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Saline Wastes in Northern Victoria - Management Strategy

Final Report

Dairy Australia

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Executive summary

THE PROJECT AIMS

RMCG was engaged by Dairy Australia to work with industry partners to develop a saline waste disposal management plan for northern Victoria. The initiative was prompted by concerns that:

- The current disposal arrangements might be unsustainable and could lead to long-term damage to productive land through raised sodicity
- The limitations on current disposal options could constrain future economic development opportunities for the region.

THE PROCESS

A working group was established with representatives from key stakeholders, including dairy processing companies; water authorities; Dairy Australia; and Regional Development Victoria (RDV). The working group met four times over the course of the study to help steer it, provide access to relevant data and validate the developing analysis.

The workplan was based around four sequential stages:

i. Collation of data on current and projected production and management
ii. Assessment of the sustainability of current disposal routes/mechanisms
iii. Review of alternative options
iv. Summary and recommendations

THE PRINCIPLES

In assessing current practice and alternative options, the study followed the *Wastes Management Hierarchy* set out in the *Environment Protection Act 1970,* which preferences 'avoidance' and 'reuse' over 'disposal'. In assessing the options, the study also prioritised options that met the following principles:

- Ecosystem impacts: i.e. one that does not lead to the degrading of a natural resource
- Practicability: i.e. one that could be implemented readily given available technical capability
- Cost: i.e. one that could be implemented within the commercial constraints of the production system.

THE FINDINGS

The study has established that there are three distinct waste-streams, each with its own issues and solutions:

- **Highly saline flows (4,000 – 40,000 EC)**: these flows represent the most significant salinity challenge for the industry. There is unfortunately, no 'silver bullet' for the management of the highly saline waste, however, the most viable option appears to be local treatment and disposal via evaporation basins and landfill. There are a number of limitations with this (it is a high cost solution and it is questionable as to whether it can continue as a long-term management solution), but it is considered to be a more viable option than the others considered due to cost and regulatory approval. To support this option, the sites need to:

- Minimise the production, or strength of the highly saline wastes wherever possible. Avoidance is the highest level in the Environment Protection Authority's (EPA) waste hierarchy and it should be consistently applied by the sites.
- Following this, the aim should be to undertake treatment so that the high saline waste can be split into a high organic, low salt stream that can potentially be reused for agriculture (e.g. pig food); and a high salt, low organic stream that can achieve good crystallisation in the evaporation lagoons. The hope then is that ongoing R&D into highly saline wastes will help to improve the reuse potential of the organic material, and perhaps the extraction of by-products from the saline material. Ongoing R&D will also hopefully help to reduce the quantity of saline waste that is ultimately produced, and therefore, the extent and cost of landfill should that continue to form part of the management solution (which, based on the research undertaken, is highly likely).
- It is also recommended that Dairy Australia or another relevant industry body engages the EPA and develops a waste classification for the crystalline waste from milk processing factories. This process has been used by other industries where the classification of their waste is not straight forward and it has helped to provide certainty to the industry around planning, costs, regulation, etc.
- The final comment for the high saline wastes is that if a dairy processor (or other industry) is considering the costs and implications of producing a highly saline waste stream, then relocation of this process close to the ocean may be the most appropriate waste management decision. This is 'easy to say, but difficult to implement', and this fact is not lost on the authors of this report. It does however remain a relevant management approach that should be strongly considered by high salinity waste producers.

- **Saline flows (1500 – 4,000 EC)**: these are largely the result of the use of cleaning products in processing plants. The current controls and disposal arrangements are broadly sustainable and capable of expansion. However, a number of recommendations are made:
  - *Control at source*: audit of cleaning practices can lead to a significant reduction in the volume of the wastewater stream. This can result in reduced salt waste and lower costs for both purchasing chemicals and managing the waste.
  - *Best practice management*: irrigation of the wastewater to pasture is a sustainable long-term practice but needs to be managed properly to well established, standard protocols, to ensure effective controls. This includes appropriate and consistent resourcing by the project partners to ensure:
    - maintenance phosphorus loading rates are adhered to
    - the shandied irrigation salinity does not exceed 800 EC (μS/cm)
    - annual soil testing is used to monitor soil salinity and sodicity concentrations and the need for soil ameliorants (e.g. gypsum or lime)
    - monthly wastewater quality monitoring is undertaken to monitor for potential loss of soil infiltration
  - Wastewater irrigation outlets should also be automated to ensure the target salinity irrigation rate of ≤800 EC is consistently met and wastewater is used consistently throughout the irrigation season.
  - Consideration should also be given to the disposal of saline wastewater to Goulburn-Murray Water's (GMW) channel system and the benefits this could provide.
- **Salty wastes (<1,500 EC)**: these are flows as part of trade-wastes discharges to sewer that are managed by the regional water corporation. These wastes can be controlled adequately through:
  - standard irrigation approaches as for 'Saline' wastes involving shandying and disposal to land
  - well founded and enforced, cost reflective trade-waste charges

  It is recommended that where the true costs of salinity/sodium management have not been established at each site, they should be. This will provide value to both the water authority and the industry.

One of the drivers behind this project was the concern that northern Victoria is not able to sustainably manage saline wastewater produced by industry. Whilst the management of highly saline wastes remains problematic for all inland areas of Victoria, it is RMCG's opinion that northern Victoria has a number of advantages for the management of 'saline' and 'salty' waste streams. Northern Victoria has three key factors that help with the management of saline wastewater:

i. Farmers in the region have a demand for the nitrogen and phosphorus that is also contained within the wastewater and can incorporate it into their annual fertiliser programs.
ii. The region has the scale to accommodate the winter storages and irrigation areas necessary to manage the volumes of saline wastewater produced.
iii. The region has access to shandy water that is vital in managing saline wastewater.

This same list of advantages is not true for other regions of the state, particularly those that have a higher intensity of agriculture and/or no access to shandy water other than rainfall. The key to northern Victoria sustainably managing saline wastewater is consistent resourcing and the application of the best management practices detailed in this report.

1 Introduction

1.1 THE CHALLENGE

RMCG was engaged by Dairy Australia to work with industry partners to develop recommendations for a saline waste disposal management plan for northern Victoria. The initiative was prompted by concerns that:

- The current arrangements for the disposal of saline wastes might be unsustainable and could lead to long-term damage to productive land through raised sodicity.
- The limitations on current disposal options could constrain future economic development opportunities for the region.

1.2 THE PROCESS

The workplan was based around four sequential stages:

i. Collation of data on current and projected production and management
ii. Assessment of the sustainability of current disposal routes/mechanisms
iii. Review of alternative options
iv. Development of recommendations.

A working group was established with representatives from key stakeholders including:

- Dairy processing companies
- Water authorities
- Dairy Australia
- Regional Development Victoria.

The working group met over the course of the study to help steer the project, provide access to relevant data and validate the developing analysis.

1.3 PRINCIPLES

The aim of the study was to develop recommendations for a management plan that would promote sustainable disposal arrangements for saline wastes.

In this study, a sustainable disposal approach was taken to be one that met a set of principles/criteria including:

- **Ecosystem impacts**: i.e. one that does not lead to the degrading of a natural resource
- **Practicability**: i.e. one that could be implemented readily given available technical capability
- **Cost**: i.e. one that could be implemented within the commercial constraints of the production system.

In assessing the alternative options, the study followed the **waste management hierarchy** contained in the *Environment Protection Act 1970*. The wastes hierarchy establishes an order of preference between approaches, with ‘avoidance’ being the most preferred option and ‘disposal’ being the least (Figure 1-1).

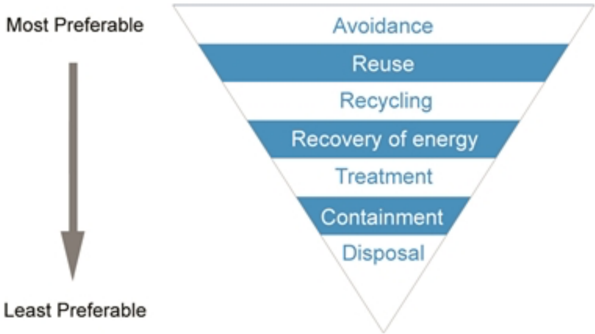

Figure 1-1: Wastes hierarchy (source EPA Victoria)

1.4 FRAMEWORK

The analysis of the wastewater data provided by the project partners identified that the effluent disposal issue fell into three distinct broad waste-streams, each of which raised different challenges:

i. Highly saline waste stream: 4,000 – 40,000 EC
ii. Saline waste stream: 1,500 – 4,000 EC
iii. ‘Salty’ waste stream: <1,500 EC

The report is structured around this framework. The following chapters confirm the current disposal technologies for each of the three waste streams, assesses its sustainability, and identifies recommendations to establish the optimal approach for each.

1.5 LIMITATIONS

The work completed for this project concerned the saline wastes produced by the project partners. Although the treated wastewater from the water authorities does cover the saline waste streams generated by most other industries in northern Victoria, it must be noted that there may be other saline waste streams in the region that have not been considered and may be of relevance.

For example, other food processors or chemical manufacturers may produce saline wastewater in the northern Victoria region, which are managed independent of the local water authorities, but may be appropriate contributors to a centralised management solution, should that eventuate. Should their saline wastes be included in the design estimates, the feasibility of a centralised management solution may be different to what is presented here.

Saline waste streams from producers other than the project partners was outside the scope of this project. The previous investigations, as discussed in the following section, does provide more comprehensive information on the range of saline waste producers in the northern Victoria region.

1.6 PREVIOUS INVESTIGATIONS

This project builds upon previous work that has been done by Dairy Australia and the project partners on saline waste management across northern Victoria. It therefore doesn’t characterise the range of salt producers within the region or each of their unique salt production circumstances; this work has already been done[1]. It

[1] GVW’s 2013 investigation (*‘Detailed Feasibility Report – Development of a Saline Management Solution – Stage 1 – Phase 1: Investigation and Problem Definition’)* records that there is over 5,000 tonnes of sodium production/load across northern Victoria each year, and of this, more than half would fall into the ‘highly saline wastes’ category.

looks for pragmatic solutions to managing classes of saline waste and picks up the outcomes and insights from these previous studies to recommend management options that may improve saline waste management.

This investigation takes a broader perspective on options for managing saline waste including various treatment options previously investigated and compares them with source control, sustainable land application and discharge to saline environments to try and understand the best possible management options that exist.

2 Highly saline wastes

2.1 DEFINITION

This element of the study involves waste-streams with concentrations in the range 4,000 – 40,000 EC. The highly saline wastes considered in this project are shown in Table 2-1.

Table 2-1: Highly saline wastes considered in this project

HIGHLY SALINE WASTE STREAM	PRIMARY CONTAMINANTS	SECONDARY CONTAMINANTS
Brine produced by cheese processing	Whey (protein, lactose), sodium chloride	Calcium phosphate, minerals, organic anions (lactate, citrate)[2]
Brine produced by nanofiltration treatment of cheese brine	Sodium chloride	Lactose, minerals[3]
Brine produced by reverse osmosis treatment of groundwater	Sodium chloride	Arsenic, iron, manganese[4]

Saline waste can also be produced during whey treatment, when whey is demineralised by ionic exchange[2].

Note that the highly saline waste streams included in this project are considerably narrow in their quality range. That is, the origin of each waste stream is a unit process and not a wastewater created from a broad mixture of point sources. This means that there is potential for the recovery of useful by-products, provided that the technology exists on a commercially viable scale. All the dairy processors included in this project separate their highly saline wastes from their lower saline waste streams, which opens up the prospect for improved management outcomes.

2.2 CURRENT DISPOSAL

The current arrangements for the disposal of high saline wastewater involves the transfer of the effluent, by tanker or pipeline, from the processing plant to a disposal site. The disposal arrangements make use of evaporation basins or pads to reduce the volume of the waste through passive evaporation processes, leaving a smaller mass of salty crystalline waste. This waste can then either:

- be left in the basin as a long-term storage facility, or
- be transferred to a formal landfill facility managed by a third party.

2.3 ASSESSMENT

There is concern that the current disposal methodology is creating a constraint on the development of new and additional food processing capability in northern Victoria. The management of highly saline wastes provides the most significant long-term challenge and risk to the dairy industry in the region, as the approach does not provide a fully sustainable disposal route.

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2 Kezia, K., Lee, J., Zisu, B, Weeks, M., Chen, G., Gras, S. and Kentish, S. (2016) Crystallisation of minerals from concentrated saline dairy effluent, *Water Research*, 101, pp300 – 308.

3 de Wit, J.N, (2001) *Lecturer's Handbook on whey and whey products*, European Whey Products Association.

4 New Moon Groundwater Treatment Plant test result data, Coliban Water, 21/11/2017.

The use of evaporation basins merely changes the form of the effluent and defers the timing of the ultimate disposal. It is assumed, therefore, that (in the absence of some new technology) at some point in the future the industry will need to rely on landfill for the crystallised slurry waste, which will involve high cost and high profile regulatory controls. For some of the project partners, the need to dispose the crystallised waste to landfill is already being realised and is a major issue for their operations.

2.4 OPTIONS

This section considers a range of potential management options that could be employed to manage the highly saline waste stream. Section 2.5 then provides more detail on those options that have been assessed as potentially viable options for on-going management of this waste stream.

It is noted that this is the most difficult of the three waste streams to manage and therefore definitive solutions that provide truly sustainable management are hard to find.

2.4.1 Research and development

Significant research into treatment technologies that could reduce the problem of highly saline wastes has been pursued for more than 20 years. An exhaustive list of possible salt-separation technologies has been prepared by the *Australian Research Council (ARC) Dairy Innovation Hub at the University of Melbourne*.

The breadth of technologies that have been investigated and even commercialised is extensive. However, in practice, there has been very limited implementation in the dairy industry. The energy required to separate sodium chloride molecules from the relatively-sized water molecules remains a primary limiting factor to the practical application of many new technologies. When additional contaminants, such as whey, dairy salts and cleaning products, are present, pre-treatment steps are required. This adds further cost to the overall waste treatment process, reducing the economic viability.

Based on the ARC Dairy Innovations Hub list of technologies, an estimation of the capital, operations and maintenance (O&M), and waste disposal costs has been made (Table 2-2). Note that this is an estimate only, as little commercial data is available.

Table 2-2: Treatment technology options

TECHNOLOGY	COSTS	BENEFITS	RISKS
Membrane separation (microfiltration, ultrafiltration, reverse osmosis)	Capital $ - $$ O&M $ - $$ Disposal $$	Well-established solution Modular designs can accommodate a wide range of flowrates and influent quality	Cost and management of equipment Further treatment or disposal of brine wastewater required
Wind aided intensified evaporation	Capital $ - $$ O&M $ - $$ Disposal $$	Low energy technology Can produce a solid salt product	Limited commercial experience with dairy wastes Salt and weather exposure is extremely corrosive to equipment Disposal costs of salt Site conditions may not be favourable
Capacitive deionisation	Capital $$ - $$$ O&M $$ - $$$ Disposal $$	Lower energy use than reverse osmosis	Technology not yet commercialised

TECHNOLOGY	COSTS	BENEFITS	RISKS
		Recovers 'clean' brine solution for subsequent evaporation/crystallisation	
Electrodialysis	Capital $$ - $$$ O&M $$$ Disposal $$	Recovers a clean salt product for resale Recovers protein and milk-sugar from acid whey for resale	No commercial dairy waste installations Very high operating costs
Forward osmosis	Capital $$ - $$$ O&M $$ - $$$ Disposal $$	Requires less pressure than reverse osmosis, therefore lower operating costs	No commercial dairy waste installations
Membrane distillation	Capital $$ - $$$ O&M $ - $$ Disposal $$	Concentrates highly saline effluent Low energy and can potentially use waste heat	No commercial dairy waste installations

The options presented in Table 2-5 are all likely to be high cost and many of them still producing a salt stream that ultimately requires stockpiling or disposal to landfill. Only membrane separation equipment is routinely used in the dairy processing industry. All other technologies are still in a development phase yet to have commercial application in the dairy sector. It appears that further R&D of potentially viable options is required to see if any will be able to reduce the volume of salt requiring stockpiling/disposal to landfill in a cost-effective way.

2.4.2 Resource recovery

Specifically, for dairy wastes, research was conducted from 2005 to 2007 by the DISCover Sub-Project Research Team into the recovery of valuable by-products from the treatment of highly saline dairy wastes. Whilst some of the salts, other than sodium chloride, present in highly saline dairy wastes may be considered to have commercial extraction potential[5], they are typically present in much smaller concentrations than sodium chloride. Therefore, the economics of their recovery shall be extremely challenging without very high market prices to counter their purification costs. There is also the issue of high organic loads in the salt streams and the impacts this has on separating out valuable by-products. Resource recovery has therefore been relatively unsuccessful.

There is, however, ongoing interest in trying to separate the various components of the waste stream, with some modern dairy facilities (see Section 2.5 and the case study provided) implementing saline waste systems aimed at trying to separate the organics and the salt. The aim is to produce salt free organics that can be reused for agriculture (e.g. pig food), and organics free salt that will crystallise better and therefore be cheaper to manage and perhaps offer opportunities for the extraction of by-products. The issue remains however that there doesn't appear to be a sustainable 'next step' for the low organics salt other than landfill after it has crystallised in evaporation basins. This remains a major challenge for all high saline waste industries and needs to be the focus of ongoing R&D.

5 Aral, H., Sleigh, R. W. and Simons, L. 2006 "Salt recovery strategies for new value-added salt products Part one" DISCover Sub-project Research Team.

2.4.3 2015 market sounding exercise

In 2015, an expression of interest was put out to industry, seeking technology solutions to the problem of saline waste in northern Victoria. A total of eight companies submitted a response to this request. The responses ranged from offers of project management services, to consortiums which can draw on a range of technologies to solve the proposed problem, to proprietary equipment vendors.

Many of the technologies included in the responses were either yet to be commercialised or had very limited commercial experience. These technologies included enhanced evapo-concentration, capacitive deionisation using graphene, membrane distillation, electrodialysis and vibratory shear membrane separation. The proven technologies offered were reverse osmosis and mechanical evaporators.

The 2015 market sounding exercise therefore offered few practical solutions to the problem of inland saline waste management and/or still presented the key issues of high cost of establishment and operation and a resultant (albeit reduced) salt product that ultimately requires disposal via landfill.

2.4.4 International experience

There is little published research or data on international saline dairy waste management. This may be due to:

- Different environmental regulation. Less stringent regulations (compared to Victoria) could mean saline wastes are discharged to land or receiving waters. More stringent regulations could mean that only mechanical treatment through to crystallisation is permitted, or that industries which produce highly saline streams could not be located inland.
- Higher water use at processing facilities, leading to greater dilution of saline wastes. Not separating high saline waste streams at the processing facility could also lead to dilution of the combined wastewater, to a TDS level that is permissible.
- Higher water use across the population, providing greater dilution for saline trade wastes discharged to municipal wastewater treatment plants.
- Most international dairy processors may be located close to ocean outfalls, especially when compared to the ratio of inland versus costal dairy processors in Victoria.
- Alternatives to evaporation ponds may not be needed, as they are seen as a suitable solution to highly saline wastes.

However, inland brine management is a growing issue for industry and government internationally. The growing interest and use of groundwater desalination as a source of clean water, as well as coal seam gas extraction, has resulted in an increasing need for inland brine management options. These industries may help drive the search for economic saline waste treatment, but based on our research, no options are currently standing out or presenting themselves.

2.4.5 Beneficial reuse

Beneficial reuse requires the use of a waste material (e.g. salt waste) as a substitute for an input or raw material without any additional environmental risk management controls other than those already in place. It is designed for an established manufacturing process where the Prescribed Industrial Waste (PIW) is reused in a controlled environment. It does not include land application or composting, which are considered ‘treatment’.

There are two forms of beneficial reuse, as follows:

- Direct beneficial reuse (DBR) – reuse of a waste material as a substitute ‘input’ without treatment
- Secondary beneficial reuse (SBR) – reuse of a waste material as a substitute ‘input’ post treatment.

While DBR can occur without EPA authorisation, SBR requires EPA approval to ensure that the PIW is exempt from general regulatory requirements.

The opportunities for beneficial reuse of salt waste requires further investigation. To date, no obvious reuse options have been identified but this could change with an improvement in the quality of the salt waste stream. For example, production of a solid salt waste free of organics and clay may allow for the use of salt waste in stock feed (e.g. salt/mineral licks), particularly given that it typically contains trace amounts of phosphorus and nitrogen that can be beneficial for stock.

The possibilities for beneficial reuse requires additional investigation, which would probably best be done through an EPA approved trial. A key issue to be investigated is the impact of metals in the highly saline waste and the impact they have on the prospects of beneficial reuse.

2.4.6 Waste to energy

Highly saline wastewater can be used to capture solar radiation, which in turn can be used to generate heat (energy). The concept of 'solar ponds' has been realised at around 60 locations worldwide[6] and presents an opportunity to realise some value out of a waste stream that is challenging to manage.

Figure 2-1 diagrammatically presents the concept behind a solar pond, which utilises convective zones created by salinity gradients to capture solar radiation and generate heat energy.

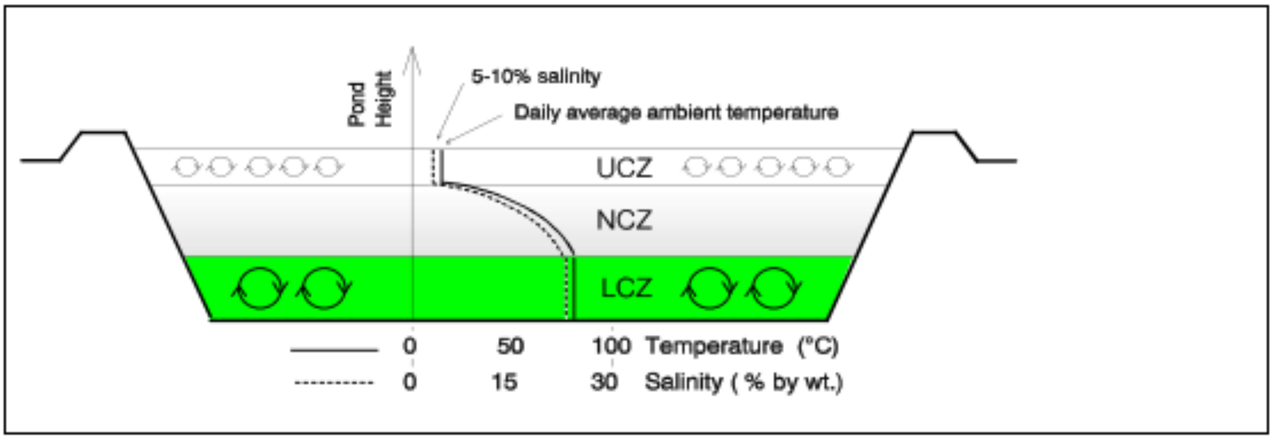


Figure 2-1: Solar pond showing three convective layers. LCZ = concentrated brine, NCZ = non-convective zone, UCZ = low salinity water.[7]

Heat stored in the bottom of the pond can be used in industrial processing, either via simple heat exchangers coupled to heat pumps or converted into electricity using an appropriate engine. Note - the latter only realises ~10 to 15% of the heat potential.

The Pyramid Salt Solar Pond (Pyramid Hill, Victoria) is the only operating solar pond in northern Victoria. The pond generates temperatures of around 60˚C to 70˚C, with an average annual heart output of 60 kW. Pond dimensions include a surface area of 3000 m^2 and volume of 9,000 m^3. Whether or not a similar technology could be adapted to a dairy processing operation requires trialling and investigation. However, given that powder dryers (i.e. a logical use for the heat) typically operate at 180˚C this may not be viable.

[6] RMIT University, Geo-Eng Australia Pty Ltd, Pyramid Salt Ltd (2002) Solar Pond Project – Stage 1: Solar Ponds for Industrial Process Heating.
[7] Ibid.

2.4.7 Options considered

Based on our research of mechanical treatment options for the highly saline waste, there appeared to be no ‘silver bullet’ technology. Therefore, our approaches to the boarder management options for highly saline dairy wastes are:

- Local treatment followed by disposal (current disposal mechanism)
- Centralised treatment followed by disposal
- Discharge to a highly saline water source such as an ocean outfall or saline aquifer.

A description of each option is provided in the following sections, along with a comparison of the costs, benefits and risks associated with each option.

Beneficial reuse and waste to energy are also options that may warrant further investigation by the Australian Dairy Industry, but there is little more to report on these options without targeted research than what is already discussed above.

2.5 LOCAL TREATMENT AND DISPOSAL

The most common disposal mechanism relies on evaporation ponds to concentrate salts to a consistency that allows for transport and disposal to a landfill site. The steps involved are:

- Transfer: the piped or tankered transfer of a liquid waste stream from the plant to a neighbouring evaporation basin
- Evaporation basin: the transformation of that waste stream into a waste product through the gradual evaporation of the liquid leaving a slurry or crystalline product
- Landfill: once the evaporation basin has been filled, this triggers the need either for:
  - a new evaporation basin (and capping of the filled basin), or
  - transfer of the solid waste to landfill.

The advantage of this broad management approach is that it is a relatively cheap solution for processors that already have suitable land for an evaporation pond. However, for processors wishing to commence the production of highly saline waste streams, the cost of purchasing a new site for an evaporation pond and the environmental permitting of this operation may be prohibitive. Although the passive treatment offered by evaporation basins is relatively cheap when compared to the cost of purchasing and operating mechanical separation equipment, the risks associated with these basins include:

- Fugitive odours
- Incomplete crystallisation (super-saline slurry)
- Crystalline salt dust
- Compromised basin liner.

Each of these risks requires management which will add to the total costs of this solution.

2.5.1 Local evaporation basins and treatment

Organic compounds in the wastewater can increase the odour risk and inhibit the salt crystallisation process, resulting in a slurry which will never achieve full crystallisation. Organics also render the solid waste unsuitable for reuse, should this be available to the processor. Some processors, therefore, include a pre-treatment step prior to pumping out to an evaporation pond, to reduce the organic content of the waste and improve its treatability. As previously discussed, the aim is to produce salt free organics that can be reused for agriculture (e.g. pig food), and organics free salt that will crystallise better in the evaporation lagoons and be cheaper to manage.

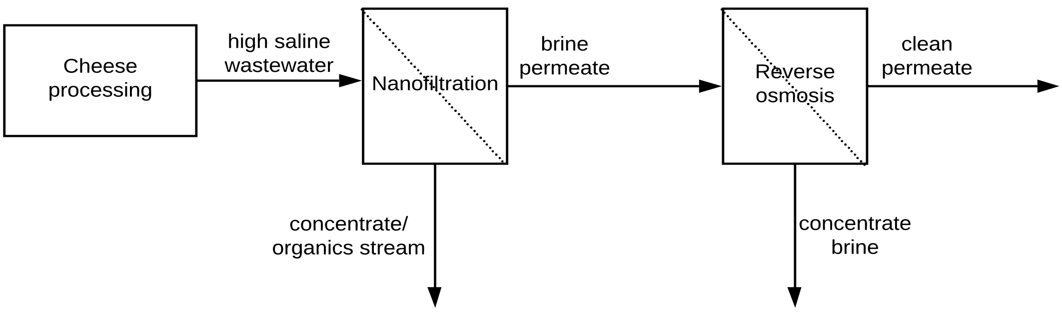
Membrane separation of highly saline dairy wastes prior to discharge of the saline stream (brine) to an evaporation pond is sometimes used for this purpose. Nanofiltration systems can be installed at the processing facility to remove contaminants in the waste stream, such as organics, other than salt and water molecules. Therefore, the highly saline waste streams have essentially been ‘cleaned up’ by the membrane filtration step, meaning (in theory) that only very concentrated saline water is left in the resulting permeate.

Anecdotally, some sites are achieving improved outcomes through processes like these, but it is not all straightforward. The organics contained within the saline waste can be so significant that fouling of the membranes occurs regularly, requiring high frequency backwashing. This backwash water can’t be reused within the factory or for irrigation due to its salt content and therefore, it is disposed of to the evaporation basins which defeats the purpose of the entire process. Experimentation with a DAF prior to the nanofiltration is being considered, which highlights the issue of organics in the high saline waste and the problems that it leads to.

Although industry reports the poor performance of evaporation basins in practice, there is little research into this problem. Anecdotally, we know that few dairy processor brine ponds ever achieve crystallisation. Rather, a super-saline slurry is the most likely endpoint. It is likely that the organic contaminants in dairy wastes are the key factor preventing crystallisation, however more research is required to understand the complex interactions in this process.

CASE STUDY: MODERN DAIRY PROCESSING FACILITY

The following case study is an example of some of the processes being used by the projects partners in managing the highly saline wastes. Companies are now looking to install the latest processing and waste treatment technology, including a treatment process for the highly saline waste (e.g. coming from a cheese plant). The modern processes see the wastewater undergone nanofiltration, with the salty permeate stream (stripped of organics) undergoing further treatment by reverse osmosis. The brine concentrate from the reverse osmosis unit is then sent to the existing evaporation lagoons.



These modern processes have the advantage of producing a ‘cleaner form’ of saline waste which can improve the performance of the brine lagoons through better crystallisation.

Based on the principals of evaporative crystallisation, water molecules require enough heat energy to overcome their vapour pressure and escape the saline solution they are in before the brine solution achieves super-saturation. This is an intermediate step on the path to crystallisation.

Once a supersaturated solution is achieved, crystallisation can only occur in a brine lagoon if primary nucleation spontaneously commences. Due to the number of salts typical in dairy waste brines (for example, sodium chloride, sodium sulphate, potassium chloride and calcium phosphate) and the complex solubility behaviour of these salts (depending on temperature, pH and the presence of impurities), the ability of these solutions to achieve reliable crystallisation is likely to be highly variable.

Therefore, it is unlikely that the crystallisation performance of dairy brine evaporation lagoons can be improved until there is a better understanding of the complex interactions. For now, we can only assume that reducing the number of contaminants in a saline waste stream will provide the best chance for crystallisation to be achieved. That is, removing dairy organics from the brine (such as nanofiltration), should have the biggest impact on achieving crystallisation.

Despite the potential problems with evaporation ponds, they do currently offer the most economical and simplest solution to highly saline waste in northern Victoria. Continued R&D is however required to improve their performance and prospects for the removal and reuse of by-products.

2.5.2 Disposal

Chemical testing in line with best practice guidance outlined in *EPA Publication IWRG631 (2009) Solid Industrial Waste Hazard Categorisation and Management* is required to determine if the salt waste is Category B, C or Industrial Waste.[8]

Category B waste requires a higher level of management and controls than either Category C or industrial waste. This is reflected in the landfill costs.[9]

Table 2-3 outlines the disposal options for each waste category, the EPA levies and an estimate of the actual disposal cost per tonne of waste material at the landfill gate.

Table 2-3: Landfill disposal options for hazard category and associated levies

CATEGORY[1]	DISPOSAL OPTION[1]	EPA LEVY[2] 2017/18 $/TONNE	LANDFILL COSTS[3] $/TONNE
A	Prescribed industrial wastes (PIWs) which require a very high level of control and ongoing management to protect human health and the environment. Wastes in this category cannot be accepted at a disposal facility without prior treatment to reduce or control the hazard.	Prohibited from disposal. Levy does not apply.	$1,500[4]
B	PIWs which require a high level of control and ongoing management to protect human health and the environment. Solid PIWs in this category can be accepted at a facility licenced by the EPA to receive this category of waste.	$250	$810
C	PIWs which pose a low hazard but require control and/or ongoing management to protect human health and the environment. Solid PIWs in this category can be accepted at best practice municipal landfills licenced by the EPA to accept this waste.	$70	$280[5] to $680
Industrial waste	Industrial wastes are not regulated as PIWs, but when disposed of to landfill, continue to be controlled by EPA. These wastes can be accepted at solid inert landfills (non-putrescible) or municipal solid waste landfills (putrescible) licenced by the EPA to accept this type of waste.	$55.46	$170[5]

1: Table 3 – EPA Publication IWRG631 (2009) Solid Industrial Waste Hazard Categorisation and Management.
2: https://www.epa.vic.gov.au/business-and-industry/guidelines/landfills-guidance/landfill-and-prescribed-waste-levies.

8 Note – Category A material cannot be disposed to landfill without prior treatment to reduce or control the hazard(s).
9 Note – only one landfill in Victoria is licenced to received Category B waste (Taylors Rd, Lyndhurst – SUEZ) and not all rural landfills are licenced to receive Category C waste.

3: SUEZ costs estimate per email Sue Adamson 22/05/18 unless otherwise noted. Note – Suez own and operate the only Cat B landfill in Victoria.
4: Estimated per comms. Sue Adamson, SUEZ, 21/05/18 includes treatment.
5: Cosgrove landfill rates – does not include transport and assume landfill will accept the waste material. http://greatershepparton.com.au/assets/files/documents/waste/Waste_Services_-_Schedule_of_Rates_-_Resource_Recovery_Centres_and_Landfill_-_2017_-_PDF_Version_for_website.pdf

Table 2-3 clearly shows that disposal of salt waste is an expensive exercise. Assuming a conservative annual salt waste production of 2,000 m^3/yr (which is easily being exceeded annually already at some sites) and a bulk density of 1.2 tonne/m^3, annual disposal costs are estimated as follows:

- Category A – $3,600,000 year including transport
- Category B – $1,944,000 year including transport
- Category C – $672,000 year excluding transport up to $1,680,000 year including transport
- Industrial waste - $408,000 year excluding transport

For dairy processing factories with existing stockpiles, the initial cost of disposal could be astronomical. For example, some stockpiles contain up to 35,000 m^3 stockpiled (equivalent to ~15 years production). To dispose of this existing stockpile as Category C PIW[10] the cost of disposal could be as high as $28,560,000 (incl. GST and transport). In addition, it would take up to one year to excavate, transport and dispose of the material using appropriately licenced EPA vehicles.

This highlights that salt disposal for land locked dairy processors is potentially prohibitive (e.g. those in central and northern Victoria). A better option would be to 'shift' product lines responsible for highly saline wastewater streams (e.g. cheese and demineralised whey) to coastal areas with ocean outfall or obtain specific hazard classification from the EPA for the salt waste that allows its disposal to rural landfills.

2.5.3 Classification for reuse or disposal

In line with Clause 11 Environment Protection (Industrial Waste Resource) Regulations (2009), the EPA can issue a general classification for industry wide waste streams (PIWs) for reuse or disposal. Examples of classification for disposal include drilling mud, firefighting dry chemical powders and arsenic compounds contained in sand, rock and mine tailings from the City of Greater Bendigo municipality.

To obtain a classification from the EPA, application must be made to the EPA demonstrating, inter alia, the following:

- Why the waste poses a low hazard
- Why local/centralised disposal will provide a better (or the best) environmental outcome
- Why the waste should be considered a lower hazard category

Classification of the salt waste for disposal at, for example, a specific landfill in central Victoria with appropriate controls (e.g. liners and leachate management systems) that is located in a suitable setting (e.g. overlying a highly saline aquifer) would provide a 'centralised' and 'streamlined' management strategy for saline waste generated in this region. While the initial investment in obtaining the classification may be high, the savings to waste generators are expected to be substantial.

It is recommended that thus type of classification be investigated further as a priority.

[10] Based on existing chemical testing and hazard characterisations.

2.6 CENTRALISED TREATMENT AND DISPOSAL

A second option is to establish a regional receival facility for these highly saline wastes at a central location in northern Victoria. Dairy processors and others would then transport their waste to this facility for disposal. This would minimise the concern that there were constraints on future regional production.

From the research discussed in Section 2.5, mechanical treatment has not been included in a centralised option. Instead, this option is based on the following two stage process:

- Construction and operation of a new regional facility based around evaporation basins to concentrate the liquid effluent into a crystalline solid waste; and
- Disposal of that solid waste to an existing municipal landfill site.

Centralised mechanical treatment has not been considered, as the contaminants present in each processor's highly saline waste stream is expected to be unique to them, and therefore each processor will require a unique mechanical treatment solution (or variation of similar technologies). This negates the potential for a regional / mechanical solution.

The cost effectiveness of mechanical treatment shall also be unique to the commercial situation of each dairy processor.

For the centralised facility to be based on evaporation ponds only, it is likely that a minimum wastewater quality would be required. Specifically, the concentration of organic dairy contaminants, such as lactose, would need to be enforced to prevent poor crystallisation in the evaporation ponds.

This approach was supported by a number of submissions to the market sounding exercise undertaken in 2015. Multiple vendors proposed local mechanical treatment, unique to each waste stream, was necessary before a centralised approach was considered for the resulting effluent.

2.6.1 Centralised evaporation basins

This solution would see the proposed new processing facility being located on a site of approximately 80 ha in size and would be required to be able to receive and process approximately 200 kL/day of highly saline waste. Based on 20,000 litre tankers, there would be approximately 10 truck movements per day with waste deliveries onto the site. After the waste has been evaporated there is a solid crystalline waste that would need to be transported off site to a landfill; this may generate two three-truck movements per week.

To build the new evaporation basins over the 80 hectare site there will need to be the following; Design, Engineering, Town Planning Permit Approval, Construction and Commissioning. It is estimated that the time line for this process, excluding any delays in VCAT with planning approval will be approximately two years.

Based on a site with good topography, no risk issues with ground water, ample high-quality clay on-site to dig out and compact for the basins it is estimated to build multiple evaporation basins covering a 50 ha area would be approximately $25M. Estimation for the land purchase, utilities connections, planning and environmental feeds, and other on-site infrastructure would be approximately $2,710,000. The additional on-site infrastructure includes:

- A receival bay for tanker deliveries
- Weighbridge
- Administration building
- Shed/workshop
- Internal roads and hardstand area
- Associated plant and equipment to manage the site

Table 2-4: Construction costs of regional receival facility[11]

VARIABLE	COST	% TOTAL COST
Site acquisition	$1,200,000	5%
Site preparation	$17,500,000	70%
Facilities/utilities	$2,190,000	9%
Capital construction cost	***$20,890,000***	
Design	$1,044,500	4%
Project Management	$2,089,000	8%
Approvals	$1,044,500	4%
Total construction cost	***$25,068,000***	

Note that construction costs can be highly variable and a conservative (conservatively high) estimate has been provided here. Typical evaporation pond costs are between $5,000 – $25,000 per ML of storage capacity. This variation can be caused by the local soil quality, scale, availability of appropriate clay material for lining, site access and topography.

The following table calculates the annual operating costs of the site to generate a unit cost of treatment. This includes capital costs, operating costs, and the costs of transport to site, and assumes an annual disposal volume of 48 ML (200 kL/day for 240 days/year). The result is a unit cost of $94/kL disposed.

Table 2-5: Evaporation basins: total and unit costs

VARIABLE	COST
Capital costs	$25,068,000
Return on capital	$1,253,400
Depreciation	$1,253,400
Annual capital costs	$2,506,800
Annual opex	$1,000,000
Transport to site	$1,008,000
Total annual costs	***$4,514,800***
Volume	48,000 kL
Unit cost of evaporation basins	***$94/kL***

2.6.2 Landfill

The solid crystallised waste would then require removal and disposal to landfill, with the classification of the saline waste having a major impact on the final landfill costs.

[11] DJR Environmental Pty Ltd, report, 6 December 2017.

As previously discussed, the cost of disposal to the landfill will depend on its classification, and to remove the current ambiguity, it is recommended that Dairy Australia or another relevant industry body applies to the EPA for a waste classification for the crystalline waste from milk processing factories.

For the purposes of this report we have assumed the crystalline waste is classified as prescribed industrial waste, and the closest landfill in north central Victoria that can receive this waste is the Cosgrove Landfill. The following calculation of landfill costs assumes that there is a 75% reduction in the volume of the effluent by the time it goes for landfill, i.e. an annual disposal mass of 12,000 tonnes.

Table 2-6: Landfill costs

VARIABLE	VALUE
Gate fee for PIW	$280/tonne (includes EPA levy of $70/t)
Transport to site	$550/load
Load size	20 tonnes/load
Unit cost	$27.50/tonne
Total unit cost of landfill	***$307.50/tonne***
Total mass to landfill	12,000 tonnes disposed/year
Total landfill cost	***$3,690,000***

2.6.3 Total costs

The following table then calculates the total disposal cost and unit costs once the site reaches a steady state, with liquid waste being deposited and solid waste being transferred to landfill.

Table 2-7: Combined disposal costs

VARIABLE	VALUE
Evaporation Basins	$4,514,800
Landfill	$3,690,000
Total cost	**$8,204,800**
Volume	48,000
Total unit cost	$171/kL

This suggests a total unit-cost for disposal of the highly saline waste-stream of around $170/kL.

This unit-cost value is dependent on the assumptions adopted regarding the characteristics of the site and processes involved. This section provides a sensitivity analysis of the impact of two key variables:

- The volume of waste deposited – it is assumed that the costs of the new facility are effectively fixed so a lower volume deposited results in a higher unit cost of treatment.
- The evaporation rate – the calculation above assumes that there is a 75% reduction in the volume. If a lower evaporation rate is assumed then a larger proportion of the initial volume needs to be transferred to land-fill incurring higher costs.

In the following table, a range of different values for these variables are tested.

Table 2-8: Sensitivity analysis of variables for unit costs

VOLUME DEPOSITED	% TO LANDFILL			
	10%	25%	33%	45%
200 kL/day	$125/kL	$171/kL	$196/kL	$232/kL
150 kL/day	$149/kL	$195/kL	$220/kL	$257/kL

This shows that the unit cost can approach $200/kL if a lower volume is deposited or a lower evaporation rate is achieved. This value compares with a figure of $213/kL for disposal of the waste-stream via the '*Brine Receival Facility*' operated by Wannon Water at Warrnambool (see Section 2.8.2).

In assessing this option, it is also worth recognising that establishing a regional receival facility in northern Victoria would involve a considerable exercise. It would require:

- Gaining agreement from an entity to develop, own and operate the site. The obvious candidate would be the City of Greater Shepparton who already operate the Cosgrove Landfill facility. There would need to be an extensive engagement process to gain the understanding and support of the Council to take on this extra role.
- Identifying a suitable site with appropriate soil condition and away from high value assets such as fresh groundwater aquifers.
- Obtaining planning permission: the development would require planning permission. Communities are generally unenthusiastic about new waste disposal facilities being constructed particularly where these involve waste products being deposited that come from other locations. Experience with developments elsewhere suggests that any application could expect to involve a lengthy process of appeals and a likely hearing at VCAT before any works could progress.
- EPA Licensing: the facility would require licensing from the EPA. The new processing will require an EPA (Vic) Works Approval and Licence to operate due to the receival and processing of prescribed industrial waste. The total process to obtain Works Approval is likely to take at least six months. Once the works approval is accepted, site works can commence to build the facility. Once the facility is completed the EPA (Vic) will issue a licence to operate based on information provided in the Works Approval application.
- The development would also require a range of specialist environmental services including odour modelling and monitoring, community consultation, traffic management plan, and noise assessment services.

The potential barriers for this option are significant and for the majority of the project partners, it represents the same management solution to what they are already doing, just at a larger scale and with increased transportation costs. If this option was able to capitalise on the scale of the combined operations and extract by-products from the waste that could be reused, then it may offer some potential. However, as this doesn't currently seem possible, its suitability as a worthy management option that could attract investment seems limited.

CASE STUDY: COLIBAN WATER BRINE STORAGE POND, BENDIGO

Brine from the reverse osmosis treatment of extracted groundwater is stored in a 270 ML brine storage pond, located at the Bendigo Water Reclamation Plant (WRP). The brine is produced at the New Moon Groundwater Treatment Plant (GWTP) located north west of Bendigo. From here it is transferred in a pipeline to the Bendigo WRP, a distance of approximately 6.6 km.

The brine pond has been sized to take into account rain and local evaporation rates. It is lined with a 300 mm layer of compacted clay covered with a 1.5 mm flexible high-density polyethylene liner.

The pond liner has a design life of 20 years, and the pond size is based on this timeframe. The pond is designed to fill steadily over the life of the project. The pond shall be left to further evaporate and Coliban Water shall eventually dispose of the concentrated waste to a suitable and approved location.

To reduce the risk of odours, aeration and mixing equipment is located in a recirculating wet well adjacent to the storage pond.

The construction of this pond was $1.64M, with additional costs (consultants, project management, etc.) bringing the total cost of the brine storage pond to $2.02M. This does not include the cost of the pipeline, land purchase (already owned by Coliban Water) or permitting/approvals.

2.7 DISCHARGE TO HIGHLY SALINE SOURCE

The last major option is to dispose of the highly saline wastes to an existing saline receiving water. There are three parallel approaches to this option:

- Relocate the plant closer to the coast
- Discharge the waste to the Warrnambool brine receival facility
- Dispose to an existing saline groundwater aquifer

In the case of the groundwater treatment brine that enters the evaporation pond at the Bendigo WRP, the volume of this stream, at 200 kL/day, is too great for any road-based transport options. Therefore, the commentary provided on discharge to the Warrnambool brine receival facility is focused at the dairy processors only.

2.7.1 Relocate plant

The first option would be for the processing company to relocate the process to a location close to the coast to facilitate disposal direct to the ocean. This is a ‘neat’ solution from a saline wastewater management perspective, however, this option is not available for most processing companies to adopt, given their business structure and existing investments. Equally, the option reduces business activity and employment in northern Victoria.

This may be a strategy that processors consider for expansion or the construction of new facilities, but it doesn’t help manage the saline waste streams currently being produced across the northern Victorian sites.

2.7.2 Warrnambool Brine Receival Facility

The second potential approach to this option is to use the brine receival facility managed by Wannon Water outside Warrnambool. This discharges a mixed waste-stream direct to the ocean through a licensed outfall. This approach has the advantage that it takes advantage of an existing facility – this obviates the need to find an appropriate site and construct and run the necessary handling and processing activities.

The facility currently has capacity to receive additional brine streams and would welcome the opportunity to discuss receival with any potential processors.

The quality and volume requirements set by this facility are detailed in Table 2-9.

Table 2-9: Saline waste quality for the Wannon Water brine receival facility

PARAMETER	VALUE[12]
Total capacity of the facility	10 B-double tanks over 24 hours
Salinity limit	Negotiable, but <100,000 µS/cm EC preferred
Chemical oxygen demand	<1,500 mg/l preferred; cost highly dependent on COD (see below)
Biological oxygen demand	<5 mg/L
pH	6 – 10
Nutrients	Negotiable

The cost for this option is ~$215/kL. This is made up of two main elements:

- The costs of transporting the load from northern Victoria to Warrnambool
- The receival facility fees – based on a high strength waste.

12 P. McLean, Wannon Water, pers comms, Feb 2018.

Table 2-10: Costs to dispose at the Wannon Water brine receival facility

VARIABLE	VALUE
Tanker load	25 kL/tanker
Tanker trip	10 hours/trip
Tanker cost/hour	$150/hour
Tanker cost per load	$1,500/trip
Tanker unit cost	$60/kL
Receival unit fee	$153/kL
Receival cost per load	$3,825/load
Total costs	$5,325
Unit costs	$213/kL

The receival unit fee of $153/kL is the highest charge the facility has for brine and reflects the high COD of the saline waste produced by dairy processing plants. If the processors were able to reduce their COD, then the cost of disposal to the brine receival facility would reduce as below.

Table 2-11: Brine receival cost – COD

COD (mg/L)	COST ($/kl)
0 – 1,500	$11.95
1,50 – 6,000	$30.60
6,000 – 10,000	$46.00
10,000 – 20,000	$76.60
>20,000	$153.20

A volumetric flow rate of 70 kL/day would equate to an annual disposal cost of around $5.5 million, which is excessive and limits the potential for this option.

Note: it may also be possible to negotiate discharge into other outfalls managed by alternative water authorities (e.g. City West Water at Altona; Melbourne Water at Werribee; Barwon Water at Black Rock). The difference is that they are not currently set-up to receive saline waste from third parties in the same way Warrnambool currently is, and therefore, some modification and new infrastructure would likely be required. The cost impediments of this option are likely to remain the same regardless of which location is selected.

2.7.3 Saline aquifers

A third possible approach would be to dispose of the ‘highly saline’ waste stream to an already highly saline groundwater aquifer. The key regulatory control on this disposal route is the SEPP *Groundwaters of Victoria.* Clause 20 of the SEPP states that:

"There must not be any direct discharge of waste to any aquifer by means of a bore" unless it can be shown to and approved by the EPA that the groundwater quality objectives are met and that there will be no detriment to any beneficial use of groundwater, land or surface waters.

Most groundwater aquifers in central and eastern parts of the GMID are relatively fresh and not suitable for disposal of highly saline wastes. Aquifers further to the west are generally more saline. However, even here, there would be significant challenges in establishing to the satisfaction of the EPA that the discharge would have no impact on potential beneficial uses and users including, for example:

- Groundwater dependent ecosystems (GDEs)
- Contamination of existing saline groundwater aquifers used to source salt from the Pyramid Creek interception scheme by Pyramid Salt Pty Ltd, where risks of contamination would be considered extreme
- Stock and domestic bores where the discharge might lead to the build-up of an elevated saline groundwater table close to the surface

Other issues to resolve would include:

- The transport arrangements from the individual plants to the disposal site
- The lack of equipment to allow disposal into the aquifer
- The likely limited time-window that any single aquifer might offer for this approach.

RMCG's experience with saline aquifer disposal is that whilst it may be technically viable in some locations across the state, gaining approval for it from EPA is extremely difficult and it has not been a potential option for other recycled water management projects. Regardless, it is an option that has some merit and conversations with EPA regarding its potential should continue. It's uncertainty however means that it can't be considered a potential option now.

2.8 SUMMARY

The following table summarises the relative scale of the costs, benefits and risks of the alternative approaches reviewed.

Table 2-12: Disposal options for highly saline wastes

OPTION	COSTS	BENEFITS	RISKS	RECOMMENDED?
Local treatment and disposal	Capital $$ - $$$ Transport $0 O&M $$ - $$$ Disposal $$	Low transport costs Under control of local management Relatively well understood technology and operations by project partners	Availability of local land for evaporation lagoons Ongoing need for landfill Questionable as to whether this can continue as a long-term management solution	The most viable option of those considered, noting its limitations. Focus needs to be on source control (avoidance) of high saline wastes from within the factory (where possible), and then treatment to produce a low salt high organic waste that may have agricultural reuse options, and a low organic high salt waste that will achieve good crystallisation of salts in the lagoons.

OPTION	COSTS	BENEFITS	RISKS	RECOMMENDED?
				The hope is that ongoing R&D will improve this option over time.
Centralised treatment and disposal	Capital $$$ Transport $ - $$ O&M $$ - $$$ Disposal $$	Ensures professional management Reduced regional constraints	High cost to establish and run Ongoing need for landfill Opposition from local communities 'Unique' salt streams from individual businesses impacts potential for combined treatment	A high cost solution with considerable challenges to establish. Does not appear to provide any benefits beyond local treatment and disposal, and will be higher cost.
Discharge to brine receival facility	Capital $ Transport $$ O&M $$ Disposal $0	Existing facility Low set-up costs No need for pre-treatment or landfill	Added transport to regional roads Possible future higher fees	Effective solution already available. High cost will limit its viability. Organic load of the saline waste may also be an issue.
Discharge to highly saline aquifer	Capital $$ Transport $$ O&M $ Disposal $0	Low capital set-up costs No landfill fees	High regulatory constraints Short-term solution Proximity of appropriate saline aquifers	Technically feasible option that is worth pursuing, but it will be very difficult to gain approval from the EPA. A potential longer-term management solution that warrants ongoing discussions with the EPA.

As discussed, there is unfortunately no 'silver bullet' for the management of the highly saline waste. Multiple options have been investigated but none of them provide a truly sustainable management option that will provide a long-term solution.

From the analysis undertaken, the most viable option appears to be local treatment and disposal via evaporation basins and landfill. There are a number of limitations with this (it is a high cost solution and it is questionable as to whether it can continue as a long-term management solution), but it is considered to be a more viable option than the others considered due to cost and regulatory approval.

To support this option, the sites need to:

- Minimise the production, or strength of the highly saline wastes wherever possible. Avoidance is the highest level in the EPA's waste hierarchy and it should be consistently applied by the sites.
- Following this, the aim of the sites should be to undertake treatment so that the high saline waste can be split into a high organic low salt stream that can be potentially reused for agriculture (e.g. pig food), and a high salt low organic stream that can achieve good crystallisation in the evaporation lagoons. The hope, then, is that ongoing R&D into highly saline wastes will help to improve the reuse potential of the organic material, and perhaps the extraction of by-products from the saline material. Ongoing R&D will also hopefully help to reduce the quantity of saline waste that is ultimately produced, and therefore, the extent and cost of landfill should that continue to form part of the management solution (which based on the research undertaken is highly likely).

- It is also recommended that Dairy Australia or another relevant industry body engage the EPA and develop a waste classification for the crystalline waste from milk processing factories. This process has been used by other industries where the classification of their waste is not straight forward, and it has helped to provide certainty to the industry around planning, costs, regulation etc.

The final comment for the high saline wastes is that if a dairy processor (or other industry) is considering the costs and implications of producing a highly saline waste stream, then relocation of this process close to the ocean may be the most appropriate waste management decision. This is ‘easy to say, but difficult to implement’, and this fact is not lost on the authors of this report. It does however remain a relevant management approach that should be strongly considered by high salinity waste producers.

3 Saline wastes

3.1 DEFINITION

For the purposes of this project, saline wastes have been defined as having an EC of 1,500 to 4,000 µS/cm. The 'saline' waste category represents most of the waste stream from dairy processing plants. The majority of the sodium comes from the caustic, sodium hydroxide, used in cleaning down processing lines and equipment between batches. This activity is commonly known as 'clean-in-place' or CIP, as it involves cleaning down the plant in situ. On average:

- More than 80% of the sodium in the waste-stream comes from CIP
- 10% as brine from the product
- Roughly 5% from salt used in additional product process, and
- 5% from product loses.

3.2 CURRENT MANAGEMENT

Typically, wastewater from a dairy processing factory undergoes solids separation before being discharged to a storage lagoon. The pH of the wastewater may also be adjusted prior to discharge. During the irrigation season, the stored wastewater is then pumped to irrigation properties where it is shandied (mixed) with channel water before being applied to pasture. Outside the irrigation season, the wastewater is held in winter storages.

A number of different practices are employed by the dairy processing companies in terms of their contracts with the irrigation farmers and how they secure the shandy water necessary to operate the schemes. In some cases, the dairy company will provide all of the channel water required to shandy the wastewater back to the salinity target. In this case, the farmer is only responsible for supplying the additional channel water required to meet the crop's full water requirements[13].

In other cases, the company provides some of the channel water (usually about half) to meet the scheme's salinity target but relies on the farmer to use their own channel water entitlements to make up the remainder of the shandy water requirements and ensure the crop's full water requirements are sustained. The consequence of the two different approaches is how much shandy water the company provides, and the cost associated with this.

Historically, the second option has been in place for dairy processing wastewater irrigation schemes. It recognised that the farmers traditionally had access to large water entitlements, either through ownership, high water allocations and/or affordable trade of seasonal (temporary) water.

However, more recently, and as companies have been updating/renewing their wastewater supply contracts with their farmers, they have been moving towards the first example. This change has been due to the changing water markets and assessment of risk:

- Farmers these days typically own less water than they have in the past, and there is far more competition for water from other agricultural industries, communities and the environment across the southern parts of the Murray Darling Basin for the water that is available (which impacts price).
- The companies are also more aware of the potential for their saline wastewater to impact the farms soils if they are not consistently managed. A key part of this management is making sure the wastewater is

[13] For example: full crop demand is 8 ML/ha/annum. 2 ML of wastewater can be applied per hectare to meet the phosphorus loading targets for the scheme, and the wastewater needs to be shandied with a minimum of 4 ML/ha/annum channel water to meet the schemes irrigation salinity target of ≤800 EC (µS/cm). This 4 ML/ha/annum is provided by the milk processing company, so the farmer would need to provide the remaining 3 ML/ha/annum of channel water entitlements to meet the full crop demand requirement of 9 ML/ha/annum.

consistently shandied at the correct rate. By providing the farmers with enough shandy water to meet the shandy requirements, the companies mitigate this risk and the potential for farmer backlash/legal challenges in the future.

Consistently applying the correct shandy management is an important part of managing saline wastewaters.

3.3 ASSESSMENT

Irrigation with shandying water provides an adequate and sustainable re-use/disposal approach, provided well-established standard controls are followed. The approach takes advantage of the presence of commercial irrigation properties across northern Victoria and the wide availability of channel supply to act as a shandying component. It also relies on good practice regarding soil testing and application of gypsum where necessary to offset risks of excess sodium.

During the drought, the price of shandying water became far more expensive and some farmers did not apply the full dilution fraction required. This led to raised levels of salinity and sodicity in the soils and heightened risks of reduced agronomic production and legacy soil salinity/sodicity issues. Best practice saline wastewater management therefore becomes a combination of:

- Appropriate irrigation loading rates to manage the salinity/sodicity and nutrient concentrations of the wastewater
- Source control to minimise the concentration of salts, and
- Automation to take away human error associated with consistently shandying the saline wastewater at the correct rate.

Each of these measures are discussed below.

3.4 BEST PRACTICE MANAGEMENT

3.4.1 Northern Victoria

One of the drivers behind this project was concern that northern Victoria is not able to sustainably manage saline wastewater produced by industry. Whilst the management of highly saline wastes remain problematic for all inland areas of Victoria, it is RMCG’s opinion that northern Victoria has a number of advantages for the management of ‘saline’ and ‘salty’ waste streams. Northern Victoria has three key factors that help with the management of saline wastewater:

i. Farmers in the region have demand for the nitrogen and phosphorus that is also contained within the wastewater and can incorporate it into their annual fertiliser programs.
ii. The region has the scale to accommodate the winter storages and irrigation areas necessary to manage the volumes of saline wastewater produced.
iii. The region has access to shandy water that is vital in managing saline wastewater.

This same list of advantages is not true for other regions of the state, particularly those that have a higher intensity of agriculture and/or no access to shandy water other than rainfall. The key to northern Victoria sustainably managing saline wastewater is consistent resourcing and the application of the best management practices detailed in this report. The importance of appropriate resourcing and the role it plays in delivering sustainable saline wastewater management cannot be underestimated.

3.4.2 Phosphorous

Interestingly, it is not salinity or sodicity that is the limiting factor for dairy processing saline waste streams, but typically phosphorus.

The maintenance phosphorus requirement for most dairy farms is typically in the range of 30-40 kg/ha/annum, and most dairy processing waste streams have 20-40 mg/L phosphorus. Therefore, to achieve the maintenance requirements, the schemes can typically apply 1-2 ML/ha/annum of wastewater.

Perennial pastures, Lucerne and other summer crops across northern Victoria typically require 8-10 ML/ha/annum irrigation water to achieve full production. So, if the wastewater is providing 1-2 ML/ha/annum of this requirement, then the farms need to supply the remaining 6-9 ML/ha/annum of channel water.

Table 3-1 below shows the resultant irrigation salinity after shandying, based on a range of different wastewater salinities and loading rates, and assuming an annual average irrigation requirement if 9 ML/ha/annum.

Table 3-1: Dilution ratios for saline wastewater

WASTEWATER SALINITY (EC µS/CM)	4,000	3,000	2,000	1,500
Wastewater ML/ha/yr	1	1.33	2	4
Channel water shandy ML/ha/yr	8	7.67	7	5
Shandy ratio	1 : 8	1 : 5.75	1 : 3.5	1 : 1.25
Applied irrigation salinity EC (µS/cm)	489	487	483	694

Whilst the scenarios presented in Table 3-1 are only a snapshot of the different combinations in operation across northern Victoria, it does highlight that if the schemes manage their phosphorus loads appropriately and irrigate according to crop demand, then the best practice salinity target for all schemes of ≤800 EC (µS/cm) will be achieved (see Section 3.4.3 below for more information on the 800 EC target).

So, a large component of salinity/sodicity management (i.e. correct shandying) will be achieved if the schemes properly manage the phosphorus concentrations also contained within the wastewater.

3.4.3 Salinity

Wastewater salinity can impact the crop in a number of different ways (e.g. osmotic, toxicity, foliar injury, migration) and whilst being mindful of all of the different modes of impact is important, the most important factor is ensuring the applied irrigation water has a salinity that will not unreasonably impact agronomic production.

Irrigation with saline waters is a well-understood across Australia and has been the focus of multiple research projects and demonstration sites across northern Victoria. Throughout the late 1970s and 1980s, Agriculture Victoria undertook extensive work on irrigated salinity and determined that an upper limit of 800 EC (µS/cm) is a good target for saline irrigation. This limit recognised that at times there is a need to irrigate with saline water, but also that soil health and crop production could be suitably maintained at this rate.

This limit has since been put in place across multiple wastewater and recycled water schemes across northern Victoria, and where consistently achieved, it has provided long-term sustainable irrigation outcomes. Annual soil monitoring has shown that soil salinities can be maintained within a Class A (<3.8 ECe dS/m) or Class A+ (<1.8 ECe dS/m) range, and farmers are able to produce the range of crops needed to operate their businesses.

Problems have arisen where this target has not been consistently met, and irrigation water with a higher salinity has been applied to soils with low permeability (i.e. much of the irrigated soils across northern Victoria). This was particularly true during the millennium drought when shandy water was expensive and scarce, but saline wastewater was still available and being irrigated.

The impact was that questions were raised regarding northern Victoria's ability to manage saline wastewater, and milk processing companies were at risk of legal action from the farmers using their wastewater due to deteriorated soil chemistry and reduced production.

The response has been for some companies to supply enough shandy water to the farmers to ensure the salinity target of ≤800 EC (µS/cm) is always met. This has resulted in these companies taking full responsibility for their saline wastewater, and minimising their risk with respect to legacy soil issues and loss of production. It does mean that these schemes have much higher cost exposures because they need to consistently source more shandy water than what they were in the past, and for that reason, companies that are delivering this form of management should also have a water procurement strategy that can help them secure the GMW water entitlements they need for the lowest risk (cost).

Automation can also play an important role in ensuring saline wastewater is shandied with the correct amount of GMW channel water prior to reaching the paddocks and removing the risk of human error.

3.4.4 Automation

Advancements in irrigation scheduling and application have been immense over the last 10-15 years, and irrigation automation is now a common practice used by many farmers across northern Victoria.

The technology now exists for salinity sensors to be placed in the farm channel and regulate the volume of wastewater that is supplied into the channel, relative to the target salinity (i.e. ≤800 EC) and volume of shandy water (channel water) that is also being delivered into the channel. Whilst there is some expense involved with these systems, the benefits are significant and include:

- Removes the risk of the required shandy not being met at each irrigation
- It can accommodate different salinity shandy water (e.g. channel water or bore water) and fluctuating wastewater salinities and still achieve the desired outcome
- It helps milk processing companies guarantee their saline wastewater has not been applied to the paddock when the correct shandy conditions aren't available
- It helps to ensure wastewater is used at every irrigation (up until that farmers licensed volume), thereby ensuring the scheme empties their winter storages over the irrigation season.

It is strongly recommended that companies implement automation across their schemes.

3.4.5 Sodium

Sodicity occurs when there is a significant proportion of sodium compared to the other cations. This causes the dispersion of soil particles and also damages the structural stability of the soil. Some of the common effects of soil sodicity are hardpans, surface crusting, blocked soil pores and ponding of rainfall runoff.

This can cause crops to have difficulty becoming established and crops can become waterlogged or anoxic due to the reduced permeability of the soil.

Soils with high clay contents are more susceptible to sodicity impacts as they tend to hold onto the sodium ions more strongly and don't readily leach excess sodium if the permeability of the soil is low.

Many Australian soils are naturally sodic. However, the addition of recycled water containing high levels of sodium can exacerbate the natural problem or cause the soils to become sodic. The application of gypsum or lime can help to improve the balance between sodium and the other ions present in the soil and thus alleviate the effects of sodicity. Lime would be used in preference to gypsum only if the soil pH is also low (i.e. <6), as the alkalinity of the lime can help to increase soil ph.

The following criteria and management controls should be used to assess the potential for sodicity issues and mitigate them if they are a risk.

1. Review latest soil chemistry results to determine gypsum/lime requirements.

Table 3-2: Gypsum/lime requirements

TOPSOIL ESP (%)	RATING	GYPSUM RESPONSE
<6	Non-sodic	0, unless wastewater EC/SAR comparison (see below) suggests slight to moderate or severe potential for reduction in rate of infiltration; then consider 0-2.5 t/ha/annum.
6-10	Low sodic	Management gypsum applications; consider 1-2.5 t/ha/annum.
10-15	Moderately sodic	Management gypsum applications PLUS avoidance of longer-term issues; consider 2.5 to 5.0 t/ha/annum.
>15	Highly sodic	Gypsum corrections; consider 2.5 to 5 t/ha/annum.

Note:

- The gypsum ranges are provided as a guide only. Final applications should be based on the review of soil chemistry data, previous gypsum applications at the site and recorded changes in soil sodium levels (i.e. review of soil test results).
- If no previous gypsum application data is available for the site, an application rate within the range specified should be adopted and the soil response monitored and used to verify/adjust future gypsum application practices.
- The above gypsum ranges can be exceeded if there is consistent data across a number of sites/years showing that an increased amount will benefit the soils. Similarly, the gypsum ranges can be reduced if there is consistent data across a number of sites/years showing that a decreased amount is all that is required to manage the soil sodium levels.
- Individual gypsum applications are not to exceed 5 t/ha/annum. In all cases, the preference for gypsum applications is ‘smaller amounts more often’. So even at the upper rate of 5 t/ha/annum, the preference is to split this application into two 2.5 t/ha/annum applications.

2. The potential for loss of water infiltration from the irrigation of wastewater will be considered using the graph below and the following advice.

Monthly wastewater quality monitoring will be used to complete the assessment.

Table 3-3: Assessment table – potential for loss of water infiltration

RATING	RESPONSE
No reduction in rate of infiltration	▪ Continue to monitor wastewater quality to verify salinity and sodicity levels, and soil chemistry for soil sodicity.
Slight to moderate reduction in rate of infiltration	▪ Improve wastewater quality so that no reduction in rate of infiltration will occur. ▪ If the above is not feasible/economic, consider shandying wastewater with a fresh source of water (e.g. condensate) and/or dose the wastewater with calcium (e.g. gypsum) to improve the wastewater quality so that no reduction in rate of infiltration will occur. ▪ If any of the above improvements to wastewater quality are not feasible/economic, apply gypsum to the soil to off-set the anticipated impact on rate of infiltration. The Final gypsum application should consider the need to manage the wastewater quality, plus any existing sodium concentrations in the soils.
Severe reduction in rate of infiltration	▪ Cease wastewater irrigation and improve wastewater quality until no reduction in rate of infiltration can be achieved, or slight to moderate reduction in rate of infiltration can be managed.

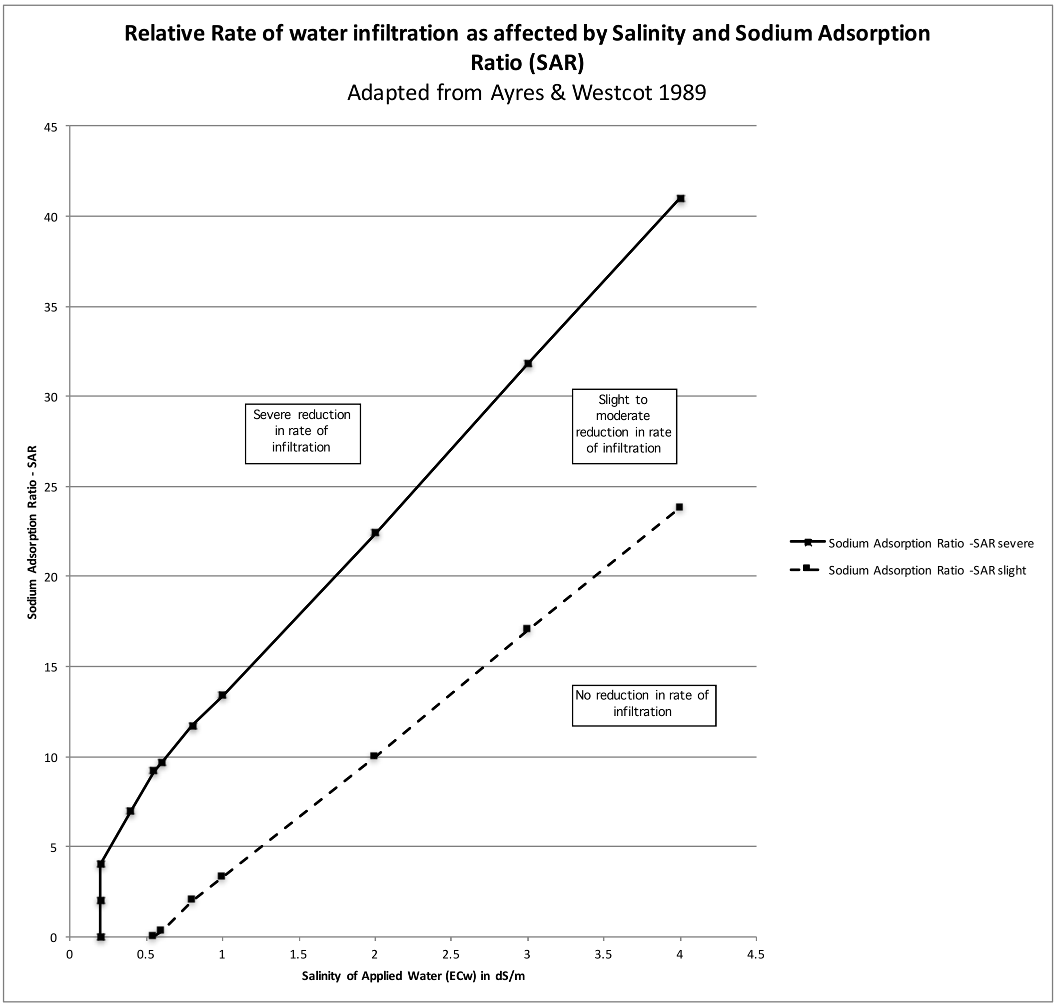


Figure 3-1: Potential for loss of water infiltration

3.4.6 Source control

Source control is the first step in reducing the environmental impact of production wastes. This approach is in line with the waste management hierarchy in the *Environment Protection Act 1970*. Minimising the quantity of saline wastes produced is not only good for the environment, it can also be the most cost-effective and lowest risk option for a processor.

The following sections summarise the routes that processors can take to reduce the volume and mass of saline waste. A focus on reducing the use of sodium hydroxide within the factory may result in a significant reduction in irrigation management costs downstream. This is particularly important when soil sodicity is becoming a limiting factor to irrigation with saline wastewaters.

Best practice cleaning

Discussions with project partners confirmed the importance of effective CIP to ensure cleanliness and minimise the risk of incomplete sanitation and product contamination. It has therefore, historically, been an understandable risk management culture to over-clean, even if at risk of generating a larger disposal stream.

Evidence from project participants was that implementing 'best practice' protocols could achieve an appropriate balance between cleanliness and disposal requirements. Periodic investigation and adjustment to CIP systems can reduce the consumption of sodium hydroxide and should be considered especially when changes are made to processing lines.

It is recognised that it is far easier to implement tighter controls when installing a new product line than to retrofit or change practices within an existing plant. The initial design and installation of process plant can also have a major effect on CIP performance. For example:

- Reducing dead legs to improve cleaning efficiency
- Installing appropriately-sized flow meters at appropriate locations within CIP systems to allow for regular monitoring of CIP performance
- Installing sensors for monitoring TDS, temperature, etc.
- Pre-rinsing of fouled CIP lines greatly reduces the quantity of product on the pipe walls. Removing this excess product before the caustic solution is introduced is a fundamental CIP step to reduce consumption of caustic.
- Analysis of the control loops on CIP systems can be a valuable tool in reducing caustic consumption. Over time, changes to valving, sensor locations, control loop programming and cleaning additives, can lead to an unnecessary over-use of caustic.

Saline waste can be reduced if CIP systems are regularly checked for performance improvements.

CASE STUDY: BEGA CHEESE, STRATHMERTON

In the summer of 2014/15, a graduate student investigated options for sodium reduction at the Bega Cheese processing site in Strathmerton. Due to impending constraints on the disposal of saline wastes to land for irrigation, the investigation included source control of sodium within the factory. A mass balance of sodium was completed and then options for reducing sodium consumption were investigated.

The mass balance found that 91% of the sodium in the wastewater came from the CIP systems. Historically, the CIP control programming had not been written with concern for the minimisation of sodium hydroxide consumption. Also, process changes over time had added to the sodium hydroxide consumption and therefore all CIP circuits were recommended for adjustment.

Recommendations to the CIP circuits included:

- Increasing the lag time on the return valve to the caustic tank during the pre-rinse cycle of the hold tube circuit. A drop in conductivity shortly after changing from pre-rinse to caustic resulted in an over-dosing of caustic. The location of the dosing sensor caused the control system to see this change in conductivity, resulting in the unnecessary dosing.
- Installing a filter on the cooker filler circuit to ensure that all residual cheese pieces are removed from the line. This will prevent solids entering the caustic tank, where they degrade the caustic for future cleaning cycles.
- Installing variable speed drives on CIP supply pumps to reduce the mixing of the caustic cleaning solution and the rinse water. This shall reduce fluctuations in conductivity measurements which result in unnecessary dosing of sodium hydroxide.
- Re-timing of each CIP circuit to ensure that the pump and valve operating times are correct for the length and size of the pipelines in each circuit.

Cleaning chemical choices

The other option to reduce sodium waste is substitution with an alternative cleaning chemical. Sodium hydroxide can be replaced by potassium hydroxide in CIP systems. However, the following points impede the change to potassium hydroxide:

- The products are more expensive
- The products are not as effective, with sodium hydroxide having better solubility and cleaning efficiency
- Approximately 40% more potassium hydroxide is needed to directly substitute with sodium hydroxide[14]
- The effluent stream would comprise a higher proportion of potassium salts which would necessitate access to a larger irrigation area or generate a larger waste disposal challenge.

There are many alternative cleaning chemicals to sodium hydroxide and potassium hydroxide, including chelating agents, additives, detergents and enzymes. These alternatives may offer a reduction in total saline waste produced without compromising cleaning performance. Periodic trials of alternatives are recommended, as is knowledge-sharing of successful cleaning practice changes within the diary processing industry.

Complementary savings

Close monitoring of CIP systems, along with periodic investigations, can bring other benefits as well as a reduced saline waste stream. Some of the benefits within the factory include:

- Reducing the consumption, and therefore the cost, of cleaning chemicals
- Reducing the quantity of hot water used
- Reducing cleaning-run times
- Improved recovery of waste product
- Some cleaning chemicals may reduce OH&S issues.

[14] Smart Water Fund (2010) Clean-In-Place Best Practice Guidelines Part III.

Reducing saline waste generation also reduces costs in the disposal stages from:

- Smaller wastewater treatment units
- Smaller winter storage volumes
- Less channel water required for shandying
- Less land for irrigation.

For processors that discharge trade waste to sewer, the feasibility of the long-term disposal of saline wastes as trade waste should be considered. As water authorities start to incur greater costs for the management of saline trade wastes, these costs are likely to be passed back to the dischargers though increased trade waste fees.

WORKED EXAMPLE: SODIUM HYDROXIDE REDUCTION COST SAVINGS
A dairy processing plant implemented a number of source control measures to reduce the concentration of sodium in their wastewater by 20% in one year. The average wastewater TDS went from 2,500 mg/L to 2,000 mg/L and their annual consumption of sodium hydroxide dropped by 90 tonnes. A breakdown of savings generated by these source control measures are shown below.
Savings from sodium hydroxide purchase:
Flowrate of wastewater = 180 ML/year
Reduction in TDS of wastewater = 500 mg/l
Saving in sodium hydroxide = 36 tonnes/year
Cost of sodium hydroxide = $55/tonne at 45% solution
Savings in sodium hydroxide cost = ($55/0.45) x 36 = $4,400/year
Savings from shandy water:
Final TDS (after shandy) = 500 mg/l
Cost of shandy water = $150/ML (average long-term price for seasonal (temporary) trade)
Reduction in shandy water requirements = 1:5 to 1:4 wastewater : shandy water
Saved shandy water = 180 ML/year
Savings from shandy water = $27,000/year

3.5 DISPOSAL TO CHANNELS

The current methodology involves irrigation to neighbouring properties with an adequate dilution factor given access to channel supply as a shandying element. An alternative option explored was to use the full channel supply as a shandying fraction. This would involve disposal of the full effluent stream into a major supply channel with the resulting diluted waste-stream then being supplied to all customers downstream. On this basis, the sodium and phosphorus would be dispersed over a far wider area than at present.

This option raises a number of issues:

- There are few incentives on GMW which manages the channels to participate – other than to add a small marginal volume to their total available resource.
- The approach would need to take account of stock and domestic customers within a defined mixing zone downstream of the discharge point. It would probably be necessary to provide a piped D&S supply for a 2-5 km distance.
- The current bulk entitlement system does not allocate a specific value to the loss allowance that GMW is assumed to hold. That means that GMW cannot gain value from any additional flow into its system. Otherwise, the contribution of an additional 1,000 ML is equivalent to the gifting of $2.5-3 million to GMW.

- One option would be for the local dairy processors to negotiate a net credit to offset the volume that they individually extract from the system.

Whilst this form of management would be a significant change from what's currently considered acceptable, it is feasible and has precedence; Murray Goulburn (Saputo) discharge treated wastewater into the Eastern Channel at Maffra under an EPA license. It is also technically feasible, as illustrated by Table 3-4 and Table 3-5 below and the following commentary.

Table 3-4: Mixed water quality – channel discharge; average scenario

Source	Flowrate (ML/day)	Salinity (EC µS/cm)	Phosphorus (mg/L)
Wastewater	5	4000	40
Channel water	1000	50	0.05
Mixed wastewater / channel water	1005	69.7	0.2

Table 3-5: Mixed water quality – channel discharge; worst case scenario

Source	Flowrate (ML/day)	Salinity (EC µS/cm)	Phosphorus (mg/L)
Wastewater	8	6000	60
Channel water	500	50	0.05
Mixed wastewater / channel water	508	143.7	1

GMW's criteria for accepting this would likely be the water quality limits they have established for accepting run-off into their regional drainage network from farms irrigated with wastewater. These quality limits are:

- Suspended solids: 30 mg/L
- Salinity: 1,200 EC (µS/cm)
- pH: 6.0-8.5
- Total phosphorus: 2 mg/L
- Total nitrogen: 5 mg/L
- 5-day BOD: 40 mg/L
- Blue green algae: 1,000 cells/mL
- *E. coli:* 150 orgs/100 ml

The dilution flow available in the channel relative to the wastewater discharge would see these limits met, and as discussed, a stock domestic pipeline could be established for the length of the mixing zone within the channel to overcome any health-based concerns regarding the supply of stock and domestic water.

This option would provide the project partners with multiple benefits including reduced cost of infrastructure, potentially improved environmental and agronomic compliance (i.e. removal of land-based salinity/sodicity and phosphorus loading issues), and the ability for this solution to be scaled up or down easily to meet the wastewater flows from the factory.

There are a number of channels within proximity of the project partners that meet the above requirements and it is recommended that the issues around this option are explored further with GMW and the Department of Environment, Land, Water and Planning (DELWP) to test its merit.

4 Salty wastes

4.1 DEFINITION

This category covers waste streams from the wastewater treatment plants operated by Goulburn Valley Water (GVW). The salt comes from residential customer wastewater and from trade-waste, with a smaller amount from saline groundwater infiltration.

4.2 CURRENT ARRANGEMENTS AND ASSESSMENT

4.2.1 Disposal

There are a number of current approaches:

- In Shepparton, the volume of wastewater from residential properties provides an adequate dilution flow for the saline discharges from industrial trade-waste customers. Therefore, no shandying with channel water has been required before reuse of the wastewater to pasture or discharge to the river.
- In Tatura, by contrast, the volume of the residential wastewater is not of sufficient scale to provide dilution flows for the dairy-wastewater discharge from TMI. In this case, GVW manages the wastewater disposal in a similar way to the 'Saline' waste category, with the shandying of the saline stream with channel water before reuse to pasture through irrigation.

The approach in Shepparton is on the limit of sustainability, as the predominately clay soils of northern Victoria are unforgiving and when shandying supply is not available then the approach leads to a slow decline in soil chemistry. Further, the volume and concentration of trade wastes received at the Shepparton WMF are increasing, and GVW are concerned about their ability to accommodate further increases by existing trade waste customers or a new industry that would provide regional development benefits.

These sections therefore focus on the management of the 'salty' recycled water being managed by GVW at Shepparton. The typical salinity range is ≤1,500 EC (µS/cm) and while the focus of this report has been the Shepparton WMF, these notes also have applicability to a range of other GVW and water authority/industry sites that fall within this category.

4.2.2 Soil chemistry and shandy requirements

GVW has adopted a pragmatic approach to recycled water irrigation across all of their schemes, with the target recycled water salinities a balance of environmental management and acceptable agronomic production.

For the private farmland receiving recycled water for irrigation (i.e. third-party farms), the limit has been ≤800 EC (µS/cm). As discussed in Section 3, this limit is based on maintaining strong agronomic production across the private farms. However, for their own farms, the limit is increased to ≤1,200 EC (µS/cm). This recognises that GVW is able to, and happy to, accept the drop in agronomic production that results from a higher salinity. This drop in production cannot be justified for the private farms whose focus is on economic returns from agriculture.

Historically, the limit of ≤1,200 EC (µS/cm) has provided GVW with good results at their Shepparton farm. However, over time, the salinity of recycled water has been consistently exceeding 1,500 EC (µS/cm), and the impacts of this on soil health and therefore sustainability are starting to be seen in annual soil monitoring results.

The following information are some excerpts from GVW's latest soil chemistry monitoring at Shepparton, which is undertaken by consultants Wrigley Dillon on behalf of GVW.

Table 4-1: 2016 Shepparton WMF Soil Chemistry

PARAMETER	UNIT	TOPSOIL	SUBSOIL	COMMENTS
pH		6 – 9.5	8.6 – 9.5	Stable but most are elevated and alkaline
Salinity (EC 1:5))	dS/m	0.04 – 0.49	0.13 – 0.47	Most slightly to moderately elevated
Olsen phosphorus	mg/kg	11 – 62	3 – 24	Topsoils good; subsoils some elevated
Sodium (ESP)	%	2 – 25	9 – 32	Most slightly to moderately elevated

- Overall conclusion: 'overall the soils on this site appear relatively resilient with stable chemical parameters and recycled water irrigation on the site can be sustainable in the long term. Providing the recommendations outlined are adopted, the assessments here indicate no reason why the application of recycled water should not continue'.
- Production: 'soil pH, sodicity and salinity are outside the range considered optimum for the growth of most agricultural crop species and accordingly, crop and pasture production, and therefore water use, are likely to be below optimum. Care is required to ensure that pasture and crop species are appropriate for the recycled water and soil conditions, particularly soil pH and salinity. It is likely that a combination of the elevated soil pH and soil salinity levels, in association with relatively clay dominant, slowly permeable soils, are the main contributors to yield decline. These agricultural production deficiencies limit the range of enterprise options thereby reducing site viability from an agricultural perspective. To help minimise yield decline from these factors, it is important to maintain optimum site management particularly in relation to drainage and irrigation scheduling'.
- Sustainability: 'this site has moderate prospects of long term sustainability. This perception is based on the elevated soil salinity, sodium and pH levels and the high nutrient levels. While these soil chemical attributes are relatively stable, they do pose a moderate risk of adverse soil impacts on site and a moderate risk of adverse off-site environmental impacts through leaching and runoff. Optimum management is required to maintain sustainability particularly in relation to crop species selection, grazing management, irrigation scheduling and drainage management'.

Whilst the overall conclusion states that there is no reason why the application of recycled water should not continue, the concern is the long-term sustainability of the site, and its capacity to continue to manage the salty waste. From the data presented, it would appear that the site would struggle to manage an increase in the salt load of the recycled water, either from GVW's existing Shepparton customers or a new customer.

The site does, however, have the ability to connect to the GMW channel system and shandy the recycled water back to a more sustainable limit. This change in management can then continue to be supported via annual soil chemistry monitoring, and gypsum applications as determined by the soil results.

The impact of this is that GVW's Shepparton farm will use less recycled water, and that GVW will need to find additional land, or a new recycled water end-use, to take up the shortfall. This has capex and opex implications for GVW, but as discussed in Section 3, northern Victoria does have the advantages of scale via available agricultural farmland and shandy water in the GMW channel system. The costs of expanding the scheme need to be dealt with via appropriate trade-waste pricing.

4.2.3 Trade-waste

Discharge of any wastewater into the sewerage system, other than domestic strength sewage, can only be undertaken under a licence and within the terms of a trade-waste agreement. That agreement specifies the allowed volume and concentration/load of specified contaminants.

Charging principles

A key question is whether the saline waste stream should be considered a beneficial re-use or an effluent waste disposal stream. This determines whether charges should be based on a ‘beneficiary pays’ principle or a ‘polluter pays’ principle:

- **Beneficiary pays:** Irrigators receive free access to water with a raised nutrient content. That is clearly a benefit to the business. If there was no benefit, then farmers would not take the supply at all. In other situations where the salinity of the recycled water is not a concern, recipients pay the water authority for a recycled water supply plus an annual service charge.
- **Polluter pays:** However, irrigators accessing saline recycled water face a number of hurdles that increase their costs and the complexity of their irrigation businesses due to the nature of the effluent stream, which is beyond a standard recycled water supply:
  - There is an obligation to take the supply every year and in all weather conditions within the irrigation season – otherwise GVW would face the need to construct far larger storage lagoons.
  - There is an obligation to shandy the supply with additional water to maintain sustainable best practice either through existing allocations or through purchase of additional allocation on the market.
  - There is a consequential obligation to monitor and manage soil health with the application of gypsum and other soil conditioners as required.

On balance, it is considered that the provision of salty wastes to irrigators represents a waste-disposal scenario. The costs should therefore be largely borne by the polluter – in this case GVW – and through it, the original trade-waste discharger. Within this, and as discussed earlier in the report, there are now examples where the saline waste producer/manager are providing the farmer with shandy water in addition to the saline recycled water to help manage any potential salinity/sodicity impacts. These scheme managers have recognised the potential impact of the saline waste to the farmers land and production, and are taking full responsibility for their waste and providing the farmer with a ‘shandied recycled water product’ that is consistently ≤800 EC (µS/cm), i.e. the long-term sustainable limit.

Providing the required volume of shandy water so that the salinity of the shandied recycled water is consistently ≤800 EC (µS/cm) is essentially a risk management approach by the saline waste manager. It reduces the potential of land degradation issues due to high salinity/sodicity, and the potential for legacy soil issues and possibly litigation. It does however come at a significant cost that needs to be accounted for.

Trade-waste charging

There are two elements of charges for trade-waste:

- **Volumetric charges**: Relatively small discharges that are similar to other discharges and that can be managed within the existing treatment capacity, are dealt with through a standard set of charges related to the volume of the discharge and four key variables related to the strength of the discharge.
- **Augmentation charge**: Where the discharge is significant in terms of current capacity, the applicant can be asked to make an up-front capital contribution towards the costs of new works (an augmentation charge) as GVW does not want to invest in significant additional assets only to discover that there is no demand for the treatment capacity after a few years. Levying an augmentation charge spreads the risk

regarding the investment in the new assets. In these circumstances the applicants are deemed Category 4 trade-waste customers and face reduced volumetric charges.

Table 4-2: GVW trade-waste charges – Shepparton for Category 4 customers

VARIABLE	CHARGE
Flow	$0.5579/kL
BOD	$0.2782/kg
Sodium	$0.7041/kg
Nitrogen	$0.983/kg
Phosphorus	$2.2333/kg

Price signals

The main principle for any trade-waste charging is that it is cost-reflective. That is, it recovers the full costs of the authority and also sends signals to current and potential customers as to the real costs that are incurred by GVW as a result of their discharge. That signal may be in the variable charge (where it should reflect the long-run marginal cost of supply) or in a specific capital augmentation charge.

Setting trade-waste augmentation charges is not a simple calculation as many industrial producers have uncertainty about their medium-term production horizons. They also have incentives to ‘game’ the system and sign up to smaller volumes or contaminant levels than they actually anticipate discharging, as this will reduce the size of any up-front augmentation charges.

In practice, GVW faces an iterative process:

- Client notifies GVW of projected future discharge levels and loads
- GVW assesses implications for its treatment capacity, and estimates the costs it will face. In the case of saline wastes this treatment train includes:
  - Winter-storage to hold volumes outside the irrigation season
  - Pipeline to transfer the waste-stream to the receiving property
  - In some cases it may include land purchase and establishment of irrigation infrastructure to account for a higher trade waste volume and/or higher strength waste
  - Contracts with farmers to take the flows
  - Monitoring, compliance and reporting
- GVW calculates the charges required to recover its costs
- Client reviews these proposed trade-waste charges and adjusts its discharge projections
- GVW revises its treatment requirements, costs and charges.

This process provides the discharger with clear choices as to whether:

- To continue to discharge the contaminants and incur charges for their treatment that reflect the real costs incurred, or
- To change its process or invest in pre-treatment to reduce the volume or mass of contaminants discharged in order to reduce the charges for which it is liable.

Monitoring

GVW monitors trade-waste licences to ensure that they continue to comply with the original agreement. However, there tends to be considerable variability between readings, and experience tends to see discharge levels gradually creeping up over time. Where GVW records a consistent history of discharges outside the terms of the agreement then it can levy a penalty fee. However, some customers merely account for this penalty as part of the continuing compliance cost.

This is an important matter for GVW as its own licence to discharge with the EPA has the requirement for a management framework that ensures the reuse of all recycled water up to a 90th percentile wet year. This sets the size of the winter-storage and irrigation area it must maintain to securely hold discharge volumes outside the irrigation season. That is a real asset requiring capital expenditure.

Therefore, if any trade-waste discharger releases a larger volume than licensed they may in turn trigger non-compliance with GVW's own licence conditions. By contrast, during the irrigation season, GVW may be able to expand and contract the area under irrigation to some extent, to match the volume of the effluent flows it receives in practice.

4.3 COSTS

It is difficult to estimate a standard cost for salinity or sodium management as all sites and schemes are different, with varying capital and operating cost influences.

However, in the case of GVW's Shepparton scheme, the cost of introducing shandying will be significant as the land area currently used for recycled water management (irrigation) will need to double. A high-level estimation of this is \$6M-\$7M (planning, infrastructure, GMW channel connection) plus the cost of land purchase (329 ha of irrigation area). This is a significant cost, and again highlights the magnitude of saline waste management and the importance of source control (avoidance) where it can be cost effectively implemented.

For schemes that already have access to shandy water and irrigation area, the cost of increased salinity/sodium will depend on the overall wastewater characteristics and whether salinity is the schemes limiting factor.

For the majority of schemes, phosphorus is the limiting factor, so the shandy requirements necessary to manage the phosphorus concentrations in the wastewater also take care of the salinity/sodicity concentrations, and will often allow for some increase. For example, a typical scheme will look like:

- Target sustainable loading rates: phosphorus 30-40 kg/ha/annum; salinity ≤800 EC (μS/cm)
- Recycled water quality: phosphorus 20 mg/L; salinity 1500 EC (μS/cm)
- Channel water salinity of 50 EC (μS/cm)
- Crop average irrigation requirement: 9 ML/ha/annum
- Given the above characteristics, sustainable recycled water irrigation would consist of:
  - A recycled water loading rate of 1-2 ML/ha/annum – at this loading rate, the applied phosphorus would be ≤40 kg/ha/annum (2 ML/ha/annum x 20 mg/L phosphorus).
  - The crop would therefore receive, 2 ML of recycled water and 9 ML of channel water; the applied salinity after this shandy would therefore be ~375 EC (μS/cm).
  - The salinity of the recycled water could increase to 3400 EC (μS/cm) before the shandied irrigation target of 800 EC (μS/cm) is exceeded.

Under this scenario, the scheme can accommodate increases in the trade waste salinity without disruption to the current operations. This won't however be the case for all schemes, and the scheme managers therefore need to know what's driving their management costs and the implications from changes in recycled water quality and volume.

Where the true costs of salinity/sodium management for each scheme have not been established, they should be. This will provide value to both the water authority and the industry in determining transparent pricing arrangements that will achieve sustainable saline waste management.

4.4 RECOMMENDATIONS

The recommendations involve a two-pronged approach:

- Introduce an irrigation shandying regime in Shepparton similar to that in place in Tatura. Include an automatic shandying capacity to ensure that the end-user manages the soil condition to ensure sustainable long-term health.
- Establish a trade-waste pricing regime to send strong price signals to current and future trade-waste customers to ensure that the costs of sustainable disposal controls are taken account of in business investment and disposal decisions.

The approach involves a number of elements:

- Confirm current discharge consents in terms of volumes and mass loading.
- Establish practical and cost issues around creating a full irrigation management disposal approach, e.g.:
  - Shandy with channel supply, test the soils and apply gypsum where appropriate.
  - Size the disposal scheme appropriately, e.g.: large enough irrigation area and winter storage with adequate shandy volumes, noting EPA's 90th percentile containment requirements
- Calculate trade-waste discharge prices based on the long-run marginal cost of supply, i.e. taking account of the full costs of establishing a sustainable disposal mechanism.
- Re-validate trade-waste controls and agreements with clear price signals that provide incentives for companies to pre-treat their waste-streams where this is cost effective.

It is recommended that where the true costs of salinity/sodium management have not been established at each site, they should be. This will provide value to both the water authority and the industry.

Whilst this discussion and recommendation have focused on GVW's Shepparton WMF, the principles behind the recommendations can be applied to any salty waste and/or trade waste arrangement.

5 Project summary

The initiative was prompted by concerns that:

- The current arrangements for the disposal of saline wastes across northern Victoria might be unsustainable and could lead to long-term damage to productive land through raised sodicity.
- The limitations on current disposal options could constrain future economic development opportunities for the region.

The study sought to develop recommendations for sustainable saline waste management. In this assessment the study has followed the waste management hierarchy set out in the *Environment Protection Act 1970.*

The study has established that there are three distinct waste-streams, each with its own issues and solutions:

- **Highly saline flows (4,000 – 40,000 EC)**: these flows represent the most significant salinity challenge for the industry. There is unfortunately, so 'silver bullet' for the management of the highly saline waste, however, the most viable option appears to be local treatment and disposal via evaporation basins and landfill. There are a number of limitations with this (it is a high cost solution and it is questionable as to whether it can continue as a long-term management solution), but it is considered to be a more viable option than the others considered due to cost and regulatory approval. To support this option, the sites need to:
  - Minimise the production, or strength of the highly saline wastes wherever possible. Avoidance is the highest level in EPA's waste hierarchy and it should be consistently applied by the sites.
  - Following this, the aim of the sites should be to undertake treatment so that the high saline waste can be split into a high organic low salt stream that can be potentially reused for agriculture (e.g. pig food), and a high salt low organic stream that can achieve good crystallisation in the evaporation lagoons. The hope, then, is that ongoing R&D into highly saline wastes will help to improve the reuse potential of the organic material, and perhaps the extraction of by-products from the saline material. Ongoing R&D will also hopefully help to reduce the quantity of saline waste that is ultimately produced, and therefore, the extent and cost of landfill should that continue to form part of the management solution (which based on the research undertaken is highly likely).
  - It is also recommended that Dairy Australia or another relevant industry body engages the EPA and develops a waste classification for the crystalline waste from milk processing factories. This process has been used by other industries where the classification of their waste is not straight forward, and it has helped to provide certainty to the industry around planning, costs, regulation etc.
  - The final comment for the high saline wastes is that if a dairy processor (or other industry) is considering the costs and implications of producing a highly saline waste stream, then relocation of this process close to the ocean may be the most appropriate waste management decision. This is 'easy to say, but difficult to implement', and this fact is not lost on the authors of this report. It does however remain a relevant management approach that should be strongly considered by high salinity waste producers.
- **Saline flows**: these are largely the result of the use of cleaning products in processing plants. The current controls and disposal arrangements are broadly sustainable and capable of expansion. However, a number of recommendations are made:
  - *Control at source*: audit of cleaning practices can lead to a significant reduction in the volume of the wastewater stream. This can result in reduced salt waste and lower costs for both purchasing chemicals and managing the waste.

- *Best practice management*: irrigation of the wastewater to pasture is a sustainable long-term practice but needs to be managed properly to well established, standard protocols, to ensure effective controls. This includes appropriate and consistent resourcing by the project partners to ensure:
  - maintenance phosphorus loading rates are adhered to
  - the shandied irrigation salinity does not exceed 800 EC (µS/cm)
  - annual soil testing is used to monitor soil sodium concentrations and gypsum or lime when soil pH is <6 is used to offset the sodium ions in the soil
  - monthly wastewater quality monitoring is undertaken to monitor for loss of soil infiltration
- Wastewater irrigation outlets should also be automated to ensure the target salinity irrigation rate of ≤800 EC is consistently met and wastewater is used consistently throughout the irrigation season.
- Consideration should also be given to the disposal of saline wastewater to GMW's channel system and the benefits this could provide.

▪ **Salty wastes**: these are flows as part of trade-wastes discharges to sewer that are managed by the regional water corporation. These wastes can be controlled adequately through:
  - Standard irrigation approaches as for 'Saline' wastes involving shandying and disposal to land
  - Well founded and enforced, cost reflective trade-waste charges.

One of the drivers behind this project was concern that northern Victoria is not able to sustainably manage saline wastewater produced by industry. Whilst the management of highly saline wastes remain problematic for all inland areas of Victoria, it is RMCG's opinion that northern Victoria has a number of advantages for the management of 'saline' and 'salty' waste streams. Northern Victoria has three key factors that help with the management of saline wastewater:

i. Farmers in the region have demand for the nitrogen and phosphorus also contained within the wastewater and can incorporate it into their annual fertiliser programs.
ii. The region has the scale to accommodate the winter storages and irrigation areas necessary to manage the volumes of saline wastewater produced.
iii. The region has access to shandy water that is vital in managing saline wastewater.

This same list of advantages is not true for other regions of the state, particularly those that have a higher intensity of agriculture and/or no access to shandy water other than rainfall. The key to northern Victoria sustainably managing saline wastewater is consistent resourcing and the application of the best management practices detailed in this report.

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