Department of
Primary Industries and
Regional Development

GOVERNMENT OF
WESTERN AUSTRALIA

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Agribusiness Development Guidelines

Suitability of Liquid Waste for Irrigation

Purpose

This document is written for owners and operators of agribusiness needing to dispose of liquid waste via irrigation. It outlines the key environmental and health considerations for determining whether an agricultural trade waste is of suitable quality to irrigate.

Principles

- An agribusiness should have a firm understanding on both the quantity and characteristics of waste.
- Wherever possible, liquid waste should be tested to obtain facility-specific data instead of using industry averages.
- If the waste is of suitable quality to irrigate, the receiving environment is suitable, and there is sufficient irrigation area, no treatment is required.

Disclaimer

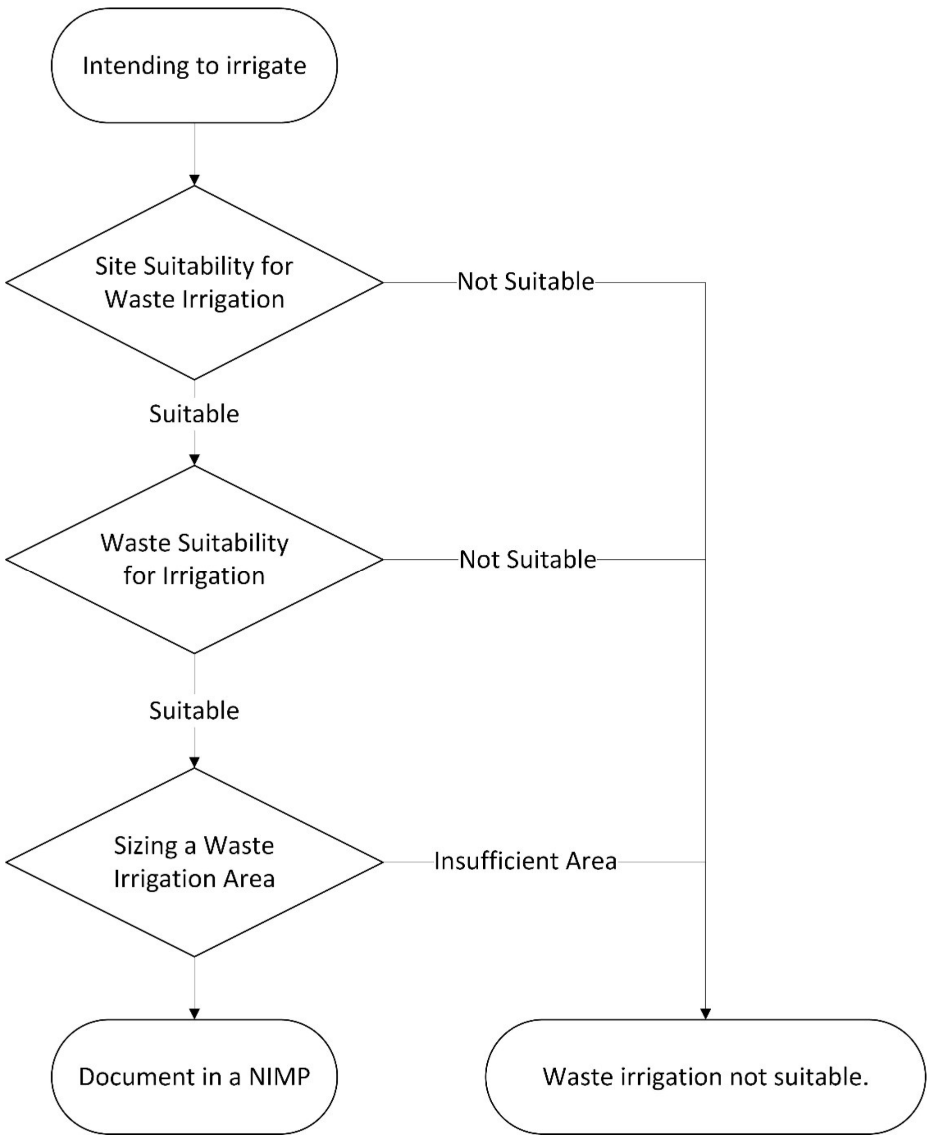
Domestic wastewater or similar sanitary wastes from kitchen, showers and other domestic fixtures are outside the scope of this guide.

Suspended solids, phosphorus and BOD can cause issues with pipe and sprinkler blockages. Operational constraints such as pipe and sprinkler blockages have not been addressed in this guide as the appropriate concentrations will vary heavily depending on the irrigation practices (flushing) and equipment (sprinklers / drippers) used.

How to use this document

This guidance is the second part of a three-document series that addresses environmental factors of waste disposal.

Whilst each document stands alone to support particular decisions, they should be read together to develop a comprehensive Nutrient and Irrigation Management Plan (NIMP) following the rationale outlined below.



Where waste irrigation is not suitable, seek professional advice or contact agribusiness@dpird.wa.gov.au

Waste Assessment

Agribusiness wastes that do not contain harmful chemicals, heavy metals or pathogens can follow the table below to determine if the waste is suitable.

Parameter	Recommended limits
pH	**6.5 - 8.5**
Salinity[1] (mg/L)	**< 2,500**
SAR:EC ratio	**< 5**
Fats, Oils and Grease (mg/L)	**< 1,500**

More attention is required when a facility:

- Uses, or is a source of strong disinfectants, petroleum products, fats, oils, pesticides, and herbicides.
- Processes large amount of animal wastes, leading to the accumulation of trace elements such as Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, and Zinc.
- Is a source of pathogens which are detrimental to human health. This is particularly important to waste streams from animal production and processing.

If the waste stream does not contain the above contaminants, then basic water quality and nutrient concentration can be gauged against the following ‘traffic light’ table[2]. This table is designed to give an early indication of what parameters are likely to require attention.

Parameter	Needs Attention	Low	Ideal	High	Needs Attention
pH	<6.5	6.5-7.5	7.5	7.5-8.5	>8.5
Salinity (mg/L)			0-600	600-2,500	>2,500
Biological Oxygen Demand (BOD) (mg/L)			0	600-1000	>1000
SAR:EC ratio			<5	5-15	>15
Total Nitrogen (mg/L)		<15	15-35	35-100	>100
Total Phosphorus (mg/L)		<1.5	1.5-4	4-10	>10

[1] Highly dependent on crop type, climate and soil type.
[2] Generated assuming that waste water is used to grow 10 t/year pasture for various climatic zones.

Ideal values for total nitrogen (N) and phosphorus (P) are recommended on the basis that agribusiness wastes commonly contain some level of nutrients, and those nutrients are generally not balanced for plant growth. Liquid waste should be irrigated in a way to maximise plant uptake; the table above shows the recommended proportions of N and P to suit plant requirements.

Measurement

This section provides advice on measuring and managing constituents associated with public health and environmental contamination.

If unsure about the wastewater characteristics of your business, it is always best to analyse your wastewater for all potential constituents, rather than assume they are not relevant. The below table shows the likely constituents to consider for common agribusinesses, if your facility does not fall under any of these categories, contact agribusiness@dpird.wa.gov.au for more information.

Agribusiness	Constituent Recommendation
Abattoir	Nutrients (N & P) BOD Fat, Oil and Grease (FOG) Pathogens Trace elements
Alcoholic Beverage Manufacturing[3] (e.g., Brewery, Distillery, Winery, etc)	pH Nutrients (N & P) BOD Salinity Sodium Adsorption Ratio (SAR) : EC
Beef Cattle Feedlots	Nutrients (N & P) BOD Salinity Pathogens

[3] Constituents based on Breweries, Distilleries and Wineries but also likely to apply for other beverage manufacturing facilities such as Cideries, Meaderies, etc..

Dairy Sheds	Nutrients (N & P) BOD Trace elements Salinity Pathogens
Dairy Processing	Nutrients (N & P) BOD Fats, Oils and Grease (FOG) Salinity
Piggeries	Nutrients (N & P) BOD Trace elements Salinity Pathogens

pH

Adjusting pH prior to irrigation is essential to maintain plant and soil health and is particularly important for alcoholic beverage manufacturing. If pH correction is carried out before long term storage of effluent, it is important to check pH directly prior to irrigation, as biological activity can cause pH change; generally, acidification by acid producing bacteria.

The ideal pH range for irrigation water is 7.0-7.5, with a broader allowable range of 6.5-8.5.

Salinity

Salinity is the salt concentration in solution; as opposed to Total Dissolved Solids (TDS), salinity refers to the salt concentration in mg/L, excluding other dissolved constituents such as organic matter.

For liquid waste high in organic matter (commonly BOD), it is important to account for the organics when converting from a measured TDS value to salinity, otherwise salt concentrations could be registering much higher than actual.

Salinity is the amount of dissolved salt in water, excluding other dissolved constituents such as organic matter.

TDS is the amount of organic and inorganic substances dissolved in water.

Salinity can be estimated by measuring Electrical Conductivity (EC) in µS/cm and multiplying by 0.64 to get the salinity value in mg/L. This is a common conversion factor for most environmental waters but will vary from 0.5 - 0.8 depending on the ions present.

If an accurate measure of salinity is required, this can be done by a chemical analysis of the major ions by a lab, the concentrations of which are then added up to give salinity.

Different plants have varying tolerances to irrigation water salinity, with most pastures and crops generally not experiencing any yield loss at salinities below 1,500 mg/L. Other more salt tolerant species such as kikuyu, barley and sorghum tolerate salinities up to 2,500 mg/L.

Irrigation with saline water can be managed by increasing the amount of water allowed to percolate past the root zone. The amount of water (including rainfall) that is allowed to percolate past the root zone compared to the total water applied is called the leaching fraction.

By increasing the leaching fraction, the resulting soil salinity in the root zone is reduced, therefore allowing wastewaters with elevated salinities to be irrigated. A leaching fraction no higher than 0.20 is recommended to maintain contact time in the root zone for nutrient uptake and BOD reduction. If soil salinities cannot be maintained to grow a productive crop with a leaching fraction of 0.20 or lower, alternative waste disposal methods should be sought.

A key factor in determining the achievable leaching fraction is the soil type, with heavier soils generally allowing a lower leaching fraction than sandy soils.

Plant salt tolerance needs to be considered if irrigation water salinity is within the 600 - 2,500 mg/L range. For salinities in excess of 2,500 mg/L, site specific modelling is recommended.

For more information on irrigating water with high salinity, contact the Agribusiness Development team at DPIRD agribusiness@dpird.wa.gov.au

Pathogens

A **pathogen** is a bacterium, virus or other microorganism that cause disease.

Zoonotic diseases are those transmitted from animals to humans; many pathogens present in animal wastes that pose health risks to animals also pose health risks to humans. These pathogens include viruses (swine hepatitis E virus), bacteria (*Salmonella*, *Listeria*) and parasites (*Cryptosporidium*). Because many are difficult to test for, indicator pathogens such as Escherichia coli (*E. coli*) are used to gauge the presence of faecal contamination.

Most strains of *E. coli* are not pathogenic, meaning that the presence of *E. coli* does not necessarily mean that the waste is pathogenic. However, the presence of *E. coli* indicates that there is the potential for pathogens to be present in the waste, therefore a potential for human health risk.

It is not recommended to irrigate animal wastes with an unknown pathogen risk on food, pasture or fodder crops.

If there is a potential for human health risk, it is important to consider treatment and exposure:

- Many treatment processes result in the reduction of pathogen load, even passive treatment types such as ponds or lagoons. Pathogens are consumed by higher order organisms, and UV radiation disinfects. Unlike solid agribusiness wastes, liquid wastes are generally easier to disinfect through chemical (adding a chemical disinfectant) or physical (UV, heat) processes. For wastes heavily loaded in solids, salts or nutrients, disinfection is more difficult.
- When predicting exposure risks of humans to a potentially pathogenic waste, the delivery method of irrigation and the amount of traffic the irrigation area receives is important. Many irrigation methods result in the production of fine mists, which can carry pathogens well beyond the irrigation area.

Spray irrigating liquid animal wastes without treatment, monitoring or disinfection poses a high risk to human health. The below table shows the recommended upper limit of *E. coli* depending on the intended use.

Intended Use	**Recommended Upper Limit of *E. coli***
Raw human food crops in direct contact with irrigation water (e.g. via sprays, irrigation of salad vegetables)	<8 cfu / 100 mL
Raw human food crops not in direct contact with irrigation water (edible product separated from contact with water, e.g. by peel, use of trickle irrigation); or crops sold to consumers cooked or processed	<800 cfu / 100 mL
Pasture and fodder for dairy animals (without withholding period)	<80 cfu / 100 mL
Pasture and fodder for dairy animals (with withholding period of 5 days)	<800 cfu / 100 mL
Pasture and fodder (for grazing animals except pigs and dairy animals, i.e. cattle, sheep and goats)	<800 cfu / 100 mL
Silviculture, turf, cotton, etc. (restricted public access)	<8 000 cfu / 100 mL

cfu = colony forming units

Table adapted from Volume 1 of ANZECC & ARMACANZ (2000) [4], and E. M. Hachich *et al*[5]. For more information and recommended controls to above table, refer to the Guidelines for Sewerage Systems: Use of Reclaimed water[6].

[4] https://www.waterquality.gov.au/anz-guidelines/resources/previous-guidelines/anzecc-armcanz-2000

[5] Hachich, E. M., Di Bari, M., Christ, A. P. G., Lamparelli, C. C., Ramos, S. S., & Sato, M. I. Z. (2012). Comparison of thermotolerant coliforms and Escherichia coli densities in freshwater bodies. *Brazilian Journal of Microbiology*, 43, 675-681.

[6] https://www.waterquality.gov.au/guidelines/sewerage-systems#reclaimed-water

BOD

Biochemical Oxygen Demand (BOD) (also known as Biological Oxygen Demand) is the measure of the amount of oxygen required to consume organic matter (mostly in the form of dissolved carbon) by bacteria. Similar to nitrogen and phosphorus, excessive BOD entering waterways can cause rapid biological growth, depletion of oxygen and ecological collapse.

Soils are generally less sensitive to BOD, in fact increasing soil carbon in most of West Australian soils is generally seen as a benefit. Soils, climates, and plant species make a multitude of different conditions; therefore, it is difficult to apply a single BOD loading rate across WA. It is important to ensure that BOD application to land is done in a way that runoff does not occur to a nearby water body, and that aerobic (containing oxygen) conditions are present in the soil. For example, irrigating heavy soils during wet weather is likely to lead to runoff, and sub-surface irrigation of high BOD wastes is likely to cause anaerobic (depleted oxygen) conditions.

Over application of BOD can cause soil clogging, anaerobic environments, and pH complications. With this in mind, a maximum BOD loading of 1,500 kg/ha/month is recommended, however much higher BOD application rates may be appropriate depending on the ecological and environmental conditions. A higher BOD application rate needs to be backed by some evidence and reasoning demonstrating it is suitable for the environment. In these cases, specialist advice is recommended.

A rest period following the application of BOD that allows an aerobic environment to be established in the soil is the single biggest factor in BOD management. This is particularly important when irrigating during cold or wet conditions.

Fat, Oil and Grease (FOG)

Unlike the more readily biodegradable compounds commonly measured as BOD, FOG is harder to break down and causes soil clogging. An upper concentration limit of 1,500 mg/L of FOG is recommended.

SAR:EC ratio

Some clays in soil rely on calcium (Ca) and magnesium (Mg) to maintain structure, these are known as dispersive clays. When an excessive amount of sodium[7] is present (in irrigation water) relative to Ca or Mg, it can replace Ca and Mg in clays causing the structure to fail; or disperse.

This section only applies to beverage manufacturers irrigating to clay soils.

If there are no clays on site, or the type of clays are known to be non-dispersive, sodium adsorption ratio (SAR) does not need to be considered. Where there is a presence of

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[7] Elevated potassium levels can also disperse clays, and may be present in wastewaters from olive oil processing, wool scouring, cheese and lactic whey and potato processing, piggery effluent and winery wastewater. Determining the Potassium Adsorption Ratio (PAR) together with soil testing is recommended if irrigation these wastes to clay soils.

clays, it is recommended to assume that they are dispersive and SAR needs to be controlled to maintain soil structure.

Due to the complex ion interactions in water, the EC of irrigation water also needs to be known. The measured values of SAR and EC can be plotted in the figure below to determine the likelihood of clay dispersion in soil. The solid line represents soils with a clay percentage of 55-65%, and the dashed line represents a clay percentage of 25-35%.

$$SAR = \frac{[Na^+]}{(0.5\ \times ([Ca^{2+}] + [Mg^{2+}]))^{0.5}}$$

Sodium, Calcium and Magnesium concentrations are expressed in milli equivalents per liter (meq/L). Converting concentration values in mg/L to meq/L can be done as follows:

$$[Na^+] = \frac{Na^+\ (in\frac{mg}{L})}{23.0}$$

$$[Ca^{+2}] = \frac{Ca^{+2}\ (in\frac{mg}{L})}{20.0}$$

$$[Mg^{+2}] = \frac{Mg^{+2}\ (in\frac{mg}{L})}{12.2}$$

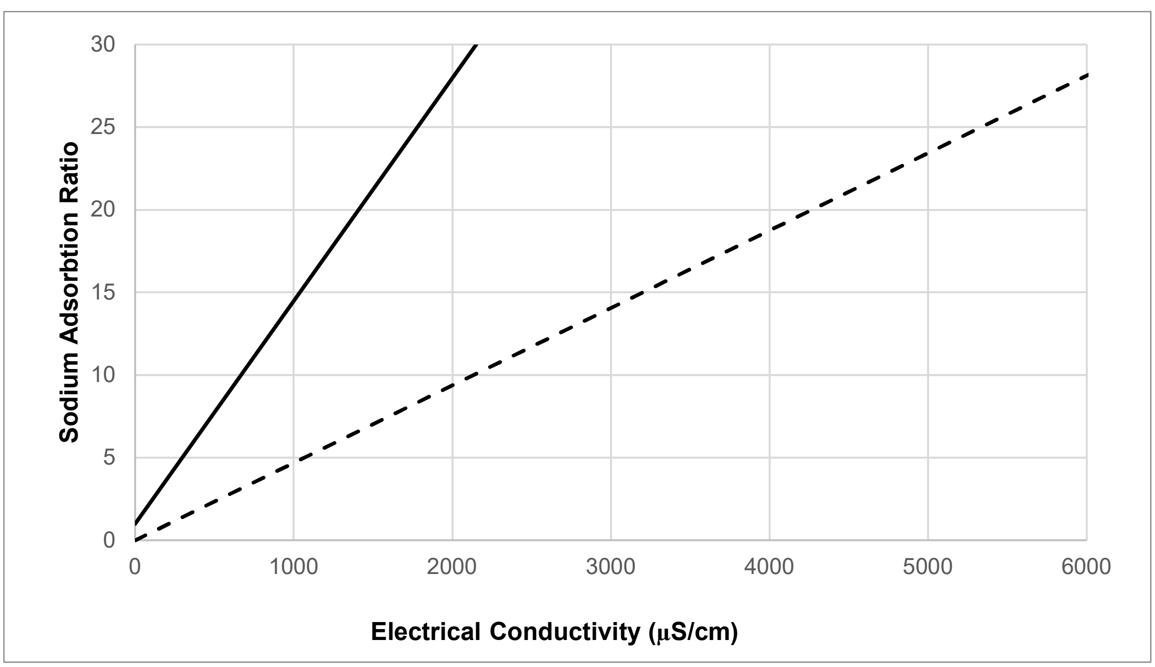

Figure 1 - Adapted from Volume 3 of ANZECC & ARMCANZ, 2000.

Nitrogen and Phosphorus

There are many forms of nitrogen and phosphorus commonly present in wastewater, and their uptake by plants and mobility in the soil profile vary. For the purpose of this guide, only Total Nitrogen (TN) and Total Phosphorus (TP) will be considered.

As a starting point, TN and TP values of waste can be compared to the traffic light table on page 4 of this guide. This table is intended to give an early indication on parameters that need attention, and not a definitive range to be applied to all cases. The table can be used to gauge:

- Whether freshwater or fertiliser supplementation is likely to be required;
- Which nutrient is going to be in excess, or deficient for plant growth;
- Approximate water treatment targets.

The mass loading (kg/ha/year) of nutrients is addressed in part 3 of this guidance series, and higher concentrations of nitrogen and phosphorus will need larger irrigation areas. To this end, the appropriate concentrations which are able to be irrigated relate to the impact to plant health.

Irrigating high concentrations of fertilisers can lead to osmotic shock in plants, commonly known as fertiliser burn. This is seen in strong fertiliser solutions where the salt concentration (or osmotic pressure) exceeds 1,500 mg/L but will vary depending on plant species, growth stage and climate. Using 1,500 mg/L as an upper limit, this would equate to a theoretical maximum TN of 1,167 mg/L (for ammonium ion) and a maximum TP of 489 mg/L (for phosphate ion). These nutrient concentrations are unlikely to be present in agricultural trade wastes.

Therefore, a maximum concentration for TN and TP does not apply as long as the mass loading approach is used in part 3 of this series.

Metals and Heavy Metals

Trace elements such a metals (Copper and Zinc) and heavy metals (Arsenic, Cadmium, Chromium, Lead and Mercury) are generally in low concentrations of raw animal wastes with the exception of piggery waste. While wastewaters are generally low in these concentrations, long term irrigation at low concentrations can result in heavy metal accumulation in the soil.

Additionally, biological treatment methods can cause these trace elements to accumulate. Therefore, any animal wastes undergoing biological treatment are recommended to be sent away for testing to verify trace element concentrations are below the recommended threshold.

If there is a perceived risk of elevated trace element concentrations for reasons other than the above, it is recommended to test.

Element	Suggested Soil Loading Limit (kg/ha)	Effluent Concentration upper limit (mg/L) up to 100 years irrigation	Effluent Concentration upper limit (mg/L) up to 20 years irrigation
Arsenic	20	0.1	2
Cadmium	2	0.01	0.05
Chromium	Not Determined	0.1	1.0
Copper	140	0.2	5
Lead	260	2	5
Mercury	2	0.002	0.002
Zinc	300	2	5

Table adapted from Volume 1 of ANZECC & ARMACANZ, 2000.

Detailed information on heavy metal management is outlined in Volume 1 of ANZECC & ARMACANZ guidelines (Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000[8]).

Chemicals used in wastewater treatment may warrant additional metals to be tested in wastewater. For example, poly aluminium chloride (PACl) is a common flocculant used in treatment and can cause phytotoxicity if not managed correctly. The recommended upper limit for aluminium is 20 mg/L for short term (20 year) use.

[8] https://www.waterquality.gov.au/anz-guidelines/resources/previous-guidelines/anzecc-armcanz-2000

Requesting laboratory analysis

Prior to collecting samples, ensure to contact the laboratory and confirm:

- What analysis is being done
- What sample sizes are required
- What sample containers are required (if any)
- Sampling method
- Transport and storage requirements

A Chain of Custody (CoC) document should be requested from the lab, completed in full stating what analysis is required. The CoC must accompany the samples.

When collecting samples, chill (≤ 6°C) all samples after collection and keep cool during transport. Do not use free ice in transport as there is increased risk of sample contamination. Pack ice in a separate sealable plastic bag or use frozen cooler bricks. Dispatch samples to the analysing laboratory promptly after collection. Some analytes (eg: pathogens) have a short time period for delivery to the lab after collection.

Unless specified, fill all samples bottles to exclude air, including in the neck of the bottle.

Some analytes (pH, salinity, EC, SAR, nutrients and major ions analysis) can be tested from a 500 mL sample. Supply additional sample if other analytes or specific bottles are required.

Analyte	Lab Request	Sampling Criteria
pH	-	-
Salinity (low accuracy)	Calculated TDS from Electrical Conductivity.	-
Salinity (high accuracy)	Calculated salinity (or ionic balance) for the following major ions: calcium, magnesium, sodium, potassium, sulfate, chloride, carbonate, bicarbonate, nitrate and phosphate	-
Pathogens	*E. coli*	Disinfect sampling point, collect in sterile sampling container provided by the lab, leave small air space at top of bottle, chill immediately to 6°C or less. Do not freeze. Keep cold in transport. Minimum sample amount is 250 mL. Deliver to lab within 24 hours.
BOD	Biological Oxygen Demand (5-day)	Chill immediately and keep cold in transport. Minimum sample size is 500 mL.
Fat, Oil and Grease	Fat, Oil and Grease	Obtain from lab correct sample bottle that has been preserved with sulfuric acid. Minimum sample size is 500 mL.
SAR:EC ratio	Sodium, calcium, and magnesium concentrations. Electrical Conductivity	-
Nutrients (N & P)	Total Nitrogen Total Phosphorus	Chill if storing for longer than 48 hours.
Trace Elements (total)	Total concentrations of: arsenic, cadmium, chromium, copper, lead, mercury and zinc	-

Summary

Once the waste stream quantity and characteristics have been identified, the information should be documented in a Nutrient and Irrigation Management Plan (NIMP). The waste suitability section of the plan will generally include:

- Expected volumes of wastewater produced compared to the production output of the facility
- A summary table of the wastewater characteristics
- Any supporting evidence including technical references, laboratory testing certificates, and engineering specifications of treatment technology.

Contact

If you require additional information, contact the Agribusiness Development team at DPIRD at agribusiness@dpird.wa.gov.au