TECHNICAL NOTE 2007/13

Department of Water, Land and Biodiversity Conservation

SUSTAINABLE WATER RESOURCES MANAGEMENT, PLANTATION FORESTRY AND A METHOD FOR THE PROVISION OF ENVIRONMENTAL FLOWS TO WETLAND ECOSYSTEMS

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EXECUTIVE SUMMARY

Water resources in the Mount Lofty Ranges are critically important to South Australians. The area provides sixty percent of Adelaide's water supply in an average year, supports more than 25,000 hectares of irrigated agriculture and contains a number of water dependent ecosystems of national conservation significance. The region has recently been placed under a moratorium on water use due to a risk to the region's water resources while a water allocation plan is developed. Hardwood plantation forestry is an industry that has recently targeted the Mount Lofty Ranges as an area for significant development.

South Australia is a signatory to the National Water Initiative. Within this framework it is recognised that some activities, including plantation forestry, have the potential to intercept significant volumes of water. The Department of Water, Land and Biodiversity Conservation (DWLBC) is assessing the significance of such activities based on an understanding of the total water cycle, to protect user access to a sustainable water resource and the achievement of environmental objectives.

Twenty-five percent of median annual adjusted catchment yield is used in South Australia as an indicator of the sustainable use limit of catchment surface water resources. DWLBC has developed an assessment procedure that integrates the assessment of conventional water affecting activities with the water requirements of nationally important wetlands and the expected impacts of plantation forestry.

The requirements of prospective water users are estimated using available information. Wetland requirements are estimated using the Fleurieu Swamp water balance model, while the impacts of plantation forestry on surface water yield are based on gauged streamflow data from the Mount Lofty Ranges. The procedure ensures that the water requirements of downstream users, including wetlands are met, while determining the maximum area of plantation forestry that can be sustainably developed within a well-defined consumptive pool. Once a maximum area of plantation is determined the development should be designed according to guidelines that address specific water resources issues in addition to industry guidelines, which address conventional land management issues.

INTRODUCTION

The water resources in the Mount Lofty Ranges are critically important to South Australians. The area provides sixty percent of Adelaide's water supply in an average year, supports more than 25,000 hectares of irrigated agriculture and contains a number of water dependent ecosystems of national and international conservation significance.

Hardwood plantation forestry is an industry that has recently targeted the Mount Lofty Ranges as an area for significant development. Despite being acknowledged as a significant water interception activity under the National Water Initiative, plantation forestry is yet to be declared a water affecting activity under South Australian legislation other than in the South East and its control remains outside regional water allocation processes currently underway.

However, the *Development Act 1993* regulations identify plantation forestry in prescribed water resources areas, including the Mount Lofty Ranges, as an activity that may give rise to water allocation issues under the *Natural Resources Management Act 2004*. The relevant development authority is required to refer forestry development applications in these areas to the Department of Water, Land and Biodiversity Conservation for advice. While acknowledging limitations in available information, the DWLBC procedure for assessing plantation forestry impacts on water resources integrates the best available technical knowledge with state government NRM guidelines to yield a transparent assessment that protects high-value environmental assets and meets the objectives of South Australian government policy and the National Water Initiative.

GOVERNMENT NRM POLICY FRAMEWORK, AGREEMENTS AND WATER ALLOCATION PLANNING

South Australia's water resources are managed according to a range of agreements, law, plans and policies. South Australia's Strategic Plan provides broad strategic policy direction; the Natural *Resources Management Act 2004* (NRM Act) provides the legal framework for state and regional management and the National Water Initiative Inter-governmental Agreement (NWI) contains issue specific commitments (Figure 1, below).

SOUTH AUSTRALIA'S STATE STRATEGIC PLAN 2007

The South Australian Strategic Plan (SASP) outlines a medium to long-term plan for South Australia, setting six interrelated objectives: Growing Prosperity, Improving Wellbeing, Attaining Sustainability, Fostering Creativity and Innovation, Building Communities and Expanding Opportunity. Ninety-eight long-term targets are grouped under these objectives (GSA 2007a).

Issues relevant to water resources management and water-dependent ecosystems are addressed within the Water and Biodiversity themes, under the objective of Attaining Sustainability. A key initiative identified to achieve this objective includes *promoting sustainable water use*. Targets specific to state-wide water resources management are:

- Water – T 3.9 Sustainable water supply (new): South Australia's water resources are managed within sustainable limits by 2018. KEY MEASURE: extent to which water resources are managed within sustainable limits (baseline: 2003).

- Biodiversity – T 3.1 Lose no species (existing – modified): Lose no known native species as a result of human impacts. KEY MEASURE: no decline, and where possible an improvement, in the regional status of known native species, or the ecological communities that they come from.

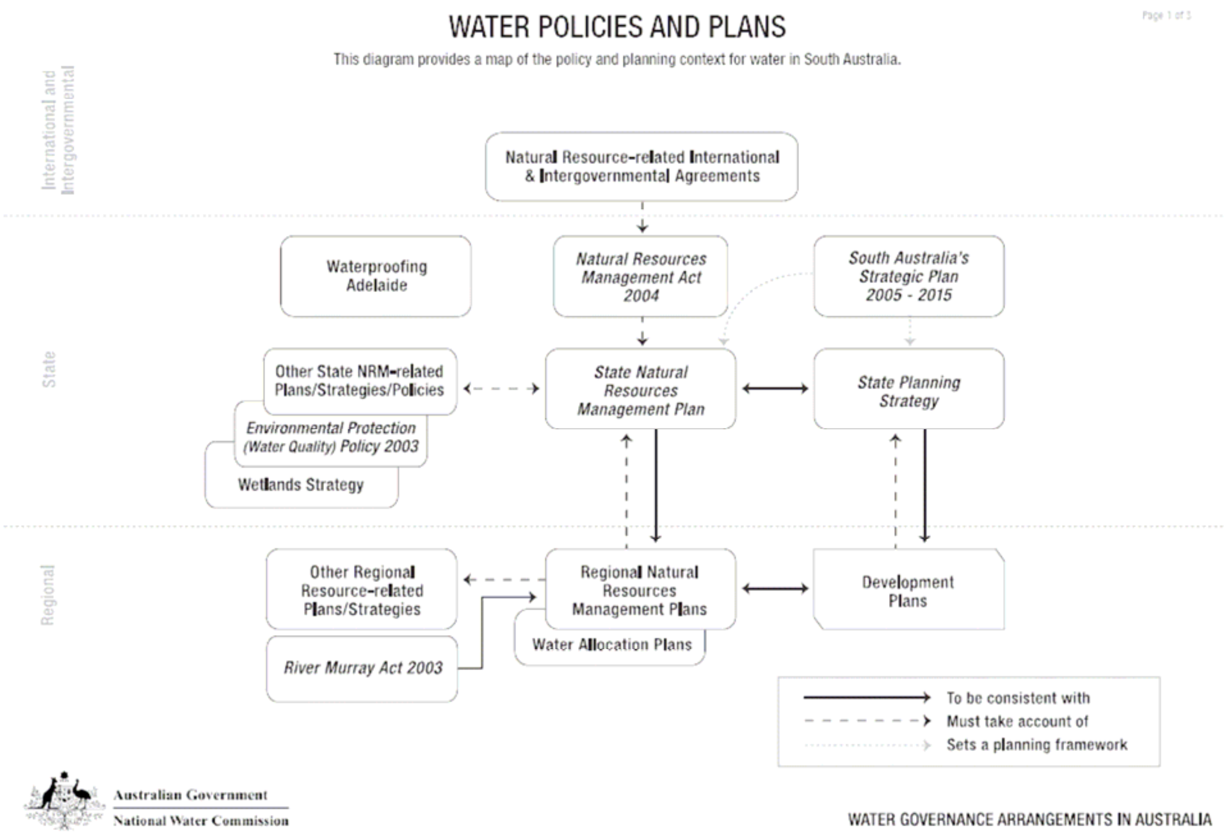


Figure 1. South Australian water policies and plans. Source: National Water Commission http://www.nwc.gov.au/nwi/water_governance/pdfs/sa-planning-urban.pdf.

T 3.1 was recently reinforced in 2007 with the release of the No Species Loss Strategy (GSA 2007b), which makes specific mention of Swamps of the Fleurieu Peninsula, the significance of which is discussed further in later sections.

STATE NRM PLAN 2006

The State Natural Resources Management Plan 2006 (NRM Plan) is a statutory plan required to be prepared under the NRM Act. It provides directions for ecologically sustainably management of natural resources for all of South Australia (GSA 2006).

The four Goals of the NRM Plan include managing natural resources within ecologically sustainable limits and minimising risks to natural systems. Guiding Principles include using the best available information in a precautionary way. Water use in areas where use is not required to be licensed, was identified as an issue for which there was cause for concern. Targets relevant to water resources management include:

- W 1 – By 2011, all ecosystems dependent on prescribed water resources have improved ecological health compared with 2006.
- W 3 – By 2015, no further net loss of wetland or estuary extent or condition, compared to 2006.
- B 3 – By 2011, no further net loss of natural habitat extent and condition below that of 2006.

Guidelines for sustainable water allocation and management

The NRM Plan provides a series of guidelines for managing ecosystems, water allocation, coastal, estuarine and marine systems, riparian, floodplain and wetland systems. Water allocation and management guidelines are contained within Appendix B and were adopted from the State Water Plan 2000 (GSA 2000) in line with the National Water Initiative. These guidelines provide an indicative precautionary sustainable use limit of surface water, for areas that do not have water resources prescribed or under the control of the relevant provisions of the NRM Act:

> *2. Outside prescribed areas, and until there is additional information, 25% of median annual adjusted catchment yield should be used as an indicator of the sustainable limit of the catchment surface water and watercourse water use. 'Adjusted' is defined as the annual catchment discharge with the impact of dam storage removed*.

(Appendix B, GSA 2006)

In considering allocating water for the environment,

> *20. In accordance with the precautionary principle, limited knowledge of ecosystems should not be used as a reason for degrading them or postponing measures to prevent their degradation.*

(Appendix A, GSA 2006)

and,

> *16. Water allocation and management decisions must take a precautionary approach by first ensuring environmental benefit outcomes, including natural ecological processes and biodiversity of water-dependent ecosystems, are maintained. It follows that further allocation of water for new consumptive uses, and any other new water resource developments, must ensure ecological values are protected.*

> *17. In systems where there are existing consumptive water users, environmental water provisions must be as close as possible to the required environmental water requirements while recognising the rights of these existing users.*

(Appendix B, GSA 2006)

The 25% Rule was first enshrined in state government policy in the State Water Plan 2000, and arose from water sharing rules developed to control farm dam development and promote sharing of water with downstream users, including water dependent ecosystems. Since that time the rule has been developed, with the collection of additional information, as the successful basis for water sharing rules in prescribed areas of the Mount Lofty Ranges and lower Mid North (CVWRPC 2000, NABCWMB 2000 and RMCWMB 2003).

Despite its empirical origins, the 25% Rule has been shown to be consistent with recent research in Victoria. The Sustainable Diversions Limit Project used an expert scientific panel approach to define sustainable surface water diversion limits for Victorian catchments that were based on sound, defensible scientific principles. A series of rules were recommended that resemble those in South Australian regional and water allocation plans, which included a maximum diversion of 23% of the mean winterfill (July to October) runoff and a requirement to pass low flows before diversions could commence. When combined, these rules resulted in a diversion volume equivalent to 10% of the mean winter streamflow (Nathan *et al* 2002, SKMCRC 2002, SKM 2003).

WATER ALLOCATION PLANNING

Outside of prescribed areas, water resources management issues are managed by the State Government according to its policies and plans. Local councils play an important role in managing development under the *Development Act 1993* (Dev Act), they may seek and consider specialist advice from State or other bodies to provide independent technical advice to inform decisions on specific developments.

Additional controls on water use are not possible in South Australia until the Minister responsible for the NRM Act is of the opinion that:

- the rate at which water is being taken is such that the available water can no longer meet the demand or is having a serious effect on the water resource and/or there is a risk that the available water would not be sufficient to meet future demand; or,
- it is necessary or desirable for their proper management to prescribe the water resources.

The evidence required to convince the Minister of the need to restrict water use or prescribe a water resource can include disputes between water users or conspicuous environmental degradation. Neither consequence reflects the principles of ecologically sustainable development (including intergenerational equity and the precautionary principle), which apply to NRM under the object of the NRM Act.

Once an area is prescribed, a regional NRM board must prepare a formal water allocation plan (WAP) for it, but additional controls also become available under the Dev Act. Within prescribed areas, commercial forestry is one of six activities recognised in the *Development Regulations 1993* (s12A, Schedule 8), that *may give rise to water allocation issues.* Proposed developments in a prescribed area that include these activities should be referred to the Minister responsible for the NRM Act for advice. Under these circumstances, councils cannot consent to or approve the development without having *regard* to the advice provided. In the absence of any additional information, the Minister should again use the 25% Rule as the primary guide to sustainable level of development.

In preparing a WAP, NRM boards must, among other things, ensure it:

- includes an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at which, or the periods during which, those ecosystems will need that water;
- provides for the allocation (including the quantity of water that is to be available for allocation) and use of water so that—

  (i) an equitable balance is achieved between environmental, social and economic needs for the water; and

  (ii) the rate of use of the water is sustainable;

- in providing for the allocation of water, takes into account the present and future needs of the occupiers of land in relation to the existing requirements and future capacity of the land and the likely effect of those provisions on the value of the land;
- assesses the capacity of the resource to meet the demands for water on a continuing basis and provide for regular monitoring of the capacity of the resource to meet those demands.

NATIONAL WATER INITIATIVE

South Australia is a signatory to the National Water Initiative Inter-governmental Agreement (NWI, AG 2004), arguably the most significant water reform in Australia's history. Its objective is to deliver a nationally-compatible, market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes (NWI, s23).

Its objectives will be met through the achievement of ten outcomes, including: transparent, statutory-based water planning; complete the return of all currently overallocated or overused systems to environmentally-sustainable levels of extraction, progressive removal of barriers to trade in water and meeting other requirements to facilitate the broadening and deepening of the water market and water accounting which is able to meet the information needs of different water systems in respect to planning, monitoring, trading and environmental and on-farm management (NWI, s23).

The required water access entitlements and planning frameworks will also identify and acknowledge surface and groundwater systems of high conservation values, and manage these systems to protect and enhance those values (NWI, s25).

Interception activities

The NWI recognises that farm dams and bores; intercepting and storing of overland flows and large-scale plantation forestry, have the potential to intercept significant volumes of water (s55). If these activities are not subject to some form of planning and regulation, they present a risk to the future integrity of water access entitlements and the achievement of environmental objectives (s56).

The NWI states an intention to base assessments of the significance of such activities on catchments and aquifers, on an understanding of the total water cycle, the economic and environmental costs and benefits of the activities of concern (s56). The integrity of water access entitlements and the achievement of environmental objectives are to be protected by applying appropriate planning, management and/or regulatory measures where necessary (NWI, s56).

Accordingly, NWI signatories agree to implement measures in relation to water interception on a priority basis, in accordance with the timetable contained in their implementation plans and no later than 2011 (NWI, s57). In systems that are fully allocated, overallocated, or approaching full allocation:

- interception activities that are assessed as being significant should be recorded, as per a licensing system;
- proposals for additional interception activities above an agreed threshold size would require a water access entitlement; and,
- a robust compliance monitoring regime would be implemented.

The agreed threshold size will be determined for the entire water system covered by a water plan, taking account of both the positive and negative impacts of water interception on regional natural resource management outcomes.

Water markets and trading

Water market and trading arrangements will: facilitate the operation of efficient water markets and the opportunities for trading and enable the appropriate mix of water products to develop, based on access entitlements which can be traded either in whole or in part, and either temporarily or permanently, or through lease arrangements or other trading options that may evolve over time.

Principles for water use and guidelines for water planning

Regulatory approvals enabling water use at a particular site for a particular purpose will be consistent with water and related NRM and planning legislation and have transparent and contestable processes in place to establish whether a proposed activity is to be approved (NWI, Schedule D).

Water planning processes should include the application of the best available scientific knowledge and adequate opportunity for consumptive use, environmental, cultural, and other public benefit issues to be identified and considered in an open and transparent way (NWI, Schedule E).

THE MOUNT LOFTY RANGES

The Mount Lofty Ranges (MLRs) are a series of hills that stretch from the Fleurieu Peninsula in the south and extend northwards for over 300 kilometres to the township of Peterborough in the State's Mid North. North of Peterborough the ranges continue as low hills and eventually form the Flinders Ranges.

The MLRs are situated between the Gulf St Vincent and the South Australian Murray-Darling Basin, their ridgeline forming a major regional catchment divide. The region west of the catchment divide is known as the Western Mount Lofty Ranges (WMLRs) and that to the east, the Eastern Mount Lofty Ranges (EMLRs). The highest point in the ranges, Mount Lofty summit has an elevation of 730 m, 13 km south east of the city of Adelaide.

The area can be conveniently described in terms of its geomorphology. Most of the WMLRs and the Flinders Ranges are underlain by the Neoproterozoic meta-sediments of the Adelaide Geosyncline, while the EMLRs are underlain by younger Cambrian meta-sediments. Both sequences are heavily deformed and faulted, the ranges themselves rise in a series of active horst and graben structures above the Tertiary sediments of the Adelaide plains to the west and the Murray Basin to the east (Drexel *et al* 1993, Drexel & Preiss 1995).

The underlying structural complexity of the basement rocks has contributed to the development of a complex mosaic of relatively small catchments, which can become particularly steep in the WMLRs. Runoff can be highly variable in both regions. Despite a small area of Permian glacial sediments in the southern Fleurieu Peninsula the groundwater of the entire region is dominated by fractured rock aquifers. Those in the WMLRs are considered better aquifers than those in the EMLRs, which have tighter fractures and generally poorer yield and water quality (GSA 2007#4).

REGIONAL CLIMATE AND HYDROLOGY

The climate is Mediterranean. Winters are short, mild and wet, seasonal rainfall is characterised by the encroachment of low-pressure frontal systems from the Southern Ocean, the yields of which are heavily influenced by orographic uplift. Summers are long, hot and dry and may bring erratic but intense storms from low latitudes (Gentilli 1979). Mean annual rainfall ranges to around 1,100 mm/year, but most of the region receives 600 to 800 mm/year (DWLBC BOM 2006).

Catchments within the WMLRs have higher rainfall and more reliable surface water resources than their eastern counterparts. The Gawler, Torrens and Onkaparinga Rivers form the bulk of the Adelaide regulated water supply system, which in a normal year supplies 60% of Adelaide's supply, the balance being transferred from the River Murray (GSA 2007#2). Runoff ranges from around 70 mm/year in areas of lower elevation, up to 140 mm/year at a catchment scale (Heneker 2003, Teoh 2002).

Limited water monitoring and regulation infrastructure in the Fleurieu Peninsula has resulted in greater uncertainty in water resources assessments. Catchments are generally much smaller than those of the greater WMLRs. Rainfall ranges from 650 mm/year at the coast to around 900 mm/year in the central upland regions, over a distance of 8 km. Runoff levels are expected to be similar to those observed elsewhere in the WMLRs (Clark *et al* 2007).

The EMLRs occupy a rain shadow behind the regional catchment divide. Mean annual rainfall is more modest and shows considerable variability along the regional catchment divide, ranging from 900 mm/year in the south to around 700 mm/year in the north. Rainfall along the eastern edge of the EMLRs, varies from around 450 mm/year in the south to 350 mm/year in the north. Runoff in wetter areas can be similar to the WMLRs, but water resources are generally much more scarce (Alcorn 2006a,b, Savadamuthu 2002, 2003).

REGIONAL WATER ALLOCATION PLANNING

Concerns regarding their current and future security have resulted in the water resources of the MLRs, including surface water, watercourse water and underground water, being subject to the highest level of state government legislative control.

On 16 October 2003, the water resources of the EMLRs were placed under a Notice of Prohibition by the Minister for Environment and Conservation under the *Water Resources Act 1997* (WR Act), and the WMLRs on 14 October 2004. A Notice of Prohibition is an instrument under the NRM Act (and the former WR Act, which it repealed), that places a moratorium on the taking of water from an area. The MLR Notices were published because the rate at which water was being taken was such that:

- the available water could no longer meet the demand or was having a serious effect on the water resource; and,
- there was a risk that the available water would not be sufficient to meet future demand.

On 8 September 2005 the EMLRs became a Prescribed Watercourse and Surface Water Prescribed Area and a Prescribed Wells Area under the NRM Act.

On 20 October 2005, the WMLR Notice was varied to ensure that Prospective Users could not take water from the EPBC Act 1999-listed Swamps of the Fleurieu Peninsula and on the same date, the WMLRs became a prescribed area.

The South Australian Murray-Darling Basin (SAMDB) NRM Board is responsible for developing the EMLR WAP, while the Adelaide and Mount Lofty Ranges (AMLR) NRM Board is responsible for developing the WMLR WAP. DWLBC is assisting both NRM boards in developing their WAPs, through completing hydrological assessments and providing scientific advice for a range of WAP-related issues, including the water requirements of ecosystems, including Swamps of the Fleurieu Peninsula and the impact of plantation forestry on water resources. DWLBC is also responsible for the overall water licensing process as well as allocating water to those who were existing users at the time the prescription process started.

SIGNIFICANT WATER DEPENDENT ECOSYSTEMS

The Mount Lofty Ranges contain a variety of water dependent ecosystems, including estuaries, permanent pools, areas featuring permanent baseflow and wetlands

Estuaries are important for supporting populations of macroinvertebrates, fish and birds, and are of particular importance as nurseries for many native freshwater and marine fish species. Permanent pool and baseflow systems are of critical importance to the ecology of the region. They act as core refuge areas for aquatic life during dry periods and provide points from which dispersal and colonisation can occur during wetter periods.

Wetlands are recognised as being amongst the most important natural assets of South Australia (DWLBC DEH 2003), and form an important component of healthy river systems, lakes, and estuaries. Wetlands of the MLRs support over 700 plant species and 180 vertebrate species, many of which have conservation status (Harding 2005). MLR wetlands include Swamps of the Fleurieu Peninsula, listed as a Critically Endangered Ecological Community under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), since March 2003 (AG 2007).

PLANTATION FORESTRY

In 2005-06, the South Australian Government forest management agency, ForestrySA, managed over 83,000 ha of standing plantation forest. Some 80,500 ha or over 95% were in softwood plantations, principally *Pinus radiata*. State forestry operations in 2005-06 yielded a net profit of $13.3 M to the Government of South Australia (FSA 2006).

At 30 June 2006, ForestrySA plantations in the MLRs, including plantations on MLR Waterworks Reserves, totaled approximately 10,000 ha or 12% of its total estate. Ninety-three percent of plantings were *Pinus radiata* and the remainder other pine and hardwood species including *Eucalyptus globulus* (FSA 2006).

The most active private forestry interest in the MLR region is Adelaide Bluegums Pty Ltd (ABL) of Victor Harbour, a consortium of private Japanese organisations comprising: Mitsubishi Paper Mills Ltd, Hokuetsu Paper Mills Ltd, AEON Co Ltd, Chubu Electric Power Co Inc, Tokyo Gas Co Ltd, Nippon Yusen Kabushiki Kaisha Line and the Mitsubishi Corporation, who in September 2002 announced a joint-venture agreement on a joint afforestation business in South Australia (Chubu 2002). Afforestation was targeted at a total of 10,000 ha of *Eucalyptus globulus*, planted at a rate of 1,000 ha/year.

Planting was scheduled to begin in 2003, with logging to start from 2014 at a rate of 1,000 ha annually. Harvested trees were to be processed on the spot into wood chips for paper production, which are to be sold exclusively to Mitsubishi Paper Mills Ltd and Hokuetsu Paper Mills Ltd (Chubu 2002).

The project is managed by Rural Solutions, a Government of South Australia-owned consulting organisation within the Department of Primary Industries and Resources South Australia, (PIRSA). In 2007 the total target area was revised down to 6,600 ha (Deering *pers comm*.). DWLBC and ABL data indicate that to date the project has established approximately 2,000 ha of forest on a combination of freehold and leased land (Deering *pers comm*.). A number of ABL proposed developments have included catchments containing Fleurieu Swamps, giving rise to discussions regarding appropriate forms of assessment and water allocation.

Other private forestry on small farm holdings represents an additional 1,000 ha (Ho *pers comm*. 2007).

SWAMPS OF THE FLEURIEU PENINSULA

The Fleurieu Peninsula region contains a range of wetland community types, including creek-line floodplains, coastal and salt marsh wetlands. The majority of wetlands within the Fleurieu Peninsula occur in the higher rainfall regions of the southern Fleurieu Peninsula (750mm per annum and above) (Figure 2). Many of the wetlands found in the higher rainfall areas are considered to be Swamps of the Fleurieu Peninsula (Harding 2005).

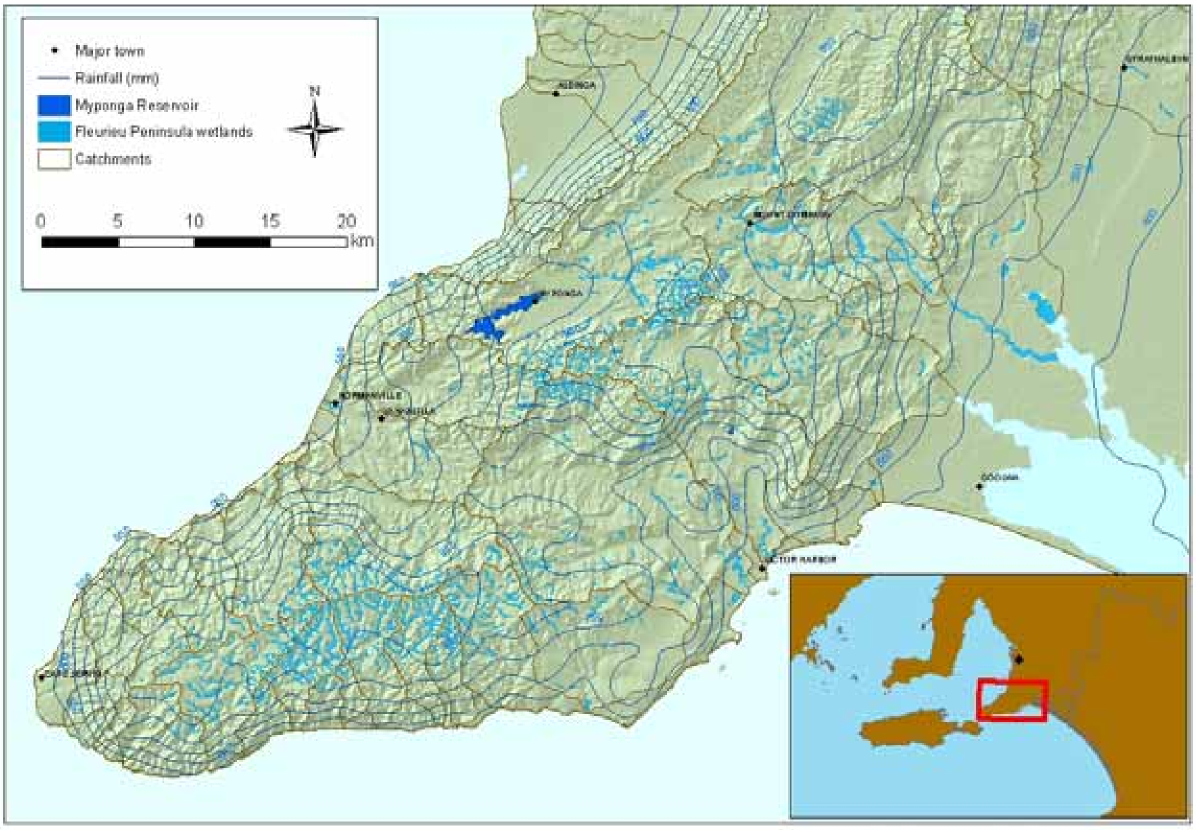


Figure 2. Swamps of the Fleurieu Peninsula

Fleurieu Peninsula Swamps occur across many landscapes, including subtle topographic depressions; between steeply dissected hills, or as perched wetlands in plateau regions. They are home to a number of plants and animals that are listed as endangered under the EPBC Act, and are found nowhere else in Australia. Foremost amongst these is the Mount Lofty Ranges Southern Emu-wren, as well as three endangered plants species — the White Beauty Spider-orchid, Maroon Leek-orchid and Osborn’s Eyebright (AG 2003).

Research suggests that the pre-European distribution of swamps and wetlands on the Fleurieu Peninsula was once much more extensive than it is today. There are indications that intact Fleurieu Swamps have been reduced by around 75% of their original extent – from an estimated 2,000 ha (Lamprey & Mitchell 1979) to approximately 500 ha (AG 2003, Duffield *et al* 2000).

STATUS

As a result of the reduction in size of wetland communities and the high conservation value of flora and fauna, the *Swamps of the Fleurieu Peninsula* have been listed as a *Critically Endangered Ecological Community* under the EPBC Act.

An *Ecological Community* is defined as:

> *an assemblage of native species that: (a) inhabits a particular area in nature; and (b) meets the additional criteria specified in the regulations (if any) made for the purposes of this definition.*

(s528, AG 1999)

Critically Endangered is defined as:

> *An ecological community is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.*

(s182(1), AG 1999)

Currently, the majority of Fleurieu Peninsula wetlands are listed under the EPBC Act. The Conservation Council of South Australia, as part of their Mount Lofty Ranges Southern Emu Wren and Fleurieu Peninsula Swamps Recovery Program, is revising the definition of the Fleurieu Peninsula Swamps Ecological Community, with implications for wetlands listed under the EPBC Act.

ECOLOGY

Fleurieu Peninsula swamps are characterised by their reedy or heathy vegetation growing on peat, silt, peat silt, or black clay soils5. The swamps provide various ecosystem services to the Southern Fleurieu Peninsula region. They act as natural water filters to trap sediments and nutrients and to break down pollutants from fertilisers and pesticides. This improves water quality for downstream use. In addition to intercepting surface flow water, many Fleurieu Peninsula swamps exist where natural springs reach the surface and discharge water, thereby providing a perennial water supply (Harding 2005).

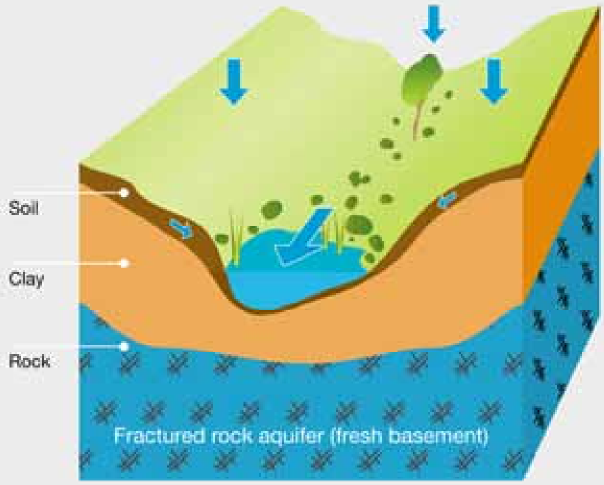
HYDROGEOLOGY, SOILS AND CLASSIFICATION

DWLBC have broadly categorised all Fleurieu Peninsula wetlands, including Fleurieu Peninsula Swamps, on the basis of their position in the landscape and their underlying geology: Perched, Fractured Rock and Permian Sand wetlands (Figure 3, below).

There will be a gradual transition between the perched wetlands near the top of the catchment, and the fractured rock wetlands near the bottom. The predominant source of water for a wetland may change as its elevation decreases down the catchment, with the boundaries of particular sources difficult to determine.

Model 1 - Perched

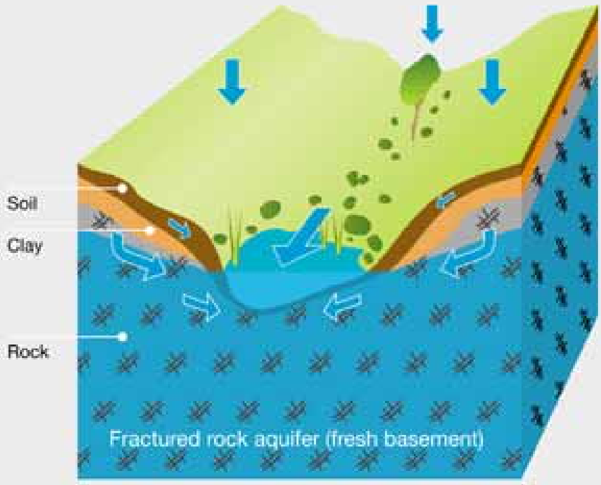
Perched aquifers occur in the upper catchments. They sit over a thick layer of clayey weathered sediments and have no connection to the fractured rock aquifers beneath the clay. This lack of connection means that their ecosystems are highly dependent on rainfall runoff, lateral subflow from unconsolidated sediments overlying the clay or upstream flow contributions. These systems are more sensitive to surface water changes than to underground water changes. Development of surface water resources or disruptions to subsurface flow will have the greatest impact on flora and fauna in this setting.



A cross-section of a wetland overlying a perched aquifer.

Model 2 - Fractured rock

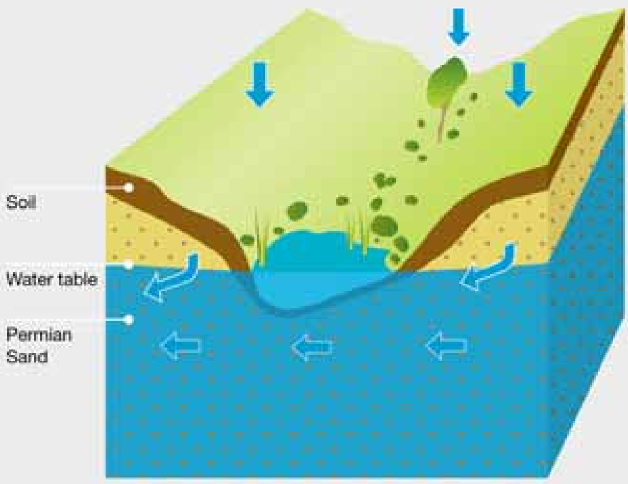
Toward the bottom of the catchments, ecosystems can have direct contact with the regional fractured rock aquifer. Important water contributions come from surface water runoff, subsurface flow and groundwater discharge. Underground water extraction from bores can cause cones of depression (lowering of the groundwater table), which can dramatically impact on the amount of water available to water-dependent ecosystems. These systems are sensitive to both surface water and underground water development.



A cross-section of a wetland overlying a fractured rock aquifer.

Model 3 – Permian sand

Water dependent ecosystems in Permian sands generally have a direct connection to the regional water table aquifer for most of the year. While surface water contributions will still be important, groundwater often delivers a large proportion of the water required by these ecosystems. Underground water extraction via bores can reduce contributions or disconnect water-dependent ecosystems from the Permian sand aquifer by lowering the water table. These systems are more sensitive to underground water development than to surface water development.



A cross-section of a wetland overlying a Permian sand aquifer.

Figure 3. DWLBC categories of Swamps of the Fleurieu Peninsula. Source GSA (2007#7)

Many of the Fleurieu Peninsula Swamps contain peat, which must remain moist at all times. Once peat dries it is very difficult to rewet and can become highly susceptible to erosion.

THREATS

The major threats to wetlands in the Fleurieu Peninsula include water resource development, weed invasion, land clearing and burning, intensive grazing pressure and forestry plantations. Water resource development, through farm dams, watercourse extractions and wells, can all significantly reduce the amount of water available to swamps and wetlands. However, other changes in land use, such as plantation forestry, can also significantly impact on a wetland receiving its water requirements. Impacts from forestry are particularly challenging as it is currently difficult to impose water-taking rules such as can be used for other permitted consumptive users.

WETLAND EXTENT METHODOLOGY

DWLBC, in conjunction with DEH and CCSA are currently working on a methodology for defining wetland extent. Current Fleurieu Peninsula wetland extent mapping has been determined either through remote sensing or through ground truthing the location of remotely sensed wetlands – that is, not ground truthing the wetland boundary, just the existence and location of wetlands . The need to determine the extent of wetlands in the Fleurieu Peninsula has grown through increasing demands for development in the region – especially with respect to plantation forestry.

The draft wetland extent methodology may be carried out on individual wetlands and includes a topographic and geomorphic remotely sensed mapping exercise prior to field verification of wetland extent through soil and vegetation sampling. It is envisaged that contractors will be trained in the methodology as preferred wetland extent assessors, with each assessment being contracted out to preferred assessors by the developer on a need-by-need basis.

WETLAND WATER REQUIREMENTS

In 2006 discussions were held between government agencies regarding the development of plantation forestry and the protection of Fleurieu Swamps. Among the issues under discussion were appropriate methods to determine protective buffer widths around wetlands and watercourses. Two methods were considered, the first using the concept of effective length in hillslopes (Aryal *et al* 2003) and the DWLBC Forest Wetland Water Balance method. The effective length method attempts to quantify the amount of catchment contributing to runoff through partial saturation using analytical Darcian concepts. Once a theoretical effective length is defined around feature, a buffer width may be defined.

As part of the inter-agency discussions, DWLBC conducted an assessment of the application of the effective length concept in determining buffer zones at two proposed ABL development sites on the Fleureiu Peninsula: ‘Greenhills’ in the Inman River catchment near Victor Harbour and ‘Hindmarsh Valley’ in the Hindmarsh River catchment.

DWLBC found that results were heavily influenced by hydraulic conductivity and the choice of soil horizons. Its application proved to be prone to subjective interpretation, limited by the availability of data and did not contribute to managing water resources within the catchment’s consumptive pool, including sharing resources with downstream users (DWLBC 2006).

In comparison the water balance approach was considered holistic, comprehensive and could be used to calculate the total maximum area of a catchment that could be forested and still maintain the health of a wetland, in a repeatable way (DWLBC 2006). Persistent concerns by some stakeholders resulted in the two methods being reviewed by independent consultants who concluded that:

> *The water balance model described can be used to assess the potential impacts of plantations on swamp water requirements and it provides estimates of maximum plantation area for a given threshold value. The model can be improved by incorporating spatial information regarding soil, vegetation, and landscape position. For example, the effective area estimated by the Aryal method can be included into the model.*
>
> *The maximum plantation area in a catchment is determined mainly by average annual rainfall and proportional swamp area. Wetter catchments with smaller swamps will be able to accommodate larger plantation areas. Site specific data such as rainfall, runoff, and plantation water use will improve model accuracy.*

(Casanova & Zhang 2007)

WETLAND WATER BALANCE

The wetland water balance model estimates the annual water requirements of a perched Fleurieu Swamp as a demand from an upstream catchment. A summary of the elements of the model is shown in Figure 4 (below). In its simplest form, assuming no change in storage, a water balance can be constructed whereby the inflows to the wetland must equal the demands of the wetland and outflows.

$$\text{inflows} = \text{wetland demands} + \text{outflows} \qquad (1)$$

The wetland inflows comprise direct rainfall and upstream flow. The wetland demands include evapotranspiration and other losses. The wetland water *requirements* are then the portion of the flow from upstream required to meet the deficit created between precipitation and evapotranspiration and other wetland losses.

$$WWR = ET + \text{other losses} - P \qquad (2)$$

where WWR = mean annual wetland water requirements (mm/year); ET = mean annual wetland evapotranspiration (mm/year) and P = mean annual precipitation (mm/year).

For much of the Fleurieu Peninsula, mean annual rainfall is around 800 mm/year while evapotranspiration is probably around 1,000 (see further discussion below). If they occurred as uniformly distributed phenomena, the daily precipitation and evapotranspiration would amount to 2 and 3 mm/day respectively, resulting in a wetland demand of around 1 mm/day. The wetland demand and its peculiar climate would combine to prohibit all runoff or groundwater losses, leaving the wetland system in perpetual water deficit.

Experience shows that this is far from the case. Rainfall occurs episodically, in seasonally distributed events with characteristic intensities, frequencies and duration. When rain falls in abundance, as is typical of MLR winters, plant interception is penetrated, soil stores are filled, the ability of wetland water dependent ecosystems to use water is exceeded and runoff is generated.

When rainfall infiltrates perched swamps that have no effective connection to regional aquifers, water becomes trapped above the impervious weathered bedrock and tends to flow down-slope as gravity driven seepage. Although direct runoff and seepage can neither be evaportranspired or used by the wetland, they form a fundamental part of the wetland hydrologic cycle and can be seen as elements of the driving integrated eco-hydrological system that delivers wetland water requirements. They must be accounted for as part of the water balance, in order for the wetland demand to be met.

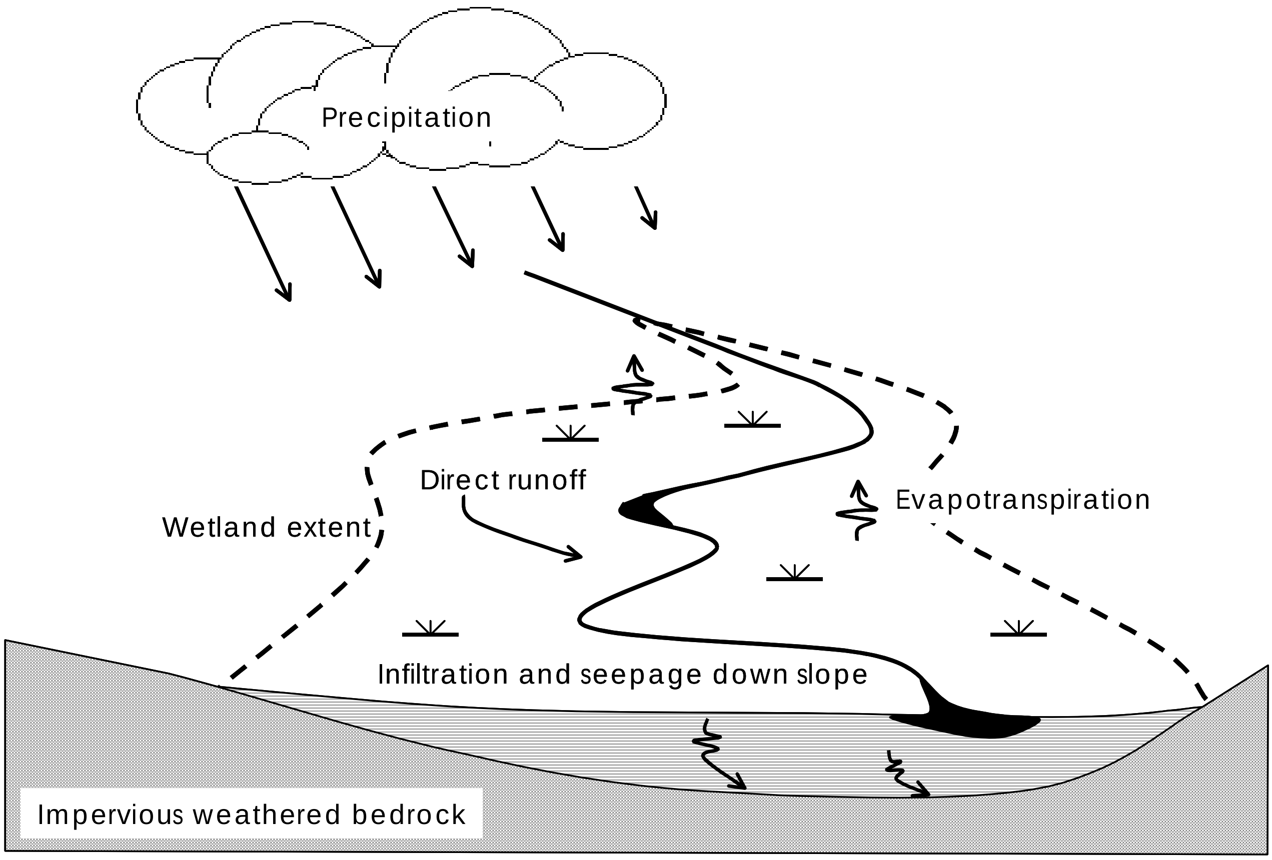


Figure 4. Elements of a water balance for a perched Swamp of the Fleurieu Peninsula

The water balance of a perched wetland may then be written as per equation (3), while the wetland water requirements may be written as in equation (4):

$$\text{upstream flows} + P = ET + DRO + SP + \text{excess outflows} \qquad (3)$$

$$WWR = ET + DRO + SP - P \qquad (4)$$

Where DRO is direct runoff (mm/year) and SP is seepage (mm/year). Using these parameters, the total wetland water requirements are then a function of wetland area and a number of highly variable hydraulic parameters, which represent a significant information gap.

Parameters

With the exception of precipitation, there is considerable uncertainty around the parameters used in the current form of equations (3) and (4) above. Until additional information becomes available, DWLBC has used those shown in Table 1 (below).

Wetland ET was estimated using Bureau of Meteorology (BOM) point potential ET, which relates to systems where ET processes do not alter local air-mass properties (BOM 2005, 2006), adjusted with a notional 'crop' coefficient of 0.7, according to the procedure of described in Allen *et al* (1998), for converting reference evapotranspiration to crop evapotranspiration.

Table 1. Wetland water balance parameters adopted to date

Parameter	Value (mm/year)	Comments
Precipitation	Varies	DWLBC BOM, (2006) 25 mm/year isohyets 1971 to 2000
Wetland evapo-transpiration	0.7 x (1,400 to1,600)	Point potential evapotranspiration (BOM 2005, 2006) adjusted with a notional coefficient of 0.7 to estimate 'actual' evapotranspiration after Allen *et al* (1998).
Wetland runoff	0.6 cleared catchment runoff	60% of the cleared catchment runoff. Represents a 'first estimate' based on expert opinion.
Wetland seepage	0.1 x (ET + DRO – P)	10% of the demand estimated using wetland area.

Catchment runoff levels in the MLRs and Fleurieu Peninsula have been determined under current land-uses through a range of State Government assessment initiatives (Alcorn 2006a,b; Clark *et al* 2007; Heneker 2003; Savadamuthu 2002, 2003 and Teoh 2002). Direct wetland runoff is a predominantly winter phenomena that depends on the saturation of the soils and the density and type of vegetation. In the absence of any other information for Fleurieu Swamps, a notional 60% of the annual cleared catchment runoff has been used. The factor neglects saturation and assumes that runoff would be less than that from a cleared catchment (Cresswell *pers comm*.).

Little is known of how these processes occur in Fleurieu Swamps. Consequently the estimate used to date represents a starting point in knowledge development and it may transpire that none of the underlying assumptions prove valid in future investigations (Cresswell *pers comm*.).

Observations of hydrostatic head within Fleurieu Swamps indicate gravity-driven, down-slope seepage along and between wetlands (Barnett *pers comm*.). Seepage is a function of wetland size, slope and hydraulic conductivity. Without specific information on hydraulic conductivity, site-by-site assessments are not possible and until more information becomes available, a surrogate for actual seepage has been used. The volume of seepage is estimated as a small proportion (10%) of the total demand calculated as the difference between mean annual precipitation, evapotranspiration and direct runoff (equation 5).

$$SP = (ET + DRO - P) \times 0.10 \qquad (5)$$

So that the total wetland water requirements from the upstream catchment become:

$$WWR = (ET + DRO - P) \times 1.1 \qquad (6)$$

STREAMFLOW REDUCTIONS DUE TO FORESTRY

The impacts of plantation forestry on water resources have been well documented. Trees use and intercept more water than pasture due to greater levels of transpiration, interception of rainfall and groundwater extraction through roots. Consequences of afforestation include reductions in runoff, and groundwater recharge and lowered water tables, which tend to be at their greatest under dry conditions (Zhang *et al* 2007).

A range of international and local studies has investigated the reductions in streamflow induced by the development of plantation forestry in cleared or mixed land-use catchments. Scott & Smith (1997) used observed data from paired catchment studies to derive empirical models that indicated maximum reductions in runoff due to pine trees of between 85% and 100% under sub-optimal and optimal growing conditions. Vertessy & Bessard (1999) developed a simple model to predict impacts of afforestation on mean annual runoff in 28 catchments of the Murrumbidgee Basin based on Holmes & Sinclair (1986) evapotranspiration-rainfall curves. Their Figure 4 and a later work by Vertessy (2001) and Vertessy *et al* (2002) indicated that if grassed catchments with mean annual rainfall of 800 mm/year and 210 mm mean annual runoff were planted to eucalypt forest, runoff maybe expected to reduce by 165 mm/year to 45 mm/year mean annual runoff (a 79% reduction) and 210 mm if planted to pines (a 100% reduction).

Bradford *et al* (2001) and Zhang *et al* (2003) constructed theoretical forest and pasture runoff curves as the difference between theoretical mean annual evapotranspiration and rainfall. The proportional difference between mean annual pasture and forest runoff ranged from 60 to 85% of pasture runoff in areas with mean annual rainfall ranging up to 1000 mm.

The low flow frequency analysis of Lane *et al* (2003) showed pine plantation-induced decreases in runoff of 100% for flows with exceedances greater than 30%, 40% and 60% for their Group 1 catchments of Redhill, Stewarts Creek and Pine Creek respectively. Under wetter conditions reductions ranged between 50 and 95% (their Figure 5, p18).

BEST AVAILABLE LOCAL INFORMATION

For South Australian water resources management, use has been made of data collected in the MLRs, at Burnt Out Creek in the Onkaparinga River catchment on the southern side of the Mount Bold Reservoir. In 1977 a *P. radiata* plantation established in the early 1960s was two thirds cleared following a bushfire. In 1978 a hydrometric streamflow gauging weir was installed and the plantation replanted. Continuous streamflow data were collected from 1978 to 1987 when it was temporarily closed. After five years the young forest had reached canopy closure. For the period 1983 to 1986 streamflow was observed to have reduced by between 75 and 89% (Greenwood & Cresswell 2007).

In 2001 the station was re-opened and remains operational. Streamflow reductions from 2002 to 2005 were observed to have remained at similar levels, ranging between 73 and 91% of the levels observed when two-thirds of the catchment was pre-forested. The average observed reduction for the period following the first five years of re-growth to 2005 was approximately 82%. If 2006, a particularly dry year when reductions exceeded 93% is included, the average reduction increases to 84% (Greenwood & Cresswell 2007).

Burnt Out Creek data show that in the rainfall range from 500 to 1200 mm/year, which covers all the areas prospective for plantation forestry in the Mount Lofty Ranges, Fleurieu Peninsula and Kangaroo Island, the expected reduction in runoff can be expected to be between 75 and 100%, depending on annual rainfall. In years with annual rainfall of 800 mm, close to average for much of the area currently of interest to forestry developers in the Mount Lofty Ranges, Fleurieu Peninsula and Kangaroo Island, reductions in runoff could be expected to be approximately 85% (Greenwood & Cresswell 2007).

These data are consistent with Australian and international studies, but have the additional benefits of being based on both observed and local information. Based on these findings, DWLBC assumes the impact of plantation forestry on surface water resources across the MLRs and on Kangaroo Island is to reduce runoff by an average of 85%. For water planning and management purposes, this reduction is equated to the expected average maximum annual water use of plantation forestry.

ASSESSMENT PROCEDURE

The method described here was developed to determine the maximum levels of sustainable of forestry in the MLRs, Fleurieu Peninsula and Kangaroo Island within the State Government precautionary NRM and policy framework. Issues around providing water for high value wetlands arise in catchments with Fleurieu Swamps, otherwise an identical procedure could be used for assessing farm dam-irrigation or any other water use. Elements of the procedure are recognizable in a range of South Australian statutory water resources management and NRM plans, whose water allocation and permit rules share a common basis in the 25% Rule (GSA 2000; CVWRPC 2000; NABCWMB 2000 and RMCWMB 2003).

The procedure requires three scales of assessment: A catchment–scale assessment to determine if capacity exists for further development; a sub-catchment-scale assessment to ensure the resource is equitably developed within the catchment and a property-scale assessment to determine the final levels of sustainable development.

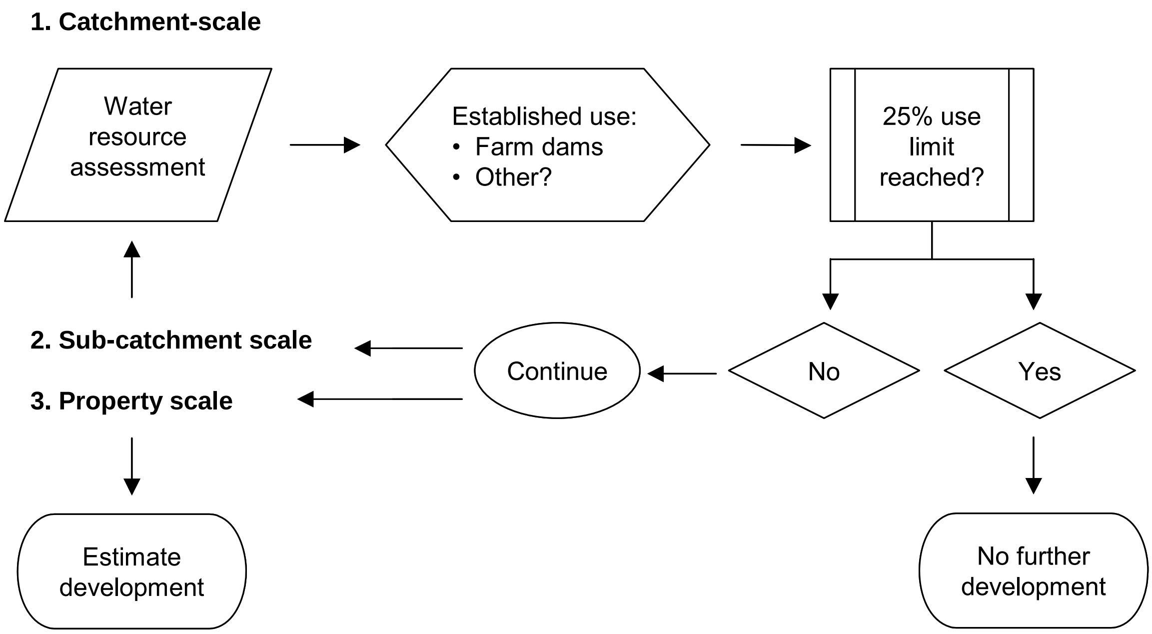


Figure 5. Assessment process

PRINCIPLES

Observed or robust modelled runoff data are used, supported by expert, local opinion if required. Methods described by Zhang *et al* (1999) and Zhang *et al* (2003) are not considered appropriate for water allocation planning as they provide an unrealistically high estimate of runoff from Australian catchments and endow them with resources that cannot be relied upon with sufficient confidence to form part of an allocation process (Greenwood 2007).

Consistent with NRM Plan guidelines (see above) and advice from Casanova & Zhang (2007), regarding protecting wetland integrity under the EPBC Act, 100% of the identified wetland water requirements need to be met. Deciding the ultimate amount of water that should be provided to Fleurieu Swamps and other water dependent ecosystems and the acceptable level of risk, is currently the subject of consideration within the regional MLR water allocation processes being run by the relevant NRM boards.

Use from farm dams is estimated at a maximum of 50% of the total farm dam capacity in accordance with the precautionary character of the assessment. Due to the lack of inflow during dry years, unharvestable spills occurring in large events and wet years, evaporation and seepage, experience has shown that only half of their volume can be reliably accessed from farm dams every year (GSA 2000). Recent assessments indicate that the figure in the MLRs may actually be closer to 30% (McMurray 2003), but is less precautionary.

Average maximum annual water use by forestry is assumed to total 85% of the cleared-catchment runoff. The maximum area of forestry is calculated as the limit of the area at which all the remaining, available water is used. Rotation and other plantation management practices may result in a lower average use over the harvest cycle of a forest, but allocating at this level would present a risk to entitlements of downstream users in years when forest water use was at its maximum.

INVOKING THE 25% RULE

The sustainable use limit (SUL) is determined using available runoff information, the catchment area and the 25% Rule. In conventional assessments half the estimated farm dam capacity (FDC) would be subtracted from the SUL to determine the water resources available for further development. Wetland requirements cannot be treated in the same way as they are effectively already integrated into the estimate of catchment runoff. Managing their allocations in this way would amount to double accounting and quickly result in depleting the available SUL. There is currently insufficient information to use runoff estimates that are adjusted for wetland use, so the problem is addressed by removing them from the estimate of total available catchment resources when estimating the SUL under the 25% Rule (equation 7).

$$SUL = (\text{Total catchment resources} - WWR) \times 0.25 \quad (7)$$

By removing the wetland requirements from the available resource, they become effectively embargoed from the SUL and always provided for before additional development can occur. On the other hand, the catchment-scale resources are only modestly reduced, meaning that the SUL is not consumed by double-accounted wetland water requirements and a more realistic amount of water is available for ecologically sustainable development (ESD).

The final amount of water available for further ESD is determined once prior use from farm dams is taken into account. The final amount of available water (AW) is:

$$AW = SUL - FD \times 0.5 \quad (8)$$

A number of decisions can be made at this stage of the assessment. If the catchment has no capacity available under the SUL, then further development may not be recommended. If a small amount of capacity is available, then development may be recommended to the level of the remaining capacity of the SUL. Given the nature of the assessment and limitations in information on which it is based, it has been the authors' preferred position to view the catchment-scale assessment as a simple indication of water resources development. Any capacity within the estimated SUL is viewed as a 'green light' to proceed to a sub-catchment scale of assessment.

CATCHMENT-SCALE ASSESSMENT

Catchment-scale AW is estimated by accounting for all farm dams, forestry and wetlands in the catchment as a lumped volume or area. Most Fleurieu catchments assessed to date do not carry significant levels of established plantation forestry. In the case of wetland demands, DRO and SP volumes generated by upstream wetlands are conceptually available to meet a portion of downstream WWRs, resulting in a large total wetland demand at a catchment-scale. Although consistent with the precautionary nature of the assessment it was decided to offset this effect and simplify the assessment, by ignoring seepage at a catchment-scale. Any capacity within the SUL is then viewed as a 'green light' to proceed to a sub-catchment scale assessment.

SUB-CATCHMENT-SCALE ASSESSMENT

The procedure is then repeated across all the sub-catchments that completely contain the development. This ensures that new water-using developments do not monopolise the remaining resources at a sub-catchment scale and deny neighbouring and downstream users, including water dependent ecosystems, access to their share of the consumptive pool.

At this scale the water balance parameters become more realistic. Direct runoff and seepage from upland wetlands contribute to the requirements of those in the downstream reaches of the sub-catchment, reducing the total amount of water needed to be provided to downstream wetlands. This makes areas in the upper reaches of sub-catchments less attractive to development since wetland water requirements are not offset by upstream contributions.

Sub-catchments with a level of prior use above their SUL should be considered closed to further development. Any part of a proposed development that falls within such an area would not be considered. However, any part of a development that lies within a sub-catchment with excess capacity under its SUL may be given a 'green light' to proceed to the final property-scale assessment.

PROPERTY-SCALE ASSESSMENT

The assessment at a property scale follows the same procedure as above. A significant difference is encountered when the development is located in a sub-catchment that contains a wetland.

In this case the total sub-catchment WWRs are estimated using the water balance method described above, allowing for contributions from upstream wetlands. The amount of the WWR that the property is obliged to provide to the wetland is estimated by multiplying the total WWR by the areal fraction of the wetland catchment the property represents.

$$\text{Property WWR} = \text{Sub-catch WWR} \times \text{Property Area/Sub-catch Area} \tag{9}$$

BUFFERS

The ultimate impacts of forestry on water resources vary according to the part of the landscape in which the plantation is established. Guidelines for the development of plantation forestry have evolved toward providing a framework for environmentally sustainable timber production (PSA 200; SV 2006; SA 2007). Much of this material aims to address land management issues, such as the establishment of fire-breaks and buffers around buildings and infrastructure. Only a relatively modest portion of this material is dedicated to water resources issues, the majority of which is primarily concerned with water quality. However, if buffers are not established to meet water resources management objectives, even sustainable levels of forestry development may have deleterious impacts on downstream users, including the environment.

Water resources management raises issues that are new to forestry developers. Principle among these are the concepts of a shared, consumptive pool and requirement to pass a shared portion of the resource to downstream users. The ability of trees to access near-surface water resources also requires that water dependent ecosystems be protected from the direct impacts of forestry by buffers.

Cleared areas completely surrounded by forestry are prohibited from contributing to catchment yield by the high levels of interception and plantation water use. Any areas isolated in this way, cannot be regarded as hydraulically separate from the plantation and should be accounted for as part of the development. Consequently, all areas with significant hydraulic connectivity to downstream systems should be buffered. A minimum 50 m buffer should be established around all streams depicted on 1:50,000 scale topographic maps and any wetlands. The width has been set as a minimum interstate (GWA 2000) and is considered sufficient by DWLBC to manage direct uptake from watercourses and wetlands by lateral root growth (20 m, Knight 1997) and water table lowering (40 m, Vertessy *et al*, 2000) and allows for a 10 m vehicular access around the perimeter of the plantation.

A 5 m buffer to the expected drip line of the plantation should also be established around all unmarked drainage lines. This will ensure rainfall is not intercepted and hydraulic connectivity is encouraged between ephemeral tributaries. The measure is analogous to low flow bypasses used in many South Australian water allocation and NRM plans, aimed at assisting significant but modest events to pass water to downstream users.

Neither buffers, drainage lines or watercourses should be used as roads or ripped or interfered with in any way to ensure the allocated shared portion of runoff passes to downstream users. A more detailed discussion on buffers to manage water resources issues of plantation forestry may be found in Greenwood *et al* (2007).

CONCLUSIONS

South Australia has a comprehensive water allocation and planning system that sits within a strategic framework of law, statutory plans, policies and government agreements. At its highest-level water allocation planning provides for the reasonable use of all water users, including water dependent ecosystems, in an equitable manner with high levels of security.

Outside areas under the highest control, water resources are managed according to state-wide policies and guidelines within the State NRM Plan 2006. Local councils play an important role. In the absence of formal water allocation plans, councils rely on advice from State Government, which requires the needs of all water users be assessed using the best available information in the context of government policies, guidelines and agreements.

The water requirements of high value ecosystems, farm dam irrigators and plantation forestry can all be accounted for as part of a sustainable consumptive pool in a transparent way, which facilitates transferring water across different land and water-uses.

Wetland water requirements can be estimated using a simple water balance model and integrated with South Australian NRM guidelines to identify the capacity of catchments to support further ESD in a systematic and equitable way. Observations at local monitoring sites that are consistent with Australian and international studies, can be used to accounted for the water use by forestry as part of the consumptive pool of any catchment in a way that enables the transparent transfer of water between forestry and other water users.

Buffer zones should be recommended around important areas to protect high value ecosystems and facilitate water resources management, ensuring shared water resources are passed to downstream users.

The entire approach provides an integrated total water cycle assessment to protect user access to a sustainable water resource and the achievement of environmental objectives.

ACKNOWLEDGMENTS

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