STATE OF THE ENVIRONMENT REPORT 2007
Western Australia

Theme 4

KEY FINDINGS

- About 80% of Western Australia’s estuaries are in good condition.
- Only about 30% of the State’s major rivers are in good condition.
- Only seventeen per cent of remaining wetlands on the Swan Coastal Plain have high conservation significance.
- Wetland vegetation on the Swan Coastal Plain is being lost or degraded at the rate of about two football ovals per day.
- Monitoring and management of inland waters is generally inadequate.

INLAND WATERS

INTRODUCTION

Western Australia has many different types of inland waters. Flowing waters on the surface of the land are referred to as waterways and may include estuaries, rivers, streams, creeks, drains and floodplains. There are about 208 major waterways with a combined length of 25 000 kilometres (km), and 171 estuaries (Water and Rivers Commission, 2000a). Standing waters on the surface of the land are referred to as wetlands and may include lakes, swamps, damplands, sumplands, springs, soaks, karst caves and waterholes. The State has thousands of waterways and wetlands that have water on either a permanent, seasonal or intermittent basis. Groundwater is located at various depths below the land surface and interacts with many waterways and wetlands.

Inland waters and the water cycle are fundamental for sustaining life and ecological processes. They are usually considered within the context of their drainage basins, catchments and discharge zones. These systems are essential for maintaining biodiversity and regulating catchment water balances (see '*Biodiversity*'). They provide economic and social benefits by providing drinking water and irrigation water supplies, supporting food production and underpinning a diverse array of recreational, spiritual, inspirational, scientific, cultural and educational values. However, these aspects will be investigated in other areas of this report (see '*Water use in settlements' and 'Water supply*').

Most inland waters in WA have been significantly modified since European settlement, especially in the South West (Finlayson & Rea, 1999; Pen, 1999; National Land and Water Resources Audit, 2002). Waterways, wetlands, floodplains and catchments have been dramatically altered to allow for settlements, agriculture, water supplies and infrastructure development. The amount and rate of alteration is largely a consequence of population growth and the consumption of natural resources to support human settlements and economic productivity (see '*Fundamental pressures*'). Alteration of areas from their natural state inevitably results in detrimental changes to water quantity and quality. If persistent, these problems can lead to a rapid deterioration of both aquatic and terrestrial ecology and human related beneficial uses.

Objectives

- Protect and improve the condition and associated values of inland waters to sustain ecosystem health and other beneficial and productive uses.
- Reduce and eliminate (where practical) the major environmental issues that degrade, or threaten to degrade, inland waters and associated values.
- Conserve inland waters and associated values identified as most important.
- Manage and use the inland water resources in a sustainable manner and rehabilitate degraded inland waters where practical.

Headline indicators

Indicator IW1: Percentage of estuaries, major rivers and wetlands that remain in a near pristine or largely unmodified state.

Seventy-seven per cent of estuaries (i.e. 132 of 171) are in a largely unmodified state (Geoscience Australia, unpublished data).

Thirty-two per cent of major river basins (i.e. 12 of the 38 that are monitored) are in largely unmodified state (Halse, Scanlon & Cocking, 2002).

Only 17% of remaining wetlands on the Swan Coastal Plain have high conservation significance (Environmental Protection Authority, unpublished data). Information about the condition of other WA wetlands is extremely limited.

Indicator IW2: Loss of wetland area on the Swan Coastal Plain.

Recent analysis indicates that wetland vegetation on the Swan Coastal Plain decreased by about 1500 hectares per year between 1996 and 2004 (Environmental Protection Authority, unpublished). This equates to the loss of an area about the size of two football ovals per day.

Indicator IW3: **Number of specific inland water assets that have had their environmental values formally declared in State Government environmental protection policies.**

Environmental values for Gnangara Mound, and the Swan–Canning and Peel–Harvey estuaries are formally declared in environmental protection policies under the *Environmental Protection Act 1986*. While environmental values have been identified informally for other inland waters, most have not been developed in collaboration with the community and have not been afforded regulatory protection under formal State environmental policy.

Overall condition

ESTUARY CONDITION

Estuaries are semi-enclosed coastal water bodies were salt water from the marine environment mixes with freshwater draining the land. They are well known for their high productivity. There are 171 identified estuaries across WA (Figure IW0.1), ranging from tidal-dominated in the North West (with tides up to 10 m in places) to wave-dominated in the South West. Estuary condition is assessed using factors such as catchment vegetation cover, altered water regimes, altered tidal regimes, land and estuary uses, impacts to floodplain and estuary ecology and introduced plants and animals (National Land and Water Resources Audit, 2002), Near-pristine estuaries are generally found only in remote areas (e.g. western parts of the Kimberley) and/or those with forested catchments protected by conservation reserves. Extensively modified estuaries (e.g. Swan–Canning, Peel–Harvey, Leschenault, Vasse–Wonnerup and Oyster Harbour) have catchments with large populations, significantly modified catchments and hydrology, and intensive agriculture or industrial land uses.

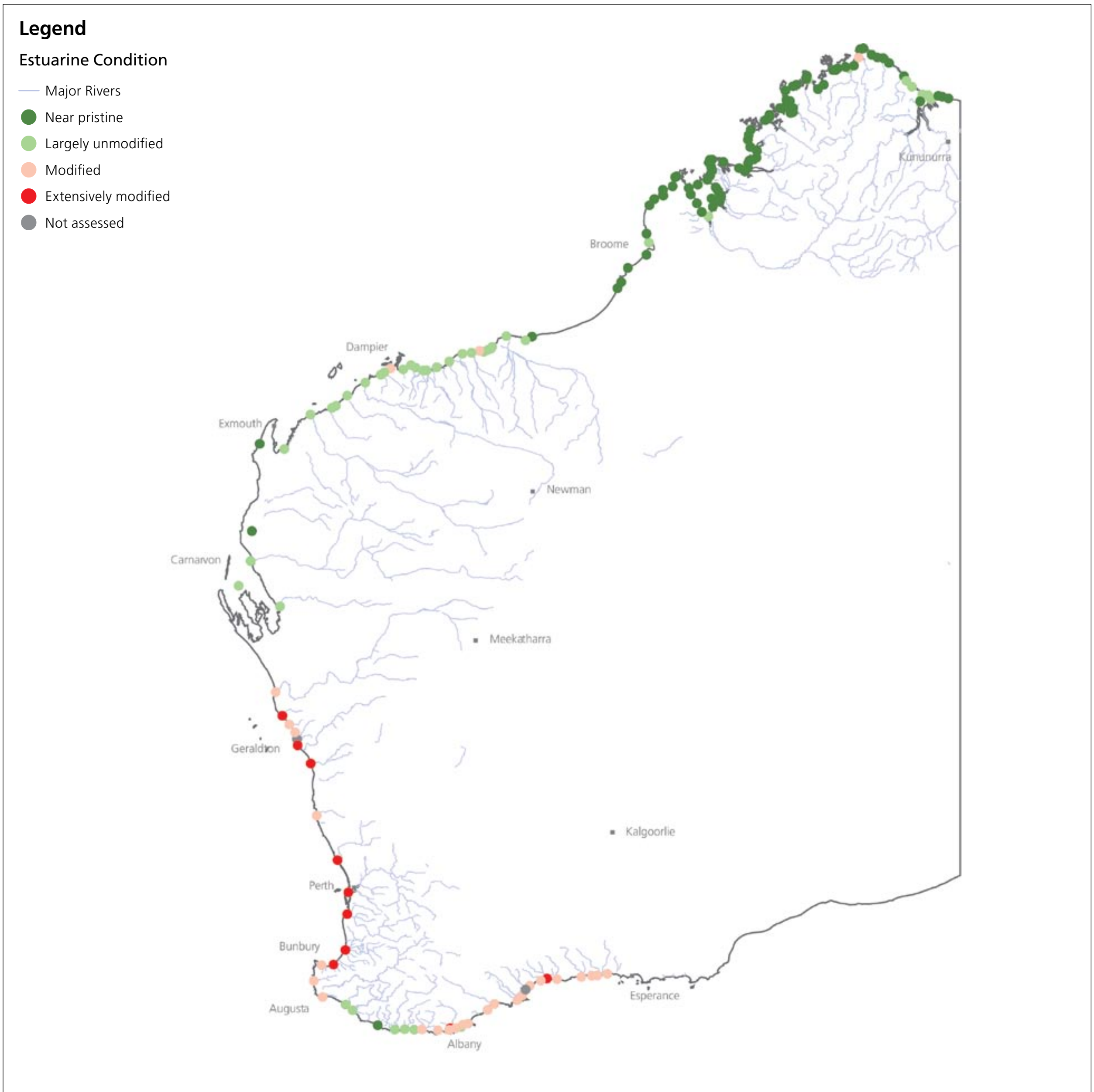


Figure IW0.1: Condition of Western Australian estuaries.

Data source: Geoscience Australia; Presentation: EPA.

RIVER CONDITION

Western Australian rivers range from permanently flowing in high rainfall areas to seasonally flowing or intermittent in low rainfall areas. Rivers are the link between land and ocean, providing estuaries and floodplains with nutrients and water needed for maintaining plant and animal life. The presence of key macro-invertebrates has been used as an indicator of the condition of river ecosystems (Figure IW0.2, Halse, Scanlon & Cocking, 2002). Rivers were found to be healthier in basins that have retained most native vegetation (i.e. in conservation reserves) or where minimal development has occurred (e.g. rivers in the western Kimberley, the Pilbara and some forested parts of the South West). Modified river basins occur throughout most of the State's South West, where many rivers have been regulated and where catchments support large settlements or intensive land uses. Some modified river basins are also found in the Mid West and the Ord River where pastoralism, river damming or mining practices have modified river ecosystems. The Avon and Esperance river basins are extensively modified due to widespread land clearing for agriculture, artificial drainage, widespread salinisation, river modification to prevent flooding, and the general loss of river structure, function and ecology.

WETLAND CONDITION

Wetlands are among the most biologically productive and diverse habitats on the planet (Environmental Protection Authority, 2004) and have a vital role in landscape functionality. At this time it is not possible to provide an overall assessment of wetland condition. Some WA wetlands of State, national and international significance are well researched and protected. The majority of wetlands are not well-documented and consequently there is little available information to determine condition. Most information is available for wetlands on the Swan Coastal Plain, as this area has been subject to ongoing development and other pressures (see '*Loss or degradation of wetlands*'; Figure IW0.3). Approximately 17% of wetlands on the Swan Coastal Plain have high conservation significance and 14% are formally protected. Wetlands in the Wheatbelt region of the South West are also under significant pressure due to altered water regimes, salinisation, eutrophication, acidification, invasion of weed and feral species, and historical widespread land clearing. Limited but intensive monitoring of 25 regionally important wetlands indicates that 26% show recent deterioration with rapidly declining biodiversity (Cale, Halse & Walker, 2004).

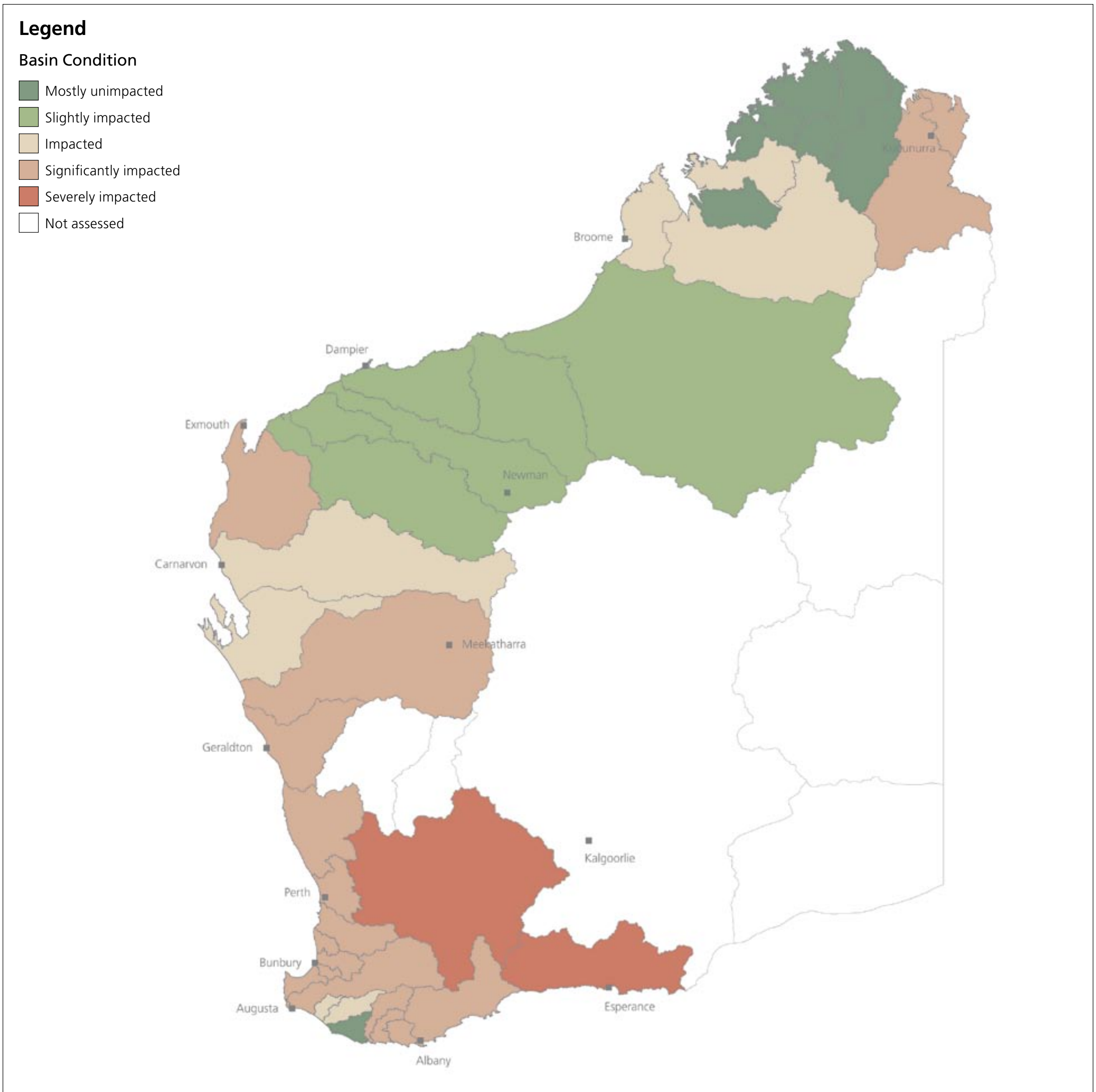


Figure IW0.2: Condition of major Western Australian rivers, by river basin.

Data source: Department of Environment and Heritage [ver. 2001]; Analysis: EPA; Presentation: EPA.

Figure IW0.3: Management categories of wetlands on the Swan Coastal Plain.

Data source: Department of Environment [ver. 2005]; Presentation: EPA.

GROUNDWATER CONDITION

Groundwater can be found across the State at varying depths beneath the land surface. It provides a common hydrological connection between catchments, wetlands and waterways. At this time it is not possible to provide an overall assessment of groundwater condition. Although hydrogeological information exists for some developed areas of the State (see '*Altered water regimes*'), there is a general lack of information about broad aquifer condition, given the sheer extent of groundwater and its complex nature. In general it is recognised that groundwater has been degraded in areas developed for urbanisation, industry and agriculture, and is coming under increasing pressure through water mining and abstraction (see '*Water supply*').

Effectiveness

Thirty-three actions were identified for inland waters in response to the 1998 *State of the Environment Report* (Government of Western Australia, 1999). Fifty-five percent of the actions are incomplete, 36% are complete but have not been evaluated, and only 9% have been both completed and evaluated. Progression and evaluation of actions has been complicated by a gradual decline in monitoring, reduced funding for rehabilitation projects, and other perceived priorities for water resource management agencies. Improved monitoring and evaluation of inland waters is urgently required. The National Action Plan for Salinity and Water Quality and Natural Heritage Trust programs intend to progress monitoring of issues such as eutrophication, sedimentation, salinisation and other inland water ecosystem health measures.

SUGGESTED RESPONSES

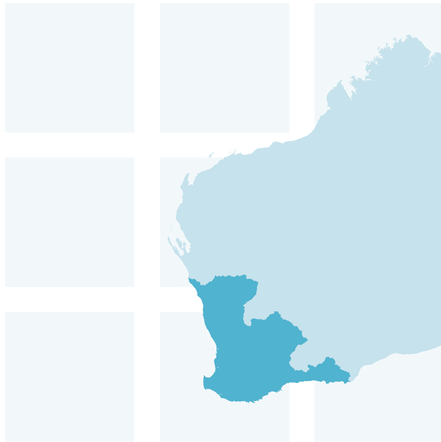
4.1 Implement the *State Water Quality Management Strategy no. 6*: a policy to ensure inland waters are managed under an approved environmental management framework.

4.2 Finalise and implement the draft *Waterways Western Australia Policy*, with oversight by a waterways management committee that has community representation.

4.3 Develop and implement a State Wild Rivers Policy that also includes rivers of high conservation value.

4.4 Finalise and implement the revised *Wetlands Conservation Policy* for Western Australia.

4.1 SALINISATION OF INLAND WATERS



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 1

KEY FINDINGS

- Salinity levels are still rising in many major South West rivers.
- Rising salinity trends have been halted in the Collie and Denmark rivers due to clearing controls and reafforestation efforts.
- Monitoring of salt affected rivers has declined by about one-third over the last five years.
- Deep drainage is a divisive issue amongst the community and requires urgent attention.

Description

Salinisation is the process that increases dissolved salts in inland waters. It occurs naturally in arid parts of WA where salt lakes exist. Native flora and fauna have gradually adapted to these naturally saline ecosystems. Problems arise when previously unaffected land and water become salinised, and associated flora and fauna are unable to cope.

Salinisation of land and water is largely due to widespread land clearing and replacement of native vegetation with shallow rooted annual crops and pastures that use less water. This alters the natural water balance of the land. Rainfall not used by vegetation seeps into the soil, passes the root zone and adds to groundwater stores. Over time, groundwater stores increase at a much faster rate than would otherwise occur naturally, causing watertables to rise and bringing salt stored in the soil to the surface. This is expressed as saline seeps and salt scalds, which allow for rapid runoff of salty water to nearby streams, rivers and wetlands. Salt is also transported by groundwater flow although this process occurs at a much slower rate. For this reason it may take up to several decades for waterways and wetlands to become salinised following widespread clearing of vegetation. Salinisation of inland waters typically affects the South West agricultural parts of the State, where dryland salinisation occurs.

Another process, 'irrigation salinity', can contribute to salinisation of inland waters, especially in high rainfall areas. This occurs when watertables are artificially raised and salt stores mobilised through excessive irrigation of agricultural crops and pastures, or through water leaking from irrigation channels. Both dryland and irrigation salinity can cause significant ecological damage to ecosystems and water supplies, and accelerate corrosion of infrastructure.

Objectives

The *State Salinity Strategy* (Government of Western Australia, 2000) lists specific goals for managing the impact of land salinisation in the South West agricultural region. Objectives relevant to inland waters include:

- To protect and restore key water resources to ensure salinity levels are kept to a level that permits safe, potable water supplies in perpetuity;
- To protect and restore high value wetlands, waterways and natural vegetation, and maintain natural (biological and physical) diversity in areas affected by salinisation.

Condition

Indicator IW4: Status and trends in salinity of inland waters.

River salinity shows a clear pattern through the South West (Figure IW1.1). Waterways originating in high rainfall (>900 millimetres) coastal areas and forests are generally fresh, with very little or no salt. Further from the coast rainfall decreases, a greater proportion of land has been cleared, and waterways have become more saline. Some of the larger waterways that originate in cleared inland areas (such as the Avon, Frankland, Blackwood, Kent and Murray rivers) are severely impacted in upper reaches and remain brackish to saline approaching the coast. Waterways and wetlands in the eastern Wheatbelt, east of the Meckering Line, have salinities that are about three to six times higher than those in the western Wheatbelt. Much of the salinity in eastern Wheatbelt inland waters is natural and salinity levels are increasing more slowly than those to the west (Commander et al., 2002).

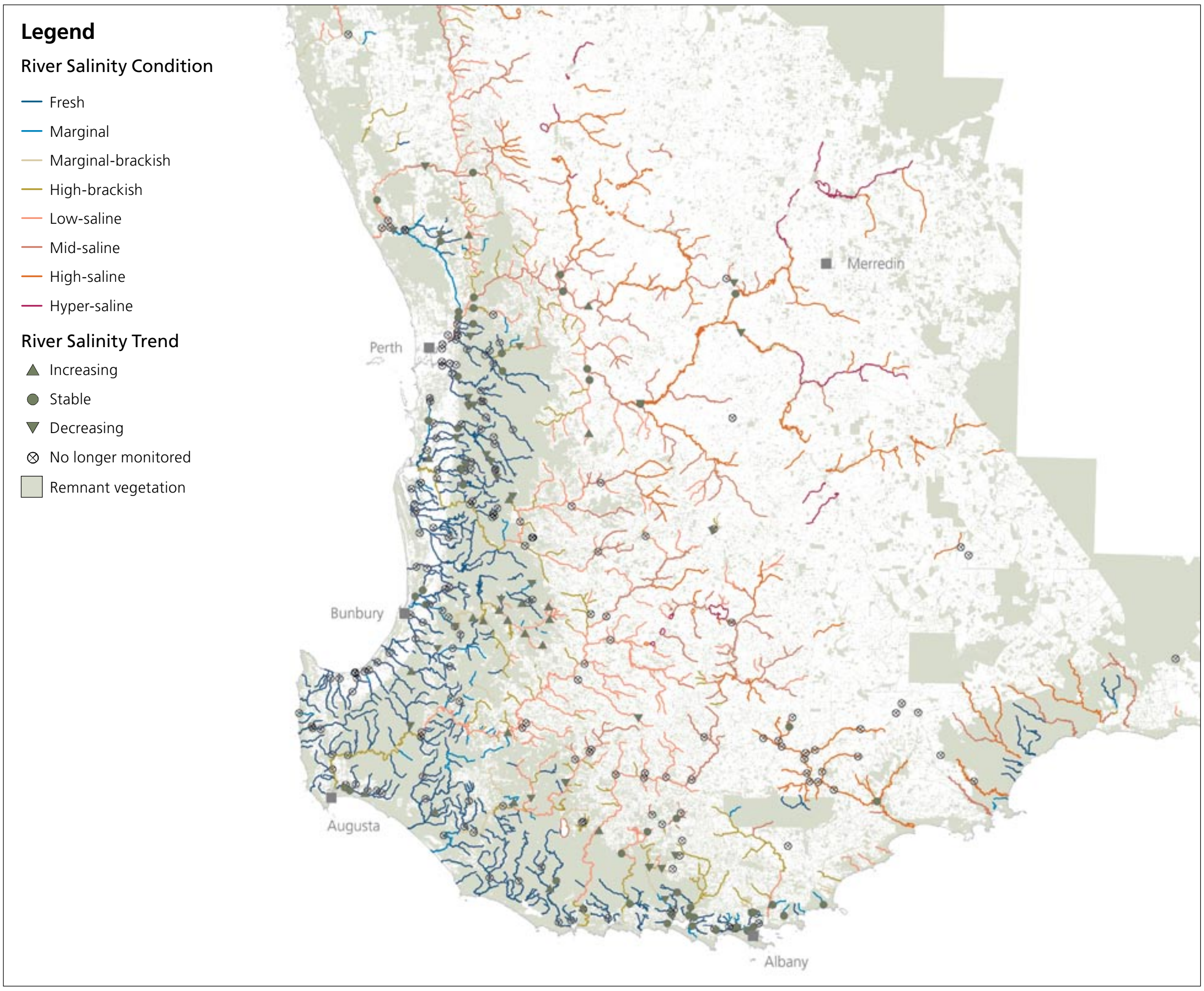


Figure IW1.1: Salinity in rivers of the South West.

Data source: Department of Environment – Stream salinity condition [ver. 2004], water quality sites [ver. 2005], Department of Agriculture – remnant vegetation [ver. 1996]. Analysis: EPA – water quality sites; Presentation: EPA.

Table IW1.1: Salinity trends for South West rivers for which long-term monitoring data are available.

Stream	Monitoring location	Period	Salinity trend – direction and size (mg/L/yr)a
Denmark River	Mt Lindesay	1980s 1990s	▲ 14 ▼ 7
Kent River	Styx Junction	1980s 1990s	▲ 42 ▲ 14
Warren River	Barker Rd crossing	1980s 1990s	▲ 15 ▲ 2[a]
Carey Brook	Staircase Rd	1980s 1990s	▼ 0.5 ▼ 0.5
Donnelly River	Strickland	1980s 1990s	▲ 2 ▲ 2
Balgarup River	Mandelup Pool	1980s 1990s	▼ 30[a] ▲ 17
Collie River	Mungalup Tower	1980s 1990s	▲ 33 ▼ 6
Collie River East	(tributary of the Collie R)	1980s 1990s	▲ 110 ▲ 200
Murray River	Baden Powell Water Spout	1980s 1990s	▲ 29 ▲ 10
Avon River	Northam Weir	1980s 1990s	- ▲ 140
Brockman River	Yalliawirra	1980s 1990s	▲ 51 ▲ 22
Helena River	Poison Lease	1980s 1990s	▲ 15 ▼ 19
Moore River	Quinns Ford	1980s 1990s	- ▲ 50[a]

Data source: Mayer, Ruprecht & Bari (2005). Note: Trends are statistically significant at 95% confidence limit except for those denoted (a) which are not statistically significant.

Impacts of salinity at Lake Eganu in the Wheatbelt (Department and Envrironment and Conservation)

Collectively South West waterways discharge about 4700 gigalitres (GL) of water and 7.5 million tonnes of salt each year. Of the total volume discharged about 44% of flow is fresh, 10% is of marginal quality, 21% is brackish and 25% is saline (Mayer, Ruprecht & Bari, 2005). Many waterways have become progressively more salty over time. The salinity of the Avon River in the Wheatbelt, for example, is estimated to be 20–40 times pre-clearing levels (Schofield, Ruprecht & Loh, 1988), and the Blackwood River, which was once fresh, now exports one million tonnes of salt each year (Figure IW1.2; Mayer, Ruprecht & Bari, 2005). Predictions of future trends have shown that, without any remedial action, salinities in five major South West rivers may increase by 15–65% above current levels (National Dryland Salinity Program, 1997).

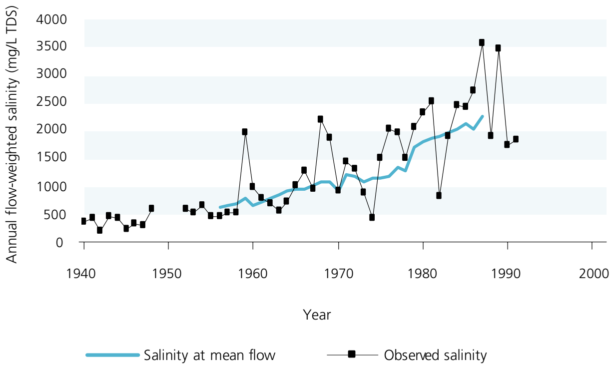


Figure IW1.2: Salinity in the Blackwood River, 1940–2002.

Data source: Mayer, Ruprecht & Bari (2005). Note: mg/L TDS, a measure of salinity, represents milligrams per litre of total dissolved salts; 'flow-weighted' means the data is adjusted for the effects of flow.

Detecting long-term salinity trends in waterways requires dedicated monitoring programs over many years (Table IW1.1). The number of salinity sites being monitored across WA has reduced by about one-third over the past 5 years due to funding constraints. Determining salinity levels in many waterways now relies more on infrequent sampling, which is not suitable for detecting long-term trends. The exceptions are those rivers within water supply catchments and water resource recovery catchments that have monitoring sites continuously measuring salinity levels over time. These are limited and do not reflect the true spatial extent of the problem.

Irrigation salinity is already a problem in some irrigated areas with poorly drained soils and shallow, naturally saline groundwater. About 20% of the southern Swan Coastal Plain, from Gingin to Dunsborough, is considered to be at risk of irrigation salinity (Government of Western Australia, 2000). Salt scalds are already evident in some areas of the Harvey River catchment (Mayer, Ruprecht & Bari, 2005). Irrigation salinity is also a risk in the Ord River Irrigation Area with groundwater salinity levels being elevated in some places. Dewatering bores are now required in some irrigated areas to reduce the risk of a rising saline groundwater table.

Salinisation of Wheatbelt wetlands is less well-documented, but there is enough anecdotal and scientific evidence to indicate it is severe and widespread (Lane & Munro, 1983; Sanders, 1991; Lane et al., 2004). For example, salinity levels in Lake Bryde appear to have increased 10-fold between 1981–94. Many other wetlands that were once fresh enough to support native vegetation prior to salinisation are now salt lakes supporting minimal vegetation (Halse, Pearson & Patrick, 1993). Substantial loss of fringing vegetation and waterbird populations is now evident at Coyrecup, Coomelberrup, Walymouring, Eganu, Dumbleyung and Parkeyerring wetlands (S Halse, Department of Conservation and Land Management, pers. comm.).

Long-term monitoring of wetlands in the conservation estate shows that 12% increased in salinity between 1977–2000 (Lane et al., 2004). Without successful management activity, other valuable wetlands (including Fraser's, Noobijup, Yaalup, Wheatfield and Kulicup wetlands) are expected to become salt affected within 10 years, leading to substantial declines in biodiversity (S Halse, Department of Conservation and Land Management, pers. comm.).

Superficial groundwater salinity is highly variable throughout the State and most is naturally brackish to saline (Figure IW1.3). Pockets of superficial fresh groundwater are found along the Swan Coastal Plain, the South West corner of the State and parts of the Pilbara and Kimberley. Deeper groundwater is less well understood. Groundwater salinity tends to be stable, except where catchment hydrology has been altered or high rates of water extraction occur (see '*Altered water regimes*' and '*Water supply*').

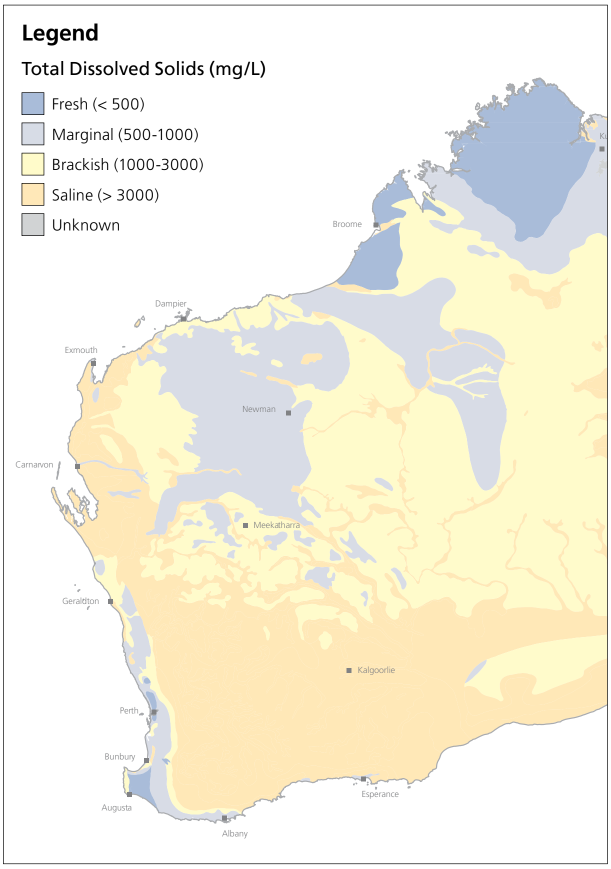


Figure IW1.3: Groundwater salinity of superficial aquifers across Western Australia.

Data source: Department of Water (2000); Presentation: EPA.

Tree death alongside the Williams River caused by rising salinty levels (Department of Environment and Conservation)

Pressures

The extent of salt-affected land has a direct relationship to the extent of inland waters affected by salinity (see '*Land salinisation*'). Historical clearing of perennial native vegetation and increased use of deep drainage are the most long-term and severe pressures for salinisation of inland waters in the South West. For example, 93% of native vegetation has been cleared in the Avon–Wheatbelt bioregion, resulting in a significant land salinisation problem and salinised wetlands and waterways (Department of Environment, 2004a). The increasing extent of land being impacted by salinity will eventually result in more waterways and wetlands becoming impacted.

Analysis of 3000 bore sites in the South West agricultural region showed no significant trend to decreasing salinity, with most showing rising or stable groundwater salinities. Modelling indicates about 16% of land (4.65 million hectares) in this region had shallow watertables in 2000 (Department of Agriculture, 2001). Assuming groundwater trends remain steady, it is projected that 20% (6.37 million hectares) of the region will have shallow water tables by 2020, and 33% (13.66 million hectares) by 2050. These figures were calculated on the basis that watertables were less than 2 m from the soil surface or between 2–5 m and rising.

In contrast, there is recent evidence to suggest that the drying climate in the South West has lowered local groundwater levels in some places. A decrease in winter rainfall and general lack of 'wet winters' is likely to have slowed the rate of salinisation for some wetlands and waterways, especially for central and eastern Wheatbelt areas. Some areas cleared a long time ago appear to be reaching groundwater equilibrium, while the trend of rising groundwater continues in recently cleared areas, such as high rainfall parts of the Wheatbelt and South Coast (Indian Ocean Climate Initiative, 2005b).

Deep drains and associated engineering works are increasingly seen by many farmers as a viable option to manage salinity and enhance productivity on their land. It has been reported that deep drains can lower the watertable up to 500 m from the drain, but this varies considerably depending on soil type and landscape characteristics. Some farm deep drains currently discharge saline water into downstream waterways and wetlands. Recent surveys (Department of Agriculture, 2006) indicate that about 27% of farmers in the South West are using deep drainage. It has been estimated that there are 14 000 kilometres (km) of agricultural drains in the South West agricultural region in 2007, with about 1000 km currently being constructed every year (extrapolated from Dogramaci & Degens, 2003).

The attraction of using deep drainage as a quick fix for agricultural production may have unintended long-term consequences for the environment. Drainage water discharged into natural waterways and wetlands has the potential to severely impact on the health of the receiving ecosystem through addition of water, salt, nutrients, sediment, heavy metals and acidity. The risk of downstream impacts may also be much larger through the cumulative effects of many deep drains. There are widely differing opinions about the efficiency of deep drainage; however, the environmental impacts are real and deep drainage remains subject to environmental harm provisions under the *Environmental Protection Act 1986* and may result in prosecution.

Current responses

State Salinity Strategy: was released in 2000 by the State Salinity Council, whose aim was to reduce and manage salinity in the South West agricultural region. It promoted a partnership-based approach, development of prioritisation tools, improved protection and conservation mechanisms, further research and development, and ways to help the farming community move to more sustainable production systems. In response to the strategy, the State Government formed the Natural Resource Management Council, initiated a prioritisation methodology (known as the Salinity Investment Framework), and promoted a stronger strategic role for natural resource management regional groups in managing salinity.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP) programs: These two Commonwealth programs aim to ensure on-ground environmental improvements occur via a targeted strategic approach at the regional level. Natural resource management groups in the South West, South Coast, Swan, Avon and Northern Agricultural areas have recognised salinisation of inland waters as a threat to natural resources and have projects to manage and protect valued natural assets considered at risk. Irrigation salinity has been recognised by the Rangelands regional group as a threat in the Ord River catchment.

Engineering Evaluation Initiative: is a State Government project to examine a range of engineering options to mitigate land salinisation. These include deep drains, groundwater pumping, diversion and surface water management. It is also investigating options for safe saline water disposal and regional drainage planning. The project is evaluating deep drains at Morawa, Beacon, Pithara, and Dumbleyung.

Wheatbelt Drainage Council: has been recently established to provide policy and assessment advice to the State Government on the most appropriate and accountable approaches to deep drainage planning, implementation and management. The Council is in the process of developing a framework to evaluate deep drainage proposals.

Agriculture extension program: The Department of Agriculture and Food promotes application of best practice by farmers to mitigate and prevent land salinisation. Recent surveys (Department of Agriculture, 2006) indicate that 35% of Wheatbelt farmers undertake regular monitoring of the watertable. The percentage of Wheatbelt farmers managing water on valley floors using surface drains (49%) and deep drains (27%) appears to have increased in 2006. Interestingly, the percentage of farmers using deep drains in higher rainfall parts of the South West more than doubled in 2006 to 27%.

Research: Several organisations are currently undertaking research on the salinisation of inland waterways and wetlands. Murdoch University has recently completed projects that improve understanding of the effects of increased salinisation on inland aquatic systems. Another project is investigating Wheatbelt deep drains and whether they are an effective strategy for alleviating salinised areas of the Wheatbelt. The CSIRO Water for a Healthy Country program is undertaking research on evaluating Wheatbelt drainage and developing models to help assess drainage plans.

Recovery catchment programs (water, biodiversity): These programs focus on the stabilisation and recovery of important natural resource assets already impacted by salinity. In relation to water resources, action is currently being taken in the Collie, Denmark, Warren, Kent and Helena rivers to stabilise and reduce salt levels flowing into dams. Recent analysis indicates that land clearing controls and reforestation in the Collie and Denmark river catchments have halted the increasing trend in salinity (Figures IW1.4

& IW1.5). The Denmark River represents a breakthrough in salinity management because it is the first time in Australia that river salinity levels have been reversed due to planting of trees, community and government actions, and application of engineering solutions (Bari et al., 2004).

In relation to biodiversity, the wetlands of Buntine–Marchagee, Drummond, Lake Bryde, Muir–Unicup and Lake Warden complexes and Lake Toolibin are receiving attention to protect and recover their unique conservation values. An estimated 80% reduction in salt load entering Lake Toolibin has occurred using combined surface water diversion and groundwater pumping, thereby preventing damage to valued flora, fauna and habitat (Wallace, 2002).

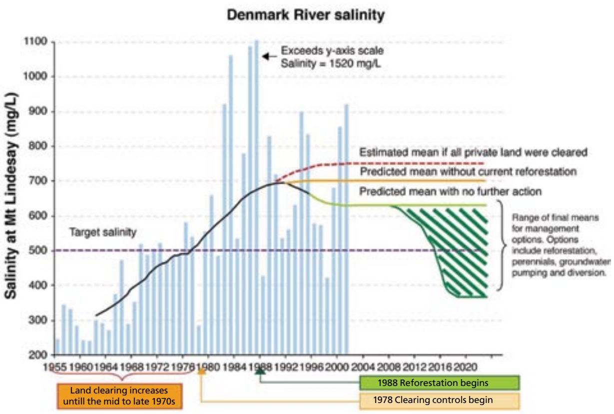


Figure IW1.4: Salinity levels and average trend in the Denmark River since 1955, and projected trends under various management options.

Data source: Bari et al. (2004). Note: Salinity is depicted in milligrams per litre (mg/L).

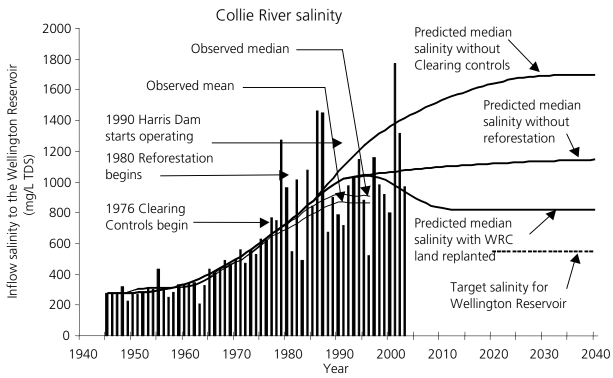


Figure IW1.5: Salinity levels and trend in the Collie River since 1952, and projected trends based on various management options.

Data source: Maugher et al. (2001). Note: Salinity is depicted in milligrams per litre (mg/L).

Implications

Excessive salinisation of inland waters results in a catastrophic collapse of aquatic ecosystems. Not only does waterway and wetland vegetation die because of rising salinity, but habitat is lost and plant and animal populations decline (Cale, Halse & Walker, 2004). Many plant and animal species in salt-affected parts of the Wheatbelt are at risk of extinction. For example, many areas of remnant native vegetation in the Wheatbelt (perhaps 80% on private land and 50% on public land) are at risk of death from rising saline water tables. Estimates suggest that 450 species of vascular plants are at risk of extinction. Salinisation of Wheatbelt wetlands has resulted in a 50% decrease in the number of waterbird species utilising them (Government of Western Australia, 2000). Salinisation exacerbates soil erosion processes leading to filling of river pools and wetlands and, along with altered water regimes, can also lead to an increased risk of flooding. Although flood risk studies are limited in salinised catchments (Bowman & Ruprecht, 2000), there are estimates that a two- to four-fold increase in shallow saline water tables may lead to a doubling in flood flows (George et al., 1999).

Removal of saline water using deep drainage is proving an extremely contentious issue in the Wheatbelt. There is a perceived lack of government direction, consistency and unity on the matter, and this is creating a sense of community frustration and confusion. Further direction and regulation is urgently required for deep drainage. Economic costs are also incurred because infrastructure such as bridge supports, buildings, drains, dams, weirs and pumping equipment is corroded by saline water. Many agricultural towns have been historically built in low-lying parts of catchments or floodplains, and are therefore susceptible to rising saline groundwater tables. The durability of sealed roads may be reduced by up to 75% in areas with rising saline groundwater. More than one-third (36%) of the South West's dams (domestic, agricultural or industrial) have become brackish or saline and a further 16% are of marginal quality (Government of Western Australia, 2000). To compensate for the loss of water supplies, development of additional water storages or extraction must occur, at a significant financial cost to the community.

SUGGESTED RESPONSES

4.5 Develop and implement a strategic policy and governance framework for agricultural deep drainage which fully incorporates environmental principles.

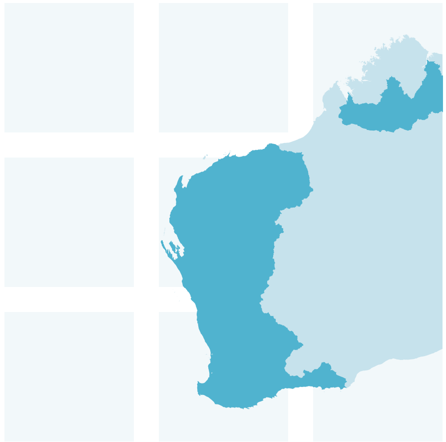
4.6 Develop and implement an evaluation framework to consider deep drainage in the context of integrated solutions where such options are environmentally sound.

4.7 Enhance routine monitoring of waterways and wetlands currently impacted by, and at future risk of, salinisation.

See also '*Land salinisation*':

- Continue to implement the recommendations of the *State Salinity Strategy*, recognising it as a component of the proposed State Soil Protection Policy. Although significant progress has been made, more focus should be given to integrating engineering and plant based solutions to cater for a variety of farm and catchment characteristics, and promoting alternative farming systems in low to moderate rainfall areas.
- Continue the Land Monitor program to provide five-yearly updates of the extent of land salinisation in the South West. Land Monitor remains one of the few tools to accurately measure regional trends in land salinisation and to evaluate the effectiveness of actions.

4.2 ALTERED WATER REGIMES



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 2

KEY FINDINGS

- Regional groundwater tables across the Wheatbelt are generally rising or stable over the long term.
- Water is being over-used at 25% of managed surface water sites and about 10% of managed groundwater sites.
- Management of water resources in the Gnangara Mound is in breach of environmental conditions.
- Dam construction on some waterways has reduced natural flows by up to 95%.
- Many Perth wetlands are drying up through a combination of excessive groundwater extraction and climate change.

Description

Inland waters have unique natural water and flow regimes influenced by climate, surface runoff, catchment size and geomorphology (Boulton & Brock, 1999). In some WA catchments, water regimes have been dramatically altered from their natural state. This has occurred through artificial increase or decrease of water levels, or alteration to the volume, velocity, duration, timing or frequency of flow events.

Many types of human activities influence water regimes within catchments. Widespread changes to vegetation cover and land uses can affect both surface water and groundwater. Direct interference to a waterway, such as the construction of dams and weirs for water storage and flood protection structures (e.g. drains, levee banks, river training) can modify surface water regimes. Extraction of water for domestic, agricultural, mining or industrial reasons (e.g. pumping, irrigation channels) can also have profound impacts on surface and groundwater regimes.

Alteration of natural water regimes is now recognised as a major contributor to loss of biodiversity and functionality of aquatic and terrestrial ecosystems. It can modify the values of inland waters and lead to other land and water problems including floods and drought-like conditions, waterlogging, salinisation, eutrophication, acidification and erosion. The maintenance of biodiversity and productive land and water systems depends on ecosystem services that in turn rely on maintenance of natural water balances and flow regimes. In severe cases, excessive alteration of natural water regimes leads to widespread loss of whole ecosystems and water supplies.

Objectives

In the context of allocating water to users, the *Environmental Water Provisions Policy for Western Australia* (Water and Rivers Commission, 2000b) identified a primary objective for managing natural water balances:

- To provide for the protection of water-dependent ecosystems while allowing for the management of water resources for their sustainable use and development to meet the needs of current and future users.

However, for broader land uses another objective is needed:

- To maintain or restore (where appropriate) natural flow regimes by encouraging sustainable land and water use in catchments.

Condition

Indicator IW5: Status of river basins with altered water regimes.

Major alterations to water regimes for surface water and groundwater are evident across most of the South West (Figure IW2.1). Moderate to major levels of change can be largely attributed to widespread land clearing, damming of major waterways, high levels of water extraction and replacement of perennial native vegetation with low water-using pastures and crops. Some major rivers near populated and agricultural areas (e.g. the Avon, Vasse, Collie and Gascoyne rivers) have had their watercourses significantly altered (i.e. straightening and levee banks constructed) to reduce the risk of flooding. Widespread artificial drainage, both surface and deep, is also evident across developed areas.

Varied water regimes of wetlands and waterways in the rangelands reflect the extreme ranges in the climate, due to episodic rainfall, cyclones, droughts and floods. However, impacts beyond their range of tolerance will result in significant ecological impacts. Most of the rangelands has minor to moderate changes to natural water regimes, which may include flood protection measures, mine dewatering and construction of water reservoirs.

Figure IW2.1: Extent of altered water regimes in Western Australian river basins.

Data source: Derived from Morgan (2001); Analysis: EPA; Presentation: EPA.

Indicator IW6: Trends in groundwater levels.

Demand for water is rapidly growing. Gnangara Mound, a major groundwater formation near Perth, has been under extreme water demand in the last 30 years. Groundwater is managed by government agencies according to specific boundaries or management units. Currently 19% of groundwater management units in this area exceed their allocation limit (see '*Water supply*'). This means in some areas groundwater extraction is exceeding that required to maintain the environment, and the water resource is being mined. Watertable levels on the mound have been declining over the last 20–30 years, falling by up to 6 m near the crest of the mound (Salama et al., 2002; Department of Environment, 2005a). This is considered to be the cumulative result of reduced rainfall, increased groundwater extraction and reduced groundwater recharge by pine plantations. This problem was highlighted in 2000–03 during a period of consecutive low rainfall years where large sudden drops in the water table occurred over most of the mound, placing considerable stress on some cave and lake ecosystems (Figure IW2.2). It been highlighted over several years that environmental conditions relating to environmental water provisions on Gnangara Mound have been breached (Department of Environment, 2005a; EPA, 2007). Due to water extraction, water levels in the deeper Leederville and Yarragadee groundwater aquifers are also declining, with falls in those aquifers ranging from 5–15 m and 5–25 m, respectively (Salama et al., 2002).

Much of WA's coastline has a freshwater superficial aquifer that overlays a thin wedge of saline water that may extend several kilometres inland. Excessive extraction of water from the superficial aquifer may result in a rising saline watertable, rendering water production bores salty and killing native vegetation. This problem is particularly apparent in Carnarvon where close management of groundwater abstraction is required to prevent salt water intruding into horticultural bores and to prevent damage to fringing vegetation along the Gascoyne River.

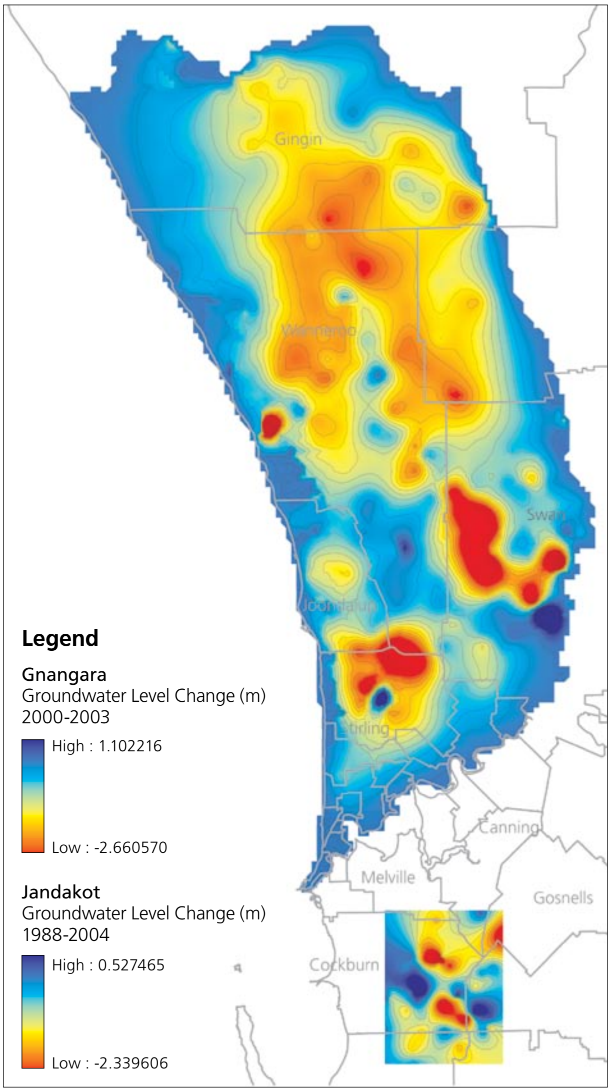


Figure IW2.2: Trends in superficial groundwater levels for Gnangara and Jandakot mounds, 2000–03.

Data source: Department of Environment (2005); Analysis: DoE, EPA; Presentation: EPA.

Superficial groundwater levels across the South West agricultural zone are generally rising and no trends of decreasing groundwater have been detected on a broad scale (Figure IW2.3; Nulsen, 1998; McConnell & Short, 2001; Ghauri, 2004). The rate of rise of groundwater varies from less than 5 cm/yr to 100 cm/yr, with many areas rising at 20–30 cm/year (George, 2002). This rise is caused by historical widespread clearing of native vegetation and replacement with annual crops and pastures, resulting in reduced water uptake (see Land salinisation). However, there are local instances where revegetation of land with perennial shrubs (e.g. tagasaste) and agroforestry has been associated with local groundwater declines of 40 cm/yr to 80 cm/yr, respectively (Nulsen, 2000).

Notwithstanding other shortcomings, artificial deep drainage in the Wheatbelt has also been effective in some areas in reducing rising saline groundwater levels. For example, a 70 km network of drains in Narambeen removes about six megalitres (ML) of excess groundwater per day from the agricultural landscape (equivalent to six Olympic size swimming pools). Disposal of this water has proven very contentious as it often affects natural waterways and wetlands.

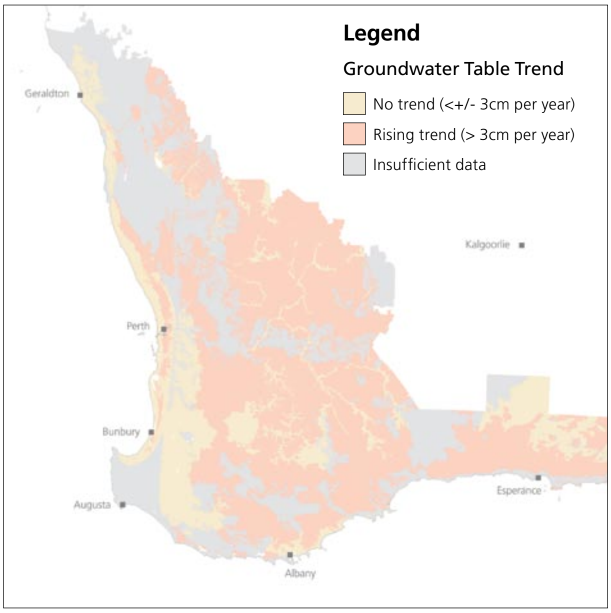


Figure IW2.3: Modelled long-term trends in superficial groundwater levels for the South West agricultural zone.
Data source: Department of Agriculture [ver. 2005]; Presentation: EPA.

Indicator IW7: Trends for water levels in waterways and wetlands.

It is well recognised that dam construction severely modifies natural flow regimes in waterways. For example in the Kimberley, construction of Lake Argyle on the Ord River has turned the river from a seasonal to a permanently flowing waterway, reducing its flows by 20% and severely limiting the frequency and intensity of high flows and flood events (Water and Rivers Commission, 2003). In the South West, damming of the Canning River has captured about 95% of its flow, turning downstream reaches into a trickling stream (Australian Academy of Technological Sciences and Engineering, 2002). In the Pilbara, damming of the Harding River has captured 80% of its flow and severely modified downstream ecology (Water and Rivers Commission, 2004).

Trends in waterway and wetland water levels are often reflected in trends in catchment groundwater levels. For example, there is anecdotal evidence that many wetlands in the Perth metropolitan area are starting to dry up, including Lake Jualbup, Perry Lakes, Lake Gnangara and Jandabup Lakes, amongst others. This may be the result of a combination of factors including increased superficial groundwater use (from bores) and the effects of climate change.

Some smaller estuaries, such as the Margaret River estuary, are slowly diminishing due to climate change and increasing extraction of groundwater for a growing population and the vineyard industry (Brearley, 2005). Other long-term changes, including a 50% reduction in volume being discharged by some South West waterways, have been linked to climate change (Indian Ocean Climate Initiative, 2005a; Water Corporation, 2005).

In other inland areas, there are estimates that a two to four-fold increase in the area of shallow water tables in the Wheatbelt (caused by widespread land clearing) will lead to at least a two-fold increase in waterway flood flows (George et al., 1999). Long-term monitoring of forty-one wetlands in the South West conservation estate has shown that 29% have increased in depth between 1977 and 2000 and 2% showed a fall in depth (Lane et al., 2004). Excessive amounts of water in wetlands can be just as detrimental as not enough water to ecological systems, through drowning wetland associated vegetation.

Pressures

Widespread land clearing (see '*Loss or degradation of native vegetation*') and replacement of native vegetation with impervious surfaces associated with buildings and roads can increase water runoff and reduce recharge to groundwater. Where land is cleared and not adequately drained, excess water may build up and contribute to a rising watertable. Similarly, replacement of native vegetation with agricultural crops and pastures that use less water leads to a gradual rise in groundwater levels. Use of drainage channels to prevent build-up of groundwater also modifies receiving waterways and wetlands by increasing or prolonging flows. Therefore, altered water regimes will occur if changes to catchment water balances happen at faster or slower rates than would occur naturally.

Climate change may also be having an effect on natural water regimes. For example, a 10–15% drop in South West rainfall since the 1970s has produced a corresponding 50% reduction in average annual flows in some South West rivers and streams (Indian Ocean Climate Initiative, 2005a). Anecdotal evidence over recent decades suggests that some of Perth's lake systems are being converted to swampy flats. Some wetlands associated with climate-sensitive groundwater systems have also experienced more frequent dry states. In drier parts of the north-eastern Wheatbelt, groundwater levels have declined in upper to mid-slope areas as a result of reduced rainfall. Groundwater levels in the central and eastern Wheatbelt are not rising as quickly as they initially did in response to widespread clearing, and in some areas with shallow watertables (less than 8 m) levels are stable or declining (Indian Ocean Climate Initiative, 2005b).

Indicator IW8: Percentage of river basins that are regulated by at least one major dam.

River systems that have water storages are known as 'regulated rivers'. Major storage structures (including dams, weirs and pipeheads) provide water primarily for urban, industrial and agricultural use. Water supply dams, while benefiting humans, impact waterway and floodplain ecology by affecting natural flows and the volume of water reaching downstream areas. Environmental water provisions (water allocated back to the environment from dams) can be made to reduce the environmental impact of river regulation.

In 2005 the State had 48 major storage dams, with most situated in the South West (Figure IW2.4). Some major river systems are under significant pressure, with multiple dams contributing to major alteration of natural water balances and flow regimes. These include the Canning (six major dams), Murray (five), Harvey (six), Collie (four), and Blackwood (nine) rivers, and Lake Argyle on the Ord River, which is Australia's second largest reservoir. With the Harvey and Ord rivers as exceptions, most rivers do not have environmental water provisions determined. It is estimated there are several thousand smaller dams and weirs constructed on both regulated and unregulated rivers by local authorities, government agencies and individuals. In these cases the effects of altered water regimes may be relatively minor, but cumulatively the environmental impacts become significant.

Canning Dam has captured about 95% of the rivers flowing water, resulting in significant downstream ecological impacts (D.Tracey)

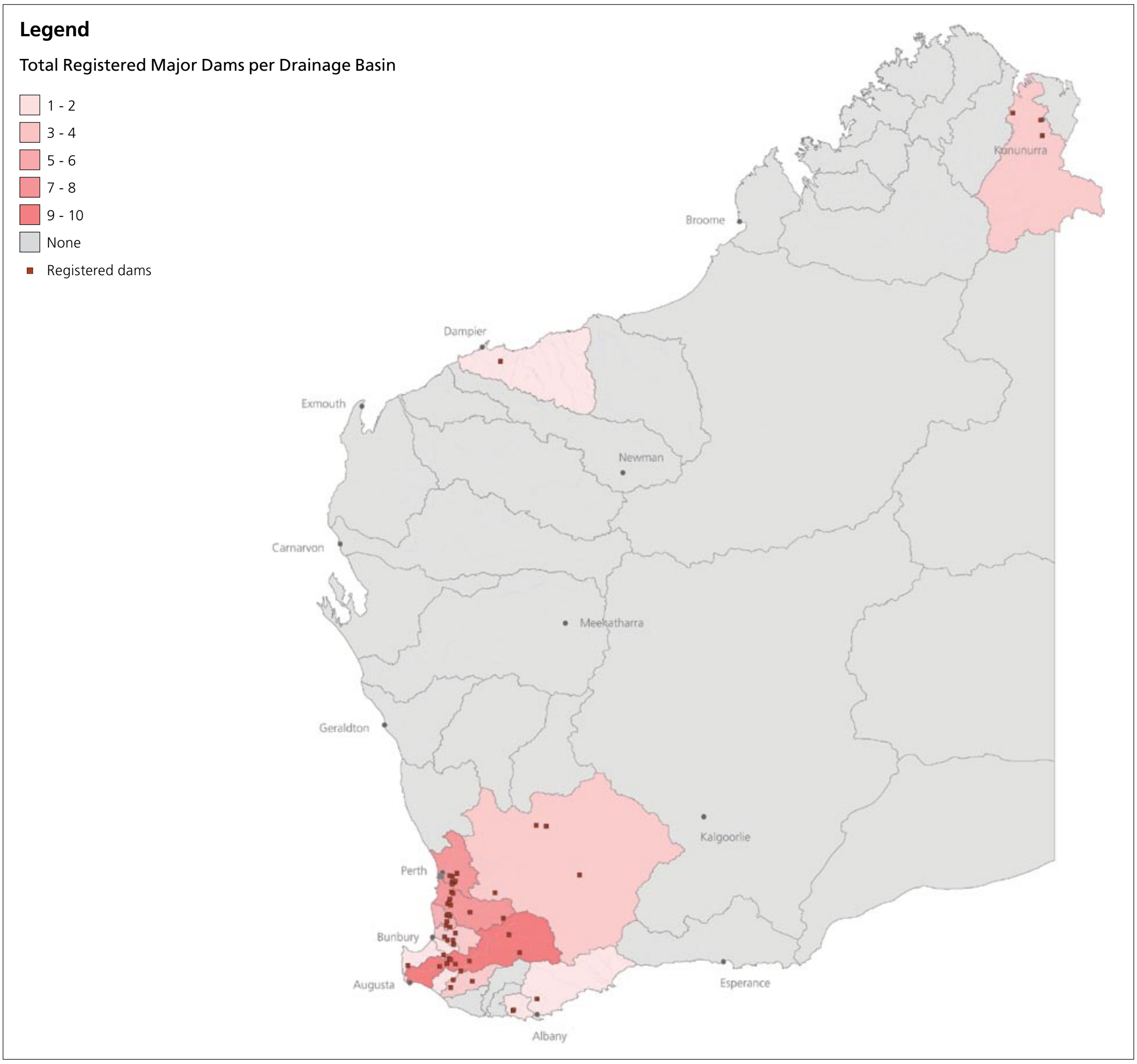


Figure IW2.4: Number of registered major dams by drainage basin.

Data source: Water Corporation [ver. 2001], Department of Environment–Drainage Basins[ver. 2002]; Analysis: EPA; Presentation: EPA.

Indicator IW9: Percentage of waterways and groundwater areas subject to water extraction at, or exceeding, sustainable yields.

If water allocations are not managed properly, water extraction from the environment can begin to exceed sustainable yields (i.e. the amount of water that can be taken without damaging the environment in the long term; see '*Water supply*'). At this point ecological systems begin to be impacted. In 1997, 36% of river basins had at least one management unit exceeding the sustainable yield and 25% of surface water management units (i.e. monitoring sites) were over-allocated (Table IW2.1). This information is now ten years old and requires urgent updating. As of 2006, about one-third of groundwater management areas are approaching or exceeding their allocation limit. Overall the number of management units that are over-allocated is relatively small (11%) (Table IW2.2). In many places, unregulated water extraction and inadequate monitoring, has made it extremely difficult to accurately calculate sustainable yields and effectively manage water resources.

Table IW2.1: Per cent of river basins that contain at least one management unit at, or exceeding, its sustainable yield, as of 1997.

Year	Per cent of river basins with at least one management unit at, or exceeding, sustainable yield	Per cent of surface water resource management units at, or exceeding, sustainable yield
1997	36% (16/44)	25% (75/304)

Data source: Department of Water.

Table IW2.2: Per cent of groundwater management areas that contain at least one over-allocated unit, as of 2006.

Year	Per cent of groundwater areas approaching or exceeding their allocation limit	Per cent of groundwater areas exceeding their allocation limit	Per cent of groundwater management units approaching or exceeding their allocation limit	Per cent of groundwater management units exceeding their allocation limit
2006	32% (12/38)	13% (5/38)	31% (216/700)	11% (74/700)

Data source: Department of Water. Note: Groundwater management areas and units only include sedimentary water resources. Fractured rock water resources have not been included. Allocations set aside for future town supplies have been included.

Indicator IW10: Kilometres of artificial drainage channel per basin.

Surface drainage in urban areas provides flood protection but also modifies natural water regimes in catchments. In urbanised areas the excessive use of drains has contributed to mass depletion of water from landscapes and prevented wetland and groundwater recharge, even during high rainfall. Some wetlands are being drowned by excess water from drains and some groundwater aquifers are not being adequately recharged. Drains also rapidly transport nutrients and other pollutants from the catchment to waterways and wetlands, with little opportunity for filtering by natural ecosystems. It has been estimated that in the Perth metropolitan area alone, there are approximately 830 km of drains managed by the Water Corporation and 3000 km managed by local governments (together, about the distance from Perth to Brisbane).

Surface and deep drainage are used in agricultural areas to intercept runoff and lower water tables, thereby improving soil productivity and enabling flood protection. However, increased drainage has severely altered water regimes in receiving waterways and wetlands. It is estimated there are 13 000 km of agricultural drains in the South West agricultural zone (four-times the distance from Perth to Sydney), with an estimated 1000 km being constructed every year (extrapolated from Dogramaci & Degens, 2003). Many farmers are increasingly seeing deep drains as a viable option to remove excess groundwater from agricultural land, but without any treatment of the water or assessment of environmental impacts. Consequently, there is a tension between the farming community and regulatory authorities, due mainly to a lack of understanding about the environmental risks and impacts of drainage water disposal options.

Current responses

National Water Initiative: In 2006, WA became a signatory to a bilateral agreement with the Commonwealth government which aims to increase the productivity and efficiency of water use, enhanced service to rural and urban communities, and to protect the health of surface and groundwater systems by ensuring sustainable levels of extraction. A draft implementation plan has been released (Department of Water, 2007).

State Water Plan: was recently released and outlines the policy direction for the sustainable management of water resources, including the development of regional water plans, strategic water issue plans and statutory water management plans (Government of Western Australia, 2007). The plan will also integrate components of the Water Reform program, which aims to reform water entitlements and create a viable water trading system.

Environmental water requirements (EWRs): are water regimes considered necessary to maintain ecological health and protect environmental values, based on risk assessment and best available scientific information. The Department of Water takes the lead in establishing EWRs, although other research organisations and academic institutions are involved in determining EWRs for inland waters.

Environmental water provisions (EWPs): are water regimes provided as a result of the water allocation process in consideration of ecological, social and economic impacts. They may meet the environmental water requirements in part or in full. The Water and Rivers Commission developed a policy in 2000 which is currently being reviewed by the Department of Water. A significant proportion of heavily allocated water resources have not had environmental water provisions determined yet (Table IW2.3).

Table IW2.3: Per cent of heavily allocated (high water use) managed sites that have environmental water provisions (EWPs), as of 2006.

	Managed surface water sites	Managed groundwater sites
Proportion of heavily allocated systems with EWPs in place	12% (2/16)	21% (8/39)

Data source: Department of Water.

Water for Healthy Country Flagship: is an Australia-wide science partnership established by CSIRO which aims to provide information and management opportunities to improve the environmental, social and economic benefits from water resources. A number of research projects are being undertaken in the South West.

Groundwater investigation program: The Department of Water assesses and reviews the State's groundwater resources to ensure sustainable management of aquifer systems and dependent ecosystems. There are approximately 3000 monitoring bores distributed throughout the State.

Stormwater management: has evolved in recent years on the principle that stormwater is a resource providing social, environmental and economic opportunities. *A Stormwater Management Manual for Western Australia* builds on the traditional flood protection approach through the inclusion of water quality management, the protection of ecosystems and providing liveable and attractive communities.

Fishways: (more commonly known as 'fish ladders') are structures built in a stream to allow fish to move around barriers that impede normal flow regimes, such as dams, culverts and weirs. Fishways have been constructed in the Margaret, Hotham and Goodga rivers and Bennet Brook, with a project also underway on Lake Kununurra Diversion Dam to enable passage of barramundi upstream.

Implications

Modified water and flow regimes can have significant social, economic and environmental impacts. Too much water can result in flooding of ecosystems, infrastructure and communities, and damage productive land. It can also result in the waterlogging and drowning of native vegetation, salinisation, loss of soil health, loss of fauna habitat and a favouring of opportunistic weed species. Too little water results in drought-like conditions, often leading to loss of inland waters, degraded ecosystems, limited habitat, acidification and eutrophication problems, and widespread death where species are unable to adapt to modified conditions. Reduced water availability also limits provision for human consumption, agricultural purposes and recreation. Changes to the timing, duration and frequency of natural flows can be just as harmful, affecting biodiversity by altering natural migration and reproduction patterns of flora and fauna. It is now recognised that adequate water provision to the environment is critical for maintaining ecological functionality of inland waters and neighbouring environments.

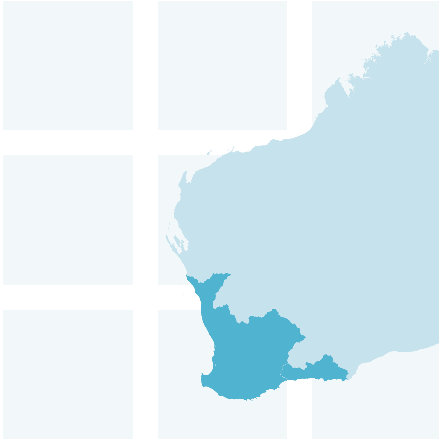
SUGGESTED RESPONSES

4.8 Develop and implement statutory water management plans for priority areas and stressed ecosystems, with accompanying allocation plans and environmental water provisions.

4.9 Develop drainage governance arrangements for urban and rural areas.

Fishways are vital for maintaining native fish populations in waterways with barriers, such as dams and weirs (S.Janicke)

LOSS OR DEGRADATION OF WETLANDS



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 2

KEY FINDINGS

- Wetland vegetation on the Swan Coastal Plain is being lost or degraded at the rate equivalent of two football ovals per day.
- About 6% of wetlands of high conservation value on the Swan Coastal Plain were lost or degraded between 1996 and 2004.
- Twenty six per cent of important South West wetlands are degrading.

Description

In WA the term 'wetland' is commonly used to refer to a standing water body or inundated land, and 'waterway' is commonly used to describe a water body flowing in a channel. Wetlands may include lakes, swamps, damplands, sumplands, springs, soaks, karst caves and waterholes. International and national definitions of wetlands are much broader and include waterways and near-shore marine areas (see text box). While the exact number of wetlands is not known, there are thousands of wetlands in WA and they range from permanent, to seasonal or intermittently inundated systems.

Wetlands are widely recognised as important wildlife habitats and as being the most biologically productive and diverse ecosystems. They directly and indirectly provide a broad range of ecosystem services, and support of a wide variety of flora and fauna. Some wetlands are of international significance, particularly as habitat for migratory bird species. Wetlands serve to purify water by removing suspended matter, biologically processing contaminants and removing plant growth nutrients. They also provide flood control by storing and retaining stormwater and runoff. Many wetlands also provide considerable enjoyment for the people of WA through recreation, tourism, landscape amenity, and for cultural and historical reasons.

In the past little regard has been given to the value of wetlands, with many people viewing these water bodies as swamps (and refuges for disease) best converted into land suitable for farming, housing or roads. This perception is now changing and wetlands are becoming more valued by the community. Despite this, wetlands in WA continue to be lost (from impacts such as filling, draining and land development) or severely degraded (though impacts such as land clearing, excessive fire, grazing, altered water regimes, salinisation and acidification).

DEFINING WETLANDS

The Ramsar Convention on Wetlands of International Importance (held in Iran in 1971), to which Australia and 99 other nations are signatories, defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres'. The *State Wetland Conservation Policy* (Government of Western Australia, 1997) accepts this definition, but separates the conservation and management of WA's rivers, estuaries and shallow marine areas due to special attributes and values of those environments. This State of the Environment Report also reflects the State policy direction, separating marine waters and flowing waterways from the above wetland definition.

Objectives

The *Wetlands Conservation Policy for Western Australia* (Government of Western Australia, 1997) outlines objectives relevant to the conservation of wetlands. Specifically:

- To prevent the further loss or degradation of valuable wetlands and wetland types, and promote wetland conservation, restoration and creation (in some instances);
- To greatly increase community awareness and appreciation of the many values of wetlands and the importance of sound management of wetlands and their catchments in the maintenance of those values.

Condition

Indicator IW11: Extent and rate of wetland loss.

Very little information is currently available about the spatial extent of WA wetlands and even less on their condition. No systematic survey of wetlands or wetland values across the State has yet been conducted, although a number of coordinated wetland mapping and classification projects have been undertaken or are underway. The State's largest and most prominent wetlands (usually large lakes) are well documented. Western Australian wetlands listed for recognition under the *Convention of Wetlands 1971* (also known as the Ramsar Convention) include the Ord River floodplain; lakes Argyle, Kununurra, Forrestdale, Thomsons, Gore and Toolibin; the Peel–Yalgorup, Vasse–Wonnerup, Lake Warden and Muir–Byenup systems; and the Becher Point wetlands. Other important wetlands (including waterways and near shore marine areas) that are nationally important have been documented in *A Directory of Important Wetlands, Third Edition* (Environment Australia, 2001).

Most available information pertains to wetlands on the Swan Coastal Plain, which is defined as the coastal strip of land west of the Darling Scarp, north of Dunsborough and south of Jurien. This is the most populated region in WA and is under significant urban development and growth pressures. Although difficult to ascertain, previous estimates indicate that 70–80% of original wetlands on the plain have been cleared, drained or filled since European settlement (Balla, 1994), although with continued wetland losses this figure is likely to be much higher. The ecological function of many remaining wetlands has been so significantly altered that they now bear little resemblance to their original state (Environmental Protection Authority, 2004). In 2004 approximately 36% of the Swan Coastal Plain was wetlands, by area. Of the remaining wetlands, about 17% have high conservation significance and only 14% are protected through formal statutory policies such as environmental protection policies (Figure IW3.1).

A review of the *Swan Coastal Plain Wetlands Environmental Protection Policy* indicates that many valuable wetlands are still in decline. Between 1996 and 2004, Land Monitor showed that 4% of vegetation in remaining wetlands was lost or became severely degraded (Figure IW3.2). This represents an approximate rate of loss of 1500 ha (equivalent to about 750 football ovals) of wetland area each year. About 6% of wetlands lost or degraded during this time were of high conservation significance (Figure IW3.2, Table IW3.1).

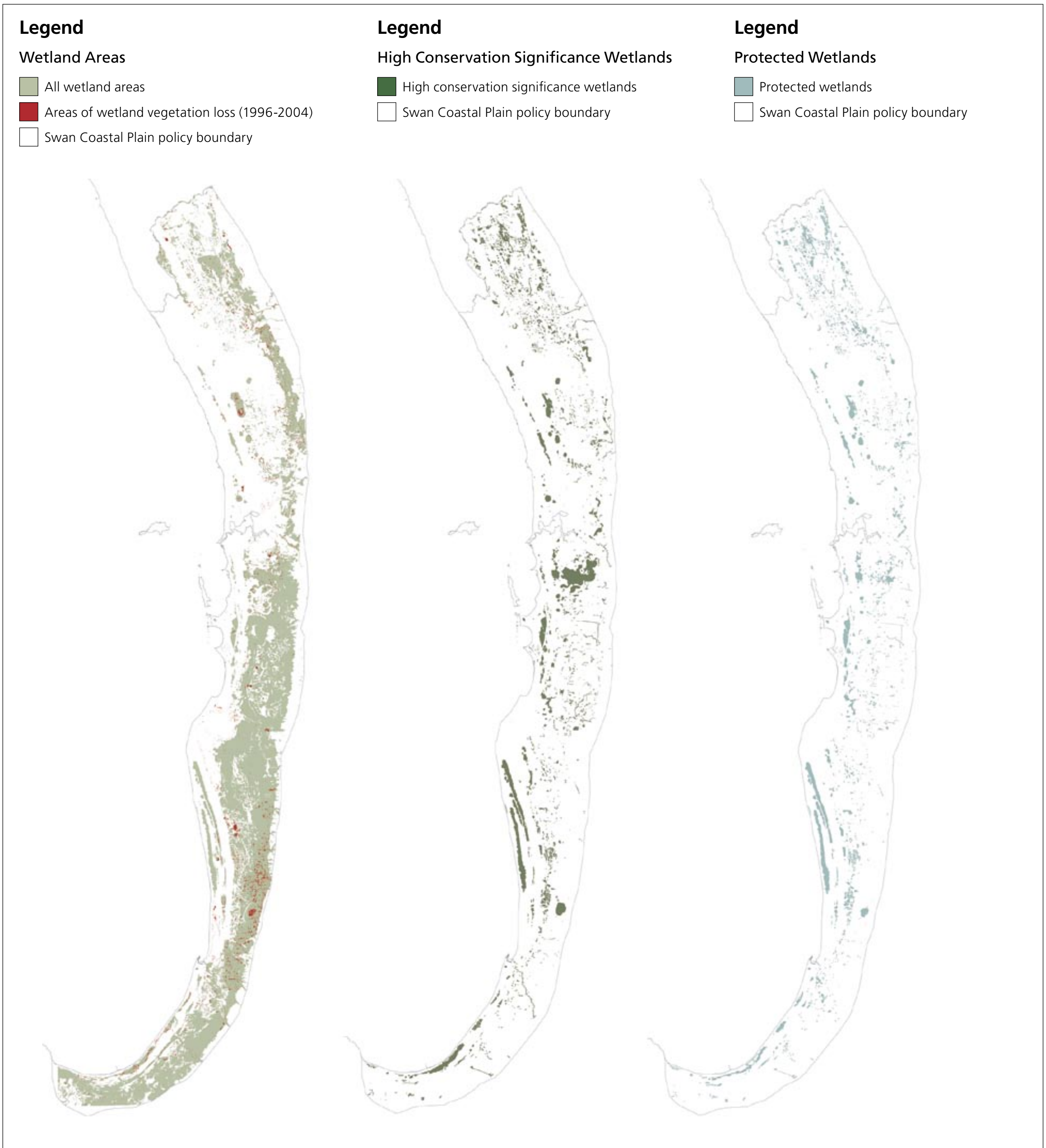


Figure IW3.1: Wetlands on the Swan Coastal Plain, with subsets of high conservation significance wetlands and those protected by formal State Government policy.

Data source: Department of Environment – geomorphic wetlands [ver. 2005], Department of Environment and Heritage – Ramsar wetlands [ver. 2002] & Directory of Important Wetlands [ver. 2001], EPA – Lakes EPP; Analysis: EPA; Presentation: EPA.

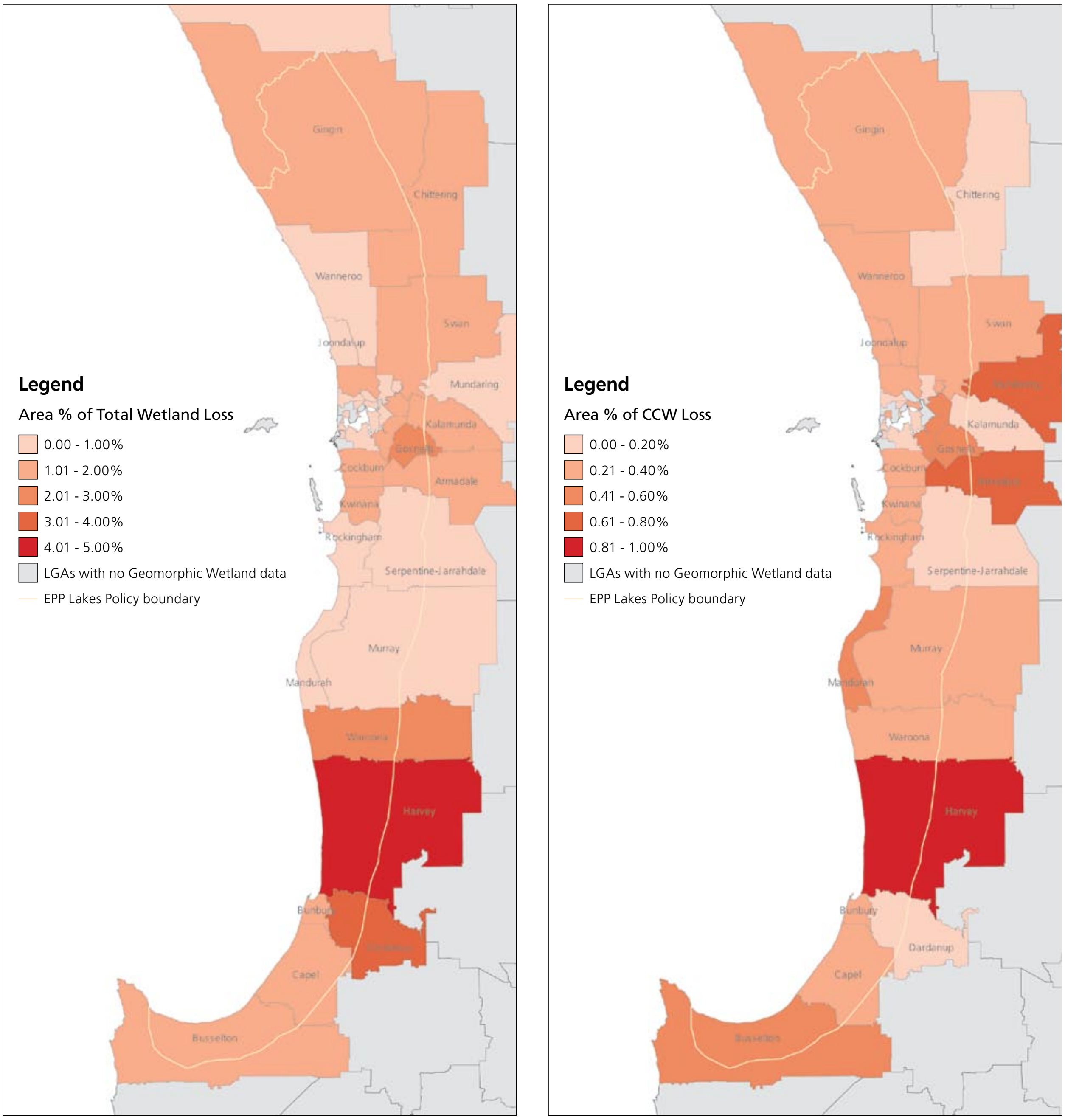


Figure IW3.2: Percentage of wetland loss or degradation, by total and conservation category wetland (CCW), on the Swan Coastal Plain by local government area, 1996–2004.

Data source: Department of Environment – geomorphic wetlands [ver. 2005], Department of Land Information – LandMonitor [ver. 2004] EPA–EPP Lakes Policy [ver. 1992]; Analysis: EPA; Presentation: EPA.

Table IW3.1: Loss or degradation of vegetation in Swan Coastal Plain wetlands, 1996–2004.

	Loss or degradation from 1996–2004		Rate of loss or degradation per year	
Wetland category	Area (ha)	Per cent of wetland type	Annual loss (ha/yr)	Equivalent in football ovals / yr
High condition (conservation significance)	2217	6%	277	139
Moderate condition	1245	6%	156	78
Low condition	8649	4%	1081	541
Unknown condition	32	6%	4	2
Total	12 143	4%	1518	759

Data source: Department of Environment – geomorphic wetlands [ver. 2005], Department of Land Information – LandMonitor [ver. 2004]; Analysis: Environmental Protection Authority.

Many wetlands of South West WA have been extensively cleared, especially in the Wheatbelt, and those remaining are under significant pressure. Limited but intensive monitoring of 25 regionally important wetlands indicates that 26% are deteriorating, with rapidly declining biodiversity (Cale, Halse & Walker, 2004). Long-term monitoring of about 40 wetlands in the conservation estate shows 12% were impacted by rising salinity between 1977 and 2000 (Lane et al., 2004). Other wetlands outside the conservation estate are likely to be significantly more degraded by dryland salinisation. Given that over 90% of land in the Avon River catchment has been cleared, many remaining Wheatbelt wetlands do not reflect their pre-European settlement condition.

Very little is known about wetlands in the rangelands and the arid interior. Further research is required to determine their condition.

Pressures

Wetlands on the Swan and Scott coastal plains of South West WA are being lost or degraded at an alarming rate by altered catchment water balances, drainage, development, salinity, acidity, pollutant discharge, dieback, weed encroachment and insensitive fire management. Climate change is also an ominous threat for remaining wetlands, particularly in the South West, where a drying climate is expected. The most extensive impacts have occurred in urban areas where wetlands have been excluded from conservation by poor town planning, excessive clearing has been allowed, or there has been inadequate buffer distances, poor drainage planning or stormwater management. Remaining wetlands in major urban and regional centres undergoing growth are facing significant developmental pressures due to increasing land values and the need to enhance supporting infrastructure (e.g. roads, railways, pipelines). Many wetlands are also being lost or degraded because landowners are generally unaware that wetlands include seasonally waterlogged and inundated areas as well as water bodies permanently filled with water. For example, a World Wildlife Fund (WWF) study of metropolitan Perth landholders with conservation category wetlands on their property reported that 70% of landholders were unaware of the presence of a wetland, let alone a conservation category wetland, on their property (C Mykytiuk, WWF, pers. comm.).

Wetlands are also being degraded through poor water quality and loss of vegetation (see '*Loss or degradation of native vegetation*'). Widespread catchment clearing and subsequent altered water regimes can pose an inundation threat to wetlands (see '*Altered water regimes*'). Over-abstraction and excessive drainage of groundwater may also lead to some wetlands drying out and becoming subject to acidification (see '*Acidification of inland waters*'). Excessive erosion of soils and leaching of nutrients from household gardens and agricultural land may lead to sedimentation and eutrophication in wetlands (see '*Eutrophication*' and '*Erosion and sedimentation*'). Livestock that access wetland areas can damage vegetation, soil and water quality, leading to enhanced erosion and sedimentation problems (see '*Loss of fringing and instream vegetation*'). Saline and acidic waters are also entering and degrading many Wheatbelt wetlands (see '*Acidification of inland waters*', '*Salinisation of inland waters*'). Contamination and fires are also impacting some wetlands (see '*Land contamination*' and '*Altered fire regimes*').

Current responses

Environmental protection policies: Two environmental protection policies (EPPs) have been developed by the EPA to protect wetlands in WA. *A South West Agricultural Zone Wetlands EPP* was established in 1998 to protect and enable rehabilitation of Wheatbelt wetlands. Placement of wetlands on the register is voluntary and so far only two wetlands are listed as protected wetlands under this policy. The *Swan Coastal Plain Lakes EPP* was established in 1992 to protect several hundred lakes. It was recently revised by the EPA with the option of extending protection to other wetland types, however the State Government decided not to implement a revised version of the EPP.

Planning policy: *A Water Resources Statement of Planning Policy* (Western Australian Planning Commission, 2006a) has been developed by the Western Australian Planning Commission to assist with the management and protection of wetlands (and other waterways) in the land use planning system. An accompanying draft *Guideline for the Determination of Wetland Buffer Requirements* (Western Australian Planning Commission, 2005) has also been released to provide advice on minimising planning and development impacts on wetlands.

Vegetation clearing regulations: In 2003 amendments were made to the *Environmental Protection Act 1986* to provide for regulations that afford increased protection for native vegetation, including that associated with wetlands.

Wetlands conservation policy: was established in 1997 with a statement of policy outlining key objectives including prevention of further loss or degradation of valuable wetlands, and promoting wetland conservation, creation and restoration (Government of Western Australia, 1997). The Wetlands Coordinating Committee was formed to oversee the policy's implementation and is currently reviewing and finalising an updated version of the policy.

Wetland protection and conservation: The Department of Environment and Conservation has a lead role in protecting and managing wetlands, including most of WA's nationally and internationally important wetlands. The Department has a lead role in the development of a framework to outline a statewide process for the mapping, classification and evaluation of wetlands. A wetland restoration and management manual is being developed to provide an understanding of how wetlands function, causes and effects of degrading processes, restoration and management techniques, and planning and legal aspects. Programs affiliated with other organisations such as Landcare, Wetland Watch or Land for Wildlife also enhance the conservation and management of wetlands through private land and pastoral lease agreements.

Wetlands education and incentives: Technical and financial support for wetland protection is available to farmers and private landholders through programs funded by the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality, the Department of Environment and Conservation's Healthy Wetland Habitats program and WWF's Wetland Watch program. Centres dedicated to wetland conservation have been established in Cockburn (Bibra Lake), Melville (Piney Lakes) and Capel. These aim to promote wetland values, conservation and sustainable ecosystem management through education and public awareness. A collaboration between universities and the State Government has resulted in the WA Wetlands Database which provides cumulative information about WA wetlands.

This conservation category wetland near Rockingham has been permanently damaged by land developers (J.Higbid)

Management groups: Traditional owners have Native Title representative bodies that help facilitate an important cultural and legal bridge between traditional obligations to look after wetlands and contemporary management. Regional natural resource management groups are also working to map, restore, rehabilitate and prevent further degradation of wetlands. Currently, the Swan, Northern Agricultural and South Coast regional groups are undertaking wetland mapping projects.

Implications

Loss of wetlands can reduce the capacity of the land to mitigate floodwaters or stormwaters, by acting as water storage points in the landscape and reducing the speed at which water moves across the land. When wetlands are cleared and filled for development, this may contribute to rising water tables and early onset of flooding, waterlogging and salinisation in susceptible areas, requiring construction of extensive and costly drainage networks in an attempt to remove excess water from the landscape. Wetlands are highly productive ecosystems providing a range of important ecosystem services. Though wetlands are most often associated with waterbirds, they provide essential habitat for a wide variety of species of birds, mammals, reptiles, amphibians, fish and insects, and are especially important as drought refuges in summer. With the current extent of wetland loss in some parts of WA, many remaining wetland flora and fauna are now rare, threatened or endangered. Loss of wetlands also removes the opportunity for enjoyment of their natural beauty, recreational and tourism opportunities, and cultural and spiritual values.

SUGGESTED RESPONSES

4.10 Develop and implement a strategy that protects Swan Coastal Plain wetlands using a combination of incentives and existing conservation and regulatory protection mechanisms.

4.11 Review the *Environmental Protection (South West Agricultural Zone Wetlands) Policy.*

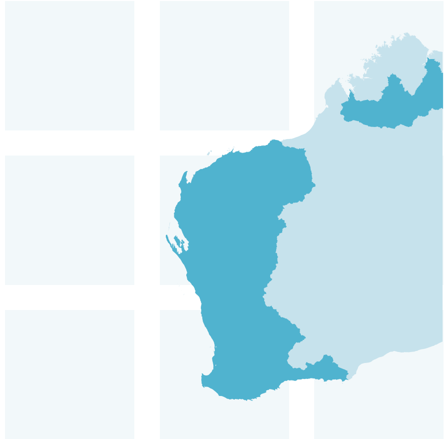
4.12 Finalise and implement the revised *Wetland Conservation Policy for Western Australia.*

4.13 Implement the *Water Resource Statement of Planning Policy* and finalise the draft *Guideline for the Determination of Wetland Buffer Requirements.*

See also '*Loss or degradation of native vegetation*'.

- Prohibit clearing in local government areas with less than 15% native vegetation remaining and prohibit further clearing of vegetation types that have less than 10% of their pre-European extent.
- Develop and implement a policy of 'no net loss' of native vegetation due to land use that comprehensively considers biodiversity values in clearing applications.
- Establish a central database to make information on all clearing activities (including environmental impact assessment) publicly available.
- Carefully monitor for illegal clearing and breaches of conditions set under the *Environmental Protection Act 1986* and take appropriate action should they occur.

4.4 LOSS OR DEGRADATION OF FRINGING AND INSTREAM VEGETATION



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 2

KEY FINDINGS

- Widespread loss or degradation of fringing vegetation occurred along many major rivers from Bunbury to Geraldton between 1996 and 2004.
- About 45–50% of farmers and 35% of pastoralists protect fringing vegetation from livestock grazing.
- There is a critical lack of monitoring of instream and fringing vegetation.
- Rehabilitation efforts are leading to a recovery of seagrass meadows in Oyster Harbour.

Description

Fringing vegetation is the vegetation that grows alongside a waterway or wetland. This issue relates to waterways, as wetland associated vegetation is covered elsewhere (see '*Loss or degradation of wetlands*'). Fringing vegetation has adapted to inundation or waterlogged conditions, has an important role in the ecology of waterways, and provides a vegetated linkage between aquatic and terrestrial ecosystems. It provides habitat for both aquatic and terrestrial fauna and provides wildlife corridors, so is essential to biodiversity conservation. Overhanging vegetation regulates light availability and temperature in the water body, preventing weed growth and algal blooms. Fringing vegetation also intercepts and filters nutrients, pollutants and sediments leaving the catchment and helps to stabilise embankments from erosion. Instream vegetation consists of aquatic plants within a waterway or wetland. It helps to stabilise streambeds, recycle nutrients in the water column and serves as food and habitat for aquatic organisms.

Historically there has been little value placed on retention of fringing and instream vegetation. In many populated areas, fringing vegetation along estuaries, rivers and wetlands has been removed to provide water views for residential development and to enhance land values. In some agricultural areas, fringing vegetation has been removed to enable farming of productive floodplain soils. Similarly, instream vegetation has been removed during dredging activities to allow boat navigation. In some waterways, nutrient and sediment pollution has contributed to significant degradation of seagrass communities.

Objectives

- To prevent the further loss or degradation of fringing and instream vegetation of valuable waterways and wetlands.
- To restore fringing and instream vegetation in inland waters where associated impacts (from loss or degradation of vegetation) have not stabilised.

Condition

Indicator IW12: Extent of inland waters with intact fringing vegetation (50 m buffer).

Information about changes in fringing vegetation remains extremely limited and has not been comprehensively updated since the *1998 State of the Environment Report*. While foreshore surveys of fringing vegetation are occasionally undertaken for waterways in the South West, the information has not been centrally collated. In contrast, foreshore assessments in the rangelands is extremely difficult given the difficult terrain, vast size of some catchments and limited accessibility. Aerial surveys and satellite imagery are sometimes used for these reasons.

Satellite imagery shows fringing vegetation of waterways is still being lost or degraded throughout the South West. Net declines in fringing vegetation are apparent in many coastal catchments between Bunbury and Geraldton, due to land development, drought and rural activities (Figure IW4.1). Declines in fringing vegetation for the Blackwood and Moore rivers and southern reaches of the Avon River are likely to be due to the effects of salinisation. Net gains in fringing vegetation are apparent for some waterways near Perth, Mandurah, Collie and Albany, and may be due to increased weed abundance or revegetation rehabilitation and restoration efforts. Further ground truthing and frequent foreshore assessments are required to verify these findings.

Foreshore condition of Mid West rivers are generally poor. For example, 50% of the sites on the Greenough, Chapman and Hutt rivers have lost more than half their native vegetation, with minimal understorey and a dominant weed presence. Specifically, about 34% of foreshore on the Hutt River was in a good or very good condition (Department of Environment, 2005b). Foreshore assessments have also shown that tributaries of the lower Avon River, such as the Brockman, Mortlock, Toodyay and Mackie rivers are in a generally degraded condition due to previous and current farming activities.

Surveys on the Swan–Canning Estuary and its major tributaries indicate minimal retention of native vegetation and a significant weed presence, with the exception of the upper reaches of the Helena and Canning rivers which remain largely forested. Most of the estuary foreshore has been found to have more than 70% weed cover, indicating a substantial shift of fringing vegetation from its natural state (Swan River Trust, 2006). Surveys of river foreshores in the Oyster Harbour catchment near Albany, found 81% to be in a degraded condition that were erosion prone or weed infested, with about 55% of foreshores fenced (Water and Rivers Commission, 1997a). In the upper reaches of the Kent River catchment, 92% of surveyed foreshore area was in a similar degraded condition, with about 67% of foreshores fenced (Kent River LCDC and Water and Rivers Commission, 1998).

Indicator IW13: Extent of inland waters with loss of instream vegetation.

Current monitoring of instream vegetation is limited to a few South West estuaries. Seagrass and macroalgal species and distribution have been periodically well researched in the Swan–Canning and Peel–Harvey estuaries, Princess Royal and Oyster harbours, and Wilson and Leschenault inlets (Brearley, 2005). Instream vegetation in rivers and wetlands is generally not monitored and it is therefore not possible to report on condition or changes over time. For estuaries it is generally understood that once seagrasses have been lost or disturbed they may never recover (Clarke & Kirkman, 1989; Kirkman & Kuo, 1990). Large declines in seagrass in the 1970s, due to massive increases in macroalgae, were documented in the Peel–Harvey estuarine system near Mandurah (McComb & Lukatelich, 1995). However, construction of the Dawesville Channel has significantly altered macroalgal distribution and diversity, and has also contributed to the loss of some fringing vegetation with increasing tides and salinity in the estuary (Brearley, 2005).

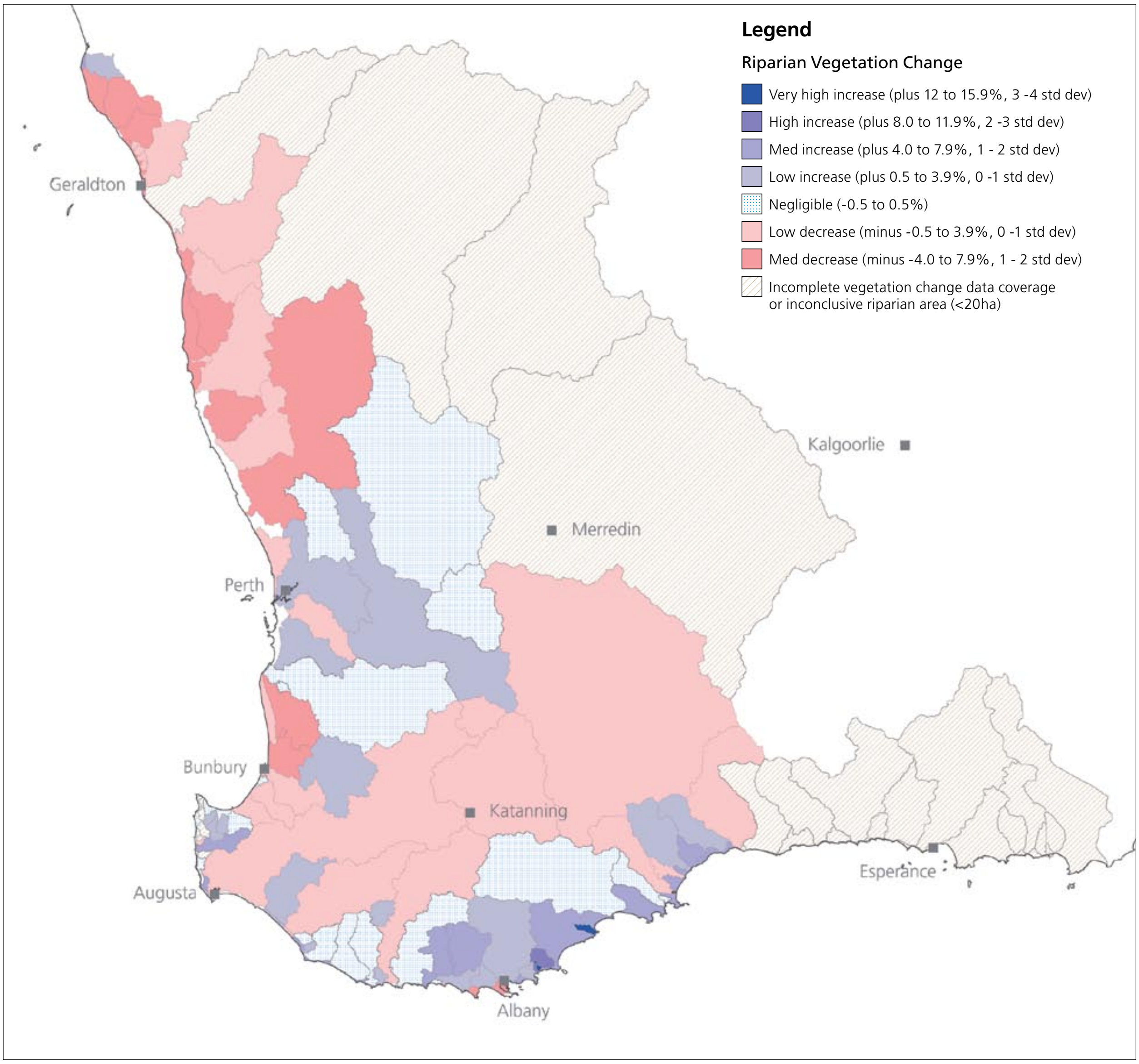


Figure IW4.1: Net loss or gain of vegetation within 50 metres of waterways in South West catchments, 1996–2004.

Data source: Department of Land Information – Land Monitor [ver. 2004], Department of Environment – Hydrology [ver. 2003]; Analysis: EPA; Presentation: EPA.

In Princess Royal Harbour and Oyster Harbour near Albany, 90% and 80% of seagrass was lost, respectively, between the early 1960s and the late 1980s (Hillman et al., 1990; Water and Rivers Commission, 1997b). However significant recovery was noted in the mid-1990s, coinciding with a series of dry years with reduced catchment runoff and decreasing macroalgae (Bastyan et al., 1996). With significant restoration and rehabilitation efforts being undertaken in Oyster Harbour, there is now emerging evidence that seagrass meadows (*Posidonia sp.*) are recovering (G Bastyan, pers. comm.). Enhanced seagrass (*Ruppia sp.*) growth was also observed in nearby Wilson Inlet during the 1980s but is now declining there due to increasing algal blooms.

Pressures

Many WA settlements were established in lowland valley areas adjacent to waterways to allow easier transportation, access to water and because of the better agricultural productivity on floodplains. This resulted in extensive removal of fringing vegetation in some areas, such as the upper Swan and lower Avon rivers. Damage to fringing vegetation is still occurring as a result of residential developmental and the cultural appeal of owning a waterfront property with water views. This is particularly evident for land adjacent to estuaries and major river systems across the South West. Pressures such as clearing, salinisation, over grazing, erosion, *Phytophthora* dieback, altered fire regimes, and feral and weed invasion are also degrading remaining fringing vegetation. Altered water regimes can seriously degrade fringing vegetation by causing flooding or reducing water availability. Increasing levels of acid, sediment and other pollutants in waterways can also contribute to loss of fringing vegetation.

In agricultural areas, acute loss of fringing vegetation continues to occur where stock has easy access to waterways and wetlands. Recent surveys undertaken in the South West agricultural region indicate that 45–50% of farmers protect river creek frontages from grazing animals (Department of Agriculture, 2006). Grazing is also a problem for waterways and wetlands in the rangelands, where stock depend on access to water in an otherwise dry landscape. The topography of the land and extent of pastoral livestock grazing areas means that it is often impractical to fence large portions of waterways and wetlands. Only 33% of pastoralists indicated that they protect river or creek frontages from grazing animals (Department of Agriculture, 2006).

The major pressure associated with loss of instream vegetation is dredging to aid navigation for recreational boating, commercial operations or tourism charters. Estuaries or major river systems with port, harbour, marina or boating facilities undertake occasional dredging of channels to prevent them filling with sediment. Sometimes removal of seagrass occurs but can be minimised with adequate management practices. Many WA estuaries including the Swan, Peel Inlet, Harvey (Dawesville), Oyster Harbour, Murchison River and Leschenault estuaries are dredged to maintain navigation channels. Sedimentation, eutrophication and salinisation can also radically affect the extent and density of instream vegetation but unfortunately there is little or no ongoing monitoring to assess these changes.

A thin band of fringing vegetation has been retained on this section of the Avon River near Toodyay (D.Tracey)

Current responses

Vegetation clearing regulations: Amendments were made in 2003 to the *Environmental Protection Act 1986* to provide regulations that protect native vegetation while allowing for approved clearing activities. The regulations extend to protection of instream and fringing vegetation of wetlands and waterways.

Planning policy: A *Water Resources Statement of Planning Policy* (Western Australian Planning Commission, 2006a) has been prepared by the Western Australian Planning Commission to assist with the management and protection of wetlands (and other waterways) in the land use planning system. An accompanying draft *Guideline for the Determination of Wetland Buffer Requirements* (Western Australian Planning Commission, 2005) has also been released to provide advice on minimising planning and development impacts to wetlands. A new State Planning Policy (Western Australian Planning Commission, 2006b) has been developed specifically for the Swan–Canning river system to ensure that new development does not compromise the health, amenity and landscape values of the rivers.

River and wetland restoration manuals: A river restoration manual has been developed to assist with restoration and long-term management of waterways (Water and Rivers Commission, 2002). A wetland restoration manual is in development by the Department of Environment and Conservation. These manuals provide information on how waterways and wetlands function, the causes and effects of degrading processes, and planning, restoration and management techniques.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP) programs: All regional Natural Resource Management groups in the South West have recognised loss of fringing vegetation as a major threat to inland waters. Many other regional groups will address this as part of estuary, waterway and wetland management. The regional groups are developing projects for management of affected waterways and protection of valued natural assets at risk.

Foreshore policy and assessment: In 2001 the Water and Rivers Commission approved a policy that provides a consistent methodology for assessment and determination of waterway foreshore and buffer areas. The foreshore assessment technique for waterways in the South West does not require expert knowledge and covers bank stability, foreshore vegetation condition, stream cover and habitat diversity.

Riverbank Program: is administered by the Swan River Trust to provide project funding for the rehabilitation and protection of foreshores along the Swan and Canning rivers. A baseline study has recently been undertaken, in partnership with the Swan Catchment Council using Natural Heritage Trust assistance, which assessed fringing vegetation condition along 61 km of foreshore. A comprehensive assessment of shoreline type, vegetation and weed cover was undertaken along the Swan Canning Estuary.

Streamlining: Streamlining of agricultural drains consists of fencing waterways and drains to prevent livestock access, and revegetating the fringes using native species. Incentives can be offered to encourage landholders to fence to exclude stock from drains and to revegetate where possible.

Fringing vegetation research: The Tropical Savannas Cooperative Research Centre is conducting a research project on fringing vegetation across Northern Australia, including in the Kimberley. The project aims to define fringing vegetation health, develop practical methods to assess foreshore condition, generate better understanding of threatening processes and evaluate techniques to manage those threats.

Implications

Loss of fringing and instream vegetation is often a contentious issue. In some urban riverside areas, fringing vegetation has been illegally poisoned to allow for improved water views. In some rural and sparsely populated areas the loss of fringing vegetation goes largely unnoticed until obvious downstream impacts on biodiversity or water quality begin to occur. There is a need to increase community awareness of the value of fringing and instream vegetation and its importance for maintaining healthy waterways and wetlands. Failure to do this will result in loss of ecological functionality of inland waters (including loss of habitat and food sources for fish and other native animals), and may impact on tourism and recreational and commercial fishing. Loss of fringing vegetation allows more light to reach the water body, enhancing weed and algal growth. Inland waters without fringing and instream vegetation will also become more susceptible to the effects of erosion and sedimentation, causing potential for flooding and navigation problems.

SUGGESTED RESPONSES

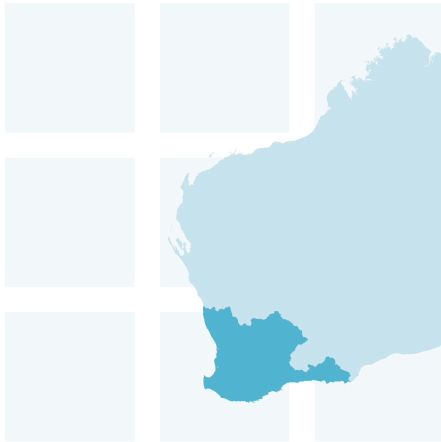
4.14 Establish an agreed baseline of the condition of fringing and instream vegetation.

4.15 Implement the *Water Resource Statement of Planning Policy* and finalise the draft *Guideline for the Determination of Wetland Buffer Requirements*.

4.16 Develop and implement a package of education, assistance and incentives for fencing and rehabilitation of waterways and wetlands on private lands.

Intensive rehabilitation efforts in Oyster Harbour are leading to a recovery of seagrass (G.Bastyan)

4.5 ACIDIFICATION OF INLAND WATERS



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 3

KEY FINDINGS

- Groundwater and wetlands on the Gnangara Mound are becoming highly acidic, with the pH less than 4 in some places.
- Deep drainage waters in the eastern Wheatbelt are highly acidic with an average pH of 3.
- Most acidic inland waters contain heavy metals such as arsenic, aluminium, cadmium and lead.

Description

Acidification of wetlands, waterways, groundwater and agricultural drains are known to occur in the South West. Natural acidity may occur in some seasonal wetlands and salt lakes due to the natural seasonal wetting and drying cycle or the gradual build-up of sulfides, iron and other trace metals. However, most natural inland waters are neutral (neither acidic nor alkaline). Acidification may also be caused by lowering of watertables resulting in oxidation of natural sulfides in rocks, soils or iron rich groundwaters. This triggers chemical and microbiological reactions that generate significant amounts of sulfuric acid, which can be extremely damaging to the environment.

Acidified soils are often called 'acid sulfate soils'. In an undisturbed state below the watertable, these soils are benign and not acidic. Acid sulfate soils in WA commonly occur in low lying wetlands, swamps, estuaries, salt marshes and tidal flats, though they are not limited to coastal areas. Some acid sulfate soils have been found in South West agricultural areas, forming in response to rising watertables and land salinisation. Environmental problems begin to arise when soils are drained, excavated or exposed to air by lowering of the watertable. This may occur during dewatering processes, construction of drains, soil excavation, excessive groundwater use, or excessive planting of trees. Under these conditions the sulfide minerals react with oxygen to form sulfuric acid. Often the soil is unable to naturally neutralise the acidity. Water flowing through acidified soil can then produce acidic inland waters. Although rare, acidification may also result from contamination events and runoff from agriculturally-acidified soils (see '*Soil acidification*').

Inland waters with increasing acidification can severely damage the environment, resulting in simplified ecosystems and a loss of biodiversity. Acid leaching of soil minerals such as aluminium, iron, nutrients, heavy metals and pesticides can also occur, presenting toxicity problems for plants and animals. Affected waters can become acidic chemical cocktails with potential to cause severe damage to infrastructure, water supplies and the environment.

Objectives

- To identify inland waters affected by, or at risk of, acidification and apply land management practices to avoid or minimise their disturbance.
- To manage and restore valuable inland waters affected by acidification.

Condition

Acidity is a reflection of hydrogen ion concentration in solution and is measured on the 'pH' scale. This varies from pH 0 (strongly acidic) to pH 14 (strongly alkaline), with pH 7 being neutral. As the pH scale is logarithmic, a fall of one pH unit (say from pH 5 to pH 4) represents a ten-fold increase in acidity. Even a small increase in acidity (i.e. a minor decline in pH) can have serious detrimental effects on biodiversity, especially where there is no history of acidity in an ecosystem (Psenner, 1994).

Indicator IW14: Status and trends in acidity (pH) of inland waters.

Most WA waterways are near neutral with a pH in the vicinity of 6.5–8.0. A few acidic waterways are found near Mandurah, Albany and on the Scott Coastal Plain (Figure IW5.1). Some natural acidity occurs due to seasonal wetting and drying of peaty soils in wetlands and waterways. In contrast, other waterways in the western Wheatbelt, the mid-west and Ord irrigation areas are slightly alkaline, their pH ranging from 8.0–8.5 (Figure IW5.1).

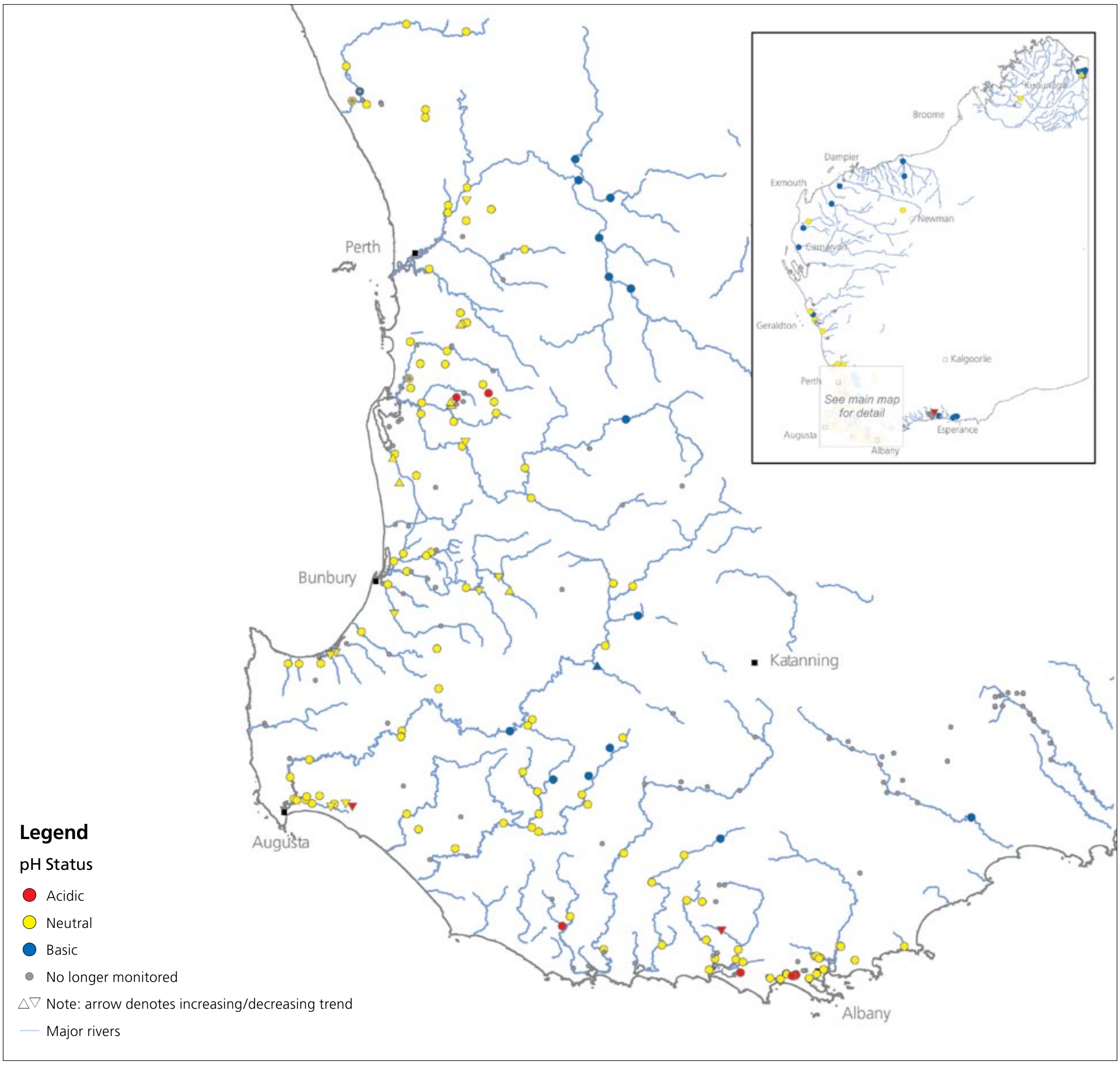


Figure IW5.1: The pH of Western Australian waterways.

Data source: Department of Environment and Conservation [ver. 2005], Analysis: EPA, Presentation: EPA.

A snapshot survey of water quality in the Wheatbelt during the winter of 2003 identified very low pH (3.0–5.0) in lakes and waterways of the upper Lockhart and Upper Yilgarn rivers, and some areas of the North and East Mortlock rivers. The high acidity of inland waters of the eastern Wheatbelt reflects a broad problem that may be linked to rising saline watertables that are also acidic. Deep groundwater in the eastern Wheatbelt is considered naturally acidic since there is evidence of some naturally acidic salt lakes and deep groundwater of pH between 3.0–4.5 (Rogers & George, 2005). Agricultural drains were found to be most acidic in the eastern Wheatbelt (east of the line between Dalwallinu and Dumbleyung), with more than half the drains sampled being strongly acidic with an average pH of 3.0. Sampling of deep drains has also shown high levels of heavy metals (including arsenic, iron, aluminium, cobalt, copper, zinc, lead and uranium) that have leached under the acidic conditions.

Coastal groundwater acidity became a prominent issue in Perth in 2002 with the discovery that water from some household bores in the suburb of Stirling was killing garden plants. The groundwater was found to be acidic (with a pH as low as 1.9 in some places) and had become contaminated with aluminium and arsenic released from the soil (Appleyard et al., 2004). Nearby urban wetlands (Spoonbill Lakes) had also acidified. Heavy use of garden bores and dewatering of a nearby wetland for a housing development caused the acidification.

Investigations have also shown that extensive acidification of shallow groundwater is also occurring on the crests of the Gnangara and Jandakot mounds, with pH levels as low as 2.4 and high levels of dissolved aluminium and arsenic present (Appleyard, 2004 & 2005). High aluminium levels can kill plants and wetland aquatic fauna. High arsenic levels pose a risk to human health if the groundwater is used for drinking water, and represents a long-term toxicological problem for ecosystems. Several wetlands on the Gnangara Mound are now permanently acidified. For example, Lake Gnangara has been acidified to a pH of less than 4 since the late 1970s, and Mariginiup and Jandabup lakes have both had temporary acidification events (McHugh, 2004). In other wetlands and waterways the source of acidity is likely to be disturbed acid sulfate soils, which have been detected in wetlands and waterways adjacent to the Swan–Canning, Peel–Harvey, Leschenault and Vasse–Wonnerup estuaries, the Scott Coastal plain and low lying coastal areas on the south coast near Albany (Department of Environment, 2004b).

Acid sulfate soils are often not identified until land is in the process of being redeveloped, when affected vegetation starts to die, or when major infrastructure damage occurs. For this reason the problem is best managed through the identification of potential risk areas. The Department of Environment has been undertaking soil investigations to map the extent of acid sulfate soil risk areas (Figure IW5.2).

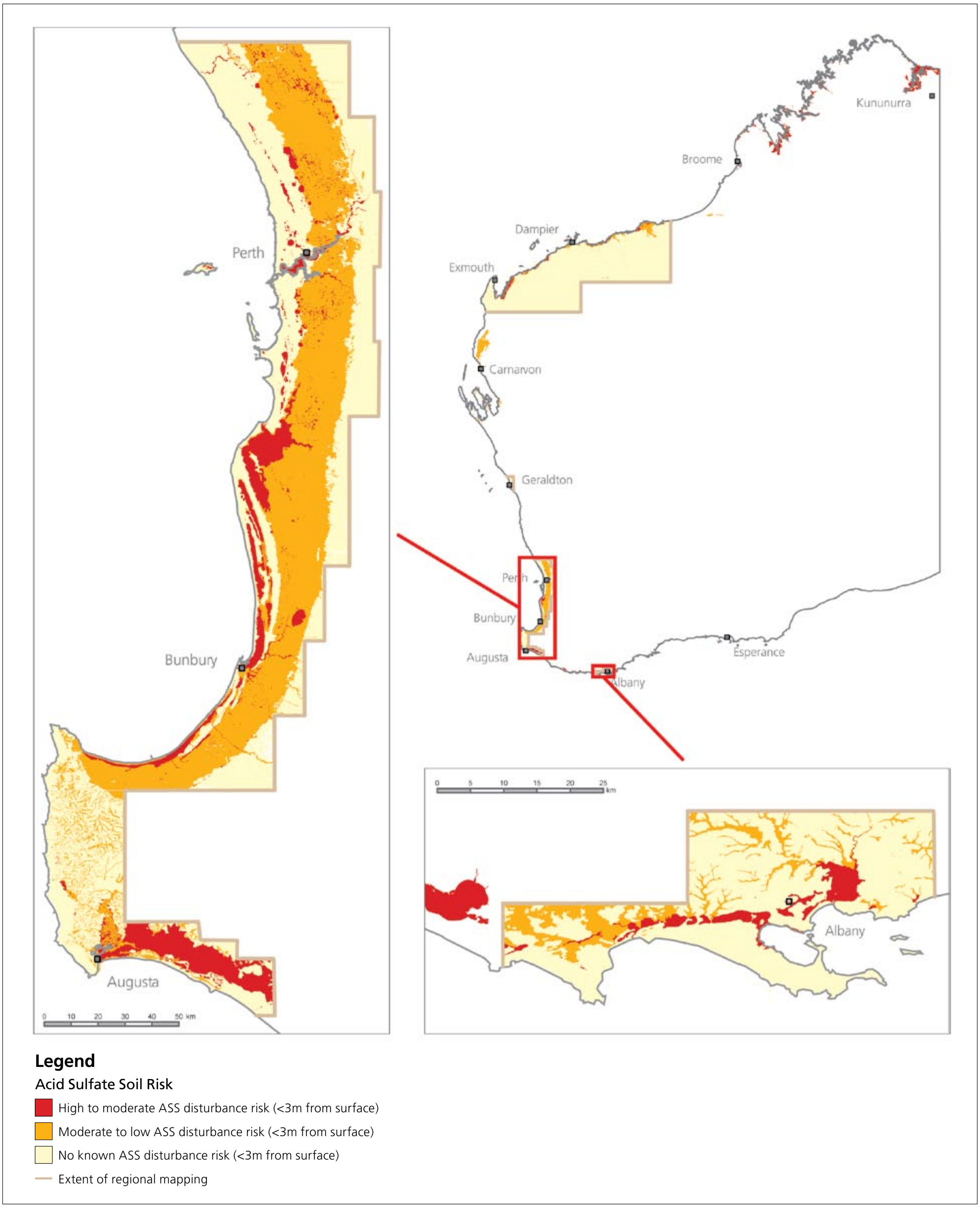


Figure IW5.2: Risk of acid sulfate soils (ASS).

Data source: Department of Environment and Conservation [ver. 2007]; Presentation: EPA.

Pressures

Acidification of ground and surface waters in coastal plain environments is largely a result of poorly planned and managed land use development. In urban areas, increased and more widespread acidification of inland waters is likely with increasing groundwater use, prolonged periods of low rainfall and the continued use of dewatering practices to enable development of wetlands. Lowering of water tables and subsequent drying of wetland soils leads to acidification when soils become wet again. Continued development of wetlands will place nearby areas under significant acidification pressures.

In coastal agricultural areas there are pressures increasing water acidification due to over design of existing drainage networks in combination with continuing declines in annual rainfall. Existing drains, that were designed and installed during a time of high rainfall, are now resulting in the excess lowering of water tables. If disturbed, areas with acid sulfate soils are likely to export acidity to wetlands and waterways.

In agricultural areas, disposal of acid drainage water is posing a significant problem. Fluctuating water tables in the Wheatbelt, caused by altered water regimes, climate variability and management interventions (such as deep drainage and pumping) are increasing the generation of acidic groundwater. Drainage water discharged into waterways and wetlands has the potential to impact on the health of the receiving ecosystem. The risk of downstream impacts may also be much larger when the cumulative effects of many acid drains are added together.

Current responses

Engineering Evaluation Initiative: is a project that aims to deliver improved engineering options to manage salinity, manage the safe disposal of saline and acidic water, and address regional drainage planning. It has also commissioned the Collaborative Research Centre for Landscape Environments and Mineral Exploration to assess the geochemical risk (acidity and trace metals) posed by saline acid waters in the Wheatbelt. It focuses on waters likely to be discharged by deep drains constructed to mitigate salinity.

Acid sulfate soil mapping: The Department of Environment and Conservation is currently identifying and mapping the extent of acid sulfate soil risk in coastal areas under high pressure from development.

Planning responses: The Western Australian Planning Commission has released a bulletin containing planning measures to ensure that acid sulfate soils are identified, investigated and managed during land development processes (Western Australian Planning Commission, 2003).

Acid sulfate soils framework: *A Proposed Framework for Managing Acid Sulfate Soils* (Department of Environment, 2004b) has been developed outlining institutional arrangements, monitoring, planning and educational requirements to effectively manage acid sulfate soils. The department has also developed a series of guidance documents to assist in the identification, management and treatment of acid sulfate soils.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP) programs: Regional Natural Resource Management groups in the South West, Swan, Avon, South Coast, and Northern Agricultural areas have recognised acidification or acid sulfate soils as a threat or potential threat to inland waters. Many regional groups will address this as part of estuary, waterway and wetland management. The regional groups are developing projects for management of affected waterways and protection of valued natural assets at risk.

Implications

Acidification is a growing problem and requires sound land use planning. Acid leachate (including heavy metals, minerals, nutrients and pesticides) can impact groundwater and surface waters causing ecological damage to aquatic and riparian ecosystems; damage to estuarine fisheries and aquaculture activities; contamination of groundwater supplies; reduction in agricultural productivity from acidic conditions and metal contamination (predominantly by aluminium); and damage to infrastructure through corrosion of building foundations, bridge supports, jetties, roads, dams, water pumps and underground pipes. Some impacts caused by subtle changes in acidity over a long period may not be apparent until irreversible changes have already occurred. Economic impacts of acidification of inland waters can occur through loss of economic water supplies, increased water treatment costs and damage to infrastructure. In the Wheatbelt the combined effects of acidification and salinisation in inland waters will rapidly accelerate corrosion of infrastructure, impact water supplies and the loss of biodiversity.

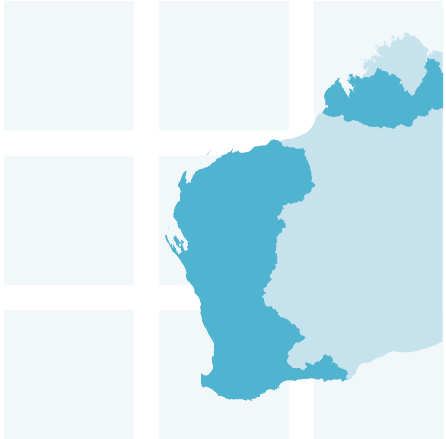
SUGGESTED RESPONSES

4.17 Review and implement the *Proposed Framework for Managing Acid Sulfate Soils*, with a view to using a risk-based approach and incorporating effective mitigation and management options.

4.18 Modify the Engineering Evaluation Initiative to incorporate ecological, economic and social risks and management options for managing acid inland waters in the Wheatbelt.

Water in Wheatbelt deep drains is often highly saline, acidic and has high levels of heavy metals (Department of Environment and Conservation)

4.6 EROSION AND SEDIMENTATION OF INLAND WATERS



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 3

KEY FINDINGS

- Erosion and sedimentation are degrading most of the State's major waterways.
- About 26 major river pools along the Avon River have filled with sediment.
- From the 1970s to 1990s, enough sediment entered Lake Argyle from the Ord River to fill between 6000 and 9000 Olympic swimming pools every year.

Description

Erosion occurs when soil becomes unstable and erodes from the land, and the banks and beds of waterways. Soil erosion is a natural process that is at its greatest during floods. Land with steep slopes and friable soils in high rainfall areas are particularly susceptible to erosion and can contribute large amounts of soil to waterways and wetlands. Erosion is exacerbated by human activities that remove vegetation cover or cause soil disturbance.

Eroded soil is gradually deposited into waterways and wetlands by wind and water erosion, or via mass collapse of soil structures (such as land slides, bank collapse and slumping). When eroded soil is deposited into waterways and wetlands it becomes sediment. Fine sediments (e.g. silt) can be suspended in water and carried quickly downstream and out to sea. Coarser sediments (e.g. sand, pebbles and rocks) slowly roll along the riverbed and deposit in pools, wetlands and river channels. During low flows, sediments begin to settle out of the water in a process termed 'sedimentation'. In contrast, during large flows and floods, sediments are scoured from the riverbed or banks of waterways and transported downstream or out to sea. Over time this dynamic process of sediment deposition and scouring contributes to the reshaping of waterways. In wetlands, sedimentation is more problematic, contributing to the gradual filling of wetlands over time.

Problems arise when erosion and sedimentation rates are too fast. Excessive erosion can damage fringing vegetation and undermine infrastructure such as bridges, roads and buildings located close to the waterline. High levels of suspended sediment can make the water muddy, affecting aquatic animals and reducing habitat. It can also exacerbate flooding of nearby land, fill water reservoirs, foul water supplies and clog irrigation and drainage pipes. Often nutrients and contaminants are bound to eroded soil and may contribute to contamination or eutrophication problems.

Objectives

- To reduce waterway erosion due to human activities and reduce the adverse effects of sedimentation processes in surface waters.
- Rehabilitate valuable surface waters affected by erosion or sedimentation where there is damage, or increased risk of damage, to environmental values or associated infrastructure.

Condition

Indicator IW15: Status and trends in suspended solids/ turbidity of wetlands and waterways.

Turbidity and suspended solids are commonly used as indicators of levels of erosion and sedimentation in waterways and wetlands. 'Suspended solids' refers to the amount of sediment or organic matter in the water column. Turbidity is a measure of the light scattering properties of water, which may be affected by sediment, organic matter or colour of the water. Most South West waterways draining forested catchments are generally low in suspended solids and turbidity. In these areas the presence of healthy fringing vegetation protects riverbanks from erosion and intercepts soils eroded from catchments. However, waterways draining agricultural catchments (such as the Avon, Blackwood, Murray, Collie, Preston, Pallinup, Oldfield, and Young rivers) have high suspended solids or turbidity. Although many monitored waterways in WA show short-term changes in turbidity or suspended solids in recent years (Figure IW6.1), further investigation is required to determine their cause.

Erosion during flooding on the Fortescue River has undermined fringing vegetation (S.Wild)

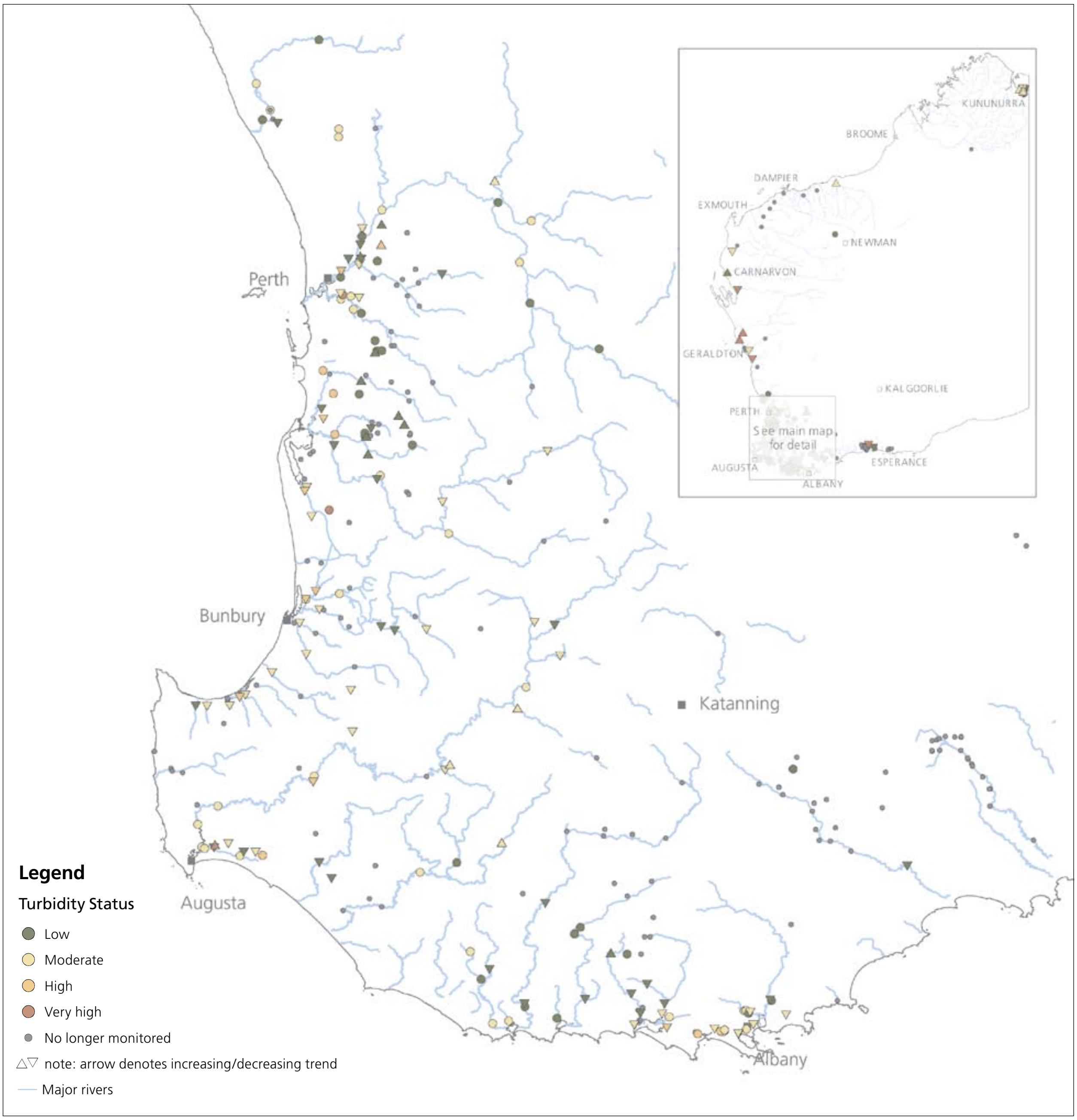


Figure IW6.1: Suspended solids and turbidity in waterways.

Data source: Department of Environment [ver. 2005]; Analysis: EPA; Presentation: EPA.

Waterways in the Mid West, Pilbara and Kimberley (including the Chapman, Gascoyne, Murchison, Ashburton, Fortescue, Fitzroy and Ord rivers) are well known for their high sediment transport rates and braided, sediment-filled river channels. Many of the catchments of these waterways are susceptible to sedimentation due to steep terrain, dry soils and low vegetation cover. Livestock access to waterways is also believed to exacerbate erosion and sedimentation in pastoral areas. For example, since Lake Argyle was constructed on the Ord River in the 1970s, sediment has been deposited at rates of 19–28 million cubic metres per year into the reservoir (Wasson et al., 1994). By 1994, sediment deposition had reduced the useable storage by 600 million cubic metres, representing a little over 10% of the original volume of the reservoir (Doupe & Pettit, 2002). Although there are no recent modelled estimates, reduced pastoral activities and effective catchment restoration efforts (Payne et al., 2004) suggest that sediment levels in the Ord River (and into Lake Argyle) may be falling. There is no other reliable information about sedimentation trends in other WA wetlands.

Indicator IW16: Loss of riverine pools due to sedimentation.

There is very little information available to determine the extent of sedimentation on river pools, with most evidence being anecdotal. For example, prior to agricultural development in the Avon River catchment there were about 26 major pools along the river between Cobblers Pool and Yenyinning Lakes, varying up to 70 m wide, 2 km long and 10 m deep. Nearly all have since filled with sediment (Pen, 1999; Water and Rivers Commission & Avon Waterways Committee, 2002), much of which has been mobilised with the rapid formation of gullies and networks of eroded channels in the upper catchment. River training (straightening of river channels) and minimal retention of vegetation near waterways has also contributed (see '*Loss or degradation of fringing and instream vegetation*'). Unlike in normal rivers, flood events appear unable to scour the excess sediments from these pools (Pen, 1999) and consequently they are unlikely to return to their previous state without significant management intervention (i.e. dredging). Similarly, mapping in 1841 indicated pools in the Brunswick River were once 2–5 m deep but they are now full with sediment (Department of Environment, unpublished data).

Pressures

Soils are more susceptible to erosion if unprotected by vegetation, or exposed to wind or water flow (see '*Loss or degradation of fringing and instream vegetation*'). Livestock can be particularly damaging if they have unrestricted access to waterways and wetlands. Fringing native vegetation may be trampled or over-grazed, thereby increasing soil disturbance and the potential for bank erosion or mass slumping. Farm machinery and herding of livestock tends to compact soil, thereby increasing the erosive potential of water runoff over land. Waterlogged and inundated areas are also susceptible to water erosion, particularly if stocked or cultivated while wet. Salinisation can also degrade soil structure making the soil more susceptible to erosion.

Clearing land for development results in large areas of soil being exposed for long periods of time (see '*Loss or degradation of native vegetation*'). Nearby wetlands, waterways and drains can be affected by high sediment levels unless developers provide measures to protect the exposed soil. When the land has been developed, the relative amount of impervious surfaces (e.g. roads, houses, paths) increases, amplifying erosion potential by increasing the speed of water runoff. Forestry, cropping, pastoralism, mining activities and fires all have the potential to increase erosion and sedimentation rates once vegetation cover is removed.

Current responses

Agriculture Extension Program: The Department of Agriculture promotes farming methods to minimise land erosion. Grade or contour banks and interceptor drains are used on sloping agricultural land to minimise erosion. Recent surveys indicate that 50–70% of Wheatbelt farmers use surface water management practices compared to only 30-40% of farmers in wetter parts of the South West (Department of Agriculture, 2006). Fencing wetlands and waterways from grazing animals is necessary to prevent bank erosion and degradation of fringing vegetation: 33% of pastoralists restrict grazing stock from river and creek frontages compared to 45–50% of farmers in the South West agricultural region.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP) programs: All regional natural resource management groups have recognised erosion and/or sedimentation as a threat to inland waters. They are proposing projects for the management of affected waterways and wetlands, and protection of valued natural assets at risk, including fencing, rehabilitation of river pools, sediment retention devices, ponding banks and rehabilitation of fringing vegetation.

Avon River Pools Recovery Program: has been responsible for rehabilitating degraded waterways, including revegetation of fringe areas, recontouring banks, introducing riffles and snags, and dredging of river pools. Much of this activity is addressing previous river training of the Avon River in the 1950s–1970s that caused significant increases in river erosion and sedimentation rates.

Ord River Regeneration Project: commenced in 1960 in response to excessive sediment entering Lake Argyle. From the 1960s to 1980s, extensive rehabilitation occurred including intensive strip contour cultivation and seeding, fencing, donkey eradication and de-stocking. In 2002 the area was surveyed to assess changes in vegetation and soils, and confirmed profound improvements in vegetation and soil condition (Payne et al., 2004).

Modelling: The CSIRO and the Centre for Catchment Hydrology are currently developing a Sednet software model that predicts sediment loss from catchments and various land use types. The model is intended for use in regional planning and to assist with setting erosion and sedimentation targets.

Implications

Erosion and sedimentation is a widespread problem affecting many WA waterways and wetlands. Better catchment and waterways management is needed to stop further degradation and reverse damage to important areas. Increased sediment in water detrimentally affects aquatic biodiversity. Finer sediment may also carry phosphorus, contributing to eutrophication problems. Sediment build-up can exacerbate flooding where channels have become shallower and outlets blocked. This in turn can increase flood magnitude and frequency, increasing the risk of damage to buildings, roads, bridges, pipes, farmland and other infrastructure. Deposition of sediments in water supply dams can reduce volume capacity and may require costly treatment to remove sediment and fine particulates. Erosion of banks can intrude on productive land, forcing landowners to act to stem further loss of valuable land or infrastructure. Often this means fencing and rehabilitating areas much larger than would have been necessary to stop the problem in the first instance.

SUGGESTED RESPONSES

4.19 Enhance routine monitoring of waterways and wetlands currently impacted by, and at future risk of, erosion and sedimentation.

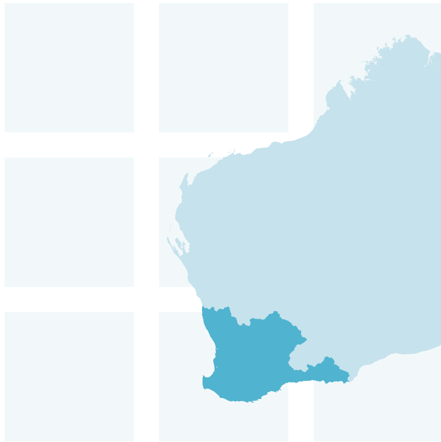
4.20 Implement appropriate planning processes to ensure foreshore development is controlled.

See also '*Loss or degradation of fringing and instream vegetation*':

- Establish an agreed baseline of the condition of fringing and instream vegetation.
- Implement the *Water Resource Statement of Planning Policy* and finalise the draft *Guideline for the Determination of Wetland Buffer Requirements*.
- Develop and implement a package of education, assistance and incentives for fencing and rehabilitation of waterways and wetlands on private lands.

Erosion of riverbanks on the Greenough River (S.Heriot)

EUTROPHICATION



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 3

KEY FINDINGS

- Over 100 wetlands and waterways in Western Australia (mostly in the South West) have experienced algal bloom problems.
- Nearly 30% of accidental fish kills can be attributed to algal blooms in waterways.
- Persistent blue-green algal blooms in the Peel-Harvey estuary have ceased due to construction of the Dawesville Channel.

Description

All wetlands and waterways are susceptible to eutrophication. The term 'eutrophic' comes from a Greek word meaning 'well fed'. Eutrophication refers to the ecological changes that result from excess levels of nutrients in waterways and wetlands, often resulting in prolific aquatic plant growth and algal blooms. Nitrogen and phosphorus are usually the most important nutrients that influence this process but other micronutrients can also play a role.

Although eutrophication is a slow natural process, it is dramatically accelerated by artificially high nutrient levels. Nutrients can either come from diffuse sources (such as fertiliser runoff from farms or urban areas), or via point sources from specific locations (such as sewerage treatment facilities or livestock feedlots). Other factors contributing to eutrophic conditions include stagnation of water, accumulation of fine sediment (with phosphorus attached) and continual accumulation and decay of organic matter. Loss of fringing vegetation can also increase water temperature and light availability, thereby enhancing the potential for algal blooms to occur.

Excess nutrients in water often result in algal blooms, proliferation of weeds and pests (e.g. midges and mosquitoes), and other ecological changes. If persistent, this may result in a simplification of an ecosystem and a loss of biodiversity. Excessive weed and algal growth may also render some wetlands and waterways unsuitable for use as water supplies or for recreation, and may also increase the risk of flooding. Some species of algae (e.g. blue-green algae) produce toxins which can be harmful or even fatal to humans, fish and animals. Fish deaths are also commonly associated with decomposing algal blooms, which causes de-oxygenation of the water. Many algal blooms also cause unsightly water discolouration and foul odours as they decay.

Objectives

- Reduce nutrient inputs to inland waters to levels that have minimal impact on human health, the environment and associated values.
- Reduce the frequency and intensity of toxic or nuisance algal blooms caused by nutrient pollution.

Condition

Indicator IW17: Status and trends of nutrients in inland waters.

Estuaries in the South West are particularly vulnerable to nutrient enrichment, as they have evolved under naturally low nutrient conditions and many catchments now support intensive land uses. Nutrient levels vary significantly in South West estuaries (Figures IW7.1 & IW7.2) and are related to estuary size, rate of flushing and catchment land uses. Estuarine nutrient levels are generally stable over time, requiring several decades of monitoring to detect change. The Peel–Harvey estuarine system is an exception, with construction of the Dawesville Channel making this estuary more marine-like and dramatically lowering nutrient levels and algal activity. While most nutrient-enriched estuaries experience elevated algal blooms, some estuaries (such as the Oldfield and Moore) have naturally dark, tea-coloured water that is less favourable for algal growth. Estuaries in the rangelands are not well monitored for nutrients or algal activity.

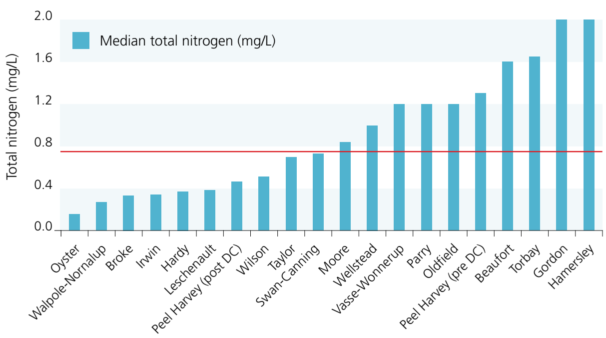


Figure IW7.1: Total nitrogen concentrations in South West estuaries.

Data source: Department of Environment [ver. 2005]. Note: Red line indicates ANZECC guideline level for estuaries in the South West (ANZECC and ARMCANZ, 2000). DC = Dawesville Channel.

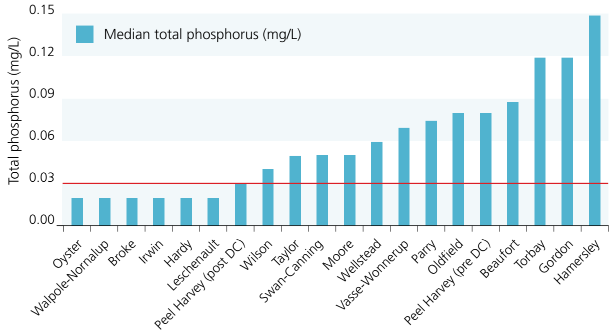


Figure IW7.2: Total phosphorus concentrations in South West estuaries.

Data source: Department of Environment [ver. 2005]. Note: Red line indicates ANZECC guideline level for estuaries in the South West (ANZECC and ARMCANZ, 2000). DC = Dawesville Channel.

About one-third of monitored rivers have low levels of the nutrients nitrogen and phosphorus. Low nutrient levels are typically found in rivers with forested catchments. High levels of nutrients are usually found in waterways draining cleared urban and agriculture catchments, such as along the Swan Coastal Plain. Many of these waterways have catchments with coastal sandy soils that are well known for leaching nutrients. Waterways in the Wheatbelt and rangelands are not well monitored for nutrients, partly due to their remoteness and the intermittent nature of flows. Short-term changes (1997–2003) in nitrogen and phosphorus levels have been noted for some rivers of the Swan–Canning estuarine system, Leschenault Inlet, Peel–Harvey estuarine system, Princess Royal and Oyster harbours, and the Blackwood River and some south coast rivers (Figures IW7.3 & IW7.4). Further analysis is required to determine if these are indicative of longer-term trends linked to catchment land uses, management practices, altered flow regimes or changes in rainfall.

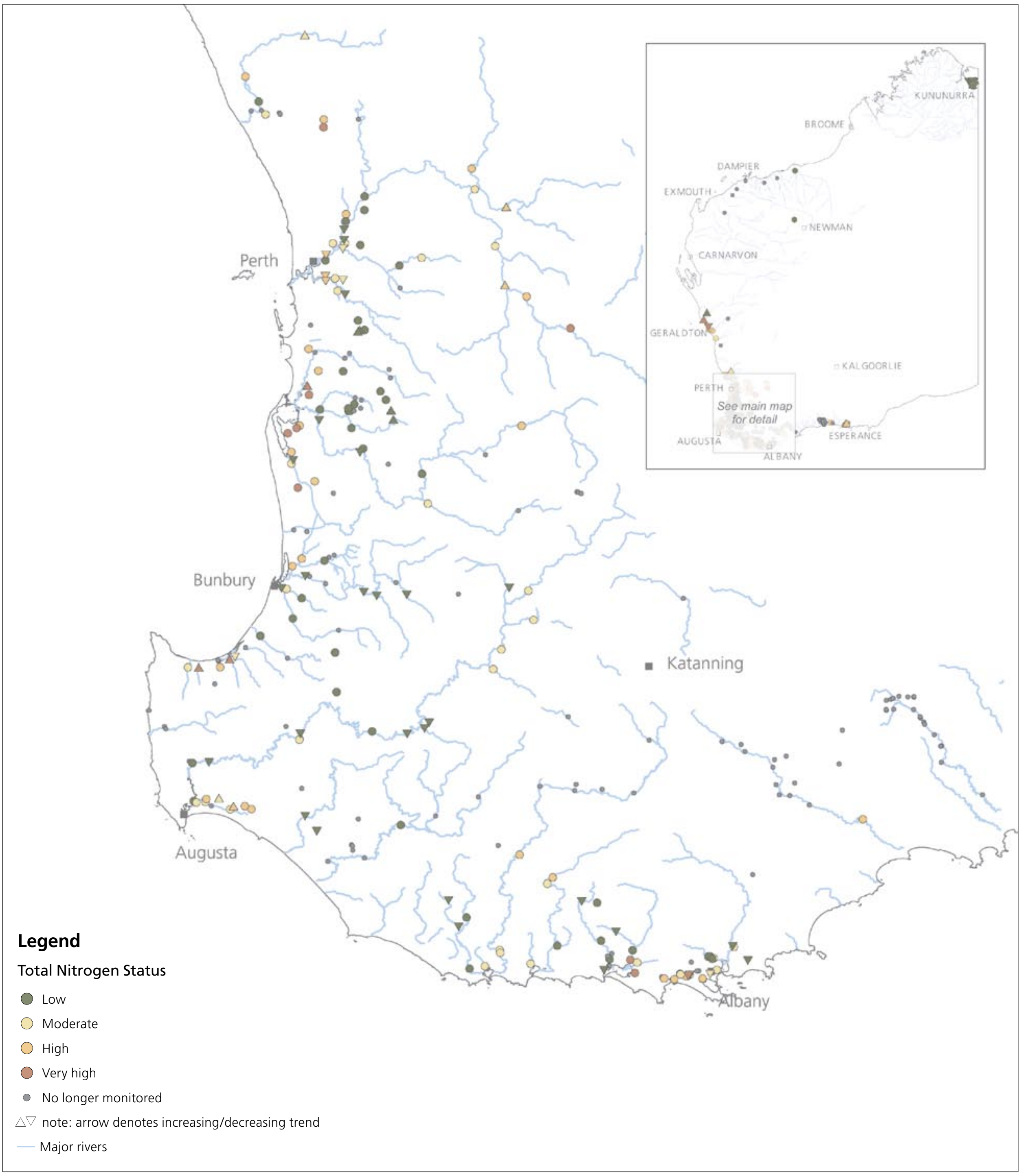


Figure IW7.3: Total nitrogen status and trend in Western Australian rivers, 1997–2003.

Data source: Department of Environment [ver. 2005]; Analysis: EPA; Presentation: EPA.

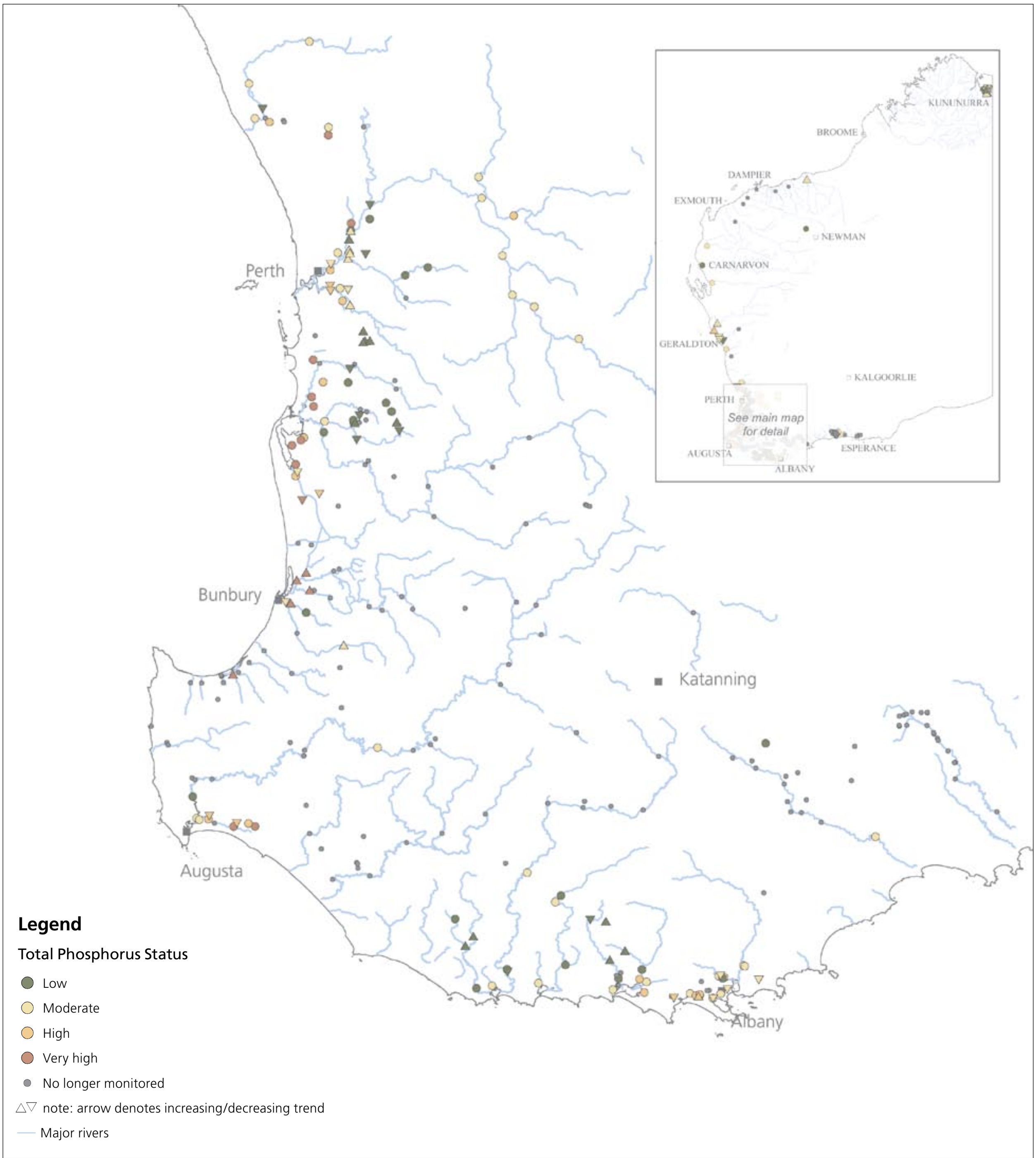


Figure IW7.4: Total phosphorus status and trend in Western Australian rivers, 1997–2003.

Data source: Department of Environment [ver. 2005]; Analysis: EPA; Presentation: EPA.

Indicator IW18: Annual number and location of significant incidences of nuisance and toxic algal blooms, as defined by management agencies.

Long term monitoring of nutrients in wetlands is mostly limited to specific research studies in the Perth urban area. For example, previous studies have found very high nutrient levels in Lake Monger, a small urban lake close to Perth city. With fertilising of nearby lawns, phosphorus concentrations of up to 0.8 mg/L were recorded and the lake experienced frequent blooms of Anabaena and Microcystis (Lund, 1995). The lake has since received significant management attention, rehabilitation and nutrient reduction efforts. Other past studies of wetlands on the Gnangara Mound found elevated phosphorus levels; for example, Gingin (0.46 mg/L), Nowerup (0.36 mg/L), Carabooda (0.29 mg/L), Neerabup (0.24 mg/L) and Coogee (0.14 mg/L) all linked to semi-rural land uses (Wrigley et. al, 1991). However, many Perth wetlands have since experienced significant catchment land use change and some are now receiving more management attention. Some Perth urban wetlands, such as Lake Joondalup and Lake Goolelall, experience ongoing midge problems linked to eutrophication.

Algal blooms and associated events (such as fish kills, unpleasant odours, mussel contamination and closure to recreation) regularly affect many rivers and estuaries in WA (Figure IW7.5). About 110 wetlands and waterways have a recorded history of algal bloom problems (V Hosja, Department of Environment, pers. comm.). Most are situated in the State's South West and many are at risk of toxic, blue-green algal blooms including those due to *Nodularia, Anabaena* and *Microcystis* species. Blue-green algae are not the only harmful types of bloom organisms, with some dinoflagellate and diatom species capable of producing toxins that accumulate in shellfish, cause fish deaths, and irritate swimmers. Harmless algal blooms are also capable of causing discolouration of waterways and causing foul odours and deoxygenation events as they decompose. Several shallow river and estuarine systems (including Vasse–Wonnerup, Leschenault, Peel–Harvey and Princess Royal estuarine systems) support excessive macroalgal growth linked to high nutrient levels.

The Peel–Harvey Estuary near Mandurah was well known for almost annual blue-green algal blooms (i.e. *Nodularia* sp.) from 1978 to 1994. Construction of the Dawesville Channel in 1994 increased ocean flushing and there have been no more blue-green algal blooms in the estuary. Unfortunately, blooms still frequently occur in the Serpentine and Harvey rivers. Catchment modelling indicates that agricultural activities contribute most nutrients to the rivers and estuary (about 70%). Developed urban areas represent 6% of catchment area but contribute about 30% of nutrient input. Estimates indicate that full development of the planning schemes for the Mandurah area will increase nutrient export up to four-fold (Department of Environment & Department of Agriculture, unpublished data)

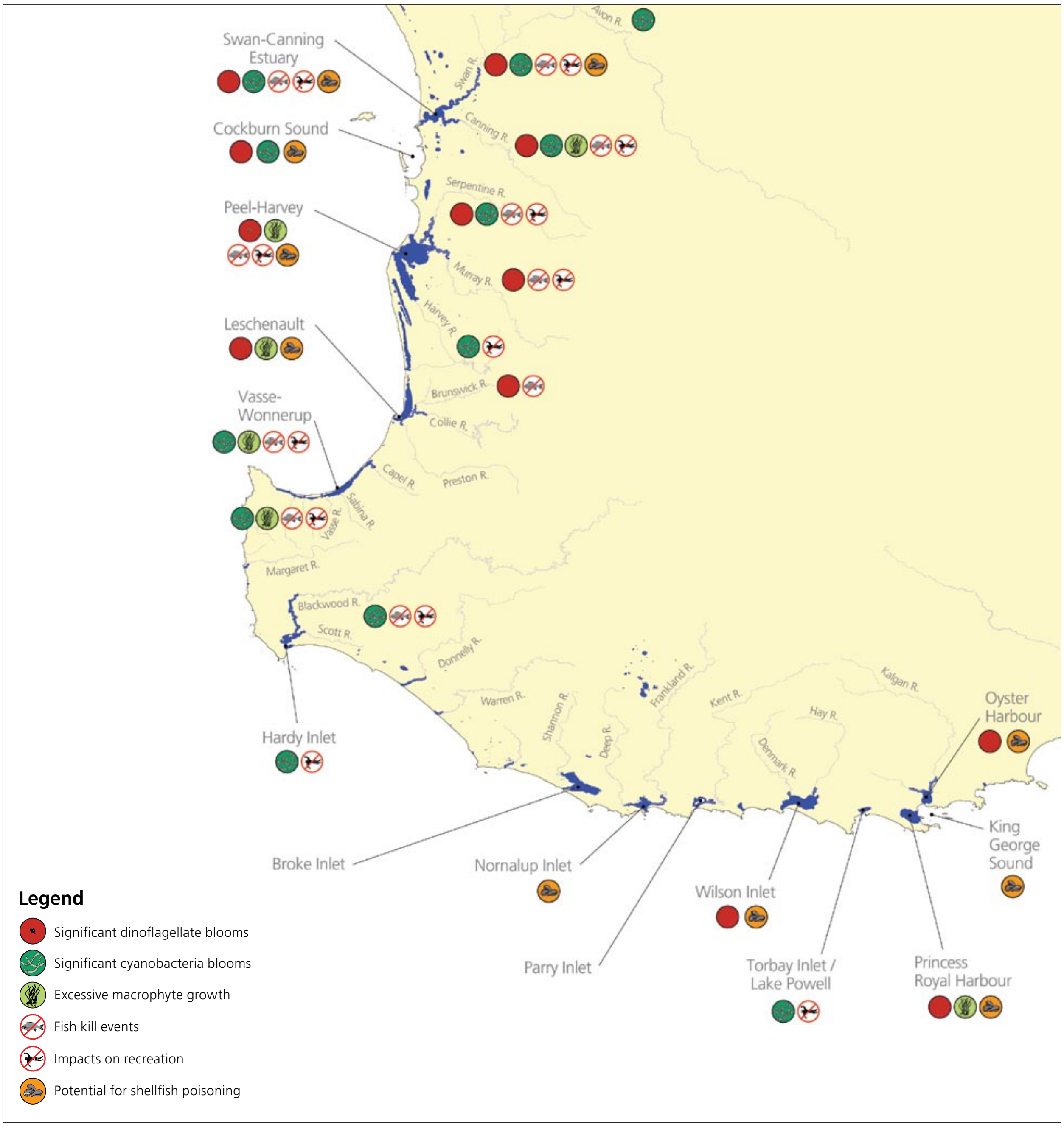


Figure IW7.5: Algal bloom and associated fish kill and swimming risk areas in the South West.

Map courtesy of Department of Environment [ver. 2005].

In January 2000 a major toxic blue-green algal bloom (Microcystis sp.) occurred in the Swan–Canning Estuary, near Perth (Swan River Trust, 2000). The bloom resulted in unprecedented closure (12 days) of the whole estuary and its rivers to fishing and recreation. Unseasonably high summer rainfall and subsequent flushing of nutrients from inland agricultural areas helped create ideal conditions for the bloom. It was estimated that over 800 tonnes of nitrogen and 35 tonnes of phosphorus entered the Swan and Avon rivers during this single event, representing 108% and 88% (respectively) of these nutrients normally delivered in one year. Perfect conditions for bloom growth were created by typical summer conditions, including high temperatures, low cloud and calm conditions. The bloom died when river flows subsided and estuary salinity levels returned to normal (summer) conditions. This incident demonstrated how catchment fertiliser use can contribute to algal bloom problems.

Indicator IW19: Annual number and location of significant fish kills.

Since 2000, about 15–35 accidental fish kills have been reported in WA each year, with 70% occurring in major waterways of the State's South West. It has been estimated that nearly 30% of accidental fish kill events can be attributed to toxic algal blooms and low oxygen levels following a bloom collapse (T Rose, Department of Environment, pers. comm.). In 2003, more than 110 000 fish died in the lower Serpentine River near Mandurah and more than 100 000 died in the Swan Estuary following dinoflagellate blooms (*Karlodinium sp.*) toxic to fish. In 2004 more than 50 000 fish died in the lower parts of the Serpentine and Collie rivers.

Pressures

Nutrients are transported to inland waters by either point or diffuse sources. Point sources (such as septic tanks, sewage treatment plants, landfill sites, industrial waste, and intensive livestock industries including piggeries, dairies and feedlots) can contribute high levels of nutrients from small areas. In contrast, diffuse sources including urban gardens, stormwater and farmland generally contribute nutrients from a widespread area. Nutrient transport through catchments can be very fast in areas with sandy, wet soils. In contrast, soils with a high clay, loam or iron content help to bind nutrients and minimise algal bloom risk to inland waters.

Clearing of vegetation or harvesting of crops can reduce uptake of soil nutrients, which may subsequently be lost to inland waters. Nutrient loss may also be enhanced where erosion or acidification processes occur. Uncontrolled livestock access to waterways and wetlands can damage fringing vegetation and contribute nutrients from faecal waste. Altered water regimes may also exacerbate algal blooms, particularly when water levels are significantly reduced and waters stagnate. Poor land use planning in the past has contributed to eutrophication problems, with a lack of consideration given to the proximity to sensitive environments of nutrient-intensive land uses.

Indicator IW20: Mass of nitrogen-based and phosphorus-based fertilisers applied.

One of the major and most widespread sources of nutrients to inland waters is from fertiliser applied to residential lawns and gardens, broadacre farms and horticulture. There is a tendency for some householders to over-fertilise lawns and gardens in the false belief that more fertiliser results in a greener garden. Lack of soil testing by farmers also results in excessive fertiliser application to crops or pastures. With only about 10% of Australia's population, WA is one of the largest consumers of fertilisers. For example, in 2002, 399 000 tonnes of nitrogen-based fertiliser (26% of Australia's total use), 428 000 tonnes of phosphate-based fertiliser (24% of Australia's use) and 495 000 tonnes of compound and blended fertiliser (28% of Australia's use) were applied to WA soils (Australian Bureau of Statistics, 2002). These levels of application are in part attributed to the State's nutrient deficient soils and large wheat crop production.

Indicator IW21: Number of sewage spills over time.

Across the State about 1000 wastewater overflows occurred in 2003–04. Of these, about 100 events were greater than 2000 L, requiring formal investigation under the *Environmental Protection Act 1986*. In Perth approximately 300 million litres of raw wastewater is collected from households, businesses and industry and transported via a network of 9000 km of pipes to treatment plants. Infrequent overflows occur due to blockages, burst pipes and power failures (Table IW7.1). The total amount of nutrients entering the Swan and Canning rivers from wastewater overflows is very small (less than 0.1%) compared to other catchment sources (Water Corporation, 2003).

Current responses

State Algal Bloom Management Strategy: A draft strategy has been developed with the intention of further developing an understanding of the causes of algal blooms, maintaining surveillance of susceptible waterways, reducing nutrient inputs, enhancing community understanding of algal blooms, and developing appropriate nutrient management options.

Legislation and policies: Various policies are in place to reduce the pressure of nutrient enrichment (and other water pollutants) on inland waters, including environmental protection policies for the Swan–Canning and Peel–Harvey estuaries and Gnangara Mound. The *Environmental Protection (Swan and Canning rivers) Policy* is to be implemented using the management framework RiverPlan. The *Swan and Canning Rivers Management Act* was enacted in October 2006 but remains inoperational as at April 2007. It proposes the establishment of a Riverpark, improved coordination of agency activities, and improved management action and enforcement. A draft State environmental policy and action plan is being considered to phase out highly soluble phosphate fertilisers within four years in environmentally sensitive areas.

A toxic blue green algal bloom (Microcystis) resulted in the closure of the Swan Estuary in February 2000 (D. Sarson)

Table IW7.1: Number of wastewater overflow events into the Swan Canning river system, by volume.

Data source: Water Corporation [ver. 2007].

Financial year	90–91	91–92	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	01–02	02–03	03–04	04–05	05–06
Number of wastewater overflows	2	1	0	9	6	2	6	8	11	7	2	6	5	7	6

Nutrient management programs: This initiative is the single largest program addressing eutrophication in WA. The Swan River Trust initiated the Swan–Canning Cleanup Program in 1994 in response to increasing incidences of algal blooms in the Swan and Canning rivers. In 1999 an action plan was released which brought government, industry, business and the community together to improve catchment management, planning processes, engineering solutions and monitoring. A recent evaluation of the plan found that 77% of initiatives had been implemented, including about one million seedlings planted, about 280 km of fencing constructed, nearly 25 km of foreshore enhancement and about 1000 property plans developed. Longer timeframes are needed to determine if the action plan has been successful in reducing diffuse nutrient sources (Swan River Trust, 2005). In 2006, the second phase of the program the Healthy Rivers Action Plan was launched, representing a 5 year $40 million program focusing on reducing nutrient input. Many other nutrient reduction programs and plans are currently underway throughout South West WA, including the *Healthy Rivers Action Plan, Wilson Inlet Nutrient Reduction Action Plan*, Dairy Catch, Lower Vasse River Cleanup Program and the development of a *Peel–Harvey Water Quality Improvement Plan*.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP) programs: All regional Natural Resource Management groups have recognised eutrophication as a major threat to inland waters. They are implementing projects to manage nutrient export to affected waterways and protection of valued natural assets at risk. The Coastal Catchments Initiative is a NHT sub-program that focuses on reducing nutrients discharged to coastal hotspots, through development of water quality improvement plans and funding of related projects. Identified hotspots in WA include the Peel-Harvey, Vasse-Wonnerup and Swan-Canning estuaries and Geographe Bay.

Wastewater: The Water Corporation is overseeing the replacement of household septic tanks with connection to deep sewerage. Before the program began in 1994, 25% of Perth properties and 40% of country properties were using septic tanks. In other state capitals the average is 4%. When the program is completed in 2019, an extra 100 000 properties will be connected to deep sewerage, diverting many hundred tonnes of nutrients from entering inland waters (Water Corporation, 2004). The Water Corporation commenced a Riverwise program in 1997, upgrading 110 wastewater pump stations close to the Swan–Canning River system. This has resulted in a 60% reduction in overflows to the rivers, thereby reducing nutrient input.

National Eutrophication Management Program: was established by Land and Water Australia and the Murray Darling Basin Commission to focus strategic research and development on nutrient sources and transport, factors initiating algal blooms, the role of sediments in transporting nutrients, and evaluation of the effectiveness of management actions. One of the focus areas for this work has been Wilson Inlet in WA where an action plan has been prepared to address eutrophication.

Agriculture Extension Program: develops and demonstrates to farmers effective agricultural practices that reduce or eliminate nutrients leaching from farms (e.g. soil testing to determine application rates, soil tillage, erosion control). Recent surveys indicate that 74% of Wheatbelt farmers undertake regular soil testing for nutrient levels, whereas 68% of farmers in higher rainfall parts of the South West undertake regular testing (Department of Agriculture, 2006). Between 45-50% of South West farmers protect river frontages from grazing animals, whereas only one-third of pastoralists use this management practice (Department of Agriculture, 2006).

Instream remediation: Several instream remediation activities have been trialled in recent years to combat existing algal blooms. Examples include the use of oxygenation (bubbling of oxygen through the water column) and sediment remediation (applying modified clays that bind phosphorus) in the Canning and Vasse rivers. Both methods have proven successful in limiting algal blooms and deoxygenation events in these rivers, although both are recognised as short-term management options. Construction of the Dawesville Channel in 1994 represents the single largest remediation project for a eutrophication problem, providing a permanent artificial breach between the Peel–Harvey estuarine system and the ocean. While controlling blue-green algal blooms, the channel has significantly modified local ecology.

Soil remediation: Alkaloam or 'red-mud' has been trialled by the Department of Agriculture in Peel–Harvey catchments to reduce phosphorus export from sandy agricultural soils. Paddock trials show that nutrient loss from agricultural soils can be reduced by an average of 50%. A modified clay developed by CSIRO has been trialled for use in the Canning and Vasse rivers, with results showing it can remove more than 95% of dissolved phosphorus from the water column (Swan River Trust, 2001).

Stormwater Management Manual: has been developed by the Department of Water to provide policy, planning principles, and on-ground best practice advice for the management and reuse of stormwater. It builds on the traditional objective of local flood protection by enhancing water quality, protecting ecosystems and providing liveable and attractive communities.

Implications

Eutrophic conditions can drastically alter biodiversity in wetlands and waterways, rapidly turning them into algae and weed-dominated systems. Algal blooms, particularly if toxic, can cause fish kills, ruin water supplies, prevent recreational activities and affect amenity values. Nutrient-enriched waters provide ideal habitat for opportunistic aquatic weeds that can rapidly grow and clog irrigation and stormwater pipes. Excessive macroalgae washing up on beaches may cause offensive smells, become a health problem for nearby residents, affect property values and be a nuisance for beach users, fishers and tourists. Many eutrophic wetlands provide ample food sources for midge and mosquito populations and occasional outbreaks of vector-borne disease can be a major health problem for local communities (e.g. Ross River virus). Nutrient enrichment of groundwater can reduce the suitability of water supplies because of the possibility of nitrate toxicity. Unless a thorough systematic approach is used to keep nutrients on the land and planning controls are strengthened, the problem will not be solved.

SUGGESTED RESPONSES

4.21 Finalise and implement the draft *State Algal Bloom Management Strategy*.

4.22 Strengthen land use controls and planning mechanisms to identify and phase out high nutrient exporting land uses that are unable to meet nutrient reduction targets.

4.23 Revise regional and town planning schemes to ensure they minimise nutrient export from various land uses.

4.24 Develop and implement a State environmental policy to phase out the use of high water soluble phosphate fertilisers in relevant catchments and soil types.

EMERGING ISSUE –
CONTAMINATION OF INLAND WATERS

Contamination of inland waters usually results from contamination of land (see '*Land contamination*'). The number of contaminated inland waters is currently difficult to ascertain, but is usually associated with identified land contaminated sites. Unsafe storage, use or disposal of chemicals in the industrial, business, agriculture or urban environment is the major cause of contamination of inland waters. This may be exacerbated by poor waste treatment or management practices. Waste by-products (such as paints, oil, solvents or chemical residues) dumped into drains because it is a cheaper and easier way to dispose of them, may form dangerous chemical cocktails that can be environmentally damaging and harmful to human health. Clean-up can be especially difficult, costly and may result in offenders being prosecuted. A survey of 522 light industries adjacent to the Swan–Canning rivers showed wastewater containing chemicals and pesticides was disposed of through soakage into soil (19%), stormwater drains (16%), septic tanks (13%) and sewers (Swan River Trust, 1999). About 50% of industrial premises did not undertake wastewater treatment and less than 5% conducted periodical testing and maintenance of their treatment facilities. Many light industries did not understand the potential contamination risk or best practices for industrial wastewater management.

Persistent chemicals that are mobile in water (such as pesticides, herbicides and organic chemicals) pose the greatest risk to aquatic flora and fauna. It is currently estimated that 11% of major fish kills can be attributed to contamination of inland waters (T Rose, Department of Environment, pers. comm.). The effect of some contaminants is increased by their ability to persist and build up in the environment over time. This can be particularly destructive for wetlands, river pools and some estuarine systems where flushing is limited. In 1997, a major fish kill occurred in an Ord River irrigation channel and the Dunham River due to pesticide (Endosulfan) contamination. Current pesticide practices have changed profoundly since the early stages of the Ord Irrigation Scheme (1960s), where highly toxic and persistent pesticides were used. However, recent sampling indicates that some pesticides persist in local fish and animals (Department of Environment, unpublished). Another pesticide spill at a racecourse in 1997 in the Swan River near Perth caused major fish death, killing over 30% of the river's bream fish stock.

In Perth, groundwater quality is generally good but there are areas where contaminants have affected shallow groundwater. In particular, leaking underground storage tanks at petrol stations are a widespread threat to groundwater, due to their large number and distribution. Leaks may go undetected for long periods and, on reaching groundwater, contaminants may affect drinking water supplies, residential or production bores, and eventually wetlands and waterways. Of about 6500 licensed premises in WA with dangerous goods, an estimated 57% have underground storage tanks. Nearly half of these are located in the Perth metropolitan area. Just over 3% (or 217) of premises have leaking tanks and many of the sites involved are being investigated and undergoing remediation.

Recent monitoring of heavy metals, pesticides and other toxicants in inland waters is limited. Occasional sampling of toxicants from stormwater drains discharging to the Swan and Canning rivers show some have elevated organic chemicals, pesticides (including DDT and Dieldrin), hydrocarbons and heavy metals such as chromium, cadmium copper, lead and zinc (Wong & Morrison, 1994; Department of Environmental Protection, 2001; Swan River Trust, 2003a & 2003b). Although the more persistent and toxic pesticides are now banned (e.g. DDT), it is possible that a gradual release of contaminants to wetlands and waterways is occurring via slow moving groundwater plumes. Monitoring in the City of Stirling and some parts of the Gnangara Mound showed some bores are contaminated with arsenic, aluminium and other heavy metals in response to acidification events (Appleyard, 2004 & 2005). Sampling of deep drains in the agricultural Wheatbelt has also shown high levels of heavy metals including iron, aluminium, cobalt, copper, zinc, lead and uranium have leached under acidic conditions (Rogers & George, 2005). Similarly, heavy metals have been found in some inland waters following acid mine drainage and where acid sulfate soils are found.

The economic costs of inland water contamination are considerable and far outweigh the substantial cost of remediation efforts. Property values may decline, fisheries may be impacted, and recreation and tourism can be detrimentally affected. If the contamination occurs in a water supply it may restrict virtually all forms of water use. Discovery of a contaminated wetland or waterway close to residential areas may cause considerable community concern and distress, irrespective of the risk of potential exposure to the contaminant. It may also present a threat to social or cultural values. Humans may also be at risk if exposed through contaminated drinking water or eating affected fish, livestock or other affected produce.

A wide range of contaminants can be discharged in untreated runoff from industrial areas (R.Spencer)

EMERGING ISSUE – LOSS OF FLOODPLAIN CONNECTIVITY

Floodplains are areas of land and water, situated alongside waterways, which are occasionally inundated during floods. They provide a range of ecosystem services. Some wetlands situated on floodplains require regular inundation to replenish them with water, nutrients, seeds for vegetation recruitment, organic matter and to maintain habitat. Fish stocks in waterways also benefit by feeding on organic matter washed from surrounding floodplains. Many settlements and agricultural lands have been established on floodplains because of their fertile soils and proximity of water supplies. For example, both Perth and Mandurah have extended settlements built on the banks of the Swan and Murray rivers respectively. In some areas, residential development on floodplains has contributed to the loss of connectivity between the river, its floodplain and associated wetlands (Figure IW9.1). Other floodplains have been extensively developed are require flood protection (e.g. Carnarvon, Moora, Busselton, Fitzroy Crossing and Northam).

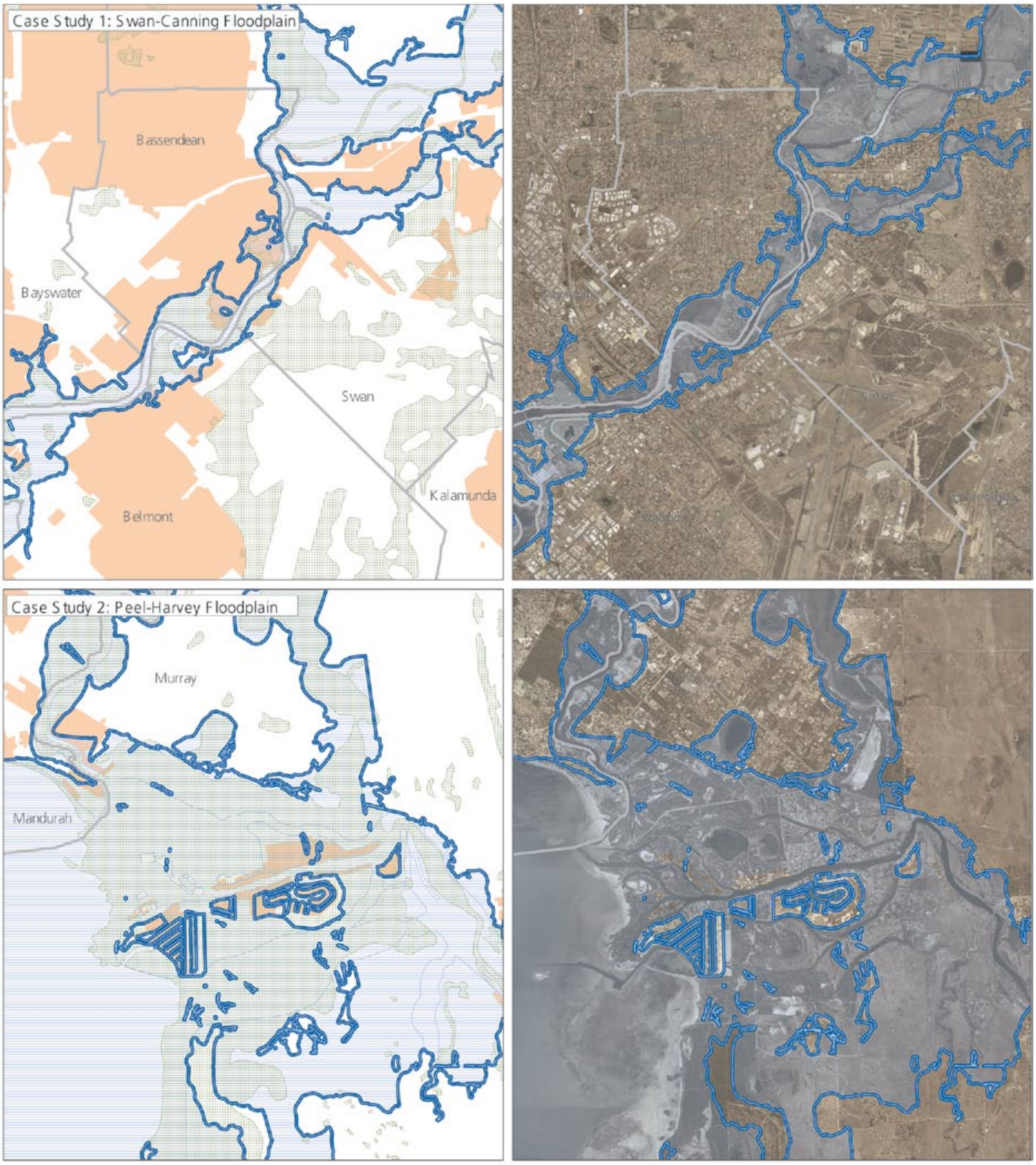
Floodplain isolation occurs when waterways are excessively modified to prevent flooding; damage to crops, stock and infrastructure; and loss of human life. Levee banks on the side of waterways have been built to contain minor and moderate flooding events, thereby reducing the floodplain area that receives regular inundation by flood waters. Some waterways have drain diversions constructed to minimise the effect of floods on nearby towns and agricultural land. Some rivers also have their channels straightened or dredged deeper to hasten water flow through the catchment. All these activities have resulted in floodplains becoming isolated or disconnected from their waterways (i.e. loss of floodplain connectivity).

Dams constructed on major rivers significantly alter the frequency, intensity and duration of floodplain inundation (see '*Altered water regimes*'). For example, on lower parts of the Ord River, construction of the Lake Argyle dam has prevented floodwaters from reaching much of its floodplain, even during a one in 100-year flood event. Flows leaving the dam do not generally exceed 1000 cubic metres per second, even though inflows to the dam have exceeded 10 000 cubic metres per second on occasions. This has resulted in a significant loss of downstream river and floodplain ecology. For example, river gum and coolibah trees that rely on flooding are diminishing, leading to weed invasion (Water and Rivers Commission, 2003).

No waterway should be isolated from its floodplain: connectivity is the key to maintaining terrestrial and aquatic biodiversity, and land and water productivity. Removing the hydrological connection of floodplain aquatic ecosystems may eventually result in them becoming terrestrial ecosystems. Floodplain isolation also impacts on river ecosystem health. Lack of organic material and debris washed from floodplains decreases the available food and habitat for fish and aquatic organisms, thereby reducing fish stocks and productivity. Studies show that river production following one day of floodplain inundation was equivalent to 82 years of production under normal conditions (Davies, Bunn & Mosisch, 2001).

It is now appreciated that healthy waterways require adequate flow regimes and hydrological connection with their floodplains. With the exception of pristine waterways and floodplains, it is now impossible to turn back the clock and protect many of the State's floodplains from development.

Development of the Swan River floodplain has severed the hydrological connection with nearby wetlands. (D.Tracey)



Legend

Extent of Floodplain Development for the Swan–Canning (top) and the Peel–Harvey (bottom).

- Urban extent 2004
- Floodplain - 100 year flood
- Geomorphic wetlands (minus palusplain and estuary classification)
- Local Government boundaries

Figure IW9.1: Examples of Perth and Mandurah residential development on the floodplains of the Swan and Murray rivers (respectively) that has contributed to a loss of floodplain connectivity.

Data source: Department of Planning and Infrastructure – urban extent [ver. 2004], Department of Land Information – aerial photography [ver. 2004], Department of Environment – floodplain mapping [ver. 2005] & geomorphic wetlands [ver. 2005]; Presentation: EPA..

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