National Water Quality Management Strategy

Rural Land Uses and Water Quality

A Community Resource Document

2000

Agriculture and Resource Management Council of Australia and New Zealand

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Contents

Preamble

The *Rural Land Uses and Water Quality - A Community Resource Document* has been prepared as part of the suite of documents constituting the National Water Quality Management Strategy (NWQMS), and within the framework of *Policies and Principles - A Reference Document*. The steps in developing and implementing plans to manage fresh and coastal waters and groundwater are described in the *Implementation Guidelines* document.

The *Rural Land Uses and Water Quality - A Community Resource Document* provides background information on a number of the principal issues which affect water quality in rural environments. The document has been written in recognition that there are a range of land uses that can impact on water quality but which are not addressed in the other NWQMS guideline documents. The document discusses a range of degradation issues but makes no judgement on the extent or scale of these issues. It also discusses the causes of water degradation in rural environments, how these impact on water quality, and then identifies some of the Best Management Practices (BMPs section 3.2) that can be adopted to minimise and/or prevent degradation. The BMPs discussed in this document can also have broader improved sustainability outcomes for other natural resources, including land and related vegetation.

Although the document is about land uses in rural environments, it must be acknowledged that rural environments can be subject to external influences, particularly from urban areas. For example, discharge from urban areas upstream and transport infrastructure such as roads and railways may impact on water quality in rural environments.

It must also be acknowledged that phenomena such as salinity and turbidity described as causes of water degradation in rural environments are normally present in some water systems, and the issue to be addressed is not the eradication of these elements but the level of exacerbation by human activities of these natural processes that can be tolerated. Best management practices described in this document are therefore aimed at preventing exacerbation of these natural processes to levels where they threaten water quality.

The document is not intended to be prescriptive nor to provide detailed or comprehensive policies, guidelines or standards aimed at particular landholders or land managers. It has been written to bring together in summary form useful resource material for individuals, agencies, community groups and organisations with an interest in natural resource management. In particular, it may assist:

- catchment management committees;
- natural resource managers; and
- peak industry bodies whose members have an interest in water quality and the rural environment, or have significant impacts on water quality.

Finally, it should be emphasised that land managers have already begun to adopt more sustainable natural resource management practices. The landcare movement, which develops partnerships between the community, industry and government, and catchment management approaches provide useful models for local and community involvement in developing and implementing appropriate best management practices to protect water quality.

With respect to forestry, the National Forest Policy Statement, the guidelines for managing Australia's native forests developed by the Joint ANZECC/Ministerial Council on Forestry, Fisheries and Aquaculture National Forest Policy Statement Implementation Sub-committee (JANIS) and State and Territory codes of forest practice provide the basis for further sustainable management of forest ecosystems to protect ecological values, including water quality.

Guidelines and documents forming part of the NWQMS are detailed in the appendix.

1. Introduction

1.1 Rural Water Quality

This publication, *Rural Land Uses and Water Quality - A Community Resource Document,* has been developed to assist the management of a range of rural land uses so that they are sustainable ecologically and economically, to reduce their adverse impacts on water quality.

Under the Federal Constitution prime responsibility for natural resource management lies with States and Territories. There is a range of State and Territory programs that assist the enhancement of water quality.

The majority of Australia's water resources are located and used in rural environments. The availability of water has influenced the distribution of population, as well as land use patterns, including agricultural and industrial development.

Commonly occurring land uses in Australia's rural environments which relate directly to the use of land, water and vegetation resources for productive purposes include agriculture, forestry, mining, processing industries, tourism and recreational activities. In many areas, these activities are the only source of employment, constituting the economic mainstay of rural communities.

The past lack of understanding of the complexity of Australia's ecosystems led to the adoption of land use management practices which have proved to be unsustainable environmentally, economically and socially. Some of these practices have caused deterioration in the quality of the nation's rivers, lakes and groundwater, particularly in rural environments.

The community is becoming increasingly aware of the consequences of continued degradation of the nation's natural resources, including our water bodies, and its implications for present and future socio-economic development.

Ecologically Sustainable Development (ESD) involves taking a long term perspective in managing the nation's water resources for this and future generations to ensure that:

- high quality water is available for a range of applications, including human and animal consumption;
- adequate water supplies are available for both agricultural and industrial use;
- ecological values are protected and enhanced;
- public health values are not compromised; and
- the community's need for water-based recreation and related amenities are met.

The first part of the document describes the key rural-based land uses and their impact on water quality. The main adverse impacts of these land uses on water quality identified in this document are: turbidity from suspended solids; nutrient enrichment; chemical contamination; salinisation of surface and groundwater; invasion by biological agents and contamination by pathogens.

The second part of the document discusses management practices which can be adopted to reduce/and or prevent these adverse impacts.

Several key national programs and policies also assist water quality improvements. These have been described in the final part of this document and include: the National Landcare Program (NLP), the Murray-Darling Basin Commission's Natural Resources Management Strategy (NRMS), National River Health Program, the Council of Australian Governments (COAG) Water Resources Policy, and the National Forest Policy Statement. Information on these programs and polices can be obtained directly from the relevant State and Territory agencies. They include State and Territory Departments of agriculture and/or primary industries, land and water conservation agencies, environmental protection agencies, water resources management agencies, forests management agencies and heritage and environment conservation agencies.

1.2 Definitions

1.2.1 Rural Land Uses

Land uses which occur in rural settings include but are not limited to the following:

- dryland farming;
- irrigation farming;
- infrastructure, including transportation networks and systems;
- forestry operations;
- recreational activities;
- intensive rural industries, including processing activities;
- extractive industries, predominantly mining;
- dam building for irrigation and hydro electricity generation;
- urban development; and
- rural subdivisions.

Rural environment
This term means those areas that lie outside large cities or metropolitan centres.

Catchment
Catchment is defined as a natural geographical area that has a common water drainage system. It also refers to a natural planning unit for the management of natural resources.

Total or integrated catchment management refers to the coordinated management, including utilisation, of land, water and related vegetation resources on a catchment basis, to balance resource use and nature conservation objectives.

2. Types of Water Quality Degradation and Their Causes

Water quality degradation in rural environments is caused by factors including:

- transportation of eroded soil, particularly from stream banks;
- excessive nutrients or nutrient enrichment;
- chemical contamination by agrochemicals and other chemicals (eg detergents/phosphates, organochlorines (although now banned));
- metal contamination, particularly from heavy metals (eg iron, lead, copper and mercury);
- salts;
- changes to natural hydrologic patterns;
- inappropriate waste disposal;
- seepage of contaminated groundwater into surface waterbodies; and
- contamination by biological material and pathogens.

These factors manifest as pollutants in aquatic systems in the following ways:

- suspended solids or turbidity;
- eutrophication, which can lead to the excessive growth of aquatic plants, including algal blooms;
- chemical and microbiological contamination; and
- salinity.

2.1 Runoff

Surface runoff plays an important role in the reduction of water quality in rural environments. Many pollutants from the land uses identified in this document enter waterbodies through runoff. Sources include:

- excess water from irrigation drains containing salt, nutrients (particularly nitrogen and phosphorous), sediment and other chemicals;
- runoff from cleared, non-vegetated land, particularly that near to drain ways;
- nutrient-rich water from intensive livestock production, particularly that used to wash floors and from waste storage areas;
- effluent disposal, as well as spills and overflow from effluent treatment facilities and sewerage systems;
- nutrient rich water from poorly maintained septic tanks;
- storm water runoff from dryland farming and grazing, particular in northern Australia;
- oils and other petroleum products from roads and sealed areas;

- spillover from farm dams, which may contain nutrients and other farm chemicals; and
- forest runoff containing natural nutrients.

2.2 Suspended Solids or Turbidity

Suspended solids in water include both soil and organic materials. The main source of suspended solids is soil erosion. Soil erosion is commonly considered a diffuse source of water pollution because it can occurs throughout the catchment of a watercourse, although streambank erosion is a major contributor.

2.2.1 How the Major Land Uses Contribute to the Production of Suspended Solids

Erosion occurs naturally as part of weathering processes. However, activities such as vegetation clearance and unsustainable land use management practices can accelerate soil erosion which may cause water quality degradation if sediments enter waterways.

The degree of erosion depends on the soil type, topography, intensity of rainfall, the land use, and management practices adopted. Vegetation cover, including pasture cover, has a major influence in protecting soil from erosion through:

- the protection it provides to the soil from raindrop impact;
- slowing down runoff;
- building up soil organic matter which improves the structure and the moisture holding capacity of the soil; and
- binding soil with its roots.

Agriculture
The following agricultural practices can contribute to accelerated soil erosion:

- vegetation removal, particularly native trees and shrubs, from lower valley slopes, gullies and watercourses for intensive cropping without appropriate measures to reduce soil exposure;
- poor cultivation practices which alter soils' physical, chemical and biological characteristics, and irrigation with unsuitable water;
- long fallow periods which leave soil unvegetated or unprotected for a long time;
- not protecting sandy or dispersive soils used for annual cropping with stubble or vegetation cover;
- long term unsustainable grazing practices, including:
  - overstocking
  - heavy grazing, particularly during dry periods leading to pasture decline and in wet periods leading to compaction of soils, destroying structure and reducing infiltration rates
  - allowing stock access to streams and
  - grazing by hard-hoofed animals which causes compaction of soils and destruction of structure resulting in the reduction of infiltration rates; and

- inappropriate use of farm machinery, particularly following wet weather.

Intensive rural industries
The causes of erosion related to intensive livestock production and processing of agricultural produce are similar to those of general agriculture and result from poor management practices. Production and processing can also contribute suspended solids to water bodies through either direct discharge of untreated organic-rich effluent, or runoff of waste applied to land.

Forestry operations
Forestry operations that are poorly managed can lead to significant soil erosion. This can arise from activities such as:

- extraction of timber, especially involving the use of heavy machinery;
- construction of roads, log landings and dumps;
- destruction of understorey;
- clear felling, especially if uncleared zones are not left around gullies and streams; and
- timber carting during prolonged wet weather.

Recreational activities
Water-based activities such as speed boating and water skiing can erode reservoir and riverbanks. Land-based activities such as off-road car and motor cycle driving and horse riding can damage vegetation cover and expose soils to erosion.

Extractive mining industries
Extractive mining industries contribute suspended solids through erosion from cleared areas, roadways, overburden and waste rock dumps and use of machinery during wet weather. Sand and gravel extraction can cause bank and bed erosion through channel deepening.

Natural sources of turbidity
Many river and stream systems are naturally turbid. This is because the mineralogy of the clay fraction, as well the salinity status of some soils, make them susceptible to water erosion. Natural turbidity levels will vary with flow, as well as with geographical location. Studies indicate that sheet erosion, riverbank and gully erosion are also major contributors of suspended solids which support the input of phosphorus into our river systems. Phosphorus from this source is generally held in a biologically unavailable form in accumulated streambed sediments. Native fauna and feral animals (eg rabbits, pigs and horses) can also significantly add to the erosion of soil through activities such as burrowing and soil compacting.

Urban development and rural subdivisions
The major impacts of urban development and rural subdivisions arise from altering land surfaces. During the construction phase, operations such as clearing vegetation, removing topsoil, landscaping, road construction and installing other infrastructure lead to the greatest risk of soil erosion. Unsealed and poorly maintained roadside drains can also be a significant problem. Rain hitting impervious surfaces such as roofs and bitumen runs off much more rapidly, increasing its erosive power. Straightening and concreting of urban

water sources also increases flow rate and therefore erosive power, although baffles and ponding of storm water can minimise the effects.

2.2.2 Impacts of Suspended Solids on Water Quality

Suspended solids from stream and river sediments and soil erosion appear as turbidity in water bodies with undesirable effects including:

- reduction in the economic life expectancy of water storage facilities such as weirs and reservoirs through siltation;
- increase in the cost of water treatment for human consumption, industrial applications and the greater potential for development of disinfection by-products which are an unwanted product of water treatment;
- degradation of the aesthetic and recreational values of water bodies;
- increase in nutrient load from sediments;
- reduced light penetration causing adverse impacts on the ecological systems of aquatic organisms such as plants, fish and invertebrates; and
- siltation and smothering of aquatic ecosystems.

2.3 Nutrient Enrichment

This refers to the accumulation of nutrients to levels that enhance and support the proliferation of aquatic organisms (eg cyanobacteria) leaving the water unsuitable for applications such as human use, industrial use and drinking by stock and other animals.

2.3.1 Sources of Nutrient Enrichment

Commonly recognised sources of nutrients to Australian river systems include:

- wastewater treatment plants;
- urban stormwater and irrigation drains;
- effluent from intensive agricultural industries;
- runoff from agricultural, grazing, urban gardens and forest lands;
- nutrient-rich groundwater;
- erosion of nutrient-rich riverine banks;
- nutrient-rich riverine sediments which release nutrients, particularly phosphorus, under suitable environmental conditions;
- natural processes such as erosion and rock and subsoil weathering, which may be accelerated by improper management techniques; and
- ageing on-site domestic wastewater systems and sewerage systems, which can pollute water resources through leakage, as can septic tanks in catchments with extensive rural residential development.

Point sources
These comprise both industrial (including intensive rural industries, like dairy factories and abattoirs) and domestic sewerage systems. Nitrogen and phosphorus are the nutrients of

principal concern. Phosphorus occurs in a variety of forms depending on its source. It occurs largely as orthophosphate in effluent, and is able to be readily used by aquatic plants, including algae. Phosphorus can also be stored in waste stabilisation pond sludges and the sediments of rivers or lakes for long periods and released into the water column under suitable conditions to become available to aquatic organisms.

Diffuse sources

Diffuse sources of nutrient enrichment are generated by poor agricultural practices, including excessive or inappropriate application of fertilisers, particularly during wet and low vegetation growth periods. However, natural rock, plant debris, leaf litter and soil weathering processes also contribute nutrients. Surface runoff or leaching, particularly in sandy soils, to surface waterbodies and groundwaters can transport fertilisers and their by-products. Nutrients can also be adsorbed onto the surface of soil particles and these can subsequently be transported to water resources through soil erosion and runoff. Nutrients from surface organic matter can also be washed into streams with runoff. Being in a more soluble form, phosphorus in this runoff can be readily used by aquatic plants, including algae.

While intensive rural industries generally create potential for point sources of pollution through effluent discharge, they can also become sources of diffuse pollution through localised surface runoff or infiltration of their effluent into groundwater. Particular problem areas for diffuse sources include:

- dairy sheds and dairy processing plants;
- market gardens;
- abattoirs;
- intensive exotic fauna farming developments (eg ostriches, alpacas etc);
- piggeries and poultry farms;
- aqueous wool scouring and carbonising;
- tanning and related industries;
- feedlots;
- storage of petroleum and petrochemical products in underground tanks;
- timber mills; and
- wineries and distilleries.

Stormwater can contribute to both point and diffuse sources of nutrients from drainage canals and surface runoff respectively. Fertilisers applied to household lawns and gardens are major sources of nutrients entering stormwater.

2.3.2 Impacts of Nutrient Enrichment on Water Quality

Nutrient enrichment can cause algal blooms and also assists the growth of weeds (including declared noxious weeds such as *salvinia* and *hyacinth*). This can have a wide range of social, economic and environmental impacts on water supplies, human health, agriculture (livestock), fish, wildlife, recreation and tourism. The increasing prevalence of algal blooms is a particular water quality problem and is dealt with in more detail in the following sections.

2.3.3 Impacts of Algal Blooms on Water Quality

Algal blooms affect water quality in a number of ways, including:

- production of toxins;
- formation of unsightly and smelly scums and tastes; for example, the production of hydrogen sulphide on decay of the algal cells which affects the taste of water;
- increased turbidity; and
- aesthetic effects resulting from discolouration of water.

Other water quality problems associated with algal blooms include:

- increased organic load reducing the availability of oxygen to aquatic life;
- blockage of filters and equipment hampering water supply operations;
- lower efficiency of water and wastewater disinfection;
- diurnal fluctuations in pH, which can affect the chemistry of water through altering chemical reactions in water treatment processes thus making treatment difficult; and
- shoreline nuisance and benthic ooze.

Toxins produced by some blue-green algae may contaminate drinking water, affect animal health and result in human health effects such as:

- potential liver damage;
- gastrointestinal upsets;
- nervous system disorders; and
- skin and eye irritations.

While no human deaths have been attributed to algal blooms in Australia, stock deaths have been widely reported. There is also evidence of wildlife being poisoned. Laboratory experiments indicate that blue-green algal toxins, particularly those produced by *Microcystis* (microcystin), may promote tumours in mice and pigs, and thus may be tumour promoters in humans, although further research is required to clarify this.

2.3.4 Formation of Algal Blooms

Algae are naturally occurring photosynthetic microscopic organisms and in low numbers, are important contributors to the aquatic ecology of our streams. Under certain conditions however, their numbers may increase to levels that produce nuisance blooms and cause serious problems for water users. The levels of bloom formation in some water bodies can be exacerbated by eutrophication resulting from human activities.

The growth of algae is influenced by a number of environmental conditions, which interact in a very complex way to produce blooms. Based on current scientific understanding, the factors considered to be most important for bloom formation are:

- high nutrient levels, especially phosphorus;
- low flow rates of water bodies;
- development of anaerobic conditions resulting in the release of nutrients bound in aquatic sediments;
- modified aquatic ecosystems;
- high light availability; and
- high temperatures.

High nutrient levels
Phosphorus is generally considered to be the most critical nutrient for growth of freshwater algal blooms. Nutrient control and reduction programs to reduce nuisance algal growth have often targeted phosphorus, particularly in aquatic systems. While phosphorus is considered to be important, there are a number of other major constituents such as nitrogen, carbon and silica.

Low flow conditions
Low flow may lead to reduced water quality. For example, relatively calm conditions experienced during low flow favour the development of algal blooms. These conditions are likely to occur in lakes and reservoirs and sections of highly regulated rivers during periods of low flow. Low flow rates and associated reduction in turbulence and mixing of water can assist nuisance algal growth by:

- increasing the availability of light due to settling of particulate matter and contributing to nuisance algal formation;
- creating long retention times in pools and lakes, causing algae to form blooms; and
- reducing the rate of oxygen replenishment in the water, creating anaerobic conditions, which may release nutrients from sediments.

Low flow can result from natural drought conditions or river regulation, including increased diversions for agricultural, domestic and industrial use. Given the high demand for water in rural environments, the majority of Australian water bodies could be affected by an algal bloom unless action is taken to reduce the risk. The long-term solution lies in the adoption of sustainable land use management practices to reduce the transport of nutrients and flow management to lessen the development of algal blooms.

Modified aquatic ecosystems
Activities such as draining wetlands, removing native vegetation, poor management of riparian zones, and dredging and de-snagging of streams, modify aquatic ecosystems and may create conditions favourable for blooms. Introduced fish such as the European carp and predator fish such as the Mosquito fish are also believed to play a role by preying on the aquatic insects which in turn prey on algae. The presence of exotic plant species such as *elodea*, *salvinia,* water hyacinth, alligator weed etc. can be an indicator of increased nutrients in the aquatic ecosystems.

Light Availability
Light availability is important to bloom formation because light contributes energy, which the algae require for their photosynthetic processes. Both the right quality and quantity of light is required for growth. Some algae are known to be capable of growing in the absence of light. The process is however relatively energy inefficient and extremely large

blooms are unlikely to be produced rapidly. It can therefore be argued that the exclusion of light may prevent the formation of algal blooms.

Temperature
Warm temperatures can assist the growth of algal blooms through increasing their metabolic processes.

2.3.5 Cost of Algal Blooms

Algal bloom formations can have local and national economic impacts. Direct costs are incurred through increased water treatment to remove toxins. In some cases, it may be necessary to provide alternative water supplies. There is a direct cost associated with the need to monitor blooms once they occur and to warn of the onset of blooms.

Indirect costs associated with algal blooms are difficult to quantify but are likely to be high, particularly in relation to their adverse impacts on tourism. The smell and appearance alone of algal blooms can deter tourists from visiting and using affected water-based recreational facilities. The need for additional research to help understand the behaviour of blooms and thus reduce or even prevent blooms from occurring in the future, contributes to the indirect costs of bloom formation.

Additional costs can arise from reduced production and stock losses as a result of livestock consuming contaminated water. Other costs may arise from the need to change management practices, such as isolating stock from water supplies, and environmental degradation.

Algal blooms can have a broader economic impact through impressions they create for overseas visitors, importers and industry investors. They may see a bloom affected area as typical of Australia's general environmental condition and be less interested in the country either as a tourist destination or as an area for investment.

2.4 Chemical Contamination

Chemical contamination refers to the degradation of water bodies by chemical compounds. Natural processes such as rock and soil weathering produce chemical compounds, which can contaminate waterbodies. However, the increased levels of chemical contamination occurring in rivers and waterbodies in Australia can be attributed to poor handling and use of manufactured organic and inorganic compounds. Chemical contamination can make water unfit for both human and animal consumption and occupation by aquatic organisms. Removing or neutralising these chemical compounds can be costly. Chemicals that can degrade water quality include:

- organic compounds, emanating from industry, agriculture and domestic sources, for example solvents, lubricants and pesticides; and
- inorganic compounds, mainly heavy metals originating from fertilisers, domestic sewerage systems, rural intensive processing, biosolid (sewage sludge) disposal/reuse on agricultural soils and extractive industries such as mining.

Hydrocarbons from agricultural machinery, general purpose vehicles, storage areas and runoff following a forest fire are a potential source of chemical contamination in both urban and rural environments.

2.4.1 Sources of Chemical Contamination

The main sources of chemical contamination to water bodies include:

- runoff from agricultural catchments following rainfall;
- drainage discharge points from irrigation developments (these have traditionally not been required to have environmental clearance);
- forestry operations;
- some intensive rural industries, particularly livestock production;
- discharges from both domestic and industrial sewerage systems;
- acid producing, usually sulphate rich soils;
- on site domestic wastewater systems;
- stormwater and drainage from sealed surfaces; and
- timber treatment plants.

Agriculture
Poorly managed agricultural systems can contribute significant quantities of agricultural chemicals to runoff. These chemicals can also infiltrate the soil profile and contaminate underground water resources. They can also enter aquatic systems through airborne drift from spraying.

The rate of release, accumulation and transport of fertiliser by-products (some of which may become toxic at increased concentrations) depend on soil type. Fertiliser and toxic by-products can be leached to a greater extent in sandy soils than in medium to heavy textured soils.

Surface runoff from irrigation agriculture can contaminate water bodies by carrying agricultural chemicals.

Intensive rural industries
Intensive rural industries and sewerage systems can contribute polluting heavy metals to water bodies. Acid drainage from mining, road construction and other excavations may be the source of heavy metals. Detergents used in a number of rural industries such as wool scouring can be another potential source of chemical compounds.

Forestry
Application of fertilisers and use of chemicals in plantation establishment and other forestry operations can contribute chemicals to rural water bodies. Additional potential sources of chemical contamination are hydrocarbon products from machinery used for forestry operations and runoff following a forest fire.

Stormwater
The increase in the area of impervious surfaces resulting from urban development such as roofs and roads, the construction of drainage works and the alteration of natural drainage patterns and evapotranspiration processes within a catchment can lead to greatly increased volumes and rates of stormwater runoff. Sources of contaminants to stormwater include:

- agrochemicals such as fertilisers and agricultural chemicals;

- hydrocarbons, including oils; and
- heavy metals such as cadmium from automotive tyres and sealed roads.

Acid sulphate soils
Most often found in coastal areas, acid sulphate soils can be a source of chemical contamination. While acid sulphate soils are a naturally occurring phenomenon in Australia, the increased release of acid drainage waters from these soils and the associated environmental problems which have occurred are a result of poor management practices.

In Australia the formation of acid sulphate soils dates back to the most recent ice age (some 20 000 years ago) when the sea was about 100 metres below present levels. Global warming subsequently caused sea levels to rise steadily (until about 6000-7000 years ago) flooding low-lying land on continental margins. As the seas rose, they mobilised coastal sediments and pushed this material landwards, depositing it on present-day coastlines and in estuaries. Colonisation of these newly formed marine sediments by mangroves and other vegetation in protected tidal flats allowed organic matter to accumulate in generally anaerobic conditions. Regular tidal flushing made it possible for bacteria to use the organic matter and to reduce the sulfate in seawater to iron sulfide - commonly known as iron pyrite - at concentrations of more than 1% in the top metre or so of the sediment profile.

This material generally remains beneath the water table, covered by a protective layer of water and forms an innocuous "potential acid sulfate soil" until it is exposed to air, and is oxidised to form sulphuric acid, creating actual acid sulphate soil. In Australia, the process of formation of actual acid sulphate soils has been accelerated through human interference for example:

- draining wetlands for dairy-farming or sugar-cane growing;
- mining; and
- residential and tourism development.

2.4.2 Impacts of Chemical Contamination on Water Quality

The presence of chemicals in water can affect certain physical characteristics such as taste, odour and hardness. High levels of both organic and inorganic compounds in waterbodies are not desirable or acceptable because they can be toxic to humans, animals (including aquatic organisms) and plants. Toxic levels of chemicals in water affect environmental and public health values including:

- human consumption;
- recreational uses such as swimming;
- use in agriculture, including irrigation and stock drinking;
- industrial application including production purposes; and
- aquatic ecosystems.

Some chemical compounds can also affect the aesthetic quality of water. Removal of chemicals can increase the cost of water treatment.

Prolonged exposure to acid waters from acid sulphate soils can be poisonous and lethal to plants. Most gilled organisms (particularly fish) are extremely sensitive to acid drainage exposure leading to rapid death. Acid outflows can mobilise heavy metals from contaminated sediments. Metal and concrete structures corrode and degrade when exposed to acid sulphate effluent unless precautions are taken. The precipitation of iron hydroxide/oxide flocs from acidic, iron-rich waters can block drains, wells and reduce the ability of groundwater aquifers to transmit water.

2.5 Salinity

Salinity is a measure of the concentration of total dissolved salts in water. Dissolved salts occur naturally in water bodies, however they cause pollution when the salinity of a water body is increased by human activity to the point where the water body can no longer be used for normal applications without treatment.

In Australia, salt is a natural feature of the soil system. However, lack of understanding of the natural systems and inappropriate farming practices have changed the distribution of salts in the soil profile. This has resulted in widespread contamination of surface and groundwater resources, and the destruction of vegetation due to rises in the watertable that lead to an accumulation of dissolved salts in the soil surface.

2.5.1 Sources of Salt

Salts occur naturally from the physical, biological and chemical processes that break down rocks for subsequent soil formation. Other natural sources include the atmosphere, as well as fossil salts deposited in the landscape in past geological times when much of inland Australia was covered by marine waters and more recently those accumulated in inland drainage basins.

Man made sources of salt include sewerage systems, effluent from intensive rural industries (eg. piggeries, tanneries, wool scours and wineries) and by-products from extractive industries such as mining.

Causes of salinisation
There are two main causes of salinisation:

- over clearing of deep-rooted vegetation (dryland salinity); and
- inefficient use of water for irrigation (irrigation-induced salinity).

Dryland salinity
Dryland salinity is caused by clearing native vegetation for agriculture and replacing generally deep-rooted perennial species with shallow-rooted crops and exotic shrubs. The generally deep-rooted native Australian tree species and pasture are able to extract water deep in the soil profile, thereby keeping the salt immobilised. In contrast, large scale clearing and replacement with annual crops and pastures have reduced evapotranspiration and increased the amount of water percolating below the root zone. This has disrupted the natural distribution of salts in the soil profile. Rising water table can result in salinisation of waterbodies, either through surface runoff or seepage of saline groundwaters interfacing with surface waterbodies.

Irrigation-induced salinity
Irrigation-induced salinity occurs when excess water dissolves salts in the soil profile and deposits them deeper in the soil profile. Excess water in the soil profile may then carry and deposit the salt in the lower parts of the landscape. The dissolved salts may directly

contaminate surface and ground waters, which can then be discharged into waterways. The excess water may also cause the watertable level to rise to the surface, bringing dissolved salts. The pressurisation of highly saline groundwater by irrigation water may replace it and then discharge it into surface waters.

2.5.2 Natural Sources of Salinity

Many naturally occurring shallow saline aquifers can potentially increase salinisation of Australia's water bodies. Disruption of their normal hydraulic flow by drainage schemes, water pondage or pumping from mines can accelerate groundwater discharge and contaminate surface streams.

High salinity levels frequently associated with coal seams are another potential source of salts in rural environments. Another source of salt is encroachment of seawater through exhaustion of coastal aquifers and backflow up rivers when natural levees are destroyed, for example by removal of sandbars for navigation purposes or buffalo wallowing.

2.5.3 Impacts of Salinity on Water Quality

Adverse impacts of salinity on water quality can include:

- changes to taste and hardness;
- water being unsuitable for stock or human consumption;
- water being unsuitable for irrigation agriculture;
- destruction of soil structure, reduced infiltration and death of vegetation resulting in soil erosion which can increase turbidity;
- destruction of infrastructure and water service equipment through rust and corrosion; and
- changes to natural ecosystems.

2.6 Changes to Flow Rates of Waterbodies

Water bodies are managed for a range of uses including extraction for domestic, agricultural and industrial purposes and electricity generation. These uses alter the flow rate of rivers and streams, affecting water quality in several ways. Increased flow rates may dilute the concentration of pollutants, which while positive, does not alter the total pollutant load. Reduced flows may increase pollutant concentration.

2.6.1 Impacts of Flow Rates on Water Quality

Water held in storage may become stratified, creating differences in temperature between the colder deeper layers and warmer surface layers. Releasing a high proportion of water from the lower layers reduces the temperature of the receiving waterbody, adversely impacting on the habitat of wildlife and plants adapted to warmer waters.

Releases from near the bottom of large storages cause unseasonably cold summer temperatures in receiving waters. This can affect invertebrates and reduce native fish spawning which is often reliant on seasonal changes in water temperature.

Water released from the lower layers in summer may contain toxic concentrations of gases such as hydrogen sulphide that can kill aquatic life immediately downstream. It may also have high concentrations of dissolved iron and manganese, which can cause further problems downstream, especially in water supplies.

Water in storage may become oxygen depleted or de-oxygenated, causing the death of fish, as well as being unsuitable for the growth of plants and animals. Continual release of de-oxygenated water from dams can kill many aquatic organisms for some distance downstream.

Water in storage often contains high nutrient levels from agricultural and urban catchment runoff. High nutrient levels can promote algal blooms and nuisance plant growth in storages and receiving waterways if the nutrients are in biologically available forms.

River regulation structures such as weirs and dams can create pools of still water in which algae may flourish. Pumping and diverting water also contributes to algal blooms by reducing flow and turbulence. Raising and lowering river water levels too quickly can cause stream bank collapse and erosion and contribute to turbidity.

2.7 Microbiological Hazards

These include the major microbiological components of concern such as pathogenic bacteria, viruses, protozoa and helminths. These can give rise to potential hazards to the health of humans, animals and plants. Increases in organism concentrations are generally a result of human activities including livestock agriculture, sewage treatment plant discharges and diffuse point sources such as on-site domestic wastewater disposal.

2.7.1 Sources of Microbiological Hazards

Principal sources include effluent from sewerage systems, seepage from on-site domestic wastewater systems and stormwater runoff, which may contain human and animal faeces. Other important sources are animals resting in stream and intensive contact recreation.

2.7.2 Impacts of Microbiological Hazards on Water Quality

The most common and widespread water quality problem associated with biological agents is the health risk due to the presence of microorganisms. The most significant impacts associated with microorganisms in water are associated with ingestion of infectious doses of pathogens and by contact through recreational activity with organisms associated with skin, eye and ear infections.

Water used for recreational or agricultural purposes should be sufficiently free from faecal contamination and pathogenic organisms to protect the health and safety of the user. The microbiological quality of water used as a source of drinking water, for recreation and agricultural purposes varies widely from sources which need no treatment to those which are heavily contaminated by micro-organisms. Adequate treatment of water ensures that consumers are not exposed to contaminated water. The cost of the treatment of this water may be passed on to the consumer and in some cases the polluter.

The natural processes in aquatic systems primarily include the breakdown of organic material by bacteria into inorganic compounds and carbon dioxide, using oxygen dissolved in water to produce energy through respiration. If too much organic material is released into a water body, the oxygen is used up more quickly than it can diffuse into the water from the atmosphere. The resulting oxygen depletion may kill fish and other aquatic organisms. If all the oxygen is used, degrading organic material in the resultant anaerobic environment may produce toxic compounds and unpleasant odours.

2.8 Groundwater Pollution

Groundwater pollution is the modification of the physical, chemical and biological properties of groundwater through infiltration by microbiological organisms such as viruses and bacteria and organic and inorganic compounds, including salts, nutrients and agricultural chemicals. The presence in groundwater of these pollutants, at high concentrations, can restrict or prevent its use in the various applications where it normally plays a part.

2.8.1 Sources of Groundwater Pollution

Groundwater pollution can be from both point sources and diffuse sources. The sources of groundwater pollution include:

- industrial sources including:
  - wastewaters which contain chemical compounds and trace elements (such as metals);
  - leachate generated by rain infiltrating through waste disposal areas;
  - accidents such as the breaking of an effluent pipeline;
  - chemical spillages and wastes from rural industries such as tanneries, timber treatment processing plants and cattle-dipping facilities; and
  - hydrocarbon contamination from fuel and oil spills and leaking storage tanks (especially underground tanks);
- domestic sources including:
  - leachate generated by rain infiltrating through sanitary landfills;
  - leaching of contaminants from both current and disused garbage disposal sites;
  - runoff of fertilisers and pesticides from lawn and gardens;
  - accidents such as the breaking of septic tanks; and
  - seeping sewerage systems in rural communities, particularly those associated with on-site domestic wastewater systems;
- agricultural sources including
  - pollution due to irrigation water or rain transporting fertilisers, minerals, salts and agricultural chemicals;
  - excessive land application of wastes from intensive animal production industries such as piggeries, poultry, cattle feedlots and dairy farms produce wastes; and
  - excessive use of inorganic fertilisers and agricultural chemicals in broadacre agriculture and horticulture; and

- pollution due mainly to seawater intrusion in coastal aquifers, resulting from increased extraction of water from these aquifers.

Groundwaters occur in a different physical and chemical environment to surface waters. Recharge occurs through the soil, streambed, or ponded areas and moves very slowly once the water table is reached. Thus their sources and paths are difficult to determine, especially in alluvial aquifers, which are often sinuous lenses of sands and gravel surrounded by clay sediments.

Bores a few metres apart can tap different water sources with salinities varying by an order of magnitude. Similar variations can occur with depth.

Pressure and exclusion from atmosphere oxygen can make the water more chemically active and therefore more prone to dissolve toxic elements. Nitrates and some pesticides are more likely to survive if excluded from light, oxygen and biological activity. The soil layer protects the groundwater by binding many organics, nutrients and metals. Aquifer vulnerability models are available to balance the degree of protection with the potential contaminants and these should be included in management strategies.

Many groundwater quality problems are associated with overuse of the aquifer. This causes a depression in the water table, changing the directions of flow and improving recharge from both desirable sources and potentially harmful sources such as seawater. Since groundwater is normally already more saline than its surface water recharge source, a marginal increase in salinity may have serious implications for beneficial uses. Contaminants bind to the interstitial clays in an affected aquifer, making it extremely difficult to restore.

Aquifers in more arid zones have high salt concentrations, including nitrates, which have a deleterious effect on groundwater quality.

2.8.2 Impacts of Groundwater Pollution on Surface Water Quality

Groundwater polluted with chemicals, salts, wastes and pathogenic bacteria can change the biological, physical and chemical characteristics of surface waterbodies through the upward and lateral movement of groundwater. Mixing of polluted groundwater and surface waterbodies can make the surface water unfit for human consumption. Discharge of polluted groundwaters into surface waters can threaten sensitive ecosystems.

3. Management Approaches

Farming and grazing activities by their very nature impact on the environment. They can distort or interrupt natural environmental processes and can cause a decline in water quality. These activities occur throughout the rural areas, and it is often difficult to attribute their effects to any one source or landholder.

To protect or improve water quality, landholders will need to be aware of the effects of grazing and farming activities beyond farm boundaries. Water quality considerations need to become part of day to day decision making and long term management planning for each farm. One way of achieving this is by applying and adopting Risk Management and Best Management Practices (BMPs) for particular regions.

3.1 Risk Management

Risk can be defined as *exposure to the possibility of an unwanted consequence of pursuing a particular course of action due to uncertainty.* The concept of risk has two elements, the probability of something happening and the consequence of it happening. Any approach to risk management therefore needs to consider whether the probability is high or the consequences are high, and to adopt appropriate procedures to ensure risk is managed efficiently and effectively.

Risk management can be defined as *the application of management procedures and practices to the task of identifying, analysing, assessing, treating and monitoring risks.* A decision making framework for risk management is provided in Figure 1, including an example of this process relating to the use of pesticides and the likely impact on water quality. This example is not exhaustive, but is included to demonstrate the process.

Appropriate management practices to eliminate or minimise a number of risks to water quality are outlined in this chapter.

Establish context

A pesticide is to be used to reduce the impact of a pest on crop yield.

The pesticide is specific to the pest and to be applied by ground spraying.

Identify risks

Water supplies that are directly sprayed with the pesticide will be unsuitable for livestock and human consumption.

Run-off after spraying occurs will contain pesticide residue, even after three days, which may effect the future use of the water supply.

Timing of the pesticide application during a high probability of a storm event may contaminate the water supply

Analyse risks

(avoiding the risk should be considered at this stage as an option in managing the risk)

Is spraying technique appropriate and unlikely to affect the water supply?

Is there an appropriate mechanism in place to intercept and hold runoff?

Is there information available on the weather forecast?

Assess and prioritise risks

Will not accept any direct spraying of the water supply: given good management practise used, low priority.

An interception pond is in place to hold the run-off for a 1 in 10 year statistical frequency storm event.

Long range weather forecast calls for rain over the next two days.

Recommended time to be left before resuming irrigation is four days, will crops survive.

Treat risks

A range of options to reduce the risks of chemical contamination is dealt with on page 29.

Review and monitor continuously

Figure 1: Example of Framework for Risk Management

3.2 Best Management Practices (BMPs)

The BMPs discussed in this document can also have broader improved sustainability outcomes for other natural resources, including land, water and vegetation. The landcare movement and catchment management approaches to sustainable resource management provide a useful model for local and community involvement in developing and implementing appropriate best management practices to protect water quality. Landcare groups, catchment management committees and agencies already undertake a range of activities to reduce resource degradation - activities that also maintain and improve water quality. It is important that community groups give priority to sustainable resource management activities that are likely to produce the best results for their efforts in terms of enhancing water quality in catchments.

The voluntary inputs by community members should also be recognised as a natural resource. This management strategy relies heavily on the inputs and efforts of individuals and groups who are under considerable economic and competitive stress. Community burnout should be recognised as a threat to sustainable water quality and should be addressed with a management approach. This should consider:

- provision of materials, equipment, infrastructure, communication and a legal identity;
- access to reliable information required to achieve their objective efficiently (ie technical information and assistance with management plans; and
- official acceptance, appreciation and involvement in joint government/community projects.

The effectiveness of BMPs in sustaining or improving the environment is not always seen in the short term. Monitoring programs, including water quality, must be designed to give fast and easily understandable feedback on improvement to whole catchment health. These would support the morale of those involved with landcare and allow them to apply peer pressure to other areas.

Further information on best management practices discussed in this document can also be obtained from the relevant State and Territory organisations and agencies. They include State and Territory Departments of agriculture and/or primary industries, land and water conservation agencies, environmental protection agencies, water resources management agencies, forests management agencies and heritage and environment conservation agencies.

3.2.1 BMPs

Increasing the adoption of Best Management Practices is critical to achieving ecological and economic sustainability in managing land uses in rural environments.

BMPs can be developed for an individual enterprise or have a local or regional focus and must consider the full range of economic, social and environmental issues associated with land, water and vegetation use. Development of BMPs must also take into consideration the needs and concerns of users, consumers and the wider community. Their development and application will help identify costs and benefits associated with the sustainable management of land uses, including environmental and social costs.

BMPs should be based on available technology and management expertise, drawing on knowledge from a wide range of experts, including agricultural extension officers, soil conservation specialists, agricultural researchers, water resources personnel, land use managers, environmental scientists and community interest groups. Land use managers will be more committed to adopting BMPs when they are involved in their development. Agreed Codes of Practice for specific industries may be an appropriate means of implementing BMPs.

Management practices described in this document only provide a framework that needs to be set in the context of broader farm management goals. Best management practices will be most effective where they are implemented by skilled land managers with an understanding of the principles involved, and a clear vision of how these practices contribute to the achievement of other economic and social goals. Different mixes of best management practices will be appropriate to different regions, soil types and farm businesses.

3.3 Integrated Catchment Management

Water quality is ideally managed using a whole-of-catchment approach. This provides an appropriate planning framework for integrating water, vegetation and land resources management to ensure long term ecological, social and economic sustainability. It is underpinned by activities including:

- regional planning and co-ordination;
- resource assessment;
- property management planning;
- landcare group support;
- research and development;
- land management policy review; and
- education and awareness.

Each State and Territory has put in place structures for whole (integrated) catchment management on catchment or regional bases.

3.4 Suspended Solids

A framework of management practices for reducing the risk of suspended solids impacting on water quality is described below for agriculture, forestry, urban development and intensive rural industries. Broadly, management practices should aim to:

- reduce and or/prevent the exposure of soils to the direct impacts of rainfall which may result in soil erosion and surface runoff into water bodies;
- protect streambanks from further erosion; and
- maintain or improve soil structure to reduce surface runoff and erosion.

Agriculture
Maintaining a permanent vegetation cover or adopting cultivation techniques that minimise erosion such as minimum or reduced tillage can reduce soil erosion. Potential chemical contamination problems associated with minimum or reduced tillage can be addressed by adopting management practices described under the section on "Chemical Contamination." Vulnerable soils and waterways can also be protected through retaining vegetation. Vegetated wetlands on farms can effectively filter sediments and a range of other contaminants from runoff. On-farm measures that can be adopted include:

- constructing graded banks or furrows disposing runoff into permanent waterways on sloping land according to slope and soil characteristics, and ploughing along contour lines;
- creating and maintaining vegetated and ungrazed buffer zones around cultivated areas and along watercourses;
- sowing and maintaining improved perennial pastures, using adequate amounts of the appropriate fertiliser, grazing and weed management;
- reducing run-off in irrigation areas by encouraging efficient water use systems and techniques;
- adopting seeding techniques which retain stubble on the soil surface;
- using crop/pasture rotations, including suitable legumes, to build up soil organic matter and improving soil structure;
- appropriate fuel management should be carried out to reduce the intensity of bushfires, in such a manner that critical areas are not bare of cover during the stormy season and ensuring that sufficient vegetative cover is left to protect the soil from erosion and filter pollutants prior to their entering water bodies; and
- adopting appropriate grazing management practices which retain more vegetation cover, (especially during drought), thereby reducing the vulnerability of soil loss and streambank erosion, particularly during periods of high intensity rainfall events which may occur following a break in the drought.

Restricting stock access to water bodies, eg by fencing and provision of alternative water facilities, can also assist in reducing erosion.

Intensive rural industries
The primary management consideration should be waste minimisation, re-use and recycling. It is important that untreated effluent containing significant contamination loads does not enter water bodies. Effluent utilisation by land application is preferred where there is suitable land and the soil will not be overloaded with nutrients. Where land is limited, appropriate treatment should be undertaken to reduce the effluent's organic and nutrient content consistent with the land's capacity or agreements reached with neighbouring properties to accept a portion of the waste as a resource for dry season cropping.

Management practices which apply to sources other than effluent include those described for urban development as well as:

- minimising site clearing and land disturbance to levels appropriate for safe operational requirements, while preserving as far as practicable natural riparian vegetative buffer zones to filter suspended material from site runoff;

- construction of legal diversion works as necessary around intensive rural industries to prevent direct runoff; and

- ensuring that the site development plan incorporates the construction of diversion works as necessary, to minimise the volume of runoff from natural catchments entering areas used for mining operations.

Forestry Operations
One of the major roles of the Ministerial Council on Forestry, Fisheries and Aquaculture is to advance sustainable forest management. The maintenance of water quality is a key component of forest management.

Managing forests for the protection of water quality principally concerns maintaining or improving soil and slope stability and preventing the products of erosion (and/or runoff) from entering stream channels. In terms of managing forestry operations to protect water quality, the critical period is during forest harvesting (including track and landing construction), and during the post-harvest period when replacement vegetation is not sufficiently developed to reinforce soils effectively. Further, track and landing surfaces are not fully stabilised, remaining susceptible to collapse and surface erosion.

Elements of a forestry/silvicultural management strategy include:

- use of specific low impact logging methods on steep slopes (eg cable or high lead methods on dispersible soils);
- construction and use of logging roads and tracks that have adequate erosion and sediment control measures installed prior to and during construction and use; and
- use of appropriate State and Territory Codes of Logging Practices.

Streamside and valley bottom areas present important challenges in the maintenance of water quality during logging operations. Management practices can and do include:

- careful management of riparian areas for protection of streams, lakes and wetlands; and
- retention of vegetated buffer zones to protect streams against inputs of sediment and other pollutants
    - riparian vegetation can also maintain stream bank stability, provide shade which lowers stream temperatures and controls algae growth, and provide a food source for aquatic life.

In steep unstable hill country where protection of water quality is a prime goal, the protection of water resources may require zoning the area for protection use only and reverting the area to indigenous scrub or forest or some stable form of self-sustaining vegetation cover. In these circumstances, production forest activities should be restricted to middle and upper slopes and any major disturbances should be kept well away from stream channels.

State and Territory forest practice codes, legislation, regulations and other mechanisms can limit harvesting operations on steep slopes or on lesser slopes of unstable soil where erosion potential is high. Applying these ensure that erosion from forestry operations is minimised and/or prevented.

It was agreed through the National Forest Policy Statement that State and Territory Governments would seek to encourage complementary management approaches for native and plantation forests on both private and public land. In this regard, the Ministerial Council on Forestry, Fisheries and Aquaculture through its Standing Committee on Forestry, and in consultation with the industry and the public, have developed the *Forests Practices Related to Wood Production in Plantations: National Principles.* Using these principles as a basis, codes of practice for plantations have been or are being developed and adopted by States and Territories through legislative or non-legislative means. More information on the National Forest Policy Statement and related initiatives is provided in the following section on key national policies and programs.

Urban development
The main source of suspended solids associated with urban development and rural subdivisions can be reduced or prevented by adopting water sensitive management practices which:

- minimise the area of disturbed land at any one time and ensure good management practices in and around disturbed sites;
- control drainage patterns by directing runoff from construction areas to treatment plants or stable areas;
- use sediment dams to reduce the suspended solids loading in runoff water;
- use velocity reduction and filtration traps, such as artificial (managed) wetlands, rock roughing of channel profiles, straw bales or geotextile cloth;
- revegetate or mulching disturbed areas as quickly as possible;
- divert upstream runoff away from disturbed area;
- use water-sensitive urban design principles and practices to minimise detrimental impacts on flows and water quality;
- plan construction drainage by not concentrating flows and ensuring drains are kept within a reasonable gradient; and
- timing the construction of operations during periods of low intensity rainfall.

Natural erosion processes
Management techniques can include:

- maintaining native vegetation on the banks of watercourses; and
- reducing and/or preventing stock access to minimise disturbance of river and reservoir beds.

Engineering structures that are consistent with catchment management approaches can also provide short and long term stability to eroding reservoir, river and stream banks.

Detailed discussion of management practices relevant to intensive rural industries is contained in the series of publications developed under the umbrella title of *Effluent Management Guidelines for Specific Industries* (aqueous wool scouring and carbonising, tanneries and related industries, wineries and distilleries, dairy sheds, dairy processing plants, and piggeries).

3.5 Nutrient Enrichment

Nutrient enrichment can degrade water quality by supporting the formation of algal blooms. The *Algal Management Strategy* developed by the Murray-Darling Basin Commission contains management strategies that may be relevant to other catchments with similar problems.* Most measures to reduce suspended solids described above can minimise the amount of nutrients and other chemicals entering surface waters. A framework of management practices for reducing the risk of nutrient enrichment impacting on water quality is described below for agriculture, forestry, intensive rural industries, extractive industries and urban development.

Agriculture

Matching fertiliser application to the nutritional requirements of crops and pastures can reduce input of excess nutrients into water bodies. Soil and plant testing will help predict the actual nutrient requirements. Fertilisers should be applied at the correct growth stage, taking into consideration the prevailing weather conditions to minimise the potential for leaching and erosion/surface movement. Other measures include:

- providing sufficient, safe and environmentally sound on-farm storage facilities for solid fertilisers and manure to prevent nutrient-rich runoff or leachate;
- taking special precautions when handling liquid inorganic fertilisers to prevent spillage;
- incorporating manure into exposed soil to minimise surface run-off and gaseous losses;
- assessing physical soil properties to ensure that ploughing or cultivation will not contribute to leaching of nutrients from the subsoil into groundwaters;
- adopting management practices which reduce the need for applied fertiliser, for example use of leguminous crops in rotation and utilising available fixed or residual applied nutrients;
- avoiding direct inputs into surface waters when applying fertiliser;
- adopting erosion control measures as most nutrients enter water attached to soil particles, particularly during wet weather; and
- restricting stock access to water courses to reduce bank erosion and thereby reducing nutrient inputs from stock waste.

Intensive rural industries

Poor management of effluent from intensive rural industries can contribute nutrients, particularly nitrogen, phosphorus and potassium, to water bodies. Land application of the stabilised effluent is the preferred management option where adequate areas of suitable land are available. Applications should aim to achieve nutrient balance enabling the effluent's nutrient content to be used as fertiliser and the organic content to improve soil structure. Where land is limited, partial or complete treatment, on-site storage for future use or off-site use should be considered. Land application of effluent should be monitored to

*Other relevant initiatives for the management of algae include the NSW Algal Management Strategy, the Victorian Nutrient Management Strategy and the ARMCANZ co-ordination of algal bloom research, particularly in response to the major outbreaks of algal blooms in 1991. Further relevant literature on this subject also exists in the other States and Territories.

ensure that adverse impacts are not occurring. Untreated effluent should not be discharged directly to water bodies under any circumstances.

The NWQMS Guidelines for Specific Industries (Appendix 1), and the Guidelines for Sewerage Systems cover managing effluent from some key rural industries. Feedlots are covered by the *National Guidelines for Beef Cattle Feedlots in Australia* (second edition) developed by the Agriculture and Resource Management Council of Australia and New Zealand in 1997.

In some States and Territories, the relevant authorities permit the controlled discharge of industrial effluent to the domestic sewerage system for subsequent treatment and discharge and/or use. Overloaded and leaking domestic sewerage systems are another potential source of nutrients to water bodies. The management of sewerage systems is covered in the *Guidelines for Sewerage Systems - Acceptance of Trade Wastes (Industrial Wastes), Effluent Management, Sludge Management, Use of Reclaimed Water* and *Sewerage Systems Overflows.*

Forestry operations
Management practices described above to reduce the transport of suspended solids are also applicable here.*

Extractive industries
Water quality problems associated with extractive industries relate to pollution from:

- sediment in runoff
    - in addition to their contribution to turbidity, sediments are often nutrient rich so sediment problems from extractive industries can also lead to nutrient contamination problems;
- hydrocarbons from fuel storage, construction vehicles and machinery; and
- acid drainage from mining, road construction and other excavations.

Best management practices described in this chapter to reduce soil erosion and transport of nutrients and manufactured chemicals into water bodies also apply to extractive industries.

Urban development
Fertilisers and pesticides applied to lawns and gardens can be transported in stormwater into water bodies. The use of significant amounts of phosphorus as an additive in detergents used in urban households, can also contribute nutrients through the sewerage system. Management options are similar to those described above for fertiliser application on agricultural land. These involve matching the application rates to the nutritional requirements of crops and lawns. Pesticides should be selected so as not to produce leachable residuals and used in accordance with manufacture recommendations.

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* The guidelines for managing Australia's native forests developed by the Joint ANZECC/Ministerial Council on Forestry, Fisheries and Aquaculture National Forest Policy Statement Implementation Sub-committee (JANIS) to achieve environmental objectives also discuss practices for protecting water quality.

The management of urban stormwater to reduce its potential adverse impacts on water quality is described in the *Guidelines for Urban Stormwater Management.*

3.6 Chemical Contamination

Appropriate application of agricultural chemicals include:

- using only the appropriate agricultural chemicals;
- applying the appropriate rate of agricultural chemicals;
- using appropriate spraying equipment that has been well maintained, including nozzles, filters and pressure gauges;
- safe disposal of chemical containers consistent with the best management practices developed for container recycling by the Agricultural and Veterinary Chemical Association ;
- applying agricultural chemicals only in suitable weather conditions;
- applying agricultural chemicals at the recommendation time; and
- where possible, limiting the choice of agricultural chemicals to only those which do not degrade into harmful by-products, and are not persistent in the environment.

Safe handling, storage and disposal of agricultural chemicals should be an integral part of a strategy to prevent and reduce the adverse environmental impact of these chemicals. Strict precautions should be taken to prevent chemicals from spreading beyond the area treated, particularly into water bodies. Measures to reduce the transport of sediment will also help to minimise and/or prevent the movement of residual chemicals to water bodies.

Agriculture
Usage patterns of agricultural chemicals that support sustainable management principles are described on the registered label. It is an offence to use a pesticide in a manner contrary to the registered label. State and Territory authorities determine offences relating to inappropriate use of agricultural chemicals, and this varies from State to State. Where in doubt about the correct procedure for applying a particular agricultural chemical, consult with either the relevant State or Territory authority or the manufacturer or its licensed distributor.

Integrated pest management systems can minimise reliance on chemical applications and reduce the potential to contaminate. Techniques include:

- using biological control methods, including where practical existing natural predators;
- regular monitoring of pests and pathogens prevalence to optimise timing and extent of control measures;
- rotating chemicals during the growing season to minimise development of chemical resistance;
- adopting low volume spray technology where appropriate;
- using high quality, disease free plant materials or seeds;
- adopting farming techniques which prevent the spread of disease between paddocks;
- increasing the adoption of crop-rotation schemes; and

- pesticide users adopting the best management practices for container disposal developed by industry and governments.

Careful choice of chemicals and adjusting application rates to suit soil type, site and environmental conditions are important in protecting non-target areas and downstream water quality.

In July 1993 the Coordinating Committee on Agricultural Chemicals (CCAC) released a report on the review of chemical spray drift which recommended a range of measures to ensure that agricultural chemicals do not adversely impact on health, adjoining properties and water quality. They included:

- developing uniform national regulations for the aerial and ground application of chemicals, as well as developing and adopting uniform national licensing requirements;
- State Departments of Agriculture/Primary Industry maintaining and strengthening their controls on commercial, aerial and ground applicators;
- maintaining and calibrating ground application equipment regularly;
- using incentives to encourage the chemical industry to develop drift minimising technologies and formulations;
- educating users to reduce the harmful impacts of agricultural chemicals;
- developing and adopting codes of practice as an integral part of chemical training programs; and
- establishing satisfactory competency standards for operators of equipment used in the application of chemicals, as well as users of agricultural chemicals.

Forestry
Management practices described above to reduce the transport of suspended solids are also applicable here. State and Territory Codes of Forest Practice set out procedures and management options to be followed during timber harvesting to minimise environmental impacts, including the protection of water bodies from contamination and pollution.

Chemicals, petroleum products and machinery used in forestry operations are potential sources of chemical contamination. Siting fuel dumps away from water bodies can prevent contamination from petroleum products. Contamination from chemical use can be prevented by careful selection of application method.

Acid sulphate soils
Options for managing acid sulphate soils and sediments are:

- avoiding draining wetlands thereby preventing oxidation;
- neutralising with lime;
- inhibition of oxidation using surfactants;
- oxidation and leaching; and
- removing pyritic material.

Given the toxicity of effluent from these soils, human and stock use of any drainage should be discouraged or prevented. Construction activities such as roadworks can disturb acid sulphate soils and exacerbate the leaching of effluent. Infrastructure development on acid sulphate soils should be avoided if alternative sites are available. Where there is no alternative, acid sulphate materials should be treated with great care.

Preventing oxidation of acid sulphate soils can be achieved by reducing the amount of wetlands drained for development purposes. Leaving areas of these soils undisturbed will reduce the amounts of acid leached into water bodies. Applying lime or dolomite can achieve neutralisation. Drainage and diversion works associated with road construction need careful planning and siting to reduce oxidation rates and transport of oxidation products into waterways.

3.7 Salinity

Management of the whole catchment, in particular the recharge areas to minimise accession to watertable will help maintain watertables at depth and reduce hydrological pressures that result in discharge areas becoming salt affected. Adopting agro-forestry farming systems and greater use of perennial pastures over a proportion of the catchment can also reduce rising groundwater levels on land devoted to grazing. Practices such as preventing further vegetation clearing and immediate revegetation of cleared areas can minimise or prevent adverse salinity impacts from many rural land uses.

Management and corrective practices can include:

- agronomic practices to maintain productivity and to stop further saline degradation. In parts of Australia, these practices have involved the use of salt tolerant pasture species, the cultivation of tall wheat grass and some clovers;
- using deep-rooted perennial plants such as lucernes and trees to help lower and maintain the watertable. High water use crops and pasture species and other vegetation can help to reduce the amount of water reaching the groundwater system;
- adopting sustainable grazing management practices including destocking, particularly on fragile, saline soils which are easily damaged; and
- adopting catchment planning including electro-magnetic surveys and hydrogeological studies and property management planning as an essential strategy for the management of salt affected land.

Another option for managing water tables so that they remain within acceptable bounds is to promote the use of groundwater as a source of water. This can be promoted as a viable option where water quality is suitable for the purpose and the aquifer is capable of yielding useable quantities of water.

3.7.1 Efficient Use of Water

Salt contamination associated with irrigation farming can be managed through practices that encourage the efficient use of water described below.

On-farm irrigation management practices
Correctly matching soil, crop type and water delivery systems can improve the efficient use of water in irrigation agriculture. Appropriate management of applied water during the growing season minimises the availability of excess drainage. Any surface and subsurface drainage should be reused where practicable. Best management practices include:

- assessing land capability through soil surveys prior to irrigation development;

- landforming such as levelling, where appropriate, to ensure evenness of water application;
- converting to more efficient irrigation systems;
- system design, including drainage, taking into account soil characteristics, crop type and method of water application;
- testing and maintaining equipment and the irrigation system itself to ensure accuracy, evenness, reliability and cost efficiency;
- accurately predicting the timing of application and the amounts required;
- using automated application systems to ensure correct timing and amounts to be used;
- reusing drainage to supplement existing supplies; and
- establishing lysimeters and groundwater monitoring network on site.

It is also necessary to maintain drains and drainage structures to ensure efficient removal of drainage waters and minimal impact on local aquifers. Best management practices include:

- desilting aged structures;
- keeping drains free from weeds
- use of soil conservation earthworks, crop rotation, conservation farming techniques and effective fertiliser usage;
- maintaining subsoil drains free from silt and plant roots;
- ensuring that drains do not run through sub-surface sand;
- avoiding using drainage lines that cut through an existing high watertable, particularly if it is saline;
- not draining excess irrigation water into district drains provided to remove stormwater as it may contain unacceptable levels of nutrients;
- avoiding using gravel pits for drainage disposal;
- preventing drainage waters entering roadside drains or into other ponded areas as this water may seep through to the watertable;
- minimising drainage by matching application rate with field needs; and
- developing property management plans to achieve an efficient drainage system.

Off-farm management practices
Delivery and drainage systems operated privately or by water supply authorities need to use water resources efficiently. Seepage from unlined supply and drainage canals is often substantial and may contribute to high water tables, increase groundwater salinity and increase the amount of water required to meet demand for irrigation. Best management practices include:

- lining canals or channels;
- improving management of water ordering and associated channel control;
- maintaining channel capacity through weed and siltation control;

- replacing open channels with closed systems where possible to minimise seepage and evaporation losses;
- monitoring drain flows and quality;
- licensing water users;
- managing waterways to minimise the impact of irrigation use on stream and river ecosystems;
- pricing water to include the total cost of delivery, infrastructure construction and maintenance, and environmental costs from system operation; and
- retaining and maintaining wetlands.

3.8 Microbiological Hazards

The numbers of pathogenic and parasitic organisms in water should be reduced through appropriate treatment techniques because of their potential adverse impacts on human and animal health. Best management practices include:

- primary treatment to remove settleable organic and inorganic solids by sedimentation, and the removal of floating materials (scum) by skimming;
- secondary treatment, following primary treatment, to remove the residual organic and suspended solids (mainly biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes);
- tertiary and/or advanced treatment as appropriate (eg microfiltration, chemical dosing, carbon filtration);
- disinfection; and
- storage, where necessary to further reduce microorganisms, as well as other constituents such as biological oxygen demand (BOD), suspended solids and nitrogen.

In some cases it may be appropriate to use combinations of these technologies to ensure the reduction in microbiological hazards, such as sedimentation followed by disinfection.

The management of sewerage systems and stormwater is discussed in the NWQMS Documents, *Guidelines for Sewerage Systems* and the *Guidelines for Urban Stormwater Management* respectively. The *Guidelines for Sewerage Systems – Use of Reclaimed Water* also covers the management aspects of microbiological agents to protect human health.

3.9 Groundwater

The nature of flow through aquifer systems results in low flow rates and inhibits clean up by regular flushing when compared with surface water bodies. The confined nature of groundwater systems enables pollution of groundwater to persist, often making clean up difficult and expensive or impossible. The best management approach is preventing contamination of groundwaters in the first place. Where a chemical spill occurs which may access an aquifer, aggressive action should take place immediately to neutralise the pollutants before leaching into the aquifers. Where polluted aquifers may come into contact with surface waterbodies, this can be prevented or intercepted by extracting the polluted plume through bores. Other best management practices involve ensuring that activities that are likely to result in contamination of groundwater are not undertaken in a recharge zone or areas with highly permeable soils such as sandy soils. The *Guidelines for Groundwater Protection in Australia* provide management options for the sustainable management of groundwater resources.

3.9.1 Changes to Flow Rates of Waterbodies

The control or regulation of the natural flow of rivers and streams to achieve beneficial uses should be managed appropriately to protect water quality.

Water storage
The volume of water released from major storage dams is often determined by demand for irrigation, town water supply or hydro-electricity generation. Releases can be the key determinant of flow in some rivers and have a major impact on water quality. The following can improve the management and quality of water in storage:

- managing the storage catchment so that all inflow to the storage is suitable for release;
- assessing the impact of storage releases on downstream water quality to determine the most appropriate timing, volume and season of release;
- investigating options for managing storage and release;
- managing releases to maximise water quality; and
- adopting management techniques that balance the need for adequate environmental flows and the supply of water for industrial, agricultural and domestic applications.

Other management options include:

- regulating the amount of water extracted by pumping and diversions from streams and rivers;
- manipulating stream flow by sediment extraction and weir and levee construction;
- improving storage catchment management by such measures as
  - establishing riparian buffer strips on the storage shore and along streams flowing into the storage
  - controlling point sources within the catchment
  - encouraging the adoption of soil and riverbank conservation techniques such as contour banks, grassed waterways and tree planting;
- installing variable level off-takes at dams;
- installing mixing and aeration devices for water circulation within the dam to prevent stratification; and
- aerating water prior to its release from dams into streams.

Water flow
The likely impacts on water quality of any proposed changes to flow regime should be evaluated before changes are implemented. The cumulative impact of water extractions and channel changes should be monitored and managed to ensure that:

- the volume and turbulence of flow is adequate to maintain in-stream process;

- the frequency of flooding maintains the function of wetland and floodplain ecosystems as pollutant filters; and

- environmental flows are maintained compatible with maintenance of the ecology of the stream with due consideration of seasonal and temporal flow variability.

Management options can include:

- making a licence condition that water extraction should not diminish water quality through reduced stream flow;
- controlling and monitoring total water extractions during periods of drought;
- controlling and monitoring sand and gravel extraction to prevent bank and bed erosion and the removal of pool/riffle sequences from streams where they occur;
- evaluating the downstream water quality impact of levee construction from reduced flooding and balancing this against assessed benefit;
- establishing the volume and seasonality of stream flow required to meet communities' water quality goals or objectives;
- better managing point sources of pollution to reduce the need for dilution flows;
- maintaining the natural seasonality, timing and frequency of flood flows and low flows; and
- creating turbulence in weir pools by maintaining flow or installing artificial mixing and stirring mechanisms.

3.10 Hydro Electricity Generation

Hydro electricity works can have significant impacts on downstream water quality. Turbine operation can lead to the oxygen supersaturation of tailwaters, possibly leading to fish kills downstream. Release of water from the bottom of hydro electricity generation dams can result in abnormally cold waters being transported downstream that can adversely affect plant and animal life.

Most strategies for avoiding water quality problems associated with electricity generation may result in sub-optimal operations from an economic point of view. Generally, the operating authorities need to weigh up losing generation efficiency against the possibility of ceasing operations should a significant environmental problem occur. Management options can include:

- avoiding supersaturation of tailwaters by measuring dissolved oxygen levels in the tailrace under a variety of turbine and air injection scenarios and developing site-specific operational strategies;
- reducing oxygen depletion by constructing drop structures to re-aerate the water or by deliberate air injection;
- managing water intakes so as to reduce and/or prevent the release of hydrogen sulphide from decaying organic matter from the reservoir bed; and
- implementing operational strategies which avoid rapid raising and lowering of reservoirs.

4. Some Key National Programs and Policies Which Assist Improvements to Water Quality

Several key national policies and programs influence the adoption of the management practices described in this document. These include the Natural Heritage Trust, with its associated programs National Landcare Program (NLP), National Vegetation Initiative, Murray-Darling 2001, National Rivercare Program and National Wetlands program, the Council of Australian Governments' (COAG) Water Resources Policy and the National Forest Policy Statement.

4.1 Natural Heritage Trust

The Natural Heritage Trust provides a framework for strategic capital investment in the natural environment to achieve complementary environmental, natural resource management and sustainable agriculture outcomes consistent with agreed national strategies and fosters partnerships between the communities, industry and all levels of government.

4.2 National Landcare Program

The National Landcare Program (NLP) supports activities that contribute to the sustainable management of land, water and vegetation resources in line with regional, State and national strategies. Emphasis is placed on providing assistance to communities to overcome the impediments to achieving sustainable management. State agencies, Local Government, community groups and industry are encouraged to work cooperatively towards the achievement of strategic goals.

The NLP objectives are to:

- promote partnership between the community, industry and government in the management of natural resources;
- establish institutional arrangements to develop and implement policies, program and practices that will encourage the sustainable use of natural resources;
- enhance the long term productivity of natural resources; and
- develop approaches to help resolve conflicts over access to natural resources in Australia.

4.3 National Vegetation Initiative (NVI)

Biodiversity protection must be addressed through vegetation protection and restoration, both on and off conservation reserves. This requires the involvement and assistance of landholders. It is only by protecting native vegetation on private land as well as public land that the extremely diverse range of ecosystems, habitats and individuals species can be secured.

The primary objective of the NVI is to reverse the decline in the quality and extent of Australia's native vegetation cover. The focus will be on addressing biodiversity loss and land and water degradation. This will be through actions which protect remnant native vegetation, including areas at risk from unsustainable clearing, and which expand the restoration of appropriate habitat through revegetation.

The NVI combines community and state involvement that can lead to lasting improvements in vegetation management. It builds on work of the former vegetation programs including Save the Bush, One Billion Trees, Grasslands Ecology, Sugar Coast Rescue (Mahogany Glider habitat), Wet Tropics Tree Planting and Corridors of Green.

4.4 Murray-Darling 2001

This initiative aims to significantly accelerate on-ground actions within the Murray-Darling Basin to:

- improve the health of key river systems;
- encourage ecologically and economically sustainable land use;
- restore riparian land systems, wetlands and flood plains; and
- improve water quality.

The Murray-Darling 2001 project will be implemented be the Murray-Darling Basin Commission through the Basin Sustainability Program. The program will promote and coordinate effective planning and management for the equitable, efficient and sustainable use of water, land and other environmental resources of the Murray-Darling Basin.

4.5 National Rivercare Program (NRP)

This program will encourage the sustainable management, rehabilitation and conservation of rivers outside the Murray-Darling Basin. It will incorporate the National River Health Program, Waterwatch Australia and elements of the Fisheries Action Program.

The NRP will build on activities under the existing programs, which have already made an important contribution towards addressing river issues. Its objectives will be achieved through a coordinated and integrated package of measures. Linkages with other Trust programs, including National Wetlands Program and existing State initiatives, will be developed to achieve the integrated management of Australia's river systems.

Community activities under the NRP will include:

- monitoring, education and awareness raising activities;
- developing watercourse management plans; and
- implementing on-ground activities at the local level which will achieve healthier rivers and waterways.

The Fisheries Action Program seeks community participation and commitment to sustainable fisheries and fish habitats and the need for sustainable management

Waterwatch Australia is a national program that encourages volunteers to get involved in water quality monitoring. The program aims to raise community awareness of the importance of the long-term health of natural waterways and river system, including the Murray-Darling Basin.

4.6 The Council of Australian Governments' (COAG) Water Resources Policy

The Council of Australian Governments' (COAG) Water Resources Policy has endorsed the preparation of a strategic framework for the efficient and sustainable reform of the water industry having regard to the technical and policy diversity that exists across the States and Territories. The COAG Policy encourages the development and management of water resources in an integrated way, with regard to the quality and quantity of surface and groundwater resources, and development of mechanisms for water resource management which aim to maintain ecological systems while meeting economic, social and community needs.

The major reforms which COAG has agreed to include:

- pricing reform based on consumption principles;
- full-cost recovery, reduction or elimination of cross-subsidies; and
- making subsidies transparent.

The policy also involves:

- clarifying property rights;
- allocating water to the environment;
- adopting trading arrangements in water;
- institutional reform; and
- public consultation and participation.

COAG reforms aim to encourage highest value uses of water and more efficient water use in order to reduce some resource degradation problems. State and Territory governments are expected to draw on a number of principles, which have been developed through collaboration between all governments and community stakeholders and are directed at addressing the fundamental causes of resource degradation including institutional reforms. These principles are:

- an integrated catchment management approach to water resource management;
- water pricing that reflects all the costs of supply and service (including social and environmental costs);
- water being employed in higher value uses, within the social, physical and ecological constraints of catchments;
- consistent approaches to pricing, property rights/entitlements, trading and environmental allocations across jurisdictions;
- institutional arrangements and responsibilities that are clearly defined;
- measures to address the structural and social impact of reform; and

- community involvement in the water reform process.

4.7 National Forest Policy Statement

A principle objective of the National Forest Policy Statement (NFPS) is the ecologically sustainable management and economic utilisation of Australia's public and private forest estate.

The major delivery vehicle for this objective is through the Regional Forest Agreement (RFA) process, which is a scientifically based process designed to balance the environmental, social, economic and heritage values associated with ecologically sustainable forest management.

In the lead up to the finalisation of an RFA between the State and Commonwealth, an assessment of water values is undertaken as part of the Comprehensive Regional Assessment (CRA) process. The assessment covers current water yields and quality, catchment soil types and land uses and will take account of all areas affected both within and outside the region. While specific water issues will vary between States, water quality issues are examined in all RFAs.

Once an RFA is signed, harvesting of timber will be prohibited from those areas set aside for a Comprehensive, Adequate and Representative Reserve System while those areas available for harvesting will be subject to agreed ecologically sustainable forest management practices. Such agreements allow for the resource to be managed in a manner which protects environmental values, including water quality and catchment values.

Four RFAs have been signed so far – Tasmania, the Central Highlands and East Gippsland in Victoria, and Western Australia.

Ecologically Sustainable Forest Management (ESFM) sections contained in each of the four RFAs commit the State Governments to finalise and/or amend their forest management systems where needed to provide for ESFM. Such amended systems are accredited by the Commonwealth under each RFA as providing for ESFM.

In the case of all four RFAs, parties have agreed to develop an appropriate set of sustainability indicators (to monitor forest changes) consistent with the Montreal Process Criteria. The Montreal Process has agreed on seven criteria for sustainable forest management which include the conservation of soil and water resources.

In Australia, no one forest type is the same, and the application and importance of the criteria and their respective indicators will vary between tenures and broad forest types. However, the implementation of the Montreal Criteria and indicators provide a mechanism that will allow the monitoring and review of the sustainability of forest management practices which is capable of being implemented at the regional level and which also provides for consistency in reporting at all levels while avoiding duplication in data collection.

The NFPS also recognises that forest plantations can provide a wide range of commercial, environmental and aesthetic benefits to the community. The *Forest Practices Related to Wood Production in Plantations: National Principles* (National Plantation Principles) establishes the framework for a consistent and scientific approach to the sustainable management of both public and private plantations, and a sound basis for the development or evaluation of Codes of Practice.

The National Plantation Principles have been developed by the Standing Committee on Forestry, and were endorsed by the Ministerial Council on Forestry, Fisheries and Aquaculture at its meeting in Perth, Western Australia in November 1995. At that meeting, Ministers agreed that export controls on plantation wood would be removed from 1 January 1996 or as soon as possible after that date subject to the satisfactory implementation of environmental codes of practice.

Under amendments to the Export Control (Unprocessed Wood) Regulations made in 1996 (which give effect to that process), CSIRO has been evaluating the adequacy of each State's code of plantation practice to provide for environmental and heritage protection across private and public tenures and through all stages from establishment through to harvesting. Assessment of each code is against criteria derived from the National Plantation Principles and which assess:

- Environmental care in the clearing of native forest for plantation development;
- Plantation management should comply with relevant planning schemes and legislation;
- Protection of water quality and, where required, management of water yield;
- Protection of natural and heritage values in road construction and other site disturbance work;
- Protection of natural and heritage values in plantation planning and management operations;
- Protection against fire, pest and disease; and
- Environmental care training.

5. Further Reading

5.1 Suspended Solids

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Kalma, J D (CSIRO Division of Water Resources) *Predicting soil water distribution and runoff from terrain attributes and weather*

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McTainsh, G (Griffith University, Faculty of Environmental Studies) *Wind erosion of grazing lands*

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5.2 Nutrient Enrichment of Water Bodies

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Water and Waste Minimisation - optimisation of water use and control of waste in abattoirs- Australian Meat Technology Pty Ltd, Rockies QLD 1995

5.3 Chemical Contamination

Davis, P E (University of Tasmania, Department of Zoology) *Effects of pesticides on freshwater invertebrates fauna*

How to recognise acid sulfate soils, Colour brochure produced by the Acid Sulfate Soils Management Advisory Committee. July 1995

Impact of Pesticides on the Riverine Environment, Workshop Proceedings 20-21 May 1992, Goondiwindi, Cotton Research and Development Corporation

Launders, T (February 1996) *Pasture and Crop Management on Acid Sulfate Soils*, NSW Agriculture

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Schofield N J, *Minimising the Impact of Pesticides on the Riverine Environment*, AWWA 16th Federal Convention, April 1995 pp 411-417

Turkington, Ross and Boys, Alan (1994) *Organic and low chemical management. Grapevine Management Guide 1994/95*. NSW Agriculture and Mudgee Grapegrowers Association, Agdex 241/10, ISSN 1036-7551,pp25-27

Walker, S R (QLD Department of Primary Industries) *Herbicide management and herbicide residue in conservation cropping*

What are acid sulfate soils? Information sheet produced by Ian Waite, Mike Melville and Rebecca Lines-Kelly, July 1995

5.4 Salinity and Efficient Water Use

Acworth, I (University of NSW, Centre for Groundwater Management and Hydrogeology) *Dryland salinity process in the Yass water supply catchment and other locations in NSW*

Driver M and Graham A (1994) The Benefits of Tree Planting in Irrigation Areas, Information pamphlet NSW Agriculture

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Appendices

Appendix 1: National Water Quality Management Strategy documents

Paper No.	Title
Policies and Processes for Water Quality Management	
1.	Water Quality Management - An Outline of the Policies
2.	Policies and Principles - A Reference Document
3.	Implementation Guidelines
Water Quality Benchmarks	
4.	Australian Water Quality Guidelines for Fresh and Marine Waters
5.	Australian Drinking Water Guidelines - Summary
6.	Australian Drinking Water Guidelines
7.	Water Quality Monitoring and Reporting
Groundwater Management	
8.	Guidelines for Groundwater Protection
Guidelines for Diffuse and Point Sources	
9.	Rural Land Uses and Water Quality - A Community Resource Document
10.	Guidelines for Urban Stormwater Management
11.	Guidelines for Sewerage Systems - Effluent Management
12.	Guidelines for Sewerage Systems - Acceptance of Trade Wastes (Industrial Wastes)
13.	Guidelines for Sewerage Systems - Sludge (Biosolids) Management
14.	Guidelines for Sewerage Systems - Use of Reclaimed Water
15.	Guidelines for Sewerage Systems - Sewerage System Overflows
16a.	Effluent Management Guidelines for Dairy Sheds
16b.	Effluent Management Guidelines for Dairy Processing Plants
17.	Effluent Management Guidelines for Piggeries
18.	Effluent Management Guidelines for Aqueous Wool Scouring and Carbonising
19	Effluent Management Guidelines for Tanning and Related Industries
20.	Effluent Management Guidelines for Australian Wineries and Distilleries