material testing

CQA plan and CQA report

Minimum expectations for the CQA plan are provided in Table 20, and minimum expectations for the CQA report are provided in Table 21.

Table 20: Minimum expectations for a CQA plan

Item	Details
Roles, responsibilities, communication lines and definitions	The plan defines clear roles, responsibilities, and lines of communication for the implementation of the plan and the responsibilities, qualifications and obligations for each party involved in the plan. This includes sub-contractors. There is clear responsibility of a specific person or organisation for the overall implementation of the CQA plan. Common definition of names, terms and roles for the project to avoid confusion on acronyms and wording. Specific roles for the implementation of the CQA plan include (but are not limited to): • Environmental Authorisation holder, typically the site owner/operator. Commonly referred to as the "Principal" in Australia Standard construction contracts. • Contract administrator, the party administering the construction contract on behalf of the EA applicant or holder. Commonly referred to as the "Superintendent" in Australia Standard construction contracts. • Contractor, the construction firm contracted to build the proposed infrastructure. Commonly referred to as the "Contractor" in Australia Standard construction contracts. • Design Engineer, a RPEQ who leads completion of the design. • CQA Engineer, the party tasked will implementing the CQA Plan. They are a RPEQ and independent of the contractor, EA holder and the design engineer. • Lining/geosynthetic installer, the specialist geosynthetic lining firm typically subcontracted to the Contractor (or in some instances, the Contractor). • Surveyor, the specialist surveying firm typically subcontracted to the Contractor. • Testing firms, the NATA accredited independent testing laboratories typically subcontracted to the Contractor (for quality control testing) and the CQA Engineer (for quality assurance testing). This may also include leak location testing firm/s. The CQA plan is developed and endorsed by the design engineer (a RPEQ).
Drawings and specifications for the proposed landfill cells and infrastructure	The Design Report and all accompanying documentation including technical specifications and drawings of the proposed landfill cells and infrastructure.

Item	Details
Materials testing	Specify a schedule for required testing by the independent CQA engineer (see Table 21) of all materials used in the landfill construction. This includes sampling locations, frequency, test methods, applicable specifications and quality standards, acceptance and rejection criteria and contingency measures in the event of testing failure.
Hold points for inspection and record keeping	Specify a schedule of inspection hold points for the independent CQA engineer (see Table 21) in the programme of construction for work that can no longer be rectified as past that point it will no longer be accessible. Procedure to record defects and nonconformance issues are detected during inspections and agreed remedial actions or repairs before another inspection to assure issues are rectified. At each hold point, the independent CQA engineer (see Table 21) will inspect the relevant work stage and review the test results of the materials used, as well as the contractors' work methods and the quality of the completed construction. Daily record keeping by the CQA engineer includes: • Weather and site conditions. • Records of the delivery, handling and storage. • Quality of underlying geomembrane. • Description of any material received at the site, including quality control data provided by suppliers. • Location of daily construction activities and progress. • Conformance to panel layout design. • Records of installation activities, consisting of panel placement, roll numbers, overlap locations, repairs and testing results for all works. • Records (including photos) of the geotextile at the time that cover soil is placed over the geotextile. • Photographs of construction works and any items of specific interest. The captions of all photographs should contain the name of the project, the date on which the photograph was taken, and the identity of the feature being photographed. • Type of equipment used in each work task (e.g., handling equipment). • Testing conducted and test methods used. • Remedial action on geotextile defects or jointing defects. • Placement of temporary protection to installed geotextile. • Record of any material or workmanship that does not meet specified designs and corrective actions taken to remediate the problem. • Details of site visits. • Summaries of any meetings held and actions taken. • Signature of CQA engineer. Detailed photo records kept for all inspections as well as key aspects and stages of construction. Records showing the CQA plan and design report are being followed.

Item	Details
Variations	Procedure on how to respond to and record proposed variations from the CQA plan and design report. Variations may include changes to the following: • Environmental risk. • Size or capacity of the landfill cell. • Construction material. • Construction method. • Technical specification. • Material performance standards. • Design change. • Emissions management systems (e.g., leachate or landfill gas). Variations that satisfy all three of the below criteria: 1. It will result in no additional, or potentially additional, harm to environmental values. 2. The conditions of the EA can still be met and are applicable, with no changes required. 3. This guideline and the applicable minimum expectations are still met. Will require the following to be recorded in the CQA report: • A written record to be provided to the administering authority advising of the design change and providing sufficient evidence that the above three criteria are met (as approved by the design engineer and the CQA engineer). • A written design variation record from the designer addressing the change to the design as an amendment of the design report. • Written acceptance from the EA holder and CQA engineer of the design change. Variations that do not meet one or more of the above criteria will require an amendment to the EA. It is recommended a pre-lodgement meeting is requested as a first step to this process.
Plan declaration	The CQA plan is accompanied by a declaration by the design engineer that the minimum expectations of this guideline are met by the CQA plan.

Table 21: Minimum expectations for a CQA report

Item	Details
Roles, responsibilities and communication lines	The CQA report is prepared and endorsed by an independent CQA engineer (certified as a RPEQ). The CQA engineer is independent of the contractor, EA holder and the design engineer. Suitable levels of experience and qualifications for the CQA engineer should align with those recommended by The Australasian Chapter of the International Geosynthetics Society (ACIGS) in *Recommendations for the minimum qualification of on-site*

Item	Details
	construction quality assurance (CQA) personnel supervising construction using geosynthetic materials. The CQA report defines consistent and clear roles, responsibilities, and lines of communication for implementing the plan, and the responsibilities, qualifications and obligations for each party involved in the plan. This includes sub-contractors. There is clear responsibility of a specific person or organisation for the overall implementation of the CQA plan and preparation of the CQA report. Definitions for the project to avoid confusion on acronyms and wording.
Drawings of the constructed landfill cells and infrastructure	To scale and labelled as-constructed drawings demonstrating the implementation of the design and an updated site plan showing the location of all works, location of interfaces to future works and any required setback required by the design. Drawings that show the prepared sub-grade, installed liner system and requite components, and the locations of all defects, repairs and testing.
Materials testing	Record of all materials testing undertaken, including data and certification provided by manufacturers of supplied materials.
Hold points for inspection and record keeping	A record of all inspections undertaken, including any defects and subsequent remedial actions.
Variations	Written record of all variations provided by the designer and agreed under the procedure set out in the CQA plan. Updates to the design report as required.
Report declaration	The CQA report is accompanied by a declaration from the independent CQA engineer that the subject works were constructed in accordance with the approved design report and CQA plan. In the case of staged cell or cell wall construction, a schedule clarifying any limits of the report and anticipated or recommended future addenda to the CQA.

Material testing requirements

As outlined above, the CQA plan should include material testing requirements. In general, this should include requirements for:

1. Representative testing for materials prior to procurement.
2. Pre-qualification material testing and/or manufacturing quality control/assurance (MQC/MQA) testing for supplied material prior to use.
3. Independent, third-party testing for the supplied material prior to use.
4. Requirements for independent visual inspection and surveys.
5. Liner integrity surveys undertaken in accordance with *ASTM D8265-2023* prior to and following placement of cover materials to identify defects and construction damage.

With reference to the above, as part of the CQA process independent, third-party testing should be undertaken for the various materials used for key applications in landfill construction works (including liner and capping materials, and leachate collection system materials). Commonly this would include independent testing of clay, geosynthetics and leachate drainage gravels for key performance parameters in relation to the landfill design.

Key aspects of the program should include:

1. Samples are taken from the actual materials to be used for the construction works.
2. Sampling is witnessed by the CQA Engineer.
3. Delivery of samples to the independent testing laboratory is organised by the CQA Engineer under a suitable chain of custody procedure.
4. Testing is completed by a third party, independent, accredited laboratory.

The testing program should be developed by the designer based on the risk profile of the construction works and the criticality of each of the various materials. This testing program should be included in the CQA plan for the construction works. The South Australia EPA landfill guideline, *Environmental Management of Landfill Facilities*, includes testing program recommendations and these could be considered by the designer when preparing their testing program. It is important that the acceptance criteria set by the designer are appropriate for the application and additional requirements should be considered and included where non-performance of materials or construction features are considered by the designer to warrant a higher level of CQA. GRI and other industry specifications are minimum standards for production or generic materials and not developed for landfill applications which are more demanding. The designer needs to also consider criteria that address site specific geotechnical requirements, loads, compatibility with the waste, leachate and temperature, construction loads, long term exposure of materials prior to waste placement.

Appendix 8 – Minimum expectations for use of landfill gas and an enclosed flare

The minimum expectations for assessing the use of landfill gas are as follows:

- Undertake an annual estimate of forecast generation (using the *NGER solid waste calculator* or other suitable model).
- Where >10,000 t CO_2-e is forecast, conduct a landfill gas pumping trial:
  - Where <100 m^3/hr (and decreasing) of landfill gas can be recovered best practice is passive controls (biofilters, microbiological gas treatment or oxidation layers).
  - Where the pumping trial demonstrates that >100 m^3/hr of landfill gas can be recovered, best practice is to implement an active landfill gas capture and enclosed flaring system.
  - Where >250 m^3/hr of landfill gas can be recovered, best practice is to implement an active landfill gas capture and landfill gas energy recovery system.
- Active extraction and flaring may also be required to address subsurface landfill gas migration risks or where required for odour control.

Enclosed Flare

The minimum expectations for an enclosed flare design are as follows:

- The flare should be equipped with a flare tip design to provide good mixing with air, flame stability, and achieve a minimum Volatile Organic Compound (VOC) removal efficiency of 98% under varied gas flow rate and meteorological conditions.
- The flare should be equipped with a continuously burning pilot or other automatic ignition system that assures gas ignition and provides immediate notification of appropriate personnel when the ignition system ceases to function.
- The flare gas train should include a slam shut valve to provide fail safe protection against venting landfill gas during shutdown.
- The flare should be designed to handle large fluctuations in both the volume and the chemical content of gases.
- Visible emissions should not be permitted for more than five minutes in any two-hour period.
- The flare should be operated in such a way that the temperature for the combustion of gas by the flare is at least 980°C with a retention time of at least 0.3 seconds.

Appendix 9 – Minimum expectations for a leachate management system

A leachate management system should be installed and operated for all landfill classifications except for lower risk inert landfills. The minimum expectations for designing the leachate management system are as follows:

- The design is based on the outputs of the site water balance assessment to accommodate the flows predicted during a >20yr minimum rainfall record that includes a period of rainfall containing both 1% AEP event and two consecutive wet years.
- Ensure the simulation includes at least 10% infiltration of interim covers and 80% infiltration in operating cells.
- Include simulation of:
  - leachate treatment and storage systems,
  - capacity of the disposal pathway and any restrictions during wet weather
  - leachate mounding.

Monitoring network for leachate

Minimum expectations for leachate head monitoring wells are:

- Established at the commencement of waste deposition in the cell and maintained during progressive filling of the cell to the final profile level.
- Be stable under the load of the surrounding waste mass and comply with the requirements of applicable Australian Standards for the pipe material.
- A minimum of 2 leachate head monitoring wells per hectare.
- Identify if leachate levels exceed 300 millimetres above the lining system.
- Continue to function effectively in the post closure management phase.

Leachate collection system

The minimum expectations for leachate collection systems are:

- Prequalification testing undertaken on the drainage aggregate used.
- Installation of the entire leachate collection system (including drainage aggregate, sumps and pipework) is done without damaging the other liner components including geosynthetics and geomembranes. A field trial should be conducted to verify construction techniques do not damage the other lining components.
- Methods of dealing with or managing wrinkles (waves) in the geosynthetics.
- Measures to provide the necessary isolation from surrounding soils and cells to allow liner integrity survey to be conducted.
- Measures to delineate haul roads of sufficient aggregate thickness for trafficking.
- Measures to minimise breakdown of aggregate during placement.
- Recovery of samples of placed aggregate to verify compliance with the grading specification has been achieved in-situ.
- Measures to prevent soil and debris entering the drainage pipework and aggregate layer.
- Supervision of sump installation and inspection of liner for damage.
- Inspection of leachate pipework, perforations, connections, including verification of removal.

Leachate ponds

The minimum expectations for leachate ponds are to:

- Achieve equivalent performance to the landfill liner. As leachate ponds are operated under exposed conditions and subject to great hydraulic head and desludging, their design and specification may differ from the landfill liner.
- Be protected from surface water, stormwater, and groundwater inflows.
- Have floors graded and provided with a gas relief system to prevent whales forming and reducing the pond capacity.
- Have a minimum 600 mm freeboard.
- Be accessible in all weather conditions for removal of leachate by tanker.
- Use liner materials that are suitable for exposure to the leachate chemistry, temperature and UV conditions within the pond.
- Manage risks of liner disturbance by wind on the exposed liner.
- Enable ‘de-mucking’ of sediments and solids while protecting the integrity of the liner system. As well as safe access for pond maintenance or leachate treatment.
- Incorporate inlets, outlets and monitoring systems that preserve the integrity of the liner system and avoid submerged penetrations.
- Be designed to manage the risk of liner and subgrade deterioration from wave action on the side slopes.
- Provide safe ingress and egress, and access for inspections, maintenance, monitoring and sampling.
- Provide a means of access control by fencing to manage safety risks and the risk of damage.
- Manage risk associated with the presence of fauna and flora, e.g., growth of weeds or other vegetation.

Leachate reinjection

The minimum expectations for leachate reinjection are:

- Reinjection is used as a storage measure only, it is not considered a disposal option, and based upon an assessment of the site leachate balance.
- Monitoring (e.g., using leachate head monitoring wells and sump) twice daily to ensure the head does not exceed 300 millimetres on top of the lining system. Leachate sump pump hours should be monitored daily to ensure the waste is able to hold its absorptive capacity.
- To reinject only at a rate that allows the waste to absorb it and there should be sufficient storage volume within the waste mass and in the leachate management system to contain leachate generated on site, as demonstrated in the water balance for the site.
- To reinject only at a rate that does not result in perched leachate being created within the waste mass or seeps from batters.
- Reinjection is only undertaken in landfill cells with a lining system incorporating an engineered leachate extraction and level-control system.
- To be designed, constructed and operated to ensure leachate is evenly distributed throughout the waste mass and the ‘zone of influence’ should be well defined to ensure the reinjection system optimises the moisture content of the entire waste mass.
- Reinjected leachate does not become an oxygen source, source of oxygen ingress, or odour emission, and be located away from leachate and gas extraction points to prevent ‘short-circuiting’ of reintroduced leachate.
- Reinjection does not compromise the performance of landfill gas collection systems.
- Contingency measures for dealing with exceedance of reinjection capacity or the need to discontinue reinjection for any reason should be included in the design.
- It should be recognised that leachate reinjection is not available during the initial stages of a landfill, when insufficient waste has been landfilled to act as a ‘sponge’ to absorb leachate.

Appendix 10 – Minimum expectations for stormwater management plan

The minimum expectations for the stormwater management plan are to describe:

- How it follows the hierarchy of control mechanisms:
  - **Preservation**—preserving existing valuable elements of the natural stormwater system, such as natural channels, wetlands and riparian vegetation.
  - **Source control**—appropriate management of the quantity and quality of stormwater, at or near the source of potential contaminants, or changes to flow by using stabilisation or avoidance principles and/or erosion controls.
  - **Structural control**—using structural measures, such as treatment techniques or sediment basins, to improve water quality and control runoff. Applying structural treatment measures on site before the runoff enters a waterway is required to capture mobilised pollutants, and mitigate geomorphic stream damage.
  - **Receiving waters management**—as a last line of control, the receiving water should be managed to avoid any residual impacts from stormwater pollutants or flows.
- How the disturbed catchment area will be minimised.
- How separate systems will be implemented and managed for:
  - Uncontaminated stormwater (e.g., water from areas onsite that are undisturbed), and
  - Contaminated stormwater (e.g., water from refuelling stations, runoff from intermediate cover, etc.).
- How a collection and retention system will be designed and constructed for expected flows to an appropriate hierarchy and standard, including:
  - Appropriate risk-based controls for extreme events and failure of diversions and controls,
  - Sufficient allowance is made for maintenance practices likely to occur,
  - 1% AEP protection against flooding of leachate and landfill gas plant,
  - 1% AEP protection against run-on, overtopping of controls or entry of surface water to cells,
  - 1% AEP protection against erosion or breach of constructed containment systems, and
  - 10% AEP protection against overtopping of constructed drains.
- How stormwater will only be discharged from the site:
  - If the water is from a stormwater storage dam,
  - After confirmation that the water is not contaminated, and
  - Contained and managed if required during extreme events.
- How erosion and sediment controls will be implemented (e.g., maintaining vegetation in areas prone to erosion, etc.).
  - In operational areas,
  - In construction areas, temporary works and stockpiles,
  - In rehabilitated areas prior to vegetation establishment,
  - In drains, channels and other points of concentrated flow, and
  - At locations of high flow velocity.

  If stormwater ponds are proposed to be located on top of capped landfill cells, it should be demonstrated suitable engineering controls are in place to minimise the risk of leaking of stormwater into the landfill cell.

Appendix 11 – Minimum parameters for the monitoring program (landfill gas, leachate, groundwater, surface water and stormwater)

A site-specific monitoring program should be designed and implemented for landfill activities. The trigger levels for landfill gas (Table 22) and the expected minimum monitoring parameters for leachate (Table 23Table 23), groundwater (Table 24), surface water (Table 25) and stormwater (Table 26) are outlined below. Note that limits of reporting for samples should be sufficient to enable comparison with all relevant water quality and air quality objectives.

Table 22: Further investigation trigger levels for landfill gas monitoring.

Location	Parameter	Trigger level	Frequency[10]
50mm above the final and intermediate cover surface including batter slopes of the landfill	Methane	100 parts per million (volume/volume, 0.2% lower explosive limit)	Monthly
Subsurface monitoring	Methane	1% (volume/volume)	Quarterly
	Carbon dioxide	1.5% (volume/volume) above natural background levels	Quarterly
Enclosed structure within 250m of waste disposal	Methane	1% (volume/volume)	Monthly
	Carbon dioxide	1.5% (volume/volume)	Monthly

Landfill gas should not exceed:

- 25% of the lower explosive limit of the landfill site boundary when measured in facility structures (but excluding facility structures used for landfill gas control and recovery, and leachate collection system components).
- The lower explosive limit in subsurface geology at or beyond the landfill site boundary.
- 25% of the lower explosive limit within service pits, service trenches, stormwater drains or other structures beyond the landfill site boundary.

The landfill gas monitoring program should include parameters such as methane, oxygen, carbon dioxide, hydrogen sulphide and odour. The potential migration pathways, ground based utility structures and sensitive receptors should be considered when designing landfill gas monitoring network. The gas monitoring can be conducted in accordance with the method prescribed in the *Guidance on monitoring landfill gas surface emissions, Environment Agency UK, 2010.* The monitoring should be carried out to using methods such as infrared gas analysers, flame ionisation detectors (FID), or photo ionisation detectors (PID).

[10] Exceedances of trigger levels at the gas monitoring wells or subsurface structures will likely require the monitoring frequency to be increased from quarterly to monthly or monthly to fortnightly. When there is an elevated concentration of methane gas at the site boundary, a methane monitoring device with the data logger should be installed to provide real-time monitoring of methane levels.

Table 23: Monitoring parameters for leachate.

Quality Characteristic	Units of measure	Frequency	Sampling method
Electrical conductivity (EC)	µS/cm	Quarterly	Probe
pH	pH units	Quarterly	Probe
Standing water level in all leachate risers	mAHD	Quarterly	In-situ
Volume	m^3	Continuous	From flow metres or pumping record of the amount of leachate
Total dissolved solids	mg/L	Quarterly	Grab sample
Total suspended solids	mg/L	Quarterly	Grab sample
Major cations and anions (calcium, magnesium, potassium, sodium, chloride, carbonate + bicarbonate, and sulfate)	meq/L & mg/L	Quarterly	Grab sample
Fluoride	mg/L	Quarterly	Grab sample
Dissolved organic matter (total organic carbon, 5 day biochemical oxygen demand and chemical oxygen demand)	mg/L	Quarterly	Grab sample
Ammonia Nitrogen, Organic Nitrogen and oxidised nitrogen (nitrate, nitrite) as N	mg/L	Quarterly	Grab sample
Total phosphorus as P	mg/L	Quarterly	Grab sample
Metals (aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel and zinc)	mg/L	Quarterly	Grab sample
Organic contaminants: • phenols • petroleum hydrocarbons • monoaromatic hydrocarbons (in particular benzene, toluene, ethylbenzene and xylene) • organochlorine and organophosphate pesticides • polycyclic aromatic hydrocarbons	mg/L	Quarterly	Grab sample
Perfluoroalkyl Carboxylic Acids - C4 to C14 inclusive	ng/L	Quarterly	Grab sample
Perfluoroalkyl sulfonic Acids - C4 to C8 inclusive & C10	ng/L	Quarterly	Grab sample
Perfluoroalkyl Sulfonamide substances - C8	ng/L	Quarterly	Grab sample

Quality Characteristic	Units of measure	Frequency	Sampling method
n:2 Fluorotelomer Sulfonic Acids – where n = 4, 6, 8 & 10	ng/L	Quarterly	Grab sample
5:3 Fluorotelomer carboxylic acid (5:3 FTCA)	n/L	Quarterly	Grab sample

Table 24: Monitoring parameters for groundwater.

Quality Characteristic	Units of measure	Frequency	Sampling method
pH	pH units	Quarterly	Probe, field analysis
Standing water level	mAHD	Quarterly	In-situ
Total dissolved solids	mg/L	Quarterly	Grab sample
Major cations and anions (calcium, magnesium, potassium, sodium, chloride, carbonate, bicarbonate and sulfate)	mg/L & meq/L	Quarterly	Grab sample
Fluoride	mg/L	Quarterly	Grab sample
Total organic flourine	mg/L	Quarterly	Grab sample
Total organic chlorine	mg/L	Quarterly	Grab sample
Alkalinity (bicarbonate and carbonate)	mg/L & meq/L	Quarterly	Grab sample
Total organic carbon	mg/L	Quarterly	Grab sample
Ammonia and nutrients (nitrate, nitrite and phosphorus)	mg/L	Quarterly	Grab sample
Metals (aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel and zinc)	mg/L	Quarterly	Grab sample
Organic contaminants: • phenols • petroleum hydrocarbons • monoaromatic hydrocarbons (including benzene, toluene, ethylbenzene and xylene) • organochlorine and • organophosphate pesticides • polycyclic aromatic • hydrocarbons.	mg/L	Quarterly	Grab sample
Perfluoroalkyl Carboxylic Acids - C4 to C14 inclusive	ng/L	Quarterly	Grab sample

Quality Characteristic	Units of measure	Frequency	Sampling method
Perfluoroalkyl Sulfonic Acids – C4 to C8 inclusive & C10	ng/L	Quarterly	Grab sample
Perfluoroalkyl Sulfonamide substances - C8	ng/L	Quarterly	Grab sample
n:2 Fluorotelomer Sulfonic Acids – where n = 4, 6, 8 & 10	ng/L	Quarterly	Grab sample
5:3 Fluorotelomer carboxylic acid (5:3 FTCA)	ng/L	Quarterly	Grab sample

Table 25: Monitoring parameters for surface water.

Quality Characteristic	Units of measure	Frequency	Sampling method
Electrical conductivity (EC)	µS/cm	Quarterly	Probe
pH	pH units	Quarterly	Probe
Dissolved oxygen	Mg/L and % saturation	Quarterly	Probe
Total suspended solids	mg/L	Quarterly	Grab sample
Total Nitrogen (organic, oxidised and ammonia) as N	mg/L	Quarterly	Grab sample
Phosphorus as P	mg/L	Quarterly	
Total organic carbon	mg/L	Quarterly	Grab sample
Total organic flourine	mg/L	Quarterly	Quarterly
Total organic chlorine	mg/L	Quarterly	Quarterly
Major cations and anions (calcium, magnesium, potassium, sodium, chloride, carbonate + bicarbonate and sulfate)	Mg/L & meq/L	Quarterly	Grab sample
Enterococci, Escherichia coli & Thermotolerant coliforms (only when downstream waters may be used for stock water, drinking water or recreational uses)	CFU/100ml	Quarterly	Grab sample
Total dissolved solids	mg/L	Quarterly	Grab sample
Fluoride	mg/L	Quarterly	Grab sample
Perfluoroalkyl Carboxylic Acids - C4 to C14 inclusive	ng/L	Quarterly	Grab sample
Perfluoroalkyl Sulfonic Acids – C4 to C8 inclusive & C10	ng/L	Quarterly	Grab sample

Quality Characteristic	Units of measure	Frequency	Sampling method
Perfluoroalkyl Sulfonamide substances - C8	ng/L	Quarterly	Grab sample
(n:2 Fluorotelomer Sulfonic Acids – where n = 4, 6, 8 & 10	ng/L	Quarterly	Grab sample
5:3 Fluorotelomer carboxylic acid (5:3 FTCA)	ng/L	Quarterly	Grab sample

Table : Monitoring parameters for stormwater

Quality Characteristic	Units of measure	Frequency	Sampling method
pH	pH units	Quarterly	Probe
Total Suspended Solids	mg/L	Quarterly	Grab sample
Ammonia Nitrogen, Organic Nitrogen and oxidised nitrogen (nitrate, nitrite) as N	mg/L	Quarterly	Grab sample
Total organic carbon	mg/L	Quarterly	Grab sample
Electrical conductivity	µS/cm	Quarterly	Probe
Turbidity	NTU	Quarterly	Probe

Appendix 12 – Minimum expectations for groundwater monitoring wells

The design, number and location of groundwater monitoring wells should be sufficient to enable the detection of any contamination of soil and groundwater from the landfill activity. This is to be implemented through regular representative sampling of groundwater from the ground water monitoring network. The network should be maintained and repaired as required. The number of groundwater wells is informed by the hydrogeological risk assessment and is a function of:

- The type and depth of waste disposed.
- Groundwater and geological characteristics.
- Number and complexity of landfill cells.
- Complexity of the hydrogeology.
- Expected rate of movement of contaminants through the groundwater.
- Proximity of environmental and social receptors.

Groundwater monitoring wells should be located:

- Immediately down gradient of the leachate source but no closer than 10 metres from the edge of a landfill area.
- Further down gradient to identify impacts outside the landfill.
- Up hydraulic gradient for monitoring of the background quality of groundwater flowing into the site. If this is not possible, down-gradient samples should be taken before construction of the landfill commences to establish background groundwater characteristics.
- Across the groundwater flow gradient to capture changes in groundwater flow direction.
- The slotted or screened sections of groundwater wells should align with the aquifer characteristics identified during the site investigation. If only one thin aquifer (less than 5 metres thick) is identified, single fully-slotted wells are sufficient. If there are multiple aquifers or an aquifer greater than 5 metres thick, the monitoring wells should be a nest of wells slotted over different intervals, a multi-port well, or an appropriate combination of both. Groundwater wells that monitor different aquifers should be as close to one another as practicable so that comparisons can be made.
- The screened sections of groundwater wells should extend through the upper 5 to 10 metres of saturated aquifers, or in the case of fractured aquifers into the first water-bearing zone.

Groundwater monitoring wells should be designed, constructed, maintained and repaired in accordance with *Minimum Construction Requirements for Water Bores in Australia, Fourth Edition 2020 (National Uniform Drillers Licensing Committee, 2020).* Each ground water well should:

- Have a minimum internal diameter of 50mm.
- Be constructed of suitable strength pipe materials.
- Include gravel-packed slotted sections comprising material that will not affect sample accuracy.
- Include cement or bentonite seals bentonite seals between the slotted sections.
- Be sealed and secured at ground level.

Be constructed in a way to prevent entry of surface water and other material. The performance of groundwater wells can be affected by the deposition of clay or silt particles, chemical precipitates and/or bacterial deposits that can accumulate in the groundwater well and block the screen. The monitoring program for groundwater should include measurement and recording of well depth to monitor solids accumulation as well as changes to yield over time.

The groundwater monitoring network should be well documented including the location, depth and screened sections of all groundwater wells. Drilling and construction of groundwater monitoring installations should be included in the CQA plan and report for the landfill site.

Appendix 13 – Minimum expectations for waste placement and compaction

The minimum expectations for waste placement and compaction are:

- Maintain an active tipping area that is as small as possible.
- Keep covering waste to maintain the active tipping area at less than 30 metres x 30 metres or as modelled as part of an odour impact assessment and leachate water balance. The active tipping area should be reduced on high and extreme fire danger days to less than 250 m^2.
- Place waste so that all unconfined faces are mechanically stable and capable of retaining cover material.
- Compact all waste deposited in the landfill.
- Place waste at the base of each lift and compact wastes in layers of less than 2 metres.
- Avoid unconfined waste slopes with gradients steeper than 2 horizontal to 1 vertical unit.
- Undertake surveys to monitor density being achieved and assess compaction efficiency.

Appendix 14 – Minimum expectations for landfill cover

The minimum expectations for landfill cover for all landfill classifications are:

- Daily cover at the end of each day's operation should be a minimum of 200mm deep and a maximum of 500mm deep.
- Daily cover should be non-combustible material.
- Daily cover should be recovered as far as practicable at the start of each working day for reuse and to decrease the potential for perched water.
- Maintain a stockpile of daily cover on site sufficient for at least two weeks of waste disposal operations.
- Apply a minimum of 300mm interim cover where no additional waste is disposed of for 30 days or more.
- Waste including shredded waste should not be used as cover. This includes wastes or shredded waste that are mixed with other cover materials.

Appendix 15 – Minimum expectations for a landfill environmental management plan

The minimum expectations for a landfill environmental management plan (LEMP) include:

- Legislative requirements and summary of standards and guidelines that have been referenced in the development of the LEMP.
- Location of the landfill including zoning, ownership details, applicable separation distances (see Appendix 1) and surrounding land-use activities.
- Summary of site conditions, the environmental baseline and CSM including climate, topography, geology, hydrogeology, groundwater and surface water.
- Site layout plan identifying infrastructure key to the management of environmental risks.
- Hours of operation and security provisions.
- Nature of operation and capacity including waste types, filling plan (e.g., rates, methodology), lifespan and related onsite activities (e.g., any resource recovery activities).
- Management structure including clearly defined roles and responsibilities of personnel.
- Technical process and design consistent with the design report for the landfill site to outline the performance criteria for the liner and leachate management system, interface between cells (as appropriate), capping and final landform, landfill gas management and stormwater management.
- Operational practices, maintenance and measures to manage amenity impacts, including those outlined in section 8.
- Operational record keeping including environmental records and reports.
- Site materials and equipment and machinery.
- Emergency response procedures.
- Contingency plans and emergency procedures to deal with foreseeable risks and hazards including corrective responses to prevent and mitigate environmental harm.
- Procedure for handling of environmental complaints.
- Staff training and awareness of environmental issues related to the operation of landfill facility.
- Monitoring programs and reporting procedures for:
    - Groundwater, surface water, leachate and landfill gas,
    - Amenity impacts (odour, dust, noise, litter, fire, light, visual, vermin and disease vector control and site security) as required,
    - Internal audits, and
    - Requirements for recording and reporting monitoring outcomes.

LEMPs will be progressively reviewed and updated as site practices and circumstances change. LEMPs should be reviewed on an annual basis as part of the landfill site's quality management process.

Appendix 16 – Minimum expectations for closure plan, rehabilitation plan and post closure plan

The minimum expectations for a landfill closure plan, rehabilitation plan and post closure plan are outlined in Table .

Table : Minimum expectations for closure, rehabilitation and post closure plan

Stage	Item
All	Define the overall aims of the plan, including: • Prevention of environmental harm, • Achieving the specified post-closure land-use, • Delivering the closure solution based on the site location, design and operation proposed at the facility's commencement, and • Delivering a permanent long-term solution. Outline overall steps and anticipated timeframes across the closure, rehabilitation and post closure phases, including detail on the key work milestones and an overall programme of closure, rehabilitation and post closure.
Closure plan	Define the objectives of closure for the site and who is responsible for the various elements of closure. Details on the following: • Detailed design of each closure element, including technical specifications for the materials and the CQA process that will apply to each element. • Programme and sequence of work for progressive closure of each individual landfill cell. The closure plan should be progressively updated to reflect variations to the landfill design, changes to the EA or other relevant changes and submitted to the administering authority. The closure plan is approved by a RPEQ.
Rehabilitation plan	Define the objectives of rehabilitation for the site and who is responsible for the various elements of rehabilitation. Details on the following: • Erosion control and slope stabilisation, • Final surface grading and contouring, • Vegetation establishment and maintenance, • Installation of new infrastructure (as applicable), • Public access and recreational facilities (as applicable), and • Emissions monitoring, management and treatment during the rehabilitation stage. The rehabilitation plan should be progressively updated to reflect variations to the landfill design, changes to the EA or other relevant changes, and approved by a RPEQ.

Stage	Item
Post closure plan	Define the objectives of post closure for the site and who is responsible for the various elements of post closure. Details on the following: • Long term emissions monitoring, management and treatment, • Long term maintenance, inspection and repair of emissions monitoring and control systems (landfill gas, leachate, stormwater), • General ongoing site maintenance and management, • Plans for any infrastructure that needs decommissioning, and • A process to review and update ensuring continuous improvement at least once every 2 years. The post-closure plan is approved by a RPEQ certified engineer and submitted to the administering authority no later than 12 months prior to the closure of the landfill facility.

Appendix 17 – Minimum expectations post-closure and for a certified statement of completion

The minimum expectations for a certified statement of completion include:

- Developed and approved by a RPEQ.
- That confirmation is developed as soon as reasonably practicable once post-closure works are all completed and this is progressively recorded. Depending on the site-specific circumstances, the post-closure phase may take many decades.
- Records provide evidence that the works were completed in accordance with the closure plan, rehabilitation plan and post-closure plan.
- Provide evidence that final capping of landfill cells is stable.
- Provide evidence that the landfill no longer presents a risk of environmental harm following cessation of active management of the rehabilitated cap, leachate, stormwater and landfill gas. Evidence should include appropriate monitoring data and assessment of risk by a AQP and consideration of the future performance of the containment system, including provision of recent monitoring data.
- Provide evidence that the site does not pose an amenity risk in terms of odour, dust, noise, litter, fire, light, visual, vermin or security.
- A declaration from a RPEQ that there is sufficient information to demonstrate the above is true.