ENVIRONMENTAL GUIDELINES

USE OF EFFLUENT BY IRRIGATION

Department of
Environment and Conservation (NSW)

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From 24 September 2003 the Department of Environment and Conservation (DEC) incorporates the Environment Protection Authority (EPA), which is established in the *Protection of the Environment Administration Act 1991* as the Authority responsible for administering the *Protection of the Environment Operations Act 1997* (POEO Act). Statutory functions and powers in the POEO Act continue to be exercised in the name of the EPA.

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Foreword

Water recycling is becoming a critical element for managing our water resources. By safely irrigating recycled water, sustainable development can be achieved while conserving our high quality water supplies. Being able to access alternative safe water sources is particularly critical in times of drought.

By providing an additional source of water, recycling can help to decrease the diversion of water from sensitive river and wetland ecosystems.

Another major benefit of effluent reuse by irrigation is the decrease in wastewater discharges to natural waterways. When pollutant discharges to waterways are removed or reduced, the pollutant loadings to these waters are decreased. Substances that can be pollutants when discharged to waterways can be beneficially reused for irrigation. For example, plant nutrients such as nitrogen and phosphorus can stimulate harmful algal blooms in waterways but are a valuable fertiliser for crops.

In some cases, returning well treated water to rivers might provide a better outcome than reuse by irrigation, for example, to supplement river flows. This Guideline will however help increase the options available for water management, particularly those sources of wastewater that are not suitable or adequately treated for safe discharge to our rivers, estuaries and oceans.

Many water needs can be satisfied with recycled water as long as it is adequately treated to ensure water quality is appropriate for the proposed use. Greater treatment and management is required for uses where there is a greater chance of human exposure to the recycled water.

Effluent can pose environmental, public health or agricultural resource risks if not managed appropriately and the information in this Guideline will support the establishment of safe effluent irrigation reuse schemes.

Water recycling has proven to be effective and successful in creating a new and reliable water supply, while not compromising public health. Effluent reuse by irrigation is now an accepted practice that will play a greater role in our overall water supply in the future.

The NSW Government is committed to encouraging and optimising the safe reuse of water. This Guideline will provide an essential information resource to help meet these goals and promote the wise use of our limited water resources.

Bob Debus

Minister for the Environment

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Figures and Tables

Symbols and Abbreviations

ABM	Australian Bureau of Meteorology
AMG	Australian Map Grid
ARR	Australian rainfall and runoff
ASS	Acid sulfate soils
BOD	biochemical oxygen demand
cfu	colony-forming unit (of thermotolerant bacteria)
COD	chemical oxygen demand
DA	Development Application
DEC	Department of Environment and Conservation
DIPNR	Department of Infrastructure, Planning and Natural Resources
dS/m	deciSiemens per metre
EC	electrical conductivity
EC_e	electrical conductivity of saturated soil extract
EIS	environmental impact statement
EMP	environmental management plan
EPA	Environment Protection Authority
ERIM	effluent reuse irrigation model
h	hour
ha	hectare
IDA	Integrated Development Assessment
HCB	hexachlorobenzene
kL/d	kilolitres per day
L	litre
LBL	Load-based licensing
LEP	Local Environmental Plan
meq/L	milliequivalent per litre
mg	milligrams
mL	millilitre
ML	megalitre
NTU	nephelometric turbidity unit
OC	organochlorine
PCB	polychlorinated biphenyl
ppm	parts per million
REF	review of environmental factors
REP	Regional Environmental Plan
SAR	sodium adsorption ratio
SEPP	State Environmental Planning Policy
STP	sewage treatment plant
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UV	ultra-violet

Executive Summary

The reuse of effluent by irrigation can make a significant contribution to the integrated management of our water resources. When the water and nutrients in effluent are beneficially utilised through irrigation some of the water extracted from rivers can be replaced and the amount of pollutants discharged into our waterways can be reduced. The Department of Environment and Conservation (NSW) has adopted a policy of encouraging the beneficial use of effluent where it is safe and practicable to do so and where it provides the best environmental outcome.

This Guideline is educational and advisory in nature. It is not a mandatory or regulatory tool and it does not introduce new environmental requirements. The emphasis is on best management practices related to the management of effluent by irrigation, to be used to design and operate effluent irrigation systems, with the goal of reducing risks to the environment, public health and agricultural productivity. The Guideline will assist decision-makers and industry members in achieving the best environmental outcome for each site at least cost.

The Guideline is not intended to provide specific guidance on every individual industry’s detailed issues. Rather it provides an information base to be used as a foundation for addressing issues that might arise in the range of situations, circumstances and industries in which effluent irrigation may be considered or underway. Industry specific guidelines or site-specific information may need to be taken into account when applying the Guideline.

Approaches to effluent irrigation management other than those outlined in this Guideline will always be considered on their merits provided that they demonstrate environmental sustainability and are safe from a public health perspective.

This Guideline has been developed through extensive consultation with industry and government and is based on national guidelines and principles where they are relevant.

The Guideline reflects the idea that a sustainable effluent irrigation system will be a function of the interactions between the site, soil, agronomic system and effluent characteristics, and diligent operational practices. These interactions require effective management to maximise the resources available in effluent and ensure that the environment is protected.

Selecting a suitable site is important for successfully establishing an effluent irrigation system. The Guideline provides criteria for assessing a proposed irrigation site, and discusses related issues important to the assessment of a site. Landform and soil characteristics can limit the use of effluent on some sites for example, because of the presence of soil that is poorly drained or excessively well drained. The relationship between effluent quality and soil characteristics that should also be considered when selecting a site are also outlined to ensure that soil structure is not likely to be adversely affected and/or pollution is not likely to be caused.

In relation to effluent quality, effluent contains valuable resources (water, organic matter and nutrients). However, in excessive amounts these can be detrimental to soils or plant growth. Effluent can also contain chemical contaminants, salts and pathogens that can pose a risk to the wider environment, public health or may cause pollution. These risks can be minimised by applying the criteria and information provided in the Guideline to during site selection, design and operation phases of an effluent irrigation system.

Best management practices which optimise the use of the water, nutrients and organic matter and reduce the potential for harm from other contaminants are also critical. For an effluent irrigation system to be sustainable, the amount of water, nutrients and chemicals that will be applied should be determined to ensure that it is the optimum for the crop or cultivar, the agronomic system employed, and site-specific factors such as climate, topography and soil. Adjustments to the amount of effluent applied or the area over which it is applied can then be made to ensure that irrigated plants and environments are not stressed by water or by the organic material, nutrients or chemicals applied.

Water and nutrient balances are used to calculate the amount of water and nutrients that should be applied, and at what times, to meet the crop requirements while ensuring increases in runoff and percolation are minimised. The water balance is calculated to determine the maximum volume of effluent that can be sustainably used. The elements to be considered in a water balance are rainfall, evapotranspiration, runoff and percolation. For some effluents, the loading rates of nutrients such as nitrogen and phosphorus can limit the quantity of effluent to be used for irrigation in a given area. In a nutrient balance the amount of the specific nutrient, (e.g. nitrogen or phosphorus) assumed to be applied in a year is compared with the amount taken up by the biological or physical processes of the crop-soil system. Pre-irrigation soil nutrient status is also considered.

In some systems the amount of effluent that can be applied is limited by potential adverse impacts of salinity, heavy metals and persistent organic chemicals. The Guideline suggests that key components in managing these types of limitations include designing the system to avoid any potential impacts, and having in place management and monitoring system to correct any emerging problems and to identify when action needs to be taken to ensure the environmental and agronomic performance of the system.

1. Introduction

Effluent irrigation is encouraged when it is safe and practicable to do so and where it provides the best environmental outcome. The NSW Department of Environment and Conservation (DEC) especially encourages substituting effluent for high quality water wherever high quality water is being used for a purpose for which effluent water would be acceptable. Where this is not possible, or would not provide the best environmental and natural resource outcome, effluent should be returned to the water cycle in an environmentally and socially responsible manner.

This document covers the broad framework, principles and objectives that should be considered when establishing an irrigation system that uses effluent (effluent irrigation system). Development of sustainable effluent irrigation schemes requires technical analyses of environmental interactions. Proponents of effluent irrigation schemes are encouraged to seek out industry specific guidelines and/or seek advice from suitably qualified personnel.

1.1 Purpose and scope

This Guideline provides information for planners, designers, installers and operators of irrigation systems that use effluent from a wide range of rural and industrial sources, including treated municipal sewage effluent.

For the purposes of this Guideline, effluent is considered to be as defined in the Protection of the Environment Operations Amendment Regulation 1999; a full definition is provided in the Glossary. In summary, effluent is wastewater from the collection or treatment systems associated with sewerage works, processing industries (livestock, wood, paper or food), intensive livestock, aquaculture or agricultural industries.

The aims of this document are to:

- encourage the beneficial use of effluent and show how this might be accomplished in an ecologically sustainable manner
- provide guidelines for planning, designing, installing, operating and monitoring effluent irrigation systems to diminish risks to public health, the environment and agricultural resources
- outline the statutory requirements that may be needed for an effluent irrigation system in NSW.

This Guideline supersedes SPCC (1979), *Design Guide for the Disposal of Wastewaters by Land Application*; WP-7 *Water Conservation by Reuse* (SPCC 1986); and revises the 1995 *Draft Environmental Guidelines for Industry – The Utilisation of Treated Effluent by Irrigation* (EPA unpublished).

The use of effluent for irrigation in non-domestic situations is the only option addressed in this document. The *NSW Guidelines for Urban and Residential Use of Reclaimed Water (NSW Recycled Water Coordination Committee 1993)* covers urban reclaimed water applications where the water has been treated and received quality control to render it suitable for general distribution through dual reticulation systems and for most non-potable uses in urban areas with open public access.

This Guideline does not cover:

- uses of effluent for purposes other than irrigation
- irrigation of effluent from single household on-site sewage treatment systems (see Department of Local Government 1998)
- selection of sites for effluent storage and transport infrastructure or their design and construction
- wastes that are classified as hazardous, Group A, Group B or Group C and will require an environment protection licence for their generation, storage, treatment or transport.

It is the proponent's responsibility to assess whether their effluent falls under the latter category. Proponents may contact DEC or refer to the Department's *Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes* (EPA 1999a).

Application of this Guideline

This Guideline is educational and advisory in nature and provides information on best management practices where effluent is managed by irrigation. This information can be used in the design and operation of effluent irrigation systems and can also be relevant and useful for meeting environmental requirements under the *Protection the Environment Operations Act 1997* (POEO Act) and in negotiations for premises-specific environment protection licences.

There are no new environmental requirements introduced by this Guideline and any requirements under the POEO Act or in environment protection licences prevail. The management practices described in this document are not the only approaches to sustainable effluent management that can be taken. Technically sound site-specific proposals and approaches are always considered on their merits where they meet environmental requirements.

While DEC and local councils encourage the safe, sustainable use of effluent, it is recognised that full reuse of all effluent is not always possible. In some cases the best environmental and natural resource outcome will be provided by a combination of reuse and discharge. In these cases, the document provides information that can be useful for the portion of effluent reused. Requirements for effluent discharge are negotiated on a case-by-case basis and in all cases, DEC aims to ensure that environmental objectives for water quality are met. However, experience has shown that for some types of effluent, the level of contamination means that opportunities to discharge to the environment are limited.

This document can be used by the designers of new sites for information on issues that are likely to constrain the use of effluent in irrigation and to develop approaches that manage environmental or public health risks.

For existing sites the need for environmental improvement will be measured against the environmental requirements under the POEO Act, in environment protection licences and environmental performance information such as the results of monitoring data. Those sites using similar management practices to those described in this document will find that the document contains information on the issues that are likely to need to be assessed to determine the likelihood of meeting environmental requirements and the potential sustainability of the site. The environmental performance objectives described in Section 1.2 should be taken into account whenever the environmental performance of an existing operation is being reviewed.

DEC and local councils are aware that some existing facilities may need to improve environmental performance over a longer time frame due to technical or economic difficulties. In these cases, a best management approach tailored to the site that meets environmental requirements will be taken and improved practices negotiated with DEC or the relevant local council over a reasonable time frame.

Related documents

Other relevant guidelines, endorsed for use in NSW by the NSW Government, should be read in conjunction with this Guideline. These include national and NSW industry-specific guidelines developed by government agencies or industry. Where national or industry-specific guidelines and this Guideline give conflicting guidance on proposals to irrigate effluent, the environmental performance objectives of this Guideline should be referred to in order to determine whether the objectives would be achieved by the proposal.

Other documents produced by the NSW Government and other agencies, such as the *National Guidelines for Beef Cattle Feedlots in Australia* (SCARM 1997); and the *NSW Feedlot Manual* (NSW Agriculture 1997) provide information on the use of effluent by irrigation and should be used to provide more industry-specific guidance where appropriate.

National guidelines are also available for some industries and provide a framework for consistent environmental management across Australia. State guidelines provide further detailed information to suit local environmental and regulatory conditions.

Relevant National Water Quality Management Strategy (NWQMS) guidelines include: *Guidelines for Sewage Systems – Reclaimed Water* (ARMCANZ, ANZECC & NHMRC 2000); and *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* in particular Volume 3, *Primary Industries – Rationale and Background* (ANZECC & ARMCANZ 2000). See Section 7.2, Further Reading for other industry-specific NWQMS guidelines.

1.2 Environmental performance objectives

The following environmental performance objectives apply to the use of effluent by irrigation.

Protection of surface waters: *Effluent irrigation systems should be located, designed, constructed and operated so that surface waters do not become contaminated by any flow from irrigation areas, including effluent, rainfall runoff, contaminated sub-surface flows or contaminated groundwater.*

Protection of groundwater: *Effluent irrigation areas and systems should be located, designed, constructed and operated so that the current or future beneficial uses of groundwater do not diminish as a result of contamination by the effluent or runoff from the irrigation scheme or changing water tables.*

Protection of lands: *An effluent irrigation system should be ecologically sustainable. In particular, it should maintain or improve the capacity of the land to grow plants, and should result in no deterioration of land quality through soil structure degradation, salinisation, waterlogging, chemical contamination or soil erosion.*

Protection of plant and animal health: *Design and management of effluent irrigation systems should not compromise the health and productivity of plants, domestic animals, wildlife and the aquatic ecosystem. Risk management procedures should avoid or manage the impacts of pathogenic micro-organisms, biologically active chemicals, nutrients and oxygen depleting substances.*

Prevention of public health risks: *The effluent irrigation scheme should be sited, designed, constructed and operated so as not to compromise public health. In this regard, special consideration should be given to the provision of barriers that prevent human exposure to pathogens and contaminants.*

Resource use: *Potential resources in effluent, such as water, plant nutrients and organic matter, should be identified, and agronomic systems developed and implemented for their effective use.*

Community amenity: *The effluent irrigation system should be located, designed, constructed and operated to avoid unreasonable interference with any commercial activity or the comfortable enjoyment of life and property off-site. In this regard, special consideration should be given to odour, dust, insects and noise.*

1.3 Uses of effluent in irrigation

A large body of research has demonstrated the value of effluent in a wide range of applications, including forestry, horticulture, pasture, turf, land rehabilitation and recreation areas.

The following uses may be considered, subject to constructing and managing an effluent irrigation scheme in a manner that does not cause pollution and meets the environmental performance objectives described herein. The major uses are:

- landscape watering
- irrigation of pasture, crops, orchards, vineyards, plantation forests and rehabilitated sites
- irrigation of golf courses, racecourses and other recreation grounds.

Special care needs to be taken when applying effluent to crops, fruit and vegetables, particularly those designated for human consumption. Where information is sought on effluent irrigation methods that do not accord with the public health protection provisions of these guidelines, the proponent should seek the advice of NSW Health.

1.4 Guidance

This document promotes the use of best management practices in the planning, design, construction, operation and management of effluent irrigation systems to achieve a beneficial environmental outcome. Best management practices are those approaches that prevent or minimise water and soil pollution at or as close as practicable to the source. Other approaches might be acceptable, provided that the resulting scheme is ecologically sustainable, and satisfies the requirements of DEC or local council and other statutory authorities.

The need for sustainability in an irrigation system is important. To this end, a program of continuous monitoring and progressive modification might be necessary to correct design flaws and deficiencies, and to adjust the system as more complete information on the site becomes available, accommodating changes in operation over time.

This document is an environmental guide; it is not a design and operations manual. Technical and scientific problems associated with the use of effluent can be complex and often require the integrated efforts of several disciplines in science and engineering. Accordingly, designers and operators might need to seek advice from specialist consultants and from government authorities such as NSW Department of Primary Industries, NSW Department of Infrastructure, Planning and Natural Resources, NSW Health, NSW Food Authority, and WorkCover NSW. Advice for using effluent in tree plantations may be obtained from the CSIRO Division of Forestry and Forest Products, Canberra.

1.5 How this Guideline is organised

This section sets out the broad scope, objectives and procedures for establishing an effluent irrigation system.

Section 2 provides guidance on the site planning for an effluent irrigation system.

Section 3 describes important characteristics of effluent when establishing effluent irrigation systems.

Sections 4 and **5** outline design and operation considerations.

Section 6 summarises statutory requirements for an effluent irrigation system.

1.6 Procedure checklist for establishing a system

A suggested checklist of procedures for setting up an effluent irrigation system follows.

Planning

a) Discuss the proposal/plans and inquire about statutory requirements with the relevant local council or DEC regional office and other authorities as appropriate (e.g. NSW Department of Primary Industries, NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) regional offices, NSW Health, and WorkCover NSW). This should occur at an early stage to ensure that all relevant issues are addressed before the design and operational phases begin. Appendix 6 summarises the specific regulatory or advisory information each agency can provide. Appendix 8 lists the DEC offices.

b) Assess effluent quality (Section 3 provides information on effluent characteristics that can have an influence on the design of an effluent reuse scheme.)

Site selection

a) Identify a suitable site and conduct a site assessment (Section 2).

Design

a) Establish the minimum area of irrigation land needed, based on limiting loading rates, i.e. hydraulic, nutrient, organic and chemical contaminants (Section 4).

b) Calculate the minimum irrigation land area and wet weather storage needed for the irrigation system (Section 4).

c) Define the operational processes to be used in effluent irrigation and management (Section 5).

Statutory requirements

a) Comply with the requirements of the Environment Protection Authority (EPA)[1], Department of Energy, Utilities and Sustainability (for local government sewerage effluent reuse schemes) or local council, and other relevant authorities in the planning and design stages (Section 6 and Appendix 5).

b) Assemble all information necessary and apply for licences or approvals where applicable (Sections 2–6).

Installation

a) Install the system in accordance with the conditions of all relevant authorities.

b) Develop a monitoring and reporting program as described in Section 5 so that the performance of the system can be objectively assessed and adjusted if necessary.

Operation and maintenance

a) Operate the system in accordance with best management practices and licence conditions where applicable. Contact should be made with DEC or local council and other regulatory authorities if design, process or operational changes to the system are intended.

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[1] The EPA is a statutory body with specific powers under environment protection legislation. In September 2003, the EPA became part of the Department of Environment and Conservation (DEC).

2. Site Considerations

When selecting a site for irrigation, it is fundamental to consider the compatibility of surrounding land uses as well as the suitability of land for irrigation, effluent storage and transport and other management requirements.

Selecting a suitable site is important for successfully establishing an effluent irrigation system that complies with the principles and guidelines set out in this document. This section provides criteria for assessing a proposed irrigation site, and discusses related issues important to the assessment of a site. Effluent quality (Section 3) should also be considered when selecting a site.

For irrigators who receive effluent on an 'as needed' basis (for example, partial reuse schemes, Section 4.1) some of the site selection criteria, such as the area of the storage facility might not apply.

See Section 7.2, Further Reading, for additional references on soils and site suitability.

2.1 Land use conflicts

When planning an effluent irrigation system, it is essential to consider the potential for land use conflict due to incompatibility with other land uses in the locality. Nuisance caused by the generation of odour, dust or noise must be considered and minimised to protect community amenity.

Activities that have the potential to significantly impact on the environment and possibly create land use conflicts are generally subject to environmental impact assessment procedures (Section 6). Consideration of these impacts is particularly important for intensive animal industries such as piggeries, feedlots, abattoirs and tanneries.

2.2 Selecting the site

Climate

The climate of the area is a major factor in determining the type of plants that can be grown and the amount of irrigation water that can be applied. These aspects are discussed in more detail in Section 5.

Preliminary investigations

Taking a staged approach to site selection can reduce the costs associated with selecting a suitable site. The first stage could be to identify how much land is likely to be needed by undertaking a preliminary water, nutrient, organic matter or salt balance (Section 4) using the expected effluent quantity and quality data. (Where the area to be irrigated is predetermined, e.g. an existing golf course, this step may not be necessary). The preferred locality should also be selected. This will usually be land located in close proximity to an existing or proposed effluent source, but in some cases the availability of 'suitable' land can be used as a criteria for determining the location of a proposed effluent producing activity.

Areas, which are likely to be unsuitable for irrigation, can be quickly eliminated by:

- use of aerial photographs/available topographic maps to exclude steep, rocky or poorly drained land (as described in Table 2.1)
- consultation with relevant government agencies (see Appendix 5).

Other technology such as electromagnetic surveys are also available to identify potentially unsuitable land affected by salinity, seasonal or permanent wetness, or shallow or excessively well drained soils (Table 2.2).

Preliminary soil investigations at representative sampling points include field morphological descriptions and laboratory tests to identify the level of salinity on samples representing soil depths up to 1m can differentiate potentially suitable from non-suitable sites (Hardie & Hird 1998).

DIPNR can provide soil data cards to assist in documenting soil morphological conditions (contact DIPNR regional offices). Data from these can be incorporated into the NSW soil database. The Soil And Land Information System (SALIS) is a database that contains descriptions of soils, landscapes and other geographic features from across NSW. SALIS can be used in a number of ways. It can be used to store and retrieve information about soils, landforms and landscapes. You can query SALIS to find out if there is any information about soil physical and chemical properties in any part of NSW. You can also compare your own soil information with data already stored in SALIS (DLWC 2000).

Detailed soil investigations

Detailed soil investigations should be confined to potentially suitable sites identified from the preliminary investigations. The aim of the detailed survey is to:

- confirm the suitability of the proposed irrigation site
- identify 'moderate' soil limitations that will require special management practices (Table 2.2)
- set up a baseline for any monitoring program (Section 5).

These soil investigations require a more intensive sampling strategy than that undertaken in preliminary investigations, robust enough to cover the topographic and geographic complexity of the area and its land use history. See Section 7.2, Further Reading, for additional information.

2.3 Soil properties

Soil properties that describe soils likely to be suitable for effluent irrigation are shown in Table 2.2. Subsoil as well as surface soil properties need to be considered and soil properties should be characterised for the appropriate soil horizon. Where a soil property limitation (in Table 2.2) is considered 'slight', no soil amelioration is generally required. If the property limitation is considered "moderate", some soil amelioration or a management response is required, for example, application of gypsum to a sodic (dispersive) soil, lime to an acidic soil, or careful irrigation of poorly drained or excessively well drained soil. Where a limitation is considered 'severe', the site may be unsuited to irrigation of some or all potential effluent products. For example, if a soil has a low phosphorus sorption potential, the irrigation of effluent with high phosphorus levels is unlikely to be sustainable.

Soil sodicity

Soil sodicity refers to the amount of exchangeable sodium (Na) cations relative to other cations in the soil and is expressed in terms of exchangeable sodium percentage (ESP).

Dispersion of soil or a poor soil structure may be associated with sodicity. Exchangeable sodium acts as a mechanism for weakening the bonds of soil aggregates creating a soil with poor structure that can impede water and plant root movement into and through the soil. The degree to which dispersion occurs is also dependent on the soil's clay content and mineralogy, pH, Ca/Mg ratio, electrical conductivity (EC), organic matter content and the presence of iron and aluminium oxides.

Australian soil scientists generally agree that soils with an ESP of greater than 5 are at risk of showing the adverse structural impacts associated with sodicity. Effluent with an SAR (sodium adsorption ratio) of greater than 6 is likely to raise ESP in non sodic soils, whereas effluent with a SAR of less than 3 may lower ESP in sodic soils (see also Section 4.4).

Soil salinity

Soil salinity refers to the amount of dissolved salts in the soil solution. Soil salinity levels are usually determined by measuring the EC of a soil suspension, which estimates the concentration of soluble salts in the soil. The soluble salts are likely to be the cations Na^{+}, Ca^{2+}, and Mg^{2+} and the anions Cl^{-}, SO_4^{2-} and HCO_3^{-}. Effluent and other soluble fertiliser may also contribute other ions such as K^{+}, NH_4^{+} and NO_3^{-} which are also plant nutrients. Effluent or the combined effect of effluent and fertilisers may raise soluble salt levels to the extent that they impede plant growth and/or create salt scalds thereby increasing the potential for soil erosion.

However, in evaluating potential impacts on soil and groundwater salinity it is important to acknowledge the role of plant uptake in removing salt from the soil (see also Section 4.4).

The concentration in the soil at which salt is hazardous varies with soil texture and plant species. An indicator of salt concentration is the electrical conductivity of a water-saturated soil paste (EC_e). This number may be derived directly, or indirectly, by multiplying results from a 1 to 5 soil water extract by an empirical soil texture factor (see Appendix 3). Where the EC_e (dS/m) of a soil is less than 2, effects on plants are mostly negligible; between 2 and 4, yields of `sensitive' plants become restricted; between 4 and 8, yields of many crops are affected; when the EC_e exceeds 8 dS/m, only salt-tolerant plants give satisfactory yields. Above 16 dS/m only very tolerant crops yield satisfactorily.

Saturated hydraulic conductivity

The saturated hydraulic conductivity (Ksat) of the soil is an important soil property for determining the suitability of a soil for irrigation. Soils with very high Ksat (e.g. sand) may allow nutrient and salt from effluent to quickly enter the groundwater. Soils with very low Ksat (typically unstructured clayey soils) are prone to waterlogging.

Ksat varies down the soil profile. Assessments should be made of the layer within the top 1m of soil that is likely to have the lowest Ksat (i.e. the layer with the most clay and/or the least structure). There is a range of methods for determining Ksat, and advice should be sought from suitably qualified persons to ensure that a reliable method is selected.

Available water holding capacity

The available water holding capacity refers to the maximum amount of plant available water that the soil can hold. Sandy soils and some clayey soils (with low cation exchange capacities) typically have very low capacities.

Estimation of available water holding capacity is important for irrigation scheduling purposes and can also be used if a daily water balance is used to estimate land areas (Section 4.2).

Soil pH

Soil pH is a measure of the concentration of hydrogen ions in the soil. It is known to be related to the availability of plant macro and micro nutrients. For most plants a pH range of between 6 and 7.5 (measured in calcium chloride) maximises the availability of plant nutrients and hence the potential for plant growth. Measurements of pH will vary depending on the field or laboratory technique used. It is advisable to measure pH in calcium chloride to ensure a consistent interpretation of results.

Cation exchange capacity and exchangeable cations

The cation exchange capacity (CEC) of a soil is the total quantity of exchangeable cations it can retain on its adsorption complex at a given pH. As a general rule, soils with high CEC have good soil structure and are better at mitigating any potential risks associated with the pH, nutrient, sodium, salt or contaminant content of effluent. Addition of organic matter (which typically has a high CEC) or the incorporation of a green manure crop (which will also increase the soils organic matter content) may improve soils with a low CEC.

Exchangeable cations in soil include Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} (exchangeable bases), and H^{+} and Al^{3+} (exchangeable acidity). The other cations such as manganese, iron, copper and zinc are usually present in amounts that do not contribute significantly to the sum of cations on the exchange complex. It is therefore common practice to measure the concentration of the five most abundant cations and use these to measure the effective cation exchange capacity (ECEC).

Emerson Aggregate Test (EAT)

The EAT is a test developed to measure the structural stability of a soil. Soils with an EAT of 1 are likely to have the least stable structure (aggregates will slake and disperse when wetted). Stable aggregates will usually have an EAT of between 4 and 7. An EAT of 8 means that the soil is so stable that it cannot be penetrated by plant roots. An EAT of 2 and 3 means that the soil has some potential to slake and disperse. Additions of gypsum, lime or organic matter can improve structural stability.

Soil phosphorus adsorption

Most Australian soils have the capacity to immobilise phosphorus (P) in soil thereby making it unavailable for plant growth. Within a particular soil profile this capacity can vary with depth. Land managers normally apply additional phosphorus above plant requirements to overcome this problem. In general, acidic soils with a high clay content that have formed in situ have a very high capacity to adsorb P while sandy soils have a very low capacity. Alluvial soils usually have a relatively low sorption capacity. All other soils typically have a medium to high capacity, unless they occur on sites that have been receiving high levels of P fertilisers or waste products over a number of years.

If the effluent has a higher P content than can be absorbed by the growing (and subsequently harvested) plant, then it will be necessary to estimate the P sorption capacity of the soil. This step is carried out to determine the risk of P leaving the irrigated site during the life of the irrigation scheme thereby potentially contaminating ground and surface waters.

Advice should be sought from recognised soil scientists and laboratories as to the best way to measure P sorption capacity. Account should be taken of the volume of the soil mantle between the irrigation area and any groundwater table or surface waterbody. It should also be noted that soils with a high degree of pedality (or cracking soils) or major geological discontinuity could act as a conduit for P rich effluent to enter a valuable water resource. The form of P in the effluent and the pH of the soil may also affect the mobility of P in soil.

2.4 Soil organic matter

Soils with a reasonably high level of organic matter (i.e. at least 2% by weight) are desirable for effluent irrigation schemes. Organic matter encourages soil microbial activity and increases cation exchange and water holding capacity thereby buffering the potential adverse impacts associated with overloading the soil temporarily with nutrients, effluent contaminants or water. Soil organic matter can be increased by incorporating green crops or by adding manures, composts or biosolids directly to the soil (taking into account any addition to the nutrient budget for the site).

2.5 Acid sulfate soils

The presence of potential acid sulfate soils (ASS) in coastal areas can create site limitations for effluent irrigation schemes. Activities undertaken in areas likely to affect or use coastal sediments (e.g. use, excavate or disturb ASS for dams and land forming works) warrant an assessment of the risk of exposing ASS. For further information DIPNR hold ASS Risk Maps that identify the risk that ASS will occur in coastal areas and the ASS Management Advisory Committee has prepared an ASS Manual (see Stone, Ahern and & Blunden 1998) that provides guidance on assessment and management of the soils. Local councils may also require development consent for ASS disturbance.

Table 2.1: Landform requirements for effluent irrigation systems

	Limitation			
Property 1	**Nil or Slight**	**Moderate**	**Severe[2]**	**Restrictive Feature**
Slope (%) (for following irrigation methods)				
– flood/surface/ underground	< 1	1–3	> 3	excess runoff and erosion risk
– sprinkler	< 6	6–12[3]	> 12[3]	
– trickle/microspray	< 10	10–20[3]	> 20[3]	
Flooding	none or rare	Occasional	frequent	limited irrigation opportunities
Landform	crests, convex slopes and plains	concave slopes and foot-slopes	drainage lines and incised channels	erosion and seasonal water- logging risk
Surface rock outcrop (%)	Nil	0–5	> 5	interferes with irrigation and/or cultivation equipment; risk of runoff

Source: Based on Hardie and Hird (1998), NSW Agriculture, Organic Waste Recycling Unit

Notes:
1. Careful consideration should also be given to potential impacts on groundwater (see 2.6 Groundwater).
2. Sites with these properties are generally not suitable for irrigation.
3. Slopes over 12% may be acceptable provided runoff and erosion risks are identified in the site selection process.

Table 2.2: Typical soil characteristics for effluent irrigation systems

Property	Limitation			Restrictive Feature
	Nil or Slight	Moderate	Severe[1]	
Exchangeable sodium percentage (0–40 cm)	0–5	5–10[2]	> 10	structural degradation and waterlogging
Exchangeable sodium percentage (40–100 cm)	< 10	>10	–	structural degradation and waterlogging
Salinity measured as electrical conductivity (EC_e) (dS/m at 0–70 cm)	< 2	2–4	> 4[3]	excess salt may restrict plant growth
Salinity measured as electrical conductivity (EC_e) (dS/m at 70–100 cm)	< 4	4–8	> 8[3]	excess salt may restrict plant growth, potential seasonal groundwater rise
Depth to top of seasonal high water table (metres)	> 3[4]	0.5–3[4]	< 0.5	poor aeration, restricts plant growth, risk to groundwater[5]
Depth to bedrock or hardpan (metres)	> 1	0.5–1	< 0.5	restricts plant growth, excess runoff, waterlogging
Saturated hydraulic conductivity (Ks, mm/h, 0-100 cm)	20–80	5–20[6] or >80[6]	<5	excess runoff, waterlogging, poor infiltration
Available water capacity (AWC, mm/m)	> 100	< 100 [6]	–	little plant-available water in reserve, risk to groundwater
Soil pH_{CaCl_2} (surface layer)	> 6–7.5	3.5[7]–6.0 > 7.5	< 3.5	reduces optimum plant growth
Effective cation exchange capacity (ECEC, cmol (+)/kg, average 0–40 cm)	> 15	3–15[8]	< 3	unable to hold plant nutrients
Emerson aggregate test (0–100cm)	4, 5, 6, 7, 8	2, 3	1	Poor structure
Phosphorus (P) sorption (kg/ha at total 0–100 cm)	high[9]	moderate[9]	Low	unable to immobilise any excess phosphorus

Source: Based on Hardie and Hird (1998), See also NSW Department of Primary Industries (2004)

Notes:

1. Sites with these properties are unlikely to be suitable for irrigation of some or all effluent products.
2. Application of gypsum or lime may be required to maintain long-term site sustainability.
3. Some high EC soils containing calcium 'salts' are not necessarily considered 'severe'.
4. Where unable to excavate to 3m, local knowledge and absence of indications of water table to the depth of sampling (1m) should be used.
5. Criteria are set primarily for assessing site suitability for plant growth. Presence of a shallow soil water table may indicate soil conditions that favour movement of nutrients and contaminants into groundwater. In such cases, careful consideration should be given to quality and potential impacts on groundwater (see 2.6 Groundwater).
6. Careful irrigation scheduling and good irrigation practices will be required to maintain site sustainability.
7. Soil pH may need to be increased to improve plant growth. Where effluent is alkaline or lime is available, opportunities exist to raise pH. If acid sulfate soil is present, site-specific specialist advice should be obtained.
8. Soil may become more sodic with effluent irrigation. In some cases, however, this soil property may be ameliorated with addition of a calcium source.
9. Soils with medium to high phosphorus sorption capacity can adsorb excess phosphorus not taken up by plants. The effectiveness of this depends not only on the sorption capacity but also, the depth and permeability of the soil. A nutrient budget must be undertaken (see Section 4.3).

2.6 Groundwater

The *NSW State Groundwater Quality Protection Policy* (DLWC 1998) and the framework *NSW State Groundwater Policy* (DLWC 1997) should be consulted for the principles and issues to be considered relating to groundwaters.

The quality of the underlying groundwater must not be downgraded to the extent that the resource is not able to support its most sensitive beneficial use. There is a risk that underlying groundwater may be downgraded as a result of irrigation with effluent. These risks are greatest when effluent with high quantities of nutrients, salt, pathogens or other contaminants is being irrigated and/or where the groundwater has a current or potential beneficial use (e.g. used for drinking water or flows to a groundwater dependent ecosystem).

These risks can be minimised by:

- avoiding areas where the groundwater has a current or potential beneficial use, is close to the soil surface or where there is evidence of dryland salinity
- ensuring that the plant/soil mantle above the groundwater table is capable of immobilising any potential contaminants in the effluent.

Groundwater vulnerability

Environmental impact assessment for groundwaters should be based on the principles set out in the *National Water Quality Management Strategy: Guidelines for Groundwater Protection in Australia* (ARMCANZ & ANZECC 1995) and the *NSW State Groundwater Policy*.

DIPNR have published groundwater availability/vulnerability maps that highlight areas that are at risk due to effluent irrigation. Groundwater investigations should take into account current groundwater chemistry and condition and the quality and quantity of the effluent to be irrigated; for example, the quality of the irrigation water should not exacerbate rising salinity in the watertable.

Where supporting technical advice has not been obtained, effluent should not be applied to land where the depth to groundwater table is considered to be less than 10 metres or where the irrigation area is located less than 1000 metres from a town water supply bore.

In areas subject to existing or potential problems, such as rising groundwater tables or dryland salinity, or where groundwater is a direct conduit discharging to surface waters, appropriate measures must be taken to ensure that the effluent irrigation system does not exacerbate these problems.

The following are appropriate ways to protect groundwater from impacts of effluent irrigation.

- Careful selection of suitable sites for irrigation.

- Implementation of a well-structured management plan that includes, details of deficit irrigation scheduling, monitoring soil moisture content and strategies to suspend irrigation when soil moisture content is high.
- Selection of areas where the presence of one or more impervious geological strata (for example, a thick layer of compacted clay) above the groundwater aquifer can prevent deep percolation from reaching the aquifer.
- In the absence of protective geological strata, an adequate depth to the normal watertable at or near the irrigation site will usually be needed for groundwater with current or potential beneficial uses. On some moderately permeable soils, a minimum depth of 15 metres may be required.

On sites with identified risks to groundwater, baseline groundwater chemistry should be established as a basis for assessing the extent of potential impacts and to develop a monitoring program, if required. Regular groundwater monitoring is required for effluent irrigation systems that operate in a location where they pose a threat to groundwater.

Water quality objectives for the groundwater (i.e. water quality needed to protect beneficial uses of groundwater) also should be considered. See also Section 4.10 Separation Distances and Management of Buffer Zones.

2.7 Surface water

The quality of streams and rivers in the catchment of an effluent irrigation scheme must not be downgraded (i.e. relevant water quality objectives need to be taken into account). There is a risk that surface waters may be degraded by poorly designed or managed effluent irrigation schemes, particularly where effluent with high quantities of nutrients, salt, pathogens or other contaminants is being irrigated. Runoff events into streams are a common cause of fish kills. Fish are particularly sensitive to oxygen depletion, ammonia, nitrate, nitrite, sulphur dioxide and organochlorine pesticides. Potential impacts on current and future downstream water users and resources need to be considered, e.g. downstream aquaculture and fishery industries.

These risks can be minimised by ensuring that:

- irrigation of moderate to high strength effluents in close proximity to surface waters is well designed and managed
- the plant/soil mantle within and down-gradient of the effluent irrigation area is capable of immobilising any potential contaminants in the effluent
- there is an adequate buffer zone between the irrigation area and the surface waterbody (Section 4.10)
- runoff control structures within the irrigation area are adequate (Section 5.4).

On sites with identified risks to surface waters, baseline surface water chemistry may need to be established. Regular surface water monitoring is required for effluent irrigation systems that operate in a location where they pose a threat to surface waters (Section 5.3).

2.8 Flood potential

Sites prone to flooding can be suitable for effluent irrigation, but only where effluent storage facilities and other equipment such as pumps are adequately protected. Any drainage lines constructed within the floodplain may need to be protected against pollution from the applied effluent. This might require the construction of diversion banks and channels. Approval must be obtained from the DIPNR before constructing flood diversion structures.

3. Effluent Quality and Irrigation Considerations

Effluent contains valuable resources, such as organic matter and nutrients, however, it also can contain concentrations of chemical contaminants, salts and pathogens that are potentially detrimental to soils or plant growth and/or pose a risk to the wider environment or public health. The constituents of effluent are discussed in general in this section. How effluent quality impacts on the design of irrigation systems is discussed in Section 4.

When designing a wastewater treatment system, effluent quality needed to ensure a sustainable irrigation system will influence the effluent treatment needed and the design and operation of the irrigation system.

3.1 Classification of effluent for environmental management

Classification of effluent as low, medium or high strength according to its concentrations of nitrogen, phosphorus, BOD_5 ,TDS, and other potential contaminants is a first step in determining environmental management issues including:

- the likely magnitude of environmental risks associated with effluent irrigation
- appropriate runoff and discharge controls.

The effluent generator should initially characterise the quality of the effluent for environmental issues based on Table 3.1. For an effluent to fall within a certain class, all constituents must be within the specified concentration range. However, where an effluent falls into a class by a nominal amount, the design overflow frequency may be interpolated proportionally. Where the characteristics of a particular effluent mean that some ions could be in effect 'double counted' then those ions could be discounted from the relevant parameter. However, care must be taken to ensure that important environmental impacts such as ionic effects are not underestimated. For example, in an effluent with high nitrogen, the amount of nitrogen could be discounted from total dissolved solids.

Where industries can establish through other means (e.g. knowledge of inputs into the wastewater stream) that the likelihood of one or more of the constituents identified in Table 3.1 is low, then there may be no need to establish the value by laboratory analysis.

Other methods for ensuring that pollution of waters does not occur, or licence conditions are met, can be proposed for a particular site. Other approaches should be based on a technically sound approach taking into account effluent characteristics, the water balance for the site, relevant environmental objectives for any receiving water, existing ambient water quality and the conditions under which a discharge is likely to occur. Monitoring is likely to be required to ensure that predicted performance is achieved.

Where reuse of effluent by irrigation is used as a method of controlling discharges of pollutants to the environment, the appropriate size of wet weather storage is, in part, determined by effluent strength (Section 4). Proposed management practices which would improve the quality of effluent discharge or runoff, before it leaves a site (e.g. further treatment before effluent moves offsite) also may be considered in determining the storage and runoff requirements described in Section 4.2.

By demonstrating that the strength of any effluent that leaves the site boundary (via a designed overflow or discharge point), is of a lower strength than the supplied or stored effluent (e.g. by further treating the effluent), then the guidelines associated with the lower strength classes for determining the appropriate size of wet weather storage may be used. This provides flexibility in meeting the required environmental and public health objectives. The effectiveness of any management practices proposed to reduce effluent strength **must** be demonstrated with the same technical rigour as other design, planning and operational elements of the scheme.

Water from municipal sewage treatment plants is likely to be low strength, whereas untreated effluent from intensive animal industries is likely to be medium to high strength. Some industries may produce more than one class of effluent.

Table 3.1: Classification of effluent for environmental management

	Strength (average concentration mg/L)[1]		
Constituent	**Low[2]**	**Medium**	**High**
Total nitrogen	<50	50–100	>100
Total phosphorus	<10	10–20	>20
BOD_5	<40	40–1,500	>1,500
TDS[3]	<600	600–1,000	>1,000–2,500
Other pollutants (e.g. metals, pesticides)	Effluent with more than five times[4] the ANZECC and ARMCANZ (2000) long-term water quality trigger values for irrigation waters must be considered high strength for the purpose of establishing a strength class for runoff and discharge controls and will require close examination to ensure soil is not contaminated.		
Grease and oil	Effluent with more than 1,500 mg/L of grease and oil must be considered high strength and irrigation rates and practices must be managed to ensure soil and vegetation is not damaged.		

Notes:
1. Average concentrations established from a minimum of 12 representative samples, collected at regular intervals over a year.
2. Effluent generated by municipal sewage treatment plants with secondary treatment will generally be considered to be low strength.
3. Refer to Section 3.7 for relationship of TDS to EC.
4. Criteria of five times the ANZECC and ARMCANZ (2000) long-term irrigation criteria have been selected as nominal criteria at which the level of those contaminants warrants a higher level of management of the reuse system for the following reasons. This criteria when applied to 1 ML/d of effluent irrigated over 100 hectares would take approximately 10 years for soil contaminant levels in the top 15 cm of soil to rise to near the soil contaminant criteria for Cadmium, Chromium and Zinc, which are the most sensitive heavy metal pollutants in this scenario. This criteria is also approximately half the value for Nickel, Mercury, Beryllium and Arsenic at which the effluent would be considered a liquid waste and would need to be managed and disposed of according to the DEC's *Environmental Guidelines for the Assessment, Classification and Management of Liquid and Non-Liquid Waste* (EPA 1999a).

This Guideline or the ANZECC and ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* may not provide guidance for all potential environmental pollutants. The onus is on the effluent producer to discuss all potential pollutants in their effluent with DEC or local council, so that an appropriate `strength' classification can be made for the effluent. Effluent producers should also determine if effluent is a controlled aqueous waste as defined by DEC's *Environmental Guidelines: Assessment, Classification & Management of Liquid & Non-Liquid Wastes* (EPA 1999a).

The concentration of pathogens is also an important effluent quality consideration in terms of public health, which affects the way effluent should be reused and managed on-site. Pathogens in effluent are discussed in Section 3.10, Treatment and Disinfection. Consideration of effluent quality in terms of its end use is important when considering potential risks to public health. Appendix 1 applies to the spray application of sewage effluent but provides a general guide to the types of end uses with different levels of risk to human health.

3.2 Organic content

Organic matter is present in many effluents, and when applied at an appropriate rate, can contribute to soil fertility.

Ordinarily, concentrations are low enough to preclude short-term detrimental effects on the soil or vegetation. Continued overloading with organic matter can physically clog soil pores, favour anaerobic soil microbes and lead to slimy bacterial scum coating the soil, blocking pores and closing up cracks. These changes could limit the effective life of the application site. Total organic loading rates can greatly influence liquid loading rates and the length of the resting period between applications required for re-aeration of the soil and to encourage bacterial die-off (see Section 4).

Organic matter in effluent can be measured as biochemical oxygen demand (BOD), chemical oxygen demand (COD), or total organic carbon (TOC). It is present in the dissolved form as well as in the form of suspended and colloidal solids.

3.3 Solids

Care must be taken if effluent has high concentrations of solids (non-filtrable residues). These may coat leaf surfaces or obstruct some types of sprinkler nozzles. It may be necessary to reduce the concentration of solids to avoid operational problems with any irrigation scheme.

Suspended solids can provide a substrate for other pollutants such as heavy metal and pathogens, therefore suspended solids or turbidity are measures of water treatment plant effectiveness when a high quality effluent is required. High turbidity can decrease the effectiveness of disinfection involving chlorine or ultra violet light.

3.4 Nutrients

Nutrients in effluent such as nitrogen, phosphorus, potassium, magnesium, sulfur and calcium are generally beneficial to plant growth. Nitrogen, phosphorus and sulfur need not be removed from effluent where it can be demonstrated that the land management system effectively uses these nutrients both in the short and long term.

To characterise the nutrient concentrations in the source of effluent, real monitoring data should be used, when available (e.g. detailed monitoring data on sewage treatment plant performance over a number of seasons). Optimal performance of treatment processes should not be assumed and a conservative estimate of treatment effectiveness will help to ensure that ground and surface waters are not contaminated.

When selecting the crop to be irrigated, information on plant nutrient requirements must be obtained. This includes not only total plant requirements but also requirements at critical plant growth periods (e.g. fruiting or flowering). The extent of nutrient recycling for the particular land management system must also be established. Harvesting crops and removing them offsite for 'green chop' or hay results in almost no return of nutrients to the site. But if pasture is grazed, nutrients are returned to the soil through faeces. Grass mown without catchers returns nutrient to the site and deciduous horticultural crops and tree plantations return nutrients when their leaves fall. These nutrient returns must be accounted for in nutrient mass balance calculations (see Section 4.3).

Nitrogen

Nitrogen (N) can be present in organic and mineral forms, the latter including gaseous (N_2), ammonia (NH_3) ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-) and urea (NH_2CONH_2). The relative amount of each of these forms depends on the original constitution of the wastewater, and the treatment and stabilisation processes used.

Total nitrogen concentrations in effluent from municipal sewage treatment plants are generally between 5 and 50 mg/L. Effluent from rural and food processing industries may contain much higher concentrations of nitrogen with total nitrogen in effluent from intensive animal industries likely to vary between 50 and 750 mg/L.

Mineral forms of nitrogen are readily transformed into other mineral forms. Some mineral forms such as nitrate, nitrite and ammonia can be taken up by plants. Nitrate is also readily leached to groundwater. High concentrations of nitrate make waters unsuitable for stock and domestic water supplies, or can nourish unwanted plants and algae. N_2 and NH_3 can be lost to the atmosphere in gaseous form. It is estimated that between 15% (cool climates) and 25% (warm climates) of applied nitrogen in the form of ammonia can be lost to the atmosphere, with up to 50% volatilised under optimal conditions (e.g. fine spray irrigation in hot and low humidity climates), (see also the nitrogen balance sub-section in Section 4.3, Nutrient Loading Rates*)*.

Interactions between organic nitrogen, plant growth and the environment are much slower than for most mineral forms. Organic nitrogen is converted to ammonium and nitrate through mineralisation processes. Table 3.2 shows the estimated mineralisation rates of organic nitrogen in raw wastewater sludge in soil. Effluent can have higher rates in similar soil environments, particularly in the first year. The remaining nitrogen is retained in residual humus, which will continue to decompose and then release inorganic forms of nitrogen. The rate of mineralisation is determined by the initial organic nitrogen and carbon concentrations and by microbial, soil and climatic conditions, but decreases markedly with time. By the fourth or fifth year, only a very small amount, if any, of the original organic nitrogen remains. In most irrigation systems, the organic nitrogen removed through mineralisation is continually replaced by the application of fresh effluent.

Nitrate can be converted to nitrogen gas through the process of denitrification. In soils, the rate of this process is dependent on a number of complex factors including the presence of oxygen, availability of water and carbon sources, and temperature. Denitrification rates are highly variable and under most effluent irrigation conditions the amount of nitrogen lost in this manner is not likely to be significant.

Gaseous losses of nitrogen and the differential rates of movement of the various nitrogen forms must be taken into account when developing nutrient budgets (Section 4). Another factor to consider is that leguminous crops have a lower nitrogen demand (but will absorb N if it is supplied).

Table 3.2: Mineralisation of organic nitrogen in wastewater sludge and effluent in soil

	% original organic nitrogen mineralised	
At end of year	**Raw wastewater sludge**[1]	**Effluent (estimated)**
1st year after application	40	60
2nd year after application	20	30
3rd year after application	10	10
4th year after application	5	0
5th and subsequent years	3	–

Source: Younos (1987).

Phosphorus

Phosphorus (P) concentrations in municipal sewage plants are between 0.5 and 10 mg/L depending on the extent of P removal processes used. Effluent from intensive animal industries and food processing may contain much higher levels of P. For example, total P loads in wastewater from intensive animal industries are likely to vary between 10 and 500 mg/L.

Phosphorus contained in effluent exists in many forms but is normally expressed as total P. The orthophosphates ($H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}) are available immediately for biophysical reactions in the plant-soil-water system. The polyphosphates are broken down more slowly to orthophosphates. Organic phosphates are broken down biologically to polyphosphates and then to orthophosphates.

The major P removal mechanisms in effluent irrigation systems are uptake by vegetation, and soil sorption by chemical precipitation and adsorption to soil particles.

Soil sorption of P (P sorption capacity) is an immobilisation reaction that renders phosphorus unavailable for plant uptake and varies widely from low levels in sandy soils to high levels in strongly weathered clay soils. Soil sorption capacity can be taken into account when developing a nutrient budget.

Further details on P sorption and information that relates phosphorus loadings to the design of irrigation systems are presented in Section 4.

Potassium

Effluent contains potassium, particularly animal effluents and effluent from wool scouring plants. While potassium is an essential nutrient for healthy plant growth, it contributes to the salinity of effluent and in excess can adversely affect the uptake of other nutrients by plants, soil stability and animal health. For example, grass tetany is a condition in dairy cattle associated with imbalances of potassium and magnesium through ingestion of fodder and soil. Salt balances should be determined for all proposed effluent irrigation schemes to ensure that management processes are in place to avoid potassium accumulation. More information on salt balances and salinity is given in Sections 3.7 and 4.4.

Proposals to apply effluent with known high concentrations of potassium such as wool scour effluent should also refer to ARMCANZ and ANZECC (1999) *Effluent Management Guidelines for Aqueous Wool Scouring and Carbonising* (see Further Reading).

3.5 pH

Effluent with a pH between 5 and 8.5 is generally acceptable for use in irrigation. If the effluent is very acidic (pH less than 5), or very alkaline (pH greater than 8.5), it may need to be neutralised before application as soil pH affects the availability of nutrients and other elements to plants.

3.6 Chemical contaminants

Effluent may contain potentially undesirable chemical contaminants, including some metal and chlorinated organic compounds. These contaminants could have an adverse effect on soil and plants if present in elevated concentrations. Maximum loadings for heavy metals and chlorinated organic compounds in topsoil are discussed in Section 4.

Where any chemical compound in effluent exceed limits established by ANZECC and ARMCANZ (2000) Water Quality Guidelines for irrigation, the background level of the chemical compound should be established in soil. In addition, the level of build up of the compound in the soil should be established through a monitoring program (Section 5).

In addition to the above, crops must be selected so that any contaminants, such as heavy metals, do not cause the crop to become unsuitable for human or animal consumption.

Industrial wastewaters containing more than trace amounts of substances such as heavy metals, solvents, chlorinated organic chemicals, agricultural chemical residues or petrochemicals are likely to be classified as a controlled liquid waste and therefore are not suitable for irrigation. Refer to DEC's *Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes* (EPA 1999a) for information on classification of liquid wastes. Wastes that are classified as hazardous, Group A, Group B or Group C, will require an environment protection licence for their generation, storage, treatment or transport.

Metals

Although some metals are essential for plant growth, many are toxic at elevated concentrations and their toxicity may be increased if soil is acidic. Therefore, it is important to establish the average concentrations of metals in irrigation effluent to avoid irreversibly contaminating the irrigation site in the long term.

ANZECC and ARMCANZ (2000) Water Quality Guidelines (for irrigation) identify the maximum concentrations of metals in irrigation waters considered acceptable for continuous use. If concentrations of one or more metals exceed these levels (based on appropriate sampling), then the proponent must examine the potential impact of the metal on the soil and the land management system. Calculations must be made to determine the length of time the effluent can be applied before soil concentrations exceed guideline limits (see Section 4.6 and cumulative concentration limit triggers in ANZECC and ARMCANZ (2000)). The land management system must be able to tolerate the higher levels of metal without detrimental effects.

It is important to regularly monitor the levels of metals which are risk factors in effluent to ensure that it is managed appropriately or as a means of reviewing estimates of the soil/plants capability of immobilising these. Soil and plant monitoring may also be required where metal levels exceed recommended levels for irrigation waters. Monitoring programs in these situations will need to be tailored to evaluate the risk posed by the metal or contaminant for the agronomic system in use. ANZECC and ARMCANZ (2000) Water Quality Guidelines (for irrigation) should be consulted for the context in which the criteria in Table 3.3 should be applied. Further advice is provided in Section 5.3 Monitoring Systems.

Table 3.3: Trigger values for metals in irrigation effluent for long term use on all soil types (up to 100 years)[1]

Metal	Total concentration (mg/L)	Comments
Aluminium	5.0	High toxicity in acid soils. Not a concern if pH of soil is above 6.5.
Arsenic	0.1	
Beryllium	0.1	
Cadmium	0.01	Higher toxicity in acid soils
Chromium VI	0.1	
Cobalt	0.05	
Copper	0.2	
Iron	0.2	
Lead	2	
Lithium	2.5	Citrus: 0.075 mg/L
Manganese	0.2	
Mercury	0.002	
Molybdenum	0.01	
Nickel	0.2	
Selenium	0.02	
Zinc	2.0	1 mg/L recommended for sandy soil below pH 6

Source: ANZECC and ARMCANZ (2000) (Refer to any current Australian Water Quality Guidelines as they are updated and endorsed for use in NSW).

Note: 1. Trigger values should only be used in conjunction with information on each individual element and the potential for offsite transport of contaminants (see ANZECC & ARMCANZ (2000) Volume 3, Section 9.2.5). See also short-term use trigger values (up to 20 years) and cumulative contaminant loading limit triggers in ANZECC and ARMCANZ (2000), Volume 1, Table 4.2.10.

Synthetic organic compounds

Several classes of organic compounds can be found in effluent, including insecticides. Organochlorine (OC) pesticides (such as dieldrin, heptachlor and chlordane) and polychlorinated biphenyls (PCBs), are known to persist in the environment. Many organic compounds have had wide commercial use in Australia. The rate of decay of the organochlorines can vary from place to place, because organic compounds are affected by climate and soil characteristics. Organophosphorus and carbamate insecticides tend to be more readily broken down (hydrolysed) and are less persistent than OC pesticides.

Trace concentrations of these chemicals may be found in effluent from municipal sewage treatment plants and they can be present in effluent from other industries. Many species of wildlife are sensitive to insecticide concentrations that have little or no effect on crops or other plants. One of the major concerns about insecticides in effluent irrigation, therefore, is the contamination of surface and groundwater, and the possible adverse effect on wildlife or soil biosystems that use this water.

It is advisable to conduct periodic monitoring of effluent for the presence of organic compounds. They have caused several contamination crises in Australia's export beef trade during the 1980s and 1990s. Their detection and management is essential for effluent reuse on grazing land.

The total concentration of these organic compounds in effluent should be less than 0.001 mg/l. The concentrations of organic compounds in soil to be irrigated should be established before effluent is applied to minimise the introduction of organic compounds into the food chain. Organic compounds such as phenols and surfactants can be toxic to essential soil organisms. They are usually present in effluent from municipal sewage treatment plants at low concentrations. In industrial effluent they can be present at high concentrations

Herbicides

Herbicides are harmful to plants. Phenoxyacid herbicides, such as 2,4-D and its derivatives, are widely used for weed control. It is therefore possible for these compounds to be in effluent. They degrade rapidly in soil, but can persist in effluent. Where there is a risk that herbicide is present in the effluent, it is advisable to conduct periodic monitoring of effluent for the presence of herbicides as these may interfere with plant growth. See further guidance in ANZECC and ARMCANZ (2000) Volume 1, Section 4.2.8.

3.7 Mineral salts

Effluent contains dissolved mineral salts, including sodium, calcium, potassium, magnesium, boron, chloride, sulfate, carbonate and bicarbonate. Most salts are present in effluent as dissolved ions (charged particles), which can conduct electric current. Irrigating effluent with high electrical conductivity (EC) (or total dissolved solids) concentrations may result in soil salinity.

To assess the salinity and sodicity of water for irrigation use (Section 2.3), a number of interactive factors must be considered. These include: irrigation water quality; soil properties; plant salt tolerance; climate; landscape (including geological and hydrological features); and water and soil management (ANZECC & ARMCANZ 2000).

A primary purpose of measuring the EC of irrigation water is to calculate the average root zone salinity, one of the critical measurements used in salinity assessment and the evaluation of plant salt tolerance. Salinity levels also need to be assessed and monitored in relation to potential impacts on soil structure and on surface and ground water quality from discharges, runoff and leaching.

Other factors that need to be taken into account when identifying salinity risk (further discussed in Section 4) include the:

- extent to which effluent will satisfy the plants total water requirement
- ease with which excess salt may leach through the soil
- sensitivity to additions of salt of any groundwater table below the plant root zone
- relative amounts of plant nutrients in the salt load
- effectiveness of the crop management system in taking up the plant nutrient load
- types of salts and their relative environmental risks
- average rainfall of the site.

A preliminary water salinity rating can be assigned to irrigation waters based on EC (Table 3.4). These ratings provide only a general guide and are not intended to be used on their own to define the suitability of irrigation water. As emphasised, other factors such as soil characteristics, climate, plant species and irrigation management must be considered.

Table 3.4: General irrigation water salinity ratings based on electrical conductivity

EC (dS/m)	Water salinity rating	Plant suitability
<0.65	Very low	Sensitive crops
0.65–1.3	Low	Moderately sensitive crops
1.3–2.9	Medium	Moderately tolerant crops
2.9–5.2	High	Tolerant crops
5.2–8.1	Very high	Very tolerant crops
>8.1	Extreme	Generally too saline

Source: Adapted from DNR (1997), cited in ANZECC and ARMCANZ (2000).

The term 'total dissolved solids' (TDS) is commonly used to express the combined concentration of salts in mg/L. TDS in mg/L may be estimated by measuring the electrical conductivity (EC) of the effluent, in dS/m and multiplying by an empirical factor ranging from 550–900. Conversely, the EC at 25ºC, expressed in units of dS/m, is calculated (with an error of within about 10%) by multiplying TDS, in mg/L, by 0.00155. When converting, the correct conversion factor should be established by measuring both properties at the commencement of any irrigation scheme.

See ANZECC and ARMCANZ 2000 Volume 3, Section 9.2.3 for comprehensive information on sustainable irrigation practice in relation to the affects of salinity.

3.8 Specific ions

The major ions that need to be considered when effluent is used for irrigation are chloride, sodium, bicarbonate and boron. See also ANZECC & ARMCANZ (2000) Volume 3, Section 9.2.4 for further guidance.

Sodium

Sodium salts are of particular concern, as excessive sodium levels relative to calcium and magnesium can adversely affect plant growth, soil structure and permeability. As discussed in Section 2.3, sodicity is a condition that degrades soil properties by making the soil more dispersible and erodible, restricting water entry and reducing hydraulic conductivity (the ability of the soil to conduct water). These factors also limit leaching so that salt accumulates over long periods of time, giving rise to saline subsoils. Furthermore, a soil with increased dispersibility becomes more susceptible to erosion by water and wind.

Both the sodium concentration and the sodium adsorption ratio of effluent must be determined.

Sodium adsorption ratio (SAR) is the relative proportion of sodium ions (Na^+) to both calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) as shown in Equation 1.

Equation 1: Sodium Adsorption Ratio (SAR)

$$SAR = [Na^+] / (([Ca^{2+}] + [Mg^{2+}])/2)^{1/2}$$

Where:

Na = sodium ion concentration (conc.) (meq/L) = (mg/L in effluent)/22.99

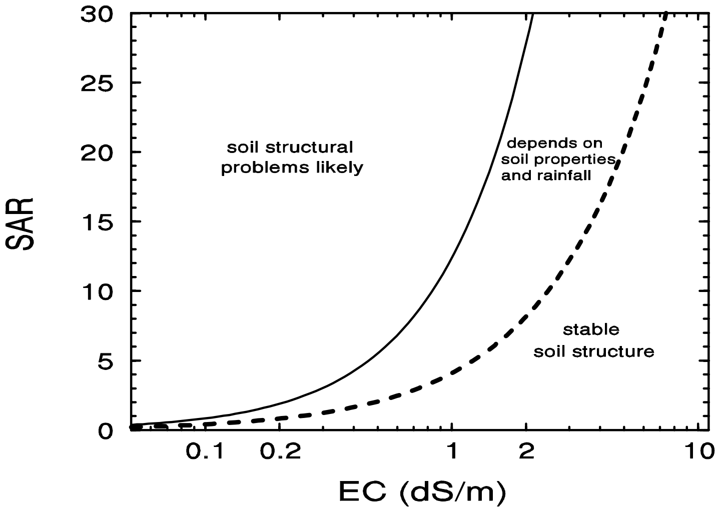
Ca = calcium ion conc. (meq/L) = (mg/L in effluent)/(40.08 x 0.5)

Mg = magnesium ion conc. (meq/L) = (mg/L in effluent)/(24.32 x 0.5)

The effects of sodium on different plants are given in the ANZECC and ARMCANZ (2000) Volume 3, Section 9.2.4.3.

Figure 3.1 shows the general relationships that can be established for many soils which indicate the combination of irrigation water EC and SAR where these dispersion problems are most likely to occur.

Figure 3.1: Relationship between SAR and EC of irrigation water for prediction of soil structural stability



Source: Adapted from DNR (1997), cited in ANZECC and ARMCANZ (2000).

Water compositions that occur to the right of the equilibrium lines (in Figure 3.1) are considered satisfactory for use, provided the SAR is not so high that severe dispersion of the surface soil water will occur following rainfall. Water quality that falls to the left of the solid line is likely to induce degradation of soil structure and corrective management will be required (e.g. application of lime or gypsum). Water that falls between the lines is of marginal quality and should be treated with caution and specifically managed with reference to soil properties.

Soil permeability and aeration problems can occur when it is irrigated with water that has a SAR above 6. There is evidence that these problems may increase with an increasing ratio of magnesium to calcium. Soils with a low cation exchange capacity will become sodic more quickly than soils with high CECs. These latter soils may become sodic with effluent SARs of between 3 and 6. Where effluent SAR is high, calcium in the form of lime, gypsum, ash or organic matter can be applied to the irrigated soil to counteract the potential negative impacts on soil structure.

Chloride and chlorine

Chloride is essential to plant growth. In excess, however, it can be toxic (see ANZECC and ARMCANZ 2000 (Volume 3, Section 9.2.4.2) for levels of chloride in effluent that can affect plant growth). In general, most woody plant species including eucalypt and pine plantations, stone fruit, citrus and avocados are sensitive to relatively low concentrations of chloride, whereas most vegetable, grain, forage and fibre crops are less sensitive.

Chloride damage to plants can occur in two ways. First, the chloride ion can be taken up by the roots and moved upwards to accumulate in the leaves. Excessive accumulation can cause burning of leaf tips or margins, bronzing and premature yellowing of leaves. Second, direct foliar absorption of chloride from sprinkler irrigation can cause damage especially on fruit trees, which are more sensitive. Generally, these effects are minimised with night applications and when water is applied at a rapid continuous rate, providing that care is taken to prevent soil erosion.

Chlorine may be added to some effluent to ensure a residual disinfection process if effluent is being delivered through long pipes. Chlorine levels in excess of 1 mg/L may affect some sensitive horticultural crops, nursery plants and cut flowers. For other crops it is likely that levels up to 5 mg/L would be acceptable.

Alkalinity

Except when applied to soils that are strongly acidic, highly alkaline effluent can adversely affect the availability and uptake by plants of calcium, magnesium and some trace elements by increasing the soil pH to levels greater than 7.5. At high pH, calcium, for example, can be precipitated as a salt. This loss of calcium accentuates the imbalance of exchangeable ions in favour of sodium, increasing the soils exchangeable sodium percentage (ESP). With time, this process will have a detrimental effect on soil structure, and will reduce the permeability of the soil.

Bicarbonate

High concentrations of bicarbonate in effluent can lead to a high concentration of bicarbonate in the soil water where it may be concentrated through the process of evapotranspiration. There is then an increased tendency for calcium and magnesium to precipitate as insoluble salts. Over time, this reduction in available calcium and magnesium will result in an increased SAR, which can adversely affect soil structure and could cause a sodium hazard.

Boron

Boron is an essential micro-nutrient for plants, however, at high concentrations it can be toxic (see ANZECC & ARMCANZ (2000) Volume 3, Section 9.2.5.6). It is also likely to remain in the soil solution and move into the groundwater because soils have a very limited capacity to absorb boron.

Fluoride

Fluoride is contained naturally in soils and in fresh water, but excess intake in plant material or soil by grazing cattle has detrimental effects on their health. Fluoride may be present in effluent and has the potential to bind to and accumulate in soils irrigated with effluent over extended periods. However, there are insufficient data from Australian soils to prescribe soil loading limits or to determine bioavailability (ANZECC and ARMCANZ 2000). Stock health monitoring procedures for effluent irrigation schemes should include checks for symptoms of excess fluoride in animals grazing treated paddocks and any suspect animals referred to the NSW Department of Primary Industries.

3.9 Oil and grease

Oil and grease in effluent can block irrigation systems, and more importantly block soil pores subsequently causing anaerobic conditions in the soil which will both reduce plant growth and potentially create odours. The rate of decomposition of oil and grease depends on soil and climatic conditions as well as the nature of the oil/grease product. Well-aerated soils in warm humid climates maximise the break down of oil and grease.

3.10 Treatment and disinfection

The major risk associated with human or animal contact with effluent are from infection by microorganisms, such as bacteria (e.g. Salmonellae), viruses (e.g. *Hepatitis sp*.), protozoa (e.g. Giardia and Crytosporidium) or helminths (tape worms). The risks to humans and the risk to animals are greatest when the effluent contains pathogens derived from the same species of animals. However, some pathogens (e.g. *Cryptosporidium parvum* and the helminth *Taenia saginata*) can infect both humans and animals and appropriate precautions must be taken.

Populations of microorganisms in wastewater are reduced when required, through the treatment process, including screening, ponding, filtration, artificial wetlands, and chlorine, ozone and ultraviolet treatments. The likely level of pathogens in the final effluent product is assessed by knowledge of the specific treatment processes and by measurement of indicator organisms such as faecal (or thermotolerant) coliforms.

The levels of treatment of effluent required depends on the end use of the plant being irrigated (e.g. a fresh food crop is more sensitive than a tree crop grown for timber); whether or not humans or animals can be excluded from the irrigation area for a period of time (withholding period); and the potential for the pathogens in the effluent to infect humans or any animals.

NSW Health should be consulted in regard to the level of treatment of effluent to be achieved when public health could be at risk through contact with irrigated effluent or products that have been produced with irrigated effluent. Advice also should be sought from the NSW Department of Primary Industries on levels of protection required to protect animal health. Levels of disinfection should be similar to those in Appendix 1 (which apply to spray irrigation of municipal sewage effluent) to achieve the same end-point criteria (depending on the end use of the effluent).

The provision of safeguards and controls (barriers) in the design and operation of the irrigation scheme may also be considered when determining the appropriate level of treatment for a proposed application. Risks can be mitigated by provision of barriers, such as reliable treatment processes; withholding periods; buffer zones between irrigation sites and public areas or sensitive water bodies; effluent application controls (e.g. to prevent spray drift); and restrictions on crops that may be irrigated. Surface pooling of effluent should be avoided as it may increase the risk of transmission of diseases (and chemical residues) to grazing animals, pets, birds and native animals.

Municipal sewage effluent

Municipal sewage effluent potentially contains large numbers of pathogens with the ability to infect humans. A number of disinfection treatments are available (including chlorine, ozone, UV radiation and membrane filtration to reduce pathogen levels). Properly applied, they are capable of reducing pathogens (as indicated by thermotolerant coliform or numbers) to acceptable levels for effluent irrigation (see Appendix 1).

Proposals for effluent irrigation systems where disinfection is necessary must include information on the scope and reliability of the proposed disinfection technique to be used. The latter should include an explanation of any limitations and means of demonstrating performance associated with the process chosen.

Because there are potential health and environmental risks associated with the use of effluent, DEC, in consultation with NSW Health, has carefully outlined the circumstances and conditions under which such schemes should operate. Appendix 1 outlines the treatment, disinfection and irrigation requirements when using treated sewage effluent for spray irrigating recreation areas and land used for landscaping, agriculture, forestry, turf and crops. These requirements are based on national Guidelines for Sewage Systems—Reclaimed Water (ARMCANZ, ANZECC & NHMRC 2000).

A number of other steps also can be taken to reduce public health and environmental risk and therefore reduce legal liabilities for effluent irrigation schemes. These can include developing a quality assurance program that covers record keeping, monitoring, reporting and auditing of effluent irrigation activities. Risk management considerations are incorporated throughout the Guidelines, in particular, Section 5, Operation and Management.

Other effluent types

For other types of effluent, such as those derived from dairies, intensive animal industries, food industry, tanneries and abattoirs, solids removal followed by ponding is normally necessary to ensure effluent can be effectively irrigated. Disinfection, in a manner similar to sewage effluent, may not be necessary in all circumstances. Management practices to prevent risks to public health or to animals are necessary in some cases (see Section 5). Advice from NSW Health should be sought wherever there is a potential risk to public health. Veterinary advice should be sought where there is any doubt about risks of animal disease.

3.11 Other factors

Where effluent is likely to have very high levels of certain constituents, other processes than irrigation may be considered.

For example, effluent from woolscour plants may contain high levels of potassium. It may be better to treat this product as a potassium fertiliser rather than as a source of water.

In some cases industry has the ability to control inputs into the waste stream, so as to produce a better quality effluent (e.g. where there is extensive detergent use, selection of low phosphorus and sodium detergents will reduce the risk of producing a high phosphorus or SAR effluent). This is particularly important where industry uses high levels of potential environmental contaminants.

4. Design Considerations

Effluent irrigation systems should use best management practices to optimise the use of the water, nutrients and organic matter. For an effluent irrigation system to be ecologically sustainable, the irrigated plants and environment must not become stressed by the effluent or by the organic, nutrient or chemical loadings applied.

The amount of water, nutrients and organic matter for optimum sustainable production of any given cropping system will be a function of the crop or cultivar, the agronomic system employed, and site-specific factors such as climate, topography and soil.

Licensing considerations in the design process

Most effluent reuse activities do not need to be licensed by the EPA[2] (see Section 6). For example, where the potential for reuse of effluent is optimised, a licence may not need to be issued by the EPA for a particular effluent producing activity. In this case the proponent of the scheme must demonstrate that there is sufficient land area and wet weather storage provided to ensure a sustainable effluent irrigation scheme without the need for regular discharges to waters. This is known as a full reuse scheme (Section 4.2).

In other cases an effluent irrigation scheme may be a part of an effluent management strategy for an effluent producing activity; for example a golf course that takes effluent on an as needs basis from a local STP with any remaining effluent discharged by the STP to a waterway. The discharge part of the scheme is likely to be licensed, but the effluent irrigation area may not require a licence unless there is a likelihood of effluent being discharged from the site. These latter types of schemes are `partial reuse' schemes (see Section 4.2). In this case it is still necessary to ensure that the irrigation activity is sustainable by modelling the fate of water, nutrients, salt and other contaminants. In addition, if the daily flow is insufficient to meet peak irrigation demands, a storage may need to be constructed to ensure the activity has sufficient effluent to ensure good plant growth all year.

Load-based licensing

Industry groups that are included in the load-based licensing (LBL) scheme administered by DEC and who reuse effluent can obtain a discount on the pollutant load fee where effluent is reused in a sustainable manner. The LBL protocol (EPA 1999b; and Appendix 2) provides background information on the circumstances under which a fee reduction can be claimed. The design

[2] The EPA is a statutory body with specific powers under environment protection legislation. In September 2003, the EPA became part of the Department of Environment and Conservation (DEC).

process for reuse schemes should take into account the savings available under LBL. Current LBL protocols should be consulted.

The use of models in design

Models are used to predict sustainable land areas and wet weather storage requirements for a specific effluent irrigation scheme. They can also be used to identify the key risks of the scheme and therefore the need for additional controls such as buffer zones, low impact irrigation systems, leaching requirements, runon and runoff controls. Models rely on carefully collected and comprehensive baseline data on site features (Section 2), including some or all of:

- effluent flow rate and quality
- climate
- plant type and proposed plant management
- landform, soil properties
- the proposed irrigation system.

The construction of models to determine the properties of an irrigation scheme that maximises reuse of effluent will differ from a model used to assess a partial reuse scheme.

Other design considerations

Other issues to consider in design include the:

- provision of buffer zones to surface and groundwater bodies, occupied dwellings, property boundaries and other areas where spray drift or runoff and percolation of effluent could have an adverse impact
- location of any wet weather storage so as to minimise impacts from any necessary discharges
- works associated with soil and water management on the property including works to minimise runon and runoff from the irrigation area
- type of irrigation system and associated electricity supplies, pumps and pipework
- location and size of pipes transporting effluent to the irrigation area.

4.1 Calculating land area and storage requirements

Full reuse schemes

In an irrigation scheme that fully uses the effluent (thereby minimising the need for discharges to water), the area required for irrigation is determined by calculating the limiting land area using a water, nutrient or contaminant balance. The limiting land area is the largest land area required to satisfy any single water, nutrient or contaminant balance to ensure a sustainable irrigation scheme. The size of wet weather storage is then calculated from the water balance using the calculated minimum land area and the allowable discharge frequency, which is determined from the strength of the effluent and any additional management practices or issues that reduces effluent strength or impacts.

Partial reuse schemes

In a partial reuse scheme, the available land area is usually pre-determined. In this case calculations are made to determine the sustainable load of water, nutrient and effluent contaminants that can be applied without nutrients, salt, metals etc. degrading or contaminating the surrounding environment. The storage is sized so that a reasonable level of plant growth is maintained throughout the year and/or to provide effluent storage capacity during particularly unfavourable effluent discharge conditions (eg. low river flows). Effluent is either received from the source 'on demand' or excess effluent is discharged.

4.2 The water balance

To have an effective effluent irrigation system, it is essential that the correct amount of effluent is applied at the right times to meet the crop requirements while ensuring increases in runoff and percolation are minimised.

A water balance should be constructed to determine the maximum volume of effluent that could be sustainably used on average each year. The elements to be considered in a water balance are:

- precipitation
- effluent applied
- evapotranspiration
- percolation
- runoff.

Significant amounts of percolation and runoff occur as a result of natural rainfall events. However, to ensure a sustainable system, percolation and runoff should not increase significantly above rain fed conditions thereby increasing the risk of pollution and changes in catchment hydrology.

The water balance is generally expressed as follows:

Equation 2: Water balance

$$\textit{Precipitation} + \textit{Effluent applied} = \textit{Evapotranspiration} + \textit{Percolation} + \textit{Runoff}$$

Precipitation

The rainfall data over a historical period is used. This data can be obtained in monthly or daily format from the Bureau of Meteorology.

Effluent applied

The amount of effluent to be applied can be expressed as volume (ML). Seasonal variations in effluent volume must be taken into account together with any impacts on effluent volume as a result of significant rainfall events.

Discounting for losses from spray irrigation can be used with caution when it is obvious that some water will be lost for example during low humidity and high temperature. However, for the amount that evaporates before reaching the ground, there will be a similar reduction in available evaporation. Therefore any estimated allowance for spray losses must be accompanied by an estimated reduction in evaporation and must be seasonally adjusted based on an analysis of local data.

Evapotranspiration

This will vary throughout the year depending on temperature, humidity, solar radiation, wind, crop type and crop growth patterns. It can be estimated by multiplying daily or monthly evaporation values for a district by the appropriate crop factor for the particular species of plant to be grown.

The crop factor takes into account plant productivity, and the meteorological factors. Some crop factors are given in Table 4.1. However, as they can be highly variable, they are a generalised guide only and will not be suitable for all circumstances. Myers et al. (1999) includes crop factors for locations in addition to Wagga Wagga. It is recommended that proponents consider site-specific conditions when adopting crop factors used for water balance determination. A useful source of information on crop water use is Doorenbos and Pruitt (1977).

Table 4.1: Crop factors[1] for some crops, trees and pasture

Crop	J	F	M	A	M	J	J	A	S	O	N	D
Lucerne	.95	.90	.85	.80	.70	.55	.55	.65	.75	.85	.95	1.00
Citrus	.55	.55	.55	.55	.50	.50	.50	.50	.55	.55	.55	.55
Grape-vines	.60	.60	.50	.40	.25	.20	.15	.20	.25	.40	.55	.60
Deciduous orchard	.75	.65	.45	.25	.15	.10	.15	.20	.30	.50	.70	.75
Pasture	.70	.70	.70	.60	.50	.45	.40	.45	.55	.65	.70	.70
Eucalypt plantation[2]	.78	.84	.94	1.17	1.21	1.15	1.13	1.33	1.33	1.26	.99	.83

Notes: 1. Crop factors are expressed as the ratio of crop evapotranspiration to pan evaporation.

2. At Wagga Wagga – Source: Myers et al. (1999). Humidity has a profound influence on the crop factor of eucalypts and values only suit climates similar to Wagga Wagga.

Crop factors are sometimes expressed on different bases. Some are expressed as the ratio of crop evapotranspiration to pan evaporation while others are expressed as the ratio of potential evapotranspiration to crop evapotranspiration. The difference between pan evaporation and potential evapotranspiration is known as the pan factor. Care should be taken when using crop factors to ensure that the correct factor is used for the calculation being carried out.

Percolation

Percolation is the movement of water down through the soil profile and is a natural phenomenon after any rainfall event that exceeds the soil moisture deficit. An irrigated site will have more percolation than a site with rainfall only. Percolation is a process that prevents build-up of salt in the root zone. In humid coastal and mountain areas percolation due to natural rainfall may be sufficient to prevent salt build up, but in dry climates, a small fraction of irrigated effluent may be all that is required to leach salts out of the root zone. The need for deliberate percolation of effluent will also depend on the salt tolerance of the plants and the salt concentration in the irrigation effluent. Percolation must not simply be used as a means to dispose of effluent to the environment as there is potential for other pollutants (e.g. nitrates) to be leached in addition to salts.

The rate of salt accumulation depends on a number of factors including the effluent salinity, hydraulic loading, rainfall and resulting natural leaching. One simple method for determining the fraction of irrigation water required to leach salts is to use the following equation:

EC (irrigation water) ÷ EC (50% yield reduction)

Where:

EC (irrigation water) = electrical conductivity (dS/m) of the irrigation water

EC (50% yield reduction) = electrical conductivity (dS/m) of the drainage water at which the relative crop yield is reduced by 50% (Tables 4.4 and 4.5).

For example, if EC (irrigation water) is 0.75 dS/m (TDS = 450 mg/L) and EC (50% yield reduction) is 8.8 dS/m (TDS = 5,280 mg/L), then the required fraction is 0.085. If the annual effluent application is 800 mm, then the annual leaching requirement is 68 mm (0.085 x 800). This value can be included in calculating area and land requirements using a monthly water balance (e.g. ERIM). This method makes a number of simplifications, most importantly the dilution of the effluent salt load and the increased hydraulic load provided by rainfall are not included. For most systems however, these simplifications do not significantly effect the estimation of the leaching fraction, which is usually found to be less than 0.1.

A number of methods to estimate leaching fraction are available and the most suitable should be used in each case, taking into account site-specific information. For example, a daily water balance, which includes algorithms to model the movement of water through the soil, can be used to estimate the need, if any, for deliberate leaching events using effluent. However, the most direct way to determine the need for deliberate leaching is to monitor salt levels in the lower part of the plant root zone. If these start to increase to above acceptable levels then leaching is required.

Runoff

Irrigation tends to increase runoff due to the reduction in the amount of rain needed to saturate soil to a point where runoff occurs. Therefore, runoff as a result of irrigation with effluent should be set to zero in a water balance. This will provide a safety factor to ensure that runoff is not used as a means to dispose of the effluent to the environment and ensure that runoff does not increase significantly above the natural baseline. Runoff, however, will occur during protracted or heavy rain. Runoff from irrigation areas also should be controlled and managed to limit soil loss and export of nutrients from the site.

Effluent storage

The effluent storage is also a key component of the water balance and can be used to optimise the land area required to satisfy water demand requirements. Section 4.7 provides information on modelling storage and land area requirements for a sustainable water and nutrient reuse.

Full reuse

Where there is to be no effective discharges of effluent to waters, adequate capacity to store effluent must be calculated from the water balance. The strength of the effluent (Section 3 and Table 3.1) is used as a tool to determine the allowable frequency of uncontrolled discharges which inevitably occur as a result of prolonged rainfall events. As a general guide, for low strength effluents, uncontrolled releases may be permitted in 50 percent of years. For medium and high strength effluent, discharges may be limited to 25 and 10 percent of years respectively. It should be noted, for example, that a 60th percentile storage requirement could be applied where the effluent is marginally stronger than the low strength (See also Section 4.7, Models). In some situations, either the strength of the effluent and/or the sensitivity of the receiving environment may be such that there should be no overflows (or less frequent overflows than those provided above as guidance) from the storage to the environment.

Partial reuse

In a partial reuse scheme wet weather storage is considered if the daily effluent flow rate is less than the irrigation demand during periods of peak plant water demand, or the effluent manager wishes to only discharge effluent under certain receiving water conditions.

The water balance can be used to calculate the monthly (or other time period) irrigation demand. The time period with the greatest irrigation demand is then compared with the actual effluent flow rate over the same time period. If the flow rate is less than the plant irrigation demand then the proponent of the scheme may choose to construct a wet weather storage to ensure that plant growth is maintained at this critical time.

Storage construction

Advice should be sought (from DIPNR, NSW Department of Primary Industries or professional engineering services) on techniques to build effluent storages to prevent failure and leakage. Overflows should have a properly constructed overflow point from the storage facility to ensure control of the overflow. Where licensed, DEC may require monitoring and reporting of overflows.

4.3 Nutrient loading rates

The loading rates of nutrients such as nitrogen and phosphorus can limit the quantity of effluent to be used for irrigation in a given area.

Under most conditions, the rate of nutrient application would need to be predicted using a nutrient balance before any scheme commences.

In a nutrient mass balance, the amount of the specific nutrient assumed to be applied in a year is compared with the amount taken up by the biological or physical processes of the crop-soil system.

Nitrogen and phosphorus retained in a standing or residual crop, as well as faeces and urine produced by grazing animals must be regarded as potential sources of soluble nitrogen and phosphorus, which could pollute surface and groundwater. Total harvesting of plants will, therefore, extend the effective life of the site.

Table 4.2 summarises the removal of nutrients by selected crops. These values should be treated as indicative nutrient uptakes only as they are affected by soil and climatic conditions and can vary considerably. Accurate and current local yield information should be used in nutrient balance calculations, where available (e.g. typical yields from other irrigation sites in a region). Actual crop yields should be monitored during operation to ensure that the figures in the nutrient balance calculations are correct.

Where nutrient balances show there is a potential for nutrient to leak below the plant root zone, groundwater monitoring will need to be considered. Where there are risks of runoff to waterways, surface water monitoring also may be applicable (see Section 6).

Table 4.2: Yield and nutrient content of crops in NSW for cultivation under irrigation with effluent

Grain Crop	Area	Average grain yield (tonnes/ha dry matter)	Nitrogen %	Phosphorus %	Potassium %
Barley	State-wide	3.5	1.8	0.4	0.69
Canola	Central–west South–west slopes	2.8 2.8	4.6	(0.7)[1]	(0.7)
Faba beans	North–west Riverina	2.0 2.0	4.1	0.5	1.5
Grain sorghum	North-west Central west Riverina	2.5 2.5 2.8	2.1	0.3	0.3
Lupins	Central west South-west	1.5 1.5	5.0	0.5	0.8
Maize	North-west Central west Riverina Coastal	5.8 5.6 7.0 7.0	1.6	0.3	0.5
Oats	State-wide	4.0	1.7	0.4	0.4
Field pea	State-wide	1.0	4.0	0.2	1.4
Soybean	North-west Riverina	3.2 3.2	6.6	0.6	1.7
Summer grain legumes: cowpeas, mungbeans, pigeon peas	State-wide	1.0	4.0	0.2	1.4
Sunflower	North-west Riverina	1.2 1.7	5.2	(0.6)	(0.7)
Triticale	Central west South-west	2.3 2.1	2.0	0.4	0.6
Wheat	State-wide	4.0	1.9	0.4	0.6
Forage millet (pennesetum)	State-wide	10	1.7	(0.2)	(1.9)
Forage sorghum	State-wide	15	1.8	0.3	1.9
Maize	State-wide	25	1.1	(0.2)	(1.0)
Summer grain legumes	North	3.0	1.7	(0.4)	(2.4)
Winter cereals	State-wide	5.0	1.5	0.3	1.4
Winter grain legumes	State-wide	4.0	2.7	0.3	1.6
Wheat straw	State-wide	5.0	0.5	0.1	1.3

Table 4.2: Yield and nutrient content of crops in NSW for cultivation under irrigation with effluent (continued)

Grain Crop	Area/season	Average grain yield (tonnes/ha dry matter)	Nitrogen %	Phosphorus %	Potassium %
Barley straw	State-wide	14.0	0.5	0.1	0.4
Oat straw	State-wide	5.0	0.7	0.1	2.4
Lupin straw	State-wide	0.5	0.6	0.05	0.9
Pea straw	State-wide	0.5	1.1	0.1	1.3
Triticale	Central West South-west	6.0 6.0	0.5	0.1	0.5
Grain sorghum	North-west Central west Riverina	3.0 3.0 3.5	(1.2)	(0.2)	(1.2)
Maize	North-west Central west Riverina Coastal	7.0 7.0 9.0 9.0	(0.9)	(0.3)	(2.2)
Soybean	North-west Riverina	5.0 5.0	(0.8)	(0.1)	(0.6)
Kikuyu	Sept–Mar	20	2.6	0.3	2.8
Phalaris	Mar–Nov	12	1.1	0.3	2.8
Perennial ryegrass	Mar–Dec	12	3.5	0.3	2.0
Fescue	All year	14	2.4	0.4	2.1
Lucerne	All year	20	3.5	0.4	2.5
White clover	Sept–Feb	20	3.7	0.4	2.6

Source: NSW Agriculture (1997).

Notes: The likely yield and growth period will vary between districts and will be affected by such factors as irrigation efficiency, soil type, variety, nutrition and grazing management where appropriate.

Figures in brackets are estimated values.

Nutrient removal may be estimated by multiplying nutrient concentration by yield.

Nitrogen balance

The behaviour of nitrogen in plant-soil systems is complex and includes additions and losses to the system as well as transformations of the forms of nitrogen. Additions of nitrogen to the system include effluent, fertiliser and nitrogen fixation by plants. The processes that reduce nitrogen include: removal of harvestable plant matter from the system; volatilisation of ammonia; and denitrification of both nitrate and nitrite to gaseous nitrogen forms. Nitrogen can also be stored in the system, for example as residue left on the ground or as humus in the soil.

Nitrogen inputs should be compared with nitrogen losses. A simple approach to the nitrogen balance is to compare the total nitrogen usage of each cultivated crop with the amount of total nitrogen available. This is a conservative approach that can be useful to ensure long-term sustainability as the total nitrogen applied plus mineralisation will balance the nitrogen removed by the harvested plants. Little information is available on nitrogen loss by denitrification but it is known to be highly variable and should not be included in the nitrogen balance unless sound information is available. Under some conditions denitrification rates will be low which can lead to excess nitrogen in the system. On the other hand, the amount of nitrogen volatilised as ammonia is significant. This varies depending on climate conditions and the irrigation method used (15% volatilisation in cool climates and up to 25% in warm climates). Under optimal volatilisation conditions (eg. fine spray irrigation in hot and low humidity climates), up to 50% volatilisation may occur.

It is important that nitrogen from any other source, such as fertiliser application or nitrogen fixation, be included when calculating agronomic rates in systems. Nitrogen storage is not included in the nitrogen balance calculation, except for forestry, as it will reach steady state for cropping systems.

Equation 4, below, shows the nitrogen (N) available for plants during the application year. Equation 5 shows the N available from that same effluent in subsequent years. When annual applications are planned, it is necessary to repeat the calculations using Equation 6 to determine the total available-N in a given year. These results will converge on a relatively constant value after five to six years if the effluent characteristics and application rates remain relatively unchanged.

Equation 4: Available nitrogen in application year

$$[NE] = [NO_3\text{-}N] + (1-kv)[NH_4\text{-}N] + f_y\,[NO\text{-}N]$$

Where:

$[NE]$ = *plant-available nitrogen in the effluent during the application year in mg/L or equivalently kg/ML effluent*

$[NO_3\text{-}N]$ = *concentration of nitrogen as nitrate in the effluent in mg/L*

kv = *fraction of ammonia volatilised*

$[NH_4\text{-}N]$ = *concentration of nitrogen as ammonium in the effluent in mg/L*

f_y = *mineralisation fraction for organic nitrogen in each year (Table 3.2)*

$[NO\text{-}N]$ = *concentration of nitrogen as organic nitrogen in effluent in mg/L.*

Total available nitrogen in any year also includes the mineralisation of residual organic nitrogen from all previous years.

Equation 5: Total available nitrogen

$$TNE_y = [NO_3\text{-}N] + (1\text{-}kv)[NH_4\text{-}N] + f_y\,[NO\text{-}N]_y + f_y\,(1\text{-}f_{y\text{-}1})[\,NO\text{-}N]_{y\text{-}1} + f_y\,(1\text{-}f_{y\text{-}1})(1\text{-}f_{y\text{-}2})[\,NO\text{-}N]_{y\text{-}2} + \ldots + f_y\,(1\text{-}f_{y\text{-}1})\ldots(1\text{-}f_1)[\,NO\text{-}N]_1$$

Where:

y = number of years in the simulation where year 1 is the first year of irrigation;

TNE_y = *total plant-available nitrogen in year y including mineralisation of residual NO from the previous year in kg/ML; and*

$[NO\text{-}N]_x$ = *the concentration of nitrogen as organic nitrogen in year x in mg/L.*

Other terms as already defined.

The calculation should be carried out for the number of years in the sequence until either the first year of application is reached or the additional terms going back in history become insignificant.

Equation 6: Nitrogen-limiting loading

$$R_y = U/TNE_y$$

Where:

R_y = *annual effluent loading in year y in ML/ha/yr*

U = annual crop uptake of nitrogen in kg/ha/yr (Table 4.2)

For irrigation systems where the nitrogen loading rate is the limiting factor, the nitrogen removal capacity of the crop should be estimated by the nitrogen content of its harvestable portion (see Table 4.2).

The above equation is one example of a nitrogen budget. Proponents of effluent irrigation schemes may seek advice from suitably qualified persons who may have different methods for estimating nitrogen balances.

For reuse schemes subject to load-based licensing, the nitrogen balance can be a factor in fee discount calculations. Load-based licensing protocols should be consulted for more detail on how nitrogen balance calculations are undertaken for industry groups included in the load-based licensing scheme.

Phosphorus compounds

The capacity of an irrigation system to use nitrogen can be maintained and restored over time since the removal of nitrogen from effluent largely depends on biological processes. In contrast, phosphorus (P) is removed from effluent through biological, chemical and physical processes in the soil. The existing P sorption capacity of the soil and the P uptake by the plants to be grown determines how much P can be introduced before the site is saturated. Soils with a high degree of pedality (or cracking soils) or major geological discontinuity (identified in the planning process) could act as a conduit for phosphorus rich effluent to enter a valuable water resource. This information gives an idea of how to sustainably manage an irrigation site over the long term.

For schemes subject to load-based licensing, the phosphorus balance is a factor in fee discount calculations. Load-based licensing protocols should be consulted for more detail on how the phosphorus balance is considered in fee calculations.

Table 4.3 shows the range of potential P sorption capacities measured from several NSW soils. Where nutrient budgets show that more P is being applied than is capable of being removed by the crop management system, assessments of P sorption capacity should be made. At the time of writing there is no universal agreement as to the best method for measuring soil P sorption capacity and advice should be sought from recognised laboratories and/or environmental scientists.

The phosphorus saturation point of most soils is probably reached between 0.25 and 0.5 of total sorption capacity (Kruger et al. 1995). If application of P exceeds this threshold, both runoff and leaching of phosphorus to surface and groundwater may occur.

When calculating the amount of P that can be sustainably applied to land, the percentage of total sorption capacity at which phosphorus leaching occurs (sorption saturation point) should be calculated and used. Other site specific details such as soil depth should also be used. The depth of the crops active root zone will determine the soil depth from which phosphorus can be used by plants and therefore removed from the site by harvesting the crop.

Example of a phosphorus sustainability calculation

Assumptions:

- Phosphorus sorption capacity = 350 mg/kg
- Phosphorus sorption capacity (critical) = 117 mg/kg (for most soils, the strength of P sorption is low to moderate, so in this example only about one third of the P sorption capacity can be used before some leaching of P occurs).
- Soil depth = 1 metre (m)
- Soil density = 1,300 kg/m^3
- Land area for irrigation = 40 ha
- Total P in applied effluent = 8 mg/L
- Volume of effluent at 1 ML/day = 365 ML/yr

Calculations:

Total P adsorbed before leaching:

= P sorption capacity (critical) x soil density x soil depth x 40 Ha

= 117 mg/kg x 1,300 kg/m^3 x 1 m x 40 Ha x 10,000 m^2 /Ha x 10^{-6}mg/kg

= 60,840 kg

Total orthophosphate in applied effluent per year

= 8 mg/L x 365,000,000 L

= 2,920 kg

Total P removed by crop per ha per year = 25 kg
Therefore total P removed by crop per 40 ha per year = 1,000 kg

Site irrigation period:

= (60,840 kg)/(2,920 kg/year - 1,000 kg/year)

= 31.7 years

Physical and chemical soil reactions provide significant phosphorus removal pathways, but are not necessarily renewable. Thus, applying effluent with a very high phosphorus concentration could shorten the useable lifetime of the site. For schemes subject to load-based licensing, the current load-based licensing protocol should be used to determine timeframes for calculating the sustainable assimilation of nutrients, on which to base nutrient application rates. Phosphorus use can be maximised by harvesting crops from the site.

Efficiency increases with the number of harvests that can be achieved per year. Ideally, phosphorus removal by harvesting should be based on the portion of the crop that can be harvested.

Table 4.3: Phosphorus adsorption potential of NSW soils (1m depth)

Location	Soil parent material	Soil classification	Total P sorption capacity (kg/ha)	P sorption capacity (critical) (kg/ha)
Sydney Basin	Hawkesbury sandstone	Soloth	5,440	2,700
Sydney Basin	Hawkesbury sandstone	yellow earth	13,600	4,600
Sydney Basin	Wianamatta shale	red podzolic soil	13,110–15,005	4,000–5,000
Sydney Basin	Wianamatta shale	Soloth	>12,015	>4,000
Coastal	sand dune	siliceous sand	25–130	25–36
South coast	Tertiary alluvial sediments	yellow earth	3,500	1,700
South coast	Holocene sand dune	siliceous sand	>150	>50
South coast	Ordovician metasediments	yellow podzolic soil	13,500	5,000
South coast	Ordovician metasediments	yellow orange podzolic soil	7,475–13,450	2,500–4,400
Central west	alluvial sediments	red earth	3,060–3,375	1,000
South-west	alluvial sediments	red-brown earth	6,070–6,830	2,000–2,300
North-west	alluvial sediments	brown cracking clay	4,305–6,130	1,000–1,900
North-west	alluvial sediments	grey cracking clay	4,980–6,870	1,500–2,100
North-west	Tertiary volcanics	structured red earths	4,510–6,360	1,500–2,100

Source: Kruger, Taylor & Ferrier (eds) (1995).

Nutrient imbalances

Effluent can supply some or all of the essential nutrients for healthy plant growth, but these are usually not supplied in the correct ratio. It might be necessary to diagnose nutritional disorders in soils and crops, and determine corrective action. It may also be necessary to add fertilisers to promote plant growth so that nutrient removal from the site is efficient. The advice of NSW Department of Primary Industries or other professional agronomists should be sought on this. Some crops (e.g. wine grapes) have particular nutrient requirements at certain times of the year. For example, applying too much fertiliser, such as nitrogen, may promote leaf growth at the expense of flowering and fruiting.

Operators should assess which nutrients are already present in the soil before applying effluent. In many cases, imbalances of micronutrients and metals may be inferred by soil pH. Usually, problems of deficiency or toxicity can be minimised if surface soils are maintained at a pH of between 6.0 and 8.0.

4.4 *Salinity control and salt balances*

Proper management is necessary to ensure that effluent irrigation does not lead to soil degradation by increasing soil salinity.

All irrigation waters contain some salt. Salt may concentrate in the root zone if there is insufficient drainage to take away any salt not utilised by the growing plant. With each effluent application, the salt concentration in the root zone may progressively increase unless leaching and drainage remove it. Without the downward water flow of leaching and drainage, salts within the root zone can be drawn towards the soil surface by water evaporation. Therefore, the prime requirement for salinity control in irrigation systems is to provide adequate leaching to prevent salt accumulation. This requires periodic monitoring of the levels and distributions of soil salinity, particularly within the root zone areas.

When using effluent that consistently contains more than 500 mg/L of TDS, a higher level of salinity control to maintain a viable and lasting system is required. More area for irrigation may be required than is calculated by water or nutrient balance equations to compensate for the high salt concentrations. It may also be necessary to dilute effluent to avoid damaging plants, especially those with a low salt tolerance. The relative tolerance of plants to saline irrigation effluent can be found in ANZECC and ARMCANZ (2000) and other references.

Modelling the movement of salt through the soil is particularly difficult as the interactions between irrigation and natural rainfall, plant uptake and recycling of specific salts and the dynamics of soil salt and sodicity levels on soil hydraulic conductivity are not precisely understood. Estimates of salt movement are possible with commercially available modelling software that calculate salt balances from inputs of parameters such as salt load, effluent volumes, climatic data, proposed cropping regime, crop water use and physical soil properties. Salt balances should be determined for all proposed schemes to ensure that salinity is appropriately managed.

For those industry groups subject to load-based licensing, the Load Based Licensing Protocol can be used to identify management and monitoring conditions for salt in effluent that will attract full or partial load-based licensing discounts as at the time of this publication. Current load-based licensing protocols should be consulted. These tables also provide information on where the saltiness of the effluent is a major determinant in minimum area requirements. Available salt models should be used with caution and advice sought on their appropriateness in the area under consideration.

Soil salinity and plant growth

Tables 4.4 and 4.5 show the soil salinities where 10% and 50% yield reductions can be expected for selected plants (figures are the electrical conductivity of the saturation extract (EC_e)). These figures can be used in determining the leaching fraction component of any water budget required to remove salts from the root zone while minimising groundwater pollution.

Table 4.4: Yield reduction of crops due to soil salinity

	Yield reduction (dS/m)[1]	
Crop	**10%**	**50%**
High tolerance		
Barley (grain)[2]	10	18
Cotton	9.6	17
Couch grass	8.5	14.7
Sugar beet	8.7	15
Perennial ryegrass	6.9	12.2
Garden beet[2]	5.1	9.6
Medium tolerance		
Wheat (grain)[2]	7.4	13
Safflower	6.2	9.9
Phalaris	6.9	11.1
Sorghum (grain)	5.1	11
Olive	3.8	8.4
Rice[2]	3.8	7.2
Cantaloupe	3.6	9.1
Tomato	3.5	7.6
Lucerne	3.4	8.8
Cocksfoot	3.1	9.6
Cabbage	2	7
Maize (grain)	2.5	5.9
Potato	2.5	5.9
Lettuce	2.1	5.2
Low tolerance		
Grape	2.5	6.7
Grapefruit	2.1	4.9
Orange	2.3	4.8
Lemon	2.3	4.8
Apple	2.3	4.8
Pear	2.3	4.8
White clover	2.3	5.7
Peach	2.2	4.1
Apricot	2	3.7
Avocado	1.8	3.7
Strawberry	1.3	2.5

Table 4.4: Yield reduction of crops due to soil salinity (continued)

	Yield reduction (dS/m)[1]	
Crop	**10%**	**50%**
Radish	2	5.0
Onion	1.8	4.3
Carrot	1.7	4.6
Green bean	1.5	3.6

Source: Reid (1990).

Notes: 1. Soil salinity refers to electrical conductivity of saturated extract at 10% and 50% yield reduction.

2. For satisfactory germination, beets require an EC_e of not more than 3 dS/m and rice, wheat and barley not more than 5 dS/m.

Table 4.5: Yield reduction of trees due to soil salinity

	Yield reduction (dS/m)[1]	
Trees	**10%**	**50%**
High tolerance	8–10	12–15
Acacia stenophylla (river cooba)		
Eucalyptus occidentalis (swamp yate)		
Casuarina glauca (swamp she-oak)		
Medium tolerance	3–5	6–10
Eucalyptus botryoides (southern mahogany)		
Eucalyptus camaldulensis (river red gum)		
Eucalyptus tereticornis (forest red gum)		
Low tolerance	2–3	5–7
Acacia mearnsii (black wattle)		
Eucalyptus grandis (flooded gum)		
Eucalyptus globulus (blue gum)		

Source: Myers et al. (1999); Marcar et al. (1995).

Notes: 1. Soil salinity refers to electrical conductivity of saturated soil extract (assumed to be an average for the notional root-zone).

Greater growth reduction can be expected for soils of heavier texture and where seasonal waterlogging is expected.

Field data are limited and compromised by interacting factors such as waterlogging, age of measurements, type of growth measure (e.g. height or stem volume), the nature of 'control' conditions and provenance variation, where in the root-zone salinity is measured (in some cases, e.g. on deep sandy loams under irrigation better tolerances might be expected).

4.5 Organic Loading Rates

In a sustainable effluent irrigation scheme, organic matter is incorporated into the soil where it can improve soil fertility and increase plant cover. However, if organic material is applied at a rate greater than the soil's ability to assimilate it, then soil pores can become clogged and anaerobic odorous conditions may result.

High organic loading increases the length of the resting period needed between applications. Successful irrigation requires well-defined rest periods within the program to allow the applied water to be evapotranspired, and for soil microorganisms to break down the organic material contained in the effluent. This would also minimise soil saturation, resultant runoff and lack of oxygen in the root zone.

The average maximum daily organic loading rate at an irrigation site should be calculated from the irrigation rate (determined from a water balance) and the BOD_5 and oil or grease (mg/L) of the applied effluent. Past experience has shown that an average loading rate of 1500kg/ha/month can be taken as the maximum organic loading for most soils. However, those industries subject to load-based licensing should refer to the current load-based licensing protocol for any relevant criteria for fee discounts. Where nutrient modelling shows there is a potential for nutrients to leak below the plant root zone, land area for irrigation should be increased.

The minimum irrigation area required based on organic loading can be estimated as follows:

Equation 7: Minimum irrigation area

$$A = CQ / (1{,}000 \times Lc)$$

Where:

A = irrigation area (ha)

C = concentration of BOD_5 (mg/L)

Q = average effluent flow rate (kL/month)

Lc = critical loading rate of constituent (kg/ha/month)

4.6 Heavy metals and persistent organic chemicals

Some trace heavy metals are found naturally in low concentrations in soil. Levels may vary with soil parent material. Addition of fertilisers, organic or industrial materials to the soil may add significant loads of heavy metals and persistent organic chemicals.

There is a risk that the long-term application of effluent could increase the concentration of contaminants in the topsoil. Grazing animals ingest between 1 and 30 % of their diet as soil. It is reasonable to assume 10 % of the diet is soil when assessing the potential effects of chemical contaminants in soil. Contamination must be prevented or the site may no longer be suitable for agriculture, or urban development. The scheme owner must not allow chemical concentrations in soil to violate legal plant and animal residue limits and must not allow the irrigation area to become an officially contaminated site.

DEC has used extensive research carried out by the former NSW Department of Agriculture (now NSW Department of Primary Industries) to set maximum allowable trace metal and persistent organic chemicals concentrations for agricultural and non-agricultural soils following biosolids application in *Environmental Guidelines: Use and Disposal of Biosolids Products* (EPA 1997). These are shown in Table 4.6 and are used to determine the upper limit in soils that are being irrigated. Further guidance on cumulative contaminant loadings can be found in ANZECC and ARMCANZ (2000) Volume 3, Section 9.2.5.

Cadmium is a critically important element in the animal and human food chains. Both soils and plants can contribute significant amounts of cadmium to those food chains. The risk of exceeding legal residue limits in edible animal tissues is increased if soil and plant levels of zinc, molybdenum and sulfate are low. Horses and other monogastric animals show adverse effects with dietary intakes as low as 1 mg of cadmium per kilogram of dietary dry matter.

Copper toxicity is a common cause of death in sheep in Australia. Dietary levels as low as 8mg of copper per kilogram of dietary dry matter can cause toxicity. This is most likely when soil and plant levels of molybdenum are low. Both soils and plants can contribute significant amounts of copper.

The maximum tolerable dietary level for lead is considered to be 30 mg of lead per kilogram of dry matter for most domestic animals. However lead residues in some tissues may still build up at this level. Young animals absorb more lead from the diet than adults. Ingested soil is the main source of lead.

Table 4.6: Maximum permitted topsoil concentration for chemical contaminants

Contaminants	Maximum concentration in topsoil[1] (mg/kg)
Arsenic	20
Cadmium	1.0
Chromium VI[2]	1.0
Copper	100
Lead	150
Mercury	1.0
Nickel	60
Selenium	5.0
Zinc	200
DDT/DDD/DDE	0.5
Aldrin	0.02
Dieldrin	0.02
Chlordane	0.02
Heptachlor/heptachlor epoxide	0.02
Lindane	0.02
Hexachlorobenzene	0.02
PCBs	non-detect[3]

Source: EPA (1997)

Notes:
1. Mean concentration values
2. Nominal value for protection of agricultural systems animals and soil health. Where effluent contains Cr VI (maximum concentration 0.1mg/L – see table 3.3) and the rate of reduction to Cr III in soil is not sufficient to prevent a soil concentration above 1 mg/L Cr VI occurring, advice should be sought from the NSW Department of Primary Industries.
3. Non-detection at detection limit of 0.1 mg/kg

Effluent containing chromium must be managed to ensure that Cr VI is reduced to Cr III prior to application to land and application must be managed to ensure that site-specific agronomic systems, soil types, food products and the environment are taken into account and protected. Livestock must not be grazed on pasture where Cr VI is likely to pose an animal health risk. The *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999) sets interim ecological investigation levels for urban soil for Cr III of 400 mg/kg and for Cr VI of 1 mg/L. To ensure that present and future use of agricultural land is not compromised, where continued effluent irrigation will impose soil loads above these levels, advice on soil types and agricultural systems should be sought from NSW Department of Primary Industries.

Where heavy metals or persistent organic chemicals are likely to be present, the cumulative concentration over time should be estimated. See below for an example calculation.

Example calculation for a persistent organic chemcial

Assumptions:

- Average dieldrin concentration = 0.001 mg/L
- Design flow = 1.0 ML/day
- Soil density = 1.33 g/cm^3 (1,330 kg/m^3)
- Topsoil depth (where dieldrin remains) = 15 cm

Calculation:

0.001 mg/L x 1,000,000 L/day x 365 days/year = 365,000 mg/year
= 0.365 kg/year

For 1 ha of land, mass of topsoil = site area x topsoil depth x soil density

= 10,000 m^2 x 0.15 m x 1,330 kg/m^3
= 2,000,000 kg (approximately)

In one year over an irrigation area of 100 ha:

0.365 kg per 200,000,000 kg of soil = 0.002 mg/kg

Therefore, if an effluent containing 0.001 mg/L of dieldrin were applied to 100 hectares over ten years, its concentration in the topsoil would have reached the maximum soil concentration allowed (0.02 mg/kg). In practice, however, some of this dieldrin will decay during this time and the maximum concentration will take longer to reach. The rate of decay for OCs in soil varies from region to region, depending on climate and soil characteristics. The half-life of OCs in soil is likely to be five to ten years in NSW, with the warmer and wetter regions producing a higher rate of decay. Hence it is important to monitor this constituent.

Herbicides

The phenoxyacid herbicides, such as 2,4-D, and its derivatives, are widely used for weed control commercially, agriculturally and domestically. It is therefore possible for these compounds to find their way into effluent. They degrade rapidly in soil but can persist in effluent, and can be harmful to plants. Table 4.7 sets out concentrations of herbicides in irrigation effluent, at which crop injury may occur. See further guidance in ANZECC and ARMCANZ (2000) Volume 1, Section 4.2.8 and Table 4.2.12 for these and other herbicides.

Table 4.7: Concentrations of herbicides in irrigation effluent at which crop injury may occur

Herbicide	Crop injury threshold in irrigation effluent (mg/L)
Acrolein	Flood or furrow: beans 60; corn 60; cotton 80; soybeans 20; sugar-beets 60 Sprinkler: corn 60; soybeans 15; sugar-beets 15
AF100	Beets (rutabag) 3.5; corn 3.5
Amitrol	Lucerne 1,600; beans 1,200; carrots 1,600; corn 3,000; cotton 1,600; grains sorghum 800
2,4-D	Field beans 3.5–10; grapes 0.7–1.5; sugar-beets 1.0–10
Dalapon (2,2-DPA)	Beets 7.0, Corn 0.35
Dicamba	Cotton 0.18
Dichlobenil	Lucerne 10; corn 10; soybeans 1.0; sugar-beets 1.0–10; corn 125; beans 5
Fluometuron	Sugar-beets, alfalfa, tomatoes, squash 2.2
Paraquat	Corn 10; field beans 0.1, sugar-beets 1.0
Propanil	Alfalfa 0.15; brome grass (eradicated) 0.15

Source: ANZECC & ARMCANZ (2000), Table 4.2.12

4.7 Models

An array of models have been developed for determining the storage and land area requirements to ensure a sustainable irrigation scheme in terms of the water, nutrient and/or salt balance. They may also facilitate the planning and assessment of environmental impacts of the effluent irrigation system. The models vary widely in their degree of complexity. Their primary function is simply to assist in designing an irrigation system appropriate to a particular site.

Water balance models are those that simulate the water cycle through plants, animals, land, waterbodies and air. They are widely used to estimate land and storage requirements for irrigation schemes on different soil types, with variable agricultural enterprises and climatic conditions. Their complexity can range from those that simply rely on monthly rainfall and evaporation to those using complex estimates of plant water use and similarly complex soil/water relationships.

Salt balance models examine changes in soil salinity over time and can predict leaching requirements to avoid excessive salt accumulation in the root zone.

Nutrient budget models examine the fate of nutrients, particularly nitrogen and phosphorus, when applied to the soil. They are based on knowledge of the cycling of nutrients and their performance in the environment. Nutrient models are widely used to estimate the application rate of nutrients and long term management of a scheme based on the soil characteristics and agricultural enterprise.

DEC has developed one such effluent reuse irrigation model (ERIM) based on water balance and the strength of the applied effluent to provide guidance for developing effluent irrigation systems. However, the DEC model (ERIM) is not considered mandatory for use in conjunction with this guideline.

There are various computer models commercially available to plan effluent irrigation systems and the assumptions and methods used to construct them can vary widely. It is therefore likely that results generated by various models can differ. Models, including ERIM, usually give at best a reasonable approximation of likely water, nutrient, storage and irrigation area requirements of an effluent irrigation system. In variable climates (mainly coastal), particularly where daily-based rainfall models are used, providing information on the extent of the rainfall variability, and on natural percolation and runoff, would assist in demonstrating a sustainable irrigation scheme. For high strength effluent the chance of storage overflow must be small, one year in ten. The mix of weather conditions that combine to cause an overflow will therefore be relatively rare and a relatively higher degree of uncertainty will be associated with these cases. Care must be taken when modelling these scenarios and interpreting results.

Care should therefore be taken to avoid over-reliance on models to establish sustainable effluent irrigation systems (e.g. models may not include inorganic fertiliser/conditioner inputs into the nutrient cycles, such as gypsum, muriate of potash and urea). It is important to emphasise, however, that DEC or local council will require the proponent to:

- demonstrate to the satisfaction of DEC or local council that the proposal is sized (storage and land area), based on sound knowledge of volume of effluent generated, natural climatic and soil conditions, and the likely nutrient, salt, organic and chemical content of the effluent (see Sections 2 and 3)
- demonstrate that realistic assumptions have been used in any model and that model outcomes are sustainable
- include a monitoring program so that model assumptions and outcomes can be tested. If the scheme performs differently from model predictions then the monitoring program is to be used to make adjustments to the scheme design and subsequent performance.

The DEC model

DEC's Effluent Reuse Irrigation Model (ERIM) provides guidance for developing effluent irrigation systems. It calculates the water and nutrient balances using monthly historical rainfall and evaporation; the amount of nitrogen and phosphorus introduced and removed by plants to be grown; the amount of applied organic matter; and soil water-holding capacity. Other inputs include the volume of effluent applied, the strength of the effluent that may leave the site, and the organic, nitrogen and phosphorus loadings to the site.

The DEC model does not incorporate salt or chemical balance considerations and hence the additional calculations as described in Sections 4.4 and 4.6 will need to be used in conjunction with this model.

Minimum irrigation areas are calculated using a water, nitrogen and phosphorus balance, and the largest area determined is the minimum irrigation area needed (with adequate storage) for the system to be sustainable.

The relationships between effluent strength, storage and land area requirements are as follows.

- Irrigation land requirements for the irrigation of low strength effluent is determined based on the 50th percentile storage requirements established in the model using the water balance equation in Section 4.2.
- For medium and high strength effluent, irrigation area requirements are determined based on 75th percentile and 90th percentile storage requirements respectively.
- Depending on the effluent quality, other percentile storage requirements may be used to determine the irrigation area requirement; for example, a 60th percentile storage requirement could be applied to establish land area for the irrigation of effluent that is marginally stronger than the low strength effluent.

The model is reliant on the availability of historical data and a significant underlying assumption is that historical data can be used to predict future climatic patterns. If 100 years of rainfall and evaporation data for a proposed site has been used, the model would provide 100 yearly storage requirements, one for each year. These indicate the size of the storage needed for each year over this historical period. If, for example, a 90th percentile storage requirement were chosen, then this would be sufficient to contain surplus effluent and prevent any overflow for 90 out of 100 years. If a 50th percentile is used, then the storage needed to contain effluent in 50 percent of the years is used. The maximum available rainfall and evaporation data set should be used in the model.

The relationship between a selected storage requirement and the land area required for irrigation can be graphically established. Within limits, irrigation area can be substituted for storage, and vice versa.

Care must be taken in using the model when effluent flow rates are variable and where a range of crop types are being irrigated from the same effluent source. The ERIM model can be used to predict the performance of partial reuse schemes provided the effluent volume for the scheme can be nominated on a month by month basis.

Details relating to the construction and use of the model are at Appendix 4.

4.8 Plant selection and land use

The effluent quality, hydraulic capacity and soil quality at the site, and the climatic conditions of the area and salt sensitivity of plants generally influence the type of plants to be grown. These factors must be clearly addressed during the design stage of the project. Relevant information regarding plant selection for an area should be obtained from NSW Department of Primary Industries where appropriate.

Effective and efficient crop/pasture and animal management in using all of the applied nutrients is also a major factor in a sustainable effluent application system, because nutrients that are not removed from the site remain in the soil and could be carried to surface water and groundwater. Grazing animals within the irrigation site, deciduous and evergreen trees can return nutrients to the soil and this aspect needs to be properly considered and managed.

The stage of crop growth also has a major influence on the crop factor used in the water balance. Double cropping, for example, involves ground preparation, planting and harvesting twice a year. During these periods there is little or no plant growth and crop factors should be set to zero.

4.9 Erosion control

The potential for erosion of the site should be considered in terms of both stormwater runoff and effluent application rates. Where crops other than pasture are to be irrigated, there should be strict constraints on irrigation rates. Advice should be sought when soils that may erode are suspected.

4.10 Separation distances and management of buffer zones

In planning for an effluent irrigation scheme consideration of the separation of irrigation areas and irrigation infrastructure from neighbours and sensitive environments must be considered. The purpose of separating these land uses is to protect a locality's amenity, ground and surface waters, other environmental and social values as well the long-term future of the effluent irrigation scheme.

The management of impacts from a scheme and therefore the provision of separation of potentially conflicting land use and the management of buffer zones are the responsibility of scheme proponents.

Separation distances and the impact mitigation strategies employed in these buffer zones vary depending on the impacts that are to be controlled. For example noise impacts can be effectively controlled over very short distances through the employment of sound barriers within the buffer zone. Impacts such as odour are much more difficult to manage and larger buffer zones incorporating vegetation are generally required to control these types of impacts.

When dealing with impacts that are difficult to measure and quantify, such as odour where the sensitivity of the receptor determines, to a large degree, the scale of the impact, impact management strategies beyond separation and impact mitigation may be required. These strategies could extend to communication forums with neighbours, public reporting of environmental monitoring and/or other strategies.

Separation distances and buffer zone management must also consider the nature of the receiving environment and its sensitivity to impacts. For example in situations where surface waters have a particular sensitivity such as supporting fish and fisheries or a high value use like drinking water supply it is critical that these values be protected. Assessment of separation distances and buffer zone management strategies will need to be detailed, comprehensive and conservative in order to protect these values. Where the sensitivity of the receiving environment is less, for example a grazing paddock, separation distances will still be required and will be based on protecting the values of neighbouring land for current and likely future uses.

In determining the suitability of a separation distance and buffer zone management strategies, designers of effluent irrigation schemes should ensure the protection of:

- surface water
- groundwater
- human health, heritage and well being
- domestic and wild plant and animal health
- native vegetation, wetlands and associated biological diversity.

In addition, proponents should recognise that:

- responsibility for the establishment and management for buffer zones rests with the proponent
- the size of the buffer zone will need to be justified based on the sensitivity of the receiving environment, the strength of the effluent, the level of effluent treatment, proposed impact mitigation strategies, the method of effluent application and irrigation management practices such as irrigation scheduling.

There are a number of easily identified sensitive receptors to the potential impacts of any effluent irrigation scheme and they are identified in Table 4.8 along with a general description of the impacts of concern. Table 4.8 identifies some of the more obvious sensitive receptors. This list is not exhaustive and the surrounding environment of any effluent irrigation scheme should be investigated to identify potentially sensitive receptors and the impacts of concern. Once these have been identified impact mitigation strategies including the separation of uses, buffer zones and selection of appropriate effluent treatment and irrigation systems can be designed and employed.

Table 4.8 Sensitive receptors of effluent irrigation schemes

Sensitive area	Impacts of concern
Natural water bodies (e.g. rivers, lakes)	Water quality, aquatic ecosystems, relevant beneficial uses
Other waters: e.g. artificial waters with beneficial uses, drainage channels, small streams, intermittent streams, farm dams	Water quality, ecosystems, relevant beneficial uses
Domestic well used for household water	Water quality and public health
Town water supply bore	Water quality and public health
Houses, schools, playing fields, public roads, public open space	Odour, noise, Water quality (pathogens, contaminants)
Environmentally sensitive areas: e.g. drinking water catchments, wetlands, stands of native vegetation	Water quality, ecosystems, soil and water nutrient status, biodiversity
Livestock and crops	Pathogens, heavy metals, organic compounds

When determining the size of a separation distance the nature of the buffer zone and techniques to avoid impacts must be considered. Where a buffer zone for a spray irrigation proposal is characterised by flat, open country where ground cover is predominantly pasture separation distances may need to be in the order of hundreds of metres to protect sensitive receptors. The same irrigation scheme may require a separation distance of only tens of metres if impact mitigation strategies such as tree and shrub planting in the buffer zone, lower height and pressure of sprayers and larger droplet sizes are incorporated.

Table 4.9 provides recommendations on appropriate buffer distances between effluent irrigation sites and water resources and public areas. These can be used where no other information is available to determine buffers or where a proponent prefers to use these values rather than determine appropriate buffers on a site-specific basis. Other factors such as pathogen levels should be taken into account when establishing buffers to protect human health. Wider buffers may be required, or narrower buffers may be allowed, depending on site- or issue-specific factors. For example, narrower buffers may be appropriate where high quality effluent, a low volume of effluent or vegetated filter strips are used. Wider buffers may be necessary where there is limiting site characteristics such as soil or slope. Proposals for narrower buffer distances must be supported by technical advice. Due regard also must be given to relevant planning requirements that specify buffers.

Table 4.9: Recommended buffer distances to water resources and public areas

Sensitive area	Separation distance (low strength effluent)	Separation distance (medium to high strength)	Impact of concern/comments
Natural waterbodies (e.g. rivers, lakes)	50 m	50 m	Protection of water quality and aquatic ecosystems. Supplementary requirements may be included for human sourced effluent to protect public health in recreation areas.
Other waters (e.g. artificial waters with beneficial uses, small streams, intermittent streams, water distribution and drainage channels, farm dams)	Site-specific	Site-specific	Protection of water quality for most sensitive water uses of the potentially affected waterbody.
Domestic well used for household water supply	Site-specific	250 m	Groundwater quality for domestic human uses protected.
Town water supply bores	Site-specific	1000 m	Water and groundwater quality for drinking water supply protected. Town bores generally pump at high rates and draw water from a large area.
Where spray irrigation gives rise to aerosols near houses, schools, playing fields, roads, public open space and waterbodies	50 m[1]	50 m	Avoidance of spray drift of effluent containing pathogens offsite. Buffers for odours and noise have separate assessment criteria and these are assessed on a site-specific basis.
Other sensitive areas (e.g. waters in drinking water catchments, aquatic ecosystems with high conservation value, wetlands, native stands of vegetation)	Site-specific	250 m	Greater buffer distances and management may be required in some circumstances to protect drinking water (e.g. within the Sydney Drinking Water Catchment the Sydney Catchment Authority would seek a buffer of 100 metres in the absence of other evidence of a neutral or beneficial effect on water quality).

Notes: 1. Recommended in ARMCANZ, ANZECC and NHMRC (2000) for the spray application of reclaimed water from sewerage systems.

Separation distances for reuse of treated sewage should also be compared with Guidelines for Sewerage Systems – Use of Reclaimed Water (ANZECC, ARMCANZ and NHMRC 2000) which apply to spray irrigation of municipal sewage effluent.

Preference should be given to locating irrigation sites down hydraulic gradient of household and town bores used for potable supply. Hydraulic gradient often corresponds with topographic gradient. Regional offices of DIPNR should be contacted for details of registered water bores. Supporting technical advice should consider the existing groundwater condition, the quality and quantity of effluent and the management of the irrigation system. See also Section 2.6, Groundwater.

It should be noted that separation distances are not a substitute for effective effluent irrigation system design. The impacts of deficiencies in design, such as soil and water degradation through the loading of soils with salts and/or nutrients, may be delayed by the use of large buffer zones but they will not be avoided or overcome through the use of this strategy. Separation distances and buffer zones are the final strategy available to provide a margin of safety to the range of impact mitigation designed throughout the system. The quality of the effluent, the irrigation method used and the nature of the environment within which the scheme is located will determine the size and composition of buffer zones.

In summary, the most appropriate buffer zone will be one that complements best effluent irrigation practices in providing a margin of safety against the possibility of nutrient pollution, aerosol drift and human and animal health impacts, without unnecessarily restricting the efficiency of the enterprise or amenity of adjacent land uses. Determination of the optimal buffer zone for a particular land use mix can only be determined following an assessment of the effluent irrigation practices proposed and the sensitivity of the receiving environment.

4.11 Irrigation

Methods

Irrigation methods used depend on site topography, soil type, the species of plants to be grown, cost, effluent quality, labour availability, power requirements and public health and environment considerations. Effluent generally should be applied to the site by trickle, spray or drip irrigation, to avoid over-application and unintended environmental effects that could occur with furrow or flood irrigation systems. Use of the latter may indicate the need for laser levelled sites.

The infiltration rate of soil is an important consideration in the type of irrigation method used and the way it is operated. Effluent should be applied uniformly and at a rate less then the nominal infiltration rate to avoid surface runoff.

In drip or trickle irrigation, pressurised water is discharged through micro-emitters. The water is dripped thereby minimising the risk of aerosols. In spray irrigation, water is pumped through pipelines and discharged through sprinklers that can vary from high pressure ‘big guns’ that can generate aerosol drifts of up to 1 km, to small low pressure microsprays that minimise the risk of aerosol drift and reduce the potential for odour. High pressure systems should only be used for effluent which meets the pathogen reduction criteria for use on raw human food crops given in Appendix 1, with buffer distances determined according to the principles given in Section 4.10. High pressure systems should not be used when weather conditions are such that spray drift will be excessive.

Flood irrigation methods include border check, border ditch, basin, contour bank, hillside and furrow irrigation. Flood irrigation generates little or no aerosol activity and gives an even distribution of nutrients in properly designed, laser graded systems. The potentially greater risks to groundwater should be managed by application of the principles given in Section 2.6.

Spray and drip/trickle irrigation systems usually involve higher capital and operating costs than flood or furrow systems, but also provide better operational flexibility and may provide greater water use efficiency. Costs of permanent spray systems may be high, however, centre pivots, travelling irrigators and semi-permanent spray systems can have a much lower capital cost per hectare than some drip systems.

Underground irrigation systems were being extensively trialed at the time of writing this document. Advice should be sought from irrigation specialists when these systems are being considered.

Suitable irrigation areas

Irrigation should only be applied to areas that are deemed suitable for irrigation from soil and groundwater analyses as described in Section 2. However, the results of soil suitability assessments may show irregular or disconnected 'suitable areas'. There are also practical difficulties irrigating 'oddly shaped' areas.

Where conventional spray systems (e.g. centre pivots, bike shifts, etc.) are being used there may be a need to incorporate small areas of `unsuitable land' within the nominal irrigation area. As far as possible, practical methods to minimise or avoid irrigation of these small areas of unsuitable land must be considered in designing the scheme.

Irrigation scheduling

The scheduling of irrigation is one of the most important functions of the irrigation manager. Excessively long intervals without irrigation can lead to water stress and crop loss. Irrigating too often can waterlog the soil and allow excess effluent to runoff or percolate to groundwater, polluting both groundwater and surface water. To ensure that the application site is not overloaded, an irrigation schedule should be based on knowledge of the water content of the soil and the water requirements of the cultivated crop.

There are direct and indirect methods available to estimate the water content of a soil. Direct methods rely on insertion of soil moisture monitors (e.g. neutron probes) at representative sites within the system. Indirect measurements estimate plant evapotranspiration by taking direct measurements of rainfall, temperature and sometimes evaporation and converting these through recognised models into predicted evapotranspiration for the particular crop being grown.

Generally, it is advisable to irrigate the soil to allow a 5 to 10 mm soil water deficit. This allows for a buffer capacity in the soil should rain fall soon after an irrigation event.

The design must allow for adequate resting periods between irrigation to avoid rainfall runoff. For most plant systems a soil moisture deficit of at least 30 mm should be allowed to accrue before further irrigation takes place.

Storage management

Management of wet weather storage is an important aspect of ensuring that the environmental impact of an irrigation system is minimised. Storage dams must be managed to ensure that they have the capacity to store effluent during wet weather. This means that irrigation needs to be carefully scheduled and carried out to ensure that the maximum amount of effluent is applied without causing undesirable impacts such as waterlogging or runoff.

Overflows from full reuse schemes will occur at the frequency used to design the system, on average. Overflows are most likely after a prolonged period of low evaporation, perhaps where there has been continual rain in later winter. However, this might not always coincide with high stream flows and therefore the in-stream dilution might not be high.

Precautionary discharges can be used to ensure that discharge occurs when conditions will minimise environmental impacts (rather than uncontrolled overflows as discussed in Section 4.2.) This approach is only permitted when licence conditions expressly allow it to occur. Licence conditions will include an in-stream trigger flow, a time horizon or lower flow limit as well as volume and effluent quality limits. The conditions will be designed to ensure that a higher load than would otherwise occur is not discharged.

5. Operation and Management Considerations

Irrigating with effluent should be governed by clearly defined and documented procedures, and should employ best management practices. To ensure sustainability, operational and management procedures must address the environmental performance objectives outlined in Section 1, paying particular attention to: controlling surface water and groundwater pollution; maintaining soil quality with respect to organic, nutrient and contaminant loading; and maintaining community amenity.

An effective effluent irrigation system will include:

- efficient irrigation facilities for applying effluent to the site
- a control system to adjust the effluent application rates or other factors to maintain optimum performance
- wet weather storage facilities where appropriate
- where appropriate, tailwater and stormwater runoff controls, including a recovery system to capture and recycle any stormwater runoff (the need for these will depend on effluent quality, topographical conditions at the site and the sensitivity of the environment downstream of the effluent irrigation area)
- effluent discharge facilities where discharge of some effluent to waterways is expected
- effluent transport facilities to convey the effluent to the site
- a site-specific management plan detailing the necessary procedures to maintain optimum performance of the irrigation system and satisfy statutory requirements
- a monitoring system to measure, record and identify any action to ensure the environmental performance of the system.

5.1 Site management plans

Site management plans are plans prepared by operators to identify potential environmental impacts from their operations and measures to minimise these impacts. They are a tool under planning legislation and may be required by consent authorities such as local councils or the DIPNR as part of a development consent or other licence or approval.

DEC encourages the development of site management plans as part of good environmental management, but under most circumstances will not require these plans using its regulatory instruments. The main reason for this approach is that DEC believes that environmental management plans should be used as a management tool, as part of a commitment to wider environmental management and integrated with other operational plans, rather than solely to meet DEC or local council requirements. Also, requiring a plan by licence condition can reduce the flexibility of operators to meet environmental outcomes by seeking out the most cost effective management approach for their circumstances.

Where a site management plan is prepared it could include:

- all information collected in the site selection process (see Section 2)
- statutory requirements relating to the protection of the environment and public health
- a copy of any relevant licences or approvals where applicable
- if appropriate, how responsibilities are shared between effluent suppliers and irrigators
- site access arrangements
- effluent transport and storage arrangements
- maximum loading rates
- the irrigation system, its management and operation of its control system
- soil erosion control
- stormwater control arrangements
- cropping practices for nutrient use
- monitoring, reporting and control systems.

5.2 Control systems

Control systems are used to minimise risks of environmental pollution caused by poor initial design, human error, weather conditions, or faulty equipment.

The application of the correct amount of effluent can be controlled through manual or automated techniques. For example, the soil moisture deficit can be simply computed using monthly average evapotranspiration and actual rainfall events. Irrigation is then applied according to the size of the deficit. The irrigator will need to know how much water is being delivered by the irrigation system over a given area. At a more sophisticated level, soil moisture monitors can be used to determine when irrigation is needed. These can be linked to a computer system.

Both methods are likely to give false results under certain circumstances and other controls must be put in place to mitigate against these. For example, regular checks of soil moisture in the topsoil should be made before and after an irrigation event to ensure firstly that the soil is dry and needs irrigation and secondly to ensure that the soil is not overly wet or dry after the event.

Anemometers may be used to determine wind speed and predict the direction and extent of spray drift and may be used to cut off irrigated systems under high wind conditions. Wind activated systems may be used to stop or start the irrigation when wind conditions suit. Cut off wind speed may be determined from a consideration of proximity to public or sensitive areas, wind speed and direction, height and droplet size and the type of irrigation system used.

The use of vegetative screens (e.g. shrubs, small trees) within buffer zones can control spray drift.

Monitoring systems, runoff and runon controls and signage, discussed below, are other examples of control mechanisms.

Control systems are particularly important where high strength effluents are being used and/or the surrounding environment is particularly susceptible to the effects of pollution.

5.3 Monitoring systems

Monitoring allows scheme operators to keep track of potential impacts so that they can adjust their management practices to prevent those impacts from reaching unacceptable levels. Monitoring results assist in demonstrating due diligence in the protection of public health, agriculture, human and animal food chains and the environment.

Monitoring programs should be developed to ensure that all public health, agricultural resource and environmental risks are monitored to provide sufficient data to manage the relative risk each poses. **Those components of the effluent irrigation scheme and its environment with the greatest risks will require more intensive monitoring than low risk components**.

Tools to assist in this process include the following:

- *Analysing the strength of the effluent*. High strength effluents will require more intensive monitoring of all the components of the effluent irrigation system than low strength effluents.
- *Use of the various models described in Section 4*. For example, a nutrient budget can be used to indicate the likelihood of nitrogen (N) and phosphorus (P) leaking to the environment if N and P concentrations are higher in the effluent than predicted, or plant uptake is less than predicted. (If there is a significant risk, then a monitoring program targeting N and P in effluent, soils and groundwater is indicated – however, if the risk appears low, then monitoring these constituents only in the effluent may be appropriate).
- *Comparison of soil properties with Table 2.2.* If soils at the proposed irrigation site have a number of moderate to severe limitations, then there is more likely to be adverse environmental impacts than if the soils had nil to slight limitations. For example, soils with high Ksat are more likely to leak nutrients to the groundwater table and hence indicate that there should be consideration of monitoring of any sensitive groundwater table within 10 metres of the soil surface.
- *Proximity to sensitive areas*. For example, groundwater lying within 10 metres of the surface, particularly if is of good quality, is more likely to be adversely affected by an effluent irrigation scheme, than a deep or poor quality resource.

Another factor to consider in developing a monitoring program is that some impacts can occur in the first years of the scheme while other, but equally important impacts are unlikely to appear until later. For example, nitrate is very mobile and an excess loading of this constituent could appear in an 'at risk' groundwater source early, whereas phosphorus is likely to be absorbed into the soil over many years before it leaches to any groundwater table. In the latter case early intensive monitoring of the groundwater table for P may give a false degree of confidence in the scheme.

In addition, small increases in measured properties may not be a concern unless they result in a downgrading of the plant, soil or water resource. For example, even in a `sustainable' effluent irrigation scheme it is likely that some soil constituents (e.g. salt and sodium) could increase in the first few years as the soil adjusts to its new environmental regime. However, if the scheme is managed properly, this increase should slow and become stable within the first 5 to 10 years.

Monitoring is a costly process and it is important to design a monitoring program that gives sound information at an affordable cost. There is a range of guidelines and standards available that provides information on sampling techniques (e.g. ANZECC (2000); AS/NZS 5667.1:1998 : Water quality - Sampling (Standards Australia 1998)). The practical limitations of monitoring (e.g. preserving samples in remote areas) should also be recognised and alternatives considered.

The following monitoring recommendations are a guide only and provide a basis for tailoring a monitoring program to an individual scheme. It is important that any monitoring program is site-specific and takes account of the above considerations. Detailed investigation of effluent, soil, surface waters and groundwater should be conducted prior to the commencement of effluent irrigation, to identify the size of environmental risks and to provide baseline data for future monitoring.

Frequency of sampling

Frequency (how often) and intensity (number of samples) of monitoring will depend on the type and scale of the scheme, sensitivity of the site and trends identified in any previous monitoring.

Provided impacts are not hidden for the first few years of a scheme (as would be the case with phosphorus), a rigorous monitoring program is recommended during the commissioning phase of effluent reuse schemes. The sampling frequency and number of test constituents could then be reduced, based on satisfactory historical records and subject to negotiation with any relevant government agency (e.g. DEC, local councils, DIPNR and NSW Health). If performance values exceed those indicated in the design of the effluent scheme, then sampling frequencies should be increased, and the irrigation management program should be adjusted accordingly. Recommendations on sampling frequency are provided below (see Table 5.1).

Effluent

As soon as practicable, effluent should be characterised for all the constituents outlined in Section 2. However, where inputs into the effluent are well known (e.g. in many effluents produced by industry), only those constituents likely to be present in the effluent need to be monitored. DEC or relevant local council may require scheme proponents to justify their effluent monitoring program. It is possible that there are other constituents in effluent with potential to pollute that have not been identified in Section 3. In this case the onus is on the scheme proponent to discuss these with DEC or local council when developing the monitoring program.

Appendix 1 provides monitoring guidelines for sewage treatment plant (STP) effluent in regard to disinfection. Advice should be sought from NSW Health and/or NSW Department of Primary Industries with regard to the need for monitoring disinfection levels in effluents other than that produced by STPs.

Table 5.1 provides generalised guidance for unlicensed schemes that follow all the practices outlined in this guideline and do not have limiting site characteristics. It is generalised due to the range of scheme sizes and effluent types that may be irrigated, different end uses, and variable site-specific factors. Schemes should monitor more frequently those effluent characteristics that will impact on the sustainability of a scheme. Some constituents may not be relevant for some effluent types. Refer to industry-specific guidelines, where available, for key constituents and sampling relevant to each industry.

Licensed premises will be required to monitor effluent in accordance with the licence or load-based licensing protocols or propose an alternative monitoring program approved by the load-based licensing Technical Review Panel.

Table 5.1: Recommended effluent sampling frequency

Constituent[1]	Low strength	Medium strength	High strength
TSS	Quarterly	Quarterly	Monthly
Oil and grease	Biannually	Quarterly	Quarterly
Total P	Biannually	Quarterly	Quarterly
Total N	Biannually	Quarterly	Quarterly
BOD_5	Quarterly	Quarterly	Monthly
PH	Quarterly	Quarterly	Monthly
EC dS/m; TDS	Quarterly	Quarterly	Monthly
Cations	Quarterly	Quarterly	Quarterly
SAR ($\sqrt{}$(meq/L))	Quarterly	Quarterly	Quarterly
Metals	Yearly	Yearly[2]	Yearly[2]
Ocs	Yearly	Yearly[2]	Yearly[2]
Herbicides	Yearly	Yearly[2]	Yearly[2]
Thermotolerant coliforms (cfu/100ml)	use specific[3]	use specific[3]	use specific[3]
Other	Advice should be sought from the Department of Environment and Conservation or local council[4]	Advice should be sought from the Department of Environment and Conservation or local council[4]	Advice should be sought from the Department of Environment and Conservation or local council[4]

Notes:
1. Units are in mg/L unless otherwise stated.
2. Higher frequencies will be required where these constituents are the constituents that determine the medium or high strength classification.
3. See Appendix 1 for municipal sewage. Other effluents may not require monitoring for thermotolerant coliforms (see Section 3.10). Obtain advice from NSW Health and/or NSW Department of Primary Industries.
4. Seek advice from the appropriate regulatory authority (see Section 6.1).
5. BOD_5 may be replaced by tests such as chemical oxygen demand provided the relationship between the two measurements is established.

Soil

Soil characteristics of the application site should be established when designing the project as described in Section 2. In addition, plant nutrient levels in the root zone should be established.

Soil sampling should be performed or supervised by a qualified person with knowledge of soil science (e.g. Certified Professional Soil Scientist, CPSS), accredited by the Australian Society of Soil Science Incorporated.

Soil samples should be taken in close proximity to the initial soil sampling locations. These initial locations are likely to be one every 2 to 20 hectares depending on the geological complexity and the size of the proposed irrigation site. As discussed in Section 2, an EM survey can be used to identify these initial sampling sites.

The NSW Department of Primary Industries has recommended a soil sampling strategy (after completion of initial site characterisation) in Table 5.2 for surface and profile soil samples at each soil location as follows.

- A composite soil sample of 40 soil cores per 1–2 ha, taken at a depth of 0-10 cm.
- Composite soil samples of 5 cores at four depth intervals to 1 metre, within a 5 metre diameter plot. The four depths should fall within 0–20, 20–40, 40–70 and 70–100 cm depth increments, and positioned within major soil horizons or layers.

The soil should be monitored for those constituents shown in Table 5.2, annually for three years. The results should then be reviewed to determine the appropriate frequency of sampling and the range of test constituents for future monitoring (e.g. some soil chemical properties change slowly while other properties such as salinity, chloride and nitrates change more rapidly). Existing schemes will often have sufficient data available to determine an appropriate long-term frequency.

Sampling for heavy metals and persistent organic chemicals in soil should reflect the risk identified in initial soil and effluent characterisation (e.g. levels in the effluent are close to or above guideline limits (ANZECC & ARMCANZ 2000), or initial soil sampling reveals topsoil levels are close to the maximum permitted concentrations specified in Table 4.6). A maximum sampling interval for soil of up to 10 years may be used where heavy metals or persistent organic chemicals are at background levels in soil and levels based on routine effluent monitoring will not lead to significant accumulation over the projected life of the system.

Permeability testing (hydraulic conductivity) may be required if permeability has been initially identified as a moderate or severe limitation, or if effluent has been identified as potentially negatively impacting on soil permeability (e.g. due to high SAR).

Monitoring soil constituents such as cation exchange capacity and organic matter can provide information to help ensure good agronomic conditions.

Changes in some soil properties such as permeability are difficult to measure with any precision. However, changes in permeability are likely in effluent irrigation schemes because of the effect of salt and sodium on this soil property. Managers of the irrigation scheme should check for changes in permeability by noting uncharacteristic waterlogging either within the irrigation area (indicating a reduction in soil permeability) or downslope of the irrigation area which could be due to an increase in irrigation area permeability or over irrigation. These observations should be related to any measurements of changes in soil sodicity/salinity to see if there is a relationship. In sodic impermeable soils, applications of lime or gypsum will, over time, increase the soil's permeability. However, solving any increased permeability in soil is complex and requires specialist advice.

See Section 7.2, Further Reading, for references on soil analysis.

Table 5.2: Recommended soil monitoring strategy

Constituent[1]	Frequency of sampling	
	Surface soil	**Soil profile at four depth increments**
pH (no units)	Annually	Annually
Electrical conductivity (EC) (dS/m)	Annually	Annually
Nitrate-N	Annually	Annually
Total N	After 3 years	N/A
Available P	Annually	N/A
Total P	After 3 years	Every 3 years
Exchangeable sodium percentage	Annually	Every 3 years
Heavy metals and pesticides	After 10 years[3]	N/A
P sorption capacity[2] (kg/ha)	After 3 years (site-specific)	Every 3 years (site-specific)

Notes: 1. mg/L unless otherwise stated.

2. As recommended by an accredited laboratory or soil scientist.

3. Or more frequently if any are identified/calculated as a particular risk factor in effluent.

Surface waters

Surface waters should be analysed several times before effluent irrigation (upstream and downstream of the effluent reuse site, if relevant), following storms and during high flows. Thereafter, depending on the frequency of effluent discharge and the strength of the effluent, a sampling program should be developed as necessary to determine and manage any impacts, or in accordance with licensing requirements for licensed premises.

Licensed premises will be required to monitor waters in accordance with the licence or load-based licensing protocols (or propose an alternative monitoring program approved by the load-based licensing Technical Review Panel).

Monitoring should be conducted in a manner consistent with the sample collection, handling and preservation principles enunciated in the current version of *Standard Methods for the Examination of Water and Wastewater* (APHA, 1998). Monitoring samples should be analysed for water pollutants by the methods set out in the DEC's *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DEC 2004). *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC 2000) provides detailed information on appropriate monitoring methods.

In general, water monitoring must provide data that is representative of the waterbody and is able to indicate contributions of any pollutants as a result of the scheme (compared to contributions of similar pollutants from upstream sources).

Attributes to be measured in surface waters include:

- pH (no units)
- EC (dS/m)
- thermotolerant coliforms (cfu/100 mL)
- BOD_5 (mg/L)
- N: total, oxidised nitrogen and ammonia (mg/L)
- P: total and plant-available (mg/L).

Groundwater

Groundwater need only be monitored if it is within 10 metres of the ground surface and/or if the existing groundwater quality is at risk from the effluent irrigation scheme. Groundwater sampling should occur on the established enterprises before crop planting, during the middle of the crop growth and quarterly/yearly thereafter (see below). Where the depth is shallow or where the soils are highly permeable, monthly monitoring may be appropriate. Hydraulic gradients should be considered when establishing groundwater monitoring. Monitoring any potential impacts on groundwater drinking water supplies also may be required (see also Section 2.6, Groundwater).

Attributes to be measured in groundwaters include:

Quarterly

- groundwater height: monitor at regular intervals where the groundwater is above 3 metres
- pH (no units)
- EC (dS/m)

Annually (site specific)

- Cations (mg/L)
- N: total and nitrate (mg/L)
- P: total and plant-available (mg/L)

Plants

Sampling of crops or pastures is good practice to determine the adequacy of any fertiliser and irrigation program. Plant sampling may be required if unacceptable levels of trace contaminants have been identified in the system. Trace elements of concern should be measured at harvest, or as appropriate. Advice should be sought from specialist agronomists or plant pathologists if there are noticeable yield problems or unusual colourations develop on the leaf foliage.

Animals

Sampling of food animals, pets, birds or native animals may be required if unacceptable levels of microorganisms or contaminants are found in effluents, soils or plants to which they have been exposed. Sampling may also be required if the animals are associated with particularly sensitive environments or markets. Monitoring should also occur when contamination is possible and the size of the risk is not known. Advice should be sought from specialist veterinarians and animal pathologists.

5.4 Tailwater and stormwater runoff control

Under Sections 120–123 of the *Protection of the Environment Operations Act 1997*, it is an offence to pollute waters and there are severe penalties for doing so. Accordingly, a key environmental performance objective is to ensure that ground and surface waters do not become contaminated by any flow from irrigation areas, including effluent, stormwater runoff or contaminated sub-surface flow. Runoff diversion measures may be needed to prevent uncontaminated runoff entering the irrigation area, and a runoff collection and storage system to prevent contaminated runoff from the irrigation site entering surface waters.

For low strength effluents these risks may be managed without the need for runoff diversion and collection systems provided suitable soils and topographic sites are selected, there is a buffer zone between the irrigation area and the water resource and a deficit irrigation regime is used. By leaving a small soil moisture deficit after each irrigation event, small rainfall events will not generate runoff and the runoff from large rainfall events is more likely to be of acceptable quality.

For medium and high strength effluents, runoff diversions and collection management are usually required. The following section describes some of the methods that can be used to ensure that runoff does not cause pollution, other techniques and management approaches can be used successfully.

Uncontaminated runoff diversion

Runoff diversion is used to divert uncontaminated runoff (originating from outside the irrigation area) away from the irrigation area. Measures include banks, gutters, drains and strategically locating irrigation areas in relation to natural land slopes so that external runoff drains away from, rather than towards, the irrigation area. Operators should consider runoff diversion wherever the local terrain directs uncontaminated runoff onto the irrigation area.

Contaminated runoff collection

Tailwater

Where irrigation can be applied evenly and at a rate that does not result in surface ponding and consequently runoff, a terminal system to collect runoff from the irrigation area may not be required. However, for medium and high strength effluents sound demonstration of how a nil runoff situation will be achieved will be required (for example there are no nearby waters and the terrain is flat with low erodibility). Flood and furrow irrigation systems will always require a tailwater collection system.

Stormwater runoff
The extent to which runoff from storms must be retained depends upon the nature and magnitude of the water pollution that might result from the discharge. Other variables include rainfall distribution and land management practices.

With terminal systems, initial calculations should be based on collecting the volume equivalent to 12 mm of rainfall runoff from effluent utilisation areas. In non-sensitive locations, alternative measures such as vegetative buffers or artificial wetlands may be used to manage the 12 mm of stormwater runoff. The performance of vegetative buffers can be variable (see Section 4.10, Separation distances and the management of buffer zones).

A collection system usually consists of catch drains that direct the runoff to a terminal collection pond and a system to return the collected runoff to the effluent storage facility and/or the irrigation supply system. In some systems, the catch drains may need to include deep drains to collect sub-surface flows. However deep drains should be avoided on potential acid sulfate soils. Ideally, where a system is needed, it would be designed to collect all tailwater and stormwater leaving the irrigation area. In practice, though, the system is usually designed to collect the tailwater and the most contaminated "first flush" stormwater. Provision should be made for any subsequent less contaminated stormwater to by-pass the terminal pond via a well-vegetated flow-way.

To function properly, terminal ponds should have sufficient length and depth to detain the flow of runoff long enough for solids to settle out and to collect the maximum volume of tailwater and/or stormwater runoff from the system. If tailwater is not generated from the irrigation system itself, the terminal pond should only be large enough to collect and store the stormwater runoff. In a situation where the collection of tailwater and stormwater runoff is necessary, the terminal pond should have a capacity to retain both the volume of the effluent irrigation tailwater and the stormwater runoff from the effluent utilisation areas.

5.5 Site access

Public access may need to be restricted during and immediately after irrigation of sewage effluent to prevent direct contact with effluent. Effluent quality criteria for treated sewage is described in Appendix 1. In most cases, effluent from intensive animal industries is unlikely to be irrigated in areas with regular public access, however appropriate occupational health and safety precautions should be taken.

In all areas with public access, all pipes and taps must be colour coded and/or signs marked, for example: 'EFFLUENT - NOT FOR DRINKING'. International diagram signs for non-English speakers may be necessary. Childproof taps should be used to prevent children from drinking non-potable water. Signs should be visible from the main point of access advising the type of reuse and any relevant restrictions to the public. Australian Standard, AS 1319–1994, *Safety Signs in the Occupational Environment* (Standards Australia 1994) should be referred to. On private properties appropriate signage for site workers and visitors should be provided. Special signage requirements may be needed in some circumstances.

NSW Health can provide advice in regard to site-specific requirements for access and signage.

5.6 Occupational health and safety issues

The maintenance of employee health and safety is a responsibility of the employer, and the operator of the effluent irrigation system must provide a safe working environment, including:

- ensuring that employees are not placed at risk through exposure to effluent
- providing adequate training so that employees can work safely and responsibly
- providing well-documented work and emergency procedures, and ensure that employees are trained to use them
- conducting regular educational and training programs to ensure up-to-date knowledge for employees
- providing employees with appropriate protective equipment, such as impervious gloves and footwear, protective masks, hats and clothing that will reduce their risk of exposure to the effluent
- ensuring the effective and safe operation of all equipment
- ensuring maintenance of all equipment
- ensuring that employees develop and maintain good personal hygiene, such as washing their hands before eating or smoking while at work, and before leaving work
- providing, where appropriate, medical assessments of employees.

WorkCover NSW or occupational health and safety experts should be consulted on these issues whenever doubt exists.

5.7 Plant and animal health

Preservation of biodiversity should be considered in the management of effluent reuse schemes. Maintenance of plant health and productivity is good practice and operational controls to preserve the purity of food entering the human and animal food chains is essential.

Where effluents are irrigated onto grazing pasture or fodder crops, it is good practice to adopt precautions to reduce risks to animal health and productivity. Risk management procedures including appropriate effluent treatment and controls should be built into an irrigation scheme to protect animal health and consumers of animal products, and ensure that animal diseases are not spread. Detrimental outcomes can include:

- reduction of intake or refusal to drink water due to taints, salinity etc.
- clinical illness from ingestion of pathogens and toxins
- amplified carrier status of animal and human pathogens
- exceedance of legal limits for chemical residues in edible body tissues, milk, eggs, etc.
- reduction in the productivity of pastures or crops
- adverse effects on soil physical, chemical and biological health
- chemical and microbiological contamination of human food crops.

The risks can be greatest when effluent is sourced from the same or similar species of animals (e.g. irrigation of washdown water from dairy farms, irrigation of abattoir effluent onto grazing pastures). Practices to minimise risks include:

- ensuring stock are healthy and vaccinated against diseases where appropriate
- not allowing animals to drink effluent
- promoting sound animal health and hygienic work practices through good farm design and management
- applying effluent straight after grazing (not before) and use of rotational grazing
- irrigating on short pastures so that effluent is exposed to more wind and sunlight which speeds up the drying and pathogen die-off process (short pastures also provide a better system for washing the effluent down into the soil. It also allows greater uptake of nutrients by short pastures, which leads to increased pasture growth)
- avoid grazing short or muddy pastures which may increase topsoil ingestion
- withholding stock from irrigation areas for at least 4 hours and up to 10 days (see Appendix 1 for effluent sourced from STPs). The time should be extended if there are likely to be faecal coliforms in excess of 1000 cfu/100mL, animal effluents are being used or prolonged wet conditions are experienced
- not using effluent irrigated paddocks for newborn animals with wet navels or animals with fresh castration or branding wounds

- not exposing pigs to reclaimed water from sewage treatment plants or to crops exposed to sewage reclaimed water to prevent the organism *Taenia solium* from establishing a life cycle in Australia
- not using pigs or poultry on irrigated areas as they naturally dig and disturb soil
- manage lactating dairy cattle with extra care due to their susceptibility to udder infections
- ensuring crop and pasture species selected are appropriate for effluent irrigation. This applies to their tolerance to salinity, and for human food crops, the risk of direct contact with effluent and how the crops are treated or processed prior to consumption
- avoiding the excessive accumulation of salts or contaminants within the soil profile by strict adherence to the approved effluent irrigation management plan.

Further information may also be obtained from the NSW Department of Primary Industries, relevant animal industry associations and animal health professionals.

5.8 Reporting on scheme performance

Monitoring results and other scheme performance information should be routinely reported to the appropriate regulatory authority, consent authority or DIPNR when required. Formal reporting may also be required as a licence condition for significant systems. These procedures would enable the operator and DEC to assess the ongoing performance of the irrigation system. Follow-up action will be taken for systems that are not adequately performing. For non-licensed premises, an annual review of the monitoring results and other information will ensure that the effluent irrigation scheme is sustainable.

5.9 Transfer of effluent to other users

Establishing the commercial responsibilities of suppliers and users of effluent can be achieved through the development of agreements between the effluent supplier and the user. Effluent suppliers might agree to supply effluent of a certain quality while effluent users might agree to receive a nominated amount of effluent. For schemes subject to load-based licensing, refer to the load-based licensing protocol in regard to licence fee discounts for transferred effluent.

6. Statistical Requirements

The Environment Protection Authority (EPA) is a statutory body with specific powers under environment protection legislation. In September 2003, the EPA became part of the Department of Environment and Conservation (DEC).

This chapter outlines the types of statutory approvals that may be required before proceeding with effluent irrigation.

Specific statutory obligations may be imposed under health, environmental, agricultural and/or food legislation in NSW and may be a condition of land development. In addition, wastewater treatment plant owners, operators and end-users may be liable under common law and under the *Trade Practices Act 1974* for the use of effluent that causes harm.

It is strongly recommended that any proposal for an effluent irrigation system be discussed at the early planning stage with DEC or local council and other regulatory or advisory authorities such as the NSW Department of Primary Industries, DIPNR, NSW Health, NSW Food Authority and WorkCover NSW. Appendix 5 summarises the regulatory or advisory information each agency can provide. Appendix 6 lists the DEC offices.

6.1 Environment Protection Licences

This guideline provides a basis for reducing the risk of pollution from effluent irrigation to a minimum. The requirements of an Environment Protection Licence are contained in the *Protection of the Environment Operations Act 1997* (POEO Act). Unless specifically required to be licensed under the POEO Act, an environment protection licence is not likely to be required for effluent irrigation schemes operating in accordance with this guideline. The EPA will, however, continue to regulate, through licenses, where it believes a premise poses a risk of environmental harm or to address noise, waste, air or odour pollution issues which are not covered in this Guideline.

Background

The POEO Act replaces the five media-specific pollution control Acts: *Clean Air Act 1961, Clean Waters Act 1970, Pollution Control Act 1970, Noise Control Act 1975* and *Environmental Offences and Penalties Act 1989.* It also incorporates all premises and activity based regulatory functions of the *Waste Minimisation and Management Act 1995.*

The POEO Act established a system of Environment Protection Licences, to minimise and control the impact of activities on the surrounding environment. Under the POEO Act, the EPA is the relevant authority for an activity whenever:

(a) the activity is listed on Schedule 1 of the POEO Act
(b) a licence to control water pollution from the activity has been granted, or

(c) a public authority is carrying out the activity or is occupying the premises where the activity occurs.

The licence can deal with the impact of an activity on any environmental media in both the construction and operating phases. This means the potential impacts of an activity on air quality (including odour), water quality, noise pollution and/or the waste stream can all be dealt with in the one licence. The licence is ongoing, but will be reviewed at least once every three years.

There is no longer a need to obtain separate EPA approvals and licences. A single licence can cover both the construction phase (scheduled development work) and the operation phase for a scheduled activity.

When is a licence required?

Scheduled activities
Schedule 1 of the POEO Act is the 'Schedule of EPA-licensed activities.' A licence is always required for Scheduled activities. Whenever effluent irrigation is ancillary to a Scheduled activity, the licence associated with the Scheduled activity may also include conditions relating to the effluent irrigation.

The Schedule generally provides a definition of each activity, and threshold criteria, which set the minimum size of an activity that requires a licence.

The Schedule includes Irrigation Corporations on the list of EPA-licensed activities. They are required to obtain a licence for their irrigation activities, independently of whether water, effluent or reused tail water is being used for irrigation.

Apart from that, effluent irrigation is not specifically listed in the Schedule, therefore it does not generally have to be licensed.

Some of the industries listed in the Schedule may consider re-using their effluent in irrigation activities. Examples include agricultural produce industries, breweries, livestock intensive industries (e.g. piggeries), livestock processing industries (such as tanneries), paper or pulp industries, municipal sewage treatment plants and others.

For those activities on Schedule 1, establishing an effluent irrigation system will not alter their licensing status. That is, they will continue to be licensed and the licence may include conditions controlling effluent irrigation.

Non-scheduled activities
Non-scheduled activities are any activities other than those listed in the 'Schedule of EPA-licensed activities.' The POEO Act does not generally require non-scheduled activities, which includes effluent irrigation, to be licensed.

Operators of effluent irrigation schemes should be able to manage their effluent to avoid pollution of water, i.e. in a manner that meets statutory obligations and the environmental performance objectives set out in this guideline. It is an offence to cause or permit any surface or groundwater pollution unless a person holds a licence that regulates the activity that caused the pollution and is operating in accordance with the conditions of the licence.

Site-specific aspects of premises (particularly proximity to sensitive environments such as waterways) still need to be considered in determining how potential environmental impacts will be managed. This may involve licensing of an activity, which is not on Schedule 1 of the POEO Act 1997, or emphasising to applicants the need to consider site-specific issues when using guidelines.

The EPA can refuse a licence if it has assessed that the activity is likely to result in unacceptable levels of pollution, or should be able to avoid pollution by following appropriate guidelines. The local council would be the Appropriate Regulatory Authority for the use of effluent at the site of the non-scheduled activity (unless the EPA considers a licence is necessary). Where the council is the owner or operator of the non-scheduled activity then the EPA becomes the Appropriate Regulatory Authority.

Assessing a licence application

In assessing an application for a licence, the EPA will generally follow the philosophy embodied in the environmental performance objectives set out in Section 1 of this guideline, in particular the:

- design, operation and maintenance of treatment and irrigation facilities with respect to environmental pollution control and public health risk
- quality and proposed beneficial use of the effluent
- the process used to select suitable irrigation sites
- the process used to identify maximum effluent loading rates and wet weather storage requirements
- the proposed site monitoring programs necessary to regulate the general health of the application site and the adjacent environment
- likelihood of any aerosols or runoff leaving the site, and the measures proposed to control this pollution
- proximity of the proposed facilities to dwellings, natural watercourses and public recreation areas.

In considering granting a licence for the use of effluent, the EPA will consider the guidance set out in this document and the requirements in the POEO Act (s45), including:

- the pollution being, or likely to be, caused by the applicant and the effect of that pollution on the environment
- the practical measures that can be taken to:
  - prevent, control, abate or mitigate that pollution
  - protect the environment from defacement, defilement or deterioration as a result of that pollution.

The EPA may require proponents to install measures to abate pollution. In some cases, adoption of such measures may eliminate the need for a licence.

Information to be included when applying for a licence

An application for a licence should include the information outlined below and the relevant documentation (as well as the design criteria in Table 6.1). Local councils may have similar information requirements when assessing proposals that will not be licensed by the EPA.

Planning horizon of the scheme

Effluent characteristics

- source of effluent
- method of treatment and disinfection
- degree of exposure to humans
- effluent quality and quantity (Table 6.1)
- effluent strength and identification of the most limiting constituent which resulted in the strength classification.

Description of site

- locality map, indicating catchment, Eastings, Northings, AMG Zone and scale
- current land use
- proximity of site to dwellings and roads, water courses, other property boundaries, urban areas, areas of natural timber and protected environmental areas (e.g. wetlands)
- location of existing groundwater bores.

Description of climate

- precipitation analysis (average monthly distribution)
- storm intensities
- evapotranspiration (average monthly distribution)
- prevailing wind (if applicable)
- description of water balance (daily or monthly) used to estimate maximum hydraulic loading.

Topography/landform

- ground slope and relief
- description of adjacent land
- erosion potential
- drainage features
- seasonal wet areas and springs

- surface rockiness
- flood potential.

Soil characteristics
- type, structure, profile features, colour, texture, electrical conductivity, cation exchange capacity, exchangeable cations, hydraulic conductivity, nutrient levels, organic matter, phosphorus sorption capacity, salinity levels and pH
- infiltration and percolation characteristics.

Groundwater
- depth to groundwater
- location of existing wells on the subject site and adjoining sites
- current use and ambient groundwater chemistry
- an analysis of the hydrogeological conditions under the site
- vulnerability of groundwater systems to pollution.

Surface water
- proximity
- quality and current use
- flow characteristics
- quality of aquatic ecosystems.

Cropping system
- crops/vegetation to be grown
- details of planting and harvesting cycles
- details of cropping or grazing management and practices.

Animal system
- animal species and types to be fed/grazed
- farm design and facilities for animal enterprise
- plan of production and health practices
- exposure of pets, birds and native animals.

Irrigation area and wet weather storage required
- details and results of nutrient, organic, salt and water budgets used to determine the proposed land area and wet weather storage.

Effluent transport
- detailed plans of effluent transport facilities
- wet weather storage facilities

- detailed plans of effluent storage facilities (including balance ponds) and any return pumping arrangements.

Irrigation system

- type of irrigation system: spray, trickle, flood or furrow –for spray systems detail the pressure at which effluent is discharged
- plan of irrigation system
- schematic diagram of the system controls, including pipes, pumps, valves, timers, alarms and runoff controls
- proposed monitoring program
- analysis of risks to environment from scheme
- how monitoring program was developed in response to risk
- details of components to be monitored
- details of tests to be undertaken
- details of analysis reporting mechanisms.

Table 6.1: Design parameters for effluent irrigation systems

Characteristic	Indicator	Unit
Effluent quantity	average annual design flow	kL/day
	design peak flow	kL/day
Irrigation area		hectares
Buffer zone allowance	area	hectares
	width	metres
Storage area		hectares
Water balance	design total annual precipitation	mm/yr
	design total annual runoff	mm/yr
	design evapotranspiration	mm/yr
	design percolation rate	mm/yr
Organic loading rate (as BOD_5)	design daily and annual rate	kg/ha/day or year
Other constituents loading rates	design daily and annual rate	kg/ha/day or year
Effluent quality	total dissolved solids (TDS)	mg/L
	electrical conductivity	dS/m
	sodium adsorption ratio	$(mmol/L)^{½}$
	Ca, Mg, K and B	mg/L
	BOD_5	mg/L
	TOC	mg/L
	COD	mg/L
	suspended solids	mg/L
	thermotolerant coliforms	cfu/100mL
	grease	mg/L
	metals and pesticides	mg/L
	nitrogen (total)	mg/L
	phosphorus (total)	mg/L
	pH	–
Application rate	length of operating season	wk/yr
	hourly rate of spray application	mm/h
	application period	hours
	average weekly rate	mm/wk
	maximum weekly rate	mm/wk
Storage capacity		kL or ML

Note: Section 1 provides a checklist of procedures to follow when setting up an effluent irrigation system

Licence conditions

The standard conditions of a licence include emission/discharge limits and operating conditions, as well as monitoring, reporting and compliance review requirements.

Site-specific conditions, however, also may be determined on a case-by-case basis, depending on the particular environmental characteristics of the effluent irrigation system. For example, a licence may include conditions relating to effluent quality and quantity limits.

Operators may be required to produce an annual environmental management report to enable assessment of the performance of the irrigation scheme. The requirements of this report will depend on the size of the effluent irrigation system and the sensitivity of the environment in which the system is located.

6.2 Environmental offences

Proponents should be aware of the range of environmental offences relating to air, water and noise pollution and conduct their activities accordingly.

It is an offence for the occupier of premises to fail to operate equipment in a proper and efficient manner, and to fail to maintain equipment in an efficient condition. Air pollution includes the emission of an offensive odour.

A licence will not protect an occupier from prosecution for these failures.

6.3 Development consent

The *Environmental Planning and Assessment Act 1979* (EP&A Act) sets out the requirements for environmental impact assessment for development consent purposes. Requirements will vary depending on the proposed development or activity.

Development consent is an approval for development issued by a 'consent authority', often the local council but sometimes also the Minister for Infrastructure, Planning and Natural Resources. 'Development' includes not only building, but also the use of the land and carrying out works on it.

Environmental planning instruments (such as LEPs, REPs and SEPPs) will determine if development consent is required for a development proposed for a certain zone. Therefore, depending on the provisions in the relevant environmental planning instruments, installing storage tanks or irrigation pipes may require development consent. Local council is the first point of contact for advice.

Not all development needs the consent of the local council. For example, in some areas zoned 'rural' many agricultural activities do not require consent.

Part 4 of the EP&A Act

Development proposals that require development consent are subject to the requirements of Part 4 of the EP&A Act. The development consent process follows the steps below:

1. Establish if development consent is required. Check the environmental planning instruments or contact the local council.
2. If consent is required:

- check if approvals by other authorities are required (such as the EPA and DIPNR). These authorities can stipulate general terms to be included in the development consent.
- assess need for an Environmental Impact Statement (EIS). The types of development requiring an EIS are listed in Schedule 3 to the Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) and are known as designated developments.
- if an EIS is required, obtain Director General's Requirements from DIPNR for the preparation of an EIS.

Integrated development assessment (IDA)

Development Applications (DAs) are 'integrated development' where certain licences or approvals are required from bodies other than a consent authority. Applicants must inform councils of any licences, approvals or permits from State agencies (such as EPA licences) required in addition to development consent, prior to lodging a DA. Council is then required to consult with the relevant State agency and obtain the agency's requirements in relation to the development.

A development consent granted by a council must be consistent with the general terms of approval proposed by the State agency. If the State agency informs the council that it will not grant an approval, the council must refuse the application.

Part 5 of the EP&A Act

Activities which are not covered by plan making or development control processes and thus, do not require development consent, fall under Part 5 of the EP&A Act. Examples of these activities are public utility installations undertaken by local councils and government agencies, which have traditionally been exempted from plans.

The steps to follow where development consent is not required are:

1. establish whether an approval, licence, permit or grant by a public authority is required
2. consult the determining authority and ascertain whether Part 5 of the EP&A Act applies

3. assess the need for an EIS. Activities that are likely to significantly affect the environment require an EIS
4. if an EIS is required, obtain Director General’s Requirements from DIPNR for the preparation of an EIS.

Further guidance can be found in *Is an EIS Required?* (DUAP 1995). The environmental guidelines, *EIS: Guidelines for Irrigation of Sewage Effluent* (DUAP 1996) is also available from DIPNR.

Examples

Sewage treatment plants (STPs)
If the proponent is a private organisation, the storage or use of effluent at a sewage treatment plant would normally require consent under the provisions of the local environmental plan (LEP) or other environmental planning instruments. Depending on scale, nature and location, this could be a designated development, falling within the sewerage systems category of Schedule 3 of the EP&A Regulation.

If the effluent is used or stored on a site not directly associated with the STP, then the proposal needs to be characterised to determine if it is permissible and whether development consent is required under the LEP. When characterising a proposal, the scale, nature and location of the proposal need to be considered.

If the proponent is a municipal council or another public authority, the storage or use of effluent at a municipal STP may not require development consent under the provisions of *SEPP 4 – Development without Consent*. However, environmental impact assessment will proceed in accordance in Part 5 of the EP&A Act.

SEPP 4 may not apply when the storage or use of effluent is not directly associated with the STP. In this case, the activity should be characterised to assess if it is permissible under the relevant environmental planning instruments.

Agriculture, forestry or landscaping
If effluent is supplied as needed and applied at rates recommended in this guideline for beneficial purposes, then the application of effluent could be considered ancillary and subsumed in the purpose of agriculture, forestry or landscaping. Such a scheme would normally not include any wet weather storage facilities (except for a balance pond, which would contain no more than 3 days maximum effluent supply). As these purposes do not usually require consent, the application of the effluent would also not require consent.

Effluent reuse schemes
If a scheme is specifically designed and managed for effluent irrigation, the LEP would help determine if it is permissible and if consent is required. Such a scheme would normally include carrying out works and installing apparatus. If development consent is required, then Schedule 3 of the EP&A

Regulation would help determine if the proposal is designated and an EIS required.

If development consent is not required, the potential environmental effects may be assessed under the provisions of Part 5 of the *EP&A Act 1979*. The determining authority must assess whether the activity has the potential to cause significant environmental effects before approving an application or granting funds to undertake a scheme. If significant effects are likely, an EIS must be prepared, publicly exhibited and considered before approval is granted.

Some effluent irrigation schemes can require a works approval under the *Water Management Act 2000*.

6.4 Other statutory requirements

A number of other statutory requirements may be relevant to the use of effluent for irrigation. They should be considered on a case-by-case basis and may include, but not be limited to the following.

Sewerage schemes managed by local government

Council's responsibilities for water supply and drainage are set out in the *Local Government Act 1993* and regulations.

Local councils operating sewerage schemes must, in accordance with Section 60 of the *Local Government Act 1993*, obtain the approval of the Minister for Energy and Utilities for sewage effluent from their areas to be discharged, treated or supplied to any person. Prior to a Section 60 approval being given, the Minister for Energy and Utilities must consider the proposal in accordance with the EP&A Act.

Activities within national parks

The Parks Service Division of DEC is responsible for the management of areas reserved or dedicated under the *National Parks and Wildlife Act 1974* and for the protection and care of fauna, native plants and Aboriginal places.

Effluent irrigation proposals in such areas are likely to require consent by the Director-General of the Department of Environment and Conservation. This approval would trigger the environmental assessment provisions of Part 5 of the EP&A Act.

A permit is also required for activities likely to damage or destroy Aboriginal relics or places.

Threatened species

The *Threatened Species Conservation Act 1995* integrates the conservation of threatened species into the development control processes under the EP&A Act. The Act sets out factors to be considered in deciding whether there is likely to be a significant effect on threatened species, populations or ecological communities and if a Species Impact Statement is required. Where there is likely to be a significant effect, the consent authority must seek concurrence of the Director-General of DEC. Further information may be obtained from the local Parks Service Division offices of the Department.

Legislation that provides for the protection of all threatened fish and marine plants came into affect on 1 July 1998. Threatened species provisions were included as Part 7A of the *Fisheries Management Act 1994*. This legislation provides for the protection, conservation and recovery of threatened species, and makes provision for the management of threats. Further information may be obtained from the local office of the NSW Department of Primary Industries.

Protection of drinking water supplies

The *Local Government Act 1993* makes it an offence if a person wilfully or negligently does any act which damages or pollutes a public water supply (or is likely to do so).

In areas controlled by water corporations or water authorities *special* or *controlled areas* might be defined. These areas have specific provisions applying to them. Proponents should contact local water supply authorities to ascertain whether similar provisions apply in their areas.

The Sydney Catchment Authority has been formed under the *Sydney Catchment Management Act 1998*. The key role of the Authority is to supply water to Sydney Water Corporation and to manage and protect Sydney's drinking water catchments. The Authority will have ownership, operation and maintenance of catchment bulk water storage facilities. The Authority is to ensure that the water it supplies meets appropriate water quality standards; the environment is protected; and risks to public health are minimised.

State Environment Planning Policy 58 (SEPP 58) came into force on 1 February 1999. SEPP 58 is an interim measure to improve planning within the Sydney drinking water catchment areas. Proponents are required to demonstrate how their development will have a neutral or beneficial effect on water quality. This SEPP gave the former Planning NSW concurrence and notification roles in planning decisions affecting water quality within the Sydney water supply catchment, and this role was taken over by the Sydney Catchment Authority from 1 September 1999. The SEPP is to be replaced by a more detailed REP addressing decisions on future development.

Animals to abattoirs

Federal regulations (Export Meat Orders 135 and 141) require the owner of cattle grazed on effluent areas to seek approval from the abattoir veterinarian before submitting the animals to any abattoir holding an export licence. The owner would be expected to demonstrate that the risks of the animals carrying pathogens (or chemical residues) originating from the effluent were being adequately managed. Advice should be sought from the Animal

Quarantine and Inspection Service, Department of Agriculture Forestry and Food, Canberra, where necessary.

Pure food legislation

The NSW Food Act 1989 and Regulation deals with maximum residue standards in meat set in the Food Standards Code (Adoption) Regulation 1989.

Australian and New Zealand Joint Food Standards Code

This code was gazetted on 21 December 2000.

- Standard 1.4.1: Contaminants and Natural Toxicants; and
- Standard 1.4.2: Maximum Residue Levels.

7. References and Further Reading

7.1 References

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Glossary

Adsorption: Increased concentration of molecules or ions on a surface, including exchangeable cations and anions on soil particles.

Aeration: A process for continuously creating new air/liquid interfaces to promote the transfer of oxygen across the interface. This may be achieved by:

(a) spraying the liquid in the air, e.g. spray irrigation of sewage

(b) bubbling air through the liquid, e.g. diffused air aeration in the activated sludge process

(c) agitating the liquid, eg. mechanical aeration in the activated sludge process

(d) allowing the liquid to flow in thin films over a weir, or

(e) other air entrainment processes such as dissolved air or two phase flows.

Algae: Simple chlorophyll bearing plants varying in form and size, most of which are aquatic.

Aquifer: Groundwater-bearing formations that are sufficiently permeable to transmit and yield water in useable quantities.

Available water capacity: The amount of water held in the entire soil profile between field capacity and permanent wilting point with corrections for salinity, fragments and root depths. AWC% = FC(%,v/v) – PWP (%,v/v). Also, loosely defined as the amount of water that a soil can store for plant growth.

BOD_5 – Biochemical oxygen demand (BOD): The decrease in oxygen content in mg/L of a sample of water in the dark at a certain temperature over a certain period of time, which is caused by the bacterial breakdown of organic matter. Usually the decomposition has proceeded so far after 20 days that no further change occurs. The oxygen demand is measured after 5 days (BOD_5), at which time 70% of the final value has usually been reached.

Carbamate: A salt or ester of carbamic acid.

Cation exchange capacity: The capacity of the soil to hold and exchange cations. It is usually expressed as centimoles of positive charge per kilo of soil (cmol(+)/kg).

Cation: A positively charged ion.

Chemical oxygen demand (COD): The oxygen equivalent of the organic matter in wastewater that can be oxidised by using a strong chemical oxidising agent in an acidic medium.

Chlorinated organic compounds: Hydrocarbons in which some or all of the hydrogen atoms are replaced by chlorine.

cmol: centimoles (ie. 10^{-2} moles).

Colloidal solids: A solid particle, generally less than 1 micrometre (µm) in size (0.001 µm to 1 µm in any dimension) that does not settle out of solution.

Controlled public access: The limitation of public access to sites so as to minimise the likelihood of direct physical contact with effluent.

Crop Factor (Kc): The proportion of potential evapotranspiration (PET) actually transpired by the crop (Et_{crop}). (Et_{crop} = Kc x PET)

Deficit (irrigation) scheduling: Scheduling irrigation used to ensure that a soil moisture deficit remains after each irrigation event (see also irrigation scheduling).

Denitrification: The biological process by which nitrate is converted to nitrogen and other gaseous end products.

Designated development: A development designated under any of the categories listed in Schedule 3 of the Environmental Planning and Assessment Regulation (or if designated by virtue of an environmental planning instrument). Examples of designated developments include sewerage systems, livestock intensive industries, livestock processing industries, depending on scale and location.

Disinfection: Destruction of disease-causing organisms.

Effluent irrigation system: Irrigation system that uses effluent. Irrigation of effluent is not synonymous with disposal.

Effluent: As defined in the Protection of the Environment Operations Amendment Regulation 1999, effluent means:

(a) wastewater from sewage collection or treatment plants; or

(b) wastewater from collection or treatment systems that are ancillary to processing industries involving livestock, agriculture, wood, paper or food, being wastewater that is conveyed from the place of generation by means of a pipe, canal or other conventional method used in irrigation (but not by means of tanker or truck); or

(c) wastewater from collection or treatment systems that are ancillary to intensive livestock, aquaculture or agricultural industries, being wastewater that is released by means of a pipe, canal or other conventional method used in irrigation as part of day-to-day farming operations.

Electrical conductivity (EC): A measure of the conduction of electricity through water or a water extract (1 part soil to 5 parts water) of soil. This can be used to determine the soluble salts content. To obtain the real soil electrical conductivity (Effective electrical conductivity) the EC of a soil water extract is converted by a factor which reflects the texture of the soil.

Eutrophication: Enrichment of waters with nutrients, primarily phosphorus, causing abundant aquatic plant growth.

Evapotranspiration: The combined loss of material from a given area during a specified period of time by evaporation from the soil or water surface and transpiration from plants.

Exchangeable cations: Positive ions such as calcium, magnesium, potassium, sodium, hydrogen, aluminium and manganese, which interchange between soil solutions and clay or organic complexes in soil.

Exchangeable sodium percentage (ESP): The relative proportion of sodium ions to other exchangeable cations in soil expressed as a percentage. ESP is the method used to determine the sodicity of a soil (i.e. ESP >5 is considered to be a sodic soil).

Field capacity: The amount of water held in soil when it has been allowed to drain.

Flood irrigation: An irrigation method that applies water or wastewater to a depth of about 0.3 metres, by means of distributors, on a land area surrounded by low earth embankments. This procedure generally allows the water or wastewater to percolate through the soil to the under drains, whence it is discharged into a main ditch or drain.

Freeboard: Spare capacity to accommodate any unexpected increase in containment requirements.

Furrow irrigation: An irrigation method that applies water or wastewater by furrows or small ditches that lead from the supply ditch.

Groundwater: Waters occurring below the land surface.

Groundwater recharge areas: Areas in the landscape where rainfall and surface water infiltrates to the zone of saturation under natural conditions.

Group A wastes: Any of the types of waste specified in the POEO Amendment Regulation 1999, Schedule 1, Appendix, Part 5.

Group B wastes: Any of the types of waste specified in the POEO Amendment Regulation 1999, Schedule 1, Appendix, Part 6.

Group C wastes: Any of the types of waste specified in the POEO Amendment Regulation 1999, Schedule 1, Appendix, Part 7.

Half-life: Time required to reduce by 50% the concentration of a material in a medium (e.g. soil and water) or organism (e.g. fish tissue) by transport, degradation, transformation or depuration.

Hazardous wastes: Any of the types of waste specified in the POEO Act, Schedule 1, Appendix, Part 3, or any waste that is otherwise assessed and classified as hazardous waste in accordance with the procedures set out in the *Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes* (EPA 1999a).

Helminth: Intestinal worm.

Holocene: Recent in geological time.

Indicator faecal coliforms: The presence of these organisms indicates that pathogenic organisms due to sewage presence may also be present.

Infiltration capacity: The capacity of the soil to take in water at its surface.

Infiltration rate: The rate at which water can enter the soil surface. It affects the rate at which a soil may recharge with water and because it affects the likelihood of surface runoff and hence erosion during heavy rain or irrigation.

Irrigation: The artificial supply of water or wastewater to plants and soils to replenish moisture lost by evapotranspiration and to grow plants. Irrigation is not synonymous with disposal.

Irrigation corporation: A company, co-operative or corporation that manages an irrigation scheme area and is listed on Schedules 1 or 2 of the *Irrigation Corporations Act, 1994*. Irrigation corporations construct, maintain, manage and operate drainage networks and water supply systems and services to users in the irrigation scheme area. To carry out the business of supplying water, the irrigation corporations must hold an irrigation corporation licence (granted by the Governor) and operate in accordance with licence conditions.

Irrigation scheduling: The monitoring of soil moisture deficits either by direct measurement (e.g. neutron probe) or indirectly by soil moisture budgeting to determine the frequency and quantity of irrigation water required. Normally used to ensure that only enough water is applied to meet plant water requirements.

Leaching fraction: Irrigation water applied in excess of the soil water holding capacity in order to leach salts to below the plant root zone. The fraction is usually smaller in higher rainfall areas and larger for higher strength effluents.

Leaching: The downward movement of a material in solution through soil.

Metasediments: Partly metamorphosed sedimentary rocks.

Micronutrients: Chemical elements such as boron, copper, zinc, iron, manganese, molybdenum and chlorine that are necessary in only extremely small amounts for plant growth.

Mole: The molecular weight of a substance expressed in grams.

Nitrification: Transformation of inorganic ammonium (NH_4^+) into nitrate (NO_3^-). In treatment processes, conversion of organic nitrogen to ammoniacal nitrogen is preceding or occurring simultaneously with nitrification. Transformation of organic nitrogen in soil is referred to as mineralisation.

Ordovician: The second of the periods comprised in the Paleozoic era, in the geological classification now generally used. Also, the system of strata deposited during that period. In older literature, it was called Lower Silurian.

Orthophosphate (PO_4^{3-}): A water-soluble form of phosphate found in soil solution, and some effluents, that is taken up by plant roots.

Pan A evaporation: Evaporation is the change of water from its liquid (or solid) phase to its vapour phase. Supply of energy (solar radiation and transport of vapour away from the surface (i.e. winds) are two main factors influencing evaporation for the earth's surface. A standard evaporation pan called a Class A pan is used a basis to estimate evapotranspiration or evaporation from open water bodies. See also evapotranspiration.

Parent material: The horizon of weathered rock or partly weathered soil material from which the soil is formed.

Pathogen: An organism capable of eliciting disease symptoms in another organism.

Percentile: Values that divide the data into one hundred equal parts are called percentiles. 50^{th} percentile corresponds to the median, 25^{th} and 75^{th} percentiles correspond to the first and third quartiles respectively.

Permanent wilting point: The point at which water in the soil is held at pressures sufficiently high that plants can no longer extract water.

Pesticide: A substance or mixture of substances used to kill unwanted species of plants or animals.

pH: Value taken to represent acidity or alkalinity of an aqueous solution; expressed as the logarithm of the reciprocal of the hydrogen ion activity in moles per litre at a given temperature.

Phenols: A group of aromatic hydroxyl compounds with the base structure containing phenol (C_6H_5OH).

Phenoxyacid (herbicides): Group I herbicides that act by disrupting plant growth (i.e. have multiple sites of action) e.g. 2,4-D, MCPA. These chemicals act as plant growth regulators in low concentrations.

Phosphorus sorption: The process by which phosphorus binds with hydrous oxides of iron and aluminium in the soil, thereby becoming unavailable for plant uptake.

Phosphorus sorption capacity: The ability of a soil material to sorb phosphorus compounds onto soil particles thereby rendering the phosphorus unavailable to plants and immobilising it within the soil itself. Soil has a finite capacity to sorb phosphorus. When the soils phosphorus sorption capacity is reached phosphorus ions will move with soil water down the profile. This process starts to partially occur, well before the full sorption capacity is reached.

Podzolic: Commonly acidic and sandy soils, with a uniform coarse texture profile, but with strongly colour-differentiated horizons.

Ponding: In the context of effluent treatment, ponding is retention of effluent in a pond for a period of time, typically exceeding 10 days.

Potable water: Water of drinking quality.

Reclaimed water: Wastewater that has been recovered for further use after appropriate treatment.

Relative crop yield: Crop yield expressed as a fraction of maximum (unstressed) yield where unstressed yield = 1.

Root zone: That part of the soil that is invaded by roots of plants.

Salinisation: The accumulation of water-soluble salts in soil to a level harmful to plant growth.

Saturated hydraulic conductivity: The flow of water through soil per unit of energy gradient. It is an important measure of the drainage capacity of the soil.

Secondary treatment: A combination of processes used to remove biodegradable organics and suspended solids in wastewater. It removes 85% of BOD and suspended solids, generally by biological and chemical treatment processes. Secondary effluent generally has BOD < 30 mg/L, TSS < 30 mg/L but may rise to > 100 due to algal solids in lagoon or pond systems.

Siliceous: Of or pertaining to silica; containing silica, or partaking of its nature. Containing abundant quartz.

Sodic soil: A soil containing sufficient exchangeable sodium to adversely affect soil stability, plant growth and land use. Such a soil would typically contain a horizon in which the amount of exchangeable sodium percentage (ESP) would be five or more. Strongly sodic soils are those with an ESP of 15 or more. Sodic soils generally have severe surface crusting, low infiltration and hydraulic conductivity, hard and dense subsoil, and are highly susceptible to gully and tunnel erosion.

Sodium adsorption ratio (SAR): The measurement of sodium ions in soil or water relative to calcium and magnesium ions.

Soil fertility: The capacity of the soil to provide adequate supplies of nutrients in proper balance for the growth of specified plants, when growth factors such as light, moisture and temperature are favourable.

Soloth: One of the great soil groups with recognised profile development. It is a mildly leached soil often with a high sodium content.

Sorption strength: The sorption strength of a soil is a measure of how strongly P is sorbed to the soil. It depends on the mineralogy and surface characteristics of the soil.

Spray irrigation: A method of applying water or effluent.

Stormwater runoff: Runoff resulting from rainfall.

Surface irrigation system: An irrigation system using bays, borders or furrows. This typically excludes spray, drip and sub-surface irrigation methods.

Surfactant: A substance that alters the surface-modifying properties of another substance, particularly water. Surfactants are used in detergents to reduce the surface tension of water so that the water is able to penetrate fabrics.

Suspended solids (non-filtrable residue): The solids in suspension in wastewater that are removable by laboratory filtering, usually by a filter of nominal pore size of about 1.2 micrometers.

Tailwater: Wastewater runoff leaving the down-slope end of an effluent irrigation area.

Terminal pond: A pond storing contaminated runoff from an effluent irrigation area, collected by catch drains.

Tertiary treatment: Includes treatment processes beyond secondary or biological processes that further improve effluent quality. Tertiary treatment processes include detention in lagoons, conventional filtration via sand, dual media or membrane filters (which may include coagulant dosing) and land based or wetland processes.

Thermotolerant coliforms: A subset of coliforms found in the intestinal tract of humans and other warm blooded animals which can ferment lactose at 44° to 44.5° to produce acid and gas. They are used as indicators of faecal pollution. They are also known as faecal coliforms and consist chiefly of *E. coli.*

Time step: Time interval between one measurement, iteration or calculation and the succeeding measurement. In soil water budgeting, this is usually days, weeks or months.

Total coliforms: Coliform organisms used as indicators of faecal contamination of water. They are gram negative non-sporing rod-shaped bacteria capable of aerobic and facultatively anaerobic growth in the presence of bile salts and ferment lactose producing acid and gas within 48 hours at 35°-37°.

Total dissolved solids (TDS): Combined concentration of dissolved mineral salts in effluent.

Total nitrogen: Combined concentration of organic nitrogen, ammonia, nitrite and nitrate.

Total organic carbon (TOC): The total organic carbon content of wastewater.

Trickle (drip) irrigation: A method of irrigation where pressurised water or wastewaters are discharged through micro-emitters. Trickle (drip) irrigation differs from other types of irrigation in that the aim is not to allow the soil profile to dry out appreciably. Instead the aim is to replace the water removed by the plant during the previous 24 hours and to place that water in a limited part of the soil profile. Application rates are small, because the water is applied daily and water loss through evaporation is small. The method is suitable for row-crops and permanent horticultural plantings.

Uncontrolled public access: Public access to sites so that direct physical contact with effluent is possible.

Volatilise: To become volatile or pass off as vapour.

Watertable: The surface of the saturated zone in an unconfined aquifer.

Waterlogging: The accumulation of excessive moisture in the soil within the zone or depth desirable for favourable root development of plants. Saturation of soil with water and the replacement of most or all of the soil air with water.

Water quality objective: Numerical concentration limits or other requirements established to support and protect ambient water quality for designated environmental values (or water uses) at a specified site, (eg. establishing instream salinity levels needed to protect water quality used for the irrigation of crops). Under the National Water Quality Management Strategy they are locally established benchmarks for water quality derived from prevailing Australian Water Quality Guidelines for Fresh and Marine Waters.

Wet weather storage (storage): A facility for storing effluent generated when the use of effluent for irrigation is not possible, such as when it is raining, or when evaporation is very low.

Appendix 1: Guidelines for the Use of Reclaimed Water from Municipal Sewage Treatment Plants

Table A1: Guidelines for treatment, disinfection and irrigation controls for the spray application of municipal sewage effluent

Type of reuse	Level of treatment	Effluent quality[1]	Effluent monitoring[2]	Controls
Urban (non-potable)				
Municipal with uncontrolled public access Irrigation open spaces, parks, sportsgrounds, dust suppression, construction sites	Tertiary and Pathogen reduction[5]	pH 6.5–8.5[7] ≤2 NTU[9] 1 mg/L Cl2 residual[10] or equivalent level of pathogen reduction Thermotolerant coliforms[3] <10 cfu/100mL[4]	pH weekly BOD weekly Turbidity continuous With disinfection system, e.g. Cl_2 Disinfection systems daily[6] Thermotolerant coliforms[3] weekly	Application rates limited to protect groundwater quality. Salinity should be considered for irrigation.
Municipal with controlled public access Irrigation open spaces, parks, sportsgrounds, dust suppression, construction sites, mines	Secondary and Pathogen reduction[5]	Thermotolerant coliforms[3] <1,000 cfu/100 mL[4]	pH monthly SS monthly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Irrigation during times of no public access. Application rates limited to protect groundwater quality. Salinity should be considered for irrigation. Withholding period nominally 4 hours or until irrigated area is dry.
Agricultural				
Food production Raw human food crops in direct contact with effluent e.g. via sprays, irrigation of salad vegetables In NSW, NSW Health does not support the use of reclaimed water for spray irrigation of salad vegetables where the effluent is in contact with the edible part of the plant.	Tertiary and Pathogen reduction[5]	pH 6.5–8.5[7] ≤2 NTU[9] 1 mg/L Cl_2 residual[10] or equivalent level of disinfection Thermotolerant coliforms[3] <10 cfu/100 mL[4] <1 intestinal nematode egg or larva/L[6]	pH weekly Turbidity continuous Disinfection systems daily[6] Thermotolerant coliforms[3] weekly	Application rates limited to protect groundwater quality. Salinity should be considered. A minimum of 25 days ponding or equivalent treatment (e.g. sand filtration) for helminth control.

Table A1: Guidelines for treatment, disinfection and irrigation controls for the spray application of municipal sewage effluent (cont)

Type of reuse	Level of treatment	Effluent quality[1]	Effluent monitoring[2]	Controls
Food production Raw human food crops not in direct contact with effluent (edible product separated from contact with effluent[11], e.g. use of trickle irrigation) or crops sold to consumers cooked or processed.	Secondary and Pathogen reduction[5]	pH 6.5–8.5[7] Thermotolerant coliforms[3] <1,000 cfu/100 mL[4]	pH weekly BOD weekly SS weekly Thermotolerant coliforms[3] weekly	Application rates limited to protect groundwater quality. Salinity should be considered. Dropped crops not to be harvested from the ground. Crops must be cooked (>70°C for 2 minutes), commercially processed or peeled before consumption.
Food production Pasture and fodder (for grazing animals except pigs and dairy animals, i.e. cattle, sheep and goats)	Secondary and Pathogen reduction[5]	pH 6.5–8.5[7] Thermotolerant coliforms[3] <1,000 cfu/100 mL[4]	pH weekly SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Application rates limited to protect groundwater quality. Withholding period of nominally 4 hours for irrigated pasture. Drying or ensiling of fodder. Helminth controls[8].
Food production Pasture and fodder for dairy animals (with withholding period).	Secondary and Pathogen reduction[5]	pH 6.5–8.5[7] Thermotolerant coliforms[3] <1,000 cfu/100 mL[4]	pH weekly SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Application rates limited to protect groundwater quality. Withholding period of 5 days for grazing animals. Drying or ensiling of fodder. Helminth controls[8].
Food production Pasture and fodder for dairy animals (without withholding period). Drinking water (all stock except pigs). Washdown water for dairies	Secondary and Pathogen reduction[5]	pH 6.5–8.5[7] Thermotolerant coliforms[3] <100 cfu/100 mL[4]	pH weekly SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Application rates limited to protect groundwater quality. No withholding period. Helminth controls[8].
Non-food crops Silviculture, turf and cotton, etc.	Secondary and Pathogen reduction[5]	pH 6.5–8.57 Thermotolerant coliforms[3] <10,000 cfu/100 mL[4]	pH weekly BOD weekly SS weekly Thermotolerant coliforms[3] weekly	Application rates limited to protect groundwater quality. Restricted public access. Withholding period nominally 4 hours or until irrigated area is dry.

Source: These requirements are based on National Water Quality Management Strategy: Guidelines for Sewage Systems — Use of Reclaimed Water (ARMCANZ, ANZECC and NHMRC 2000).

Notes: DEC/local council will adopt the criteria set in any updated national guidelines except where NSW Health provides different requirements particular to NSW or local conditions.

Consistent with the national guidelines, it should be noted that in some cases, the Department of Environment and Conservation/local council or NSW Health may adopt more stringent requirements than those outlined in the national document, eg. It is possible that NSW Health may apply the national guideline values as maximum levels rather than median levels.

Intensive animal industries should check for specific animal health protection measures.

SS = suspended solids

NTU = nephelometric turbidity unit

CFU = colony-forming units

1. Effluent quality refers to its quality following treatment appropriate for a particular application and prior to mixing with receiving waters. The guideline levels apply to the treated effluent feeding into the reticulation system, after the point of treatment and disinfection. The effluent should not degrade in quality while it is being stored or while travelling through a reticulation system. Chlorine may need to be added as a primary or secondary disinfectant to allow for a residual disinfection.
2. Monitoring demonstrates effluent water quality at the point of supply rather than at the treatment plant. In most cases this will be the point of entry to the reticulation system or other suitable representative sampling location.
3. Thermotolerant coliforms (see Glossary).
4. Median value. Refer to statistical treatment of data in ARMCANZ, ANZECC & NHMRC (2000) or future updates
5. Pathogen reduction beyond secondary treatment may be accomplished by disinfection (eg. chlorine) or by detention (eg. ponds or lagoons). Systems using detention only do not provide reduction of thermotolerant coliform counts to <10 per 100 mL and are unsuitable as the sole means of pathogen reduction for high contact uses.
6. Disinfection systems refer to chlorination, ultraviolet irradiation or other disinfection systems. Monitoring requirements may include checking chlorine residual or operational checking of UV equipment. Monitoring frequency for pond and lagoon systems will be site-specific and dependent on factors such as detention time.
7. 90% compliance for samples.
8. Helminths controls include measures such as removal by treatment, veterinary inspection, cattle husbandry and/or a withholding period prior to grazing. For pasture and fodder applications, other options may be used to control helminth infection in grazing animals if they are acceptable to the NSW Department of Primary Industries.
9. Limit met prior to disinfection. 24 hour mean value. 5 NTU maximum value not to be exceeded.
10. Total Chlorine Residual after a minimum contact time of 30 minutes.
11. In NSW, NSW Health specifies that for raw food crops separated from contact with effluent by peel, the level of treatment should be the higher category of 'Raw food crops in direct contact with effluent.'

Appendix 2: Load-based Licensing

At the time of publication of this Guideline some activities are subject to the EPA's load-based licensing (LBL) scheme. The following information is from the Load Calculation Protocol referred to in the Protection of the Environment Operations (General) Regulation 1998 (the Regulation). The full Protocol sets out those activities that are subject to LBL and the methods that must be used to calculate assessable pollutant loads. A revised Load Calculation Protocol may be issued from time to time and should be referred to. These revisions are notified in the Government Gazette. Copies of the full and most recent LBL Protocol, and relevant legislation are available from DEC's web site at www.environment.nsw.gov.au, or contact the Department.

Effluent irrigation schemes subject to LBL can obtain a discount on the pollutant load fee where effluent is reused in a sustainable manner. In the case of reuse of effluent, weighted loads are calculated by multiplying the actual loads of each pollutant by 'reuse discount factors'. There are different performance criteria for achieving discounts for each pollutant. The reuse discount factor for each pollutant is the sum of a 'pollutant management factor' (0, 0.25 or 0.5) and a 'water management factor' (0, 0.25 or 0.5). Better performance leads to a lower factor and thus a higher fee discount; i.e. the best possible score is 0 + 0 = 0 (100% discount), and the least beneficial is 0.5 + 0.5 = 1 (nil discount).

If a range of discount factors applies to different portions of the effluent (e.g. different disposal or reuse methods for parts of the total load), the load is divided into portions, the appropriate discount factors are applied to each portion, and then the values are summed to calculate total weighted loads of each pollutant.

Refer to the full and most recent LBL Protocol available from DEC or the Department's website at www.environment.nsw.gov.au.

Appendix 3: Soil Texture Factors for Soil Salinity Measurement

The following table can be used to convert EC 1:5 soil-water solution to saturated extract (EC_e) (see Section 2.3, Soil Salinity).

Table A3: Soil texture factors for converting EC 1:5 soil-water solution measurement to saturated extract

Soil Texture	Multiply EC 1:5 by the factor below to get EC_e
Sandy loam	11
Sandy clay loam	10
Clay loam	9
Light medium clay	8
Medium clay	7
Heavy clay	6

Source: Based on NSW Agriculture (2000).

Appendix 4: The Effluent Reuse Irrigation Model (ERIM)

The design of a sustainable agronomic system for the use of water, nutrients and organic matter in effluent is central to these guidelines. This appendix explains the basis upon which DEC's Effluent Reuse Irrigation Model was constructed. The following is an extract from a paper presented at a WaterTech Conference (EPA 1996).

Model description

The Effluent Reuse Irrigation Model (ERIM) is based on historical rainfall and evaporation data supplied by the Australian Bureau of Meteorology. The computer implementation of the model is interactive and allows the user to supply local data to generate design criteria for the storage and land requirements of a sustainable irrigation system through a range of graphical displays.

ERIM is designed to be general in that it functions in the same way regardless of location, although site-specific parameters must be provided.

Initially, the evaporation at the selected site is adjusted by a set of crop factors to yield evapotranspiration, which is a measure of water usage by the crop. The crop factors depend on the site, crop grown, agricultural practice, agronomic considerations and month of year.

The deficit of rainfall over evapotranspiration (referred to as irrigation demand) is used to define the potential irrigation pattern, which is established for as many years as historical data is available. A cumulative distribution of yearly irrigation demands is used to pick a lower and upper limit on the depth of irrigation between which a solution will be determined. By default, the lower limit is half the lowest recorded irrigation demand and the default upper limit is the 10% point on the cumulative distribution, but both may be adjusted if they are unsuitable. It is extremely unlikely that a feasible solution will exist outside these two nominated limits.

The historical rainfall and evaporation data is used to calculate the wet weather storage that would have been used for each target irrigation depth from the whole range identified above. The guidelines associate a level of acceptable environmental risk of wet weather storage overflow with defined effluent strength (low, medium or high). The storage sizes necessary to reflect the various environmental risks are determined by counting down the appropriate number of yearly peaks.

The computer implementation of the model will then display these given storage sizes for the range of irrigation depths previously determined. A subsequent graphic display shows the same relationship but plots storage size in megalitres (or equivalent days of dry weather flow) against irrigation land area required (in hectares).

Model assumptions

- The future weather will behave like past weather, as supplied in the historical data.
- The input to the scheme is deterministic. (The volume of effluent from the treatment facility cannot be adjusted day-to-day in response to scheme operations. For example the effluent supply to the scheme cannot be suspended during difficult periods where storage approaches maximum volumes.)
- The rainfall and evaporation at the site are similar to the rainfall and evaporation at the chosen Australian Bureau of Meteorology (ABM) station(s).
- There will be sufficient water to enable the crop to survive during drought so that the crop will be able to use water when required.
- Crop factors can be determined to reflect water usage by the scheme.

Decisions

The major decisions and alternatives considered in constructing this model and its computer implementation are discussed in this section.

Modelling method

Two alternatives were considered for the basis of the irrigation demand calculation:

- **Direct calculation**: Australian rainfall and runoff (ARR) can be used to estimate the total volume of rain falling on a site during a range of storm events (Pilgrim 1987).

  These figures have often been used to calculate the size of terminal ponds protecting the downstream ecology of irrigation sites. Additionally the yearly rain expected may also be estimated from ARR or directly from rainfall tables. This rainfall estimate could be subtracted from average evaporation (or evapotranspiration) to yield an irrigation demand. Such direct calculations could be carried out for a 50 percentile, 75 percentile and 90 percentile rainfall year to estimate irrigation depths (or land area) and storage required. The assumed environmental risks would be set to 50%, 25% and 10% of years of wet weather storage overflow.
- **Historical simulation**: The alternative is to use historical rainfall and evaporation in a simulation to determine the patterns of rainfall deficit or irrigation demand for each year. These patterns will determine the yearly depth of irrigation possible and requirements for wet weather storage.
  In most of NSW, although the pattern of evaporation is reasonably constant from year to year, the yearly rainfall pattern is by no means well defined. This is exemplified by the long periods of drought and then high intensity rain leading to floods. Two different years at a high rainfall level (for example the 90th percentile) will almost certainly have different

rainfall patterns throughout the year and hence different irrigation demands. This leads to inconsistencies with the direct calculation approach.

DEC guidelines have adopted a 'difficult to irrigate' concept measured by maximum wet weather storage required during the year. This is reasoned from a perspective of environmental protection. Such a measure translates into risk of storage overflow with the possibility of ecological harm. This, in turn, requires the historical simulation approach used in the DEC model instead of direct calculation.

Model time step

Generally, the accuracy of a simulation model increases as the time step decreases. This is correct for coarse time steps, but by no means true for fine time steps. The computations involved (and hence solution time) increase as the time step becomes finer. Cumulative numerical errors are of more concern in finer time step models, especially where they involve subtraction of similar sized values. Greater attention needs to be paid to the model components when reducing the simulation interval as will be discussed below.

A time step smaller than a year is clearly required to model the irrigation demand pattern referred to above. A natural time period would be a combination of rainfall event and irrigation cycle. This is known as an event based non-uniform time step. Such a time step could form the basis of an acceptable model, but it was felt that the non-uniform step size would present problems making the model general (i.e. not site-specific). The choices that DEC actively considered were monthly, weekly and daily. The size of data files required is inversely related to the time step size. The ABM has daily and monthly rainfall and evaporation data readily available. Weekly data would require preliminary processing of daily data. The total size of data files for distribution with the computer implementation was one concern.

A daily time step model must address the issue of soil moisture levels. It is inappropriate to directly apply the deficit approach in daily modelling. As irrigation potential is set to the rainfall deficit, a simple daily approach would have the land continually irrigated so that when rain eventually falls most will be lost as runoff and/or drainage to groundwater. This is because the soil is at or near field capacity. To accurately reflect appropriate agricultural practice in irrigation, the soil water content needs to be modelled and irrigation scheduled only on those days where soil water has decreased to an irrigation trigger value. This should decrease the likelihood of moderate rain being lost. Hence, a daily time step model involves a lot more than just a scaled up version of a longer time period model. This is an example of the time step complexity discussed above.

A monthly time step model can overestimate the amount of wet weather storage required in schemes where a terminal pond below the irrigation area is not required. This could be the case for a scheme using low strength wastes not in the vicinity of sensitive waters. The limited monthly model will implicitly try to store and irrigate all the rainfall runoff during the month.

The design chosen in the DEC model is a compromise between the monthly and daily time step. It uses a monthly time step for rain and evaporation but, additionally, the number of rain days in each month is used to better model rain events. Also included, and discussed below, is the water holding capacity of the soil and the capacity of terminal ponds.

Percolation

A reuse water scheme should ideally not pollute either surface or groundwaters. However, with unpredictable rain this will not always be the case, though the scheme design should minimise such occurrences. This goal, however, must be modified in the case of saline wastes. From a land management perspective, undesirable changes will occur if saline water is irrigated and all the water and nutrients are taken up by plants. The salt will not be absorbed, and over time will accumulate in the soil. Therefore, percolation of effluent is advisable so that introduced salts can be leached from the root zone to promote healthy plant growth. Fortunately, salts are very soluble, so that with minimal percolation to groundwater the salt build-up in the root zone can be prevented.

Where the underlying groundwaters are naturally brackish, then the leaching of salts will have little or no impact. If however, natural groundwaters have a low salt content, then the impact caused by leaching must not be excessive to the point where it lowers the beneficial use of the groundwater.

In the DEC model, an amount of irrigation over the monthly demand can be applied for the purpose of salt percolation. This over-irrigation only occurs when such percolation is not naturally supplied by rain, and in any case is strictly limited in the computer implementation. The maximum percolation value of up to 15 mm/month (EPA 1995) has been a considerable debating point. Some arguments suggest that the proposed value is inadequate. Although DEC or local council would, of course, consider any reasoned proposal for a higher figure, the current DEC opinion is that higher values would represent wastewater disposal, not reuse, and would increase the risk of groundwater pollution. It should be noted here that in coastal NSW, with high rainfall, DEC does not expect that schemes will need any irrigation-supplied percolation.

Capacity independent solution method

Any reuse scheme design process should answer two related questions: i) what land area is required; and ii) what volume of wet weather storage is required? It is possible that in certain cases one of these is of fixed size, but in general both need to be determined. In fact, there is likely to be a trade-off between them, and the knowledge of the rate of substitution is necessary for cost minimisation analysis.

To facilitate this calculation the DEC model determines the storage required at each grid point in a range of irrigation depths. This gives the (increasing) relationship between storage required and irrigation depth. Hence the 'solution' given by the DEC model is in fact not a solution at all but, rather, the substitution curve for a given environmental risk. Initially the curve is in terms of millimetres of irrigation and so is independent of actual effluent volumes. Doubling the effluent volume will obviously double both the land and storage required.

For easy interpretation in the computer implementation, the values for effluent volumes are used to re-scale the capacity independent relationship in terms of storage volume in ML (or days of supply) versus land area.

Crop factors

The crop factors are the adjustments to evaporation to reflect actual crop usage of water. For simplicity, the DEC model combines all the influences into one site-specific set of monthly factors. DEC crop factors also include the 'pan factor' which relates the Pan A evaporation to evaporation from a surface (i.e. soil or crop surface). The actual crop factors to be used on any particular scheme should be supplied at the design stage. Therefore there is no crop-specific or site-specific values fixed by the DEC model. This was implemented to ensure that the model is useable independent of location.

Rainfall runoff and terminal pond sizing

As discussed above, a monthly time step may be too coarse at some sites, forcing recycling (by irrigation) of too much rainfall runoff. To this end, the model now includes buffer storage, which are the actual soil water-holding capacity and the terminal pond capacity. It is now possible for high strength effluents to have a buffer storage level even higher than the level stipulated in the draft version of the model (EPA 1995). On the other hand, if the scheme and waste strength do not warrant terminal ponds, this part of the buffer storage can be set to zero.

Evaporation, rainfall and the storage pond

Evaporation and rainfall adjustments to the storage pond were neglected in the draft model (EPA 1995), and comments suggested that the model had either:

- overestimated (the wet-weather storage/irrigation depth relationship) because evaporation from the storage would decrease the amount of water available for irrigation, or
- underestimated, because additional rain on the storage would add to the total volume of water to be irrigated.

As a result of the comments, the model was adjusted to reflect both evaporation and rainfall in the wet weather storage area. While in some cases these calculations may change the solution found, nevertheless, for most feasible schemes, the surface area of the wet weather storage would be at most 10% of the irrigation area, and so any such adjustment would be small.

This change was implemented by including a storage surface area to irrigation area ratio. For example, consider the case when a suitable solution has been identified and a storage size selected in ML. The surface area of the actual storage will be the identified volume divided by the average height (after scaling for correct units). The model can then be re-run to gauge the changes in the model solution that result from halving the average height. This is done by supplying a surface area to irrigation area ratio, double the previous value.

Discounting rainfall for tree canopy interception

DEC believes that, overall, the effect of tree canopy interception of rainfall is insignificant. The rain caught by the tree canopy will be responsible for reduced evaporation by the crop during the time of the tree canopy water evaporation. Hence, a discounted rainfall must be matched by an almost equal discounting of evaporation. To be accurate, special crop factors would need to be included for this water evaporation from the tree canopy.

Adjusting rainfall and evaporation for tree canopy interception was omitted for three reasons: the overall effect of the adjustment is small; it is very difficult to accurately model the adjustment; and the adjustment would further complicate the model. Adjusting only rainfall, and not evaporation, for tree canopy interception will lead to designs which underestimate storage and/or land area.

Discounting irrigation for spray misting

Discounting for spray irrigation is proposed in some irrigation models because it is obvious that some water will be lost in spray irrigation. However, there appears to be little scientific justification for this position (Jensen 1981; J. Murtagh, pers. comm. NSW Agriculture, 1995).

On examining the fate of the 'missing water' it is possible to see that what is lost must re-enter the equation elsewhere. For the amount that evaporates before reaching the ground, there will be a similar reduction in available evaporation. Compare this with the discussion concerning rainfall discounting above. The amount of spray that drifts away will either fall on another part of the irrigation site (therefore, it is not lost) or on the surrounding buffer strip. By notionally including in the calculated area that part of the buffer strip on which drift spray falls, the model can successfully determine the area required. It should be noted that this marginal increase in land area does not include most of the buffer strip, which would receive very little drift spray. For this reason, neither the model nor the computer implementation includes any discounting of irrigation.

Wet weather augmented flows

Even the best sewer systems leak to some extent. Sewage leaks out and water gets in. Additionally, illegal cross connections from the stormwater system will provide increased flows after rain. This is unlikely to be the case for factory generated wastes, where total control of the waste stream is possible. But at the other extreme, runoff carrying wastes from animal feedlots will only be of significant volumes following rain. The model was expanded to accommodate wet weather flows to enable both use for feedlot schemes and better estimation for STP effluent.

The wet weather flow is modelled as a linear function of rainfall between two limits. The lower limit is set in terms of millimetres of rain before runoff (or wet weather flow) is assumed to occur. That is, the value can be set so that light showers will not produce wet weather flow. The upper limit is set in terms of flow volume, and for a sewer system would represent the maximum hydraulic flow of the pipe-work. For animal feedlots, this upper limit would be the maximum design storm event that the scheme will be required to deal with. The function relating rainfall to wet weather augmented flow is as simple as possible while still being compatible with current practice using runoff coefficients.

Method of characterising schemes

There are two methods of characterising reuse schemes. They are 'partial reuse' and 'maximum reuse'. The partial reuse method expresses (usually as a percentage) the ratio of water successfully irrigated to total effluent delivered to the scheme. The maximum reuse method expresses the average number of years between storage overflows, i.e. the risk of overflow.

The Department of Environment and Conservation model and guidelines use the maximum reuse method to characterise schemes, based on the direct link with the frequency of environmental disturbance, and hence environmental protection. For example, high strength waste schemes are to have an associated environmental risk of storage overflow no more than one year in ten. Such a scheme would have a reuse proportion greater than 90%, because nine years in ten all effluent is used for irrigation. In fact, as all the effluent will not overflow during the one year in ten, such schemes will have reuse coefficients generally greater than 95%.

However, for the range of solutions determined by the DEC model, the reuse coefficients will not be fixed at a given environmental risk. For high strength effluent with low environmental risk (one year in ten), the possible range in the reuse coefficient is small (typically 95% to 99%). With the lower strength wastes, the correspondence will be weaker. This means that when a scheme is designed against a 75% reuse target, it has a range of overflow frequencies probably ranging from one year in two to one year in four.

The proportion reuse characterisation of a scheme (the late E. Corbin, pers. comm., NSW Agriculture, 1994; J. Murtagh, pers. comm., NSW Agriculture, 1995) can be more intuitive, so the computer model includes the actual reuse proportion calculation and display in the implementation, though it is not used as a basis of calculation.

Precautionary discharges

Precautionary discharges can be used to ensure that discharge occurs when conditions will minimise environmental impacts (rather than uncontrolled overflows as discussed in Section 4.2.) This approach is only permitted when licence conditions expressly allow it to occur. Licence conditions will include an in-stream trigger flow, a time horizon or lower flow limit as well as volume and effluent quality limits. The conditions will be designed to ensure that a higher load than would otherwise occur is not discharged.

Even with correctly designed reuse schemes, there will be storage overflows, most likely after a prolonged period of low evaporation, perhaps where there has been continual rain in later winter. At the time of overflow, heavy rain may have long since finished so that the flow in the waterway (where the overflow will discharge) will have subsided from its peak immediately following the heavy rain. This means that the in-stream dilution is not as high as it might be.

The precautionary discharge concept has been added to the model for situations where there is a high probability of an overflow within a set time. A discharge may be made to a waterway that is experiencing higher than normal flows. The actual time horizon, in-stream trigger flow and size of discharge will depend on the local situation but would probably be in the range of 60 days, 70 to 80 percentile flow and 10 to 20 days effluent flow respectively.

The overall effect of such releases will be a single discharge into a strong flowing waterway with good dilution potential, instead of an extended period of continual discharge, albeit at a lower volume per unit time, into a river with lower dilution capacity.

Formal model specification

This description uses the following indexes and convention.

- m - 1 .. 12 — indexes months in year
- y - ymin .. ymax — indexes years (e.g. 1912 .. 1995)
- g - 1 .. ng — indexes grid points of irrigation depths (e.g. 1 .. 20)
- XX[x%] — represents the x% point from the ordered enumeration XX

Let

- CF_m — be the crop factor for month m,
- $R_{y,m}$ — be the rainfall for year y, month m,
- $E_{y,m}$ — be the evaporation for year y, month m

then

- $MID_{y,m} = (E_{y,m} \times CF_m) - R_{y,m}$ is the irrigation demand for year y, month m
- $ID_y = \sum MID_{y,m}$ is the yearly irrigation demand.

From the cumulative distribution of ID_y identify

- $G0 = ID[0\%] \div 2$ (half the lowest value) and
- $GL = ID[10\%]$ (10% point on cumulative distribution)

as lower and upper grid limits for depth of irrigation. These may be adjusted but usually give good limits.

For all grid points define

$S(g) = G0 + (GL - G0) \times (g - 1) \div (ng - 1)$
as supply levels for the range of irrigation depths

Set

- $F_{y,m}$ to be the fraction of yearly flow in year y, month m. Here yearly flow is dry weather flow plus average yearly wet weather flow. Note that $SF_{y,m}$ m=1.12 may exceed 1 for years with significant wet weather flows
- $ADJ_{y,m}$ to be the net adjustment for rain and evaporation over the storage area
- $UD_{y,m}$ to the unsatisfied irrigation demand due to lack of effluent water
- $PD_{y,m}$ to precautionary discharges (mostly = 0)

then

$ADD_{g,y,m} = S(g) \times F_{y,m} + ADJ_{y,m} - [(ID_{y,m} - UD_{y,m}) + PD_{y,m}]$

is the net addition to storage for irrigation rate g in year y and month m;

$Q_{g,y,m} = \sum ADD_{g,j,n}$ {j, n} = {ymin,1} .. {y,m}

is the storage volume for irrigation rate g in year y and month m;

$QY_{g,y} = \max\ Q_{g,y,m}$ defines yearly storage maximums.

Using the cumulative distributions $QY_{g'}[x]$, derived from $QY_{g,y}$ select the value corresponding to environmental risk r% of overflow using all years.

$QS(g)_r = QY_{g',[100 - r\%]}$ is the model solution storage level given irrigation depth g for environmental risk r%. Note for a given environmental risk r QS is a function of irrigation depth g.

Appendix 5: Government Agency Roles

Table A5: Summary of key agency regulatory and advisory roles

Department of Environment and Conservation (incorporating the EPA)	Licensing of schemes on Schedule 1 of POEO Act or where a licence is necessary for protection of waters. Noise, waste, air or odour issues/licensing. National Parks matters Management of all reserves and dedicated areas under the *National Parks and Wildlife Act 1974*. Concurrence on provisions of the *Threatened Species Conservation Act 1995*. Management of Aboriginal relics and places.
NSW Department of Infrastructure, Planning and Natural Resources	Natural Resource matters: Advice on: Farm Dam Policy; and clearing of native vegetation. Protection of groundwater consistent with State Groundwater Policy: site suitability; potential impacts; beneficial uses. Administration of the *Water Management Act 2000* including Water diversion licensing, works approvals and regulatory responsibilities. Provision of Soil Landscape Mapping series; groundwater vulnerability & availability maps; broad-scale derivative maps detailing soil and landform limitations to land-based application of effluent and Acid Sulfate Soils Risk Maps. Planning matters: Planning approvals for land-use and development under *Environmental Planning and Assessment Act 1979*. Content of Environmental Impact Statements. Land use zoning. Preparation of planning instruments. Provision of Environmental Impact Statement Guidelines, e.g. for Irrigation of Sewage Effluent. Acid Sulfate Soil Management Advisory Committee.
Department of Energy, Utilities and Sustainability	Approval of works under *Local Government Act 1993* (Section 60) and provide for sewage being discharged, treated and supplied to any person.
NSW Department of Primary Industries	Advice on: agricultural best management practices; site management and assessment; soil, pasture/crop and irrigation management; animal health; and constructing and managing effluent storage dams. Development of industry specific guidelines. Concurrence on threatened species provisions of the *Fisheries Management Act 1994*. Advice on important fish and fisheries and proximity to sensitive fish habitats.
NSW Health	Advice on health protection measures for effluent irrigation schemes. Advice on the level of effluent treatment to be achieved. Site-specific advice on public access to irrigation sites and appropriate hazard signage.

NSW Food Authority	Food hygiene and contamination.
Local councils	Planning approvals for land-use and development. Determination of Environmental Impact Statements. Regulatory Authority for pollution control for irrigation schemes that are not regulated by the EPA through a licence, i.e. most schemes on Schedule 1 of the POEO Act.
Water Authorities	Management of special or controlled areas for drinking water supplies. Developers of reuse schemes.
WorkCover NSW	Occupational health and safety.
Sydney Catchment Authority	Concurrence and notification roles in planning decisions affecting water quality within Sydney water supply catchment.

Appendix 6: Department of Environment and Conservation Offices

Department of Environment and Conservation offices are open 8.30 am to 5.00 pm weekdays, except public holidays. An answering service is generally available at times when district offices are not attended.

DEC Head Office

59-61 Goulburn Street, Sydney
PO Box A290, Sydney South 1232
Phone: (02) 9995 5000 (switch)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Pollution line: 131 555 (information & publications; local call in NSW)
Email: info@environment.nsw.gov.au
Web: www.environment.nsw.gov.au

Contact details for regional and district DEC offices can be found at www.environment.nsw.gov.au/about, or by calling Pollution Line on 131 555.