WATER *recycling*

Natural Heritage Trust

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A Commonwealth Government Initiative

Environmental Guidelines for the Use of Recycled Water in Tasmania December 2002

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Tasmania

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FOREWORD

These Guidelines were produced to provide an appropriate benchmark for wastewater producers, consultants, and regulators when designing and assessing the environmental impacts of water recycling projects. They replace the previous DELM document *Guidelines for the Re-use of Wastewater in Tasmania June 1994.* These Guidelines are designed to be consistent with the *State Policy on Water Quality Management 1997* (SPWQM) diffuse source management framework, section 38 *Re-use of wastes by land application*. If further guidance is required to manage the environmental impacts of point source discharges please consult the SPQWM or contact Environment Division's Wastewater Management Unit for further guidance.

The project was conducted between August 1998 and December 2002 by the Department of Primary Industries, Water and Environment.

These Guidelines are intended to provide a framework to allow the sustainable re-use and recycling of wastewater in a manner which is practical and safe for agriculture, the environment and the public. In addition the Guidelines should allow this to happen in a manner consistent with industry standards and best practice environmental management.

This edition of the Guidelines has been produced as the result of several drafts. They are intended to be a working document and therefore shall change through time to reflect increased knowledge. These Guidelines will be reviewed 5 years after the date of publication to take into account the experiences and knowledge gained through their implementation, and to incorporate new research data.

Cover Photography

Background: Young wheat crop irrigated with recycled water in Brighton Tasmania

Starting top centre and moving around clockwise:

Pivot Irrigator in action with wastewater in Brighton area, Chris Gunn inspects cabbage seed crop irrigated with wastewater, Windmill with water storage and grain crop irrigated with wastewater Tea Tree area, Chemical free UV disinfection Selfs Point Wastewater Treatment Plant Hobart, Two grains –top irrigated with wastewater, bottom not irrigated –Brighton area, Excavators and Engineers at Swansea Lagoon upgrade and water recycling project, Low flow river markers –water recycling helps take pressure off our rivers, and Soil moisture and conductivity probes Cornelian Bay Water Recycling Scheme.

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GLOSSARY OF TERMS

ANZECC	Australia and New Zealand Environment and Conservation Council
Advanced Treatment	A process of further filtration and nutrient reduction
Aquifer	A geological formation or structure that stores or transmits water in useable quantities.
Best Practice	The practice of seeking out, emulating and measuring performance against the best standards identifiable
Biochemical Oxygen Demand (BOD)	A measure of the oxygen demanding substances in wastewater – which indicates the level of pollution present. It is expressed as the amount of oxygen required by micro-organisms to oxidise the organics in a litre of the water over a period of time. It is expressed as milligrams per litre (mg/l)
Chlorination	A chemical method of disinfection which destroys pathogenic micro-organisms.
CG or WWRCG	The inter-governmental Wastewater Re-use Coordinating Group that assesses the environmental impact of wastewater re-use schemes.
Director	The Director of Environmental Management as defined under the ***Environmental Management and Pollution Control Act 1994***
Disinfection	A process that destroys inactivates or removes pathogenic micro-organisms.
Division	The Environment Division of DPIWE.
DHHS	Tasmanian Department of Health and Human Services
DPEMP or EMP	Development Proposal and Environmental Management Plan or Environmental Management Plan. The regular review of the DPEMP becomes an EMP and the review is typically on a 3 yearly basis.
DPIWE	Tasmanian Department of Primary Industries, Water and Environment
EC_{iw}	Electrical conductivity of irrigation water (EC) dS/m or µS/cm
E.coli (***Escherichia coli)***	This is a thermotolerant coliform organism, predominantly faecal coliform and used as an indicator of recent faecal contamination. It is expressed as organisms/100ml.
EMPCA	***Environmental Management and Pollution Control Act 1994***
EPN	environment protection notice
ESP (%)	Exchangeable Sodium Percentage, used to determine the effects of sodium content of effluent on the soil from both salt and carbonate sources.
Groundwater	Water located beneath the land surface.
ICM	Integrated catchment management
Irrigation	The application of wastewater to land to replace soil moisture lost by evapotranspiration and to promote the growth of plants.
Nephelometric turbidity unit (NTU)	A unit of measure of the turbidity of water which occurs due to suspended, colloidal and particulate matter.
NH&MRC	National Health and Medical Research Council
Nutrients	Substances that stimulate and enhance growth. Generally refers to nitrogen and phosphorus in waters.
Operator	The responsible authority managing and operating a wastewater scheme
Organic matter (%)	A measure of the available carbon in the soil, and is affected by BOD in effluent.
PAC (kg/ha)	Phosphorus Adsorption Capacity of soil.
Potable Water	Water suitable for human consumption as drinking water or in the preparation of food.
Primary Treatment	Initial treatment of wastewater involving screening and sedimentation to remove solids
Reclaimed water	Water that has been reclaimed from wastewater or sewage and treated to a standard which is satisfactory for its intended use.
Re-use	The application of appropriately treated wastewater for a specific purpose

Secondary Treatment	A level of treatment that removes approximately 85% of BOD and suspended solids, generally by biological or chemical treatment processes. Secondary effluent generally has BOD of 30 mg/L, SS <30mg/L but may rise to >100 mg/L due to algal solids in lagoon or pond systems
Sewage	Any waste containing human excreta or domestic wastewater. Also called blackwater.
Sodium adsorption ratio, SAR or Adjusted SAR	Sodium absorption ratio for determining the contribution of wastewater to possible salinity and soil structure decline. A measure of the amount of sodium, relative to calcium and magnesium, to indicate the effect on soil structure and reduced rate at which water moves through the soil.
Soil pH	($CaCl_2$ + H_20) 1:5 soil:water suspension
SPWQM	State Policy on Water Quality Management 1997
Suspended solids (SS)	The non-filtrable residual solids which are suspended in sewage or effluent. It is expressed in milligrams/litre (mg/L).
Tertiary Treatment	Includes treatment processes beyond secondary or biological processes which further improve effluent quality. Tertiary treatment processes include detention lagoons, conventional filtration via sand, dual media or membrane filters which may include coagulation dosing and land based or wetland processes.
Treated Effluent	Effluent that has been subjected to biological oxidation and clarification to secondary standard. Such effluent may not have been disinfected.
Treatment System	A device or means of treating waterborne wastes from individual households or other sources with similar types and volumes of wastewater.
Water balance or water budget	Irrigation requirements for an average year given seasonal rainfall & evaporation data, and crop irrigation requirements
WWTP	Wastewater Treatment Plant

1 INTRODUCTION

1.1 Background

Wastewater is part of the total water cycle. Like rainfall or groundwater, it is a resource available for use. At a community level, appropriate utilisation of this resource is a benchmark for sustainable development. Creative thinking will find many innovative ways in which wastewater may be used – for example, urban green spaces or high value food crops. In practical terms, wastewater recycling brings positive benefits in the areas of water conservation and pollution abatement. While there are environmental and public health issues associated with wastewater - whether recycled or discharged to waterways - appropriate management techniques will minimise risk to acceptable levels.

1.2 Purpose of Guidelines

This publication, *Environmental Guidelines for the Use of Recycled Water in Tasmania*, is the primary reference document for the effective management of wastewater re-use systems in Tasmania. In these Guidelines, wastewater means any domestic and industrial effluent that has been treated to an appropriate standard to enable it to be safely re-used under the management arrangements proposed.

The aims of this document are to:

- Foster awareness and encourage the beneficial use of treated wastewater.
- Provide guidance on best practice environmental management for managers and operators of sewage or wastewater treatment plants for the planning, design, operation and monitoring of wastewater re-use systems involving land application in a manner that minimises risks to public health and the environment.
- Outline the procedures required for the environmental assessment and approval of a re-use system.

This document replaces the 1994 DELM publication *Guidelines for Re-use of Wastewater in Tasmania* and will facilitate the re-use of treated wastewater whilst achieving environmental objectives. It is the key Tasmanian reference document for water resource managers, local government personnel, engineers, consultants and irrigation system designers.

1.3 When to Use the Guidelines

These Guidelines provide irrigation design, discharge and operating specifications for the use of wastewater in any effluent re-use scheme or activity. The Guidelines apply only to the recycling of treated wastewater – <u>not waste disposal.</u> The Guidelines apply to both the public and private sectors.

The Guidelines set rules for the treatment, control mechanisms and monitoring of wastewater re-use and should be used in conjunction with other relevant guidelines, codes of practice and information sources – including the references listed in these Guidelines. These Guidelines do not apply to on-site treatment and re-use of a septic system.

The Guidelines will assist in managing re-use operations in a sustainable way that protects public health (including workers on the scheme) and the environment. It is, nevertheless, the responsibility of those involved to ensure that no harm results from wastewater re-use.

1.4 Potential Re-use Applications

Parts of Tasmania regularly suffer from water shortage. It makes sense then that all potential uses for wastewater should be explored as an alternative to using scarce freshwater resources. In light of the high costs for nutrient removal processes, many municipalities and other operators of wastewater treatment plants (WWTP) utilise wastewater as a resource for its nutrient content, seeing re-use on land as a viable alternative to treatment and disposal to waterways.

All municipal councils should take an active role in investigating and evaluating all possible uses for wastewater, establishing goals and targets for re-use. Typical categories for augmenting water supplies using wastewater are listed below.

Urban/Residential Recycling: Wastewater can be excellent for municipal landscape watering of gardens or grassed areas. It contains nutrients essential for plant growth and can be used in public areas - subject to simple precautions - as an alternative to discharge into nutrient-sensitive waterways. Other uses may be for watering of golf courses, racecourses, aerodromes or for dust suppression on roads and sewer flushing. It could also provide added capacity for emergency fire fighting.

Agricultural Use: Wastewater is a valuable resource for agricultural activities such as food crop and wine grape production. Use of wastewater on food crops which require processing before eating is preferable to use on those eaten unprocessed. Irrigation of pasture for cattle or sheep grazing, fodder crops or cereals are other common uses of wastewater. Constituents of wastewater, such as nitrogen and phosphorus, are beneficial to crops and can readily be used to produce protein and fibre, to enhance grass and other vegetation or to produce processed food crops – many agricultural irrigation needs can be met by wastewater re-use. Proponents of wastewater irrigation often report better plant growth than is obtained from chemical fertilisers, and with the added benefit of improving soil quality.

Industrial Applications: Wastewater use in industrial situations (including agro-forestry, horticulture, turf and landscape interest areas) reduces the demand on freshwater supplies. Re-use of process water can defer the need for expensive upgrading of potable supplies and treatment facilities to a water quality standard which exceeds the needs of industry.

1.5 Environmental and Public Health Protection

Irrespective of use, minimisation of risk to the public and the environment requires that recycling of wastewater must comply with following performance requirements:

- use of wastewater for direct domestic potable purposes is not permitted
- primary treated wastewater is not considered acceptable for irrigation re-use in Tasmania
- wastewater may only be used where the quality achieves the level required for that particular beneficial use
- maintenance of high levels of pathogen reduction is required to safeguard health where domesticated grazing animals are present or public access is possible
- the impacts of nutrients and other substances on the soil, water and plant environment need to be assessed and managed by the user to avoid adverse impacts.

1.6 Sustainable Wastewater Re-use

To summarise, sustainable wastewater re-use is the beneficial application of wastewater to land that contributes to the water, nutrient, and trace element requirements of the crop being irrigated, without endangering public health, causing contamination of ground or surface waters, or contributing to long term land degradation.

2 GROUNDRULES FOR DEVELOPING A SUSTAINABLE SYSTEM

2.1 An Integrated Approach to Project Planning

As wastewater is inextricably part of the hydrological cycle, any management system must recognise linkages to the land, water, vegetation and other natural resources within a catchment. Community expectations and requirements are also reflected in legislative requirements or regional management plans. The identification of, and response to, these factors during planning and operational phases are referred to as integrated catchment management (ICM) or natural resources management (NRM). This approach adopts an holistic or big picture view of natural resources and their interaction with development and land use, designing best-bet responses/solutions to catchment or regional issues.

In terms of sustainable wastewater application, an integrated approach requires assessment of potential community and environmental impacts both on-site and at a wider catchment or regional scale. The key considerations are:

- Regulatory framework — Page 17
- Wastewater quality requirements — Page 23
- Wastewater treatment — Page 53
- Site requirements — Page 59
- System requirements — Page 69
- Operational requirements — Page 95

This document provides detail on best practice measures which address these key principles for use of recycled water. Below is a tabulated summary of the options for wastewater re-use and the mandatory treatment and monitoring requirements.

Table 2-1: Wastewater Uses and Required Quality

Use of Wastewater	Mandatory Effluent Quality	Mandatory Treatment Requirement	Options for Wastewater Re-use	Suggested Treatment Measures	Monitoring	Management Requirements
Class A Recycled Water	< 10 median thermotolerant coliforms per 100ml pH 5.5 – 8.0 BOD <10mg/l Nutrient, toxicant and salinity controls	Advanced treatment with disinfection	Indirect potable groundwater recharge by spreading Indirect potable groundwater recharge by injection Non-potable municipal irrigation (uncontrolled access) Urban non-potable (general household use) Fire and water protection systems Agricultural: Direct contact of reclaimed water with crops consumed raw. Stream augmentation and groundwater recharge Urban use (garden watering and toilets) Aquaculture (human food chain) Other uses subject to approval	Treatment – Coagulation, flocculation, advanced filtration and other best practice treatment processes to remove nutrients, sediments and other contaminants Disinfection – microfiltration, U.V, ozonation and chlorination Chlorination may be best practice if a residual is required to prevent the bacterial regrowth	pH – weekly BOD – weekly SS – weekly Disinfection – daily Turbidity and chlorine residual – continuous Coliforms – daily Viruses and parasites – twice yearly Nutrient, toxicant and salinity – regularly	Municipal uses may include irrigation of open spaces, sports grounds, parks, dust suppression and land rehabilitation areas. The system must be managed to prevent spray drift. No spray drift must be detected beyond the boundaries of the irrigation area.
Class B Recycled Water	< 1,000 median thermotolerant coliforms per 100ml (< 100 thermotolerant coliforms per 100ml in special cases *) pH 5.5 – 8.0 BOD < 50mg/l Nutrient, toxicant and salinity controls	Secondary treatment with disinfection	Crops for human consumption: Crops to be consumed raw but not in direct contact with reclaimed water (edible product separated from contact with effluent, eg. By peel or use of trickle irrigation) or crops sold to consumers cooked or processed Pasture and fodder (no pigs or poultry): for grazing animals withholding period applies – 5 day for dairy, 4 hour for non-dairy Industrial processes (open system) Non-potable municipal irrigation with controlled access Note * <100 thermotolerant coliforms per 100ml (stock drinking standard) applies for pasture and fodder crops (dairy and non dairy) <u>without</u> withholding period	Treatment – High rate processes such as activated sludge, trickling filters Lagoon treatment with separate polishing lagoons is acceptable for <1000 thermotolerant coliforms per 100 mL Disinfection – chlorination, UV and ozonation. Detention lagoons will not be sufficient if a concentration of <100 thermotolerant coliforms per 100 mL is required	pH – weekly BOD – weekly SS – weekly Turbidity – continuous in high rate processes Disinfection – daily Coliform – weekly Nutrient, toxicant and salinity – regularly Monthly monitoring for re-use schemes less than 1 ML/day	The system must be managed to prevent spray drift. No spray drift must be detected beyond the boundaries of the irrigation area. Dropped crops not to be harvested from the ground. Crops contacted by effluent must be cooked (>70°C for 2 minutes), commercially processed, or peeled before consumption. Restricted public access. Withholding period of nominally 4 hours or until irrigated area is dry. Withholding period 5 days for grazing animals.
Class C Recycled Water	< 10,000 median thermotolerant coliforms per 100ml pH 5.5 – 8.0 BOD < 80mg/l Nutrient, toxicant and salinity controls	Secondary treatment	Agriculture (non-human food chain eg. forestry, cotton) Industrial processes (closed system) Non-human food chain aquaculture	Lagoon based systems No additional disinfection required	pH – monthly BOD – monthly SS – monthly Disinfection daily except for 30 day maturation ponds Coliform – weekly Nutrients, toxicants and salinity – regularly Quarterly monitoring for re-use schemes < 1ML/day.	The system must be managed to prevent spray drift. No spray drift must be detected beyond the boundaries of the irrigation area. Restricted public access. Withholding period of nominally 4 hours or until irrigated area is dry. No human food chain crops.

3 REGULATORY FRAMEWORK

3.1 Regulatory Drivers

Sustainable development is the focus of Tasmania's Resource Management and Planning System (RMPS). Wastewater re-use activities must comply with the requirements of the RMPS. As outlined in Schedule 1 of the *State Policies and Projects Act 1993* this requires:

"…managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety while –

1. *sustaining the potential of natural and physical resources to meet the reasonably foreseeable needs of future generations; and*
2. *safeguarding the life-supporting capacity of air, water, soil and ecosystems; and*
3. *avoiding, remedying or mitigating any adverse effects of activities on the environment. "*

Two key components of the RMPS are the *Environmental Management and Pollution Control Act 1994 (EMPCA)* and the *State Policy on Water Quality Management 1997*.

The objectives of the environmental management and pollution control system established under *EMPCA* include prevention of

"...environmental degradation and adverse risks to human and ecosystem health by promoting pollution prevention, clean production technology, re-use and recycling of materials and waste minimisation programmes.." (Schedule 1, EMPCA).

The *State Policy on Water Quality Management 1997* encourages the recycling and re-use of wastewater and, where appropriate, the irrigation of wastewater to land to maximise its beneficial use while protecting the quality of surface waters. The Policy also requires that land application of wastewater be carried out in accordance with the current Tasmanian re-use guidelines (Part 38).

Wastewater re-use is also consistent with the national approach outlined in the National Water Quality Management Strategy which supports the use of wastewater as a sustainable resource. Two recently published documents are of particular value. *Guidelines for Sewerage Systems – Use of Reclaimed Water* (ANZECC-ARMCANZ 1999) provides national guidelines to facilitate the use of reclaimed water as product resulting from the treatment of wastewater to a level acceptable for beneficial use. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC-ARMCANZ 2000) is an important reference tool for the development of catchment management plans and policies, allowing governments and the community to make informed decisions about water quality requirements and the consequences of management decisions.

3.2 State Government Responsibility

Under the *Environmental Management and Pollution Control Act 1994* sewage treatment plants treating more than 100kL/day are level 2 activities and are regulated by the Environment Division of DPIWE. Wastewater re-use schemes are not level 2 activities and are not, therefore, directly regulated by the State. However, in recognition that it has regulatory control over how wastewater from wastewater treatment plants is disposed of, DPIWE has taken on the role of assessing the environmental effects and sustainability of wastewater re-use schemes. Recognising the interests and expertise that a number of other Government agencies have in this area, DPIWE has established the Wastewater Re-use Co-ordinating Group (WRCG) to foster a whole of government approach to the re-use of wastewater from wastewater treatment plants and to facilitate an efficient and comprehensive assessment process.

The key responsibilities of the WRCG are:

- Provision of advice in relation to the formulation of management conditions, limitations and restrictions attached to any wastewater re-use supplier/user agreement, permit or environment protection notice (EPN).
- Periodic review of the sustainability of scheme performance (e.g. effluent quality, soil impacts, public health etc.).
- Periodic review of these environmental guidelines.

Membership of the WRCG and their respective responsibilities relevant to wastewater re-use are as follows:

ORGANISATION	ROLE
Department of Primary Industries, Water and Environment (DPIWE), Environment Division, Wastewater Unit	Assessment, licensing and monitoring of level 2 sewage treatment plants (average dry weather flow (ADWF) > 100 kL/day) including effluent treatment and disposal; and Protection of the environment.
DPIWE, Water Resources Division, Water Management Branch DPIWE, Resource Management and Conservation Division, Land Management Branch DPIWE, Food, Agriculture and Fisheries Division	Advice on land capability, irrigation technology, wastewater suitability and food safety for specific irrigation schemes.
Department of Health and Human Services, Public and Environmental Health Section	Protection of public health.
Department of Infrastructure, Energy & Resources, Mineral Resources Tasmania	Groundwater protection
Local Government Representative, Wastewater Engineer	Plumbing issues Planning Issues

The WRCG will assess proposals for wastewater re-use from wastewater treatment plants. Recommendations of the WRCG will be implemented as appropriate by the Environment Division through the permit conditions for wastewater treatment plants. Other proposals linked to wastewater re-use, such as those from industrial premises, will be assessed by the Environment Division and/or the Environmental Management & Pollution Control Board with input from other agencies as appropriate.

The WRCG will examine issues including suitability of the effluent for re-use, suitability of the site, protection of groundwater quality, and other specific management issues. Where necessary, the WRCG may require additional information or data to be presented within a Development Proposal and Environmental Management Plan (DPEMP) for the proposed scheme. The final DPEMP document will form the basis for regulating the re-use activity's operation.

3.3 Local Government Responsibility

Operation of wastewater re-use schemes may involve the following responsibilities for local government.

- All wastewater re-use proposals must be discussed in the first instance with the local Council as the planning authority for the area to determine if a formal development application is required. All wastewater re-use proposals with level 2 activities acting as the supplier must also contact Environment Division to determine the approval process and requirements.

- Where the wastewater is being generated from a plant that is not a level 2 activity (and therefore, is not regulated by the Environment Division) the local Council will have a role in ensuring that the re-use scheme is operated in accordance with an agreed management plan or set of parameters to protect human health and the environment.

- If local government is the supplier of wastewater to a re-use scheme, or a re-user, it may be subject to a 'supplier-user' contractual agreement. Compliance with the agreement, particularly on issues such as end use of wastewater, must be ensured by the supplier.

- If local government is a user of wastewater, it may itself be responsible for ensuring that the re-use is carried out in accordance with a management plan and any regulatory requirements.

- Local government also administers public health and food safety legislation that requires that activities such as effluent re-use do not cause public harm and that all food produced for human consumption is safe to eat.

3.4 Mechanisms to Manage and Regulate Re-use Schemes

The specific legal mechanism/s for each re-use site will be determined by the requirements of different planning schemes and the level of complexity and associated risk of the proposed scheme. There are four mechanisms which may be utilised to ensure that re-use schemes are appropriately and sustainably operated and in accordance with commitments or conditions of approval.

1. Conditions may be attached to the permit to operate the wastewater treatment plant that produces effluent destined for a re-use scheme. The conditions may prevent effluent being discharged to the re-use scheme unless certain requirements and undertakings are met. These can include ensuring that the re-use scheme is operated in accordance with agreed parameters, monitoring the quality of effluent being discharged to the re-use scheme, and ensuring that appropriate supplier-user agreements are in place.

2. A 'supplier-user' agreement is a legal contract between the supplier and the user that specifies issues relating to the quantity and quality of wastewater as well as environmental management and public health requirements. The supplier is responsible to ensure the user complies with all conditions in the agreement.

3. In some circumstances, a permit to establish and operate the re-use scheme may be required under local government planning schemes. If a permit is required, conditions which detail the various

planning, environmental management and public health requirements will be specified by the planning authority.

4. An environment protection notice (EPN) could be served either by local government or by the Director of Environmental Management to apply environmental management and public health requirements.

This guideline document outlines the requirements for environmental and public health protection. These requirements will be specified in the conditions contained in supplier/user agreements, EPNs or permits. Both the supplier (as holder of a level 2 or level 1 permit) and the user (as regulated by supplier/user agreement, permit or EPN) are bound to comply with these conditions which reflect the legislative requirements of the *Environmental Management and Pollution Control Act 1994*, the *Public Health Act 1997* and the *Food Act 1998*.

3.5 Environmental Impact Assessment

3.5.1 Environmental Management Plan

It is in the interest of the landholder on whose land wastewater is being re-used, the supplier of the wastewater, the regulator and the community, that wastewater is applied to land in a manner that is sustainable and does not cause environmental harm or a public health risk. The Environmental Management Plan for a re-use scheme is the basic mechanism for ensuring that the proponents of the re-use scheme have addressed all of the relevant issues to ensure that these objectives are achieved, and that there is agreement on the key management prescriptions.

Proponents planning the use of wastewater should review the *Guidelines for the Preparation of Development Proposal and Environmental Management Plan for the Irrigation of Treated Wastewater on Land.* A copy is included in Appendix A. Updated copies are also available from the Environment Division of DPIWE.

All level 2 activities planning to undertake wastewater re-use must develop an approved Environmental Management Plan to the satisfaction of the Director of Environmental Management for the proposed project as part of level 2 permit requirements.

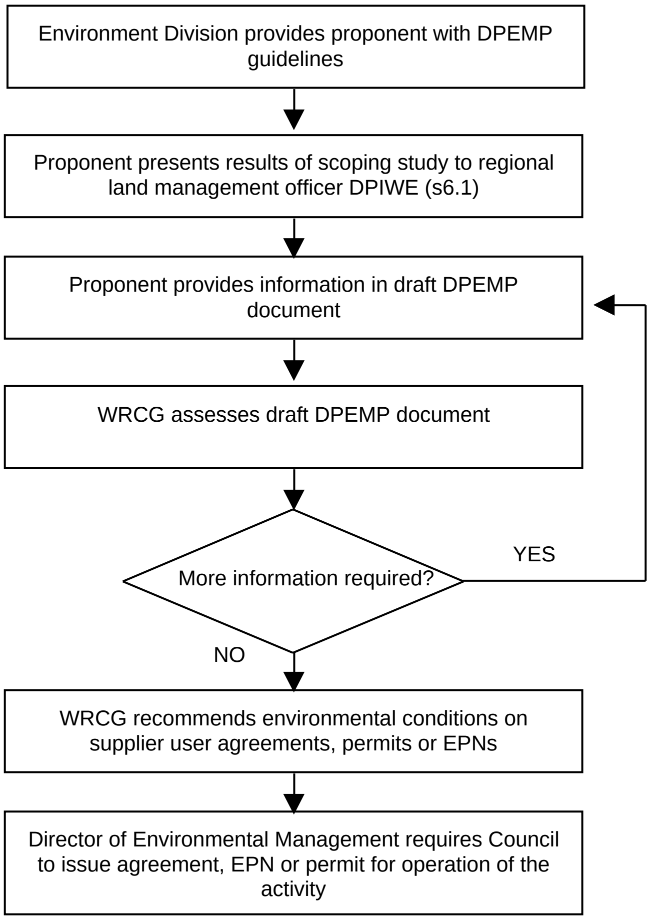


Figure 3-1: Environmental Assessment Process

DPEMPs must supply adequate detail on the design and implementation of all the environmentally relevant activities and management practices for a proposed wastewater re-use scheme. The DPEMP will also provide a framework for annual monitoring of the ongoing sustainability of the wastewater re-use project. Therefore the DPEMP documents must be clearly understood, applied and accessed by the operators, managers and the public.

Once the initial site scoping process has been completed, the proponent should meet with the regional land management officer for the area to discuss the agricultural and soil sustainability issues prior to preparing the draft DPEMP for the WRCG.

4 WASTEWATER QUALITY REQUIREMENTS

Each type of re-use has its own particular water quality requirements to ensure that the use is sustainable and that no adverse effects result from the re-use. It is convenient to consider quality either in terms of health or environmental aspects, although for some quality indicators (for example toxicants), these considerations may overlap.

The major uses of treated wastewater and associated application methods and minimum disinfection requirements are shown in Table 2-1. The wastewater treatment facility must be able to provide records showing full compliance with the disinfection requirements for a proposed use for a trial period of not less than six consecutive months before the wastewater can be approved for that use.

4.1 Human Health Protection

There are public health risks associated with the utilisation of some treated wastewater. While both chemical and microbiological aspects can influence human health, waterborne enteric diseases are more common and are the focus of most management strategies to minimise public health risk.

The Director of Public Health may require a health impact assessment to be included in any environmental assessment of a wastewater re-use activity, under section 74(5) of EMPCA. Any re-use proposal DPEMP must include a specific section in the supporting documentation that clearly addresses public health concerns. A separate map showing buffer zones to sensitive areas, residences, public access areas, signage location and details of fencing and potable water supply are to be supplied.

There is also a need to consider food safety and to ensure that foods for human consumption that are produced using treated wastewater are safe to eat. The principal requirement to produce safe food is contained in the *Food Act 1998* and *applies to all food intended for human consumption*. The subject of food safety and the application of food safety legislation is further discussed below.

4.1.1 Health Concerns

The sewerage system we have today has been the most important contributor to our standard of living and the elimination of waterborne diseases. To prevent health problems and epidemic outbreaks from the use of wastewater, it is important to recognise the risk factors. Human contact with wastewater creates a risk of infection from micro-organisms. Pathogens of concern are detailed below.

- Viruses, while derived from human faeces, can survive for long periods in the water. Filtration and disinfection to the levels specified minimise the risk to human health.
- Pathogenic bacteria can be excreted by an apparently healthy population and many of the very large numbers of bacteria found in the wastewater can cause disease. Some bacteria, particularly thermotolerant coliforms (also known as faecal coliforms), are indicators of

faecal contamination. *E. coli*, which is found in the intestinal tract of humans and other warm-blooded animals, may be used as the specific indicator of faecal contamination.

- Protozoa can cause disease in humans and infective forms may be present in wastewater as cysts. Enteric protozoa, including *Giardia spp.* and *Cryptosporidium spp.*, are of particular importance and can cause moderate to severe enteritis.
- Parasitic helminths (for example roundworms and flatworms) have a complex life cycle and many require an intermediate host. Taeniasis in cattle can be a major veterinary problem and a nuisance parasite in humans. The best practice measure to control risks from the micro-organisms is to ensure that infective doses of a pathogen are not found in wastewater and an infective dose can not reach a human host.
- Radioactive substances may originate from medical or extractive industry sources. Wastewater from these sources must contain less than 0.1 becquerel per litre gross alpha activity and 0.1 becquerel per litre gross beta activity in water used for irrigation.

4.1.2 Food Laws

Food is a fundamental human need and a prerequisite to good health. Access to safe food is a basic human right and ensuring that the food we eat is safe is a major function of both government and industry.

In Tasmania, food safety is governed by several pieces of legislation, including the *Food Act 1998*. This Act is administered by the Department of Health and Human Services and by local government officers. Importantly the Act requires that all food intended for human consumption must be safe to eat - regardless of whether it is primary food production or retail and whether it is produced conventionally or with treated wastewater.

There are also national laws adopted under the *Food Act 1998* governing the standards of safety, composition and labelling of food products produced here. The principal national legislation is the *Australia New Zealand Food Standards Code* which sets national standards for the microbiological and chemical safety of foods, and the minimum labelling requirements for packaged and some unpackaged foods. The Code also contains four food safety standards that govern matters such as personal hygiene, temperature control, skills and knowledge, food premises construction and operation and food safety programs.

It is important to note that the Code is part of a system of nationally consistent food safety legislation that is designed to ensure the safety of the food supply in Australia and to minimise the incidence of food-borne illness. Both the Code and the *Food Act 1998* is applicable to all sectors of the food industry, including primary food production and the use of treated wastewater on food crops.

4.1.3 Food Safety

Effective food safety practices must focus on identifying, understanding and reducing hazards. This principle applies to all stages of food production from “paddock-to-plate” and includes growing, harvesting, packing and transporting food produce.

Effective food safety practices identify risk and implement procedures that prevent, reduce or eliminate the hazard before it reaches the consumer. However, in many cases it is not possible with current technologies to eliminate all potential food safety hazards associated with the food we eat, particularly fresh produce that will be eaten raw. In these cases, the aim is to reduce the risk to an acceptable level rather than trying to eliminate all risk.

A food safety hazard consists of a chemical, biological or physical substance or property that can cause food to become a health risk to consumers. There are three main categories of food safety hazards – biological, chemical and physical.

Microbiological contamination is the main biological hazard and this may occur through the use of organic animal products, including treated wastewater. Chemical contamination may also occur through the use of treated wastewater because most treatment systems cannot remove all chemical contaminants. Contamination may occur through direct contact of the edible portion of the crop with the treated wastewater, or indirectly through contact with contaminated soil or water.

In most cases where re-claimed wastewater is used, food safety is assured by separating the edible portion of the crop from the wastewater. This may be achieved in several ways, for example by the use of drip-fed irrigation directed at the root zone of fruit trees, thereby avoiding contact with the edible portion. However, it is also necessary to ensure that wind-fall fruit and other fruit that contacts treated wastewater is not harvested for human consumption as it may be contaminated.

An alternative approach to managing biological and chemical hazards is to treat the wastewater to a sufficiently high standard to ensure the safety of the food. However, the use of treated wastewater on ready-to-eat produce should be approached with caution. Crops to be consumed raw will require a high standard of tertiary treated wastewater that satisfies extremely stringent standards for the reliability of the irrigated wastewater quality and the management of on-farm food safety. Proponents should also be aware that there may be some marketing resistance from customers to purchasing ready-to-eat produce grown with treated wastewater.

4.1.4 Good Agricultural Practice

Good agricultural practice is an approach to primary food production that seeks to ensure that identified food safety hazards are addressed in a systematic way. Typically this is done by the use of check-lists that identify sources of potential hazards and put in place mechanisms to deal with them. Good agricultural practice is consistent with the approach taken in the food retail and food manufacturing sectors where food safety programs based on Hazard Analysis Critical Control Point Principles (HACCP) are used to identify and control hazards.

To be effective, a check-list should examine all facets of the production system including growing, harvesting, packing and transporting. Under each of these areas, a more detailed examination should be made of the inputs (for example, water, fertiliser, pesticides etc.) and the likely hazards (for example, biological, chemical or physical). For each of these hazards, a control mechanism is required, for example, it may be necessary to regularly test water sources for pathogenic indicator organisms.

In addition to identifying and managing hazards, it is also necessary to recognise that food handler skills and knowledge are critical to managing food safety. As a general principle and in order to reduce the risk of producing unsafe food, all food businesses, including primary food producers, must make sure that workers know how to do the job that they are employed to do. Indeed, under new national food safety laws, food handlers and supervisors in retail and manufacturing are required to have adequate levels of skills and knowledge in food hygiene and food safety.

Skills and knowledge requirements can be met in a number of ways, including formal training, on-the-job training, prior experience or in-house training. The particular training approach is up to individual businesses to decide and may depend on the seriousness of the hazards identified. However, generally speaking, more serious hazards will require more extensive food handler skills and knowledge.

Further information about food safety requirements can be obtained from local government, the Department of Health and Human Services at www.dhhs.tas.gov.au or from Food Standards Australia New Zealand at www.foodstandards.com.au

Specific information about on-farm food safety for fresh produce can be obtained from www.affa.gov.au

4.1.5 Micro-organisms in Wastewater and Soils

Faecal coliforms, and *Escherichia coli* (E. coli) in particular, usually do not cause disease but may indicate the presence in wastewater of other disease-causing organisms. Wastewater treatment should reduce the number of potentially harmful organisms to safe levels. The required standards of disinfection for irrigation waters are better understood when compared with typical faecal coliform counts for other waters. Faecal coliform counts typically found in upland streams range from 0-100 cfu (colony forming units) per 100 ml; in farm dams concentrations would be from 10-1000 cfu per 100 ml; and for raw sewage, levels would be from 1 million to 10 million cfu per 100 ml.

Sunlight and evaporation following irrigation are important agents which destroy micro-organisms remaining on the soil surface. The residual levels of bacteria on plants grown with reclaimed water treated to secondary standard are not significantly different to those grown without reclaimed water (McNeill 1982, in Victoria EPA 1993)

While some micro-organisms infiltrate with the irrigation water into the soil, they do not survive indefinitely. Survival depends on many factors including moisture, temperature, pH, nutrients, organic matter and the presence of antagonistic organisms or toxins. The main factors limiting transport of bacteria, eggs of intestinal worms and cysts of protozoa through soils are straining, sedimentation and adsorption. Removal of these organisms and other particles is closely related to soil texture. Fine-textured soils, such as silt or clay loam, remove more suspended matter from percolating wastewater through a given depth than coarser sandy soils.

In addition to bacteria, wastewater may contain disease-causing viruses. The mobility of viruses in soils is related to: properties of the viral protein coat; cation exchange capacity; pH; hydraulic conductivity; surface area; organic matter content and texture of the soil; ionic strength and flow rate of the percolating fluid. Soils containing clay and organic matter with high cation exchange capacities remove viruses more efficiently than highly permeable soils.

4.1.6 Public Health Requirements

The levels of disinfection consistent with the intended use and degree of human contact are categorised according to the degree of public access as follows:

Table 4-1: Disinfection requirements as related to public access

Class A, Recycled Water	No restriction on public access	< 10 cfu /100ml Thermotolerant Coliforms
Class B, Recycled Water	Limited restrictions apply	<100 cfu /100ml or < 1,000 cfu/100 mL Thermotolerant Coliforms depending upon type of application
Class C, Recycled Water	Access restricted	< 10,000 cfu/100ml Thermotolerant Coliforms

4.1.7 Potable Re-use

The use of treated wastewater for drinking or other related domestic purposes, or for any body contact recreational applications (e.g. filling swimming pools) is not envisaged, due to the very high treatment and disinfection standards required, and has therefore not been considered in these Guidelines. It has been specified as a possibility as a part of the National Water Quality Management Guidelines system, but these Guidelines do not apply to the issues surrounding potable re-use.

Irrigation of treated wastewater to riverside land upstream of a town water supply off-take would require a high standard of control both at the usage site and over the town water supply. Wastewater re-use is an appropriate risk reduction strategy for wastewater treatment systems discharging above potable water supply intakes.

Special care needs to be taken in the application of treated wastewater to crops. Crops to be consumed raw, for example, will require a high standard of tertiary treated wastewater that satisfies extremely stringent standards for the reliability of the irrigated wastewater quality.

The Department of Health and Human Services or the Environment Division can provide more information on public health issues as required.

4.2 Environmental Protection

The impact on the environment over a period of time depends upon the type and concentration of pollutants contained in the wastewater. This pollutant load may limit the amount of wastewater that can be used in a sustainable manner without causing harmful effects.

Toxicants are substances which may, even in trace amounts, poison living organisms or damage their life processes in some way. The persistent hazardous substances include heavy metals, pesticides and petroleum products. These pose a potential risk to the biota in the soil surface and in ground waters by remaining intact, or in toxic form, for decades. Accumulation in tissues of aquatic life and soil organisms may adversely affect other organisms, including humans, further up the food chain. These toxicants must be reduced to the lowest practical levels as they may resist conventional treatment.

Nutrients released after the break-down of organic matter may be washed into waterways and stimulate the growth of aquatic plants. High inputs of nutrients may produce 'eutrophic' waterways subject to undesirable levels of algal growth. Best practice is achieved by control measures to reduce or eliminate the run-off from land irrigated by wastewater.

The level of salinity in wastewater is important in determining its suitability for many agricultural or industrial uses. Certain crops are particularly sensitive to increased salinity in irrigation waters. As a general rule, it is desirable that the total dissolved solids of the wastewater are less than 1000 mg/L and preferably less than 500 mg/L. Table 4-4 lists management practices required for 5 salinity classes in wastewater.

For physio-chemical properties, it is not feasible to quantify all the chemical compounds in wastewater. Consequently, the practice of measuring only biochemical oxygen demand (BOD) and suspended solids (SS) is often sufficient to assess the quality of wastewater. To achieve a high quality water for re-use with low microbiological risks, a water quality of very low BOD and SS levels is required for effective disinfection. A good secondary effluent has a BOD_5 of less than 20 mg/L and SS of less than 30 mg/L. The BOD of industrial wastewater is, in some circumstances, site specific. In the process of water purification, bacteria use the oxygen in the water to break down the organic matter. If all the oxygen in the water is used, unpleasant odours may result.

4.3 How Wastewater Quality affects Soil Condition & Plant Growth

The level of management required by any wastewater re-use scheme depends on the condition of the soils and crops to be irrigated. This section deals with water quality indicators as they relate to the soil and plant growth. This subject is very complex and further research is encouraged beyond the design and management methods provided within these Guidelines. Any of the potential problems, aspects or indicators referred to in this section of these Guidelines may be a key limiting factor to the application of wastewater to land.

Problems that may arise from wastewater irrigation can be broadly classified as follows:

1. Those caused by materials which accumulate in, or leach from, the soil with potentially harmful effects on the soil, groundwater or surface waters. The problems that fall into this group include those caused by heavy metals and dissolved salts, particularly sodium. The severity of the problem depends on wastewater quality, soil characteristics and management approach.

2. Those which cause changes to pasture composition or kill vegetation but can be readily corrected. The problems of this group are generally associated with organic wastes which, if application is excessive, may cause temporary deficiencies in essential plant nutrients and oxygen in the root zone.

The problems described in the first group are the more serious where toxicity to plants, animals or humans is involved. Further information on these substances is given in the following sections.

4.4 Trace Elements and Heavy Metals

The large variation in the concentration of trace elements in soils under natural conditions complicates the setting of general limits for wastewater application to soil. The only satisfactory safeguard is sampling and analysis of soil and vegetation before irrigation commences and regular monitoring during the life of the irrigation scheme. In addition, the concentration of potentially toxic components in the waste stream should be regularly monitored. Requirements covering soil loading and wastewater concentrations for a range of contaminants are outlined in Section 4.4.6. Those contaminants which may be more characteristic of water sourced from WWTPs are discussed briefly below.

4.4.1 Copper, Zinc and Nickel

Among those heavy metals that may limit the use of wastewater for irrigation, cadmium (Cd), copper (Cu), nickel (Ni), and zinc (Zn) are singled out for their potential toxicity to plants. Although Cu, Ni and Zn are essential trace elements required by plants, excessive levels are toxic. For Cu and Zn, wastewater input levels are generally below the amounts routinely used to correct trace-element deficiencies in the soil. While nickel may be in excess of plant requirements, it should not produce any short-term problems.

4.4.2 Cadmium

Unlike Cu, Ni, and Zn, cadmium (Cd) is not an essential element for crop growth. In the soil, the problems associated with the additions of cadmium are two-fold. Cd is usually toxic to plants (and animals) at low concentrations and the Cd added to the soil may drastically elevate the Cd level in the affected plant tissue before any symptoms are detected. The tolerance of plant species to levels of Cd added to the soil is highly variable. A long-term study (Metcalf & Eddy 1991) undertaken at a site in Melbourne (Werribee WWTP) that had been receiving wastewater for 76 years revealed no significant increase in cadmium accumulation in plants when compared to plants grown on a control site that had received no wastewater over the same period. It is conceivable, however, that the annual Cd input may become a factor limiting the application of some wastewater to land. Cadmium monitoring in soils and wastewater should be undertaken at regular intervals.

4.4.3 Boron

The role of boron (B) in wastewater irrigation is somewhat unusual. In municipal sewage, boron probably occurs in the form of un-dissociated boric acid. It is not removed very effectively during wastewater treatment. Being uncharged, boron also passes through soils much more rapidly than the other trace elements. Although boron is essential for crop growth, the margin between levels considered essential to plant growth and those considered toxic to plants is extremely narrow. Boron requirements and levels of tolerance will also vary between crop types. Volume 3 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC-ARMCANZ 2000) suggests concentrations of less than 0.5 mg/L in irrigation water should not cause adverse affects on plants and other organisms in the long term. It does, however, advise that different plant species have varying degrees of sensitivity - ranging from very sensitive plants such as lemons at <0.5 mg/L to a very tolerant crop such as asparagus which can cope with concentrations up to 15 mg/L.

Unlike other elements (e.g. Cd, Cu, Ni, Zn, Pb, Cr, Fe, Mn, Se, Mo, As, Hg, Sb and Al) that tend to deposit near the ground surface following application, boron is only weakly adsorbed and may rapidly pass through the soil with leaching water. For this reason, cumulative effects commonly important to other trace elements do not apply to boron and any effects could be more immediate.

4.4.4 Molybdenum

While large quantities of molybdenum (Mo) may be added to the soil with little effect on crop growth, it is readily absorbed by crops. Its availability to crops increases as soil pH rises. As a micro-nutrient, Mo is required in small amounts by plants and is also essential, at low concentrations, in the diet of animals. For some livestock animals (particularly ruminant animals), however, concentration as low as 5 mg/kg in the feed may be toxic. Molybdenum toxicity and its severity are directly related to the amount of Mo ingested relative to that of Cu and SO_4. High Mo and low Cu levels in forage constitute the worst possible situation. The potential hazard associated with Mo accumulation in plant tissue should be carefully evaluated before industrial wastewater is used for irrigating forage crops or grazing pastures.

4.4.5 Aluminium

Aluminium retards the root development of plants in strongly acid soils and it may also affect the availability of phosphorus. Potable water treatment plants using alum as a flocculant can be a source of aluminium if the settled sludge is discharged into a sewerage system. Some soils are naturally high in aluminium and sensitive plants such as lucerne will not thrive.

4.4.6 Maximum Loadings

Table 4-2 indicates the maximum allowable concentrations of trace elements and metals in irrigation waters for long term use. The concentration of heavy metals in plant tissues is considered unlikely to be a problem using irrigation waters containing metals below these listed recommended levels. As previously stated, monitoring should be undertaken to ascertain long term effects at the site.

Table 4-2: Recommended Maximum Concentrations of Metals in Irrigation Waters (ANZECC 2000)

Element	Suggested Soil CCL kg/ha	LTV over 100 years mg/L	STV over 20 years mg/L	Plant effects
Aluminium	ND	5	20	Toxic at pH <5.5
Arsenic (As)	20	0.1	2	toxicity varies depending on species
Beryllium (Be)	ND	0.1	0.5	toxicity varies depending on species
Boron (B)	ND	0.5	< 0.5 - 15	toxicity varies depending on species Refer Vol. 3, ANZECC
Cadmium (Cd)	2	0.01	0.05	toxic at low conc. bio-accumulation issues
Chromium (Cr VI)	ND	0.1	1	low toxicity
Cobalt (Co)	ND	0.05	0.1	toxic at high concentrations
Copper (Cu)	140	0.2	5	toxic at high concentrations, increased plant uptake where soil pH < 5
Fluoride (F)	ND	1	2	Not active in neutral to alkaline soils
Iron (Fe)	ND	0.2	10	Not toxic in aerated soils. Nutrient possible imbalance at Fe > 5mg/L
Lead (Pb)	260	5	20	low toxicity, inhibits growth at high conc
Lithium (Li)	ND	2.5	2.5	0.075 mg/L if used on citrus crops
Manganese (Mg)	ND	0.2	10	Toxicity depends on Fe/Mn ratio and soil pH
Mercury (Hg)	2	0.002	0.002	No guideline at this time
Molybdenum (Mo)	ND	0.01	0.05	Low toxicity to plants, toxic to animals fed crops grown on high avail. Mo
Nickel (Ni)	85	0.2	2	Toxicity increases with soil pH <7
Selenium (Se)	10	0.02	0.05	Toxic to plants. Toxic to animals fed on high Se pasture
Uranium (U)	ND	0.01	0.1	
Vanadium (Vn)	ND	0.1	0.5	Toxic to plants, required by some algae
Zinc (Zn)	300	2	5	pH dependant. Higher levels on pH 7+

Notes: ND = Not determined insufficient background data to calculate CCL
CCL = Cumulative contaminant loading limit – is the maximum contaminant loading in soil, defined in kg/ha, above which site specific risk assessment is required if contaminant addition is planned (assuming application rate of 1000mm / year, inorganic contaminants in top 150 mm of soil profile & soil bulk density is 1300 kg/m^3) .
LTV = long term trigger value – is the maximum concentration (mg/L) of contaminant in irrigation water which can be tolerated given 100 years of irrigation.
STV = short term trigger value – is the maximum concentration of contaminant that can be tolerated over 20 years assuming same annual irrigation loading assumptions as LTV

Table 4-3 presents suggested maximum loadings for heavy metals in soils. The assumed typical concentrations of heavy metals for wastewater shown are representative of treated municipal sewage. Very long time spans are required for soils to reach the maximum loadings for metals at the specified concentrations, provided that metals have not already accumulated before irrigation commences. Table 4-3 may be used for comparison of the relative rates of metals accumulation in soils and for monitoring purposes. Should metals be detected in soils at levels greater than the indicative maximum concentrations shown in Table 4-3, then background levels and possible sources of contamination must be investigated.

Table 4-3: Maximum Loadings for Heavy Metals in Soils (Victoria EPA 1993)

Metal	Typical conc. in waste water (mg/L)	Annual Loading at 5ML/ha (kg/ha)	Average loading after 100 years (mg/kg dry soil)	Contaminated Site Maximum Concentrations (mg/kg dry soil)	Maximum Loadings (kg/ha) for CEC (me/100g) range		
					<5	**5-15**	**>15**
Cadmium	0.005	0.025	0.8	5	5	10	20
Copper	0.050	0.250	8.0	100	125	250	500
Nickel	0.005	0.025	0.8	100	125	250	500
Zinc	0.050	0.250	8.0	500	250	500	1000
Lead	0.010	0.050	1.7	150	500	1000	2000
Mercury	<0.001	<0.005	0.17	2	No data	No data	No data

4.5 Salinity

Salinity is a process whereby salts accumulate in the soil at levels which are deleterious for normal plant and crop growth. As a form of land degradation, salinity potentially results in loss of agricultural production, loss or damage to natural vegetation and contamination of surface and ground waters.

In coastal regions, the salt load deposited each year from the atmosphere to the land can reach hundreds of kilograms per hectare. Where ground water process concentrate salt in the upper soil layers only very salt-tolerant plants survive and agriculture is impossible. The success of farming in many of these areas is due in part to the fact that most of the salt is leached by rainfall from the surface to below the root zone. Ideally, these natural processes are sufficient to maintain a salt balance in which salt outputs are equal to salt inputs. Soluble salts leached from the root zone will be transported by groundwater and may enter inland surface waters and, ultimately, the sea. This process can be extremely slow and is dependent upon complex interactions between the water cycle and the physical and chemical nature of the soils and underlying rocks. The effect of leachate from a small, isolated wastewater irrigation area is unlikely to exceed the range of salinity variation from normal surface water runoff to the receiving waters and will generally have less environmental impact than low-saline wastewater discharges direct to surface waters.

As plant growth and evaporation remove water from the soil, the concentration of salts in the soil solution increases. This can reduce growth and unless soil water is replenished, plants will die from the effects of salt toxicity and insufficient water.

It is important to understand that the salinisation problems associated with irrigation in Tasmania can result from both salts contained in the applied irrigation water and the effects of naturally saline groundwater rising to within the crop root zone. Where saline groundwater rises to within 1.5 metres of the surface, the salt is likely to be concentrated by evaporation. Salts may also be transported laterally by groundwater and brought to the surface at a lower elevation, sometimes a long way from the irrigated land. The environmental and economic consequences of this are serious.

All wastewater contains soluble salts, these usually originate from foods, cooking salts and body excreta. Predicting the effect of saline irrigation on soils, crops and other waters is difficult as salinity involves a complex interaction between, soils, climate, prior salinity, land use, drainage and vegetation. Potential impacts from the improper use of saline waste water include, vegetation damage from direct contact with highly saline wastes, accumulation of salts within the crop root zone, reduced productivity or crop failure, leaching of salts to groundwater, increasing saline seepage or increased salinity of surface waters.

In selecting the location of wastewater re-use sites, consideration must be paid to the salinity of the wastewater, nature of soils and drainage at the site, climate, local and regional aquifers, and the salt tolerance of the intended crop.

4.5.1 Irrigation Water Salinity Hazard

Irrigation water is typically classified according to the salinity hazard, the sodium hazard and other specific ion hazards. All three should be considered when determining the suitability of a wastewater for irrigation.

The salinity of water can be conveniently measured using electrical conductivity. The capacity of water to conduct an electrical current increases in proportion to the concentration of electrolytes in the water. This provides a useful and fairly reliable way to estimate the amount of soluble salts in irrigation waters and allows calculation of expected average root zone salinity. The salinity hazard of irrigation water is classified according to the TDS content as shown in Table 4-4 below:

Table 4-4:Salinity Classes of Irrigation Waters (Source Hart 1974)

Class	TDS (mg/L)	Electrical Conductivity (µS/cm)	Electrical Conductivity (dS/m)
1	0-175	0-280	0-0.3
2	175-500	280-800	0.3-0.8
3	500-1500	800-2300	0.8-2.3
4	1500-3500	2300-5500	2.3-5.5
5	>3500	>5500	>5.5

Notes: Total dissolved salts (mg/L) = µS/cm x 0.64 or dS/m x 640. The electrical conductivity (EC) of water is measured at 25°C and reported in deciSiemens per metre (dS/m) or microSiemens per centimetre (_S/cm). One dS/m is equivalent to one thousand _S/cm. The electrical conductivity value can be roughly converted to milligrams per litre (mg/L) of total dissolved salts (TDS) using the values given in Table 4-4

Class 1: TDS 0 to 175 mg/L (0 - 280 _S/cm) - can be used for most crops on most soils, with all methods of water application, with little likelihood that a salinity problem will develop. Some leaching is required, either by winter rainfall or by the application of excess irrigation water, however this occurs under normal irrigation practices, except in soils of extremely low permeability.

Class 2: TDS 175 to 500 mg/L (280 - 800 _S/cm) - can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown, usually without special practices for salinity control. Sprinkler irrigation with the more saline waters in this class may cause leaf scorch on salt-sensitive crops, especially at high temperatures in the daytime and with low water application rates.

Class 3: TDS 500 to 1500 mg/L (800 - 2300 _S/cm) - the more saline waters in this class should not be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and the salt tolerance of the plants to be irrigated must be considered.

Class 4: TDS 1500 to 3500 mg/L (2300 - 5500 _S/cm) - for use, soils must be permeable and drainage adequate. Water must be applied in excess to provide considerable leaching, and salt-tolerant crops should be selected. Leachate disposal must be carefully planned and monitored.

Class 5: TDS more than 3500 mg/L (>5500 _S/cm) - not suitable for irrigation except on permeable well-drained soils under good management, especially in relation to leaching. Restrict to salt-tolerant crops, or for occasional emergency use.

Most wastewater systems produce class 2 or 3 water which can be used for irrigating moderate to high salinity tolerance crops, provided that soils have adequate drainage and salts are able to be safely leached from the root zone.

Class 4 and 5 water is generally too saline to be used for irrigation and should only be considered under ideal conditions. Use of wastewater with Class 4 and 5 salinity is difficult as the leaching required to prevent salt accumulation in the root zone requires either soils with high natural subsoil drainage or the installation of sub-surface drains. Collected drainage poses additional difficulties as this must be disposed of in a 'safe' means (preferably other than a waterway). Lost leachate or drainage is also likely to impact on ground or surface waters adjacent the site. An alternative method of waste management may need to be found for wastewater of these classes. Dilution with potable water, low TDS wastewater or evaporation may be a practicable means of dealing with some cases.

4.5.2 Determining the suitability of irrigation water salinity for a crop

The electrical conductivity of irrigation water (EC_i) is used to determine whether a crop is likely to be affected by the irrigation water salinity by calculating the average root zone salinity (EC_{se}). This requires estimation of the average root zone leaching fraction (LF) of the soil being irrigated (i.e. the proportion of applied water [irrigation plus rainfall] that leaches below the root zone (section 4.7)). Approximate average LF values for four broad soil types are listed in Table 4-5. EC_{se} can be calculated using the following equation:

$$\mathbf{EC_{se} = EC_i /(2.2 \times LF)}$$

where: EC_{se} = Average root zone salinity dS/m

EC_i = Electrical conductivity of irrigation water in dS/m

LF = Average Leaching Fraction

Table 4-5: Soil type and average root zone leaching fraction

Soil Type	Average root zone LF
Sand	0.6
Loam	0.33
Light Clay	0.33
Heavy Clay	0.2

The EC_{se} value can then be used to assess the general level of crop tolerance to irrigation water salinity by comparing with values in Table 4-6. Alternatively, the EC_{se} can be compared with the relative salt tolerances of specific crop and pasture species (refer to Saltpak (DPIWE 1992) for tolerance of Tasmanian crops and species).

Table 4-6: Soil and water salinity criteria based on plant salt tolerance groupings

Plant salt tolerance grouping	Water or soil salinity rating	Average root zone salinity EC_{se} (dS/m)
Sensitive crops	very low	<0.95
Moderately sensitive crops	Low	0.95 – 1.9
Moderately tolerant crops	Medium	1.9 – 4.5
Tolerant crops	High	4.5 – 7.7
Very tolerant crops	very high	7.7 – 12.2
Generally too saline	Extreme	>12.2

4.5.3 Soil Salinity Hazard

Soils which are naturally saline pose a threat to the operation and longevity of wastewater re-use sites. Ideally wastewater re-use sites should not be located in or adjacent to saline areas. All options to relocate the site should be fully investigated before attempting to manage additional salts at a known saline area.

If the Local Area scoping study indicates the possibility of saline soils (section 6 and see Figure 4-1 SCRAMM WR below) then an EM31 survey must be conducted prior to further detailed investigation. The Electromagnetic Induction Meter (EM31) is used produce a map of apparent soil conductivity and possible areas of salt storage. The apparent soil conductivity map is used in conjunction with other available information to locate a strategic drilling program, and soil investigation pits to determine the actual soil salinity and calibrate the EM map. Bore holes may also be used to assess the depth to any water-tables, determine some ground water flow information and used for future monitoring.

If an experienced organisation is used, it is estimated that a full SCRAMM study would cost about $30-$50 per hectare depending on scale.

4.5.4 Additional Management Practices for Areas of Moderate Salt or Localised Sub-Surface Salt

After the SCRAMM process determines that an area of land displays the characteristics of moderate salt or localised sub surface salt, the following additional management practices may be necessary to ensure sustainable irrigation:

- Avoid salt areas
- Use high efficiency irrigation and minimise infiltration
- Use of minimal fallow periods (for shallow groundwater areas)
- Improve drainage where possible
- Consider winter leaching through soil profiles
- Consider salt tolerance of crops

4.6 Crop Tolerance

The presence of high levels of soluble salts in soils may result in reductions in plant productivity or, in extreme cases, elimination of any form of vegetation. Irrigation with saline water may also increase soil salinity resulting in loss of production or crop failure. Salinity affects plants in a number of ways such as specific ion toxicity, uptake of ions in excessive levels and reduced water uptake, and ‘drought effect’ due to increased osmotic potential of soil water. The level at which plants are affected by salinity varies enormously between species (refer to Saltpak DPIWE 1992).

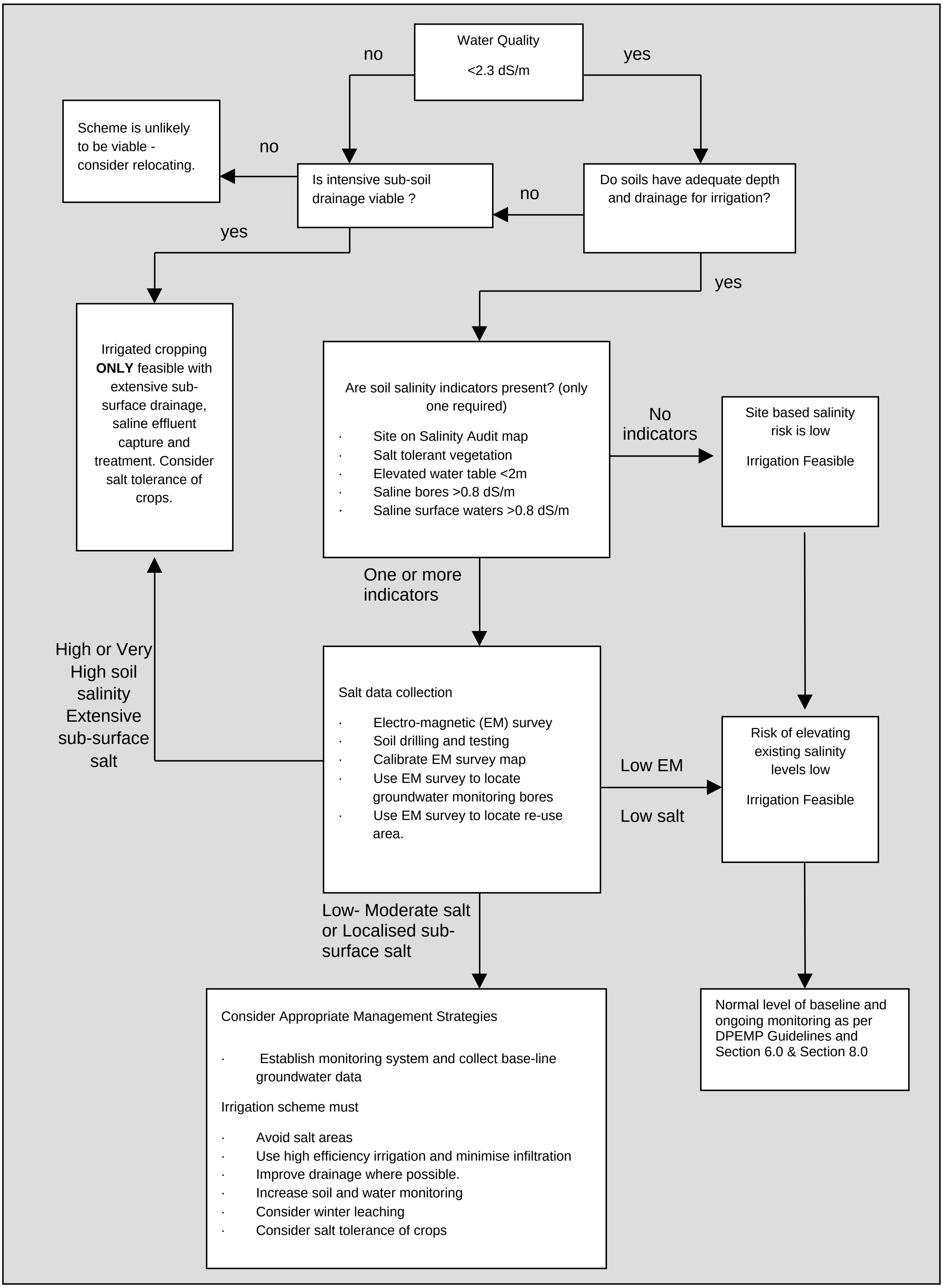


Figure 4-1: Salinity Containment Risk Assessment Monitoring and Management (SCRAMM) for Wastewater Re-use (Source: C. Bastick, M. Hardie, D. Dettrick DPIWE 2002)

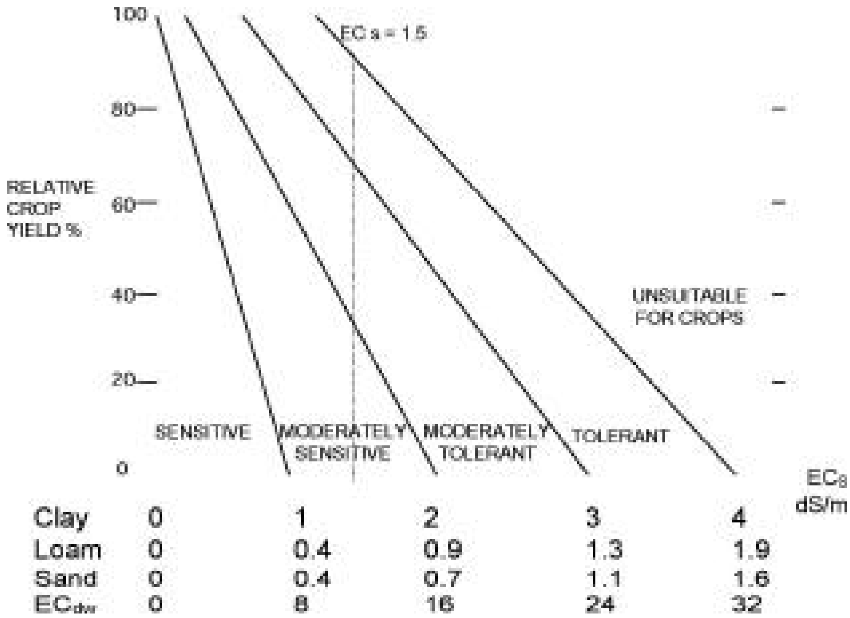


Figure 4-2: Effect of soil salt on crop yields (Adapted from Victorian EPA 1993)

Notes: *EC_s is the electrical conductivity of a 1:5 soil-water suspension and is not to be confused with saturated soil extracts. ECs (dS/m@25^{0}C) x 2,970 = mg/kg TSS (Total Soluble Salt). EC_{dw} is the electrical conductivity of the drainage water or leachate and relates to crop selection and the salt balance in the root zone.*

Figure 4-2 is a guide to relative crop yields for a range of soil salinity levels as it relates to the salt tolerance of the vegetation. For example, moderately sensitive crops on clay soil with electrical conductivity (ECs) of 1.5, will produce up to 30% of their potential yield; moderately tolerant crops 37-70%; and tolerant crops 70-95%.

If ECs in the root zone of a proposed irrigation site is greater than 1.0 dS/m, the existing salt balance must be further investigated. If salt is accumulating naturally, or as a response to changes in plant-soil-water relationships caused by land clearing, irrigation with wastewater is likely to accelerate the salinisation process.

Good irrigation design, crop selection and management is preferable to living with a salt problem. Expert advice should be sought at the planning stage. Personnel from the Food, Agriculture and Fisheries Division of DPIWE can advise on pasture/crop species best suited to the locality and provide more information on the salt tolerance of vegetation. Further information on the salt tolerance of Tasmanian fruit crops, vegetable crops, field crops, and pasture plants is provided in Saltpak (1992).

4.7 Salt Leaching

The water needed to transport salt from the root zone is called the leaching requirement. This concept excludes the effect of rainfall and prevailing drainage conditions, but it is a useful guide to understanding the salt balance in the root zone. The amount of water required for leaching depends on the salt tolerance of the vegetation and the salt concentration in the irrigation water. The leaching requirement (LR) can be calculated using the following equation.

$$LR (\%) = 100 \times (EC_{iw} / EC_{dw})$$

Where: EC_{iw} = electrical conductivity of the irrigation water (dS/m)

EC_{dw} = electrical conductivity of drainage water with relative crop yield of 50% (Table 7-9).

The following is an example for a moderately salt-tolerant crop:

EC_{iw} = 1.88 dS/m (1200 mg Salt/L)

EC_{dw} = 12.00 dS/m (7500 mg Salt/L)

Hence LR = 100 x (1.88 / 12) = 16 %

If the annual irrigation depth is 450 mm, then the leaching requirement is:

0.16 x 450 = 72 mm (72 L/m^2)

The salt applied by irrigation is:

(450 mm x 1200 mg/L) / 1000 = 540 g/m^2

A volume of 72 litres of drainage water (leachate) at the threshold salt concentration would remove:

72 L x 7500 mg/L = 540g/mL

This is equal to the amount of salt added by irrigation. It follows from this, that if the hydraulic conductivity of the soil is extremely low, waterlogging and possibly salinisation may result from irrigation.

Using a leaching fraction to prevent salt accumulation within the root zone is only applicable to soils with adequate subsoil drainage and irrigation systems designed to apply water in excess of the water holding capacity of the soil. In Tasmania, many of the duplex soils (Sodosols, Kurosols, and Chromosols) have poor to imperfect subsoil drainage, effectively preventing the application of a leaching fraction. In addition, most centre pivot or low pressure irrigation systems are only capable of deficit irrigation and not able to supply an additional leaching fraction. Fortunately in Tasmania winter rains frequently saturate the soil profile allowing accumulated salts to be leached from the root zone.

The effectiveness of winter rains to leach salts from the root zone can be approximated by determining whether rainfall over the winter period is sufficient to over fill the crop root zone on at least one occasion. Following the water balance approach detailed in Table 7-1, the winter leaching efficiency is calculated as the ratio between the amount of rainfall infiltrated into the soil vs the soil water storage capacity of the crop root zone. This analysis is conducted using average monthly data for winter months when rainfall exceeds evaporation.

Winter Leaching Efficiency = [(R x Rc) – (Kc x Ev)] / (Rd x TAW)

R = Rainfall (mm)
Rc = Runoff factor (0.7)
Ev = Evaporation (mm)
Kc = Direct Crop Co. (Table 7-1)
Rd = Rooting depth (Table 7-3 & max soil depth)
TAW = Total Available Water (Table 4-7)

If the winter leaching efficiency is less than one then winter rains are not likely to remove accumulated salts from the crop root zone. If the winter leaching efficiency is greater than one then rainfall is likely to leach salts from the root zone (i.e. fill the crop root zone) at least once over the winter period.

For example Lucerne crop on loam soil: Average winter rainfall = 367 mm, Average winter evaporation = 146mm, K_c (lucern) 0.55, Root depth 1.0m, maximum soil depth 2.0 m, TAW (loam) 1.6mm/cm.

WLE = [(367 x 0.7)- (146 x 0.55)] / (100 x 1.6)

WLE = 176.6 / 160 = >1

Leaching of salts through winter rains is likely.

Table 4-7 Total Available water for different textured soils

Soil Texture	Total Avaiable Water (mm/cm)
Sand	0.7 – 1.0
Sandy Loam	0.9 – 1.5
Loam	1.4 – 1.9
Clay Loam	1.7 – 2.2
Silty Clay	1.8 – 2.3
Clay	2.0 - 2.5

Source: James , L.G (1993) Principles of Farm Irrigation System Design. Krieger Publishing, Florida.

Applications to irrigate with wastewater should include an explanation of how salt will be exported from the root zone without causing salt damage to external land and ground and surface waters. This includes assessment of the leaching requirement and the efficiency of winter rains to leach accumulated salts from the root zone.

4.8 Soil Structure Decline

Irrigation with wastewater may also have a secondary effect on plant growth through its effect on soil sodicity. Wastewater low in salinity, but high in sodium salts, may result in the accumulation of sodium ions within clays. Increased sodicity results in decreased soil permeability, increased runoff, lower soil moisture storage and reduced drainage.

Loss of soil permeability reduces the ability of the land to accept wastewater. There are two main causes for loss of permeability:

- chemical: adsorption of sodium ions to soil particles leading to dispersion of colloidal clay with consequent blockage of soil pores. Increased swelling of affected clay also occurs in the presence of low salinity water.

- physical or mechanical: intensive cultivation, compaction by stock or machinery, or intense rain on unprotected soil causes slaking or disintegration of soil particles on wetting, especially if organic matter is lacking.

To assess the risk of soil structure decline, a 1:5 soil/water suspension is analysed for total cation concentration (TCC), electrical conductivity (ECs), sodium adsorption ratio (SAR), exchangeable cations (CEC) and the ratio of calcium to magnesium. Interpretation of soils analysis results and application of amendments to the soil should be left to specialists or the Department of Primary Industries, Water and Environment.

4.8.1 Sodicity

Sodicity is the presence of a high proportion of sodium (Na^+) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in soil and water. In wetted soil, sodium attached to clay weakens the bonds between soil particles and allows the breakdown of soil aggregates into individual clay particles in a process called dispersion. Sodicity will degrade soil structure, making the soil more erodible and less permeable to water (as the spaces in soil become clogged) causing chronic waterlogging. This reduces plant growth.

Similar problems may occur if sodic soils are irrigated with low salinity water or if the irrigated effluent is high in carbonate and bicarbonate ion concentration. In this cases irrigation will have to be reduced, and there will be a loss in production from the land. The effects of sodium on soil structure may not be obvious while undertaking irrigation with effluent. However, once land is returned to rain-fed agriculture or irrigated with fresh water, excessive sodium build up can cause collapse of the soil structure, sealing off the air gaps, and causing water logging.

The presence of carbonate and bicarbonate ions (alkalinity) may precipitate calcium. This can increase the effect of the sodium in the soil solution and increase the risk of causing reduced soil permeability. Grossly excessive application of phosphorus can have the same effect. Consequently, wastewater should be analysed for sodium (Na^+), calcium (Ca^{++}), magnesium (Mg^{++}), electrical conductivity, carbonate and bicarbonate alkalinity. While other ions may contribute to alkalinity if pH is above 8.3, such highly alkaline water may not be suitable for irrigation because of corrosion and fouling of water reticulation infrastructure and reductions in trace element availability to plants from irrigated soils. To measure of the amount of sodium present in the wastewater relative to calcium and magnesium, the sodium adsorption ratio (SAR) is calculated using the standard equation:

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

The SAR can be adjusted to estimate the amount of calcium that will remain in the soil water after irrigation allowing for salinity and precipitation or dissolution. The "Adjusted SAR" is calculated using the equation below and Table 4-9. To use Table 4-9, the irrigation water salinity (EC_{iw}) in dS/m and the bicarbonate to calcium ratio (HCO_3^-/Ca^{++}) using milli-equivalents per litre (me/L) must be known from the irrigation water analysis.

$$\text{Adjusted SAR*} = \frac{Na}{\left[\frac{(Ca_x + Mg)}{2}\right]^{0.5}}$$

* Na^+ and Mg^{++} concentrations are taken from water analysis and converted to milli-equivalents per litre (me/L) using Table 4-8. Ca_x is obtained fromTable 4-9.

Table 4-8: Conversion of mg/L to me/L (Victorian EPA 1993)

Na (me/L)	= Na^+ (mg/L) x 0.0435
Ca (me/L)	= Ca^{++} (mg/L) x 0.0500
Mg (me/L)	= Mg^{++} (mg/L) x 0.0833
HCO_3 (me/L)	= HCO_3^- (mg/L) x 0.0164
$CaCO_3$ (me/L)	= $CaCO_3$ (mg/L) x 0.02

Table 4-9: Ca_x values for Adjusted SAR (Victorian EPA 1993)

	EC_{iw} Irrigation water salinity (dS/m)											
Ratio HCO_3/Ca	0.1	0.2	0.3	0.5	0.7	1.0	1.5	2.0	3.0	4.0	6.0	8.0
0.05	13.2	13.6	13.92	14.4	14.8	15.26	15.91	16.43	17.28	17.97	19.07	19.94
0.1	8.31	8.57	8.77	9.07	9.31	9.62	10.02	10.35	10.89	11.32	12.01	12.56
0.15	6.34	6.54	6.69	6.92	7.11	7.34	7.65	7.9	8.31	8.64	9.17	9.58
0.2	5.24	5.4	5.52	5.71	5.87	6.06	6.31	6.52	6.86	7.13	7.57	7.91
0.25	4.51	4.65	4.76	4.92	5.06	5.22	5.44	5.62	5.91	6.15	6.52	6.82
0.3	4.0	4.12	4.21	4.36	4.48	4.62	4.82	4.98	5.24	5.44	5.77	6.04
0.35	3.61	3.72	3.80	3.94	4.04	4.17	4.35	4.49	4.72	4.91	5.21	5.45
0.4	3.3	3.4	3.48	3.6	3.7	3.82	3.98	4.11	4.32	4.49	4.77	4.98
0.45	3.05	3.14	3.22	3.33	3.42	3.53	3.68	3.8	4.0	4.15	4.41	4.61
0.5	2.84	2.93	3.0	3.1	3.19	3.29	3.43	3.54	3.72	3.87	4.11	4.3
0.75	2.17	2.24	2.29	2.37	2.43	2.51	2.62	2.70	2.84	2.95	3.14	3.28
1.0	1.79	1.85	1.89	1.96	2.01	2.09	2.16	2.23	2.35	2.44	2.59	2.71
1.25	1.54	1.59	1.63	1.68	1.73	1.78	1.86	1.92	2.02	2.1	2.23	2.33
1.5	1.37	1.41	1.44	1.49	1.53	1.58	1.65	1.7	1.79	1.86	1.97	2.07
1.75	1.23	1.27	1.3	1.35	1.38	1.43	1.49	1.54	1.62	1.68	1.78	1.86
2.0	1.13	1.16	1.19	1.23	1.26	1.31	1.36	1.4	1.48	1.54	1.63	1.7
2.25	1.04	1.08	1.1	1.14	1.17	1.21	1.26	1.3	1.37	1.42	1.51	1.58
2.5	0.97	1.00	1.02	1.06	1.09	1.12	1.17	1.21	1.27	1.32	1.40	1.47
3.0	0.85	0.89	0.91	0.94	0.96	1.0	1.04	1.07	1.13	1.17	1.24	1.3
3.5	0.78	0.8	0.82	0.85	0.87	0.9	0.94	0.97	1.02	1.06	1.12	1.17
4.0	0.71	0.73	0.75	0.78	0.8	0.82	0.86	0.88	0.93	0.97	1.03	1.07
4.5	0.66	0.68	0.69	0.72	0.74	0.76	0.79	0.82	0.86	0.9	0.95	0.99
5.0	0.61	0.63	0.65	0.67	0.69	0.71	0.74	0.76	0.8	0.83	0.88	0.93
7.0	0.49	0.5	0.52	0.53	0.55	0.57	0.59	0.61	0.64	0.67	0.71	0.74
10.0	0.39	0.4	0.41	0.42	0.43	0.45	0.47	0.48	0.51	0.53	0.56	0.58
20.0	0.24	0.25	0.26	0.26	0.27	0.28	0.29	0.3	0.32	0.33	0.35	0.37

Figure 4-3 is a guide to the permeability hazard of irrigation waters used on susceptible soils. It illustrates the relationship between SAR and electrolyte concentration and likely effects on soil and plant growth.

Practices such as land forming and irrigation usually modify the physico-chemical properties of soils. Permeability may remain stable with a high concentration of electrolytes in the soil, but if leaching and drainage are restricted for any reason a salinity problem, possibly compounded by waterlogging is likely to develop. It should be noted that some crops exhibit sodium toxicity symptoms at low SAR values.

Soils affected by sodicity can be rehabilitated through cultivation, or by the addition of gypsum and organic matter. However, this is a long and costly process and irrigation may not be possible during the rehabilitation process.

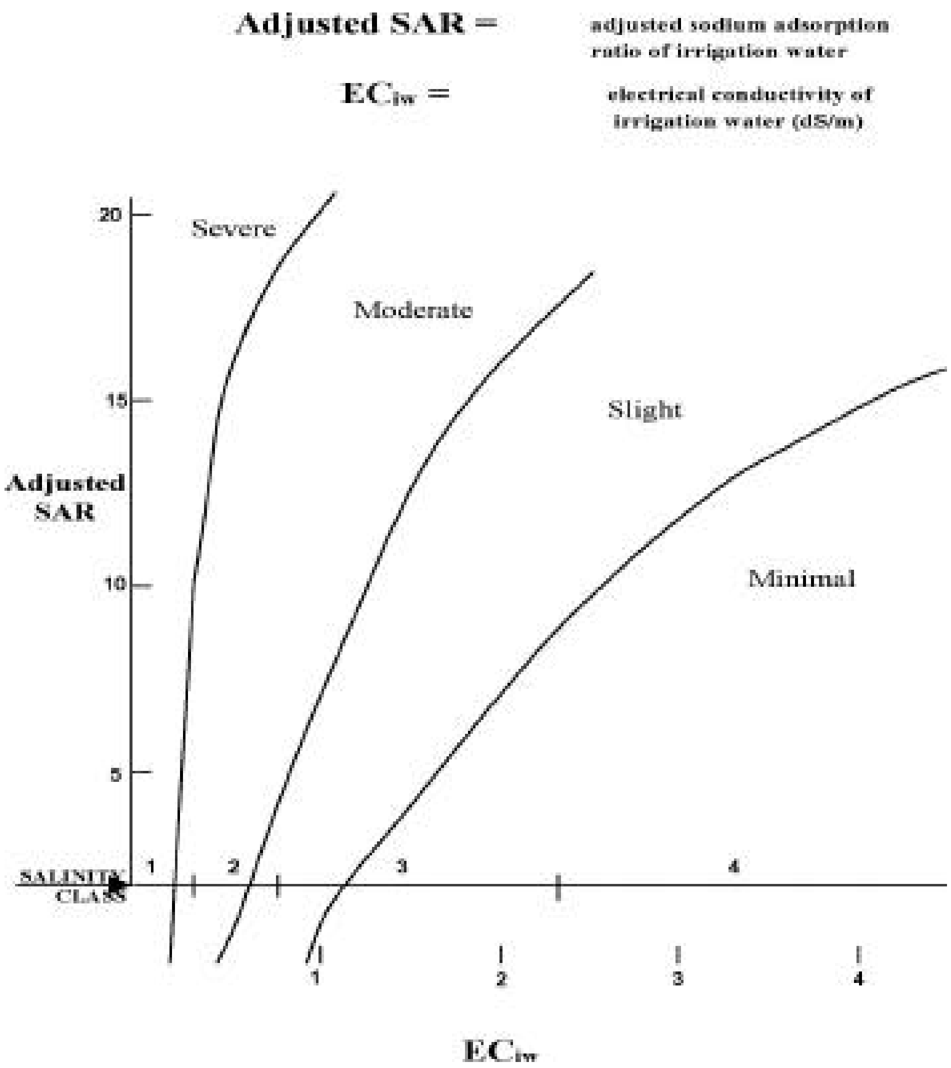


Figure 4-3: Risk of Soil Permeability Loss in Relation to Salt Content of Wastewater (Victorian EPA 1993)

4.8.2 Gypsum Response Classes

The gypsum response (GR class) classes shown in Table 4-10 are useful for assessment of soils and management requirements. These classes are not applicable to soils containing free lime (e.g. self-mulching soils) or soils with pH (in water) less than 5.0.

Table 4-10: Gypsum response (GR class) classes (Victorian EPA 1993)

GR Class	Soil Response Description
Class 1	Soils are dispersive and will have problems associated with surface crusting and waterlogging under any management system. Gypsum applications are necessary and regular soil testing is suggested.
Class 2	Soils are potentially dispersive.
2(a)	Soils are unlikely to require gypsum if supporting an established pasture or if cropped using minimum tillage methods. Periodic application of gypsum to these soils is necessary when the soils are subjected to regular surface cultivation or row cropping.
2(b)	Sodic soils (SAR exceeds 3). As for 2(a) but higher rates of gypsum application are required to reduce sodium levels.
2(c)	These soils are poorly structured and have production problems associated with excessive salinity. Salinity can be reduced by gradual leaching of the soil with water of lower salinity. Regular soil tests are necessary to monitor the progress of the leaching. Removal of salinity by leaching will move these soils into class 2(b). When this happens these soils will become responsive to gypsum.
Class 3	These soils are well structured but plant growth may be limited by salinity.
3(a)	Salinity will restrict growth in this soil class. Follow management outline given for Soils in 2(c).
3(b)	Well-structured soils because of their high gypsum content. Salinity is generally not a problem due to low field solubility of gypsum.
3(c)	Ideal soils with no salinity or gypsum requirements.

The three broad classes are identified in Figure 4-4 which illustrates the relationship between sodium adsorption ratio (SAR) and salt levels and required use of gypsum to control soil structure.

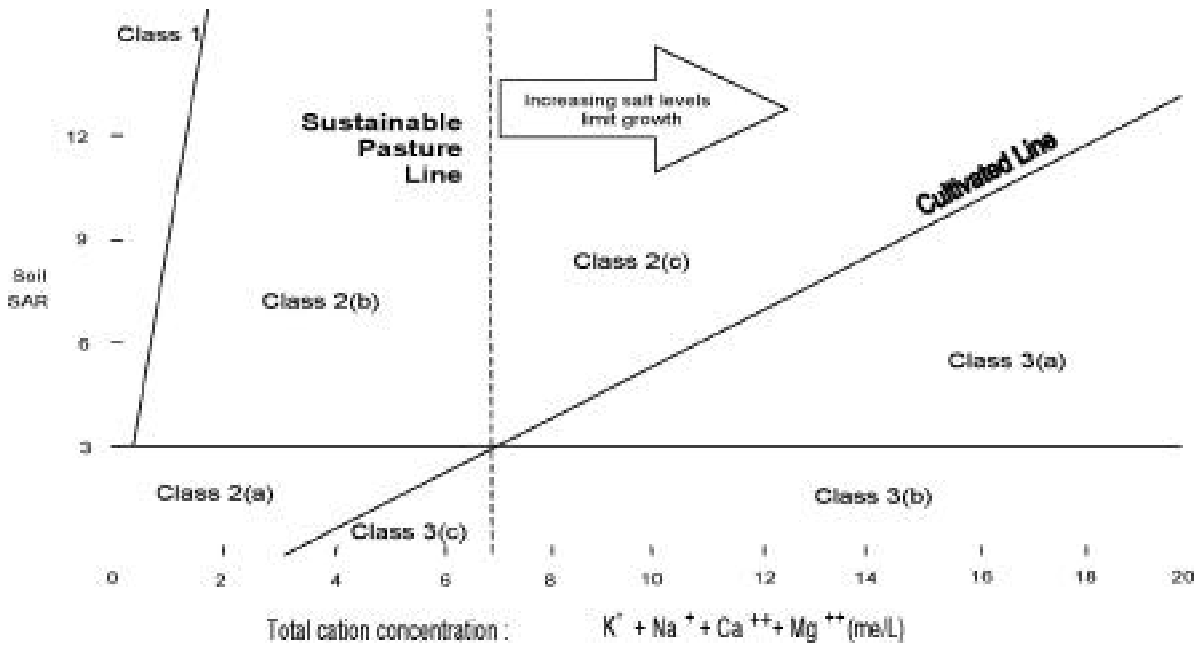


Figure 4-4: Gypsum Response of Soils (Victorian EPA 1993)

Note that if soils are already acidic application of large amounts of gypsum is likely to further reduce pH. Consideration should be given to applying high quality finely crushed lime. Lime ($CaCo_3$) is a suitable source of calcium for the treatment of sodic soils. In addition lime also increases pH and can contain useful levels of magnesium. Lime is however considerably slower acting than gypsum and may need to be applied 6 months before planting, and require future applications.

4.9 Specific Ions

Plants vary in their sensitivity to ions such as aluminium, sodium, boron and chloride. The effects range from deficiency to acute toxicity and the range between these two extremes may be quite narrow. It is possible that in some cases the concentration of certain ions, rather than water uptake, may be the key limiting factor that dictates the amount of wastewater that can be applied by irrigation.

Nutrient imbalances may be caused by wastewater irrigation. The ratios of dissolved substances and minerals are not necessarily ideal and the water and nutrient demands may not be parallel. Fortunately, this is not a serious problem with treated domestic sewage provided that irrigation is not excessive. Ammonium and potassium provide two examples of where adverse effects arise from normally beneficial ions being supplied in excessive concentrations. Excessive amounts of these ions can reduce magnesium uptake and this has important implications for animal health.

High concentrations of any ions in the wastewater should be investigated. The principal irrigation water quality indicators are shown in Table 4-2 and Table 8-2 (page 104).

4.9.1 Chloride

Chloride causes leaf burn in sensitive plants, particularly if sprayed on the foliage in hot weather. Tree crops and woody plants are the most susceptible.

Waters containing less than 100 mg/L of chloride are considered safe for spray irrigation. The effect of higher chloride levels varies with plant species and management. Night irrigation can be used to minimise chloride damage. Higher chloride levels can be tolerated in flood irrigation systems but severe damage to plants can be expected when chloride exceeds 350 mg/L.

4.9.2 Nitrogen

Nitrogen is an essential nutrient in plants. As a building block in protein development, nitrogen uptake enables plant growth. Applications of large amounts of nitrogen can, however, result in soil acidification; groundwater contamination through leaching; surface water contamination if there is run-off from the site; and in extreme cases, metabolic disorders in animals grazing on the site. The cycling of nitrogen through air, water, soil and living organisms is complex and highly variable. To ensure long-term sustainability a balance should be sought between effluent nitrogen loading and crop uptake.

Nitrogen may be present in a number of forms in wastewater, such as organic nitrogen, nitrate and ammonia. Most laboratories report in terms of elemental nitrogen e.g. nitrogen as ammonia. Nitrogen can be removed from wastewater in several ways following irrigation:

1. Nitrogen can be taken up by vegetation and removed from the site in a crop or in animals that may eat the vegetation.

2. Nitrogen as ammonia can volatilise from the waste or from the excreta of animals.

3. Denitrification, particularly under waterlogged conditions, can result in the loss of nitrogen from the soil. Unfortunately, conditions conducive to denitrification can result in poor plant growth and a reduction in the irrigation requirement.

4. Nitrification occurs in the presence of oxygen and involves the conversion of ammonium to nitrate by the action of micro-organisms in the soil.

5. Nitrogen as nitrate can be leached from the soil depending on factors such as:

(i) the nitrate concentration in the soil;

(ii) the nitrogen requirement of the pasture or crop;

(iii) the permeability of the soil; and

(iv) the hydraulic loading as rainfall plus irrigation.

Where wastes are applied year round the total nitrogen load should not exceed 100 kg N/ha/yr.

The amount of nitrogen applied can be calculated using the following equation.

$$N = 0.01 \times C \times Y$$

Where: N = total annual nitrogen loading (kg/ha/yr)

C = total elemental nitrogen concentration in wastewater (mg/L)

Y = annual wastewater loading (mm/yr)

Nitrogen 'fixed' by legumes should be taken into account as well as the season and the soil type. To prevent nitrate build up in groundwater, irrigation should cease in winter when there is more rain and less plant growth. As the amount of nitrogen removed is related to the nitrogen content of the harvested crop the annual nitrogen loading should be no more than the nitrogen uptake capacity over the summer period. The relative uptake of nitrogen by plants is directly related to productivity. Therefore, if nitrogen removal from the soil is the objective, the crop selection should be for high dry matter production in addition to the rate of nitrogen uptake.

Table 4-11 Mineralisation of Organic Nitrogen in Wastewater in Soil Over Time

	% Organic Nitrogen Mineralised	
At end of year	Biosolids*	Wastewater
1	40	60
2	20	30
3	10	10
4	5	
5	3	

*Source: Younos 1987. Table Adapted from NSW EPA 1999

To minimise the risk of odour from rotting vegetation in open channels, nitrogen-rich wastewater should be conveyed by sub-surface pipelines where practicable. Wastewater discharges must not prejudice the values of receiving waters.

4.9.3 Phosphorus

Phosphorus is essential for plant growth. Unlike nitrogen, phosphorus is not lost to air and has low mobility in soil. Consequently, the application of phosphorus, whether as artificial fertiliser or as a constituent of recycled water, has as its goal matching input to crop demands. Surplus phosphorus transported off-site in dissolved or particulate form may produce oxygen-depleting or toxic algal blooms in surface waters. Excessive levels of phosphorus in irrigated wastewater may also lead to the rapid algal growth, causing blooms in storages, blockages in irrigation infrastructure (filters, pipes and outlets) or algal contamination of crops.

In some soils (e.g. Krasnozems) phosphorus can be readily removed from wastewater by fixation in the topsoil. Fixation is the adsorption and precipitation of phosphorus, commonly involving aluminium and iron. The process reduces the availability of phosphorus to plants, depending on pH. Alternatively, excess phosphorus can reduce the availability of copper, iron and zinc in alkaline soils. Excessive irrigation, particularly on sands and gravels containing little clay and organic matter must be avoided. Correctly scheduled summer irrigation with wastewater should supply regular small quantities of available phosphorus to maximise uptake by vegetation.

To minimise potential off-site impacts associated with the phosphorus component of wastewater, the phosphorus removed in the harvestable portion of crops and the phosphorus adsorption capacities (the application threshold over which run-off and leaching of phosphorus to surface and groundwater may occur) of soils and other fertiliser inputs into the soil must be considered. As a rule, the annual application of phosphorus should not exceed the crop or pasture removal rates shown in Table 4-12, nor should phosphorus be applied at a rate that will overload the Phosphorus Adsorption Capacity (PAC) of soil during the life of the irrigation scheme.

Phosphorus adsorption capacity changes with soil type and soil history, and plants poses different phosphorus removal abilities. This means that site specific data needs to be assessed when determining the acceptable contaminant concentration (ACC) for phosphorus application within wastewater. The following model should be used to calculate an ACC for phosphorus. This is to prevent phosphorus in irrigation water from overloading the soil's PAC during the life of the wastewater irrigation scheme and prevent environmentally significant concentrations of phosphorus moving from soils into water bodies.

$$\mathbf{ACC = P_{es} + P_{sorb} + P_{removed}}$$

Where: ACC = acceptable phosphorus concentration in irrigation water (mg/L/year).

P_{es} = environmentally significant P concentration i.e. > 0.05 mg/L algal blooms likely.

P_{sorb} = total phosphorus in irrigation water sorbed by soil (mg/L).

$P_{removed}$ = P removed from irrigation water in harvestable portion of the plant (mg/L).

For calculation of P_{sorb}:

$$P_{sorb} = \left\{ \frac{\left[\frac{(\text{Depth} \times \text{BD} \times P_{ssc})}{100} \right] - P_{fert}}{I_w \times 10} \right\} \div \text{Years}$$

Where: P_{sorb} = total P sorbed from water by soil (mg/L or g/m^3)

Depth = soil depth (m)

BD = topsoil bulk density (kg/m^3, 0-70 cm)

P_{ssc} = phosphorus sorption capacity of soil (g/tonne or mg/kg) when 50 _g P/L in solution at equilibrium.

I_w = irrigation water height (m)

P_{fert} = phosphorus input from fertiliser (g/ha)

Years = years water will be applied

P_{ssc} should be calculated from a P sorption curve measured as described by Rayment and Higgenson (1992, Method 9J1). An example is given in Figure 4-5. The P_{ssc} should be taken when the extractant P concentration is 50 _g P/L (i.e. the P_{es} value). Ideally this value should be included within the points determined by the buffer curve (e.g. from Figure 4-5, if x = 50, y [mg P sorbed by soil/kg soil] = 57).

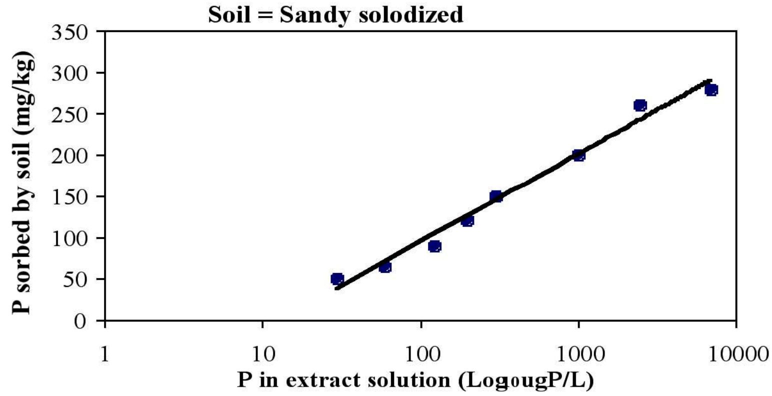


Figure 4-5: Example of soil phosphorus sorption curve (data modified from Holford 1983)

Example of P_{sorb} calculation (ANZECC 2000)

$$P_{sorb} = \left\{ \frac{\left[\frac{0.15 \times 1300 \times 57}{100}\right] - 15}{1 \times 10} \right\} \div 20 = 0.48 \text{ mg/L}$$

And for calculation of $P_{removed}$:

$$\mathbf{P_{removed} = \frac{P_{harv}}{I_w \times 10}}$$

Where: $P_{removed}$ = phosphorus removed from irrigation water by harvested portion of the plant (mg/L)

P_{harv} = phosphorus removed from soil in harvestable portion of crop (kg/ha) calculated by multiplying the mean P concentration of the particular crop by the expected yield.

I_w = Irrigation water height (m)

10 = converts kg/m^3 to mg/L

An example calculation of $P_{removed}$ where 1 metre of irrigation water applied to cabbage.

$$P_{removed} = \frac{50 \times 0.6}{1 \times 10} = 3.0 \text{ mg/L}$$

In the above the example, the phosphorus ACC would be as follows:

$ACC = P_{es} + P_{sorb} + P_{removed}$

ACC = 0.05 + 0.48 + 3.0 = 3.5 mg/L

The calculated ACC for phosphorus should primarily be used as a starting point for detailed design figures. These figures will need fine tuning over the life of the scheme in relation to actual observed behaviour in the field since each crop and soil type vary from site to site.

4.9.4 Potassium

Potassium is required by plants for various cellular processes. Treated municipal sewage contains enough potassium to replenish uptake by irrigated eucalypts and by animals grazing on irrigated pasture. Potassium leaches readily from sandy soils and the crop response depends on the amount of available potassium in the soil. Potassium is most likely to become deficient if annual crops are harvested and removed, so potassium supplements are normally required. Unlike nitrogen, potassium can not be fixed from the atmosphere or be released to the atmosphere, thus a potassium balance is essentially application less the removal in harvested material.

4.9.5 Nutrient Balance and Plant Nutrient Requirements

It is essential that wastewater nutrient content should be matched to crop requirements. This is termed the nutrient balance for the particular crop and wastewater being used to irrigate.

The plant nutrient requirements for a particular crop type may be obtained from the Department of Primary Industries, Water and Environment. Table 4-12 gives an indication of nutrient removal for some plants that may be irrigated with wastewater. Secondary treated municipal sewage typically contains 20 to 30 kg of nitrogen per Megalitre and 5 to 10 kg of phosphorus per Megalitre.

Table 4-12: Indicative Nutrient Removed in Farm Products and Optimum Soil pH Ranges for some Plant Species

Crop	Av. Yield Tasmania t/ha *	Av. Dry yield t/ha	Av. Nitrogen Removed kg/ha **	Av. Phosphorus Removed kg/ha **	Av. Potassium Removed kg/ha **	Av. Sulphur Removed kg/ha **	Optimum Soil pH
Barley/ Wheat	2.3	2.0	48	5	8	3	-
Oats	1.9	1.6	32	5	8	3	5.0-7.9
Lupins	2.0	1.7	97	7	17	6	-
Field Peas	2.1	1.8	74	7	20	5	-
Rapeseed	2.0	1.8	72	11	16	18	-
Potatoes	40	8.0	120	12	220	9	-
Onions	50	6.5	91	21	98	26	-
Cabbage	20	2.0	110	20	100	-	-
Cauliflower	14	1.4	49	10	59	-	-
Broccoli	12	1.2	70	11	53	-	-
Brussel Sprouts	20	2.0	110	20	100	-	-
Carrots	45	6.8	61	27	116	-	-
Green Peas	4	0.6	29	2	7	1	-
Green beans	7	1.1	34	3	29	2	-
Grapes	12	-	-	-	-	-	6.1-7.9
Hops		2.3	124	17	140	-	-
Apples	30	-	11	1	17	-	-
Pears	25	-	9	1	14	-	-
Ryegrass/Clover	5.0	4.3	125	9	82	8	-
Lucerne	6.5	5.6	174	13	112	11.2	6.1-7.9
Cereal Straw	3.5	3.2	22	2	58	5	-

** From Australian Bureau of Statistics (ABS) statistics or DPIWE trials*
*** Using local information where available. The figures are a guide only, actual removal may vary.*

A worked example is provided below for calculation of nutrient limits which will place restrictions on irrigation for a specific site.

Area available for irrigation	91 ha
Irrigation rates assumed @300 mm/yr	3ML/ha/yr
Hydraulic loading (910,000 m^2 x 0.30 m/yr)	273 ML/yr

① Nitrogen uptake - grass @ 100 kg/ha/yr

Nutrient loading (91ha x 100kg N/ha/yr)	9100 kg N/yr
Required effluent nitrogen concentration (9100/273 ML)	**33 mg/l**

② Phosphorus uptake - grass @ 15 kg/ha/yr

Nutrient loading (91ha x 15 kg P/ha/yr)	1365 kg P/yr
Required effluent phosphorus concentration (1365/273 ML)	**5 mg/L**

Therefore, for this example with an average sewage lagoon wastewater containing 30mg/L nitrogen and 8 mg/L phosphorus, the crop phosphorus requirement (5 mg/L) limits the irrigation while the crop nitrogen requirement (33mg/L) does not. Phosphorus is the factor that limits the irrigation of this wastewater as there is an excess to the grass crop requirements.

4.9.6 Soil Amendment

A typical mixed pasture has the ratio of N:P:K:S:Na of 17:2:14:1:1 within pasture biomass. Wastewater will generally have a N:P ratio of 3:1 and may have a K:Na ratio of 1:2. Therefore, to achieve sustainable harvests and to avoid plant toxicity, soil supplements will be required. Wastewater will have to be applied at the rate dependent on the nutrient that limits the maximum application. Depending on different soil and plant combinations, any one of these nutrients may limit application. To achieve healthy cropping on most soils, nitrogen based fertilisers will be required.

If the agricultural ratio is not maintained and crop production is not consistent, then the crop will not be removing the appropriate amounts of nutrients required to make the irrigation sustainable.

4.9.7 Calculation of Loadings

In many cases, such as with wastewater from intensive animal industries or areas with unusual soil types, the key limiting factor for site capacity may be the nutrient or salt loadings, not the hydraulic loading (irrigation water requirement). For example, the recommended nitrogen removal with rye grass/clover is 125 kg/ha/year. If the total nitrogen content of the waste is 40 mg/L, the irrigation requirement to apply the limiting quantity (125 kg/ha) is calculated using the loading equation below.

In the Brighton area pasture is to be irrigated with wastewater to extend productivity. From local weather records, the annual pasture irrigation requirement in this area is approximately 600mm.

$$\mathbf{Y = 100 \times L / C}$$

Where: Y = hydraulic loading (mm/yr)

L = limiting quantity (kg/ha/yr)

C = concentration of limiting parameter (mg/L)

Example: 100 x 125 / 40

So in this case the hydraulic loading Y = 310 mm/year which is insufficient to meet the needs of the pasture of 600mm.

This shows that irrigation can be severely limited if the waste is not treated to a sufficient standard.

Pre-treatment of wastewater by solids removal followed by retention in properly designed lagoons is an effective way to reduce the strength of wastewater, thereby increasing land use efficiency. In areas with a high irrigation deficit requirement of >600mm/year, such as in the above example, the wastewater will have to be further treated to a standard of around 20 mg/L of Total Nitrogen, to meet the full hydraulic needs of the crop. Treatment may also be required to meet the public health criteria given in Section 4.1.1, depending on the type of waste.

Shandying of wastewater with appropriate quality environmental water is also a possible solution to lowering concentrations of macro or micro-nutrients. In this case, however, the final mixed irrigation water is still considered to be the same class of effluent after shandying and the results need to be monitored for thermotolerant coliforms to confirm the quality of the wastewater and more importantly, confirm the quality of the environmental water (such as stormwater).

4.10 Organic Matter

Organic matter (OM) present in the suspended and colloidal forms in most wastewater is unlikely to be detrimental to vegetation and soils. OM helps to maintain or improve nutrient and moisture retention and also the structure of the soil. Plants can grow well in nutrient-rich solutions or in mineral soils without any OM at all, and also in 'soils' that are 100% organic matter, if fertilisers are added. Soils, climates, and plant species combine to make a multitude of different ecological and environmental conditions which vary the OM concentration to fit each circumstance. It would therefore be misleading to specify a maximum permissible OM loading.

Surface soils in Tasmania can contain up to about 20% OM. Building a soil up to, and maintaining, say, 5% OM is not likely to be harmful. For example, if a sandy loam contains 160 t/ha (5% w/w) of OM in the top 200 mm, and if 50% of this is oxidised annually, it could be maintained at 5% OM by applying a weekly average of 1500 kg OM/ha.

The decomposition products of OM should be considered in relation to soils and plant growth where heavy loadings are proposed. It is important to ensure that the OM will not release excessive amounts of salts, nitrogen or metals as it decomposes. Cultivation accelerates the decomposition of OM and the release of the nutrients it contains. Liming is sometimes necessary to counter soil acidification caused by nitrification and some decomposition products.

Dissolved OM (as Biochemical Oxygen Demand, BOD_5) can be indirectly harmful to most plants if the soil is poorly drained and therefore lacks oxygen which is essential to growth and root function. The resting periods which are necessary in the irrigation cycle should provide the time required for micro-organisms to break down some of the OM applied to the soil. Wastes consisting primarily of solid OM and defined as sludges may be applied to land but they are generally not classified as wastewater. For further information refer to the 1999 *Tasmanian Biosolids Re-use Guidelines* available from Service Tasmania or from the DPIWE website.

The organic load can be calculated from the BOD concentration of the waste and the anticipated hydraulic loading using the equation below.

$$\mathbf{OM = 0.01\,C \times Y}$$

Where: OM = total organic load (kg/ha/year)

C = organic matter concentration (BOD mg/L)

Y = hydraulic loading (mm/year)

4.11 Suspended Solids

Excessive amounts of suspended solids in irrigation water may clog the surface of the soil, depending on the nature of the solids and the soil. This leads to a reduction in the infiltration rate of the soil and makes irrigation less effective. The problem can be rectified to some extent by regular light cultivation, but it is preferable to control suspended matter within the treatment process. As a minimum standard, gross solids should be removed from the wastewater before irrigation by a screen of 2 and 5mm spacing.

4.12 pH

Most soils are buffered i.e. they resist pH change. However, toxicity to plants, nutrient deficiency and soil structure problems may be caused by strongly acidic or alkaline irrigation waters. Therefore, the pH of the wastewater should be in the 6.5-8.4 range. Seasonal fluctuations may be expected if the wastewater is stored prior to irrigation.

A soil pH of 5.5 to 8.0 is favourable to plant growth. pH strongly influences many soil characteristics including the plant availability of nutrients, the solubility of potentially toxic elements, and microbial activity. On mineral soils, most agricultural crops do best in slightly acid soils (pH 6.5); for organic soils, crops do best about pH 5.5. The optimum soil pH range for some plants is indicated in Table 4-12. Chemical amendment of soil pH, e.g. with lime, can be helpful for establishing some crops and pasture species. Specialist advice should be sought as to the lime requirement of soils.

Determination of the soil pH in a 0.01 M solution of calcium chloride is preferred because it gives a more reproducible result than in water, particularly for saline soils and is more representative of pH in the field.

4.13 Synthetic Organic Compounds

The presence of pesticide residues in waters has become an issue of public concern in recent years. Pesticide residues and other synthetic compounds are deemed to have potentially harmful impacts on irrigated crops and pastures, and to the health of human consumers and to aquatic ecosystems receiving drainage waters. Wastewater containing more than trace amounts of substances such as agricultural chemical residues or petro-chemicals are unlikely to be suitable for irrigation. The DPIWE publication *Guidelines for Acceptance of Liquid Wastes to Sewer* contains threshold limits for some of these compounds going into the wastewater treatment plant. Conventional wastewater treatment processes can greatly reduce the number and concentration of trace organics and, during wastewater irrigation, transformation processes such as adsorption, volatilisation, and biodegradation will affect the fate of trace organic substances.

In situations where the inputs of residual pesticides to soils by way of wastewater irrigation are smaller than the direct application of pesticides, the impact of their presence in irrigated wastewater is unlikely to be significant.

4.14 Wastewater Unacceptable for Re-use

Types of wastes not to be used for wastewater re-use, include:

- Radioactive materials with a half life of more than a few days;

_ Pharmacologically active compounds;

_ Non-biodegradable toxic organic compounds;

_ Wastes containing elevated levels of total dissolved salts;

_ Wastes containing high concentrations of metals; and

_ Petrochemical and mining industries output.

The DPIWE publication *Guidelines for Acceptance of Liquid Wastes To Sewer June 1994* should be consulted for more detail on possible levels of pollutants.

5 WASTEWATER TREATMENT & DISTRIBUTION

Wastewater treatment should achieve the following objectives:

1. Provide a level of treatment consistent with the proposed use.
2. Treat wastewater to a level that protects the beneficial uses of soil, ground and surface waters from the effects of polluted run-off.
3. Treat wastewater to a level to protect human health from the effects of toxicants and micro-organisms.

The above objectives may be satisfied by achieving the following minimum requirements:

- As a minimum, the level of treatment for wastewater satisfies the quality limits specified in these Guidelines (see Table 2-1).
- Treatment and re-use of wastewater is managed to satisfy the criteria specified in these Guidelines.
- The wastewater treatment process has the capacity to effectively treat the maximum daily flows.
- The wastewater disinfection process is able to reduce or deal with infectious components to the levels for the intended use or degree of public access that satisfies the requirements detailed in Section 5.2.1.
- Discharges of wastewater into the sewerage system do not contain hazardous substances exceeding the limits specified in *Guidelines for Sewerage Systems – Acceptance of Trade Waste (Industrial Waste)* (ANZECC 1992).
- The wastewater treatment process has the facilities to effectively manage the bio-solids generated in an environmentally acceptable way.
- The wastewater treatment process is the best available considering factors such as required level of treatment, system technical capabilities, stand-by systems and ability to handle extreme events.

5.1 Levels of Treatment Technology

The quality of wastewater depends upon characteristics of the catchment (rural versus urban etc.) and the type of industries serviced. Wastewater for recycling may include water from domestic and industrial sources, stormwater infiltration and urban run-off. The level of treatment required depends upon the application. Typical levels of treatment required to achieve the required quality for re-use are shown in Figure 5-1. The broad treatment categories are:

Primary Treatment : This is a physical treatment process to remove settleable organic and inorganic solids by settling, and floating material by skimming.

Secondary Treatment : This follows a primary process and is where aerobic biological treatment removes the organic matter and some of the nutrients. The activated sludge, trickling filter and waste stabilisation ponds then provide an environment where high concentrations of micro-organisms are used for metabolism of organic matter.

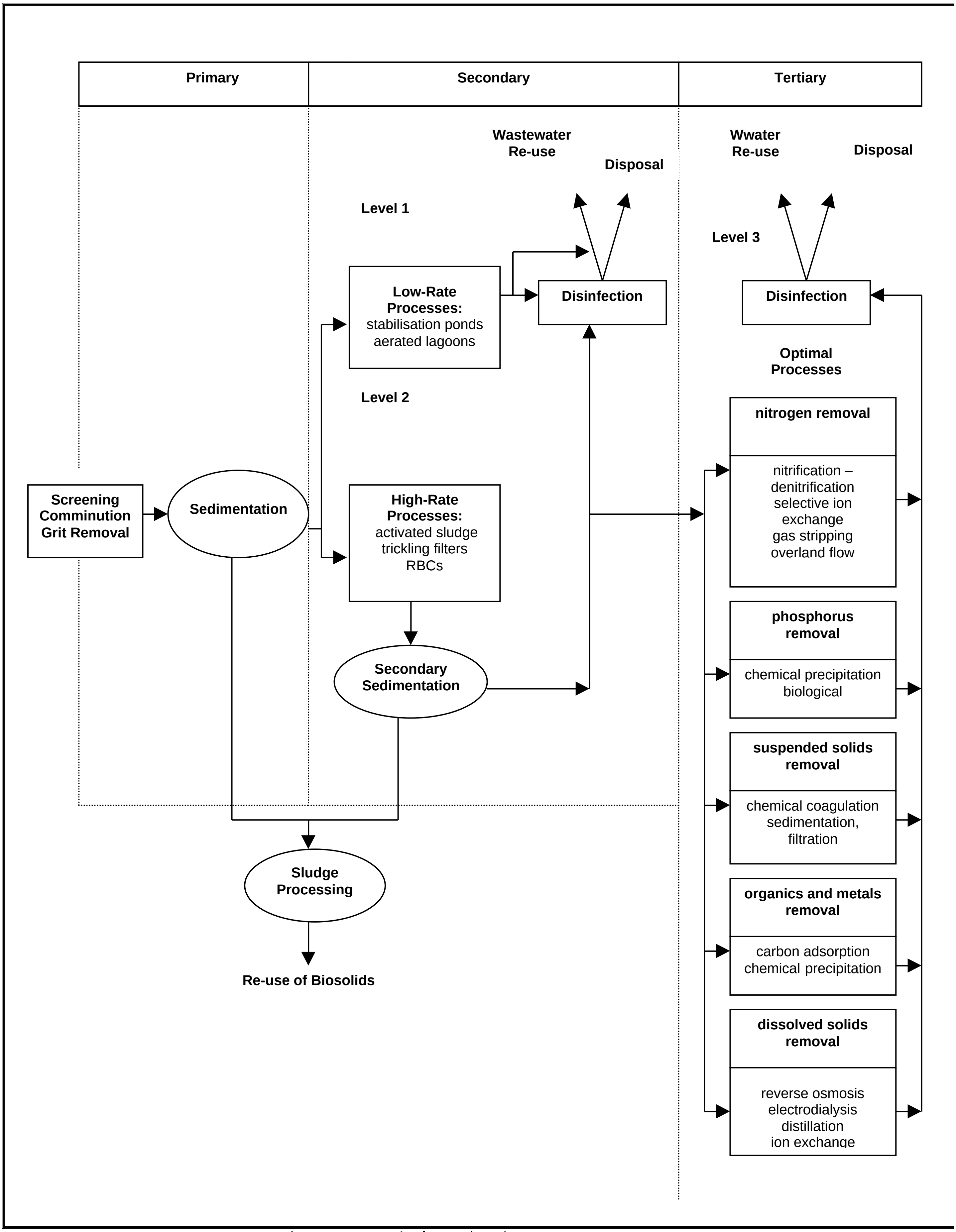


Figure 5-1: Typical Levels Of Wastewater Treatment

Advanced or Tertiary Treatment : Advanced treatment processes are used where high quality reclaimed water is required for uses such as irrigation of urban landscaping, food crops, contact recreation and some industrial uses. Processes may include disinfection, nutrient removal, dissolved and suspended solids removal, organics and metals removal.

These Guidelines take a demonstrative and presumptive approach with a class of water requiring both an appropriate technology and disinfection level.

5.2 Key Treatment Indicators

As it is not practical to monitor wastewater for all the chemical indicators or disease organisms of concern, several common indicators are universally accepted to gauge efficacy of treatment. Continuous monitoring is not possible for some indicators.

5.2.1 Bacteria

The most important part of the treatment process is the removal of pathogens from the wastewater by disinfection. Some bacteria, particularly thermotolerant coliforms (also known as faecal coliforms), are indicators of faecal contamination. *Escherichia coli*, which is found in the intestinal tract of humans and other warm-blooded animals, is often used as the specific indicator of faecal contamination. The presence of *E.coli* over certain threshold concentrations is indicative of different levels of risk that pathogens such as viruses and helminths may be present.

The levels of disinfection consistent with the intended use and degree of human contact are categorised as follows:

- Class A, Recycled Water < 10 cfu /100ml
- Class B, Recycled Water <100 cfu /100ml or < 1,000 cfu/100 mL depending upon use
- Class C, Recycled Water < 10,000 cfu/100ml

The ultraviolet (UV) radiation method of disinfection provides best practice technology as it does not produce by-products that may be toxic to the receiving environment. High levels of suspended solids will, however, affect treatment performance, and UV disinfection is only effective with the highest quality of wastewater. A chemical residual, such as chlorine, may be required with UV disinfection to limit bacterial regrowth or growth of slimes in downstream pipe-work.

Disinfection systems should be standby systems with automatic alarms in case of failure. Effective maintenance and a quality assured system will minimise the risk of treatment failure.

5.2.2 Biochemical Oxygen Demand and Suspended Solids

The indicators biochemical oxygen demand (BOD_5) and suspended solids (SS) provide the best recognised indicators of treatment performance. Organic matter (measured as BOD_5) is food for micro-organisms and its removal affects disinfection requirements. The importance of SS removal is related to the role of particulate material in shielding the disease organisms from the disinfection process. For reliable performance in the removal of pathogenic micro-organisms, particulate matter must be reduced to very low levels. Best practice wastewater treatment will achieve turbidity levels of less than 2 NTU (nephelometric turbidity units) prior to disinfection.

To provide a degree of certainty in performance, continuous monitoring of turbidity in the water stream will act as a surrogate measure for suspended solids concentrations (where a numerical relationship has been established).

5.3 Trade Waste Treatment

Wastes discharged to sewers must be treatable to the standards required for irrigation waters and this should be reflected in Trade Waste Agreements. Treatment at source or alternative disposal of the waste or specific components of the waste may be necessary in some circumstances.

It is sometimes practical to isolate low quality industrial wastewater streams at source for disposal by evaporation. A small amount of caustic washwater in the milk processing industry, for example, can have a major detrimental effect on wastewater treatment and irrigation. The surface area required for evaporation lagoons can be calculated using the equation below. The oxygen demand of the waste must also be considered. To avoid odours, lagoon surface loading should not exceed 5g BOD/m^2/day.

$$\mathbf{A = (1000 \times V) / ([0.8 \times E] - R)}$$

Where: A = surface area of lagoon required (m^2)

V = annual waste loading (kL)

E = median annual evaporation (Class A Pan) (mm)

R = median annual rainfall (mm)

5.4 Distribution System Controls

General system controls are required to avoid potential health risks to the user and the wider public and to safeguard the environment. These controls consist of elements to maintain separation and prevent cross-connection between wastewater and the potable water supply and also the provision of warning signs to users and the public that wastewater is not suitable for drinking. Wastewater treatment plants must be designed in accordance with the relevant codes or guidelines as required by the Director of Environmental Management (see sections 8.1 and 8.2).

5.4.1 Cross Connection Control

The design of the treated wastewater distribution system must prevent cross-connection (whether temporary or permanent) between the treated wastewater and potable water systems to avoid health risks. The following best practice measures are suggested to prevent cross connection:

- All plumbing and drainage must comply with Australian Standards.
- Domestic wastewater reticulation systems installed to comply with AS 3500, *National Plumbing and Drainage Code*. Effluent re-use piping requires a local government plumbing permit.
- All pipes, conduits and valves and all other components of the treated wastewater distribution system must be marked clearly in accordance with *AS 1345 –1995 Identification of the contents of pipes, conduits and ducts*
- Above ground distribution systems must be at least 100 mm from potable water pipes. Below ground distributions systems must be at least 300 mm from potable water pipes or within 100 mm when crossing any potable water main.
- The wastewater piping is constructed in a different material to the potable piping supply.
- All above and below ground distribution systems must be distinctively colour coded lilac and marked with the words “WARNING: RECLAIMED WATER – DO NOT DRINK”.

- The reclaimed residential water supply is operated at a lower pressure than the potable supply service and the potable supply has back-flow prevention devices, complying with *AS 2845.1: Water supply - Backflow prevention devices - Materials, design and performance requirements.* This specifies requirements for the materials, design and performance testing of back-flow devices used to prevent contamination of potable water supplies.

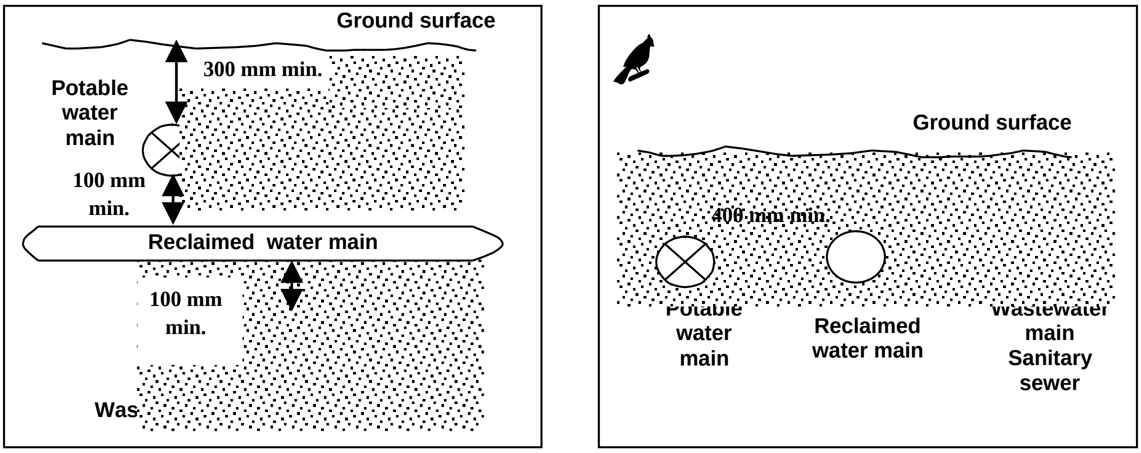


Figure 5-2: Seperation requirements for wastewater mains

5.4.2 Back-flow Prevention

Back-flow is the undesirable reversal of flow of non-potable water through a cross-connection and into the piping of a public water system or consumer's potable water system. As back-flow into a potable water system can make the water in that system unusable or unsafe to drink, potable water suppliers must take reasonable precautions to protect their reticulation system against back-flow.

Each wastewater supplier should ensure that a proper back-flow preventer meeting appropriate AS/NZS standards is installed and maintained at the water service connection to each system or premises that poses a significant hazard to the public health. Hence back-flow prevention fittings should be installed in all connections to irrigation feed lines to prevent contamination of potable water systems.

A back-flow preventer is a means or mechanism to prevent back-flow. The basic means of preventing back-flow is an air gap, which either eliminates a cross-connection or provides a barrier to back-flow. The basic mechanism for preventing back-flow is a mechanical back-flow preventer, which provides a physical barrier to back-flow. The principal types of mechanical back-flow preventer are the reduced-pressure principle assembly, the pressure vacuum breaker assembly, and the double check valve assembly.

Field testing and maintenance programs are required for back-flow prevention devices in accordance with AS 2845.3 *Water Supply – Backflow prevention devices*. Additional information on back-flow prevention is also available on internet sites such as that of the American Backflow Prevention Association (http://www.abpa.org/).

5.4.3 Plumbing Codes

To protect potable water supplies, appropriate plumbing controls are necessary to avoid cross-connections. Effective cross-connection and back-flow prevention requires the following measures:

- maintenance of as-built pipelines plans
- standard pipeline identification

- training/education of operators and users
- programmed inspection and testing.

5.4.4 Warning Signs

Warning signs with both a pictorial sign and words indicating that reclaimed water is being used should be placed in strategic positions. Content should be consistent with the examples provided below. Two-tone colouring should be used with black picture and text and red symbol. The number of signs and size of wording should be determined on the basis of the visual distance from the observer (for example, 100 mm wide sign at a distance of 3 m, *AS 1319 Safety signs for the occupational environment*).

Tap signage

Agricultural fence signage

Municipal use signage

Figure 5-3: Scheme signage requirements

5.4.5 Security

All waste treatment facilities, pumps, valves and controls should be locked, fenced or enclosed as necessary to prevent unauthorised access or interference. Storage lagoons are required to be fenced when on publicly accessible land, such as a golf course. For agricultural storages, a fence is only required in the absence of a property boundary fence.

5.5 Emergency Re-treatment, Storage and Disposal

Where problems may arise with the wastewater treatment or distribution system, emergency storage facilities should be provided to store, retreat or safely dispose of treated wastewater that does not meet the required standard for re-use. Depending on the health and environmental risk associated with the re-use system, storage systems may need to be designed for 24-hours or longer retention capacity. Depending on circumstances it may be required that a separate land parcel be set aside for emergency irrigation measures.

6 SITE REQUIREMENTS

Selecting land for irrigation involves consideration of many factors including the physical characteristics of the land and its position in the landscape. The objective is to select an appropriate site that will have no unacceptable impact on community amenity; pose no risk to public health, soils, ground or surface water; and with sufficient area for the land application of water.

There is no simple formula that can be applied in considering these factors but rather a combination of measurements and value judgements. Thorough site analysis will, however, avoid the need for costly construction and/or operational measures to satisfy environmental or health performance objectives.

6.1 Local Area Scoping Assessment and Suitability Map

A local area scoping analysis should be used to evaluate a re-use scheme's viability. Selection based upon consideration of the following factors should identify one or more suitable sites. The scoping exercise involves a desktop study and field inspections. An appropriate field inspection will involve the use of a hand held conductivity meter for checking salinity of local dams, bores and surface waters.

The best possible sites within the local area need to be identifed (mapped) using the processes outlined below, on the basis of suitability for irrigation.

The local area scoping assessment should be discussed with the proponent and the appropriate Land Management Officer for the region. The regional Land Management Officer will help identify the most suitable sites, and provide feed back on the identification of risks within the sites presented

One or more of the factors below may be the limiting factor that determines the amount of effluent actually applied to land. It is important to realise that many of these factors are dynamic, interrelated and may change over the useful life of the irrigation scheme. Monitoring and evaluation is therefore important to detect changes to the particular limiting factor. Assessment criteria include the following:

Critical Distances

- within a practical distance from the source of the waste but away from sensitive developments
- capacity for future expansion without being detrimental to beneficial uses of the environment
- buffer zones to separate and screen activity from existing and future residential areas

Climate

- sufficient yearly evaporation demand
- prevailing wind speed, directions and wind breaks protect sensitive areas or impact on irrigation opportunity

Local Landscape

_ site topography is suitable for the proposed land use and crops

_ site is free of geological features which may impede cropping or allow uncontrolled water movement

_ area of minimal erosion risk

_ appropriate information sources been consulted -Topographic map, Geological map, Soil map, Land capability, Land system map, Hydrogeological map

Known Cultural Heritage

_ protection of heritage features

Soils Suitable for Irrigation

_ are soils shallow or rocky?

_ are the soils deep sands?

Salinity Risk Assessment

_ irrigation water salt levels

_ land system characterised by salinity

_ salt tolerant vegetation present (indicator species)

_ elevated water tables (<2metres)

_ saline bores (>0.8 dS/m)

_ saline dams or surface waters in in local area (>0.8 dS/m)

Water Movement

_ no flooding of water re-use area

_ located away from defined watercourses

_ the land not in groundwater discharge or seepage area

_ rapid groundwater recharge areas (gravels, sands, fractured rock)

_ an appropriate site for wastewater storage

Offsite effects

_ will this site have adverse effects on wetlands, sensitive flora or fauna, or surface waters?

Threatened Species

_ protection of threatened flora and fauna from likely direct and indirect impacts

6.2 Public & Environmental Protection - Critical Distances

While irrigation areas must be within a practical distance of the waste source, selected sites should be away from sensitive developments and environments. The capacity for possible future expansion also needs to be considered to ensure the beneficial uses of the environment will be maintained.

Buffer distances are an effective tool to protect the public and other sensitive receptors from residual aerosol emissions, unpleasant odours, or offence arising from aesthetic considerations. Irrigation areas should be situated away from dwellings, public roads and recreation areas to avoid conflict arising from these factors.

A performance based, site specific approach is preferred as a mechanism for setting buffer zones for spray drift and restricting lateral movement of wastewater. The system must be managed to prevent undesirable offsite effects arising from spray drift, lateral movement of irrigated wastewater, and groundwater recharge. Appropriate buffer zones for surface waters, roads and boundaries will vary depending on the irrigation water quality, the method of irrigation, topography, vegetative screening and the intensity of the adjoining land or road use. A physical setback distance should not be the sole method used to reduce the effects of fugitive emissions. Approvals for irrigation works will normally specify that irrigation must not commence or continue during weather conditions that may be expected to cause spray drift, odour or run-off beyond the boundary of the irrigated land.

Where a performance based, site specific approach is not possible, the standard buffer distances in Table 6-1 are provided as minimum distances from irrigation works to the nearest road or off-site dwelling.

Table 6-1: Standard Minimum Buffer Distances

Type of activity	Minimum buffer to nearest road or dwelling (m)	Reason for Buffer
Storage lagoons/holding dams [a&b]	250	Odour
High pressure spray irrigation (including mini & micro sprinklers) [a,b&c]	100 [f]	Spray drift
Pivot irrigators	Dependent on technology	Spray drift
Wastewater transfer & irrigation pumps [b&c]	50	Noise
Flood irrigation [e]	50	Odour and runoff
Drip irrigation (including bubble type emitters) [b&d]	20	Odour and runoff
Surface Waters	Dependant on dilution and movement of water	Water Quality Protection

Notes:

a. The possible effects of local winds, particularly in spring, should be considered in addition to prevailing winds

b. Appropriate fencing and warning notices are required. (Refer to section 5.4 and 7.1).

c. For waste treated to secondary standard as in (c)(i) below. A greater distance may be required for low quality wastes.

(i) Human sewage effluent treated to secondary standard & other wastewater with median BOD less than 30mg/L.

(ii) Distance measured from the edge of the wet surface created by the sprinkler(s).

d. Subject to pump type, wastewater quality and appropriate noise controls.

e. For wastewater treated to secondary standard as in (c)(i) above. Lower quality wastewater may require more restriction to public access such as secure fencing.

f. for design wind speed 10 km/h. For each 10 km/h increase of wind speed above this, double the buffer distances for high pressure sprays

6.3 Climate

Local climatic conditions such as temperature range, rainfall and wind patterns are critical determinants of on-site water availability and plant growth and combine to determine the viability of wastewater re-use. The amount of wastewater applied should not exceed the requirements of the plants growing on the site. To be sustainable, irrigation should cease in winter to allow leaching and to avoid possible build up of salt and nutrients. Areas of high rainfall will usually meet the water requirements of any crop, which means that waste water re-use is unlikely to be suitable for high rainfall areas of the state. Locations with a warm, dry climate for at least part of the year provide the conditions for crop growth where plant water uptake and evapotranspiration exceeds rainfall. This reduces the risk of ponding or run-off from irrigated wastewater.

Irrigation changes the micro-climate for the local soils and plants by providing the extra water in times where evapotranspiration and evaporation exceed ambient rainfall. These changes must be sustainable to both soil and crop.

Climate variability from year to year requires a conservative system design, especially where winter storage is required. Computer irrigation systems can be installed to control all aspects of irrigation and take inputs from wind direction and speed, weekly and daily collected rainfall. This approach can be complemented by the use of soil moisture probes.

6.4 Local Landscape

Flat or gently sloping land with relatively uniform grades is optimal for wastewater irrigation. While slopes of up to 10% should generally be suitable for spray irrigation, areas of greater slope may be acceptable where works are instituted to prevent any erosion caused by accelerated run-off or run-off of contaminated water. Other irrigation methods will generally require more level ground. The topography of the irrigation area should be such that ponding will not occur.

The irrigation areas should generally be free of geological features such as rock outcrops, faults, coarse colluvial or alluvium that may allow percolation of wastewater to ground or surface waters.

The Tasmanian Land Capability Classification System (LCCS) is used to assess, classify and map land according to its ability to support a range of crops on a long term sustainable basis. The evaluation is based on the degree of limitation imposed on that land by a variety of physical factors which include erosion, soils, wetness and climate. Land managers should utilise the land capability classification system to address sustainability issues on their properties by ensuring land use practices are matched with the ability of the land to support those practices.

6.5 Soil Characteristics

Soils should be reviewed as to their nutrient levels and water absorption characteristics. Ideally, the soil should be deep and well structured with no sub-surface hardpans or restricting layers. It should allow adequate infiltration and drainage but have sufficient clay and organic matter to retain nutrients and prevent percolation to groundwater.

6.5.1 Soil & Subsoil Sampling Assessment

Prior to commencement of wastewater irrigation, a thorough soil survey and analysis must be undertaken by a suitably qualified person. The survey serves two main purposes:

- Investigation to assess suitability of the site for irrigation and for storage lagoon construction and
- To provide baseline data in relation to chemical and physical soil characteristics.

Soils assessment is a key part of the site selection process and must be adequately addressed in any proposal. The assessment must determine the long term sustainability of wastewater irrigation in the area by analysing characteristics both of the soils and the treated wastewater to be utilised. Particular regard must be paid to soil structure and salinity issues.

Soil profile descriptions to a depth of at least 2 metres (or until bedrock) of locations representative for the irrigation area are to be provided. Major soil and sub-soil horizons should be identified graphically through illustrations, colour photographs or a combination of both. The soil profile description is to address the following characteristics of each major soil horizon - soil type classification; infiltration capacity; permeability rate (vital for heavy clay soils); water holding capacity; depth (total depth to bedrock, depth to seasonal watertable); structure; texture; cracks; rocks; moisture and colour; and biological features such as organic matter, worm burrows, and roots should also be included. The choice of location and number of required soil pits is dependent on the uniformity of the area. If there is little variation in soil types and topography, a single pit may be sufficient for 5 –10 hectares. The plan of test pit locations must be included in the environmental assessment. Existing information, such as contained in larger scale soil maps or the Tasmanian ‘Land Systems’ documents, should be utilised where available.

Sampling and chemical analysis of soils is required for a range of key parameters which will provide detailed information on the sustainability of wastewater irrigation at the proposed site. Composite top-soil and composite sub-soil samples should be taken from a suitable number of locations within the areas used for irrigation purposes prior to cropping and/or irrigation (a minimum of 2 per hectare is recommended). At least one sample should be taken from an adjacent control area of similar soil type which has not been subject to irrigation. The sampling depths should be between 100-150 mm for top-soil and 300-400 mm for sub-soil. The sampling locations should be representative of the subject land (i.e. not be near fences or boundaries, on bare ground or dung & urine patches). Permanent reference points should be established for future monitoring purposes (measured from fixed landmarks or using a geographical positioning system) to establish a baseline for determining fluctuations in soil and sub-soil quality. This work must be undertaken by suitably experienced personnel and enough sites on the area to be irrigated are to be assessed to provide a good representation of the whole irrigation area.

All soil samples should be collected as outlined in Australian Standard *AS 1289 Methods of testing soils for engineering purposes*. The soil samples should be analysed for the parameters listed below.

- pH ($CaCl_2$ + H_20) (1:5 soil:water suspension)
- Electrical conductivity (EC) dS/m or μS/cm
- Organic matter (%)
- Exchangeable sodium percentage (ESP)
- Chloride - as necessary (check EC)
- Cation exchange capacity - as necessary (check SAR, see 4.8.1)
- Total cations (inc. Na, Ca, Mg, K)
- Organic carbon (%)
- Heavy metals - as required, dependent on source of the treated wastewater
- Trace elements
- Chloride
- Soil infiltration rates
- Soil permeability rates
- Phosphorus adsorption capacity (PAC) (kg/ha)
- Available phosphorus (Colwell P)
- Total nitrogen

Soil type may determine which tests are appropriate. For example, where the soils are heavy throughout the profile or have heavily cracked clay subsoil, infiltration rates (movement of water into the soil surface), permeability rates (vertical transport of water through the soil profile) and phosphorus adsorption capacity should be determined. Presence of a layer with restricted permeability may lead to seepage problems down slope.

Soil monitoring programs should be designed to detect changing conditions across a site perhaps due to different soil types or different fertiliser and management history and through the depth profile where, for example, organics and phosphorus may concentrate on the soil surface, while potassium and salts accumulate at various soil depths due to leaching by irrigation water and rain (Peverill *et al.* 1999).

6.6 Water Movement

Knowledge regarding the hydrology of proposed sites is a key requirement for both planning and operational phases. The movement of water onto and off the site needs to be considered in detail. Failure to consider issues such as stormwater run-off, groundwater movement and water storage requirements in the planning stage may affect the viability of the irrigation scheme.

6.6.1 Irrigation Volume

The volume of water required for irrigation also depends upon factors such as the proposed plants/crops, soil type, evaporation and annual rainfall. The calculation is based on the limiting criterion of:

1. hydraulic load - see Section 4.9.7 Calculation of Loadings
2. nutrient load (nitrogen and phosphorus) - see Section 4.9.2 Nitrogen; Section 4.9.3 Phosphorus
3. salt load - Section 4.5 Salinity

All three calculations should be carried out. The lowest volume recorded is the estimate requirement for sustainable annual water usage for the field area. It needs to be remembered that the application of wastewater is only one component of on-site water balance. Aspects such as flooding, stormwater management, groundwater movement and on-site storage also require consideration.

6.6.2 Flooding

Areas selected for irrigation or wastewater storage should not be subject to flooding. An annual exceedance probability (AEP) of less than 1% is required (flooding frequency of 1 in 100 years).

6.6.3 Stormwater

Effective surface drainage is necessary to prevent external stormwater from running **onto** the irrigated land. Run-off from higher ground reduces the irrigation requirement and prolonged inundation is harmful to vegetation.

The site selection process needs to recognise operational restrictions on water flowing **off** the site. For Class B and C effluent, the distance will depend on soil characteristics, irrigation method, the standard of treatment and the size of the watercourse. A set-back distance for wastewater use of 800m BUFFER from a potable water storage or off-take controlled by a statutory authority and at least 100m from any surface waters is required where a performance based, site specific approach is not possible. Re-use should be avoided in designated water supply sub-catchments or aquifer recharge areas unless the wastewater treatment system resides within these areas and transporting the wastewater is not feasible.

Source control management practices are the best way to prevent land surface pollutants from entering surface waters. Nutrients, such as nitrogen and phosphorus, are the most common pollutants in stormwater run-off from irrigated areas.

Where warranted, and where practicable, the first flush effect of washing accumulated pollutants from an area should be minimised by collecting the first part of the storm event run-off. Provision of a tail-water and stormwater terminal pond to collect the first 10 mm of run-off from a storm event in the irrigation area should result in capture of up to 90% of the pollutants. This water can be directed to the storage pond or applied directly to land.

6.6.4 Groundwater

An environmental assessment for the proposed site should assess the beneficial use or environmental values of the groundwater that may be affected by the irrigation scheme, the nature and risk of such effects on the groundwater resource and any connected environmental receptors. This will determine the extent and type of monitoring required.

The groundwater should be at least 3 metres below the surface for the area to be irrigated. Soils should have a permeability in the range of 60 – 2000 mm/day. If this is not the case, safeguards should be implemented as part of operational practices.

It is important to distinguish between fresh and wastewater irrigation in terms of the potential salinity hazard. Where groundwater is close to the surface and drainage is poor, irrigation with saline water is likely to contribute to the development of a salinity problem on or off site, possibly compounded by water logging. Where continuous wastewater re-use occurs, the salt will accumulate if it is not periodically removed by leaching.

The overuse of treated wastewater, leading to excessive deep percolation of wastewater to groundwater, will not be permitted. Mineral Resources Tasmania should be consulted for information on groundwater reserves and uses. Future users of ground water reserves must be taken into account. It may be necessary to incorporate bores within the irrigation area to enable ongoing monitoring and feedback so that operators can protect groundwater from over-saturation or percolation effects. Existing bore-holes in the area may be suitable for this use.

6.6.5 Storage Requirements

The on-site availability of suitable clay and stable ground conditions for construction of storage lagoons also needs to be considered. Irrigation water is not required at times when rainfall is sufficient to meet the plants needs. At such times, wastewater must be held in storage. All re-use schemes should have temporary storage facilities to handle both daily and seasonal supply demands. The required storage volume can be estimated using the water budget method or by recognised computer modelling. Reclaimed water site storages require lining with a layer of compacted clay-rich material or other measures to ensure there is no impact on groundwater. Environment Division has set some performance based and also minimum standard guidelines for liner systems and these are available upon request. As is the case for the areas to be irrigated, storage facilities should not be placed in flood prone areas.

6.7 Vegetation Requirements

Two aspects in particular need to be considered in site selection - appropriateness for the crop to be grown and protection of vegetation adjacent to site from adverse effects. While selection of the appropriate crop is determined by a range of factors, not all of which are site specific (economics, climate etc.), site characteristics such as soil type, local water quality, and groundwater depth will have some bearing on crop choice. The potential impacts of irrigation on adjacent vegetation also need to be considered. Whether the issue is potential health risks associated with adjacent crops (not within the re-use scheme) or is one of nutrient sensitivity of native bushland to additional nutrient loadings, site selection will need to assess the likelihood of such risks and develop appropriate management strategies.

6.8 Threatened Species

Threatening processes are defined in the *Threatened Species Protection Act 1995* as any action which poses a threat to the natural survival of any native taxon of flora or fauna. These actions can influence the survival of species in the short or long term and can operate as a single threat or, more often, as part of a range of threats. Degradation of water is identified as a threatening process in the *Threatened Species Strategy* (NP&WS 2000).

Activities such as dam construction and irrigation potentially impact on water channels, wetlands, and hydrological processes. These processes influence the quality, quantity, and availability of habitat within or surrounding the water body and may cause resident species to decline or become locally extinct. The loss of the soil profile and the vegetation it supports can result in increased run-off, siltation and turbidity of adjacent water bodies, and 'downstream' threats to aquatic and marine plants and animals.

When considering site selection, consideration should be given to possible impacts on the local water system and possible management prescriptions required to:

- protect threatened species from damaging levels of pollution and habitat disturbances to water systems;
- maintain the ecological health of waterways; and
- maintain or restore natural water systems and hydrological processes.

An approach based on best practice environmental management should include identification of management techniques for protecting water systems and water quality. It should also ensure water storage developments or drainage proposals include an assessment of impacts on threatened species and manage aquatic and riparian environments to protect threatened species. The Resource Management & Conservation Division of DPIWE should be contacted for advice on threatened species management.

6.9 Cultural Heritage

Site selection should incorporate an assessment of Aboriginal heritage and other archaeological features in the areas proposed for irrigation and for development of supporting infrastructure. The Cultural Heritage Branch of the Tasmanian Heritage Office should be contacted for more information on cultural heritage issues.

6.10 Overcoming Site Limitations

It is difficult to find a site where all the conditions are optimal but adjustments can usually be made to compensate for deficiencies. Design and management based on a sound understanding of site specific conditions is essential. For example:

- A higher level of treatment will be necessary if buffer zones or public exclusion is difficult to ensure;
- An efficient run-off collection and return system may allow relatively steep land to be irrigated;
- Low surface infiltration may be acceptable if the irrigation rate is adjusted accordingly or if the soil can be improved by gypsum, cultivation and organic matter.

Adequate finance, management and operational skills must be available to ensure continued success given the characteristics of the subject land.

7 SYSTEM REQUIREMENTS

A critical component with wastewater irrigation is scheme management. Poor management is a significant cause of problems with irrigation systems. The following sections deal with the methods of wastewater irrigation system design and management. Best practice environmental management should address both public health and environmental issues.

Management of public health risks should have as a focus safeguarding the health of operators and users of wastewater and the wider community who may have access to, or be in proximity to, land irrigated with wastewater.

The basic environmental principles for land application of treated wastewater are:

- The build up of any substance in the soil should not preclude sustainable use of the land in the long term;
- The use of wastewater is not detrimental to the vegetative cover;
- Any change to the soil structure should not limit the use of the land in the long term;
- Any runoff to surface waters or percolation to groundwater should not compromise agreed environmental values; and
- There should be no gaseous emissions to cause nuisance odour.

7.1 Public Health

A wastewater re-use system in any public recreation area must be designed in accordance with the following public health requirements. The Department of Health and Human Services or the Environment Division can provide more information as required.

- Spray systems must be designed to avoid misting from sprinklers and spray drift beyond the actual irrigation area. There should be no spray irrigation within 100m of the boundary of any residential property (see Table 6-1 for details on buffer zones). There must be no drift onto neighbouring residential or public access areas. This may require using dripper systems around boundaries, or underground seepage systems to avoid the aerosols associated with spray irrigation. Vegetative zones can be used to good effect if designed with a view to aerosol collection. Wind direction and wind speed should be monitored continuously and the system should automatically shutdown irrigation if speed or direction becomes a concern.
- There must be no above ground water outlets from the irrigation system. Any outlets for temporary connection of hoses or portable sprinklers shall be in a below ground valve box with an appropriate warning sign.
- Drip systems must incorporate a filter system to prevent blockage.
- There must be no ponding of irrigant on areas accessible to the public or areas with continual high moisture content.
- There must be no run-off of irrigant beyond the

designated irrigation area

- In general, irrigation on publicly accessible land should only be conducted at night. Public access to the area should be restricted before the commencement of irrigation and the irrigation event must terminate not less than 4 hours before public access to the area is permitted.
- Where public access cannot be prevented, such as on unfenced municipal gardens, verges or median strips, clear signs advising of the use of treated wastewater must be placed on the boundary of the irrigated area. These signs must also advise the public to avoid the area during irrigation periods and must be erected at regular intervals around the perimeter of the irrigation area.
- Any area used for irrigation must be adequately signposted and incorporate where appropriate Australian Standard recognisable signage (see *AS 1319: Safety signs for the occupational environment*). The Department of Health and Human Services can provide details as to the appropriate Australian Standards for public health warning signs.
- Irrigation systems must be designed and clearly identified in order to prevent the possibility of cross-connection to potable water supply lines and to prevent access by members of the public to the treated wastewater. Back-flow prevention devices must be installed to minimise accidental leakage of effluent in the case of pipe breakage.
- Public drinking fountains, natural or artificial water bodies, barbecue and picnic areas must be protected from contamination by spray drift or run-off from irrigated areas.

All re-use proposal DPEMPs must include a specific section in the supporting documentation that clearly addresses all of the above public health concerns. A separate map showing buffer zones to sensitive areas, residences, public access areas, signage location and details of fencing and potable water supply is to be supplied.

7.2 Storage and Irrigation Design Method

The major design element to be incorporated into irrigation systems when abstracted from soil requirements is climate requirements. Two methods of designing an annual seasonal irrigation plan are presented in these Guidelines: the water balance method and the Soil Dryness Index (SDI) method. DPEMPs using soil dryness index methods should contain the results of designs using both methods in order to determine the storage requirements over the winter months when irrigation is not feasible.

Due to the high construction costs, winter storage at about $4000/m^2 is one of the single biggest budget items in the expenditure requirements of a successful land irrigation, wastewater re-use scheme. As a consequence, it is often the main target for cost cutting. The water balance method, because it is a conservative approach to forecasting irrigation requirements, generally produces larger values for storage requirements and hence higher construction costs. The SDI method, which pursues more opportunities for irrigation, particularly during winter periods, generally forecasts lower storage requirements and hence lower construction costs.

The risk of year-to-year weather fluctuations producing an unwanted surplus of wastewater in an already full storage lagoon in winter becomes the trade-off for lower construction cost. Examination of historical weather records will determine what fluctuations can reasonably be expected in a local area. Rainfall records and particularly pan evaporation records may be difficult to find for some regional areas in Tasmania due to the limited number of sites where data are collected. In the absence of good climate records, a conservative approach, as provided by the water balance method, may be necessary.

Many existing WWTP that are pursuing re-use through land irrigation may be able to maintain a limited form of disposal to the aquatic environment, in winter via the plant outfall, to avoid overloaded storage situations. Such discharges are subject to the requirements of published emission limit guidelines for sewage treatment plants or to site-specific discharge requirements set by the regulator. However, there have been several WWTP designed and constructed in Tasmania for 100% re-use which are not permitted to have this flexibility. Management options will be influenced by wastewater quality and site characteristics and there will generally be a number of re-use options available. Sections 7.12 and 7.13 deal with some of these options utilising vegetation and stock.

Any wastewater re-use proposal will need to demonstrate the water balance method in its design. Proposals involving the use of SDI methods for designing storage should demonstrate both water balance and SDI methods, and clearly detail the design considerations undertaken in the applied SDI method.

7.3 Water Balance Method

Facilities for wastewater storage and irrigation should be designed and constructed to contain all waste in at least the 90 percentile wet year (the wettest year in 10 years, on average). Adequate provision of land and storage should be made for present and expected future requirements. While it is not necessary to contain all stormwater on the site, provision must be made to capture, store and re-use stormwater run-off which may be contaminated.

This design process is an iterative one, as the size of the storage lagoons is determined through this process, and yet the size of the storage lagoon influences the amount of evaporation that can be expected from the storage. The water balance for the final design storage requirement should be included in the DPEMP.

The area required for irrigation can be determined using rainfall and evaporation data which are available from the Bureau of Meteorology (http://www.bom.gov.au). Local rainfall data sources can also be useful and should be considered if available.

Water balances should be compiled for irrigation seasons with both median and 90 percentile rainfall and evaporation. Table 7-1 is a worked example of a water balance for pasture irrigation. A blank water balance calculation sheet suitable for photocopying is provided as an attachment to the *Guidelines for the Preparation of a Development Proposal & Environmental Management Plan for the Irrigation of Treated Wastewater on Land* in Appendix A.

Table 7-1: Example - Water Balance/Budget Table (EPA Victoria 1993)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Evaporation (mm) E_v	156	142	102	63	47	33	44	56	72	92	110	145	1062
Rainfall (mm) R	56	51	63	76	78	72	79	95	93	105	97	82	947
Effective Rainfall (mm) R_{eff} (see Table 7-2)	43	37	42	47	46	46	46	60	60	66	66	63	622
Potential Evaptransp. (mm) $E_{pot} = K_c \times E_v$	109	99	71	38	24	15	18	25	40	60	77	102	677
Irrigation Required (mm) $I_{req} = E_{pot} – R_{eff}$	66	62	29	0	0	0	0	0	0	0	11	39	207
Net Evap from Pond (kL) $E_{net} = 10 \times (0.8\ E_v – R) \times A_{sto}$	138	125	37	-51	-81	-91	-88	-100	-71	-63	-18	68	-195
Volume of wastewater (kL) Vol	388	350	388	375	388	375	388	388	375	388	375	388	4566
Water for Irrigation (kL) $I_w = Vol – E_{net}$	250	225	351	426	469	466	476	488	446	451	393	320	4761
Area required (ha) $A_i = I_w / (10 \times I_{req})$													2.3
Cumulative Storage (kL) S_{to}	1517	316	0	426	895	1361	1837	2325	2771	3222	3362	2785	
Direct crop coeff. K_c													
Pasture	0.7	0.7	0.7	0.6	0.5	0.45	0.4	0.45	0.55	0.65	0.7	0.7	
Lucerne	0.95	0.9	0.85	0.8	0.7	0.55	0.55	0.65	0.75	0.85	0.95	1.0	
Eucalypts													
Age 1 year	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
Age 2 year	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	
Age >4 years	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	

Note: E_v = class A pan evaporation. For the worked example it is assumed pasture is being irrigated; soil water storage capacity was 75mm, so no correction factor is required; a negative value is a water gain for the 0.2 ha Lagoon; negative values for I_{req} = 0

Not all rainfall is available to plants. The portion of rainfall that becomes available to plants in a defined location, but does not include evaporation, run-off and water that percolates below the roots of the plants, is called the effective rainfall (R_{eff}). The effective rainfall can be estimated using the tables below.

Table 7-2: Effectiveness of Rainfall on Pasture - Monthly R_{eff} (EPA Victoria 1993)

	Monthly median evapotranspiration E_{pot} (mm)									
Monthly median Rainfall (R)	25	50	75	100	125	150	175	200	225	250
12.5	8	8	9	9	10	10	11	11	12	13
25	16	17	18	19	20	21	23	24	25	25
37.5	24	25	27	28	30	31	32	33	35	38
50	32	34	35	37	39	42	44	47	50	>38
62.5	39	41	43	46	49	52	54	57	61	
75	46	48	52	54	57	61	64	68	72	
87.5	>46	56	59	62	66	69	73	78	92	
100		62	66	70	74	78	82	96	102	
112.5		69	73	76	81	86	91	96	>102	
125		80	85	89	95	100	106	112		
137.5		87	92	97	103	109	115	121		
150		94	98	104	111	117	124	132		
162.5		100	107	112	118	125	132	140		
175		>100	116	119	126	134	141	150		
187.5			120	127	134	142	150	158		
200			133	141	150	159	167	>158		

A correction factor is applied to the above values where the net depth of available water that can be stored in the root zone at the time of irrigation is greater or smaller than 75 mm. The correction factor to be applied to the effective rainfall (R_{eff}) is:

Table 7-3: Root Zone Storage - multiply value from Table 7-2 by factor to get R_{eff} (EPA Victoria 1993)

Root storage (mm)	20	25	37.5	50	62.5	75	100	125	150	175	200
Factor	0.73	0.77	0.86	0.93	0.97	1.00	1.02	1.04	1.06	1.07	1.08

Notes: Effective root zone storage is determined as the mid value available water capacity of soils(from Table -7-5) multiplied by 2, and then multiplied by the root depth (Table 7-4).

Before the net evaporation (E_{net}) from the storage lagoons can be completed, the surface area of treatment and storage lagoons must be known, or alternatively, it may be estimated using the following equation:

$$A_{sto} = 10^{-4} \left(\frac{BOD}{L \times 0.001} + \frac{V \times 30}{1.2} + \frac{W}{D} \right)$$

where: A_{sto} = is the total surface area of lagoons (ha)

BOD = is the primary lagoon BOD_5 loading (kg/day)

D = is the depth of the storage lagoon (average depth).

L = is the surface BOD_5 loading (g/m^2/day).

V = is mean daily flow (kL)

W = is total waste volume for the months in which the numbers in which the irrigation requirement (Ireq) are negative (kL)

The following equation is used to determine cumulative storage:

$$\mathbf{S_{to} = I_w + previous\ months\ - (10 \times I_{req} \times A_i)}$$

where: S_{to} = cumulative storage (kL)

I_w = water for irrigation (kL)

I_{req} = irrigation required (mm)

A_i = area required (ha)

To calculate the cumulative storage, start on the month before the first month in which the number in which the irrigation requirement (I_{req}) is zero or negative (i.e. March in Table 7-1). The volume of stored water accumulates, taking rainfall and evaporation into account. The peak storage volume usually occurs in the spring months, just before irrigation commences as indicated by positive numbers for irrigation requirement. Carry the balance forward for each month in succession. The balance for December is carried back to the start of the row (January). The supply of stored irrigation water should run out before the start of the next storage period.

For mixed irrigation of crops, trees and pasture, it is necessary to calculate a mean monthly crop factor weighted in proportion to the area of land under each type of vegetation, e.g. if 60% and 40% of the land is under trees and pasture respectively, a typical mean crop factor would be:

$$(0.6 \times 1) + (0.4 \times 0.7) = 0.88$$

Figure 7-1 shows how the irrigation season and storage period can be extracted and graphed from the water balance.

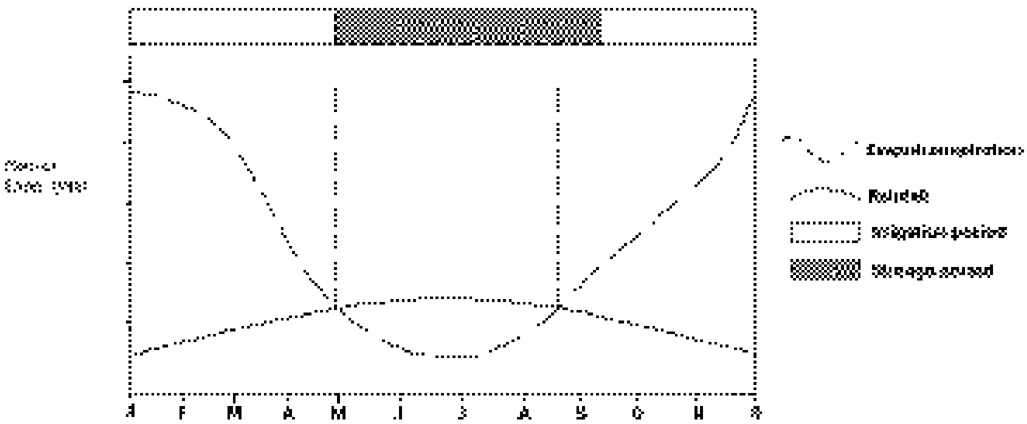


Figure 7-1: Irrigation Season and Storage Period

7.4 Soil Dryness Index (SDI) Method Applied To Irrigation Systems

The Soil Dryness Index (SDI) model is a hydrological model which is used in catchment hydrology to predict water flow and storage. The model which is used in many parts of Australia for catchment hydrology and fire danger predictions has been adapted for use in irrigation systems. This adaptation has been recognised as an approved method for determining the water balance for wastewater re-use in Tasmania since 1994.

The SDI model uses a daily water balance to calculate the moisture content of the soil. In the model the moisture content is expressed as soil dryness in millimetres, which is equivalent to the amount of rainfall the soil can absorb before reaching field capacity. Actual historical data for maximum daily temperature and daily rainfall is used in the calculations to determine soil dryness. It is considered that the minimum time period for analysis to enable a representative result should be ten years, preferably longer if reliable data are available.

The SDI daily water balance uses the evapotranspiration (combined plant transpiration and evaporation from plants and soil) as related to solar radiation (indicated by maximum temperature) to calculate water loss. Water loss due to flash run-off and application beyond field capacity (caused by heavy rainfall) is also taken into account.

The irrigation adaptation of the model calculates the daily irrigation that can be applied to the soil without exceeding the set safety margins. Irrigation is not permitted on days when significant rainfall occurs or when the soil is close to saturation. The amount of water in storage also limits the irrigation application.

7.4.1 Comparison to Monthly Water Balance Method

The Monthly Water Balance method uses monthly rainfall and pan evaporation data to calculate the monthly difference between evapotranspiration and rainfall. This difference, if positive, is deemed as the amount that can be irrigated in that month. If, for example, there is a heavy rain period in one part of the month that exceeds the calculated evapotranspiration, then it is deemed that no irrigation can occur in that month, even if the weather was very dry for the remainder of the period. The evapotranspiration used in the water balance model is based on a vegetation factor applied to pan evaporation data. The water balance method of calculation of evapotranspiration may be less precise than the SDI method as a result.

The SDI model uses measured evapotranspiration data and relates it to the daily maximum temperature and soil dryness. This can then be adapted to the local area by examining pan evaporation relationships and vegetation types. Unlike the Monthly Water Balance method, this relationship reflects the energy required for the plant to remove water from the soil under different conditions. By examining the soil dryness on a daily basis, an accurate determination can be made as to whether irrigation should occur and what quantity should be applied.

7.4.2 Data Requirements for Wastewater Re-use Schemes

To use the SDI Irrigation model the following data are required:

1. Daily maximum temperature and rainfall records for at least 10 years;
2. Pan evaporation data (daily) for local area, or nearest applicable data;
3. Daily volume of wastewater;
4. Maximum storage pond area and depth (based on location);
5. Area of land available for irrigation;
6. Type of irrigation system with specification application rates;
7. Minimum feasible daily irrigation (usually dependent on point 6);
8. Maximum permissible daily irrigation (if applicable); and
9. Margin to retain between soil dryness after irrigation and field capacity.

Further information should be incorporated into the model applicable to specific situations. For example, if the wastewater volume data represent inflow into a treatment plant, rather than outflow to the irrigation system storage pond, then evaporation from the treatment plant ponds should be taken into account where surface area is known. If the wastewater volume varies with rainfall (i.e. includes stormwater), this variation should be included where data are available. Irrigation systems using multiple areas and/or travelling irrigators can also be catered for in the model. Historical SDI data obtained from the Bureau of Meteorology can be used to check the model data.

7.4.3 Results Provided by SDI Model

The SDI model analyses the irrigation requirements for a minimum period of ten years and provides data on the appropriate irrigation program had the system been running over that period. These data can be used to set up automated irrigation systems which measure soil dryness and to provide guidelines for operator controlled manual irrigation systems. The SDI model supplies the size of storage that would be necessary based on the meteorological data processed.

7.4.4 Procedure for SDI Model

The procedure to be followed applying the SDI model to irrigation systems is shown in

Figure 7-2. There are several computer based systems available for processing the information required to design an effective SDI based irrigation system. These programs have the ability to produce graphs of the variation of wastewater stored, soil dryness, irrigation applied and rainfall over time. Data on storage pond evaporation and rainfall collection is also usually supplied. Variations can be included in these programs to cater for a wide variety of irrigation applications.

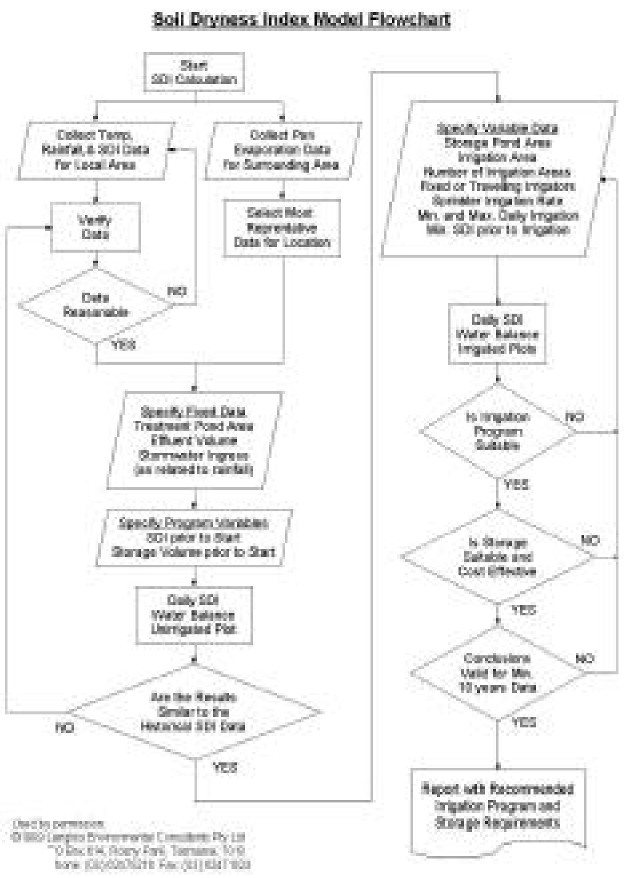


Figure 7-2: Soil Dryness Index Model Flowchart

7.5 Total Land Area Requirement

The total site area for a scheme where all waste is to be retained on site will be the summation of:

1. Treatment lagoon area;
2. Storage lagoon area;
3. Run-off collection area;
4. Irrigation area;
5. Other areas including dry areas, stockyards, channels, drains, machinery, equipment and vehicle storage; and
6. Buffer distances (in accordance with Table 6-1: Standard Minimum Buffer Distances).

7.5.1 Storage Lagoons

Storage lagoons should be designed to hold the expected waste flow plus rainfall during the wetter months. Excess water remains in storage for the next irrigation season. Management is necessary to ensure that irrigation water is available to meet the peak summer demand. To avoid irrigating or discharging waste during unfavourable weather conditions, sufficient storage capacity is essential. The storage requirement is the highest value of cumulative storage (S_{to}) of Table 7-1.

During periods when the wastewater flow is less than that experienced in the wettest year in 10, the water level in the storage lagoon will be below the top water level. The lagoon outlet structure should be designed to permit draw down from any level. This may also be necessary to allow for some management of blue-green algae blooms.

The elevation of the storage lagoon is important for gravity irrigation systems. The storage lagoon must be capable of providing flow rates high enough to ensure uniform irrigation. Inadequate water supply usually results in slow irrigation cycles in which the land closest to the supply channel is over-watered while lower areas may receive little or no water. This problem is likely to worsen as the irrigation season progresses as the storage level falls and the water demand increases. A pump may be necessary to draw down water at a sufficient rate for irrigation.

Storage lagoons usually contain wastewater which has been treated to secondary standard. To minimise the risk of odour, the surface BOD loading for a storage lagoon should not exceed 5 $g/m^2/day$.

7.5.2 Irrigation Area

The equation below can be used to determine the area required for irrigation:

$$\mathbf{A = 100 \times (V / [E_{pot} - R_{eff}])}$$

Where: A = Area (ha)

V = Volume of wastewater (ML)

E_{pot} = Potential evapotranspiration (mm)

R_{eff} = Effective rainfall (mm)

If the size of the irrigation area is designed for the 1 in 10 wet year, it follows that in drier years there will be a shortage of water. Cropping, stock and water management should allow for this. Withholding irrigation from areas which may be prone to moisture retention is a useful way to conserve water late in a dry season. Management plans should provide for part of the irrigated land to be rested for a year in every 3- 4 years as dry pasture or for rehabilitation purposes. Allowing soil to dry out thoroughly helps to maintain soil structure and healthy soil biota.

If the irrigation season is shortened by higher than average rainfall, additional land may need to be irrigated by way of re-use subject to the emergency irrigation provisions of these Guidelines. In years which are wetter than the 90 percentile wet year, discharges of treated wastewater may be permitted subject to the conditions discussed in Section 8.12. Contingency plans for this possibility should be a part of every re-use DPEMP.

7.6 Irrigation Efficiency

The design and management of irrigation systems aim to achieve both maximum agronomic production whilst minimising environmental risk. Regardless of the type of irrigation, design and management of irrigation systems should aim to:

- minimise irrigation losses
- minimise and / or capture runoff
- minimise deep drainage to watertables
- minimise accumulation of salts in the rootzone
- maximise root zone wetting,
- maximise application efficiency

Regardless of irrigation type, the consequences of poor irrigation management may include; groundwater contamination, polluted run-off, erosion, salinity, waterlogging and soil compaction. In the case of waste water disposal, losses from deep drainage, runoff and wind drift are of particular concern as they have potential effects on public health and regional salinity. Sustainable use of irrigated wastewater requires selection of a suitable irrigation system, good design and layout, high application efficiency and effective irrigation scheduling. This work demands highly developed skills and experience. The Irrigation Association of Australia can recommend suitably qualified irrigation designers and contractors (refer to website: *www.irrigation.org.au*). Further information can be obtained from the relevant codes of design practice and DPIWE.

7.7 Soil Water

The amount of water held in the soil is a function of the soil texture, structure and organic matter. However, not all soil water is available to plants. The plant available water (PAW) represents the amount of water stored in the soil between field capacity (soil moisture after drainage) and the permanent wilting point (soil moisture content after which further water extraction will result in death of the plant). The PAW represents the maximum amount of water that can be extracted by plants. However, the PAW does not account for the increasing difficulty encountered when extracting each successive amount of water from the soil. The point at which further soil water extraction will result in crop stress or lower production is known as the refill point. The refill point is the minimum soil moisture content that soils should be allowed to reach before irrigation. The amount of water held between field capacity and the refill point is known as the readily available water content (RAWC) and represents the amount of water that can easily be used by crops. The relationship between soil moisture limits is presented in Figure 7-3.

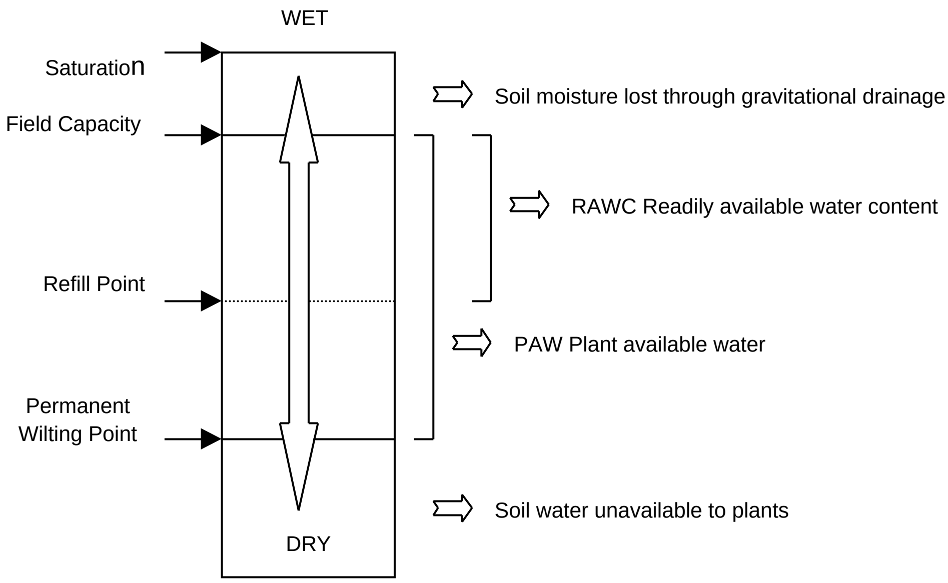


Figure 7-3 Relationship between soil moisture limits and plant availability to extract soil moisture.

In sandy soils, approximately 80% of PAWC is readily available. In clay soils, only 45-50% of the PAWC is readily available, because more of the water is held in small pores. The actual amount of soil water that is readily available to plants is dependent on the structure of the soil, organic matter and rooting depth. The depth of the root zone is influenced by soil texture, structure, levels of calcium to magnesium, soil density, and the depth to the water table. Measurement of compaction or penetration resistance is often required to determine the presence of soil layers which could restrict root growth (penetration resistance > 2 MPa). As the more active roots tend to be relatively close to the surface, it is not always practical to irrigate down to the bottom of the root zone. Table 7-4 presents the effective rooting depth of some mature plants. Irrigation scheduling should adopt the lower figures.

Table 7-4: Effective Root Depth of Some Mature Plants (EPA Victoria 1993)

Plant type	Root Depth (metres)
Orchard	
Citrus	0.6 - 2.0
Eucalypts	1.5 - 2.0
Grapes	0.45- 0.6
Broad acre	
Lucerne	0.75 – 1.8
Millet	0.3 – 0.6
Oats	0.6 – 0.75
Pasture	0.3 – 0.75
Peas	0.45 – 0.6

Note: Unless higher values have been determined in the field, the lower value should be adopted

Determination of the refill point and RAWC is required to determine both the likely irrigation schedule and irrigation depth. For each of the major irrigated soil types, the PAW and RAWC can be determined by laboratory desorption techniques, field based measurement and monitoring, or approximations based on soil type and rooting depth. Laboratory techniques require undisturbed soil cores to undergo desorption at matric potentials corresponding to field capacity, permanent wilting point, and the refill point for specific crop types. In heterogenous or duplex soils each major soil layer will need to be sampled. Field techniques involve monitoring of soil moisture with *in situ* soil moisture monitoring probes to determine soil moisture contents at field capacity and the refill point. With all techniques it is important to recognise that both field capacity and the refill point are dynamic, due to changes in soil structure and root development through the growing season.

Traditionally the RAWC has been viewed as a variable equal to the irrigated depth. Where the required irrigation depth is calculated using the following equation:

Irrigation depth = W x D

Where: W = **50%** of available water capacity (mm) (from Table -7-5)

D = the effective depth of the root zone (m) (The lower values given in Table 7-4 are usually adopted for irrigation scheduling**.)**

Note that this approach is both static and subject to considerable errors associated with the estimation of rooting depth and the 50% correlation between readily available water content and plant available water content.

In addition to knowing the irrigation depth, it is important to know the final infiltration rate such that the irrigation application can be matched to the soil's capacity to prevent ponding and runoff. This is particularly important with the re-use of waste water as ponding and runoff can lead to excessive odours and health risks. Table 7-6 relates infiltration rates to soil texture. However, infiltration is controlled by a range of soil properties including compaction, macropore continuity, and crusting such that infiltration rates tend to vary significantly within soil types and over time.

Infiltration rates are typically determined by double ring infiltration or disk permeametry. Alternatively, established irrigation systems can be employed to determine infiltration rates matching the occurrence of ponding and runoff to irrigation application rates. Infiltration rates are also dynamic. The infiltration of cultivated soils often decreases over a cropping cycle as slaking and raindrop impact form surface crusts and soils resettle. Irrigation with high SAR water can also result in structural breakdown and reduced infiltration (section 4.5).

Table -7-5: Plant - Available Water Capacity of Soils (EPA Victoria 1993)

Soil Texture	50% Available Water Capacity per metre of soil depth (mm)
Coarse Sand	15- 35
Sand	25- 40
Fine sand	25- 40
Very fine sand	30- 40
Loamy coarse sand	25- 35
Loamy sand	30- 40
Loamy fine sand	40- 55
Loamy very fine sand	45- 55
Coarse sandy loam	45- 60
Sandy loam	50- 65
Fine sandy loam	65- 75
Very fine sandy loam	70- 85
Loam	70- 90
Silty loam	75- 100
Silt loam	75- 100
Sandy clay loam	70- 90
Clay loam	85- 105
Silty clay loam	85- 105
Sandy clay	65- 85
Silty clay	70- 85
Clay	60- 85

Notes: For the purposes of irrigation scheduling, adopt the mid-range value.

Control of application rate is particularly difficult with centre pivots as the inner areas are irrigated at a considerably lower rate than the outer areas of the pivot circle. For example a 300m radius pivot with a cycle time of 9 hours, would take approximately 1.7 minutes to irrigate a meter length of soil, 50 metres from the pivot point. However, at 300m the irrigator takes only 0.3 minutes to irrigate a meter of soil. Although both areas should receive the same amount of irrigation, at 300m distance from the pivot, irrigation is supplied to the soil approximately 6 times faster than at 50m.

Table 7-6: Typical Infiltration Rates (IR) Related to Soil Texture (EPA Victoria 1993)

Soil Texture	Representative IR (mm/hr)	Normal Range (mm/hr)
Sand	50	20-250
Sandy Loam	20	10-80
Loam	10	1-20
Clay Loam	18	2-15
Silty Clay	2	0.3-5
Non Cracking Clay	0.5	0.1-8

The relationship between application rate, soil type and slope is provided for overhead irrigation systems in Table 7-7. Note the irrigation rate for sprinklers should not exceed either the water application rate or soil infiltration.

Table 7-7: Water application rates for sprinklers. (10 mm = 1 kL/100 m^2 or 100 kL/ha) (EPA Victoria 1993)

Soil Texture	**Application Rate (mm/hour) for slope of..**							
	0-5% level to slightly undulating		**5-8%** undulating		**8-12%** undulating to low hills		**12% and over** low to steep hills	
	With cover	**Bare**	**With cover**	**Bare**	**With cover**	**Bare**	**With cover**	**Bare**
Coarse, sandy soils to 2 m depth	50	50	50	38	38	25	25	13
Coarse, sandy surface soils with compact subsoils	44	38	31	25	25	19	19	10
Light, sandy loams – uniform	44	25	31	20	25	15	19	10
Light, sandy loams over more compact sub-soils	31	19	25	13	19	10	13	8
Silt loams over more compact sub-soils	15	8	13	6	10	4	8	3
Heavy textured clays or clay loams	5	4	4	3	3	2	3	2

7.8 Irrigation Scheduling

Irrigation scheduling is an essential component of all irrigation systems. Irrigation scheduling aims to replace transpired water before soil moisture falls below a level that restricts plant growth or induces moisture stress (refill point). Irrigation scheduling also aims to determine the amount of water that has transpired or the amount of irrigation required to bring soils back to field capacity.

7.8.1 Indirect methods for estimating evapotranspiration

Direct and indirect methods of irrigation scheduling have been developed. Indirect methods of calculating crop water use rely on correlating evaporation from a pan (Class A pan) with crop evapotranspiration. While determining actual evapotranspiration is difficult, daily or yearly measures of pan evaporation allow the crop water use to be estimated. Only observations of daily rainfall and evaporation at, or close to, the site should be used for determining evapotranspiration. The correction factor between class A pan evaporation and crop water use is known as the crop coefficient (K_c). Selection of appropriate crop coefficients is complicated by variation between seasons, climates and crop growth stages. Figure 7-4 demonstrates K_c variability in a number of American crops**.** Typical crop coefficients are can be found in irrigation literature. Estimates of annual potential evapotranspiration are useful for indicating the likely irrigation requirement or estimating the required volume of wastewater storage.

Potential evapotranspiration = $(K_c \times E_v) - R_{eff}$

Where: K_c = the direct crop coefficient
E_v = class A pan evaporation (mm)
R_{eff} = effective rainfall (mm)

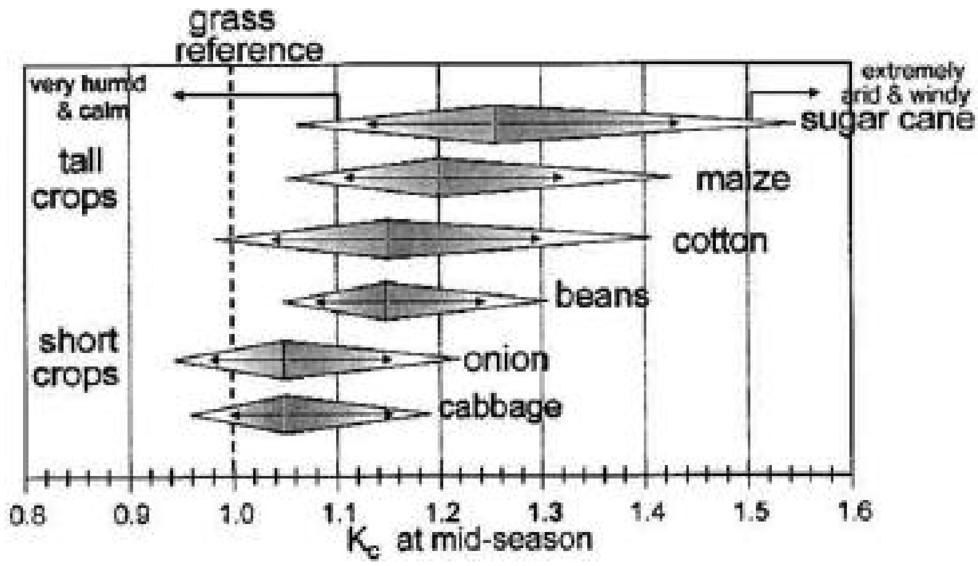


Figure 7-4 K_c Values for a Range of Crops

Effective rainfall is the proportion of actual rainfall that becomes available to plants in the soil. Not all rainfall is effective because some rainfall runs off, percolates below the root zone, or is intercepted by vegetation and evaporates. Effective rainfall can be estimated using Table 7-2. An alternative approach is to assume 50% effectiveness for a rainfall event of less than 12 millimetres and 70% for a rainfall event of greater than 12 millimetres.

The above methods for estimating the effectiveness of rainfall on pasture may not be reliable for wood-lots due to the deeper root systems and greater leaf surface area of trees relative to pasture. However, based on lysimeter studies (Dunin et al. 1987), 70% rainfall effectiveness is a reasonable guide for eucalypt wood-lots. Rainfall losses due to leaf interception and run-off have both been reported as 15% for immature eucalypts growing in a southern New South Wales forest. It was also reported that leaf interception of rainfall by pine trees is more than twice the amount caught by eucalypts.

Appendix B is a map showing the estimated average irrigation requirements for perennial pasture in Tasmania.

1.3.2 Direct methods for determining crop water use

Direct measurement of soil moisture for irrigation scheduling can be conducted by a number of means including gravimetric sampling, neutron meters, capacitance probes, time domain reflectometry (TDR), electrical resistance, heat pulse and tensiometry. Use of neutron techniques has decreased significantly in recent years and mobile and in-situ capacitance probes have replaced expensive difficult to use neutron and TDR devices.

Capacitance probes are available as either roving units that measure the soil moisture profile from any one of a number of access tubes (ie. Gopher, Diviner), or can be installed for permanent logging or data telemetry at multiple depths from a single access tube (EnviroSCAN and C-Probe systems). For wastewater re-use in-situ capacitance probes with radio telemetry offer the ability to monitor instantaneous soil moisture at multiple depths, monitor short term opportunities for wastewater irrigation, determine deep drainage, determine the depth of irrigation, and other functions from a single base station.

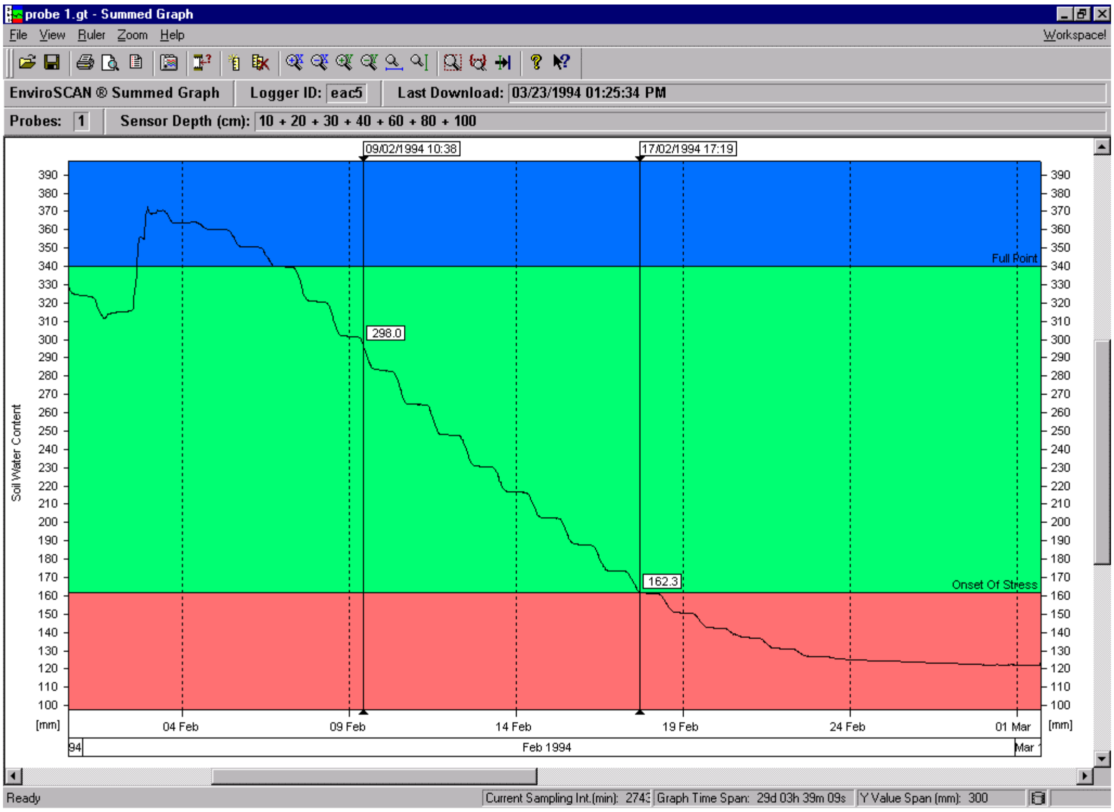


Figure 7-5: Example of EnviroSCAN software showing soil moisture status. Black zone represents soil moisture between saturation and field capacity, Dark Grey zone indicates ideal soil moisture, and the Light Grey zone indicates soil moisture is beneath the refill point

In soils of high permeability and consequently high groundwater recharge risk, soil moisture probes are an essential component of the irrigation management system. However, given that the technology and data management generated by scheduling probes is beyond the skill of most growers, the use of this equipment will require a combination of training, individual assistance and supervision over a considerable period. It is suggested that consultants or some other form of assistance be provided to train growers with the use of these systems. Details should be provided on how the information obtained from irrigation scheduling devices will be used by the grower to manage irrigation practices.

7.9 Irrigation Methods

Numerous irrigation techniques may be considered for the irrigation of treated wastewater. The suitability of different techniques depends on a number of factors including: soils, topography, vegetation, climate, water quality, management, health risks, labour and cost. Irrigation is usually conducted in one of three ways, spraying, surface application or drip/subsurface application.

While a great deal of literature is available on the engineering and agronomic aspects of irrigation, further consideration must be given to the specific requirements of wastewater irrigation. It must be recognised that no system will meet the required environmental standards without proper management. However, sustainable use of irrigated wastewater is assisted by selection of a suitable irrigation system, good design and layout, high application efficiency and effective irrigation scheduling. This work demands highly developed skills and experience. The Irrigation Association of Australia can recommend suitably qualified irrigation designers and contractors (refer to website: *www.irrigation.org.au*). Further information can be obtained from the relevant codes of design practice and DPIWE.

The expected efficiencies of different systems have been described below (Table 7-8). All types of irrigation are capable of having unacceptable levels of irrigation efficiency. For wastewater re-use, more efficient delivery systems such as centre pivots, drip and micro irrigation systems are usually preferred as these systems tend to allow greater management control and have potentially lower irrigation losses that may pose either a health or environmental risk.

Table 7-8: Irrigation Technique Efficiencies

Type of System	Expected Efficiency
Surface Irrigation	
Basin	80-90%
Border	70-85%
Furrow	60-70%
Sprinkler	
Permanent	70-80%
Hand-move	65-75%
Travelling Gun	60-70%
Centre Pivot & Linear move	75-90%
Micro	
Point source	75-90%
Line source	70-85%

7.9.1 Surface Irrigation

Basin, border and furrow irrigation are the primary methods of surface irrigation. Other surface methods include water spreading and contour ditch which are too inefficient to be considered suitable for responsible wastewater irrigation.

Basin or border irrigation is where water is confined between soil ridges each side of accurately graded, rectangular bays with minimal cross-slope. The bays fall from a supply channel or pipe at the top to a drain at the bottom. Channels and drains should be graded so that they are free draining, otherwise anaerobic conditions may lead to the development of offensive odours. Border or basin irrigation can be used on land with slopes in the range of 2 in 100 (2%) to 1 in 1,000 (0.1%). Border and basin irrigation are not suitable for crops which are sensitive to wet soil conditions, or on steep or uneven land. Border irrigation is suitable for pasture, fodder crops and woodlots. The borders or check banks should be protected from trampling by stock with electric fencing, at least in the early stages.

Deep, sandy soils or other highly permeable soils are not suitable for surface irrigation because the water rapidly percolates below the root zone and may raise the water table and/or affect groundwater quality. Clay, sandy or silty soils at least 200 mm deep with clay subsoils are preferred. The slope and dimensions of the bays and the rate of water supply needed to achieve high irrigation efficiency and even penetration across the basin or border can be determined for specific soil types using irrigation modelling tools such as SIRMOD (Surface Infiltration Runoff Model) and SURFER.

7.9.2 Spray Irrigation

The term spray irrigation is used to describe various water application techniques from fixed mini-sprinkler systems to "big guns". Permanent, relocatable and travelling sprinkler systems may be used depending on the topography, soils, crop, labour and cost. High pressure systems are generally unsuitable for wastewater re-use as water may be projected high into the air or may produce very small airborne droplets (aerosols) which can travel considerable distances.

Modern spray irrigators such as centre pivots have been developed to provide a high level of control and accuracy. Programmable controllers are available which can be interfaced with soil moisture and rain sensors, anemometers, water supply and re-use systems. Automation offers accurate irrigation control and substantial labour savings, however, automated systems still require field inspection and good management to ensure soils are irrigated appropriately.

Sprinkler efficiency can be reduced by distortion of the wetting pattern by wind and by evaporation in hot, windy weather. The foliage of sensitive crops can be damaged by spraying with saline water, particularly on hot days. Selection of the correct equipment and an appropriate management response, such as night irrigation, can help to mitigate these effects. Night irrigation also takes advantage of off-peak power charges (if available).

Community concerns about high pressure spray irrigation are usually associated with odour and the transport of aerosols from the site. The buffer distances shown in Table 6-1 are indicative only. Each site must be assessed in terms of risk given the specific set of conditions. It is important to establish designed vegetative screens to prevent transport of aerosols in irrigation schemes that are close to urban areas. Three rows of trees with open leaf growth (e.g. some eucalypt species) have been found to encourage air flow through and hence more leaf contact, rather than creating a flow over the top of the vegetation as will occur with dense leaf growth.

7.9.3 Micro-irrigation

Micro-irrigation is similar to the systems used in home gardens and is well suited for tree growing. The effective operation of a micro-irrigation system depends, among other things, on the correct choice of emitter. A range of emitters is available with widely varying performance characteristics suited to different applications. Water must be applied in the correct position for optimum uptake by plants. The type, number and position of emitters are important design considerations because water requirements and root systems differ between plant species. Also the roots of established plants are likely to be distributed differently from those which have always been irrigated.

The information provided here is by no means exhaustive. Numerous variations are possible and new innovations and products are continually being introduced. For instance, pressure compensating and self-flushing emitters have reduced costs and improved irrigation control and efficiency. Micro-jets, mini-sprinklers and drippers are the main micro-irrigation forms.

Micro-jets: These have no moving parts. Water is discharged through an orifice against the "anvil" of the emitter which is set at 90^o to the direction of the flow. The water is deflected horizontally and may wet an area of 3 to 9.5 metres in diameter, but more commonly 3 - 4 metres. The size of the orifice controls the rate of discharge. This can be from 15 to 130 litres per hour at pressures of 50 - 300 kPa. Micro-jets are used for vineyards, orchards, horticulture and landscaped areas. They are likely to produce aerosols and are therefore not suitable for irrigation with low quality water at windy locations, particularly where dwellings and public places may be affected.

Mini-sprinklers: These operate in the 100 - 200 kPa water pressure range and cover an area of up to 10 metres diameter at a rate of about 25 litres per hour. Part or full circle coverage is possible from each sprinkler. Mini-sprinklers are good for deep, sandy soils where smaller but more frequent water applications are used. Mini-sprinklers with large orifices operated at low pressure are useful for under-tree applications. The droplet size is large and the risk of spray drift is low.

Bubblers: These distribute water at low pressure over a diameter of 1-2 metres as multiple streams or as an "umbrella" pattern with part or full circle coverage. The discharge rate is much higher than for mini-sprinklers, micro-jets or drippers. The use of bubblers is probably limited to small areas where surface flooding for a short time during irrigation is acceptable and preferable to sprinklers.

7.9.4 Drip Irrigation

Drip irrigation consists of a filtration system and lines of tapes with embedded drippers. The tapes may be placed on the soil surface or buried in the upper root zone. Drip emitters deliver between 1 - 8 litres per hour to individual plants at about 100 kPa. The orifices are 1 mm diameter or less. Water use is very efficient and competition from weeds is reduced because only a very small area of the soil surface receives water. The physical properties of the soil determine the distribution of water below the surface. The wetted diameter is about 200 mm for sands and 1.5 metres for heavy clay. The number and the required spacing of emitters depends on both the soil type and the crop.

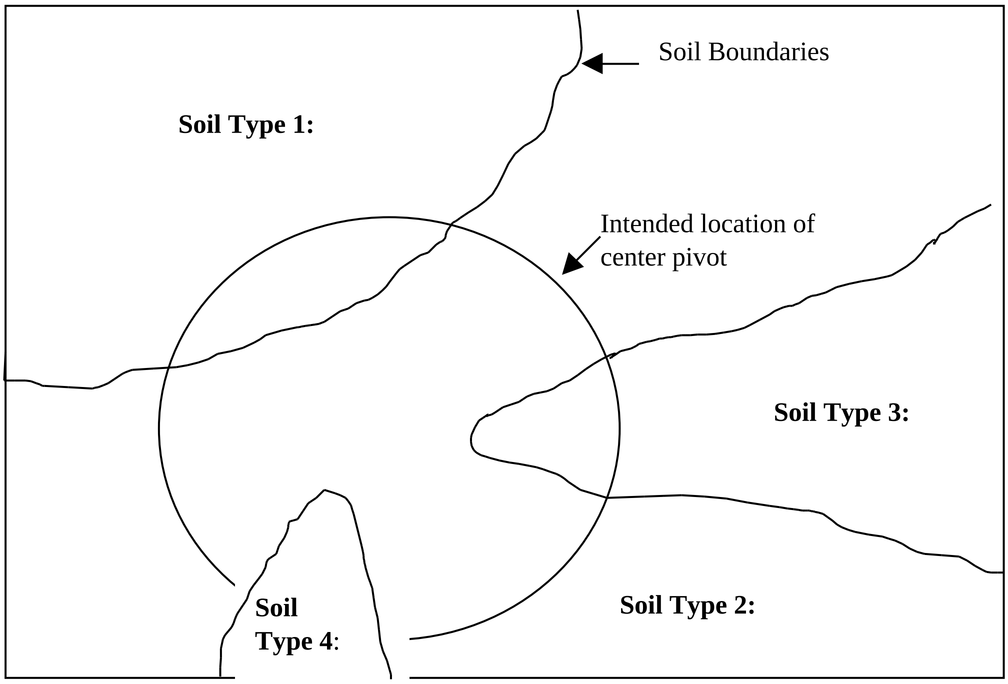
Drip irrigation can be adapted to "corners" or other areas which cannot easily be watered using other systems. Installation of drip systems is costly but operating costs including energy and labour are comparatively low. System efficiency depends more on operator skill and diligence than for other systems. Drip irrigation systems can be highly automated and are adaptable to many different combinations of slope, soils and crops. The risk of aerosol drift is negligible.

Wastewater often contains dissolved substances and suspended matter which can block the emitters directly, or as a result of corrosion. Maximum filtration of the wastewater immediately before irrigation is necessary to minimise blockages. Efficient drip irrigation depends on regular checking of operating pressures and maintenance of filters, emitters and control equipment.

With drip irrigation scheduling should maintain a constant supply of plant-available water in the root zone. For large plantations, moisture sensors in the root zone integrated with automatic control equipment are preferable. Otherwise, the irrigation requirement is determined by potential evapotranspiration. For trees in summer, this may be greater than 10 mm/day. The equivalent volume (100 kL/ha) can be applied in rotation to plantation sectors. In drip irrigation it is necessary to apply sufficient water in excess of evapotranspiration to ensure that salt is removed from the root zone by the wetting front as it advances downwards into the soil. About 10% extra water is sufficient for drip-irrigation of moderately salt-tolerant plants using water of salinity classes 1-3 (see Section 4.5.1).

Field design and layout.

Proposed irrigation schemes should provide detail on the management of irrigation devices. The location of discrete soil-irrigation management units should be clearly identified and mapped. Where centre pivots are located on more than one soil type the area under each pivot should be broken up into separate 'arc' segments according to the most limiting soil type. The infiltration rate, RAW or irrigation depth, leaching fraction, and refill point should be detailed for the most limiting soil type in each arc. The type of scheduling device should be identified and the location of probes and depth of sensors outlined for each arc or management unit. Details should be provided on how each of the soil management units is to be managed in terms of irrigated depth, irrigation application rate, and leaching fraction. Where salt accumulation from deficit irrigation is likely, detail should be provided on how the leaching requirement will be met.



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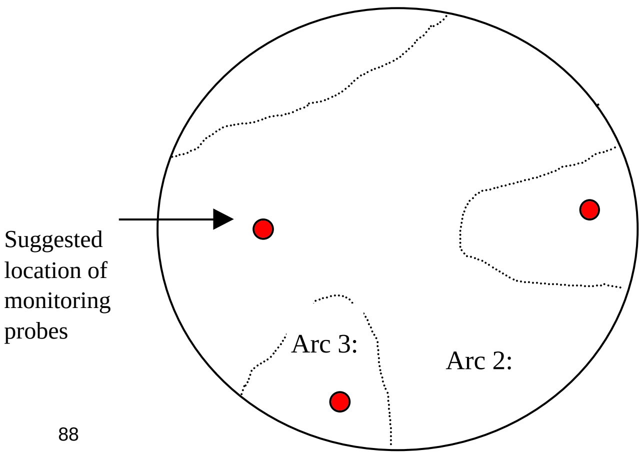
Soil Type	Description	Readily Available Water (RAW) mm	Infiltration Rate (IR) mm/hr
1	Gradational Clay Dermosol	80-90	10 - 30
2	Duplex Sodosol	50-70	5-15
3	Poorly Drained Hydrosol	80-100	0-2
4	Deep Sandy Podsol	40-50	80-150

Figure 7-6 Example of Soil and Irrigation Management Maps.

The intended location of the center pivot irrigator lies on four different soil types, each with its own management requirements. Environmental concerns at the site include secondary salinity resulting from greater accession to the watertable and evidence of salinity associated with soil type 3. Management must ensure that irrigation is prevented on soil type 4 and deep drainage limited on adjacent soil types.

The area under the pivot has been divided into three management arcs with suggested maximum RAW and infiltration rates according to the most limiting soil type.

Figure 7-7 Irrigation Management Map



Arc 1: Should receive no irrigation due to salinity risk.

Arc 2's: Should be managed for the second soil type as it is the most limiting. The RAW is between 50-90mm, however the rate of water application will need to be low IR 5-15 mm/hr.

Arc 3: Requires separate management to prevent deep drainage. However application can be rapid >80 mm/hr. Maximum RAW 40mm

Minimising Salinity Risks with Irrigation.

Two forms of salinity risk are associated with the irrigation of saline or partly saline wastewater; regional salinity resulting from changes in watertable depth, and salt accumulation in the root zone through inadequate leaching.

Regional salinity results from groundwater intersecting saline soils and rocks. When the watertable is within the root zone or in some cases within 2 metres of the soil surface, salinity may affect crop production, result in salt scalds or cause other off site impacts. Irrigation in saline environments must ensure that both irrigation and rainfall following irrigation do not result in deep drainage to the watertable. This can be achieved by not allowing the irrigation depth to exceed the root zone storage (RAW), and by incorporating weather forecasting into management decisions. In areas with salinity risks, the use of scheduling equipment with sensors mounted within and below the root zone are required to determine the required irrigated depth (RAW) and monitor irrigation practices to ensure minimal accession to the watertable. For more information on salinity refer to section 4.5.

In saline and non-saline areas, deficit irrigation with saline wastewater is likely to result in an accumulation of salts within the root zone. Unless rainfall is able to leach salts from the root zone, provision must be made to supply a leaching fraction to the irrigated depth several times a year. This is particularly difficult if the maximum delivery rate of the irrigation infrastructure is less than the RAW plus leaching fraction (i.e. only capable of deficit irrigation). Soil moisture monitoring tools with sensors mounted beneath the root zone can be employed to determine if the frequency of leaching from rainfall and irrigation is adequate.

7.10 Groundwater

If too much water is applied, the groundwater surface, known as the water table, may rise significantly. If saturated conditions persist within 1-1.5 metres of the surface, salts present in the groundwater tend to accumulate in the topsoil as water evaporates from the surface and is extracted from the soil by plants.

Under natural conditions, the water table rises and falls in response to infiltration of rainfall. Groundwater transmission may be extremely slow and its quality is affected by the nature of the materials through which it passes. Some natural groundwaters contain large amounts of dissolved salts and are not suitable for irrigation use.

Irrigation of carefully selected and well managed sites which are relatively small and isolated is unlikely to modify the regional groundwater regime. Small additions to groundwater for controlled leaching are unlikely to adversely affect any beneficial uses of groundwater provided that no bores or wells used for human or stock water supplies are likely to be affected.

Clearing of land for irrigation is likely to change the local water balance. In poorly drained areas a perched water table created by irrigation may be very expensive to remediate. Investigation of the deep subsoil should be carried out before clearing to assess the natural subsoil drainage characteristics. Groundwater recharge and discharge areas also need to be identified.

A set of groundwater monitoring bores is necessary for most wastewater irrigation sites (Section 8.13.5) and the level of the water table should be recorded at least once each month. The design, depth and location of these bores is critical, requiring specialist advice from a groundwater geologist.

7.11 Drainage

Drainage of the site and surrounding land should be considered at the planning stage.

7.11.1 Surface Drainage (off-site)

Surface run-off from areas uphill of the site may need to be prevented from flowing on to the irrigation site. Run-on, as it is called, will reduce the irrigation requirement and may cause waterlogging. A system of diversion banks and cut off drains is usually sufficient to prevent run-on.

7.11.2 Surface Drainage (on-site)

Surface drainage is important, particularly on fine-textured soils if water infiltration is slow. Irrigation systems should be designed to avoid ponding of wastewater. The drainage system will vary depending on site-specific conditions, but in general, all drains should be designed for run-off resulting from at least the 1 in 10 year recurrence, 1 hour rainfall event. The drains should be graded and maintained so that they will be free-draining.

7.11.3 Sub-surface Drainage

On permeable soils, sub-surface drainage should be necessary only if excessive irrigation has caused the water table to rise. Sub-surface drainage, although it may be feasible, is expensive and there can be problems with disposal of the drainage water with wastewater irrigation. With adequate natural subsoil drainage and careful irrigation, the need for constructed sub-surface drainage should not arise.

7.11.4 Run-off Re-use

Soils which may have lower permeability and or infiltration rates may require some commitment to run-off collection, storage and re-use. The soil assessment undertaken in the process of preparing the DPEMP will determine whether this is required and what methods will be undertaken to prevent wastewater from escaping the irrigation site.

Where there is a high rate of pathogen regrowth in soil, there may be a requirement for a run-off re-use system to be developed that collects run-off from storm events and returns it to the storage system for future irrigation.

7.12 Vegetation

Soil is not simply a physical medium supporting vegetation. Complex bio-chemical systems exist in which organic and inorganic matter is constantly transformed and recycled. Soils influence vegetation; vegetation influences the soil.

Plant growth depends on the maintenance of a salt balance in the root zone. Normal crop yields are obtained when leachate salinity (EC_{dw}) values giving relative yields of 50% are selected to calculate the leaching requirement. This is because in the field, salinity increases from a value similar to that of the irrigation water at the top of the root zone, where the roots are concentrated, to a much higher value at the bottom of the root zone.

The Department of Primary Industries, Water and Environment can provide information on the salt tolerance of plants. Table 7-9 provides some detail on acceptable root zone concentrations for a range of plants.

Table 7-9: Maximum allowable salt concentration in the lower root zone for some plants which can be grown using wastewater irrigation. (EPA Victoria 1993)

TOLERANT		MODERATELY TOLERANT		MODERATELY SENSITIVE	
EC_{dw} (dS/m)	**Species**	**EC_{dw} (dS/m)**	**Species**	**EC_{dw} (dS/m)**	**Species**
15-20	Kikuyu grass	8.8	Lucerne	4.9	Big trefoil
15-20	River red gum	9.6	Cocksfoot	4.9	Cow Pea
15-20	Swamp she-oak	10	Birdsfoot trefoil	5.7	Alskie clover
19.4	Tall wheat grass	11.1	Phalaris	5.7	Red clover
		12.2	Perennial Ryegrass	5.7	White clover
		13.0	Barley (forage)	5.7	Strawberry clover
		13.3	Tall fescue	5.7	Subclover
		14.4	Sudangrass	6.7	Grapes
		14.7	Bermuda grass	7.6	Vetches
		14.7	Couch grass	5-10	Citrus
		10-15	Balansa clover	5-10	Millet
		10-15	Bent grass	5-10	Oats
		10-15	Blue gum	5-10	Sorghum
		10-15	Bokhara clover		
		10-15	Demeter fescue		
		10-15	Flooded gum		
		10-15	Rhodes grass		
		10-15	River sheoak		

Table 7-10 lists the chloride tolerance of some crop species.

Table 7-10: Chloride Concentration and Crop Damage (ANZECC 1992)

Sensitivity	Chloride (mg/L)	Affected Crop
Sensitive	<178	Almond, apricot, plum
Moderately sensitive	178-355	Grape, pepper, potato, tomato
Moderately tolerant	355-710	Alfalfa, barley, corn, cucumber
Tolerant	>710	Cotton, safflower, sesame, sorghum, sugar-beet, sunflower

EC_{dw} values can be used to calculate the extra water required for leaching of salts from the root zone in low rainfall areas. Leaching water also needs to be applied when using efficient sprinkler or micro-irrigation systems and for more saline irrigation waters, particularly where accurate control is required to prevent groundwater from rising into the root zone. Table 4-4 describes the appropriate salinity limits for irrigation waters.

7.12.1 Pasture and Crops

Improved pasture for wastewater irrigation sites is commonly based on perennial rye grass because it is moderately salt-tolerant and highly productive. The ideal pasture composition would be a balanced mix of perennial, deep-rooted species to maximise water and nutrient uptake while providing the nutrient requirements of livestock. Forage crops can be a source of income and supplementary stock feed but more intensive management is required.

The Department of Primary Industries, Water and Environment should be consulted about pasture species selection and establishment. As systems are designed for the 90th percentile wet year, irrigation water may not be available to meet the peak demand in drier seasons. This should be taken into account when selecting pasture species. It may also have important implications for irrigation system design and layout. For instance, a moveable system will provide greater operational flexibility than a fixed irrigation system.

Where the nutrient content of the wastewater is within the requirements of the pasture, cattle grazing is a suitable use of perennial pasture provided that the irrigation water complies with the quality standards set out in these Guidelines (Table 2-1). The best way to maximise nutrient uptake is to select pasture species that are highly productive in terms of the removed component. Some estimates of crop nutrient uptakes are provided below.

Table 7-11: Typical annual crop nutrient uptakes (NSW Agriculture and Fisheries 1990)

Crop	**Yield (per ha)**	**Nitrogen (kg / ha)**	**Phosphorus (kg / ha)**	**Potassium (kg / ha)**
Corn	6 m^3	207	28	199
Corn silage	50 t	165	65	206
Hay lucerne	7.5 t	209	19	141
· clover	5 t	163	15	125
· grass	5 t	100	15	92
Sorghum grain	9 t	280	45	186
· forage	7.5 t	75	11	112
· silage	25 t	100	17	100
Wheat	2 m^3	140	25	102
Barley	-	48	4.8	8.2

Regular harvesting of the pasture or crop as hay or green feed and its removal from the site may be necessary to aid in nutrient removal from the site. Distribution of the harvested vegetation may be limited by health regulations.

Bare ground should be protected by cover crops such as oats or field peas possibly undersown with pasture. The additional organic matter and root development helps to maintain soil structure and reduces erosion. Green manure crops can be planted between rows of vines or deciduous trees.

Permanent pasture has the following beneficial characteristics when used for wastewater irrigation:

- As a perennial it potentially can be irrigated all seasons;
- The constant cover allows uninterrupted use of the site;
- Soil structure is improved with a constant supply of organic matter and vegetative cover which protects the soil from erosion; and
- Effective site management can be achieved at relatively low cost.

7.12.2 Trees

Many species of trees, particularly eucalypts, have grown well under irrigation with wastewater in Tasmania and elsewhere. Species selection depends on wastewater quality, soils, climate and the proposed method of irrigation. The feasibility of growing trees requires a proper economic analysis of the circumstances in each case.

The trees are planted at a density of up to 1,500-2,000 per hectare and may be irrigated by flood, drip or sprinkler methods depending on the site conditions. Correct selection of the site and the tree species, site preparation, planting, weed and insect control, mulching, watering and protection of seedlings from wind and animals is essential for successful establishment of tree plantations. Management is critical during the first 12 to 18 months until canopy closure. Thinning and pruning operations may be required as the trees grow.

Some advantages of irrigating trees are as follows:

- Established trees extract more water from deeper in the soil profile than pasture or crops. For instance, eucalypts may have active roots down to at least 1.5 - 2.0 metres, depending on the soil type and groundwater conditions. Therefore a smaller area of land is required for the same amount of irrigation water with trees compared to pasture.
- Winter active trees extract water when many pastures are saturated and virtually dormant.
- Tree plantations are usually aesthetically acceptable to the public and may be used to visually enhance almost any locality.
- Tree plantations are useful for visual screening, stock shelter and groundwater control even if most of the site is under irrigated pasture.

Some disadvantages of irrigating trees are as follows:

- Water use by eucalypts varies from 40% to 150% of pan evaporation depending on nearby land use, the age of the trees and the size of the plantation. Although these factors are not necessarily disadvantages, they tend to moderate expectations about the capacity of trees to absorb wastewater. Moreover, if the concentration of the nutrients nitrogen and phosphorus in the wastewater remains fairly constant, it follows that as the quantity of irrigation is increased, so will the quantity of applied nutrients. Eventually, a point is reached beyond which the water requirement of the trees exceeds the nutrient requirements. If the quantity of irrigation is not adjusted according to the nutrient requirements, the excess nutrients will either accumulate in the soil or they will leach into the groundwater. Table 7-12 gives an indication of nutrient removal rates for eucalypts.

Table 7-12: Indicative nutrient uptake and optimum soil pH range for eucalypts. (EPA Victoria 1993)

Plant species	Nitrogen (kg/ha/yr)	Phosphorus (kg/ha/yr)	Potassium (kg/ha/yr)	Optimum soil pH
Eucalyptus	90	15	60	Moderately to slightly acid (5.6 –6.9)

- Apart from the species mentioned in Table 7-9, information on the salt tolerance of native trees is lacking. The values given in Table 7-9 assume adequate drainage and that the salt concentration of the groundwater in the lower root zone will be up to 10 times that of the irrigation water.
- Young trees may need intensive management to protect them from weeds and attack by insects and animals. The irrigation requirement will be reduced by poor growth or defoliation.
- To optimise the water and nutrient requirements and potential returns, tree plantations may need pruning, thinning, coppicing and leaf litter removal.
- Efficient irrigation of trees involves considerable establishment and maintenance costs.
- Complex micro-irrigation systems are sometimes suggested but these require skilled operation to operate efficiently on a large scale in the long term.

- Under-tree sprinklers are preferred because the risk of blockages is less than with drip emitters and because the water distribution pattern encourages spreading root development. Initially, however, drippers promote deep root growth and eliminate the problem of leaf scorch associated with sprinklers if the wastewater contains more than 100 mg/L of chloride. Converting from drippers to sprinklers after canopy closure might be a solution, but it would involve considerable cost.
- Irrigated tree plantations of mixed species combined with pasture and annual crops is a potentially valuable part of an 'agro-forestry' approach to irrigation with wastewater. Lightly irrigated or dry tree plantations with, or down-slope of, irrigated trees and crops have the potential to act as 'scavengers' of excess water and nutrients from deeper levels in the soil below the root zone of irrigated plants. A mixture of species is preferred because diversity is the key to stability in living systems. Monocultures (single species plantations) are more susceptible to disease and attack by insects.
- Pruning, thinning and harvesting operations or fire could seriously damage above-ground irrigation systems. Malicious damage and theft are, unfortunately, a potential threat to exposed micro-irrigation components.

7.13 Livestock

Cattle grazing on pastures irrigated with treated wastewater must comply with health requirements. Recently released guidelines under the National Water Quality Management Strategy states that drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL as a median value.

Livestock must be excluded from wastewater treatment and storage lagoons, channels, drains and tree belts. The location of services, lagoons, dams, pipelines, channels, drains, laneways, gates, fences, yards, buildings and stock-water points also need to be carefully considered.

The management of stock affects the irrigation requirement. Pasture should be grazed in rotation as required to maintain pasture composition. Evapotranspiration is related to the leaf area of the plants so overgrazing will reduce the irrigation requirement. There should be a drying out period of at least 3 days after irrigation to allow the pasture to recover and to prevent stock from "pugging" wet soil. Dry land is required to permit resting of the irrigated land during very wet weather which may occur even during the irrigation season. A considerable amount of plant nutrients is present in animal manure and overstocking will adversely affect the quality of run-off. Table presents estimates of annual nutrient removal by livestock.

Table 7-13: Nutrient Removal by Livestock (Source: Meat Research Corporation 1995)

Livestock	Part	Yield	Nutrients removed (kg/ha)		
			N	P	K
Beef	Live weight	1250 kg/ha	34	9	2.5
Dairy Cattle	Whole milk	3500 Litres	21	3.5	7
Lambs	Live weight	400 kg/ha	8	2	1
Sheep	Wool		4	0.25	3

8 OPERATIONAL REQUIREMENTS FOR WASTEWATER RE-USE

It is the responsibility of both wastewater supplier and user to ensure that effluent is used sustainably and that no environmental harm results from the use of wastewater. While these Guidelines provide a management framework for water users, the consequences of adverse use remain the responsibility of the user.

Suppliers and users of wastewater require clear-cut and effective procedures to comply with the performance objectives of these Guidelines. To achieve these objectives both supplier and user have a mutual obligation to collaborate on the implementation of best practice procedures.

8.1 Quality Standards for Treatment Plant and Effluent Re-use Systems

Wastewater treatment systems with associated wastewater re-use activities must be designed and managed to operate reliably and consistently in order to ensure a quality controlled product is eventually re-used. Best practice measures are a requirement under EMPCA in Tasmania, therefore reliability of the treatment plant and irrigation system must meet appropriate standards. The measures to achieve best practice include:

- Application of the waste management hierarchy in overall system design (*State Policy on Water Quality Management 1997*);
- Designing systems in accordance with relevant Australian Standards and Codes of Practice;
- Implementation of “at source” pollution reduction such as trade waste controls;
- Reliable and consistent treatment processes;
- Safeguarded disinfection systems;
- Secure distribution systems;
- Appropriate technology for irrigation control;
- Qualified and trained operators and caretakers;
- Continual improvement of performance, maintenance, inspection monitoring and reporting programs; and
- Contingency plans for system failures.

8.2 Quality Assurance and Design

All design, construction and operational activities should be carried out within a quality assurance system acceptable to the Environment Division, DPIWE (see Section 8.6). Wastewater treatment plants must be designed in accordance with the relevant codes or guidelines as required by the Director of Environmental Management. These include:

- DELM (now DPIWE). *Sewerage Management Programme Guidelines for Acceptance of*

Liquid Wastes to Sewer. June 1994.

- DPIWE *Design Guidelines for the Minimisation of Pollution from Sewage Pumping Station Overflows.*
- DPIWE *Emission Limit Guidelines For Sewage Treatment Plants That Discharge Pollutants Into Fresh And Marine Waters.* June 2001.
- EPA Victoria Publication 500 – *Code of Practice for Small Wastewater Treatment Plants*

The treated wastewater distribution system must comply with:

- Any requirements within these Guidelines.
- Occupational health and safety plans/procedures (see Section 8.7).
- AS 3500-1992 *National Plumbing and Drainage Code* (Parts 1 and 2).
- AS 1345 *Identification of the Contents of Piping Conduits and Ducts.*
- AS 2698.2 *Plastic pipes and fittings for Irrigation and Rural Activities.*
- Tasmanian *Sewers and Drains Act 1954.*
- *Tasmanian Plumbing Code* and *Plumbing Regulations 1994.*

8.3 Trade Waste Controls

Suppliers of treated wastewater from WWTP must ensure that trade waste producers within the sewerage catchment are implementing waste minimisation plans to reduce the levels of potential contaminants and toxicants being discharged to sewer. Cleaner production technologies and waste minimisation pursued by trade waste producers should encourage re-use of wastewater at these industrial sources, through the use of on-site recycling and re-use of wastewater.

8.4 Effluent Standards and Treatment Reliability

The complex system of a sewage treatment plant should be designed, operated and managed to continuously improve reliability and achieve the final effluent quality requirements required of the re-use system. Major aspects of plant operation to focus improvement upon are:

- Power supply – back up power supplies;
- Disinfection process – emergency storage for unacceptably treated wastewater;
- Maintenance programs – alarm systems, automatic controls and on-line monitoring to detect process failures and illegal discharges;
- Operating personnel – appropriate training, contingency planning for plant and equipment failures;
- Monitoring of illegal trade waste discharges; and
- Quality assurance in design of sewage treatment plant systems.

The higher the quality of the effluent required to protect public health and the environment, the more important treatment reliability becomes.

8.5 General Responsibilities of Suppliers and Users

Agreements are necessary between suppliers and users to define the precise roles and responsibilities covering wastewater re-use. Municipal councils or other recycled water suppliers managing recycled water must be satisfied that any re-use scheme involving wastewater from their premises complies with these Guidelines. Suppliers are to:

- confirm proposed measures for the re-use scheme with DPIWE and ensure that the re-use activity has the appropriate permit to operate
- keep a register of all uses and users to which water is supplied, including the location, quality and quantity. These records should be submitted annually to the Environment Division
- satisfy themselves that the intended use is sustainable and have regular inspections and site reviews to check that this is the case
- deliver water of acceptable quality to the user
- monitor in accordance with guidelines
- supply monitoring data to users
- provide information and training to users
- notify users and agencies of any exceedance or incidents, and
- if the supplier and user are not the same entity, enter an agreement that covers the scope and responsibilities of each party.

The users of the treated wastewater must ensure the application site and scheme is managed in accordance with these Guidelines and the supplier/user agreement. A range of measures are required of the user:

- advise the community and consult with neighbours where relevant
- undertake adequate training and staff development
- satisfy themselves that the wastewater quality is appropriate
- manage the site and system in accordance with guidelines for sustainable use
- notify the supplier if there are changes in usage
- enter into suitable agreement with the supplier
- regular inspection of the irrigation site to check for obvious problems (uncontrolled run-off, odour, soil structure degradation etc.)
- notify the supplier and agencies of any exceedance or incidents

8.5.1 Supplier/User Agreements

A formal agreement must be developed between the supplier and user of reclaimed water. While these should be case-specific, tailored to the particular requirements of the supplier and user, there are a number of mandatory measures that must be included in these agreements to satisfy the requirements of these Guidelines. The agreement should include:

- Definition and allocation of roles and responsibilities to ensure compliance with these Guidelines
- Cost of treated wastewater
- Contract duration and conditions for termination
- Ownership of facilities
- Responsibility for emergency reporting, operation, monitoring and auditing processes

- Liabilities and insurance
- Restrictions on the use and sale of wastewater product
- Restrictions on the use and sale of irrigated produce or product
- Site management plan

Examples of supplier/user agreements are available upon request from the Wastewater Unit of DPIWE.

8.6 Environmental Management Systems

An Environmental Management System (EMS) establishes an organisation's internal planning, auditing, reporting, and review functions to meet the environmental objectives required of any particular activity. Australia has adopted the ISO 14001 series for EMS as the standard for developing an EMS in any environmentally relevant activity.

The EMS framework is based on these three fundamental principles – (1) producer responsibilities, (2) quality assurance, and (3) continual improvement. EMS uses the concept of continual improvement achieved through performance feedback to achieve the social, legal, and economic goals of the re-use activity, even though these goals may change through time. The environmental monitoring requirements listed in Section 8.13 would form part of the basis for reviewing environmental performance under these systems.

The principle of EMS based quality control can be simply stated: "quality is not an accident". To achieve desired outcomes from a complex system, careful planning is necessary. It is now widely agreed that this planning takes the form of several fundamental steps which form a continual process (Figure 8-1: EMS Quality Assurance Cycle).

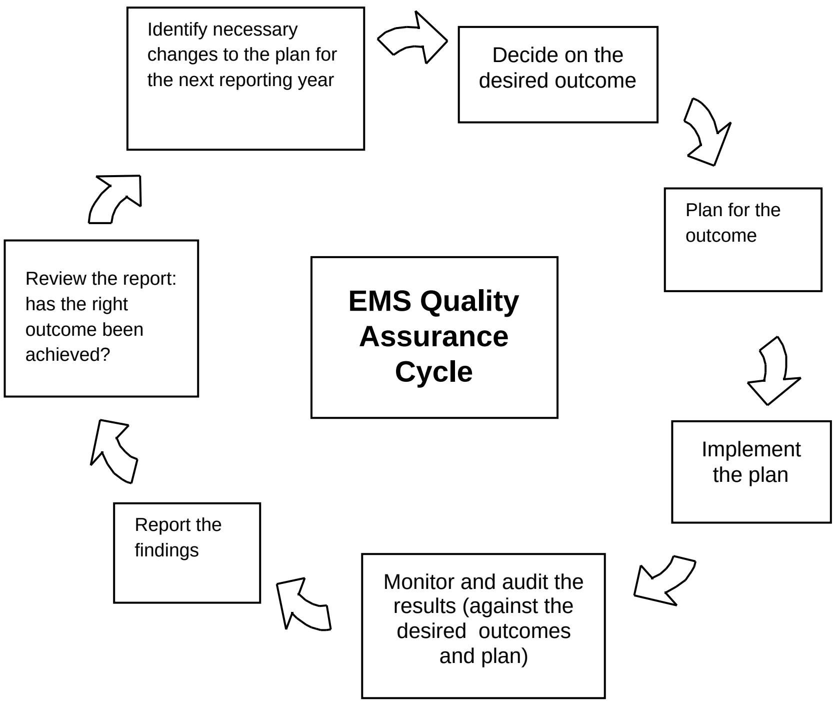


Figure 8-1: EMS Quality Assurance Cycle

To satisfy requirements for best practice under EMPCA, large wastewater re-use schemes should develop an environmental management system (EMS) to provide a framework for managing the environmental, health and legal risks involved in the re-use of treated wastewater. Management systems will include audit checks of standard procedures (for example, air gaps and other separation measures as required by plumbing codes), training/education and regular inspection of services.

The implementation of an effective environment management system demonstrates application of due diligence to the supply and use of wastewater. The important features of an environment management system are shown in Table 8-1.

Table 8-1: Management Checklist for EMS

Legislation and Standards · due diligence checklist · licences and permits **Communication Plan** · responsibilities assigned · reporting systems · feedback on performance · statutory authorities · community groups · emergency services **Management Plan** · land (soil, geological conditions) · water (surface and groundwater) · air emissions · aesthetics of sewage re-use · recreational resources · roles and responsibilities **Environmental Monitoring** · background monitoring · on-going monitoring performance monitoring · monitoring of improvements · on-going water quality improvements	**Management Systems** · security and public safety · environmental safeguards · quality assurance systems · contingency plans · data and inventory management · performance reporting **Training Systems** · management · public relations and operating staff **Environmental Audit System** · improvements in management · nutrient utilisation · monitoring performance · physical and environmental risks · financial risks and liabilities · spill and leak prevention · record keeping

8.7 Occupational and Public Health

These notes are a summary of issues to be considered when qualified occupational health and safety consultants and others prepare occupational and public health management plans for re-use of waste water. Typical applications for these Guidelines would be golf courses and farms irrigating with waste water.

The regulatory framework of the re-use process is described previously in this document. Many occupational and public health issues are already specified in these Guidelines e.g. signage and access. These Guidelines should be examined very carefully for such issues when preparing management plans for waste water re-users. The Management Plan should be consistent with accepted occupational health and safety management systems used by the organisation for which the Plan is being prepared. For example:

- SAFETY MAP Management System, prepared by the Victorian Occupational Health And Safety Authority.
- Australian Standards that relate to occupational health and safety management or quality management systems (such as *AS/NZS 4801:2001 Occupational health and safety management*

systems - *Specification with guidance for use*; *AS/NZS 4804:2001 Occupational health and safety management systems* - *General guidelines on principles, systems and supporting techniques*).

There is very little literature on the development of Occupational Health and Public Health Management Plans for re-users of wastewater. The hazards are similar to those dealt with in wastewater treatment plants themselves, where infectious agents in the water are in much higher concentrations. However, it is not sufficient to merely scale back the plans for treatment plants, because wastewater re-users have certain qualitative differences:

- Increased likelihood of being smaller businesses or solo operators with less organisational backup.
- Operators with limited or no training in health and safety.
- There may be a risk of occasional unidentified up-stream treatment system failure.

The following issues are among those that will affect the level or risk to workers or the public and help determine the controls needed to deal with them:

- Category of waste water (whether Class A, B, or C). More organisms means a higher level of risk.
- Potential for aerosol inhalation as it relates to proximity and duration.
- Potential for direct skin and hand to mouth contact.
- Presence of especially susceptible persons: i.e. children, elderly.

The standard procedure of using the hierarchy of controls for dealing with hazards should be used, i.e. aiming for preventive rather than protective solutions. Some relevant procedures may include:

- Documented work procedures with appropriate training and supervision.
- Minimising spray drift.
- Irrigate when fewest people are nearby
- Personal protection equipment: respirators and gloves when exposure cannot be eliminated
- Consider immunisation for Hepatitis A and B.

Several web-sites are suggested below which provide further information on occupational health and safety issues.

- http://ohioline.ag.ohio-state.edu/b860/index.html
- http://www.who.int/environmental_information/Information_resources/worddocs/Human_viruses.html
- http://www.who.int/wnvironmental_information/Information_resources/documents/wastreus.pdf

8.8 Supervision

Wastewater re-use schemes require supervision by suitably trained and experienced operators. Training for wastewater schemes is often the same as is required for potable water. Suppliers of wastewater should designate a person to be responsible for compliance with these Guidelines. Wastewater schemes should be functional, reliable and straight-forward to operate and maintain.

8.9 Information/Training

Users should be given simple, concise information explaining:

- the purposes for which wastewater may be used
- the purposes for which re-use is not permitted

- correct uses of wastewater
- supervision of children using wastewater
- OHS management plan

8.10 Community Consultation

It is important that community information and communication programs reflect the local circumstances of an operator’s activities. In some cases, it is advisable to take pro-active measures to inform neighbours (for example about environmental and health safeguards to be implemented). After the initial assessment of the potential for wastewater re-use has been made and a long term site proposed, public involvement may be necessary to determine viability and, where favourable, system design can begin. Neighbourhood acceptance of re-use schemes can be developed by providing information and involvement in any proposals, visits to similar re-use schemes and community attitude surveys.

Public acceptance of wastewater re-use has been surveyed for a variety of applications. Public opinion towards wastewater re-use appears to be influenced by:

- Conservation Issues
- Availability of other sources ofwater
- Level of human contact
- Health issues
- Environmental issues
- Treatment levels
- Distribution system
- Cost/price
- Community expectations

A high level of public acceptance is essential for projects involving public contact with irrigated wastewater to be successful. This acceptance is generated when there is confidence in sewerage system operations and trade waste controls. There is a high level of goodwill towards the concept of wastewater re-use and community attitudes towards the practice are fairly consistent. In general the higher the level of public contact or the closer the proximity to the application, there is an increased possibility of unfavourable attitudes. Particularly in these situations it may be necessary to consult with the public about options for wastewater re-use.

If there are no other determining factors, low contact uses are a good first option to be examined for wastewater re-use projects.

8.11 Contingency Planning

Contingency plans should be developed for wastewater re-use systems in the possible occurrence of a non-compliant event. The contingency plans should include, but not be limited to:

- Treatment plant failures;
- Disinfection system failures;
- Treated effluent non-compliance;
- Irrigation failures,;
- Failure of backflow prevention devices and
- Spills or overflows.

8.12 Emergency Discharges

Under exceptional and unforeseen circumstances, the Division may grant an emergency permit to discharge for a limited time and subject to whatever conditions are deemed appropriate.

In an emergency, waste can only be discharged with the approval of the Director of Environmental Management or a permit or environment protection notice issued by the Environment Division. Notification of such an emergency would be expected some time before any discharge is allowed, in order for the Division to help determine the correct remedial action.

In years when rainfall exceeds the 90 percentile, the quality of stored wastewater will usually be improved with dilution by rainwater. Opportunities may occur for off-site discharges at times when environmental conditions do not favour nuisance weed growth, for instance, in the receiving waters.

Adverse environmental effects are more likely to occur if wastewater is released during warm, dry conditions. Generally, winter and early spring are the preferred times for discharge of excess water. Discharge during cloudy weather when the receiving water is cold will help to minimise the potential for eutrophication in the receiving waters. Many WWTP may have outfalls already designed for discharge to a receiving water body as part of an older disposal system. These outfalls can be put to good effect if storage ponds are at maximum volume and require emergency lowering.

8.13 Environmental Monitoring (post-commission)

All suppliers and users of wastewater have a responsibility to implement a planned program for monitoring and recording environmental performance following commissioning of the scheme. Collected data will demonstrate to the user that the water quality is suitable for the intended use; will identify and monitor the fate of various waste constituents in the environment; and will quickly highlight any problems with the wastewater treatment system and allow corrective / remedial action to be taken.

Effluent quality and quantity may change with time as a result of the seasonal nature of some industries or changes to production or treatment processes. As already discussed, changes can also occur in the physico-chemical and biological nature of soils as a result of wastewater irrigation. Adjustments to irrigation, vegetation, soil or stock management may then become necessary.

Management systems must include processes to monitor for these changes on a continual basis and implement appropriate changes in irrigation practice when required. To ensure that remedial action can be taken early, the following are recommended:

- flow monitoring (influent and effluent)
- wastewater quality monitoring (influent and effluent)
- soil monitoring
- groundwater monitoring
- surface waters monitoring

8.13.1 Monitoring Indicators & Recommended Frequencies

Monitoring of wastewater for re-use is undertaken at times and frequencies specified in Table 2-1 and represents the minimum requirement for assessment of wastewater quality. In brief, this establishes that best practice for Class A quality recycled water will include:

- volume supplied (quarterly)

- on-line monitoring of turbidity and chlorine residual (where chlorine is used for disinfection)
- daily checking of the disinfection system
- weekly monitoring of treatment indicators (BOD, SS and thermotolerant coliforms) and
- regular monitoring for viruses and parasites.

It is not possible to provide continuous monitoring of water quality for some indicators. For indicators such as turbidity, however, continuous on-line monitoring is possible and provides a degree of certainty as to the quality of the water. Where the risk factor is greater, such as where there is public access, then continuous on-line monitoring is warranted.

For Class B quality water, where there is some public access, weekly monitoring of treatment indicators and daily checking of the disinfection systems is appropriate. Where there is restricted public access for Class B and Class C quality water, monthly monitoring for most indicators is sufficient.

Food safety requirements may dictate more intensive monitoring than the monitoring systems proposed in Table 2-1.

8.13.2 In-flow Monitoring

The volume of waste passing into the treatment works should be continuously monitored and recorded. This information is valuable for determining the size of treatment and waste management facilities and the need for flow balancing.

8.13.3 Wastewater Quality Monitoring

Monitoring should be carried out annually if the waste quality is expected to be reasonably constant. More regular monitoring is necessary for low quality wastes and if water quality is expected to fluctuate. The quality indicators will vary depending on the waste characteristics and will be detailed on the EPN or permit.

Table 8-2 lists the recommended tests for various types of wastewater. Other tests may be required, depending on the source of the wastewater and intended use (see relevant sections or contact the Environment Division for further information). All samples must be collected and analysed in accordance with the relevant Australian Standards or other standard(s) approved by the Director of Environmental Management. Analysis should be undertaken by laboratories with National Association of Testing Authorities (NATA) accreditation or approved in writing by the Director.

Table 8-2: Recommended Wastewater Tests

Parameter	Food Processing	Sewage	Animal Wastes	Other Industrial
pH	✓	✓	✓	✓
Alkalinity (HCO_3-)	✓	✓	✓	✓
B		✓		✓
Ca	✓	✓	✓	✓
BOD_5	✓	✓	✓	✓
Cl	✓	✓	✓	✓
COD	✓			✓
Cu		✓		✓
Electrical Conductivity	✓	✓	✓	✓
Faecal Coliforms	✓	✓	✓	
Fe				✓
K	✓	✓	✓	✓
Mg	✓	✓	✓	✓
Mn		✓		✓
Mo		✓		
Na	✓	✓	✓	✓
$NH_{3\text{ -}}$ N	✓		✓	✓
Ni				✓
$NO_{3\text{ -}}$ N	✓	✓	✓	✓
TKN	✓	✓		✓
Total P	✓	✓	✓	✓
Pb				✓
NFR	✓	✓	✓	✓
SAR	✓	✓	✓	✓
SO_4		✓		
Zn	✓	✓		✓
Synthetic Compounds	✓	✓	✓	✓

8.13.4 Soil Monitoring

Effluent monitoring can give an indication of the possible effects of wastewater on the irrigated land. However, soil testing should be used to detect and verify undesirable soil changes and to apply amendments before actual symptoms appear in the vegetation. The type of soil testing required depends on land use and the characteristics of the irrigation water supply. Some indicators are suggested below. The number and frequency of tests depends on the individual circumstances of each case.

Soil testing becomes more important as wastewater salinity and sodium adsorption ratio (SAR) increase, especially with some fine-textured clay soils. Below is a list of the ongoing soil tests required for effective management of the environmental and public health issues associated with wastewater re-use, and for assessing cropping requirements on the site.

Table 8-3: Operational soil monitoring requirements

Parameters	Units	Frequency
pH		Annual
Electrical conductivity	dS/m or µS/m	Annual
Available Phosphorus *	mg/kg	Annual
Available Potassium	mg/kg	Annual
Total Nitrogen	mg/kg	Annual
Total cations (inc. Na, Ca, Mg, K)	mg/l	Annual
Cation Exchange Capacity	meq/100g	Annual
Exchangeable Sodium Percentage	meq/100 g	Annual (Indicator for soil structure decline, required for soils which are prone to sodicity)
Chloride	meq/l	Annual (If chloride levels are high in the effluent)
Trace elements	ppm	i) Annual (where wastewater application > 5ML per year or where high value crops) or ii) 5-yearly (where wastewater application < 5ML per year)
Heavy metals	ppm	i) Annual (where wastewater application > 5ML per year) or ii) 5-yearly (where wastewater application < 5ML per year)
Organic carbon	%	Annual

** Using Colwell soil test which employs 0.5 M $NaHCO_3$ at pH 8.5, a soil to extractant ratio of 1:100 and a 16 hour shake (refer Colwell 1963).*

Frequency of ongoing soil monitoring for above parameters will depend upon irrigation volume:

- where greater than 5 ML of wastewater is irrigated per year, annual soil sampling is required for all of the above parameters.
- where less than 5 ML of wastewater is irrigated per year, monitoring frequency for trace elements and heavy metals is every five years. Other parameters still require annual monitoring.

Frequency of soil monitoring will also depend upon perceived level of risk:

- more frequent soil sampling may be required where the concentrations of particular contaminants in the source water may be at levels with the potential to cause environmental or public health impacts, or
- where baseline soil monitoring has detected existing concentrations of contaminant/s at high levels with the potential to cause environmental or public health impacts.

Frequency of soil monitoring will also be dependant upon the cropping regime. Intensive cropping will require annual information on key nutrient and trace element concentrations as a basis for determining fertiliser requirements. An agricultural consultant can provide advice on these monitoring requirements.

8.13.5 Groundwater Monitoring

Any re-use scheme that may potentially impact on potable groundwater resources requires a comprehensive monitoring program to ensure a sound management system is in place preventing contamination of such a high value resource.

Less monitoring may be required for a scheme underlain by saline water where there is no apparent public health risk and no risk of impact on adjoining sensitive environments. Contamination may result from induced lateral displacement of the saline groundwater or mounding of the water table (according to New South Wales findings saline groundwater with TDS of 2000 mg/l at 2 m depth from the surface triggers dry-land salinity).

8.13.6 Bore Location

A typical groundwater monitoring program may involve a system of monitoring bores (3 as a minimum) installed at suitable depths and locations within the area likely to be affected by the scheme. The objective is to provide representative water level and water quality data for aquifer systems. Groundwater data should be recorded:

- Up-gradient of the irrigation scheme;
- beneath each irrigation area;
- down gradient of each irrigation area; and
- adjacent to the lagoon system, so that any leakages can be detected.

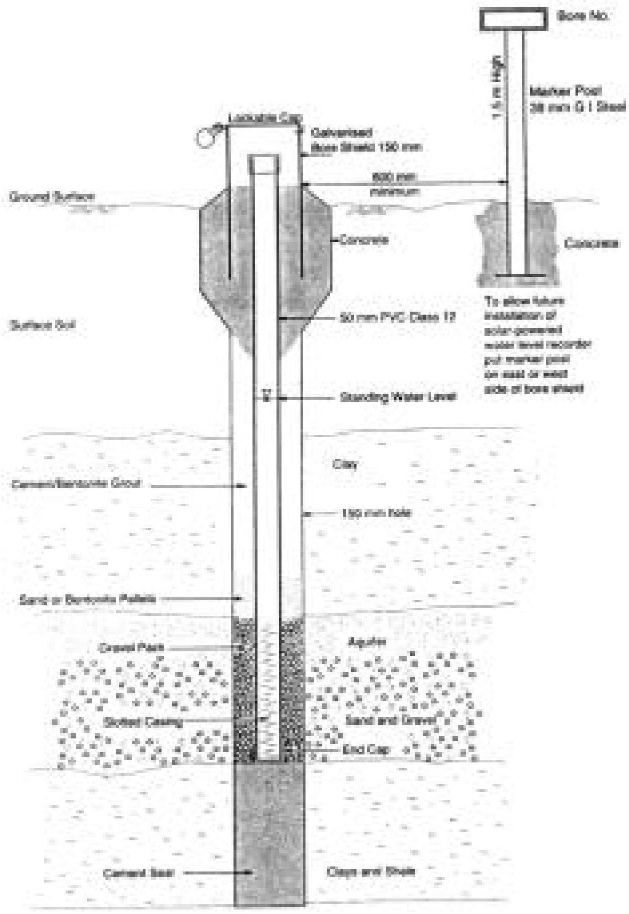


Figure 8-2 : Water monitoring bore (ARMCANZ 1997)

8.13.7 Bore Construction

The basic characteristics of monitoring bores are outlined in:

- *AS 2368 Test pumping of water wells*;
- *AS/NZS 5667.1: Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*;
- AS/NZS 5667.11: *Water quality - Sampling - Guidance on sampling of groundwaters*; and
- the 1997 ARMCANZ document, *Minimum construction requirements for water bores in Australia*, also provides details on bore construction. Casing should be 50 – 100 mm slotted and/or screened, normally of low yield construction but providing for accurate water quality sampling and water level measurements. Annulus seals and selective filter packing are used when necessary to isolate the zone being monitored. Care must be taken during drilling operations and in selecting drilling methods to ensure that there is no contamination of samples. Casing, filter pack and sealing or grouting materials should also be selected so that their chemical properties have minimum or no effect on proposed sampling requirements. Construction details for a monitoring bore are shown in Figure 8.2.

8.13.8 Background Information

Natural variations in groundwater quality and Standing Water Levels (SWL) pre-dating irrigation should be documented. Any available background data for the area provided by Mineral Resources Tasmania should be supplemented with new information. A sampling regime of every three months for one year prior to the irrigation, and every three months for a period of 12-18 months during irrigation is desirable. After the initial 12-18 months, the sampling frequency maybe changed depending on the results obtained.

The measurement of the standing water levels in boreholes should be carried out prior to the start of the treated effluent irrigation to obtain current oscillation patterns of groundwater levels. A date and the SWL in metres should be recorded. This should be recorded on a regular basis during irrigation. These measurements should be more frequent prior to irrigation and may be reduced after irrigation commences.

8.13.9 Groundwater Monitoring Parameters

A typical chemical and microbiological analysis should include the following items:

Table 8-4: Operational sampling requirements for groundwater

Parameters	Unit	Sampling Frequency
pH		Quarterly
Electrical conductivity ***One dS/m is equivalent to one thousand EC units / 640 ppm (salinity)***	µs/cm	Quarterly
Total dissolved solids	ppm (mg/l)	Quarterly
Carbonate CO_3^{2-}	ppm	Quarterly
Bicarbonate HCO_3^- ***Alkalinity in excess of alkaline earth metal concentrates is significant in determining suitability of water for irrigation***	ppm	Quarterly
Chloride	ppm	Quarterly
Iron	ppm	Quarterly
Sulphate	ppm	Quarterly
Fluoride	ppm	Quarterly
Aluminium	ppm	Quarterly
Sodium	ppm	Quarterly
Calcium	ppm	Quarterly
Magnesium	ppm	Quarterly
Potassium	ppm	Quarterly
Total Phosphorus and Phosphate	ppm	Quarterly
Total Nitrogen, NH_4^+ Nitrogen and NO_2/NO_3^- Nitrogen	ppm	Quarterly
Sodium Adsorption Ratio		Quarterly
Faecal coliforms (thermotolerant coliforms)	cfu/100 ml	Quarterly
Faecal streptococci	cfu/100 ml	Quarterly

8.13.10 Surface waters monitoring

Surface waters, particularly those used for drinking and recreational purposes, must be protected from the adverse effects resulting from the irrigation of wastewater. Routine sampling (grab-samples) is required from waterways within, or adjacent to, wastewater re-use sites at six monthly intervals(only if water is present in waterways), and after heavy rainfall events which immediately follow an irrigation event. Suitable sampling locations need to be identified as a component of the environmental assessment of the proposed scheme. Analysis for the following parameters is required:

Table 8-5: Operational monitoring requirements for surface waters

Parameters	Units	Frequency
pH		Six monthly
Electrical conductivity	µS/m	Six monthly
BOD_5	ppm (mg/l)	Six monthly
Total Phosphorus	ppm	Six monthly
Total Nitrogen	ppm	Six monthly
Nitrate – Nitrogen	ppm	Six monthly
Nitrite – Nitrogen	ppm	Six monthly
Faecal coliforms (thermotolerant coliforms)	cfu/100 ml	Six monthly
Faecal streptococci	cfu/100 ml	Six monthly
Chlorophyll "a"	ppb	Six monthly

8.14 Reporting Requirements

Reporting procedures relating to the activities of both the wastewater supplier and user are to be put in place.

- to provide arrangements for the submission of performance reports to agencies, users and the community
- to alter management practices to best protect environment and public health
- to identify incidents of non-compliance with the Guidelines and to ensure the appropriate people and agencies are notified

Wastewater treatment operators have monitoring and reporting requirements imposed by their permit or EPN. Typical best practice management will require:

- annual reports summarising monitoring data
- listing or register of re-use schemes
- suppliers providing reports to users on a regular basis

There is formal monthly reporting of the wastewater monitoring data where the supplier is a Level 2 WWTP permit holder.

Monitoring and record keeping requirements will also be included in the permit or EPN for a wastewater re-use activity. Regular inspections and maintenance of treatment and re-use facilities are to be undertaken and details recorded. Records of monitoring results should also be kept in order to demonstrate ongoing compliance with the objectives of these Guidelines.

An annual report of wastewater irrigation to land scheme should include:

- Summary of performance assessed against performance indicators in the DPEMP including exceedance of quality limits;
- Discussion of any problems or potential problems with details of incidents and corrective action taken;
- Inspection and maintenance reports;
- Monitoring data for effluent, soil and groundwater;
- Identification of areas of management/practice that may be improved; and

- A record of water flow data, even in an un-metered scheme, is essential for the management of wastewater. Flow data meters at the water treatment facility should at least record the total flow.

The supplier of wastewater notifies users of any quality compliance problems. Similarly, the user is to notify the supplier of any problems. All supplier or user incident reports (non-compliance with objectives) are submitted in writing to the appropriate agency as soon as practical. Repeat sampling and testing is immediately undertaken if any result does not comply with the water quality limit and appropriate action is taken.

8.15 Incident Reporting and Notifications

In the event of any environmental risk, emergency or incident involving public health (for example, cross-connection with potable water, overflow from storage dam to a water course or excedance of health criteria on edible crops) suppliers and users should inform the Wastewater Unit, Environment Division DPIWE.

Email: wastewater@dpiwe.tas.gov.au Phone: 1800 005 171

If there is an acute public health risk then the Department of Health & Human Services should also be notified directly.

8.16 Management Indicators

As well as regular reviews, monitoring of the waste stream and the soil of the irrigated land, there are a number of physical signs that can indicate the development of problems. Some indicators, the potential causes of problems, and possible solutions are tabulated below. Contact the Coordinating Group or DPIWE for more advice in this area.

Table 8-6: Some Management Indicators

Signs	Problems	Action
Free water remains on soil surface, reduced growth of pasture or crop, foliage droops, pale leaf colour.	Waterlogging due to runon, poor soil drainage, soil clogging, and excessive irrigation.	Check soil pH and EC first. Improve and/or modify drainage systems, use alternative irrigation methods.
Changes in pasture composition and reduced growth, emergence of salt tolerant species, bare patches of soil, plants dead despite moist soil.	Salinity and/or sodicity due to high saline watertable or irrigation with saline wastewater.	Stop irrigation with wastewater, cultivate, add gypsum, plant salt tolerant species, and reduce irrigation.
Yellowing and browning-off of vegetation.	Metals or other toxicants in the wastewater, pH of wastewater, nutrient deficiencies etc. Thorough investigation necessary.	Reduce or stop irrigation. Analyse soil and vegetation.

8.17 Algal Blooms in Stored Wastewater

Algal blooms can alter the treatment level of wastewater before re-use, and compromise effluent quality. Blue-green algae in particular may produce serious toxins which pose a risk to human and environmental health. The conditions provided by winter storages and sewage lagoons (high nutrient level, still conditions) can provide optimum conditions for algal growth.

Best practice measures to deal with algal blooms include:

- Design for multi-level off-takes in storage ponds and sewage lagoons to minimise the use of effluent containing algae;

- Inclusion of screening or filtering systems before supply or application that will return the screenings for further treatment or disposal;
- Monitoring of chlorophyll-a and nutrient content in the stored wastewater to help detect potential algal blooms;
- Use of aeration in the storage ponds to prevent still conditions, particularly in summer months; and
- Where economical, shading of storage surface.

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AS 1319: Safety signs for the occupational environment.

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AS 2368 Test pumping of water wells

AS 2698.2 Plastic pipes and fittings for Irrigation and Rural Activities.

AS 2845.1 Water supply - Backflow prevention devices - Materials, design and performance requirements.

AS 2845.3 Water Supply – Backflow prevention devices.

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APPENDIX A.

Guidelines for the Preparation of a Development Proposal & Environmental Management Plan for the Irrigation of Treated Wastewater on Land

Wastewater irrigation schemes should be designed and operated so that various aims are achieved simultaneously. These aims are as follows:

a) To prevent run-off, groundwater contamination, damage to the soil, land degradation and any other forms of environmental harm (i.e. the system must be **environmentally sustainable in the long term**).
b) To prevent impacts on human health and amenity.
c) To maximise plant growth by adding nutrients and water.

When considering points a) and b), relevant statutory requirements must be taken into account, such as:

- The *Environmental Guidelines for Re-Use of Recycled Water in Tasmania* (DPIWE 2002) or any subsequent updates of this document, and
- The *State Policy on Water Quality Management 1997*, in particular Section 6 (d) (Objectives of the Policy – Integrated Catchment Management), Section 30 (Diffuse Sources of Pollution) and Section 38 (Re-use of Wastes by Land Application).

A COMPREHENSIVE MANAGEMENT STRATEGY WITH THE ABOVE AIMS SHOULD BE PREPARED. IT SHOULD ADDRESS, BUT NOT BE RESTRICTED TO, THE FOLLOWING ISSUES:

1. Re-use options

Statement of re-use programme to include:

- Type of re-use - whether urban/residential, agricultural or industrial applications
- Identification of key limiting factors to be considered in scheme development and operation

2. Locality map

A locality map (scale 1:25,000) detailing the irrigation site and the surrounding area showing:

- land zoning (according to the relevant Planning Scheme);
- a description of surrounding land use and ownership within a 1.0 km radius of the proposed irrigation site;
- any existing or proposed houses, public buildings, public land, shops etc. within 250 m of the boundary of the proposed irrigation site;
- any existing or proposed access roads;
- areas prone to flooding, erosion or landslips.

3. Site plan of the irrigation area

A site plan of the irrigation area (scale 1:1,000 to 1:5,000) showing:

- the extent of the irrigation area
- natural features such as contour lines, permanent or intermittent watercourses, springs, existing and proposed groundwater bores, existing shelterbelts and other vegetated areas which may act as a buffer
- slopes greater than 10% should be clearly marked
- location of any source of water supply, including dams
- proposed irrigation infrastructure - e.g. drainage lines, pipes, pumps, sprinklers, storage tanks
- groundwater bore sites
- location of drinking water reservoirs and any potable water supply lines in the vicinity of the proposed irrigation area
- available areas for possible future use
- buffer zones to any sensitive uses (e.g. houses, public roads) or natural features (e.g. watercourses) that may require a buffer zone

- fire hazard assessment

4. Significant natural and cultural features

A description of significant natural and cultural features is to be provided. The proponent should contact the relevant DPIWE agencies regarding the following issues and provide details of the outcomes from this consultation.

- current and past land use practices
- sensitive flora and fauna (Resource Management & Conservation Division)
- Aboriginal heritage features and other archaeological features (Cultural Heritage Branch)

5. Climate

A description of the local climatic conditions including:

- rainfall (annual & monthly distribution on a long-term average and 90 percentile wet year basis)
- evaporation (annual & monthly distribution on a long-term average and 90 percentile wet year basis)
- prevailing winds (direction and strength; seasonal patterns)

6. Geological features

A description of geological features of the irrigation area including

- lithology
- faults/tectonics
- rock types (structural permeability)
- rock outcrops
- soil parent material
- depth to bedrock

7. Drainage

A map of the re-use area showing:

- Water flow direction
- Stormwater flow map and discharge points

8. Monitoring program

A monitoring program should be developed which reflects the specific concerns of the proposed irrigation scheme.

The following key areas must be addressed:

- Ongoing monitoring of wastewater quality, both at the discharge point from the wastewater treatment facility and at the holding dam or tank;
- Determination of hydraulic application rate per area;
- Periodic soil testing and interpretation of results by a qualified person;
- Soil moisture monitoring;
- Groundwater monitoring (key parameters);
- Frequent visual assessment and log-book keeping to determine noticeable impacts such as damage to soil and plants or evidence of run-off from the site.

In most instances, an extensive monitoring program will be required during the start-up phase, which may be cut back in frequency and / or number of sampling parameters once sufficient data are available to establish reliable trends.

9. Groundwater Assessment

The aims of the groundwater assessment are to determine and describe the current groundwater resources in the area and to determine the risk of contamination through wastewater irrigation. Where groundwater is encountered, its quality must be determined to generate baseline data. The investigation should refer to the following:

- depth of permanent and seasonal groundwater tables;
- location of existing groundwater recharge and discharge areas;

- groundwater flow;
- groundwater quality as determined by chemical and microbiological testing; and
- present and proposed future groundwater uses.

Where suitable groundwater bores exist, all available information should be collected from the landowner, the local Council, and Tasmanian Development & Resources (Mineral Resources). If suitable groundwater bores do not exist, they have to be established by a suitably qualified person and in accordance with appropriate standards. In order to establish groundwater flow, a minimum of three groundwater bores is required. However, depending on site-specific circumstances, more locations may be required.

- The location of existing and new bores should be detailed on the site map.

Groundwater samples must be taken prior to the commencement of irrigation. Ideally, sampling should occur over the period of 18 months at three monthly intervals to capture seasonal variations. Depending on practicality, monitoring should be carried out after heavy rainfall events. Samples should be analysed for the parameters specified below:

Parameters	Unit	Sampling Frequency
pH		Quarterly
Electrical conductivity One dS/m is equivalent to one thousand EC units / 640 ppm (salinity)	µs/cm	Quarterly
Total dissolved solids	ppm (mg/l)	Quarterly
Carbonate CO_3^{2-}	ppm	Quarterly
Bicarbonate HCO_3^- ***Alkalinity in excess of alkaline earth metal concentrates is significant in determining suitability of water for irrigation***	ppm	Quarterly
Chloride	ppm	Quarterly
Iron	ppm	Quarterly
Sulphate	ppm	Quarterly
Fluoride	ppm	Quarterly
Aluminium	ppm	Quarterly
Sodium	ppm	Quarterly
Calcium	ppm	Quarterly
Magnesium	ppm	Quarterly
Potassium	ppm	Quarterly
Total Phosphorus and Phosphate	ppm	Quarterly
Total Nitrogen, NH_4^+ Nitrogen and NO_2/NO_3^- Nitrogen	ppm	Quarterly
Sodium Adsorption Ratio		Quarterly
Faecal coliforms (thermotolerant coliforms)	cfu/100 ml	Quarterly
Faecal streptococci	cfu/100 ml	Quarterly

10. Wastewater quality

Irrigation with treated wastewater has the potential to affect soil permeability, hydraulic capacity, soil salinity and organic matter content. Waterlogging, salinity or toxic effects may affect plant growth. Furthermore, the irrigation of wastewater of a low disinfection standard may present a public health risk. The following information therefore needs to be provided:

- The annual and approximated daily amounts of wastewater intended for irrigation.
- Full wastewater analysis for the following parameters to illustrate compliance with recycled water standards:

Parameters	Unit	Sampling Frequency
pH		Refer to Table 2.1 in the ***Environmental Guidelines for the use of Recycled of Wastewater in Tasmania***
BOD_5	ppm (mg/l)	As above
Suspended solids	ppm	As above
Faecal coliforms	cfu/100 ml	As above
Faecal streptococci	cfu/100 ml	As above
Blue-green algae content (if relevant)		As above
Electrical conductivity	µs/cm	As above
Oil and Grease	ppm	As above
Total Phosphorus	ppm	As above
Total Nitrogen, NH_4 -Nitrogen and NO_2/NO_3 -Nitrogen	ppm	As above
Sodium Adsorption Ratio		As above
Trace elements as required (e.g. Chloride, Boron, Molybdenum)	ppm	As above
Zinc, Copper, Lead (other metals as required)	ppm	As above
Other substances of particular concern (e.g. for industrial wastewaters).	ppm	As above

Note: The proponent must be able to demonstrate compliance with the relevant disinfection requirements for a period of not less than 6 consecutive months before the wastewater can be approved for the intended use.

The Waste Water Treatment Plant will routinely monitor many of these parameters. Frequency of sampling will be dependent upon the class of water (Class A, B or C) and the intended re-use of water. Refer to Table 2.1 in the *Environmental Guidelines for the use of Recycled of Wastewater in Tasmania* (DPIWE 2002). Composite sampling may be required in high-risk situations.

11. Soil survey

Prior to commencement of wastewater irrigation, a suitably qualified person must undertake a thorough soil survey. The survey serves two main purposes:

- To assess the suitability of the site for irrigation and for storage lagoon construction; and
- To provide baseline data in relation to chemical and physical soil characteristics.

The survey should include, but not be limited to, the following information:

11.1 Soil profile

Soil profile descriptions to a depth of at least 2 m (or until bedrock) of locations representative for the irrigation area are to be provided. The choice of location and number of required soil pits is dependent on the uniformity of the area. If there is little variation in soil types and topography, a single pit may be sufficient for 5 –10 hectares. Existing information, such as contained in larger scale soil maps or the 'Land Systems' documents, should be utilised where available. The soil profile description shall address the following characteristics of each major soil horizon:

- soil type classification
- infiltration capacity
- permeability rate (vital for heavy clay soils)
- salinity
- water holding capacity
- depth (total depth to bedrock, depth to seasonal watertable)
- structure
- texture
- cracks
- rocks
- biological features
- moisture and colour

11.2 Soil analysis

Composite top-soil and composite sub-soil samples should be taken from a suitable number of locations within the areas used for irrigation purposes (a minimum of 2 per ha is recommended). At least one sample should be taken from an adjacent control area of similar soil type which has not been subject to irrigation. The sampling depths should be between 100-150 mm for topsoil and 300-400 mm for sub-soil. The sampling locations should be representative of the subject land (i.e. not be near fences or boundaries, on bare ground or dung & urine patches). Permanent reference points should be established for future monitoring purposes.

Baseline monitoring

Each of the topsoil samples shall be analysed for the following parameters to provide baseline data in relation to chemical and physical soil characteristics prior to irrigation commencing:

Parameters	Units	Frequency
pH		Baseline & annual
Electrical conductivity	dS/m or µS/m	Baseline & annual
Available Phosphorus (Colwell test)	mg/kg	Baseline & annual
Available Potassium	mg/kg	Baseline & annual
Total Nitrogen	mg/kg	Baseline & annual
Total cations (inc. Na, Ca, Mg, K)	mg/l	Baseline & annual
Cation Exchange Capacity	meq/100g	Baseline & annual
Phosphorus Adsorption Capacity	kg/m^3	Baseline
Exchangeable Sodium Percentage	meq/100 g	Baseline & annual (Indicator for soil structure decline, required for soils which are prone to sodicity)
Chloride	meq/l	Baseline & annual (If chloride levels are high in the effluent)
Trace elements	ppm	Baseline & … i) annual (where wastewater application > 5ML per year or where high value crops) or ii) 5-yearly (where wastewater application < 5ML per year)
Heavy metals	ppm	Baseline & … i) annual (where wastewater application > 5ML per year) or ii) 5-yearly (where wastewater application < 5ML per year)
Organic carbon	%	Baseline & annual

Operational monitoring

Frequency of ongoing soil monitoring for above parameters will depend upon irrigation volume:

- where greater than 5 ML of wastewater is irrigated per year, annual soil sampling is required for all of the above parameters.
- where less than 5 ML of wastewater is irrigated per year, monitoring frequency for trace elements and heavy metals is every five years. Other parameters still require annual monitoring.

Frequency of soil monitoring will also depend upon perceived level of risk:

- more frequent soil sampling may be required where the concentrations of particular contaminants in the source water may be at levels with the potential to cause environmental or public health impacts, or
- where baseline soil monitoring has detected existing concentrations of contaminant/s at high levels with the potential to cause environmental or public health impacts.

Frequency of soil monitoring will also be dependent upon the cropping regime. Intensive cropping will require annual information on key nutrient and trace element concentrations as a basis for determining fertiliser requirements. An agricultural consultant can provide advice on these monitoring requirements.

A site map, which specifies all sample locations, shall accompany the soil assessment. Advice shall be sought from an agricultural extension officer with regard to the fertility status of the soil in the areas under long-term irrigation.

12. Surface waters

Grab-samples are to be taken from waterways receiving surface run-off from start up of irrigation operations. Suitable sampling locations need to be established and are to be shown on the site map. Analysis for the following parameters is required:

Parameters	Units	Frequency
pH		Six monthly (only if water is present in waterways), after heavy rainfall events immediately following an irrigation event.
Electrical conductivity	µS/m	As above
BOD_5	ppm (mg/l)	As above
Total Phosphorus	ppm	As above
Total Nitrogen	ppm	As above
Nitrate – Nitrogen	ppm	As above
Nitrite – Nitrogen	ppm	As above
Faecal coliforms (thermotolerant coliforms)	cfu/100 ml	As above
Faecal streptococci	cfu/100 ml	As above
Sodium adsorption Ratio		As above
Chlorophyll “a”	ppb	As above

13. Irrigation strategy

The following calculations are vital for the assessment of the sustainability of the system:

- a water balance and the calculation of required storage facilities for the worst-case scenario (90 percentile wet year);
- irrigation rate (mm/ha/yr);
- nutrient loading rate (N:P:K in kg/ha/yr);

- selection of crop(s), details of crop rotation if applicable and intended crop end use;
- comparison of the nutrient loading rate to relevant fertiliser recommendations for the chosen crop;
- effluent salt leaching requirements.

Note: A pro-forma for the calculation of the wastewater storage requirements and the irrigation area requirements is attached (Attachment 1).

A description of the proposed management practices should be given, including:

- the type of land application scheme (e.g. overland flow, slow infiltration, rapid infiltration)
- details regarding the particular type of irrigation system used (e.g. automatic or manual operation, mobility, above-ground or under-ground installation, hourly throughput, sprinkler type, nozzle size, location of distribution pipework)
- the irrigation schedule for each area/crop
- anenometer controls and impacts on available irrigation times
- specification of any other equipment used and available back-ups for key items of equipment (e.g. pumps)

Methods must be specified by which the hydraulic capacity of the site at the time of application will be determined. Options are the use of the Soil Dryness Index, the use of portable or fixed tensiometers, capacitants, gypsum blocks and neutrometers.

14. Public health

Measures to safeguard public health as well as occupational health and safety of workers on site must be developed. Issues to be considered are:

- strategy in place to ensure irrigation only takes place when wastewater quality standards are achieved
- the likelihood and potential impact of spray drift
- the possibility of cross-connections between potable water and wastewater supplies
- appropriate warning signage that is strategically placed around paddock perimeter
- access restrictions to storage dams and tanks, including fencing and signage
- access restrictions to the irrigation site if required
- appropriate timing of irrigation events where the site is accessible by the public
- buffer requirements which are to be complied with
- Occupational Health and Safety plan to prepared by a qualified consultant

These aspects should be detailed on a map relating to public health and safety.

15. Systems Management

To help satisfy requirements for best practice under EMPCA (Environmental Management & Pollution Control Act 1994), large wastewater re-use schemes should develop an environmental management system (EMS) to provide a framework for managing the environmental, health and legal risks involved in the re-use of treated wastewater. Management systems will include audit checks of standard procedures (for example, air gaps and other separation measures as required by plumbing codes), training/education and regular inspection of services.

The implementation of an effective environment management system demonstrates application of due diligence to the supply and use of wastewater. The important features of an environment management system are shown below:

Legislation and Standards	Management Systems
- Due diligence checklist - Licences and permits **Communication Plan** - Responsibilities assigned - Reporting systems - Feedback on performance - Statutory authorities - Community groups - Emergency services **Management Plan** - Land (soil, geological conditions) - Water (surface and groundwater) - Air emissions - Aesthetics of sewage re-use - Recreational resources - Roles and responsibilities **Environmental Monitoring** - Background monitoring - On-going monitoring performance monitoring - Monitoring of improvements - On-going water quality improvements	- Security and public safety - Environmental safeguards - Quality assurance systems - Contingency plans - Data and inventory management - Performance reporting **Training Systems** - Management - Public relations and operating staff **Environmental Audit System** - Improvements in management - Nutrient utilisation - Monitoring performance - Physical and environmental risks - Financial risks and liabilities - Spill and leak prevention - Record keeping

The personnel responsible for the day to day management and operations of the system must be identified. These personnel must be adequately trained in operational procedures.

16. Additional information

Other information may be required to assist the Waste Water Co-ordinating Group in assessing scheme proposals.

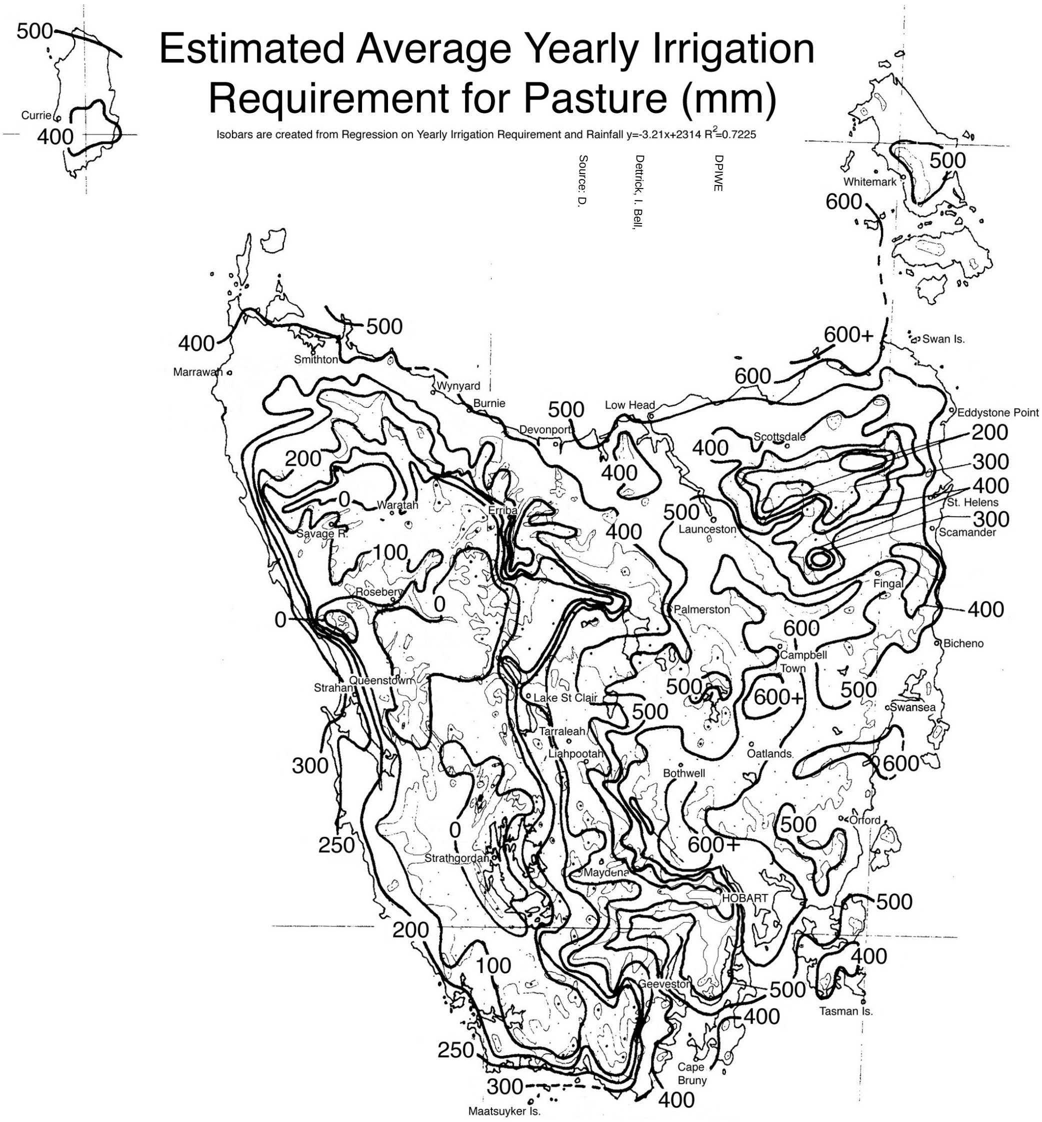
- Any lease or other agreement for land in other ownership
- Any agreement between the supplier of wastewater and the irrigator, accompanied by definitions relating to the respective roles of suppliers and irrigators
- A short discussion addressing the expected impacts on the soil and crops through possible effects of the effluent application, i.e. increased salinity levels, heavy metals and trace element inputs, must also be included. Relevant guidelines providing benchmark concentration limits should be considered, e.g. the *Environmental Guidelines for the use of Recycled of Wastewater in Tasmania* (DPIWE 2002) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* (ANZECC/ARMCANZ 2000)
- Where irrigation of effluent has been practised in the past, any observed effects of this practice shall be described, i.e. build-up of organic matter on the surface, invasion of exotic plants, other visual observations, odour development.
- Advice shall be sought from an agricultural extension officer with regard to the fertility status of the soil in the areas under long-term irrigation.

Attachment 1: Water Balance Calculation Sheet - This pro-forma has been extracted from the Guidelines for Wastewater Irrigation, Victorian Environment Protection Agency's, Publication No. 168 (dated 1983 & revised 1991).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Evaporation (mm) E_v													
Rainfall (mm) R													
Effective Rainfall (mm) R_{eff}													
Potential Evaptransp. (mm) $E_{pot} = C_r \times E_v$													
Irrigation Required (mm) $I_{req} = E_{pot} – R_{eff}$													
Net Evap from Pond (kL) $E_{net} = 10 \times (0.8\ E_v – R) \times A_{sto}$													
Volume of wastewater (kL) Vol													
Water for Irrigation (kL) $I_w = Vol – E_{net}$													
Area required (ha) $A_i = I_w / (10 \times I_{req})^4$													
Cumulative Storage (kL) S_{to}													
Direct crop coeff. C_r													
Pasture	0.7	0.7	0.7	0.6	0.5	0.45	0.4	0.45	0.55	0.65	0.7	0.7	
Lucerne	0.95	0.9	0.85	0.8	0.7	0.55	0.55	0.65	0.75	0.85	0.95	1.0	
Eucalypts													
Age 1 year	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
Age 2 year	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	
Age >4 years	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	

Note: E_v = class A pan evaporation. It is assumed pasture is being irrigated, 0.2 ha Lagoon, negative values for I_{req} = 0.

APPENDIX B.



Notes:

1. *This map is not intended for design purposes*
2. *It is for indicative use only, perhaps useful as a site selection guide*
3. *The values indicated are only 70% of the possible variation*
4. *The values refer to irrigation with potable water*

APPENDIX C: BASIC WASTEWATER IRRIGATION SCHEME REVIEW PROCESS

Wastewater Re-use Scheme:	
Review compiled by:	Date:

Issue	Table	Possible Score	Your Score
Permits and Records	1	24	
Nutrient and Chemical Management	2	45	
Irrigation Area and Wet Weather Storage	3	30	
Soil Moisture Management	4	40	
Ground water Pollution	5	20	
Surface Runoff	6	20	
Emergency Preparedness	7	25	
Total Score		**200**	

How do you Rate?

If your total score is:

150 - 200 It is likely that your wastewater irrigation scheme is well designed and managed and only causing minor environmental impact. A brief yearly review of operations is all that is required for your operations

120 - 150 It is likely that your wastewater irrigation scheme is performing adequately but there is room for improvement. Look at the scores for individual tables and identify poor performance. Focus efforts on improving these aspects of the operation.

60 - 120 A thorough review of the wastewater irrigation scheme is required. The low score suggests that the system itself is probably inadequate and skilled professional advice is probably needed. There are likely to be operational problems that should be identified and improved to be compliant with these Guidelines.

<60 You've got problems! This situation must not be allowed to linger on or put in the too hard basket. Prompt action is required to rectify major problems in the next six months. Review your low scoring areas and if you cannot sort out the problems get expert advice.

TABLE I Permits and Records

Issue	Answers/Method	Scoring	Your Score
Planning Approval What are the permitted uses of the land? (check with local Council if unsure) Is wastewater irrigation allowed without consent? If “no” do you have planning consent	Yes/No Yes/No	Yes = 4 No = 0	
Environmental Permits Does the Wastewater source have permit? Does the Wastewater re-use activity have a permit or environment protection notice? Are all the required permits current? (check the files) Are you complying with all the conditions of the permit?	Yes/No Yes/No Yes/No Yes/No	Yes = 4 No = 0	
Inspections How many inspection visits have you had in the last year regarding the irrigation system? How many of these visits were due to an incident or complaint? Have <u>all</u> matters noted by inspectors been fixed?		If 0 go to “Neighbours” below Yes = 3 No/Unsure = 0	
Neighbours How close is the nearest residence to the boundary of the irrigation area? How many written or telephone complaints have you received in the last year relating to: · Odour · Spray drift · Runoff into creeks Total complaints		>500m =3 300-500 =2 100-300 =1 <100m = 0 Total Complaints 0 = 5 1-10 = -5 >10 = -10	
Records Do you have a complete set of records of irrigation volume, water quality, soil conditions and cropping?	Yes/No	Yes = 5 No = 0	
TOTAL SCORE			

TABLE II Nutrient and Chemical Management - Nitrogen

Issue	Working	Example	Your Score
Nitrogen (N) A. What is the average total nitrogen content of the wastewater to be irrigated onto the land (mg/L)?		200 mg/L	
B. How many days per year does the irrigation scheme operate?		150 days	
C. What is the average daily output of the wastewater provider in kL/day?		500 kL	
D. Calculate the total yearly output of nitrogen (kg) = (A x B x C) / 1000	(______x_____x______)/1000	(200x150x 500)/1000= 15000kg or 15tonne/yr	
E. What is the total area of land irrigated each year (ha)?		50 ha	
F. Calculate the average nitrogen loading (kg/ha/year) = D / E		15000/50= 300kg/ha	
Calculate your Score: Irrigation area is grazed F < 200 Score = 25 200 < F < 300 Score = 10 F > 300 kg/ha Score = 0 Irrigation area is cropped (crop harvested and removed from land) F < 350 Score = 25 350 < F < 500 Score = 10 F > 500 Score = 0		Grazed land: score = 10	___________

TABLE III Nutrient and Chemical Management - Phosphorus

Issue	Working	Example	Your Score
Phosphorus (P) G. What is the average total phosphorus content of the wastewater to be irrigated onto the land (mg/L)?		30 mg/L	
H. Calculate the total yearly output of nitrogen (kg) = (A x B x G) / 1000	**A & B** (see Table I) (______x_____x______)/1000	(30x150x 500)/1000= 2250kg	
I. Calculate the average phosphorus loading (kg/ha/year) = H / E	**E** (see Table I)	2250/50= 45kg/ha	
Calculate your Score: Irrigation area is grazed I < 100 Score = 25 100 < I < 200 Score = 10 I > 200 kg/ha Score = 0 Irrigation area is cropped (crop harvested and removed from land) I < 150 Score = 25 150 < I < 250 Score = 10 I > 250 Score = 0		Grazed land: score = 25	________

TABLE IV Nutrient and Chemical Management – BOD and Salt

Issue	Working	Example	Your Score
BOD (Biochemical Oxygen Demand) J. What is the average BOD content of the wastewater to be irrigated onto the land (mg/L)?		50 mg/L	
K. Calculate the total yearly output of BOD (kg) = (A x B x J) / 1000	**A & B** (see Table I) (______x_____x______)/1000	(150x500x50)/1000= 3750kg	
L. Calculate the average BOD loading (kg/ha/year) = K / E	**E** (see Table I)	3750/50= 75kg/ha	
Calculate your Score: L < 10,000 Score = 5 10,000 < L < 15,000 Score = 3 L > 15,000 kg/ha Score = 0		<10,000 : score = 5	___________
Salt Content Total dissolved salts in effluent to be irrigated(mg/L) Score 0 – 175 10 175 – 500 5 500 – 1500 0 1500 – 3500 -5 >3500 10		TDS=300mg/L Score = 5	_________
Total Score Table II, III & IV			__________

Table V Irrigation Area and Wet Weather Storage

Issue	Working	Example	Your Score
Where is the wastewater plant located?		Brighton	
What is the average annual pan evaporation (in mm)?		2,000mm	
What is the median annual rainfall (mm)?		1,200mm	
Deficit = evaporation – rainfall(mm) (if answer is less than 500 adopt 500mm)	_____-_____ = _____	2,000 – 1,200 = 800 mm	
Number of days per year of operation		235	
Average daily flow of effluent (kL)		1,250	
Total effluent flow per year (kL)	_____ x _____ = __________	235 x 1250 = 293,750 kL	
Determine the "Basic" irrigation area (ha) required for effluent disposal	_______/(______x10) =__________	293,750/ (800x10) = 37 ha	
What area (ha) is used in one year for irrigation of effluent?		85 ha	
Ratio of actual area to "basic" area Scoring: * Ratio less than 1.5 Score = 0 * Ratio 1.5 – 2.5 Score = 10 * Ratio greater than 2.5 Score = 15	_____/_____ = _______	85 / 37 = 2.3 Score = 10	
What is the total volume of wet weather storage available (in kL)?		65,000 kL	
How many days storage of average flow does this represent?	_____ / _____ = ______	65,000 / 1,250 = 52 days	
Look up figure in Appendix B and find the nearest climate analysis site within the same climatic zone.		Brighton	
In Table ?? read the required days of storage at that location for the nearest multiple of the "Basic" irrigation area * Less than quoted range Score = 0 * Within quoted range Score = 10 * Greater than range Score = 15		For 2.3 times "Basic" area, required days storage: 40 – 110 Score = 10	
Total Score		10 + 10 = 20	___________

Table VI Soil moisture management

Issue	Example	Your Score
How far from the irrigation area is the nearest rain gauge? * less than 500 m Score = 4 * 500 m to 2 km Score = 2 * More than 2 km Score = 0	Gauge 1 km from area Score = 2	
How often is the rain gauge checked? * Daily at a regular time Score = 3 * When it has rained Score = 1	When it rains Score = 1	
How often do you measure soil moisture in the irrigation area? * Weekly Score = 15 * A few times per year Score = 10 * Never Score = 0	Never Score = 0	
Do you stop irrigating when it has rained significantly? * Yes Score = 5 * Sometimes Score = 3 * No Score = 0	Sometimes Score = 3	
How do you measure/estimate effluent which has been irrigated? * Measure at least weekly from an in-line flow meter Score = 5 * Measure pump running time Score = 4 * Measure water level in the pond Score = 1 * Estimate from wastewater plant Score = 2	Estimate from water use Score = 2	
Do you keep a daily chart or table of rainfall and irrigation? * Yes Score = 4 * No Score = 0	No Score = 0	
Do you check the uniformity of watering by measuring soil moisture at several places in the field or block, checking spray distribution with a row of buckets or checking advance and recessive times for surface irrigation? * Yes Score = 4 * No Score = 0		
Total Score	2+1+0+3+2+0+0 = 8	____________

Table VII Groundwater pollution

Issue	Example	Your Score
How important is the aquifer beneath your land disposal area? * No aquifer known, or groundwater in negligible quantities, or aquifer grossly contaminated Score = 4 * A minor aquifer which does not produce large quantities of water, but is important for local supplies and providing base flow to local rivers Score = ?? * A major aquifer which is highly productive and used for public water supply and/or other large users Score = ?? * Don't know Score = 0	No aquifer Score = 4	
What is the geology of the aquifer and its overlying strata? * Fractured rock or low permeability clay/silt Score = 3 * Moderately permeable alluvial material containing some silts and/or clays Score = ?? * Highly permeable sand and gravel Score = ?? * Don't know Score = 0	Don't know Score = 0	
What is the depth to the water table below your land irrigation area? * Greater than 15 metres Score = 3 * 5 to 15 metres Score = 1 * Less than 5 metres Score = 0 * Don't know Score = 0	Greater than 15 metres Score = 3	
How well are nutrients and water being managed? Total scores from end of table III + table VI * Greater than 60 Score = 4 * 40 – 60 Score = 2 * Less than 40 Score = 0	30 + 9 = 39 Score = 0	
Intensity of groundwater monitoring (a) Number of groundwater monitoring wells (b) Total irrigation area (ha) (c) Wells per ha = (a)/(b) If wells/ha is: * greater than 0.1 Score = 2 * 0.05 – 0.1 Score = 1 * <0.05 Score = 0	4 200 4 / 200 = 0.02 Score = 0	
How often is water taken from the wells for chemical analysis? * 12 months or less Score = 2 * 12 to 24 months Score = 1 * More than 24 months Score = 0	12 months Score = 2	
Typical total nitrogen concentration in groundwater * Less than 5 mg/l Score = 2 * 5 - 10 mg/l Score = 1 * Greater than 10mg/l Score = 0	<10 mg/l Score = 2	
Total Score	4+0+3+0+0+2+2 = 11	____________________

Table VIII Surface runoff

Issue	Working	Example	Your Score
How many days does irrigation take place?		150 days	
What area is irrigated each day? (ha)		5 ha	
Total *e*ffluent flow per year? (kL) (from table 2.7)		293,750	
Average daily irrigation depth (mm) = average daily volume / daily irrigated area	(_____ / _____) / (____x10) =______	(293,750 / 150) / (5 x 10) = 39	
Score for average daily irrigation If above question is greater than 40 Score = 0 If above question is 20 to 40 Score = 4 If above question is less than 20 Score = 7		Score = 4	
Which of the following best describes the topography of the irrigation area? * Less than 1% slope and has been laser graded Score = 3 * Slope 1% to 2%, no depressions Score = 1 * Slope 2% to 5%, undulating Score = 0 * Slopes 5% to 10% rolling Score = 2 * Slopes greater than 10% Score = 3		1-2% Score = 1	
What are the soils in the irrigation area? *Sands and Sandy Loam Score = 0 * Clay loam and Loam Score = 1 * Silt clay and Clay Score = 2		Loam Score = 1	
Does the irrigation area have drains to catch runoff? * Yes Score = 3 * No Score = 0		No Score = 0	
Where does water that drains from the irrigation area go to? * Drains to a separate storage pond Score = 3 *Drains to a natural depression Score = 1 *Drains to creek or gully Score = 0		Natural depression Score = 1	
Is collected runoff pumped for irrigation re-use? *Yes Score = 2 * No Score = 0		No Score = 0	
Total Score		4+1+1+1 = 7	___________

TABLE IX EMERGENCY PREPAREDNESS

Issue	Example	Your Score
How is the irrigation pump turned off? * Automatic time clock Score = 2 * Manually Score = 1	Manually Score = 1	
Is irrigation area visible from the irrigation pump site? * Yes Score = 2 * Partly Score = 1 * No Score = 0	Partly Score = 1	
How often does someone check the irrigation area? * At least 4 times per day Score = 6 * Daily Score = 2 * Weekly Score = 0	Daily Score = 2	
Where would the effluent go in the event of spillage? * Caught in pond within the irrigation area Score = 5 * Onto neighbours land Score = 2 * Into creek Score = 0 * Onto a public road Score = 0	Neighbours land Score = 2	
Does the irrigation system operate at night? * No Score = 2 * Yes Score = 0	No Score = 2	
How many people know how to turn off the irrigation system? * More than 3 Score = 2 * 2 or 3 Score = 1 * 1 Score = 0	2 people Score = 1	
Are emergency procedures written down? * Yes Score = 2 * No Score = 0	Yes Score = 2	
Do plant security personnel (eg the gate attendant) have a copy of the emergency procedures and have they been instructed what to do? * Yes Score = 2 * No Score = 0	No Score = 0	
Is a list of emergency contact names and phone numbers clearly displayed at: * Irrigation pump * Main office * Maintenance shed * Front gate	Main office and front gate (count half a point for each) Score = 1	
Total Score	1+1+2+2+2+1+2+0+1=12	__________________