Wastewater

Guidelines

Wastewater lagoon construction

Updated April 2019

EPA 509/19: This guideline replaces Wastewater and evaporation lagoon construction (2004). *It advises those proposing to build wastewater lagoons on construction techniques that should assist in meeting obligations under the* Environment Protection Act 1993 *and relevant environment protection policies. The guideline is intended for wastewater lagoon proponents and their engineers or consultants. This guideline is not intended for leachate lagoons for landfill facilities. For further guidance on the requirements for landfill facilities, refer to* Environmental management of landfill facilities – solid waste disposal.

Purposes of the guideline

The principal objectives of this guideline are to:

- safeguard the protected environmental values of surface or groundwater
- minimise the potential for site contamination
- provide clarity regarding criteria used for the assessment of wastewater lagoon proposals
- assist wastewater lagoon proponents in meeting the requirements of:
  - the *Environment Protection Act 1993* (the EP Act) and
  - relevant environment protection policies (EPP).
- provide guidance on reasonable and practicable measures to prevent or minimise environmental harm resulting from undertaking an activity that pollutes or might pollute waters (in compliance with the general environmental duty in section 25 of the EP Act).

The guideline will apply to new lagoon proposals and is not intended for lagoons that are already in place before the implementation of this guideline. Proponents who are upgrading existing lagoons should have regard to this guideline.

A note on terminology:

- The term **should** is used where a particular course of action is considered by the EPA as best practice.
- The term **must** is used where a failure to comply with the action stated in the guideline will, in the EPA's view, expose the environment to a risk of harm or may lead to a breach of the EP Act or relevant EPPs.

EPA South Australia

Summary of engineering requirements to meet environmental obligations

Proponents must:

1 obtain the relevant information in order to complete the risk assessment matrix provided in Appendix 1

2 be guided by the corresponding recommendations of Appendix 2 in developing a design for their wastewater lagoon

3 demonstrate that the design and construction will ensure the ongoing integrity of the lagoon lining.

By doing so, proponents and operators can demonstrate that all reasonable and practicable measures have been taken to prevent or minimise any resulting environmental harm to waters from their wastewater lagoons in accordance with section 25 of the EP Act and relevant EPPs.

The below is intended to summarise the key engineering requirements and reference pages within this document which provide further information, context and reading.

For all wastewater lagoons:

- Lagoons must be designed and constructed so that wastewater in the lagoon cannot intersect any underlying seasonal water table. p. 7
- Lagoons must be designed and constructed so as not to be liable, as far as practicable, to inundation or damage from flood waters. p. 7
- Lagoons must be designed and constructed to ensure that the contents of the lagoon do not overflow (unless the overflow has been contemplated in the approved design and normal operation) into waters or onto land in a place from which they are reasonably likely to enter any waters. p. 8
- Lagoons must be constructed with an appropriate liner which achieves the required permeability criteria and minimises leakage. p. 9
- The prepared subgrade must be proof-rolled to determine the presence of zones that may require subgrade improvement. The subgrade must be smooth and free of stones prior to geosynthetic liner placement. p. 9
- Lagoons must be designed and constructed in accordance with appropriate leakage detection requirements. p. 11

For lagoons with in-situ clay lining:

An extensive investigation must be conducted by a geotechnical professional to confirm the efficiency of this barrier. p. 9

For lagoons with constructed clay-lining:

- The compacted clay liner must have a minimum thickness of 300 mm and be constructed in two layers of 150 mm following compaction with an in-situ coefficient of permeability of less than 1×10^{-9} $m.s^{-1}$. p. 10
- The finished liner thickness must be surveyed to confirm it meets the design specifications and be tested in-situ to ensure that it meets the specified permeability criteria (AS:1289 6.7.3). p. 10

For lagoons with geosynthetic lining:

- A layer of the geosynthetic liner must be anchored (in accordance with manufacturers' guidelines) to cover the entire floor and all sloping sides of the lagoon. p. 11
- All welded joints and seals must be watertight. Geomembranes must be free of blisters and contaminants. p. 11
- Geosynthetic linersmust be laid in accordance with manufacturer's specification. p. 11
- Geomembranes must be assessed for liner integrity. Geoelectric testing through a liner integrity survey assessment (LISA) is recommended. p. 11

- GCLs must be confined by at least 6–8 kpa. This pressure can be achieved by applying a minimum 300 mm of non-dispersive fine grained soil which will confine a swelling GCL when it becomes hydrated p. 11
- Appropriate thickness of geomembrane liner must be determined by the proponent's engineer/consultant based on wastewater characteristics, groundwater/aquifer characteristics, climatic factors and warranty considerations p. 11

Introduction

Wastewater[1] management is an inherent aspect of many industrial operations. Wastewater from sewage treatment facilities, food, beverage and agricultural processing activities, and effluent from animal husbandry activities also contain valuable nutrients that are beneficial for crop production.

The EPA advocates the waste management hierarchy and recognises the importance of recycled water as an alternative water supply. For this reason, the EPA supports the reuse of treated wastewater provided it is undertaken in a sustainable manner.

Lagoons (or ponds) have been used extensively in the past to collect, naturally treat, store (prior to reuse or discharge) or dispose of wastewater via evaporation. The uses and applications of these lagoons have increased in recent times. However, poorly constructed lagoons can lead to surface and groundwater pollution as well as odour and health impacts.

This document provides basic guidance on the siting, construction and lining of wastewater lagoons. It covers the types of lagoons which, treat or store water with a higher concentration of pollutants, are constructed for the purpose of treating a waste stream, or represent a significant risk to the environment, including;

- wastewater treatment, recycled water storage, polishing and evaporation lagoons used in sewage treatment facilities; food, beverage and agricultural processing industries; animal husbandry activities; and aquaculture purposes
- wastewater sedimentation basins, leachate ponds for composting activities, irrigation dams used for holding and mixing treated or untreated wastewater, and ponds on industrial sites used for capturing potentially contaminated stormwater runoff from their premises
- processing and wastewater lagoons for chemical, manufacturing and mining industries[2]
- lagoons used for digestion, dewatering and drying wastewater and water treatment sludge.

The term 'wastewater lagoon' will be used collectively in this document to refer to all of the above. Constructed wetlands and lagoons used to store irrigation runoff or public stormwater are considered forms of wastewater lagoon. This guideline only applies insofar as requiring that a person who constructs a lagoon of this type must take all reasonable and practicable measures to prevent or minimise environmental harm to waters resulting from that activity. This guideline does not provide guidance on the detailed construction of such lagoons.

Guidance on the design and construction of constructed wetlands and treatment wetlands is provided in the Further Reading section.

[1] Wastewater includes (a) human wastewater (b) sewage and (c) water containing food or beverage waste (d) wash down water or cooling water (e) irrigation runoff or stormwater (f) water containing any trade or industrial waste (g) a combination of any one or more of the above.

[2] Guidance on the construction requirements of tailings dams is provided in the *Guidelines for miners: tailings and tailings storage facilities in South Australia*, Minerals Regulatory Guidelines MG5, Primary Industries and Resources South Australia and Environment Protection Authority (SA) 2009.

The guideline does not include lagoon sizing, operation, biochemistry, sampling[3] and effluent reuse[4]. Proponents are advised to seek assistance from suitably qualified and experienced professionals[5] when designing and constructing wastewater lagoons, as well as when addressing the other aspects.

Legislation

The principal legislation addressing pollution in South Australia is the EP Act. In particular, section 25 imposes a general environmental duty on all persons undertaking an activity to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

Environment protection legislation also includes environment protection policies, which may specify required outcomes (enforceable by way of an environment protection order) or impose mandatory requirements for the protection of a particular aspect of the environment. This may include obligations on certain industries to incorporate a wastewater management system[6], which may include a wastewater lagoon.

Persons intending to construct wastewater lagoons should also be aware of the requirements and provisions of the *Development Act 1993* (and *Regulations 2008*) and other legislation in relation to obtaining the relevant approvals.

Approval and operational requirements

Wastewater lagoon proposals are normally assessed by the EPA as part of development applications for wastewater treatment facilities or industrial developments. Conditions relating to the design, construction and commissioning of the lagoon can be imposed by the relevant planning authority following advice or direction from the EPA. In the case of licensed facilities, the EPA may also include conditions in the licence for ongoing risk assessment (monitoring) of the integrity of wastewater lagoons at the premises. This risk assessment could be in the form of geoelectrical integrity assessment, monitoring of leakage detection systems, groundwater monitoring and water balance monitoring.

In order to complete the assessment of a wastewater lagoon proposal, the EPA will need sufficient information to appropriately assess the risk. The information required by the EPA can be broadly categorised as:

- siting of the lagoon to assess risk based on proximity to watercourses and groundwater, roads and sensitive receptors
- nature of the wastewater to assess reactivity and potential for harm
- design of the lagoon and details of construction (depth, volume, subgrade, lining, leak detection and embankments) to assess containment risk.

These factors will influence and are required to complete the assessment of any proposed wastewater lagoon by the EPA. Failure to provide this information in a clear form will prolong the assessment process. Details regarding these factors and the assessment process are provided throughout this document.

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3 Guidance on wastewater and groundwater sampling are provided in *Regulatory monitoring and testing – water and wastewater sampling* (EPA 2007) and *Regulatory monitoring and testing – groundwater sampling* (EPA 2019) respectively.

4 Guidance on wastewater reuse for irrigation is provided in *Wastewater irrigation management plan (WIMP) – a drafting guide for licensees* (EPA 2009).

5 Selected consultants must demonstrate competencies and experiences relevant to the work to be undertaken; comprehensive knowledge of the EP Act and associated legislation, policies and guidelines; and knowledge of scientific literature and technologies relevant to the work to be undertaken.

6 A wastewater management system is designed and operated for the purpose of collecting and, managing wastewater so as to minimise the adverse impacts of the wastewater to the environment.

The *Environmental management of landfill facilities – solid waste disposal* (EPA 2019) provides guidance on the preparation of technical specifications and As Constructed Reports (ACR).

The scope and detail of required technical specifications or reports will depend on the nature and complexity of the project, and the sensitivity of the location. The EPA recommends that proponents discuss these requirements with the EPA prior to lodging their development application. Technical design specifications at a minimum should address;

- physical properties of clay liners
- material properties of geosynthetic liners
- construction detail and methodology

Depending on the nature and complexity of the proposal the EPA may require an application to include specific technical documents such as a Construction Quality Assurance (CQA) Plan and a Construction Management Plan (CMP).

The CQA Plan assures construction quality and demonstrates to stakeholders (owner, contractors, consultants, regulator and the general public) that all reasonable and practicable measures have been taken to ensure the integrity of the lagoon and prevent water pollution.

The CMP provides a means of managing potential environmental risks (eg noise, dust and water pollution) during construction to ensure compliance with section 25 of the EP Act.

Once construction is completed and before a lagoon is commissioned, proponents may also be required to submit an As Constructed Report (ACR) to confirm whether the lagoon was constructed in accordance with the technical specifications.

EPA risk assessment process

The EPA uses a risk-based approach when determining the construction and type of liner required for a particular lagoon proposal by considering groundwater, wastewater characteristics and nature of the wastewater lagoon. The EPA has developed a risk assessment matrix (RAM), illustrated in Appendix 1, which is to be used in conjunction with the Table of Suggested Construction and Lining Categories (SCL) shown in Appendix 2.

The SCL table outlines the EPA's preferred level of risk management corresponding with the output of the RAM. The EPA's preference regarding risk management may include suggestions regarding type of lining, CQA and requirement for ongoing leakage detection. An explanation of criteria and terminologies used in both appendices is provided in Appendices 3A and 3B.

To enable assessment of a proposed wastewater lagoon, proponents must obtain and provide the relevant information described in Appendices 1 and 2 with their application.

It should be noted that the content of Appendices 1 and 2 was developed as a tool for the EPA to efficiently and effectively assess applications to construct wastewater lagoons. Proponents are encouraged to contact the EPA or a suitably qualified consultant to discuss the use of Appendix 1 and 2 prior to finalising the lagoon lining and construction details.

While the EPA would prefer that a wastewater lagoon be designed based on the requirements suggested after using the RAM and the SCL table, a lower construction and lining category may also be approved if appropriate risk management measures are to be implemented. Likewise, an alternative lining technology or combination will also be considered if the proponent can demonstrate that it would achieve a similar or better outcome than that suggested under the relevant category in the table of Appendix 2.

Siting of the wastewater lagoon

To minimise the impacts of odour, the risk of leakage to groundwater and the risk of polluting groundwater or surface waters, the construction of wastewater lagoons should be avoided in the following locations[7]:

- within the floodplain known as the '1956 River Murray Floodplain' or any floodplain that is subject to flooding that occurs, on average, more than one in every 100 years
- within 100 metres of a bank of a major watercourse (eg Murray, Torrens, and Onkaparinga Rivers), or within 50 m of a bank of any other watercourse[8]
- within 500 m of a high-water mark
- within an area where the base of the lagoon would be less than 2 m above any seasonal water table
- within 200 m of a busy public road (>50 vehicles per day)
- within 50 m of other public roads (<50 vehicles per day), and
- in areas where a potentially contaminating activity[9] has been undertaken.
- Construction of wastewater lagoons may be allowed in these areas provided appropriate risk management measures are undertaken with the approval of the EPA.

Separation distance considerations

The *Evaluation distances for effective air quality and noise management* (EPA 2019) provide recommended separation distances to prevent odour and noise impacts on sensitive receptors (for example dwellings) from aerated and facultative lagoons in sewage treatment works and community wastewater management systems (CWMS), wineries and distilleries.

Separation distances for recycled water storage lagoons are not specified. This is because air (odour) and noise issues are not generally associated with these lagoons, providing wastewater has been treated to minimise odour and they contain no mechanical treatment processes which generate noise. For recycled water storage lagoons a site-specific assessment should be undertaken to determine appropriate separation from sensitive receptors.

The guideline also outlines recommended separation distances for food and agricultural operations. The EPA will make an assessment on a case-by-case basis regarding wastewater lagoons associated with these operations. In some cases, the EPA may require the proponent to undertake odour measurements based on the *Ambient air quality assessment* (EPA 2016).

Guidance on the determination of suitable separation distances for piggery and feedlot effluent lagoons is provided by the following documents;

- *National environmental guidelines for indoor piggeries* (2018)
- *Guidelines for the Establishment and Operation of Cattle Feedlots in South Australia* (2006)
- *National Guidelines for Beef Cattle Feedlots in Australia* 3rd edition (2012)

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7 Proponents are advised to seek guidance from other agencies about other possible siting restrictions.

8 Watercourse means (whether or not temporarily wet or temporarily dry) a river, creek or other natural watercourse (whether modified or not), a lake, wetland, swamp, dam or reservoir or other body of water that collects water or through which water flows, the Coorong, an artificial channel, a public stormwater system and includes part of a watercourse.

9 A potentially contaminating activity (PCA) is an activity that has an increased risk of introducing chemical substances on or below the surface, above background concentrations, that may result in site contamination. PCAs are prescribed in the *Environment Protection Regulations 2009*. If a PCA has been undertaken at the site, an environmental site assessment is necessary to confirm whether it is suitable for wastewater lagoon construction. Further information: https://www.epa.sa.gov.au/environmental_info/site_contamination/assessment_and_remediation

Groundwater considerations

The major environmental concern of wastewater lagoons is the potential leakage to or intrusion of groundwater. There is also the risk that a rising seasonal water table could also impact on the integrity of the lagoon liner.

The level of lagoon lining and construction will depend on the type of aquifer, occurrence and depth to groundwater in the proposed location, and groundwater usage and quality. A wastewater lagoon must be designed and constructed so that wastewater in the lagoon cannot intersect any underlying seasonal water table. The minimum required distance between the engineered subgrade to the liner and the water table should be decided based on site-specific risks. Further information on groundwater characteristics that are relevant for risk assessment is provided in Appendix 3A.

Drainage provision will be required by the EPA where the completion of the risk assessment matrix (Appendix 1) indicates a category 6 design requirement. This will be triggered if there is potential for groundwater to intersect the base of the lagoon liner.

Flooding considerations

Depending on lagoon siting, engineered flood mitigation controls may need to be considered. A wastewater lagoon must be designed and constructed so as not to be liable, as far as practicable, to inundation or damage from flood waters.

Nature of the wastewater

Depending on inputs and processes, wastewaters contain a range of pollutants (eg organics, nutrients, salts, metals and microbiological organisms) the character of which can vary with the production cycle. In order to assess the suitability of a proposed wastewater lagoon, details regarding the nature and variability of the wastewater that is to be introduced to the proposed lagoon must be provided to the EPA.

One particular concern is the potential for the wastewater to react with, and compromise, the material selected to line the lagoon to minimise leakage.

Acidic, alkaline or saline wastewater (from wineries, distilleries and reverse osmosis plants) could react with clay and compromise the long-term integrity of clay liners. Chemical and manufacturing industries often involve hazardous substances that require the highest level of lagoon lining and construction. In the case of lagoons used in mining projects, innovative testing, design and construction approaches are often required to cope with harsh conditions in these environments[10].

Recycled water presents less environmental risk as the wastewater has undergone secondary and/or tertiary treatment to reduce chemical pollutants and biological contaminants. However, the level of treatment will correspond to the end-use requirements to ensure the water is fit for purpose. This results in a highly variable recycled water quality (particularly in terms of chemical pollutants such as nutrients) which in most cases means a risk to groundwater and surface water remains. As a result the need to prevent those nutrients from entering groundwater or surface water is required.

This risk is also increased due to the volume of recycled water held in storage (or its ‘hydraulic head’) in terms of overflow or liner leakage. The extent of engineering requirements to meet environmental obligations may be reduced in some cases, however generally, standard lagoon lining requirements and leakage detection will be needed according to the outlined risk-based approach.

The level of lagoon lining and construction will need to consider the nature, reactivity and variability of the wastewater that is to be introduced to the lagoon. Further information on wastewater characteristics that are relevant for risk assessment is provided in Appendix 3A.

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[10] Common challenges in mining applications include very high loads, harsh environments, remote locations, compressible subgrade fills and foundation stabilisation over historic mine workings (Lupo and Morrison 2003).

Design of the wastewater lagoon

Nature and depth

The contained wastewater exerts 'hydraulic head' or water pressure, which is proportional to the depth of water in the lagoon. This pressure could impact on liner performance. Depth could vary depending on the type of lagoon and the capacity requirements of the site. Further information on types of lagoons is provided in Appendix 3A.

Evaporative lagoons are normally less than one metre in depth so the hydraulic head is often not an issue. However, clay linings are not considered suitable because the liner may shrink and crack if the lagoon dries out. Unless mechanisms to prevent desiccation of the clay liner are included in the design, geosynthetic liners will be recommended by the EPA.

Treatment lagoons rely on either mechanical aerators (eg aerated lagoons, activated sludge lagoons, sequencing batch reactors), or natural biological processes (eg aerobic, anaerobic, facultative lagoons) to remove organics and nutrients[11]. Mechanically aerated lagoons[12] are normally deeper with a wider radius to accommodate the aeration equipment and facilitate the mixing process. In such cases, the EPA recommends that proponents engage a suitably qualified engineer experienced in geosynthetic lining systems.

For very large lagoons, the environmental consequences of liner failures are also very high. It is recommended that smaller lagoon sections are constructed to minimise impacts to groundwater from accidental damages, and to facilitate desludging, repair and regular maintenance.

Storage lagoons holding recycled water are generally large to maximise storage capacity, and deep to minimise evaporation and footprint. Geosynthetic liners are recommended. For very large lagoons and where appropriate the use of in-situ clay lining may provide a more cost feasible option. In such cases, the EPA recommends that proponents engage a suitably qualified engineer experienced in clay lining systems.

Volume and overflow

Lagoons must be designed and constructed to ensure that the contents of the lagoon do not overflow (unless the overflow has been contemplated in the approved designed and normal operation) into waters or onto land from where the contents reasonably likely to enter any waters.

The capacity of the lagoon should be such that, in addition to the stored wastewater arising from an average year's net inflow and discharge, it can deal with rainfall runoff without overflowing. The EPA recommends a minimum 600 mm freeboard to prevent overflow arising from normal rainfall events and wind-driven waves.

A one-in-25-year, one-day duration storm event on the contributing catchment (with rainfall intensity based on the local catchment area and runoff estimated based on the procedures set out in *Australian rainfall and runoff – a guide to flood estimation* has traditionally been used as a guide. However, as consequences of overflow could vary depending on location and community sensitivities, it is recommended that a risk assessment be undertaken to determine the appropriate lagoon capacity or freeboard allowance for a particular scenario.

The cost of wastewater management increases with the volume of water handled by the system. The EPA recommends stormwater inflows from other areas be minimised by raising lagoon embankments and diverting clean stormwater from the lagoon.

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11 It should be noted that such treatments alone are not adequate to remove the nutrients and salts in wastewater. In the case of nutrient-rich wastewaters, tertiary (or polishing) treatment is often necessary to further reduce the nitrogen and phosphorus components. In the case of saline wastewaters, cleaner production alternatives or advanced treatment (eg reverse osmosis) is necessary to reduce the salt loads.

12 In the case of mechanically aerated lagoons lined with geosynthetic liners, they also require ballast on the liner to prevent the uplift of liner and to support the aerator when the water level is lowered (Peggs 2007).

Any overflow should be treated as contaminated wastewater and captured on site. This overflow could be returned to the lagoon when capacity permits, or transported to an EPA licensed wastewater facility capable of accepting the liquid.

The *Code of practice for wastewater overflow management* (EPA 2017) provides guidance to assist wastewater system operators to prevent the occurrence of overflows and to minimise the frequency and volume of such overflows.

Embankments

The EPA recommends that side walls should generally have batter slopes not exceeding a gradient of one vertical to three horizontal (1:3) to enable proper access during compaction of the subgrade, liner and fill. In the case of clay-lined lagoons, consideration of the mechanical strength of the wall to withstand erosion from rainfall and stormwater runoff is required. The internal faces should be protected from erosion that might be caused by wind-driven waves. Internal lagoon banks must be kept free of vegetation that could cause liner damage. Trees must not be allowed to grow in either the base or on banks of the lagoon.

Hydraulic design

Good hydraulic design of a lagoon (particularly larger lagoons) incorporating appropriate compartments, baffles and inlet/outlet structures is important in the design phase to ensure treatment efficiency and reduce short circuiting. Consideration of hydraulic design requirements and how this will be coordinated with lagoon lining requirements is essential. The design should be supported by relevant published documentation.

Lining and subgrade materials

All wastewater lagoons must be constructed with an appropriate liner which achieves the required permeability criteria and minimises leakage. The three main lining categories are;

- in-situ clay lining
- constructed clay lining
- geosynthetic liners

Generally the EPA recommends geosynthetic liners over clay lining due to the ability to incorporate effective leakage detection systems in the design and construction of the lagoon.

Subgrade preparation

In the case of compacted clay-lined lagoons and lagoons lined with geosynthetic liners, good subgrade preparation is necessary to provide a sound and stable base for liner construction. Topsoil and organic material should be removed. The subgrade should be compacted to achieve a minimum dry density ratio of 95% relative to standard compaction (AS 1289 5.1.1) to a minimum depth of 150 mm. The prepared subgrade must be proof-rolled to determine the presence of zones (such as uncontrolled fill, voids and weak or compressible materials that are susceptible to collapse) that may require subgrade improvement. The subgrade must be smooth, unyielding and free of stones prior to geosynthetic liner placement.

In-situ clay lining

Where the natural geology of the site is proposed as the barrier system, an extensive investigation must be conducted by a geotechnical professional to confirm the efficiency of this barrier. The in-situ clay liner should be ripped and compacted in-situ. This assessment should include:

- the distribution of aquifers, groundwater flow and groundwater quality

- the depth, extent, geotechnical integrity of the barrier layer/liner, eg presence of any imperfections that may compromise its effectiveness (such as root holes, cracks, gravel layers), and dispersivity[13] when wet
- the permeability of the material to the wastewater to be stored at varying water contents and bulk densities[14]
- any possible reactions between the barrier layer/liner and the wastewater to be stored.

Constructed clay lining

The EPA expects that the material used as a clay liner be well graded, of low permeability and conforms to the particle size distribution, plasticity index and other characteristics listed in Appendix 4A.

The material should be free of topsoil, tree roots and organic matter, and compacted to achieve a minimum dry density ratio of 95% relative to standard compaction (AS 1289 5.1.1). The compacted clay liner must have a minimum thickness of 300 mm and be constructed in two layers of 150 mm each following compaction with an in-situ coefficient of permeability of less than 1×10^{-9} $m.s^{-1}$. The finished liner thickness must be surveyed to confirm it meets the design specifications and be tested in-situ to ensure that it meets the specified permeability criteria (AS: 1289 6.7.3).

An effective bond should be created between successive layers. Prior to placement of each layer the surface of the previous layer should be scarified and moisture conditioned if necessary, to bond the layers to prevent laminations at the layer interface. The final surface should be smooth and evenly graded.

Clay lining should be maintained to avoid desiccation during construction. Also if water is encountered while preparing earthworks[15], the site should be dewatered and dried to an appropriate level before being lined with clay.

Geosynthetic liners

Geosynthetic liners may be used as an alternative or supplement to a compacted clay liner and could be in the form of:

- geosynthetic clay liner (GCL)
- geomembrane
- combination of GCL and geomembrane
- combination of GCL or geomembrane and other material that meets permeability criteria.

A brief discussion of key considerations for the various situations regarding available materials is presented below. This is in no way meant to be exhaustive and proponents are encouraged to contact the EPA or a suitably qualified consultant to discuss this in detail.

Geosynthetic clay lining

A GCL is normally fabricated by incorporating bentonite or other clay into a woven fabric. There are two types of bentonite, powdered and granulated. Powdered is preferred, however where granulated is specified then it must be hydrated before confinement to prevent leakage. GCL could be used as a replacement for clay lining in wastewater lagoons. Due to its nature, the material is not suitable for reactive wastewaters subject CEC (cation exchange capacity) assessment.

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13 The physical separation of primary soil particles from one another.

14 The oven-dry mass of a soil divided by its total volume.

15 The suitability of the site and design of the lagoon may need to be reconsidered if a perched water table is encountered.

Geomembranes

The most common geomembrane used for wastewater lagoon lining is HDPE (high-density polyethylene). This is preferred for its durability, however this material could fail due to stress cracking[16] and extended UV exposure.

Key considerations

Considerations in the installation of geosynthetic liners include the following:

- A layer of the geosynthetic liner must be anchored (according to manufacturers' guidelines) to cover the entire floor and all sloping sides of the lagoon.
- All welded joints and seals must be watertight.
- Geomembranes must be free of blisters and contaminants.
- Geosynthetic liners must be laid according to the manufacturer's specifications.
- Geomembranes must be assessed for liner integrity. Geoelectric testing through a liner integrity survey assessment (LISA) is recommended.
- GCLs must be confined by at least 6–8 kpa. This pressure can be achieved by applying a minimum 300 mm of non-dispersive fine grained soil which will confine a swelling GCL when it becomes hydrated. This will ensure liner permeability and performance is maintained. The confinement layer must be placed immediately following GCL installation.
- Venting infrastructure may be necessary depending on site and specific lagoon characteristics.
- Appropriate thickness of geomembrane liner must be determined by the proponent's engineer/consultant based on wastewater characteristics, groundwater/aquifer characteristics, climatic factors and warranty considerations.
- Further guidance on the installation of geosynthetic liners is provided in the *Environmental management of landfill facilities – solid waste disposal* (EPA 2019).

As part of the ACR, the EPA may require documentation confirming that the geomembrane liner used complies with the specified requirements for the purpose and has been installed based on the specifications and manufacturer's requirements. Product and installation warranty documentation should also be retained, and inspection and maintenance requirements associated with the warranty should be followed. Products with guaranteed service life of not less than 20 years are preferable.

Leakage detection

Detection of lagoon leakage can be undertaken using a number of methods including geoelectrical integrity assessment, leakage detection systems, groundwater monitoring and water balances (or a combination of methods). Consideration of specific leakage detection requirements for liner quality assurance at installation, scheduled maintenance (such as desludging) and ongoing monitoring are required based on site-specific risks. Lagoons must be designed and constructed in accordance with appropriate leakage detection requirements. Liner design engineers can recommend lagoon leakage detection technologies that are suitable for a specific application.

For geomembrane lined lagoons, a liner integrity survey assessment undertaken using electrical methods[17] at installation and after scheduled maintenance is considered the most effective method to assess the integrity of the liner and long term performance. These methods can also be used for ongoing monitoring purposes as required.

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[16] Stress cracking within seams, which is a function of the stress cracking resistance of the specific HDPE resin and the effectiveness of its antioxidant additives often arises from overheating of the seams and geomembrane during installation (Peggs 2003).

[17] These methods are based on the premise that a geomembrane liner is an effective insulation, and that if an electrical potential is applied across the thickness of a geomembrane, the only way a significant current can flow is through a hole in the seam (Peggs 1990)

The installation of leakage detection systems during construction is another effective method to assess the ongoing integrity of the liner. Such systems are normally designed using geocomposite drainage layers under the primary liner, draining at a minimum grade of 1% to a sump, that must be located at the lowest point of the lagoon and be accessible via a riser pipe to the surface to enable liquid detection, sampling and pump out if required.

Ideally leak detection systems are double-lined, for example a primary liner (HDPE) overlying a geonet, overlying a secondary liner (clay/GCL). Wastewater captured by the leakage detection system must be disposed of in a lawful manner. Designs with leak detection sumps can also be geoelectrically assessed through the use of an electrode in the sump and on the membrane.

Electrical integrity assessment and leakage detection systems provide a higher level of certainty of lagoon liner integrity and a more cost-effective means of monitoring to manage groundwater risks, as opposed to the installation and monitoring of groundwater bores. Groundwater monitoring of bores installed in a manner to detect leakage from lagoons, may not provide accurate information due to the nature of groundwater movements and characteristics. Higher ongoing monitoring and reporting costs should also be considered.

Electrical integrity assessment and leakage detection systems also allow a more immediate response, as potential leakage will generally be detected earlier than leakage detected through monitoring and analysis of bores. If groundwater monitoring bores are installed (in the case of clay lined lagoons) they must be installed based on *Regulatory monitoring and testing – Groundwater sampling* (EPA 2019) in order to adequately monitor any potential impact of the wastewater lagoon on groundwater.

Interceptor drains

In areas of high rainfall, site-specific engineering solutions may need to be considered during the planning and design stage. Impacts form high rainfall can cause significant liner integrity and lagoon capacity issues. To mitigate this interceptor drains can be installed to intercept surface and/or subsurface runoff and divert it around the lagoon and away from the liner.

Construction Quality Assurance (CQA)

In the case of clay lined lagoons, the EPA will generally require *Level 1 Supervision* (as specified in AS 3798:2007) unless other CQA measures are undertaken in accordance with AS 1289 and Appendix 4A with its approval[18]. The primary objective of Level 1 inspection and testing is for the Geotechnical Inspection and Testing Authority (GITA) to be able to express an opinion on the compliance of the work. GITA will have competent personnel on site at all times while earthwork operations are undertaken. Under Level 1 Supervision, GITA is required to provide a report setting out the inspections, sampling and testing it has carried out, and the locations and results.

Guidance on EPA CQA requirements for clay lining installation, geosynthetic liner placement and subgrade preparation (as listed in Appendix 2) is provided in *Environmental management of landfill facilities – solid waste disposal* (EPA 2019)

As outlined earlier, proponents may be required to submit an As Constructed Report (ACR) in addition to CQA plans prior to commissioning the lagoon depending on the nature and complexity of the project and the sensitivity of the location.

[18] Some industries such as the pork industry have rigorously developed their own environmental guidelines. The *National environmental guidelines for indoor piggeries* or NEGIP (2018) outline the industry's requirements for piggery effluent pond construction. The EPA will accept CQA Plan and ACR that are aligned with the NEGP and the NEGP reference document *Constructing effluent ponds (*QLD Department of Employment, Economic Development and Innovation 2009)

Health and safety

Proponents should consult with the Department of Health and Ageing and other relevant agencies for storage in lagoons of substances that could pose health and safety risks to site employees or neighbouring communities.

Lagoons lined with geosynthetic liners could be very slippery when wet. For work, health and safety purposes, it is necessary to ensure that safety provisions (eg access rope or stairs, inflatable safety gear) are available. The EPA recommends that proponents consult with Safework SA for further information on this matter.

Sampling and inspection access

The performance of the liner should be evaluated through regular leakage monitoring and visual inspections to ensure that it remains an effective pollution barrier. The manufacturer's product warranty and advice on the anticipated service life should be considered when undertaking repairs and scheduling replacements. Regular sampling and monitoring of wastewater quality is often necessary to assess ongoing lagoon effectiveness and determine pollutant loads. Safe access should be provided to enable these activities to be undertaken.

Desludging provisions

When deciding on the design of a lagoon, consideration should be given to site-specific desludging requirements. Proponents are advised to seek guidance from their engineer and liner manufacturer or installer on appropriate liner design and desludging methods.

The lagoon should be designed to allow access for desludging. In the case of large lagoons, access from a number of locations may be required. Geomembranes may require a suitable fine grained material cover to protect the liner during desludging. The cover must be applied in a manner that does not damage the lining and allow access for machines to desludge the lagoon without damage to the liner.

For geomembrane-lined lagoons a liner integrity survey assessment undertaken using electrical methods after desludging is recommended to ensure the integrity of the liner.

Sludge sometimes contains organics and nutrients that may be beneficial to crops as a soil enhancer. However, lagoon sediments could also accumulate toxic metals and other potentially hazardous substances over time. Prior to spreading this material onto land, reference should be made to the *Standard for the production and use of waste derived soil enhancers* (EPA 2010) and the draft *South Australian biosolids guidelines* (EPA 2009) or as updated.

Security provisions

Lagoons can attract both humans and animals as water supply. Well-formed crusts can also conceal the presence of anaerobic ponds. Lagoons used in mining projects can contain hazardous materials and are often located in remote areas. For these reasons, the EPA recommends that adequate fencing, bird deterrents and signage be installed around lagoons where appropriate. Fencing would also ensure that wandering livestock and other animals cannot damage the membrane liner or become entrapped in the lagoon.

Equipment support

Some types of lagoons including aerated, covered anaerobic and attached-growth treatment lagoons require proper support mechanisms to hold equipment or devices such as aerators, gas collection systems and biological growth media. Liner manufacturers and suppliers normally provide recommended engineering designs for equipment and pipe-work installations for lagoons with geosynthetic liners.

Decommissioning

Prior to decommissioning a lagoon, an appropriate site assessment may be required to check the suitability of the site for any intended future use. Guidance on this is provided in the *Guidelines for the assessment and remediation of groundwater contamination* (EPA 2018).

Further reading

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Legislation

Development Act 1993 (and Regulations)

Environment Protection Act 1993

Environment Protection (Water Quality) Policy 2015

2003 Environment Protection Regulations 2009

Disclaimer

This publication is a guide only and does not necessarily provide adequate information in relation to every situation. This publication seeks to explain your possible obligations in a helpful and accessible way. In doing so, however, some detail may not be captured. It is important, therefore, that you seek information from the EPA itself regarding your possible obligations and, where appropriate, that you seek your own legal advice.

Further information

Legislation

Online legislation is freely available. Copies of legislation are available for purchase from:

Service SA Government Legislation Outlet
Adelaide Service SA Centre
108 North Terrace
Adelaide SA 5000

Telephone: 13 23 24
Facsimile: (08) 8204 1909
Website: https://service.sa.gov.au/12-legislation
Email: ServiceSAcustomerservice@sa.gov.au

General information

Environment Protection Authority
GPO Box 2607
Adelaide SA 5001

Telephone: (08) 8204 2004
Facsimile: (08) 8124 4670
Freecall: 1800 623 445 (country)
Website: https://www.epa.sa.gov.au
Email: epainfo@sa.gov.au

Appendix 1 Risk assessment matrix

The matrix is located at https://www.epa.sa.gov.au/files/8430_risk_assessment_matrix.xlsx

APPENDIX 1 RISK ASSESSMENT MATRIX

Instructions: Select one category under each criteria by clicking "Y" in the blue column opposite the category. Additional explanations are provided in Appendix 3A.

SITE:

		Points	Yes/No	Score	Notes/Comments	Instructions
1	**Groundwater occurrence**					
1a	none	0				Select YES (Y) for the most appropriate scenario in blue cells
1b	confined	0.2				
1c	semi-confined	2				
1d	unconfined (covered)	6				
1e	unconfined	10				
2	**Aquifer type**					
2a	Clay or crystalline rock	0.25				Select YES (Y) for the most appropriate scenario in blue cells
2b	Silt, fractured rock or limestone	3.75				
2c	Sand,gravel or Fill	10				
3	**Minimum distance of groundwater from base of lagoon lin**					
3a	greater than 50m	0				Select YES (Y) for the most appropriate scenario in blue cells
3b	>20m to 50 m	0.1				
3c	>10m to 20 m	1				
3d	>5m to10 m	2				
3e	>2m to 5 m	6				
3f	2 m or less	10				
4	**Groundwater usage**					
4a	Not Likely	0.5				Select YES (Y) for the most appropriate scenario in blue cells
4b	Possible	2.5				
4c	Current	10				
5	**Groundwater salinity**					
5a	>10 000 mg/L	0				Select YES (Y) for the most appropriate scenario in blue cells
5b	>5000 to10000 mg/L	0.2				
5c	>1500 to 5000 mg/L	3				
5d	1500 mg/L or less	10				
6	**Nominal capacity of lagoon (excluding freeboard)**					
6a	Small (5ML or less)	0.2				Select YES (Y) for the most appropriate scenario in blue cells
6b	Medium (>5ML to 10ML)	1.2				
6c	Large (>10ML to 30 ML)	4.8				
6d	Very Large (>30ML)	10				
7	**Max lagoon water depth**					
7a	1m or less (evaporative)	0.2				Select YES (Y) for the most appropriate scenario in blue cells
7b	>1m to 3m (aerobic/facultative)	1.2				
7c	>3m to 6m (anaerobic)	4.8				
7d	deeper than 6m	10				
8	**Nature of wastewater (see Appendix 3A for definitions)**					
8a	contaminated stormwater	0.2				Select YES (Y) for the most appropriate scenario in blue cells
8b	treated wastewater	0.8				
8c	composting	4.2				
8d	organic/nutrient	4.2				
8e	reactive	6.4				
8f	hazardous	10				

Rating			Select YES (Y) in the appropriate blue box if either of the scenarios in blue text apply
Preliminary category			
A. Is the lagoon located within 100m of a watercourse?			
B. Is there potential groundwater that may intersect the base of lagoon liner?			

RECOMMENDED CATEGORY

Appendix 2 Table of suggested construction and lining categories

1 The EPA may consider an alternative lining technology or combination other than those suggested in this table provided the proponent can demonstrate that it would achieve a similar or better outcome than that prescribed under the relevant category.

2 High risk lagoons (eg those with large capacities or located in sensitive areas) may be required to submit an 'As Constructed Report' (ACR).

3 The EPA may consider a lower construction and lining category than the one determined from Appendix 1 if risk management measures are to be implemented with approval from the EPA.

4 Please refer to Appendix 3B for definition of key technical terminologies.

	Ponds lined with clay materials		**Ponds lined with geomembrane materials**			
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Category 6**
Lining and quality assurance	**If clay is used** • Minimum 300-mm thick clay liner (or 2 layers with minimum of 150 mm compacted thickness each) **If GCL is used:** • Minimum 300-mm soil confining layer (<10-mm grain size).	**If clay is used** • Minimum 300-mm thick compacted clay liner with $k \leq 1 \times 10^{-9}$ m/s (or 2 layers with minimum of 150 mm compacted thickness each) • Construction Quality Assurance (CQA) plan for clay lining that includes Level 1 supervision (in accordance with AS 3798:2007) unless other CQA measures are undertaken in accordance with AS 1289 and Appendix 4A with the approval of the EPA.	• 1.5-mm thick HDPE or greater# • Leakage detection required	• 1.5-mm thick HDPE or greater# • CQA plan for HDPE placement • CQA plan for subgrade preparation. • Leakage detection required	• Double HDPE lining (1.5-mm thick or greater for each liner) # with CQA plan for HDPE placement **or** • A combination of **HDPE liner** (1.5 mm thick or greater; with CQA plan for HDPE placement as in category 4) and a **clay liner** (with CQA plan as in category 2) • CQA plan for subgrade preparation	• Site generally not suitable for wastewater lagoon construction unless effective drainage control is put in place • If to be allowed, apply category determined after Question (A) in Appendix 1 plus drainage provision.

	Ponds lined with clay materials		Ponds lined with geomembrane materials			
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Category 6**
		• CQA plan for subgrade preparation **If GCL is used** • CQA plan for GCL placement • Minimum 300-mm soil confining layer (<10mm grain size). • CQA plan for subgrade preparation			• Leakage detection required	
Subgrade	Minimum 150-mm subgrade preparation to provide a sound and stable base for liner construction or installation. Subgrade preparation should include compaction until no rutting or pumping is observed. Workmanship should be supervised by a suitably qualified and experienced professional. Level 2 Supervision may be required.					

Appropriate thickness of HDPE liner must be determined by the proponent’s engineer/consultant based on wastewater characteristics, groundwater/aquifer characteristics, climatic factors and warranty considerations.

Appendix 3A Explanation of terms used in Appendix 1

Groundwater occurrence could be classified as:

- **Confined** – if aquifer is bound above and below by a confining bed with a low hydraulic conductivity that does not transmit water in any appreciable amount, if at all.
- **Semi-confined** – if aquifer is confined by a low permeability layer that permits water to flow through it slowly. Recharge to the aquifer can occur across the confining layer during pumping of the aquifer.
- **Unconfined** – if there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer.
- **Unconfined (covered)** – the same as unconfined aquifer but covered by separate, distinct permeable geologic formations, either solid rock or unconsolidated sediments.

Groundwater usage could be classified as:

- **Not likely** – if there is a low potential for the beneficial use of the local groundwater in the future.
- **Possible** – if the aquifer could be used for future potable, recreational irrigation and industrial uses.
- **Current** – if groundwater bores are present (whether in use or not) to draw water for the various uses outlined above.

Nature/types of lagoons include:

- **Evaporative –** a shallow, uncovered lagoon with large surface area designed for the purpose of wastewater disposal by evaporation or drying of sludges and slurries.
- **Aerobic –** a lagoon where wastewater is stabilised by biological activity utilising oxygen either through natural or enhanced aeration.
- **Facultative –** a lagoon that is generally deeper than aerobic pond, and where wastewater is treated by bacterial action occurring in an upper aerobic layer, middle facultative layer and lower anaerobic layer.
- **Anaerobic –** a deep lagoon generally free of dissolved oxygen to promote anaerobic conditions. Anaerobic lagoons are generally used to treat high-strength wastewater due to the lower energy requirement and lesser biomass production rates.
- **Processing –** a lagoon where product-rich liquid is stored prior to further processing such as those used in the mining industry.

Nature of wastewater varies as follows:

- **Contaminated stormwater** – if stormwater contains pollutants listed in Schedules 2 and 3 of the *Environment Protection Water Quality Policy 2015* or any material that could be reasonably prevented from entering the pipes, gutters and other channels used to collect and convey the stormwater. Depending on pollutant nature and concentration in stormwater, it is also possible that this water could be classified more appropriately under the other categories listed below.
- **Treated wastewater** – if wastewater has undergone secondary and/or tertiary treatment and where the residual contaminants pose low risk to the receiving environment. This includes recycled water from municipal treatment works and community wastewater management schemes (CWMS).
- **Composting leachate** – any liquid that has come into contact with or generated from composting or landfill activities.
- **Organic/nutrient-rich** – includes untreated or partially treated sewage, or wastewater from food processing or agriculture-based industries such as abattoirs, rendering plants, dairies, cheese factories, fruit processing facilities, aquaculture, piggeries, saleyards, and cattle feedlots. These types of wastewater could also be classified as treated

wastewater if further treatment or cleaner production measures have been undertaken to reduce nutrients and salts to levels comparable to secondary and/or tertiary treated sewage effluent.

- **Reactive** – acidic, alkaline or highly saline wastewater such as untreated or partially treated wastewater from distilleries, wineries and reject streams from reverse osmosis plants.
- **Hazardous** – includes most of the wastewater generated by chemical, manufacturing and mining industries.
- **Mineral processing wastewater** –includes wastewater resulting from the chemical or mineral processing of ore. This water may be highly reactive and/or hazardous.

Appendix 3B Explanation of terms used in Appendix 2

Plasticity Index	The Atterberg Limits consists of two parameters; the plastic limit and the liquid limit. The ***plastic limit*** (PL) is defined as the moisture content in percent, at which the soil crumbles, when rolled into threads of 3.2 mm in diameter. The plastic limit is the lower limit of the plastic stage of soil. The moisture content of a soil at the point of transition from plastic to liquid state is the ***liquid limit*** (LL). The ***plasticity index*** (PI) is the difference between the liquid limit and the plastic limit of a soil [PI = LL – PL]. Generally, clay soils for low plasticity liner construction would have a plasticity index of greater than 10%.
Permeability coefficient	The flow of water through porous medium can be expressed as follows: **v = ki** where: **v** = discharge velocity, which is the quantity of water flowing in unit time through a unit gross cross-sectional area of soil at right angles to the direction of flow; **k** = hydraulic conductivity (otherwise known as the coefficient of permeability); **i** = hydraulic gradient. Hydraulic conductivity is generally expressed in cm/sec or m/sec.
As constructed report (ACR)	A documentation of work performance and Construction Quality Assurance (QCA) associated with a construction project. Guidance on drafting an ACR is provided in Guidelines for construction specifications and documents for landfills, leachate ponds, composting facilities and wastewater Lagoons (EPA currently in draft).
Level 1 Supervision	A CQA requirement for clay-lined infrastructures. The Geotechnical Inspection and Testing Authority (GITA) needs to have competent personnel on site at all times while the following earthwork operations are being undertaken: • completion and removal of topsoil • placing of imported or cut material • compaction and adding/removal of moisture • trenching and backfilling, where applicable • test rolling • testing. On completion of the earthworks, the GITA is required to provide a report setting out the inspections, sampling and testing it has carried out, and the locations and results thereof. Further information on Level 1 Supervision is provided in Guidelines for construction specifications and documents for landfills, leachate ponds, composting facilities and wastewater lagoons (currently in draft).

Appendix 4A Clay liner testing for ponds and acceptance criteria

Item	Test method	Pre-qualification testing frequency	Frequency of field compliance testing	Acceptance criteria
Particle size distribution (PSD)	AS 1289 3.6.1	3 per material source	3 per pond liner	As provided below
Particles passing 53-mm sieve	AS 1289 3.6.1			100%
Particles passing 19-mm sieve	AS 1289 3.6.1			>90%
Particles passing 2.36-mm sieve	AS 1289 3.6.1			>70%
Particles passing 0.075-mm sieve	AS 1289 3.6.1			>30%
Maximum particle size	AS 1289 3.6.1			40 mm
Atterberg Limits	AS 1289 3.1.2, 3.2.1, 3.3.1, 3.4.1	3 per material source	3 per pond liner	As provided below
Plasticity Index	AS 1289 3.3.1			≥10% and above Casagrande A line
Liquid Limit	AS 1289 3.1.2			30–60%
Permeability (remoulded)	AS 1289 6.7.3	2 tests per material source		≤1 x 10^{-9} m/sec (300-mm thick clay pad liner
Permeability on undisturbed tube samples collected from the completed pad liner	AS 1289 6.7.3		2 tests per constructed pad liner	≤1 x 10^{-9} m/sec (300-mm thick clay pad liner
Emerson Class Number	AS 1289 3.8.1	3 per pad liner	3 per pad liner	>4
Calcium Carbonate content	USEPA	3 per pad liner	3 per pad liner	<15%

Item	Test Method	Pre-qualification testing frequency	Frequency of Field Compliance Testing	Acceptance criteria
Dry Density	AS 1289 5.1.1 or 1289 5.7.1		As provided in Table 8.1 of AS 3798–2007	Minimum dry density ratio of 95% relative to standard or a minimum Hilf density ratio of 95% standard
Moisture Content	AS 1289 5.1.1 or AS 1289 5.7.1		Same as for Dry Density testing	0% to +3% of the Standard Optimum Moisture Content (SOMC) or within a Hilf moisture variation of 0% to +3%