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Australia's State of the Forests Report 2013

Criterion 4

Conservation and maintenance of soil and water resources





Michael F Ryan

Original Cotter Dam, ACT, before it was enlarged in October 2013.

Criterion 4

Conservation and maintenance of soil and water resources

This criterion is concerned with two of the fundamental resources of a forest ecosystem: soil and water. Forests are important for soil conservation because they contribute directly to soil production and maintenance, prevent or reduce soil erosion, and provide and protect water supplies. In addition, forests provide quantities of clean water for a range of uses. This criterion has five indicators, the first of which is relevant for both soil and water. The second and third indicators address soil, while the remaining two indicators focus on water.

Management of forest for protective functions

The identification of forest managed primarily for protective functions, and specifically for protection of soil or water, is not always straightforward in Australia. This indicator calculates the area of forest managed primarily for protective functions as all public nature conservation reserves, plus (for some states and territories) those parts of multiple-use public forest in which harvesting and road construction are not permitted (such as on steep slopes and certain soil types, and in riparian—streamside—zones), plus catchments managed specifically for water supply. However, conservation of soil and water values is usually one of several forest management objectives across multiple-use public forests more broadly.

Disturbances that can directly affect soil and water in forested areas include road construction and maintenance, wood harvesting, fire, grazing, recreation, and the activities of feral animals.

Many government agencies, conservation organisations and community groups across Australia plant trees to protect riparian zones, counter rising water tables and salinity, provide wildlife corridors, and prevent or minimise soil erosion.

Management of risks to forest soils

Appropriate management of soils is fundamental to sustainable forest management. Minimising soil erosion protects soil and water values in forested areas, and is critical to maintaining many other forest values. Soil erosion on forested lands can be minimised through careful planning and management of road crossings and forestry operations, with detailed prescriptions depending on the nature of particular forest soils and the activities being undertaken.

Degradation of soil physical properties (such as soil structure, density, texture, permeability, and water-holding capacity) can affect seed germination and the growth and survival of trees, and can lead to increased water runoff and soil erosion. It is important, therefore, that forest management does not result in permanent adverse changes to soil physical properties.

Management of the risk to water quality and quantity

In Australia, large areas of forested land are used to provide reliable and clean supplies of water for human consumption, as well as for irrigation and industrial uses. Forested catchments provide a lower risk to water quantity and quality than do catchments carrying other, non-forest land uses. Establishment and growth of plantations on previously cleared land also affects water yields from this land.

The quantity of water available in streams and rivers flowing from forested catchments depends, among other things, on the quantity of rainfall, the volume of water used by forest vegetation or otherwise evaporated, and the volume that enters groundwater systems. The amount of water used by a forest stand depends on its age, density, species mix and growth rate. Major fire events influence water yields by changing the age-class structure of native forest, and changes in stream-flow can last for decades after a severe fire.

Management practices likely to increase or decrease water yields in forested catchments include the timing, scale and location of wood harvesting; the thinning of regrowth forest; management of planned and unplanned fires; and control of woody weeds.

Forested catchments are highly valued as sources of drinking water because forest vegetation, soil and litter serve as natural filters, and the quality of water flowing from such catchments is therefore usually very high. Natural disturbances such as fire can have negative impacts on water quality—for example, through increased runoff resulting in an increased erosion risk. Construction and maintenance of forest roads and tracks can also have adverse impacts, including through increased movement of sediment into water bodies. In addition, water quality can be adversely affected by fertiliser and herbicide residues from runoff and spray drift. Protective measures employed routinely in Australian forests include maintaining forested streamside buffer zones to minimise sediment movement (these also provide habitats and corridors for wildlife), and carefully planning and managing spray operations.



Claire Howell

Babinda Boulders, Wooroonooran National Park, tropical north Queensland.

Key findings

Key findings are a condensed version of the Key points presented at the start of individual indicators in this criterion.

Management of forest for protective functions

- A total of 29.8 million hectares of Australia's public forest (24% of the total forest area, almost entirely native forest) is managed primarily for protective functions including protection of soil and water values. This area comprises all public nature conservation reserves; in some states and territories, those parts of multiple-use public forests in which wood harvesting and road construction are not permitted; and catchments managed specifically for water supply.
- In catchments managed specifically for water supply, jurisdictions either do not allow human disturbances, or approve limited activities such as public access and some restricted wood harvesting. As far as possible, natural disturbances such as fire are also managed.

Management of risks to forest soils

- Most Australian states and territories have in place regulatory instruments, such as codes of forest practice, guidelines and management plans, that provide for the prevention or mitigation of soil erosion as a result of activities on forested land, and to protect soil physical properties.
- In some jurisdictions, the forest practices system includes comprehensive soil assessment measures to manage associated soil erosion risk in multiple-use public forest. Knowledge of soil erosion risk is generally high for multiple-use public forest, but is lower in other tenures.
- Compliance in multiple-use public forest with soil mitigation measures for wood harvesting, and with associated standards for road and track construction and maintenance, has been assessed as 'high' in most jurisdictions.

Management of risk to water quantity and quality

- Most Australian states and territories have in place regulatory instruments, such as codes of practice, guidelines and management plans, that provide for management of water yields from forests. These regulatory instruments also mandate or guide practices that must be carried out to assist in maintaining water quality.
- The potential impacts of forestry operations on water quantity are managed by practices such as seasonal restrictions on wood harvesting, and limiting the annual proportion of catchments subject to wood harvesting. Some forestry operations such as thinning to decrease stand density can increase water yield.
- Water use by tree plantations continues to be the subject of community attention and scientific research.
- Major wildfires during the reporting period, and water use by the resultant natural regrowth, are expected to change water yields in some affected catchments in coming years. Wildfires also caused temporary declines in water quality during the period, mainly in Victoria and Western Australia.

Indicator 4.1a

Area of forest managed primarily for protective functions

Rationale

The area of forest land where priority is given to protecting soil and hydrological functions provides an indication of the emphasis being placed by society on the conservation of these values. This indicator includes areas managed to protect soil and water by excluding incompatible activities.

Key points

- A total of 29.8 million hectares of public forests in Australia, representing 24% of Australia's total forest area and comprising almost entirely native forest, is managed primarily for protective functions including protection of soil and water values. This represents an increase over the reporting period of about 3.5% in the proportion of Australia's forest area that is managed primarily for protective functions.
- This forest area includes all public nature conservation reserves and, in some states and territories, those parts of multiple-use public forests in which harvesting and road construction are not permitted, such as steep slopes, certain soil types, riparian zones or other reserved areas. This area also includes forested catchments managed specifically for water supply.
- Nationally, a total of 1.4 million hectares of forest land is recorded as being managed specifically to supply water for human or industrial use; however, current data are not available for all jurisdictions. In catchments managed specifically for water supply, jurisdictions either do not allow any human disturbance activities to occur or approve limited activities, including public access and some wood harvesting. As far as possible, natural disturbances such as fire are also managed.
- National-level programs such as Caring for our Country and other initiatives have encouraged re-establishment, restoration and maintenance of native vegetation, including forests, for protective functions.



Forests are vital for soil conservation, preventing soil erosion, protecting water supplies and maintaining other ecosystem functions. States and territories have measures in place to recognise and safeguard these functions.

Identification of forest managed primarily for protective functions—specifically, forest managed primarily for soil or water protection—is not always straightforward. In most states and territories, forests in public nature conservation reserves may be considered as 'managed primarily for protective functions'. Moreover, preservation of soil and water is usually one of several forest management objectives, including in multiple-use public forests.

The area of forest reported in this indicator is the area of forest from which wood harvesting is excluded, and therefore includes nature conservation reserves, but not the majority of multiple-use public forests. However, some areas of multiple-use public forests (such as those on steep slopes, on erosion-prone soils or close to streams) are managed for protective functions, with harvesting not permitted in these areas to ensure their protection. As far as possible, these areas are included in the reported areas (see notes for Table 4.1).

Some of the types of disturbance that can directly affect soil and water assets in forested areas are road construction and maintenance, wood harvesting, fire, grazing, recreation and disturbance by feral animals. Codes of forest practice, and licences issued by regulatory authorities, set out precautionary and mitigation measures to be undertaken in or near waterways, in erosion-hazard areas and in water catchments to minimise the impacts of disturbance, particularly from wood harvesting and road construction or maintenance. A comprehensive account of legal and non-legal instruments that are in place to protect forest areas managed for soil and water protective functions is given in Indicator 7.1a.

Table 4.1: Area of public forest from which wood harvesting was excluded, 2011

Jurisdiction	ACT ^a	NSW ^b	NT ^a	Qld ^a	SA ^a	Tas. ^c	Vic. ^b	WA ^b	Australia
Area ('000 hectares)	114	6,119	3,781	6,510	2,112	1,828	4,318	5,026	29,808

^a Area of forest in Collaborative Australian Protected Area Database (CAPAD) International Union for Conservation of Nature (IUCN) categories I–VI (see Indicator 1.1c, Table 1.23); does not include forests on informal reserves in multiple-use public forests. CAPAD figure for Queensland includes Indigenous Protected Areas, and is substantially larger than the figure provided by Queensland in SOFR 2008.

^b Area of protected native forest on formal and informal reserves, and forests protected by prescription in multiple-use public forests (see Indicator 1.1c, Tables 1.18, 1.20 and 1.21).

^c Derived from figures published in *State of the forests Tasmania 2012* (FPA 2012); does not include the area of private land excluded from harvesting.

Source: Australian Bureau of Agricultural and Resource Economics and Sciences; Australian Government Department of Sustainability, Environment, Water, Population and Communities—CAPAD for IUCN data; PSMA Australia Ltd; state and territory agencies.

Management of forests for protective functions

Legally and non-legally binding instruments exist in all states and territories to control and limit forest disturbances in designated water supply catchments. State and territory governments protect soil and water values through legislation, codes of practice, and various environmental management plans and standards. These are generally applied to catchment protection, areas vulnerable to erosion and slope instability, and riparian zones.

Forests NSW⁹⁸ plans and classifies its road network according to the *Forest Practices Code* (State Forests of NSW 1999). In accordance with this code, all forest road systems in public forests and plantations should be based on the principles of minimising the combined cost of log extraction and roading, and environmental care. The principle of environmental care requires that soil, water catchment, cultural and landscape values are protected by careful planning, location, construction and maintenance of roads and tracks, and regulation of their use. Areas of New South Wales state forests are assessed for soil erosion hazard before wood harvesting commences, as part of the harvest planning process. An environment protection licence is required to conduct specified forestry activities in areas of state forest that come under a NSW Forest Agreement or a Regional Forest Agreement. An integrated forestry operations approval (IFOA) is required for any forestry operations on state forests or other Crown timber lands, including in the western part of the state not covered by a Regional Forest Agreement. The New South Wales Government has also implemented a Private Native Forestry Code of Practice that sets minimum operating standards for harvesting (NSW EPA 2013).

In South Australia, various pieces of legislation and other instruments contribute to appropriate forest management to protect soil and water resources. These include the *Natural Resources Management (NRM) (Commercial Forests) Amendment Act 2011*, the *Environment Protection Act 1993*, the eight regional Natural Resource Management Plans, the state Natural Resources Management Plan and the *Guidelines for Plantation Forestry in South Australia 2009* (PIRSA 2009).

In Victoria, many catchments supplying water for domestic, irrigation or other purposes, including some catchments containing forest, are protected under the *Catchment and Land Protection Act 1994*. This assists planners and those

managing land disturbance or development activities to determine the suitability of proposed activities within these catchment areas. Once a catchment is declared, approvals for activities conducted under other statutes and statutory planning schemes must be referred to the responsible land management authority for approval. There is also a range of mechanisms to protect water supplies under the *Victorian Water Act 1989*, including the declaration of water supply protection areas.

In the Northern Territory, the *Codes of Practice for Forestry Plantations* published in 2004 consists of 26 goal statements that collectively cover the main requirements for sound plantation planning and management. The Northern Territory also has Land Clearing Guidelines⁹⁹ developed by the then Department of Natural Resources, Environment, the Arts and Sport¹⁰⁰.

In Tasmania, soil and water values are protected on forest land, particularly through two key mechanisms: the *Forest Practices Code 2000* (Forest Practices Board 2000) and the *Tasmanian Reserve Management Code of Practice* (Parks and Wildlife Service et al. 2003). The *Forest Practices Code 2000* prescribes specific management measures for forest lands, particularly for activities associated with roading, harvesting or reforestation.

Area of public forest managed for protective functions

The area of forest from which wood harvesting activities that potentially affect soil and water values were excluded, across all tenures, totalled 29.8 million hectares in 2011 (Table 4.1). This represents 24% of the total forest area in Australia, an increase of about 3.5% during the reporting period, and comprises almost entirely native forest.

The absolute area of public forest excluded from wood harvesting has remained relatively stable in this reporting period. The area reported here (29.8 million hectares) is slightly (0.6 million hectares) smaller than that reported in 2008, largely as a result of the reduction in the total reported area of forest in the Northern Territory and South Australia, where areas described as forest in 2008 are now reported as woody non-forest vegetation (see Indicator 1.1a).

Across Australia, there has been an increase in the area of public land excluded from wood harvesting, as a result of both the declaration of new nature conservation reserves and the establishment of new formal and informal reserves

⁹⁸ From January 2013, the Forestry Corporation of NSW.

⁹⁹ www.lrm.nt.gov.au/natveg/guidelines.

¹⁰⁰ From October 2012, the Department of Land Resource Management.

on multiple-use public forest. For example, in Victoria, approximately 130 thousand hectares of new national parks and state parks have been established since 2006 on previous multiple-use public forest. This includes new parks and additions to existing parks at Cobboboonee, Barmah, Gunbower, Lower Goulburn, Warby-Ovens, Terrick Terrick and elsewhere along the Murray River. Wood harvesting is now excluded from all of these areas.

In Tasmania, the total area of forest excluded from wood harvesting within multiple-use public forest increased during the reporting period by 163,500 hectares. This is mainly due to an increase in informal reserves in state forest, including areas that are excluded from harvesting coupes for reasons such as steepness, potential erosion hazard and access. The total area of forest in public nature conservation reserves in Tasmania increased by 50 thousand hectares. There has been a net decrease of 12 thousand hectares of total forest in informal reserves on other publicly managed land. Across all public tenures, Tasmania has had an increase of 202,500 hectares of forest where wood harvesting has been excluded, reducing potential disturbance to water supply catchments (FPA 2012).

Areas of forest specifically managed to supply water for human or industrial use (Table 4.2) are a subset of areas of forest from which wood harvesting is excluded (Table 4.1), with the exception of Western Australia where, in the south-west forest region, catchments managed for water supply can include multiple-use public forest where wood harvesting is permitted.

The Cotter River catchment is almost wholly located within the Australian Capital Territory and feeds into the Corin, Bendora and Cotter dams. Much of the 48 thousand hectares of the catchment area, which includes parts of Namadgi National Park, is forested. The entire catchment is closed, with no farms or houses, and with restrictions on activities within the catchment in order to protect the quality of the water (ACTEW Water 2011).

In New South Wales, approximately 178 thousand hectares of forest are managed specifically for water supply in closed catchments from which human disturbance activities are excluded. Another 77 thousand hectares of forest in closed water catchments are available for wood harvesting, subject to scientifically based mitigation measures to protect soil and water values.

There has been no change in the total area of closed water catchment in the Northern Territory over the period 2006–11. The combined area of the Manton Dam and Darwin River Dam catchments is 28,800 hectares. This area is set aside solely for the protection of domestic water supply.

Collectively, Victoria's water supply catchments cover approximately 1.3 million hectares of nature conservation reserves, 1.9 million hectares of multiple-use forests and 2.2 million hectares of other land (not necessarily forested), totalling 5.4 million hectares. This total includes 157 thousand hectares of closed catchments, which comprise approximately 77 thousand hectares of nature conservation reserves, 71 thousand hectares of multiple-use forests and 9 thousand hectares of private land.

Current data are not available for the area of forests in catchments explicitly managed for water production in Tasmania. However, many catchments in the Comprehensive, Adequate, Representative (CAR) reserve system are used for water production, although the majority are not specifically reserved as water catchment areas. One reserve explicitly recognised as a water catchment is in Mount Field National Park, and another is in Wellington Park. The Lake Fenton/Lady Barron Creek drinking water catchment covers 1,530 hectares of the Mount Field National Park and supplies 20% of the drinking water of Hobart and its environs. The slopes of Mount Wellington are also managed for the supply of water to Hobart and adjacent localities (FPA 2012).

In Western Australia, the area from which wood harvesting is excluded includes nature conservation reserves, informal reserves and fauna habitat zones in multiple-use public forest. There has been minimal overall change in the total area managed specifically to supply water for human or industrial use. Public drinking-water source areas include both underground water pollution-control areas and catchment areas, including water reserves. Catchments identified as sensitive to rises in saline groundwater are managed to minimise this risk by re-establishing deep-rooted perennial vegetation over significant parts of the landscape. The existing commercial pine plantation on Perth's Gnangara Mound will be replaced with other land uses over time to increase the recharge of that water resource.

Table 4.2: Area of forest in catchments managed specifically to supply water for human or industrial use, 2011

Jurisdiction	ACT	NSW	NT	SA ^a	Tas.	Vic.	WA	Total
Area ('000 hectares)	48	178 ^b	29	1	5	157	948 ^c	1,366

^a Area of multiple-use public forest managed by ForestrySA (pine forests on land managed by SA Water); does not include native vegetation and grassland areas in reservoir protection areas.

^b Area of closed catchments on multiple-use public forest only.

^c Includes only the public drinking water source areas on multiple-use public forest and conservation reserves in south-west of Western Australia.

Note: Only ACT, NSW, NT, Vic. and WA provided new data for 2011. Data for SA and Tas. are from SOFR 2008. Data were not available for Qld.

Rehabilitation and reforestation for protective functions

Many conservation organisations and community groups across Australia plant trees to protect riparian zones, counter rising watertables and salinity, provide wildlife corridors and arrest soil erosion. These plantings include a large range of projects supported by the Australian and state and territory governments and the private sector.

For example, during the five-year period to 2010, the national environmental organisation Greening Australia planted more than 15.5 million seedlings, direct-seeded 19 thousand kilometres of tree line, collected 18,250 kilograms of native seed, conserved more than 340 thousand hectares of native vegetation (including forest and non-forest areas) and constructed more than 8 thousand kilometres of protective fencing.



Environmental tree planting by a community group to protect a creek line and provide habitat for the endangered regent honeyeater (*Anthochaera phrygia*), Benalla, Victoria.

Case study 4.1: Caring for our Country

‘Caring for our Country’ is an Australian Government initiative that began in July 2008, following earlier Australian Government natural resource management programs (the National Action Plan for Salinity and Water Quality, and the Natural Heritage Trust). The goal of Caring for our Country has been to create an environment that is healthy, better protected and well managed, and that provides essential ecosystem services, such as food production, in a changing climate. It supports individuals, regional natural resource management organisations, Landcare and other non-government organisations, and community and Indigenous groups that are working to conserve Australia’s natural environment and productive farmland. The Australian Government allocated more than \$2 billion over five years to June 2013 under the Caring for our Country program.

In 2008–09, Caring for our Country invested \$432 million in new projects involving farmers, Indigenous rangers, regional natural resource management organisations, Landcare and other voluntary environmental protection groups across Australia. With regard to soil protection measures, these investments included working to improve water quality in the Gippsland Lakes (Victoria) and Tuggerah Lakes Estuary (New South Wales). Under the Environmental Stewardship Program, five funding rounds were conducted in 2008–09 and 2009–10. From these rounds, 201 land managers will receive funding from the Australian Government for up to 15 years to manage box gum grassy woodland on their land. These contracts will result in the protection of 27 thousand hectares of this critically endangered ecological community.

Source: www.nrm.gov.au/about/caring/report-card; www.nrm.gov.au/funding/previous/stewardship/box-gum/index.html.

Indicator 4.1b

Management of the risk of soil erosion in forests

Rationale

This indicator assesses the extent to which the risk of soil erosion has been explicitly identified and addressed in forest management. The avoidance of soil erosion reflects the extent to which associated values, including soil fertility and water quality, are protected.

Key points

- Most Australian states and territories have codes of forest practice, guidelines and other instruments in place that provide for the prevention or mitigation of soil erosion as a result of activities on forested land, and that regulate clearing of forest land.
- In some jurisdictions, the forest practices system contains comprehensive soil assessment measures to determine soil properties and manage associated soil erosion risk in multiple-use public forests. Mechanisms exist in most of these jurisdictions to ensure compliance with mitigation measures for soil erosion.
- This indicator reports mainly on multiple-use public forest and nature conservation reserves because, in most jurisdictions, limited information is available for forested land under other tenures. Knowledge of soil erosion risk is generally high for multiple-use public forests, but lower in other tenures.



Soil erosion is the relocation of soil by environmental forces—that is, the loss of soil from one area and its deposition into another. Minimising soil erosion is essential to protecting soil and water values in forested areas, and is critical to maintaining many other forest values. Minimising soil erosion, and soil conservation measures in general, are therefore an essential part of sustainable forest management.

Soil erosion on forested lands can be minimised through careful planning and management of forestry operations. The actions taken to manage soil erosion can vary greatly, depending on the nature of the particular forest soils and the activities being undertaken in the forest. Key forestry

management considerations with regard to minimising soil erosion include use of appropriate machinery, avoiding disturbance in high-risk areas, and retaining vegetation. Activities for which soil management needs to be considered include road construction and alignment, operations in or near streams or riparian areas, construction of extraction tracks or other temporary tracks, placement and management of log landings, wet-weather operations, use of vehicles on slopes, clearing on slopes, and development of infrastructure facilities.

This indicator reports on prevention and mitigation measures with regard to soil erosion on forested land, and external auditing of compliance with implementation of these measures. The indicator reports mainly on multiple-use public forest and nature conservation reserves because, in most jurisdictions, limited information is available for forested land under other tenures. Performance ratings reported are the results of self-assessment by the jurisdictions, and review of documents published during the reporting period.

Legal and non-legal instruments in Australian state and territory jurisdictions provide guidance and measures to address soil erosion associated with forestry operations. Codes of forest practice, for example, generally require wood harvesting to occur in ways that prevent and/or mitigate soil erosion, particularly for locations that are most susceptible. Soil erosion can also result from wildfire and recreational activities, particularly around roads, walking trails, picnic areas and campsites. The risk of soil erosion caused by recreational activities is generally managed through appropriate design, construction, access to and use of relevant infrastructure, especially during rehabilitation after wildfire.

Instruments to address the risk of soil erosion

General mitigation measures that can be undertaken during forestry operations to minimise soil erosion include:

- excluding identified vulnerable areas, including karsts, wetlands, and areas with high erosion hazard or landslide potential
- providing road drainage, such as well-designed bridges, culverts and table drains, and providing drainage to log extraction tracks by cross-drains and grips
- appropriate arrangement of log extraction tracks, for example, contouring; walk-over extraction, where applicable; and appropriate location of log dumps and landings, for example on ridges and saddles
- minimising stream crossings
- protecting riparian zones using buffers or filters
- closing operations during wet weather
- rehabilitating log landings and extraction tracks through, for example, ripping, replacement of topsoil or planting.

In all jurisdictions, measures to mitigate soil erosion were in place for the reporting period, but they did not necessarily cover all forest tenures. In Victoria and Tasmania, however, such measures apply to all forest harvesting operations regardless of tenure. Internal and external audits at various levels are used to ensure compliance with codes of forest practice.

The *Code of Practice for Timber Production* (DSE 2007a) is a key regulatory instrument that applies to commercial wood production in both public and private forests and plantations in Victoria. It is a statutory document under the *Conservation, Forests and Lands Act 1987*, and compliance of forest management activities with this code is required under the *Sustainable Forest (Timber) Act 2004* and the relevant Victorian planning provisions. The code states:

Soil erosion and water pollution are minimised by avoiding harvesting in inappropriate areas or slopes and undertaking necessary preventive measures.

During or following wet weather conditions, timber harvesting operations are modified or where necessary suspended to minimise risks to soil and water quality values.

Site preparation operations are appropriate to the characteristics of the particular site, and take into account the maintenance of soil and water values as well as site productivity.

Forests NSW¹⁰¹ has a comprehensive soil assessment program for forestry operations, consisting of four modules: inherent soil erosion and water pollution assessment, mass movement assessment, dispersibility assessment, and seasonality. Forests NSW is required to apply all four assessment modules during a pre-operational planning phase, which precedes commencement of any forestry activities.



A log landing prepared to protect soil values during harvesting activities, Gippsland, Victoria.

In the Northern Territory, the *Soil Conservation and Land Utilisation Act 1980*, the *Planning Act 2009*, the Forest Practice Code¹⁰² (which is currently being reviewed) and *Land Clearing Guidelines* (DNRE 2010) prescribe ways to minimise and mitigate soil erosion following soil disturbance. In addition, management plans for conservation reserves include provisions to ensure that soils are managed to minimise soil erosion.

Western Australia's *Forest Management Plan 2004–2013* (CCWA 2004) has aims that include protecting soil and water values, and adopting a proactive approach to management. The plan provides a framework for the management of forest areas for a range of environmental, social and economic uses. It focuses on the management of state forest and timber reserves, and prescribes measures to prevent damage, as well as remedial measures to restore soil when damage occurs.

The Western Australian *Soil and Water Conservation Guideline* (DEC 2009a) is the implementation guide for soil and water conservation aspects of the *Forest Management Plan 2004–2013*. It has the overall objective of minimising the extent and severity of impacts on soil values. Ten guiding principles are described to protect soils, including rehabilitation of damaged soil, and protection of soil from erosion as a result of wood harvesting and associated forest management activities. The guideline sets out the key requirements for protecting soil, based on the types of disturbance (using visible soil disturbance categories), and limits activities for various levels of disturbance. For example, where visual soil disturbance indicates that the subsoil is removed and parent material is exposed, or subsoil is mixed with parent material, erosion control measures need to be installed. Rehabilitation needs to be conducted soon after severe or very severe soil disturbance, to facilitate soil repair. Together with associated manuals and reference material, the guideline provides a framework for, and guidance on, soil conservation associated with forestry operations in Western Australia.

¹⁰¹ From January 2013, the Forestry Corporation of NSW.

¹⁰² www.planningplantations.com.au/assets/pdfs/management/regulation/nt/KeepDraftNTCodesofPracticeforForestryPlantations.pdf.

In Tasmania, the *Forest Practices Code 2000* (Forest Practices Board 2000), together with a number of supporting manuals, other regulatory instruments, forest certification standards (such as the Australian Forestry Standard), and internal agency or company operational guidelines, provides a framework and good guidance for protecting soil values during forestry activities. The *Forest Practices Act 1985* requires assessment of risks to soils when a forest activity is carried out, irrespective of land tenure or forest type. Assessments are also commonly undertaken on public forests and large, industrially managed private forests in relation to road and site developments and ongoing maintenance, although these are not specified under the *Forest Practices Act 1985*.

The Sustainable Forest Management System of VicForests was certified to the Australian Forestry Standard in February 2007. Since then, VicForests has been independently audited every six months, and was recertified in January 2010 for a further three years. Targets of the Sustainable Forest Management System include maintenance and conservation of soil and water resources of state forests (VicForests 2012).

Assessment of legal instruments and regulatory framework

The extent to which a state or territory regulatory framework requires the maintenance of soil values is analysed according to five categories (Table 4.3). Ratings against these categories are used to assess the extent to which legally and non-legally binding instruments, such as codes of practice, guidelines and forest management plans, address soil values across state and territory jurisdictions (Table 4.4).

Legally binding instruments are in place in New South Wales, Victoria, Tasmania and Western Australia. South Australia's ratings relate to assessment under the *Environmental Management Guidelines for Plantation Forestry* (ForestrySA 1997), which have been endorsed by the plantation industry in that state. Native forest harvesting is not allowed in the Australian Capital Territory or South Australia, and only limited harvesting occurs under licence on private land in the Northern Territory. In New South Wales, the significantly lower risk of erosion assessed for nature conservation reserves means that prescriptions in that tenure are not as stringent as in multiple-use public forests. Overall, there has been no major change during the reporting period in the way legally and non-legally binding instruments address the risks to maintenance of soil values.

Table 4.3: Categories of the extent to which the regulatory framework requires the maintenance of soil values

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk of soil erosion from disturbance activities: <ul style="list-style-type: none"> • rainfall intensity • slope • soil erodibility • management practices resulting in soil disturbance. The instruments are also applicable to all erosion processes (wind, sheet, rill, gully, tunnel, stream bank, wave and mass movement).
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks of soil erosion for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks of soil erosion when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks of soil erosion.

Source: SOFR 2008.

Table 4.4: Extent to which legally and non-legally binding instruments address the risk of soil erosion due to forest operations, road and trail works, and recreation activities

Instrument	Tenure	Assessed category						
		ACT	NSW	NT	SA	Tas.	Vic.	WA
Legally binding	Multiple-use public forests and plantations	5	1	3	4	1	1	4
	Public nature conservation reserves	5	2	1	4	1-2	1	4
Non-legally binding	Multiple-use public forests and plantations	3	1	3	1-4	1	3	3
	Public nature conservation reserves	n.r.	1	3	n.a.	1-2	3	4

n.a. = not applicable; n.r. = not reported for this indicator

Notes:

Ratings relate to categories in Table 4.3.

Data were not available for Qld.

Source: State and territory agencies.

Assessment of erosion hazard

Erosion hazard is generally assessed using a combination of available information as overlays in geographic information systems. Relevant information includes erosion hazard maps, geographical settings such as slope, soil erodibility, rainfall intensity, and management practices that could contribute to soil erosion. This provides forest managers with information on the level and location of erosion hazards, which is then used to determine appropriate mitigation measures. The extent to which risks of soil erosion are assessed in planning processes is analysed according to four categories (Table 4.5).

Table 4.6 shows the area of multiple-use public forest for which disturbance activities were planned in 2010–11, the proportion of the area that was assessed for risk to soil values, and the category of assessment (from Table 4.5). In New South Wales, South Australia and Victoria, virtually all areas of multiple-use public forest subject to disturbance were assessed for risk to soil values.

In the Australian Capital Territory, the *ACT Code of Forest Practice* provides guidance for and describes actions to be taken during forest activities, based on the potential for the soil to erode (its erodibility). The code groups soil

erodibility into five classes, and provides guidance for operations according to the soil erodibility class for a given area. In addition, a *Soil Erodibility and Maintenance Manual* (Environment ACT 2006) provides land managers with a general quick reference on:

- determining a soil's erodibility
- management of erodibility
- management of sodic soils, eroded soils and unstable regolith
- erosion control measures
- sediment retention measures.

In South Australia, formal soil erosion risk assessments are generally only undertaken for initial site establishment of plantations (during assessment of land-use capability). However, plantation management practices take into account soil erosion risk and aim to reduce it.

All Forests NSW¹⁰³ operations must meet the requirements of an environment protection licence, issued by the New South Wales Office of Environment and Heritage. This requires the agency to undertake comprehensive soil assessments as part of the planning process before wood harvesting. These identify the hazard category (risk of soil erosion and water pollution) and determine the level of protection required at each site to conserve soil and water values.

Table 4.5: Categories of the extent to which the risks of soil erosion are assessed in planning processes

Category	Category description
1	The soil erosion risk assessment system comprehensively takes account of rainfall intensity, slope, soil erodibility and management practices that could contribute to soil disturbance.
2	The soil erosion risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to soil values for the particular disturbance activity and geographical setting.
3	The soil erosion risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for these factors.
4	The soil erosion risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Source: SOFR 2008.

Table 4.6: Area of multiple-use public forest where disturbance activities were planned, proportion assessed for risk of soil erosion, and assessed category, 2010–11

Disturbance activity	Metric	NSW	SA	Tas.	Vic.	WA
Native forest harvesting and silviculture	Area (hectares)	27,484	0	16,000	5,250	n.r.
	Proportion assessed for risk of soil erosion (%)	100	n.a.	100	85	100
	Assessed category ^a	1	n.a.	1	2	3
Plantation operations	Area (hectares)	14,068	n.r.	4,600	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	100	100	100	n.a.	n.a.
	Assessed category ^a	1	1	1	n.a.	n.a.
Road construction and maintenance	Area (hectares)	n.r.	n.r.	n.r.	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	n.a.	100	100	n.a.	100
	Assessed category ^a	n.a.	3	1	n.a.	3
Fire management	Area (hectares)	36,936	n.r.	n.r.	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	100	100	100	90	n.a.
	Assessed category ^a	1	3	1	2	n.a.

n.a. = not applicable; n.r. = not reported for this indicator

^a Ratings refer to categories in Table 4.5.

Note: Data for Tas. and WA are from SOFR 2008. Data were not available for ACT and Qld. NT has no multiple-use public forests.

Source: State agencies.

¹⁰³ From January 2013, the Forestry Corporation of NSW.

Soil erosion knowledge base

The knowledge base on soil erosion continued to improve in the reporting period, particularly in the areas of soil disturbance by machinery, and assessment of soil erosion hazards in multiple-use public forests (Table 4.7). The impact of fire on the erosion of forest soils has also been the subject of investigation (see Indicator 4.1c).

In Tasmania, a number of soil management guidance documents, combined with ongoing research and training and the experience of forest managers, ensure that sufficient knowledge is available for identification and mapping of soil types, and for recording their characteristics and distribution. The recreation impact monitoring program undertaken by the Parks and Wildlife Service in the Tasmanian Wilderness World Heritage Area regularly records soil data. Knowledge developed through these activities enables identification and management of risks arising from the interactions between various factors, including slope, climate, soil type, rainfall, stream management and vegetation cover.

Compliance with measures to mitigate impacts on soils

Compliance with mitigation measures for soil impacts is assessed in various ways across Australia, including internal and external audits. Compliance is categorised in this report using the descriptions in Table 4.8. Table 4.9 provides an indication of the compliance outcomes for some jurisdictions. Tasmania achieved the highest level of satisfactory outcomes.

As an example of compliance reporting, the report on the end-of-term audit of performance under the *Forest Management Plan 2004–2013* (CCWA 2012a,b) for Western Australia noted that severe and highly visual forms of soil damage, such as rutting, puddling and mixing, were rarely seen in association with wood harvesting operations. It also found that major effort has gone into minimising soil compaction. Surveys in harvest coupes indicated that soil disturbance limits were exceeded at a relatively small number of sites each year between 2005 and 2011. The Department of Environment and Conservation investigated instances where allowable limits were exceeded and ensured that such instances were addressed appropriately. Tracks created by harvest vehicles accounted for the majority of occurrences where limits were exceeded.

Table 4.7: Knowledge base on soil erosion and soil physical properties, by jurisdiction

State	Soil knowledge base
ACT	Soil landscape mapping at the 1:100,000 scale was completed for the eastern half of the ACT, and published in 1993 and 2000. In this work, soil types (based on the Australian Soil Classification) were identified for each soil landscape, and their qualities and limitations were documented, including soil physical and chemical properties. Completion of 1:100,000-scale soil landscape mapping for the western half of the ACT, scheduled for 2015, may provide additional information relevant to the Forest Soil Erodibility Classes described in the <i>ACT Code of Forest Practice</i> , and may be useful in identifying soil limitations specific to plantations in the western half of the ACT.
NSW	A good knowledge of the impacts of activities and a comprehensive soil assessment procedure exist for multiple-use public forest. The assessment procedure is designed to minimise soil erosion and protect soil physical properties. For conservation reserves, there is reasonable knowledge of activity impacts on soil values, but improved knowledge is needed for some risk factors.
SA	There is reasonable knowledge of the impacts of activity on listed values, including local knowledge and training, and codes of practice. However, a need for improved knowledge has been clearly identified for some risk factors.
NT	Soil erosion knowledge is well developed, and the knowledge base is supported by published research, GIS tools, decision-support tools, codes of practice, local knowledge and training, and site-specific research and models. Private freehold land in urban and peri-urban regions is covered by legislation and plans designed to mitigate disturbance, whereas on Indigenous private lands the knowledge base is limited. A need for improved knowledge has been clearly identified for some risk factors.
Tas.	There is a sound knowledge base with regard to soil erosion on forest land. Ninety-five soil types with different properties and erosion risks have been identified throughout the state, mostly in multiple-use state forest, and soils on major areas of state forest in northern Tasmania have been mapped at 1:250,000 scale. Areas at risk from erosion are identified in plans, and protected or managed appropriately under the <i>Forest Practices Code 2000</i> (Forest Practices Board 2000). Landslides are recorded on a joint Forest Practices Authority/Mineral Resources Tasmania database. Research continues on erosion by headwater streams. Regular training is given to foresters and forest managers. However, for nature conservation reserves, knowledge of the impacts of forest activities on soil erosion is often site-specific and limited to areas of management interest, such as World Heritage Area walking tracks.
Vic.	There is reasonable knowledge of the impacts of activity on listed values for both multiple-use public forests and nature conservation reserves, including local knowledge and training, and codes of practice. A need for improved knowledge has been clearly identified for some risk factors.
WA	The Department of Environment and Conservation ¹⁰⁴ and the Forest Products Commission have invested substantial resources into planning and managing operations to reduce soil damage, which has improved the protection of soil under the Forest Management Plan. A combination of measures, including assessing the soil dryness index, a two-stage approvals process, operational controls and monitoring protocols, is used to manage the risk of soil damage according to seasonal conditions, soil type and operation type. Forest Products Commission officers and their contractors apply a risk-based combination of visual surveillance triggers and formal survey techniques to monitor operations and suspend the movement of heavy vehicles before soil damage limits are exceeded. Knowledge of the use of cording and matting to reduce soil compaction and rutting under moist soil conditions fed into improvements in guidance documents and operational practices.

Source: State and territory agencies. No data available for Qld.

¹⁰⁴ From July 2013, the Department of Parks and Wildlife.

Table 4.8: Categories for the performance of forest managers in complying with prescribed mitigation measures for soil impacts

Category	Category description
1	Fully compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts
2	Generally compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts
3	Fully or generally compliant with all process requirements and environmental outcome requirements, but with moderate adverse impacts
4	Not generally compliant with process requirements and environmental outcome requirements, with minimal adverse impacts
5	Not generally compliant with process requirements and environmental outcome requirements, with significant adverse impacts
6	Insufficient or no objective evidence to make a judgment
7	No formal audit conducted

Source: SOFR 2008.

Table 4.9: Compliance outcomes for soil impacts achieved in multiple-use public forests, 2005–06

Disturbance activity	Assessed category				
	NSW	Vic.	SA	Tas.	WA
Native forest harvesting	2	3	NA	1	3
Plantation operations	2	2	3	1	4
Roads and trails	2	2	6	1	4
Fire management	2	2	3	1	4

Notes:

Ratings refer to category descriptions in Table 4.8.

Data for some jurisdictions have not been reported since SOFR 2008. No data available for Qld.

Source: State agencies.

Factors that influence the ability to remain below allowable soil disturbance limits were forest type, the type of vehicles used for harvest, topography, dimensions of the harvest area, and compliance with forest hygiene requirements.

Fire

Wildfire affects soils directly—for example, through the loss of carbon and nutrients—and indirectly through rendering the soil more susceptible to erosion. In 2009, the Black Saturday and associated bushfires in Victoria burnt 170 thousand hectares of state forest, 100 thousand hectares of nature conservation reserves, 15 thousand hectares of other Crown land, and 120 thousand hectares of private land.

Environmental care principles of the *Victorian Code of Practice for Bushfire Management on Public Land* (DSE 2012) include a requirement that the soil be protected during fire management activities, either by preventing inappropriate destruction of its physical and chemical properties or by promoting stabilisation of bare or disturbed earth following disturbance. Under this code, the Department of Sustainability and Environment must prepare maps that show areas that are particularly sensitive to soil disturbances,

and these maps must be considered when planning the use of heavy machinery during firefighting operations. Although effects are much greater for intense fires, low-intensity fires such as prescribed burns can also increase the risk of erosion, particularly on erodible soils, where terrain is steep, or when there are subsequent, intense rain events.



A research weir in a forested catchment (Clem Creek, Victoria), shortly after a fire event.



The same research weir two years post-fire, showing siltation and soil movement after rain.

Indicator 4.1c

Management of the risk to soil physical properties in forests

Rationale

This indicator measures the extent to which the risk to soil physical properties in forests has been explicitly identified and addressed. The protection of soil physical properties, including minimising soil compaction and redistribution, affects soil integrity and, as a consequence, many associated values.

Key points

- In most states and territories, measures to protect soil physical properties in forests were in place for the reporting period.
- These measures include a mix of legally and non-legally binding instruments, including codes of practice, guidelines and management plans.
- Assessment of the measures required to protect soil physical properties during disturbance activities associated with forest management continued to be comprehensive, particularly for multiple-use public forests.
- In most states and territories, almost all forests that were subject to disturbance activities associated with forest management were assessed for risk to soil physical properties.
- Compliance with soil mitigation measures for wood harvesting and associated road and track construction and maintenance in multiple-use public forest has been assessed as high in most jurisdictions.



Appropriate management of soils as the substrate for forests is fundamental to sustainable forest management. Soil physical properties include soil structure, density, compaction, texture, permeability and water-holding capacity. Degradation of these properties can affect seed germination and growth and survival of trees, and lead to other consequences, such as increased water runoff and consequent erosion. It is therefore important that forest operations do not result in permanent adverse changes to soil physical properties.

This indicator reports on the measures undertaken to minimise adverse impacts on soil physical properties on forested land. It focuses on multiple-use public forest and public nature conservation reserves because, generally, limited information is available for other forest tenures.

Impacts of forestry operations on soils

The principal areas of concern for impacts of forestry operations on physical properties of soils are wood harvesting, activities at log dumps and log landings, site preparation, and construction of roads, trails and log extraction tracks (snig tracks). Common impacts of these forest disturbance activities are soil compaction, soil redistribution, and removal of organic matter. The impact of heavy tracked vehicles, in particular, on the physical characteristics of soils is immediate and generally obvious, but the degree of impact depends on the soil type, the soil moisture content, the loading pressure, and the duration and frequency of such pressure, including the number of passes over the track (CCWA 2012a).

Acid sulphate soils could cause problems for forest ecosystems if such soils are exposed through excavation activities. However, forestry operations are unlikely to create such problems because they do not generally involve substantial excavation.

The physical impact on soils from wood harvesting can be minimised by using appropriate harvesting equipment, harvesting methods (e.g. walk-over slash, cable or 'shovel logging'), extraction track layout, timing of operations to avoid high soil moisture, and protection of soils with matting or cording. Modern harvesting vehicles and accumulated operational knowledge have combined to greatly reduce soil impacts (e.g. reducing ground pressure by using rubber-tyred vehicles).

In all states and territories, measures to protect soil physical properties were in place for the reporting period. In some jurisdictions, these have been implemented in multiple-use public forests for many years, but only in Victoria and Tasmania are these measures applied to all forest harvesting operations, regardless of tenure.

A range of measures are undertaken to maintain soil physical properties, varying with the nature of the soils, the seasonal conditions and the type of activities being undertaken.

Measures undertaken to protect soil physical properties include actions relating to:

- felling and log extraction operations in or near streams or riparian areas
- cording and matting
- construction and maintenance of extraction and other temporary tracks
- size, placement and management of log dumps and log landings for storage, and loading of logs for transport
- wet-weather shutdowns
- selection of harvesting machines, including whether machines are tracked or tyred

- machinery restrictions on slopes
- restrictions on clearing steep slopes for plantations
- infrastructure development.

Instruments in place to address risks to soil physical properties

Table 4.10 provides a set of category descriptions used to assess legally and non-legally binding instruments, such as codes of practice, guidelines and forest management plans, that address soil properties. The ratings for various jurisdictions are shown in Table 4.11 for both legally and non-legally binding instruments.

Legally binding instruments relating to soil physical properties are in place in New South Wales, the Northern Territory, South Australia, Tasmania, Victoria and Western Australia.

Operational-level requirements or guidance to manage impacts on soil physical properties are described in various legally and non-legally binding instruments, particularly codes of practice, at state or territory and regional levels. The general principles

Table 4.10: Categories of the extent to which a regulatory framework requires the maintenance of soil physical properties

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to soil physical properties from disturbance activities: <ul style="list-style-type: none"> • site factors, including the soil properties of moisture content, organic matter content, soil type and texture; presence of litter, trash or slash; slope; and rainfall distribution and intensity • management factors, including timing of operations (season), harvesting system, harvesting pattern and slash distribution • vehicle factors, including machine configuration, vehicle weight, dynamic load, tyre size, tyre inflation pressure, wheel slip, tracks or wheels, vibration, number of passes, vehicle speed, area affected, and whether logs are dragged, lifted or carried.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks to soil physical properties for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to soil physical properties when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to soil physical properties.

Source: SOFR 2008.

Table 4.11: Extent to which legally and non-legally binding instruments address the risk to soil physical properties from forest operations, road and trail works, fire management and recreation activities

Instrument	Tenure	Assessed category ^a					
		NSW	NT	SA	Tas.	Vic.	WA
Legally binding	Multiple-use public forests	1	1–5 ^b	4	1	1	4
	Public nature conservation reserves	2	2	4	2	1	4
Non-legally binding	Multiple-use public forests	1	5	1 ^c	1	3	3
	Nature conservation reserves	2	5	4	2	3	4

^a Values refer to category descriptions in Table 4.10.

^b Extent to which instruments address the risk to soil physical properties varies between 1 and 5 for different management disturbance activities.

^c The *Guidelines for Plantation Forestry in South Australia 2009*¹⁰⁵ were released during the reporting period, and supersede the *Environmental Management Guidelines for Plantation Forestry in South Australia* (ForestrySA 1997).

Note: Data were not available for ACT and Qld.

Source: Compiled by the Australian Bureau of Agricultural and Resource Economics and Sciences from information obtained from state and territory agencies.

¹⁰⁵ http://www.pir.sa.gov.au/_data/assets/pdf_file/0020/104735/guidelines_for_plantation_forestry_in_sa_web.pdf.



Bark and branches being used as brush matting at a log landing to protect the soil from vehicle tyres.

of the codes of practice are that the extraction of logs is to be carried out in a manner and by methods that do not result in significant soil disturbance. Consequently, any potential damage is mitigated. In addition, damage caused by the operation, including damage to soil physical properties, is to be repaired. Aspects that are covered in codes of forest practice include assessment and management of soil compaction, mitigating soil movement, creation and management of filter strips or buffers, and consideration of appropriate machinery to protect soil physical properties.

In Queensland, the *Code of Practice for Native Forest Timber Production on State Lands* (EPA 2007) requires soil assessment to be used to identify soil compaction hazards. The document provides guidance for managing these hazards, including estimating the soil compaction rating, which is subsequently used to determine operational restrictions.

The Queensland code covering native forest on freehold land, *Field Guide. Code applying to a Native Forest Practice on Freehold Land* (DNRW 2007), sets a minimum acceptable environmental management standard to ensure that soil physical fertility is protected from compaction or mass movement. This code specifically requires that a native forest practice must not occur in areas where an activity will disturb acid sulphate soils, unless soils are managed in accordance with the soil management guidelines in the *Queensland Acid Sulfate Soil Technical Manual* (Dear et al. 2002); the manual requires that roads and tracks must not be used when soils are saturated and surface water pools or flows in table drains. In 2009, Timber Queensland produced a draft code for stakeholder consultation covering private plantation forests in the state, titled the *Code of Practice for Queensland Commercial Private Plantations*¹⁰⁶, which includes soil protection as one of its goals, and specifies guiding principles to achieve this goal.

Harvesting activities by Forests NSW¹⁰⁷ in multiple-use public forests in New South Wales require a comprehensive soil assessment procedure, designed to minimise soil erosion and protect soil physical properties. These assessments must meet the requirements of environment protection licences issued by the New South Wales Office of Environment and Heritage. The licence ensures adherence to several Acts, including the New South Wales *Soil Conservation Act 1938*.

In Tasmania, forest activities carried out under the *Forest Practices Act 1985* require assessment of risks to soil physical properties in accordance with the *Forest Practices Code 2000* (Forest Practices Board 2000), irrespective of land tenure or forest type.

In the Northern Territory, the draft *Northern Territory Codes of Practice for Forestry Plantations*¹⁰⁸ aims to protect soil quality by requiring a range of mitigation measures to prevent structural change during forestry operations. Minimising adverse impacts on soil, such as compaction and fertility loss, is a major focus during forestry and associated operations.

In Victoria, the *Code of Practice for Timber Production* (DSE 2007a) covers operations in both native and plantation forests. It requires each forest to have a Forest Coupe Plan to describe measures to protect and rehabilitate soils. For example, in protecting soil physical properties, the code requires that the machinery must not enter any set filter strip, except at stream crossings. It also requires that the potential for mass soil movement must be assessed when operating on steep soils, and necessary preventive actions must be undertaken; these include felling trees out of filter strips to reduce soil disturbance, and using techniques such as cable logging to minimise soil movement.

In the Australian Capital Territory, all operations carried out within a forest need to be conducted according to an Operational Plan based on the *ACT Code of Forest Practice* (Environment ACT 2005). The code emphasises that protection of soils must be considered of high importance in the management of forested land, and that measures to mitigate the impact of soil disturbance need to be an integral feature of all operational plans. The code also requires that soil compaction and rutting depth are considered when assessing suitability of machinery for operations, particularly in areas where low-impact machinery is required.

The Western Australian *Forest Management Plan 2004–2013* (CCWA 2004) covers the main wood production areas in the state, and places strong emphasis on the protection of soil and water values. The plan recognises that wood harvesting is the operation with the greatest potential to affect the physical structure of soils, particularly since it can occur over larger areas than some other activities (e.g. extraction of minerals), and the plan identifies protection of soil resources in forested areas as one of its key goals. For example, it requires the Forest Products Commission, which is responsible for the harvest and sale of the state's wood resources, to conduct its operations in a manner that protects soils in accordance with the *Code of Practice for Timber Plantations in Western Australia* (FIFWA 2006).

¹⁰⁶ www.timberqueensland.com.au/Docs/News%20and%20Events/News/Draft-Qld-private-plantation-code-of-practice_stakeholder-consultation_Oct09.pdf.

¹⁰⁷ From January 2013, the Forestry Corporation of NSW.

¹⁰⁸ www.planningplantations.com.au/assets/pdfs/management/regulation/nt/KeepDraftNTCodesofPracticeforForestryPlantations.pdf.

In addition to the *Forest Management Plan 2004–2013*, instruments in Western Australia that assist in the protection of soil physical properties include the *Soil and Water Conservation Guideline* (DEC 2009a) and the *Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests* (DEC 2010a). The *Soil and Water Conservation Guideline* provides a number of guiding principles, supported by relevant strategies, for the conservation of soil values. The *Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests* provides a guide for managing soil properties, including a trafficability index that defines soil management risk periods and permissible activities in relation to soil moisture. The manual also specifies the additional planning and approval requirements for operations during the wetter part of the year, and includes definitions of soil disturbance categories and procedures for assessing and monitoring soil disturbance.

Assessment of risk to soil physical properties during planning processes

Assessment of the potential risk to soil physical properties is usually covered in the codes of practice and other instruments. It is generally carried out by forest managers, in conjunction with an assessment of soil erosion hazard, using the various processes reported in Indicator 4.1b. These assessments usually consist of a combination of office-based assessments and field verification. Many forest managers make such assessments using similar parameters to those in Table 4.12 as a series of overlays in a geographic information system.

Table 4.13 shows the area of multiple-use public forest for which disturbance activities were planned in 2010–11, the proportion of that area that was assessed for risk to soil physical properties and the category of assessment used (using categories defined in Table 4.12). In New South Wales, South Australia, Tasmania and Western Australia, almost all areas of multiple-use public forest subject to disturbance were assessed for risk to soil physical properties.

Table 4.12: Categories of the extent to which soil physical properties are assessed in planning processes

Category	Category description
1	The soil physical properties risk assessment system takes into account all the following factors: <ul style="list-style-type: none"> • site factors, including the soil properties of moisture content, organic matter content, soil type and texture; presence of litter, trash or slash; slope; and rainfall distribution and intensity. • management factors, including timing of operations (season), harvesting system, harvesting pattern and slash distribution. • vehicle factors, including machine configuration, vehicle weight, dynamic load, tyre size, tyre inflation pressure, wheel slip, tracks or wheels, vibration, number of passes, vehicle speed, area affected, and whether logs are dragged, lifted or carried.
2	The risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to soil physical properties for the particular disturbance activity and geographical setting.
3	The risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for these factors.
4	The risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Source: SOFR 2008.

Table 4.13: Area of multiple-use public forest where disturbance activities were planned, proportion assessed for risk to soil physical properties, and assessed category, 2011–12

Disturbance activity	Metric	NSW	SA ^a	Tas.	Vic.	WA
Native forest harvesting and silviculture	Area (hectares)	27,484	n.a.	n.a.	5,250	n.r.
	Assessed for risk to soil properties (%)	100	n.a.	100	25	100
	Assessed category ^b	1	n.a.	1	3	3
Plantation operations	Area (hectares)	14,068	n.r.	4,600	n.r.	n.r.
	Assessed for risk to soil properties (%)	100	100	100	90	n.r.
	Assessed category ^b	1	1	1	2	n.r.
Road construction and maintenance	Area (hectares)	n.r.	n.r.	n.r.	n.r.	n.r.
	Assessed for risk to soil properties (%)	100	100	100	60	100
	Assessed category ^b	1	3	1–2	2	3
Fire management	Area (hectares)	36,931	n.r.	n.r.	n.r.	n.r.
	Assessed for risk to soil properties (%)	100	100	100	90	n.r.
	Assessed category ^b	1	3	1–2	2	n.r.

n.a. = not applicable; n.r. = not reported

^a South Australia does not harvest native forest.

^b Ratings refer to category descriptions in Table 4.12.

Note: Data were not available for ACT, NT and Qld.

Source: State agencies.

Knowledge base on soil physical properties

The protection of soil during wood harvesting and other disturbance operations has been an area of considerable development during the past decade (CCWA 2012a). The potential impacts on soils of various forest activities—in particular, disturbance by machinery—are well known. Assessments of risks to soil physical properties and management of such risks are generally carried out in multiple-use public forests in all state and territories according to science-based procedures. Table 4.7 in Indicator 4.1b describes the knowledge base on soil erosion and soil physical properties.

The knowledge base is less developed for nature conservation reserves. In that tenure, knowledge is generally site-specific, since it has been developed to meet specific needs such as recreational activities.

Knowledge of risks to soil properties is progressively incorporated into appropriate state and territory legally and non-legally binding instruments, and disseminated to the industry in various ways. For example, in Tasmania, dissemination of knowledge occurs through the Forest Practices Authority, which provides landowners and managers with access to soil management resource materials, including manuals and fact sheets. Combined with ongoing research and training and the experience of forest managers, these



Rolling dip construction, south-west Western Australia. Rolling dips divert water off roadways and reduce the risk of soil erosion.

resources assist with the identification and mapping of soils, and enable assessment and management of risks arising from the interactions of factors such as slope, climate, soil type, rainfall, stream management and vegetation cover.

The coverage and detail of mapping of soils in forested areas varies across states and territories. For example, major areas of state forest in northern Tasmania have been mapped at 1:250,000 scale, and 95 soil types with differing properties and erosion risks have been identified throughout the state, mostly in multiple-use state forests. The Forest Practices Authority has issued 34 forest soil fact sheets for forest managers.¹⁰⁹

¹⁰⁹ www.fpa.tas.gov.au/publications/document_list.

Indicator 4.1d

Management of the risk to water quantity from forests

Rationale

This indicator measures the extent to which the risk to water quantity has been explicitly identified and addressed in forest management. Water quantity is important for ecosystem health and water supply for human use.

Key points

- A widespread drought from 1997 to 2009 contributed to the recent increase in awareness among Australians of the importance of managing water resources effectively.
- Most jurisdictions have in place regulatory instruments, such as codes of practice or management guidelines, to manage water yields from forests.
- Practices such as selecting the location of forest to be harvested, limiting the proportion of catchments to be harvested in a year, and thinning to increase water yield, continue to be implemented to manage potential impacts of forestry operations on water quantity.
- Understanding of the impacts of forest type, age, growth rate and density on water yield continues to improve, but the ability to predict changes in water yield in specific circumstances is less well developed.
- Water use by tree plantations continues to be the subject of community attention and scientific research. The Murray–Darling Basin Plan includes coverage of water interception by commercial plantations.
- Major wildfires during the reporting period, and water use by the resultant natural regrowth, are expected to change water yields in some affected catchments in coming years.



Large areas of forest land are used to provide reliable and clean supplies of water for human drinking, as well as for irrigation and industrial uses. The quantity of water available in streams and rivers flowing from forested catchments depends on the combination of rainfall, water use by the forest vegetation, run-off, and entry to groundwater systems. Rainfall varies seasonally and across longer periods, and the amount of water used by a forest stand depends on its age, density, species mix and growth rate. In general, however, forested catchments provide a lower risk of variation in water quantity and quality than do catchments with other (non-forest) land uses.

Management practices likely to affect water yields in forested catchments include the timing, scale and spacing of wood harvesting; thinning of regrowth forest; fire management; control of woody weeds; modifications to rotation length; and land-use change (e.g. deforestation for agriculture, or reforestation of former agricultural land).

Major bushfire events can also influence water yields by changing the age-class structure of native forests. Bushfires pose a risk to water yields in forests in all tenures, including both nature conservation reserves and multiple-use public forests, because the greater water use by regrowth forest can result in stream-flow reductions. Recent large bushfires in Australia (see Indicator 3.1b) and the subsequent establishment of regrowth forests are expected to affect current and future water yields in some burnt areas.

Most of south-eastern Australia was subject to drought from 1997 to 2009, a period sometimes referred to as ‘the big dry’ (Gergis et al. 2011) or, more formally, the millennium drought. This drought affected water availability, agriculture and ecosystem function in a region that supports about 60% of Australia’s population and 40% of the nation’s total agricultural production. Australia officially became drought free in the first half of 2012 (Ludwig 2012).

The millennium drought contributed to a recent general increase in awareness among Australians of the importance of managing water resources effectively (Heberger 2012). It also

prompted steps towards a more proactive approach to drought management, and preparing land managers, particularly farmers, for a potentially increasingly variable future climate.

Climate change is predicted to cause rainfall deficits in southern Australia, reducing water yields (see Indicator 3.1a), and to affect forest productivity (ABARES 2011a). Climate change could also increase the impact of forest activities on water yields, especially in drier parts of Australia.

Instruments in place that address the risk to water quantity

Regulatory instruments, such as codes of practice and management guidelines, specify measures to be implemented to maintain stream flows and water quantity in particular locations. These instruments also provide benchmarks against which the management of water quantity can be assessed. Table 4.14 sets out the various categories of regulatory instruments, and Table 4.15 indicates the extent to which legally binding and non-legally binding regulatory instruments address the risk to water quantity posed by forest management activities in multiple-use public forests.

In Tasmania, the *Forest Practices Code 2000* restricts wood harvesting to no more than 5% of any water supply catchment in any given year.

In Victoria, Melbourne's water supply catchments include large areas of national parks and some state forests. VicForests conducts wood harvesting in certain state forest catchments (e.g. Thomson, Tarago, Bunyip and Yarra tributaries) after forest areas have been allocated for harvesting by the Department of Sustainability and Environment¹¹⁰. The Victorian *Code of Forest Practices for Timber Production* regulates wood harvesting; it contains measures to protect water yield and water quality, including leaving buffer zones along streams, installing drainage on harvesting tracks, and ensuring that access roads are well maintained. In the Yarra tributaries (four small catchments in the Warburton area), wood harvesting is conducted in only one catchment per year. During the period of harvesting (December–April), water from the harvested catchment is not used for urban water supply and, instead, is delivered to the Yarra River as an environmental flow.

In South Australia, draft water allocation plans that address the impacts of forest management (principally in plantations) have been released for the lower Limestone Coast (south-east South Australia), eastern Mount Lofty Ranges and western Mount Lofty Ranges. Water quantity policies are also included in the 2009 Kangaroo Island Regional Natural Resources Management Plan (see <http://www.naturalresources.sa.gov.au/kangarooisland/about-us/our-regions-plan>). In November 2011, the South Australian Parliament amended the *Natural Resources Management Act 2004*, to enable natural resource management boards to control significant plantation water use through licensing or a forest permit system.

In New South Wales, operations in public multiple-use native forests are required to be dispersed in space and time under conditions of integrated forestry operations approvals; these include environment protection licences, as required by the *Forestry and National Park Estate Act 1998*. Harvesting activities are generally restricted to 1–2% of the total catchment area in any one year.

In Western Australia, a 10-year forest management plan (the *Forest Management Plan 2004–2013*) is applied to the main wood production areas in the state's south-west. The plan includes a broad requirement to maintain water quantity.

Across Australia, and in line with management objectives, there is generally very little disturbance apart from fire in forested public nature conservation reserves. Where planned disturbance occurs (such as during road construction, trail maintenance, fire management or infrastructure development), legal instruments in all states and territories require the protection of water values.

Water quantity knowledge base

Knowledge of the effects of forest operations on water quantity is well developed, particularly in New South Wales and Western Australia (Table 4.16). Capacity to model the effects of forest type, forest age, soil type and climatic variation on catchment water yield improved during the reporting period (Benyon et al. 2009, Bren et al. 2011), and continues to be a key area of research.

In Victoria, a range of studies have been undertaken on the impacts of wildfires on stream flow. Modelled impacts on water yields are very sensitive to assumptions about the mortality and recovery of forest vegetation in response to fire severity, and about post-fire rainfall.

In New South Wales, Forests NSW¹¹¹ has been conducting catchment-scale research on the impacts of forest management activities on water quantity for more than 30 years. This includes studies in the Red Hill plantation catchment near Tumut (Case study 4.2) and the Canobolas plantation catchment near Orange (Webb 2009), as well as modelling work in the south-east native forests (Webb 2012).

Long-term hydrological studies in three types of mixed-species eucalypt forest in New South Wales found an increase in water yield after harvesting, dependent on the proportion of the catchment area harvested. The increase persisted for at least three years, after which water yield returned to pre-harvest levels, before progressively declining in regenerating forest in some catchments by up to 20% of the pre-harvest yield; this reduction was generally temporary and was related to changes in forest species composition, basal area and stocking rates. The water yield reductions observed in studies in other states on ash eucalypt forests do not typically occur in mixed-species eucalypt forests in New South Wales (Webb et al. 2012b).

¹¹⁰ From April 2013, the Department of Environment and Primary Industries.

¹¹¹ From January 2013, the Forestry Corporation of NSW.

Table 4.14: Categories of the extent to which regulatory frameworks aim to maintain water quantity after disturbances associated with forest management

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to water quantity posed by forest management-related disturbance activities: <ul style="list-style-type: none"> • local and regional requirements relating to water yield, and the sensitivity of the water supply system to changes in water yield • age structure of stands in forested catchments • the conversion of mature stands to regrowth • rotation lengths • stand density.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with a low risk to water quantity for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to water quantity when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to water quantity.

Source: SOFR 2008.

Table 4.15: Extent to which legally binding and non-legally binding instruments address the risk to water quantity from forest management activities in multiple-use public forests (including plantations)

Type of instrument	Assessed category				
	NSW	SA	Tas.	Vic.	WA
Legally binding	2	2	1	2	4
Non-legally binding	2	4	1	2	5

Note: A lower number implies a higher level of prescriptive detail in the regulatory instrument (see Table 4.14 for category descriptions). No data available for Qld.
Source: Compiled by the Australian Bureau of Agricultural and Resource Economics and Sciences from information obtained from state agencies.

Table 4.16: Knowledge base on water quantity, by jurisdiction

Jurisdiction	Water quantity knowledge base
ACT	Increasing knowledge of how pine plantations affect the quantity of water collected in catchments.
NSW	Well-developed knowledge based on long-term (30-year) forest hydrology research on catchments in a number of locations. Research has been published. Models have been developed to assess the impacts of operations in plantations and native forests.
SA	Reasonable knowledge of impacts of activities on water quantity, including local knowledge and training, codes of practice, published research and geographic information systems. However, the need for improved knowledge to assist managers with some risk factors has been identified.
Tas.	Increasing knowledge of impacts of activities on water quantity, including local knowledge, modelling, research results, training and codes of practice. Models have been developed to assess the impacts of plantation growth.
Vic.	Reasonable knowledge of impacts of activities on water quantity, including local knowledge and training, modelling and codes of practice. However, the need for improved knowledge to assist managers with some risk factors has been identified.
WA	Well-developed knowledge, including published research, geographic information systems, decision-support tools, codes of practice, local knowledge, training and site-specific research models.

Note: Data were not available for NT or Qld.

Source: State and territory agencies.



Native forest protecting a riparian zone in a softwood plantation in southern New South Wales.

This prediction of a relatively small change in water yield is supported by a recent study that investigated the impact of native forest harvesting on water yield in Murray–Darling Basin catchments (Bren et al. 2011). The study showed that, for most of the Murray–Darling Basin, native forest harvesting would increase water yields by a small amount compared with the yield in mature forest. However, catchments with high rainfall—namely, the Goulburn/Broken River, the Ovens/Kiewa River and the upper Murray River catchments—showed decreased yields for a period after harvesting. The study also found that cessation of harvesting would lead to a small decrease in flow, before flows increased after about 20 years. Potential water yield gains would take a long time to achieve and would depend on the absence of natural disturbances, such as fire, that would result in further forest regeneration. Overall, the study concluded that it is possible to manage native forests to achieve an optimal level of wood and water production through a combination of carefully scheduled harvesting and fire management.

A study undertaken as part of the CSIRO Water for a Healthy Country Flagship assembled and analysed data spanning 19 years on forests and catchments in the south-west region of Western Australia (Li et al. 2010). The study demonstrated the effects of forest density on run-off, and provided new information and tools to predict changes in run-off under various forest management and rainfall scenarios.



Toorong Falls on the Toorong River, managed production forest, Gippsland, Victoria.

Plantations

In Australia, forest plantations occupy only a small percentage of the catchments in which they occur (Gavran 2012). The location and management of plantations are subject to land-use policies and planning controls. Sustainability considerations are encompassed by forest management systems, including codes of practice and management prescriptions. Development of large-scale plantation forestry was included as one of the land-use changes to be considered by the *Intergovernmental Agreement on a National Water Initiative*¹¹², which provided a framework for considering the impacts of activities that could intercept water.

Water use by trees varies with species, soil type, rainfall and location. Because rainfall and hydrological factors are highly variable, it is difficult to measure the impact of plantations on water yields in small catchments if the plantations occupy less than 15–20% of the catchment; this threshold is lower in larger catchments. Nevertheless, community concern about water use by plantations has increased in the past decade as the prolonged drought has affected the availability of water in many catchments. This has created policy questions about water allocation and the entitlement of land managers to water resources, including rainfall.

The Murray–Darling Basin Plan (MDBA 2012) lists commercial plantations as a form of water interception, and specifies the maximum amount of water that commercial plantations may take from each sustainable diversion limit resource unit.¹¹³ Under certain circumstances, the Murray–Darling Basin Plan requires that water resource plans set out a process for monitoring the impact of commercial plantations on water resources. Water resource plans also need to identify actions to be taken if such monitoring shows that a commercial plantation (alone or with other types of water interception) is compromising the environmental water requirement, or that there is an increase in the quantity of water being taken by the plantation.

Concerns about plantations and water use expressed in the literature have been built on assumptions that have not necessarily been tested. Many factors affect plantation water use, and alternative approaches to the design and management of forest plantations to maximise water-use efficiency have been proposed, but few have been tested (Vanclay 2009).

¹¹² http://nwc.gov.au/_data/assets/pdf_file/0008/24749/Intergovernmental-Agreement-on-a-national-water-initiative.pdf.

¹¹³ A sustainable diversion limit resource unit comprises the water resource, or particular parts of the water resource, of a water resource plan area, and is either a surface-water sustainable diversion limit resource unit or a groundwater sustainable diversion limit resource unit.

Case study 4.2: Response of stream flow to afforestation and thinning at Red Hill, near Tumut, Murray–Darling Basin

Competition for water resources in the Murray–Darling Basin has led to a need to account for changes in water use arising from land-use change, including establishment and management of plantation forests. Generalised forest conversion models have been used in the past to assess the likely impacts of future afforestation on stream flows within the Basin. These models are a useful starting point, but do not account for changing forest age or for silvicultural interventions such as thinning. At various locations in the Basin, Forests NSW¹¹⁴ has been conducting research into, and monitoring, plantation water use at the catchment scale since 1989. The aim is to improve the models so that they more accurately determine stream flow, leading to improved management of the impacts of plantations on water interception.

Forests NSW analysed 20-year stream-flow monitoring results from the Red Hill paired catchment study to see if forest age is a significant factor in determining stream flow. The analysis compared the Kileys Run pasture catchment with the Red Hill catchment, which is afforested with *Pinus radiata* plantations. Stream flow in the Red Hill catchment declined steadily over time, particularly six years after planting, when stand basal area rapidly increased.

Mixed-effect model analysis indicated that, over the first 20 years of the plantation rotation, the mean annual impact of afforestation with pines (that is, the increased water use per unit area compared with pasture) was 155 mm, peaking at 211 mm in year 14. Thinning at age 14 years had a significant positive effect on stream flow, which persisted for at least 6 years. Drought conditions, coupled with a process of recharging the catchment soils, contributed to a delayed response of stream flow to thinning.

Collectively, the results indicate that factors such as forest age and thinning can usefully be incorporated into models used in water resources planning to allow more accurate prediction of the hydrological effects of afforestation.

Source: Webb and Kathuria (2012).



Plantations in Tasmania.

¹¹⁴ From January 2013, the Forestry Corporation of NSW.

Indicator 4.1e

Management of the risks to water quality in forests

Rationale

This indicator measures the extent to which the risk to water quality has been explicitly identified and addressed in forest management. Water quality is important for forest ecosystem health and water supply for human use.

Key points

- The effect of forest management activities on water quality is reasonably well understood. The knowledge base improved during the reporting period and informs mitigation of potential risks to water quality that arise from forest management activities.
- In most states and territories, instruments such as legislation, codes of forest practice or best management practice manuals mandate or guide practices that must be carried out to assist in maintaining water quality.
- Assessment of the risk to water quality posed by wood harvesting is reasonably comprehensive across most jurisdictions.
- Assessment of compliance with mitigation measures to protect water quality occurs in all states and territories. Compliance is generally high for wood harvesting operations. There is limited monitoring of the effects of forest management on water quality.
- Bushfires during the reporting period caused temporary declines in water quality across forest tenures, mainly in Victoria and Western Australia.



This indicator reports on the mitigation measures that are in place to protect water quality during forest management activities. The focus of reporting is on multiple-use public forest and public nature conservation reserves, with data generally not available for other tenures in most states and territories.

Water quality

Large areas of forest land supply water for human consumption, as well as for irrigation and industrial uses, with the forest soil and litter acting as a filter that produces clean water. In general, forested catchments provide a lower risk of variation in water quantity and quality than catchments with other (non-forest) land uses. Forestry activities and other disturbances such as fire, however, can have negative impacts on water quality, unless planned, managed or mitigated appropriately—for example, through measures such as drainage of extraction tracks, and maintaining vegetated streamside buffer zones to reduce sediment movement into streams (and also provide habitats and corridors for wildlife).

Four broad disturbance activities that can affect water quality in forested areas are roading, wood harvesting, burning and recreation. The most common impact associated with forest management activities is the generation and movement of sediment into water bodies. However, a number of other factors can also negatively affect water quality. These include pollution from fertiliser and herbicides, elevated water temperature in clearings, and an increase in biological oxygen demand (the oxygen required for breakdown of organic matter by microorganisms).

Reforestation can reduce adverse impacts of dryland salinity and waterlogging, by lowering groundwater levels and decreasing the volume of saline groundwater entering streams.

Planned and unplanned fires have the potential to affect water quality through increased erosion risk, coupled with more intense run-off, which increase flows of sediment, nutrients and other determinants of water quality such as trace elements. Recent examples of major bushfires that caused temporary declines in water quality are the Victorian Black Saturday fire of 2009 and the Western Australian Margaret River region fire of 2011. Although the 2009 wildfires burned 30% of Melbourne's water supply catchments, water quality in storage reservoirs returned to pre-fire condition in nine months, with storm-driven turbidity peaks rapidly returning to baseline conditions (Frame et al. 2009, Smith et al. 2011).

Planning to reduce the impact of recreation infrastructure and activities (such as roading and traffic) on water quality in reserves is managed under various pieces of state and territory legislation. Although recreation activities are often permitted in reserved forests, a relatively small area is used for access and other visitor infrastructure. Hence, most of the area of nature conservation reserves is not subject to such disturbance activities that might affect soil and water values. Wildfire is the major threat to water quality in reserved forests.

Instruments in place that address the risks to water quality

Generally, instruments are in place to control the risks of forestry activities impacting on the quality of water in forested catchments. However, the level of control varies across jurisdictions.

Using the categories described in Table 4.17, the extent to which legally and non-legally binding regulatory instruments, such as codes of practice, guidelines and forest management plans that address water quality, exist across state and territory jurisdictions is rated in Table 4.18. Key mitigation measures include providing adequate drainage for roads, trails and tracks; and protecting streambanks with buffer or filter strips that minimise soil movement into streams.

Legally binding regulatory instruments are in place in New South Wales, South Australia, Tasmania and Victoria. South Australia also has non-legally binding guidelines for its plantation estate that seek to minimise the risk to water quality by considering streams, drainage lines, water bodies and slope, and by specifying appropriate management practices and streamside buffers.

Table 4.17: Categories of the extent to which the regulatory framework requires the maintenance of water quality

Category	Category description
1	The regulatory instruments require the following components to be taken into account in addressing the risk to water quality from disturbance activities: <ul style="list-style-type: none"> stream and drainage lines (e.g. including exclusion zones) road drainage and stream crossings (e.g. cross-draining of log extraction tracks) slope sensitive aquatic habitat.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks to quality for the particular disturbance activity and geographic setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to water quality when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to water quality.

Source: SOFR 2008.

Table 4.18: Extent to which legally and non-legally binding regulatory instruments address the risk to water quality from forest operations, road and trail works, fire management and recreation

Instruments	Tenure	Assessed category ^a				
		NSW	SA	Tas.	Vic.	WA
Legally binding	Multiple-use public forests	1	4	1	1	4
	Public nature conservation reserves	1	4	1	1	4
Non-legally binding	Multiple-use public forests	1	1	1	2	1 (NF) 3 (P)
	Public nature conservation reserves	1	n.a.	1	2	4

n.a. = not applicable; NF = native forest; P = plantation

^a A lower number implies a higher level of prescriptive detail in the regulatory instrument (see Table 4.17 for category descriptions).

Note: Data were not available from ACT, NT or Qld.

Source: State agencies.

All states and territories undertake auditing in some form. For example, in New South Wales, all forestry operations in multiple-use forests are audited through a four-tier system, along with a monitoring and review exercise. These audits assess both the implementation of systems and the application of specifications or prescriptions, including standards of planning and compliance with regulatory approvals, codes of practice, Australian standards, and statutory requirements such as the *Pesticides Act 1999*. Compliance and monitoring results are reported. As part of the implementation of the Forests NSW¹¹⁵ Environmental Management System, all operational control documents are periodically reviewed and updated.

In Victoria, the *Code of Practice for Timber Production* (revised in 2007) applies to all timber production on private and public land, and outlines specific requirements to prevent soil sediments, nutrients, chemicals, petroleum products and fertilisers from entering waterways. Mitigation measures outlined in the code include the establishment of buffer and filter strips, the installation of appropriate drainage systems and stream crossings, restrictions on disturbances on steep slopes, the use of silt traps alongside roads, and road closures in wet weather. The *Code of Practice for Bushfire Management on Public Land* addresses the potential impacts of fire disturbance on water quality.

Western Australia has limited legally and non-legally binding instruments, which do not address all the aspects listed in Table 4.17. However, the *Forest Management Plan 2004–2013*, which is currently being reviewed and updated, covers all of the main wood production areas in the state's south-west. The plan places strong emphasis on the protection of water values.

In Tasmania, the risk to water quality is assessed for forest activities when they are carried out under the *Forest Practices Act 1985*, irrespective of the land tenure or forest type. The *Forest Practices Code 2000*, supporting manuals such as the *Guidelines for the Protection of Class 4 Streams*, and forest certification standards such as the Australian Forestry Standard, are also used to minimise the risk to water quality from forestry activities.

In 2009, Timber Queensland produced a draft *Code of Practice for Queensland Commercial Private Plantations*¹¹⁶, which was circulated for stakeholder consultation. The draft code covers private plantation forests in the state. Along with Queensland's *Code of Practice for Native Forest Timber Production* for public land, this aims to address some of the potential risks that forestry activities may pose to water quality.

Assessment of the risk to water quality

Water quality is generally monitored at many sites across the states and territories to determine whether water for different uses, including drinking water, meets the required standards. Not all these sites are located in forests. It is not always possible to identify the causes of changes in water quality because many factors that determine the spatial and temporal impacts of forest activities are difficult to measure at the local level.

Assessment of the risk of forestry activities to water quality is generally based on field monitoring of water at a limited number of locations, and comparing water quality parameters against recommended thresholds set out in various guidelines and standards. Many forest managers make such assessments using similar categories to those listed in Table 4.19 as a series of overlays in a geographic information system, and then seek advice from the relevant regulatory agencies, if necessary.

Table 4.20 shows disturbance activities planned in multiple-use public forest in 2010–11, the proportion assessed for risks to water quality and the category of assessment, by jurisdiction.

In New South Wales, South Australia, Tasmania, Victoria and Western Australia, assessments of the potential risks to water quality are conducted for forest activities and roading operations in multiple-use public native forests and plantations. However, the assessments have varying levels of robustness. In the states and territories for which data were available, almost all the proposed activities were assessed for risks to water quality.

Water quality knowledge base

The knowledge base of water quality relating to forestry activity is generally reasonably strong (Table 4.21).

The knowledge base is highly dependent on knowledge of soil erosion and appropriate soil erosion mitigation measures. Supported by research, the knowledge base continues to develop, particularly for suspended sediment exports and concentrations after wildfire.

In New South Wales, Forests NSW¹¹⁷ is undertaking a water-monitoring program in native forests to assess the impacts of its activities on water quality, principally sediment loads (Webb 2008; Webb et al. 2012a). In addition, state and territory authorities in New South Wales, the Australian Capital Territory and Victoria are designing a decision-support system for the management of run-off from unsealed roads.

In South Australia, the Environment Protection Authority monitors water quality to protect environmental values, as set out in the *Environment Protection (Water Quality) Policy 2003*.

A recent study (Smith et al. 2011) reviewed nutrient losses following post-wildfire salvage harvesting of a radiata pine plantation catchment in south-eastern Australia, and compared it with an adjacent eucalypt forest catchment that

¹¹⁵ From January 2013, the Forestry Corporation of NSW.

¹¹⁶ www.timberqueensland.com.au/Docs/News%20and%20Events/News/Draft-Qld-private-plantation-code-of-practice_stakeholder-consultation_Oct09.pdf.

¹¹⁷ From January 2013, the Forestry Corporation of NSW.

Table 4.19: Categories of the extent to which risks to water quality are assessed in planning processes

Category	Category description
1	The water quality risk assessment system comprehensively takes account of all the following factors: <ul style="list-style-type: none"> • stream and drainage lines (e.g. including exclusion zones) • road drainage and stream crossings (e.g. cross-draining of log extraction tracks) • slope • sensitive aquatic habitat.
2	The water quality risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to water quality for the particular disturbance activity and geographic setting.
3	The water quality risk assessment system takes into account some of the factors listed in category 1 or only partially accounts for these factors.
4	The water quality risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Source: SOFR 2008.

Table 4.20: Proportion of disturbance activities in multiple-use public forest assessed for risk to water quality in 2010–11, and assessed category

Disturbance activity	Metric	ACT	NSW	SA	Tas.	Vic.	WA
Native forest harvesting and silviculture	Assessed for risk to water quality (%)	n.a.	100	n.a.	100	95	100
	Assessed category ^a	n.a.	1	n.a.	1	1	2
Plantation operations	Assessed for risk to water quality (%)	100	100	100	100	95	100
	Assessed category ^a	1	1	1	1	1	3
Road construction and maintenance	Assessed for risk to water quality (%)	100	100	100	100	95	100
	Assessed category ^a	2	1	2	1 (MUF) 2 (NCC, C, Pv)	1	2
Fire management	Assessed for risk to water quality (%)	100	100	100	100	95	–
	Assessed category ^a	2	1	2	1 (MUF) 2 (NCC, C, Pv)	1	–

– = not available; C = Crown lands; MUF = multiple-use forest; n.a. = not applicable; NCC = nature conservation reserve; Pv = private

^a Ratings refer to categories in Table 4.19.

Note: Data were not available for NT or Qld.

Source: State and territory agencies.

Table 4.21: Knowledge base on water quality, by jurisdiction

Jurisdiction	Knowledge base
ACT	The ACT Government has well-developed knowledge on best management and continuous improvement of water quality within its plantation estate. Codes of practice have specific clauses for protection of riparian zones and drainage lines, for authorisation by the Environment Protection Authority, and for ongoing water monitoring.
NSW	Forests NSW ¹¹⁸ has a well-developed system of research catchments and has published research results. Forests NSW has also developed models to assess impacts of plantation and native forestry operations on water quality.
SA	There is reasonable knowledge on the impacts of forest management activities on water quality. Data on breaches and non-compliance are recorded in ForestrySA's auditing process and in the auditing of other businesses that have forest certification.
Tas.	Tasmania has well-developed knowledge for multiple-use public forest and some private forest. This includes published research, GIS tools, decision-support tools, local knowledge and training, and site-specific research models. Code of practice has specific requirements for protection of watercourses and water quality. The Forest Practices Authority provides regular training to forest managers.
Vic.	There is reasonable knowledge of the impacts of forestry activity on listed values, including local knowledge and training, and codes of practice. However, for some risk factors, a need for improved knowledge to assist managers has been clearly identified.
WA	There is well-developed knowledge, including published research, GIS tools, decision-support tools, codes of practice, local knowledge, training and site-specific research models.

GIS = geographic information system

Note: Data were not available from NT or Qld.

Source: State and territory agencies.

¹¹⁸ From January 2013, the Forestry Corporation of NSW.

was also burnt but not harvested. Median values of total suspended solids and turbidity returned to pre-fire levels within three years in both catchments. Maximum levels of total suspended solids during storm events in the harvested pine catchment exceeded maximum levels in the eucalypt catchment. In contrast, the impact of harvesting in the pine catchment on solute concentrations was minor, and most solutes returned to pre-fire levels within 2–3 years in both catchments. Nutrient exports from the pine catchment exceeded those from the eucalypt catchment.

Substantial monitoring undertaken in Tasmania indicated that streams within catchments with significant forestry operations showed no significant impacts of these operations on river health. Harvested catchments, for example, had similar macroinvertebrate communities to those without such operations. However, some plantation establishment activities caused minor contamination of water supplies and streams, especially where long-term residual herbicides such as simazine had been applied on soils (McIntosh 2007, 2008). This finding prompted a significant reduction in the use of simazine.

The Tasmanian Department of Primary Industries, Parks, Water and Environment maintains an extensive water quality and river health monitoring network in major rural catchments. Water quality is regularly monitored at 52 sites for a range of nutrients, turbidity, dissolved oxygen and pesticides, and river health is monitored at 60 sites. Floodwaters are also tested for a range of pesticides in four catchments with significant forestry activities.



A water gauge, used to monitor stream flow from a forested water-course, Tasmania.

Compliance with water quality measures

Assessing compliance with requirements for the protection of soil values and water quality is part of the process of assessing compliance with measures to prevent soil erosion (see Indicator 4.1b).

Forestry Tasmania conducted extensive water monitoring tests at sites downstream of chemical application operations between 2006 and 2011. It did not detect any contamination that exceeded Australian drinking water guidelines.

In New South Wales, legislation, codes of practice and the conditions of environment protection licences are implemented in state forests to ensure that any adverse impacts of forest management activities on the quality of water supplies are minimised. Forests NSW¹¹⁹ monitors the environmental effects of its forestry activities, including on aquatic habitats and water sources, and has implemented a comprehensive, mandatory water quality monitoring program, called the 'Phase 1' program, since 1999. The aim of this program is to determine whether forestry activities have an identifiable impact on water quality, such as turbidity and suspended sediment concentration, and, if so, to quantify the level of impact.

A catchment experiment conducted in a control native forest catchment and two pine plantation catchments within Canobolas State Forest, Orange, New South Wales (Webb et al. 2007) found that plantation catchments that were harvested in 2002–03 using legislated best management practices did not have significant impacts on water quality indicators such as turbidity and suspended sediment concentration. In these catchments, the management practices used were adequate to protect streams from the effects of forestry activities. Similarly, a replicated catchment experiment in native eucalypt forest in Kangaroo River State Forest, near Coffs Harbour, New South Wales, showed that selective harvesting using best management practices did not affect suspended sediment yields in two of three treated catchments; in the third catchment, an increase in event sediment loads and concentration, at the time of harvesting, subsided within 12 months (Webb et al. 2012a).

Victoria has a network of stream water quality monitoring sites that record parameters such as acidity, dissolved oxygen, electrical conductivity, sediments and total dissolved solids, temperature, phosphorus and nitrogen, mostly in or downstream from forested areas. Melbourne Water plays a key role in monitoring. It has five water quality monitoring sites on waterways within forested catchments: one in the upper Dandenong Creek catchment and four in the upper Yarra catchment. Monthly grab-sample data have been collected at most of these sites since 2007. The data from these and others sites in the Melbourne Water network are combined with other information to assess the overall health of waterways in the region.

¹¹⁹ From January 2013, the Forestry Corporation of NSW.

Case study 4.3: Water quality in forested catchments

Stream water quality can depend on many factors, including the topography, geology and vegetation upstream of the monitoring point, and the history of natural or management disturbance in the catchment. Forestry Tasmania researchers used an eight-year dataset collected for 15 streams in the Warra Long-Term Ecological Research site in southern Tasmania (www.warra.com) to compare the relative influence of environmental and disturbance factors on water quality, predominantly assessed by colour and turbidity.

Mean turbidity and mean water colour showed a strong association with landscape position: grouping catchments by water quality attributes (Figure 4.1) produced similar results to grouping catchments geographically (Figure 4.2). Large, high-altitude, reasonably steep catchments in the west of Warra (Crystal, Isabella and Tomalah) contained water that was pale in colour with little suspended sediment; these catchments also had a low proportion of wet sclerophyll forest and a low road density, but high rainfall and good drainage. Streams draining to the south (Bren, Tahune, Leighs, Johns and Laurel creeks) had higher turbidity (possibly from inorganic sediments) and moderate colour. Streams in the central-east (including Glovers, King, Warra, Kroanna and Swanson creeks) had reasonably low turbidity but dark-coloured water, probably resulting from greater input of organic matter to these streams from relatively poorly drained catchments. Water quality therefore varies between catchments according to a range of geographic factors.

Principal component analysis showed relatively strong relationships between geographic and environmental variables and water quality, but weaker relationships between disturbance variables and water quality. This indicates that natural variation in stream water quality in this area of southern Tasmania plays a more important role in water quality at the landscape level than does the catchment history of fire, roading or harvesting.

Figure 4.1: Scatterplot of mean turbidity and mean colour over eight years for water in 15 catchments in the Warra Long-Term Ecological Research site

CU = colour unit;
NTU = nephelometric turbidity unit (a unit of turbidity measured by light scattering).

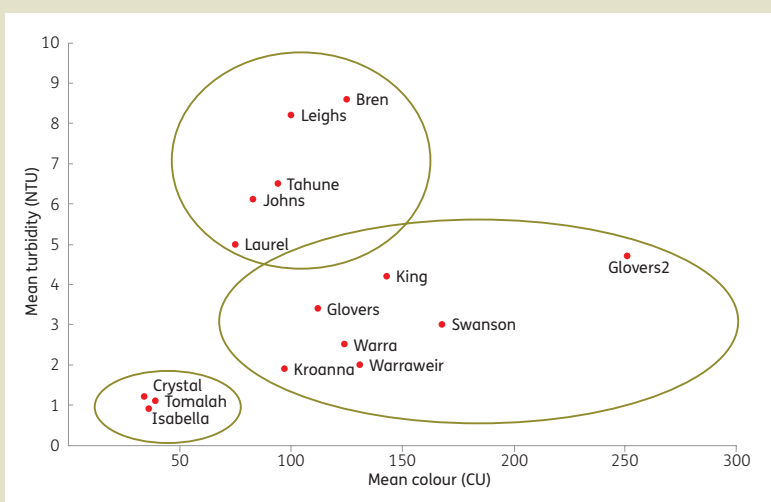
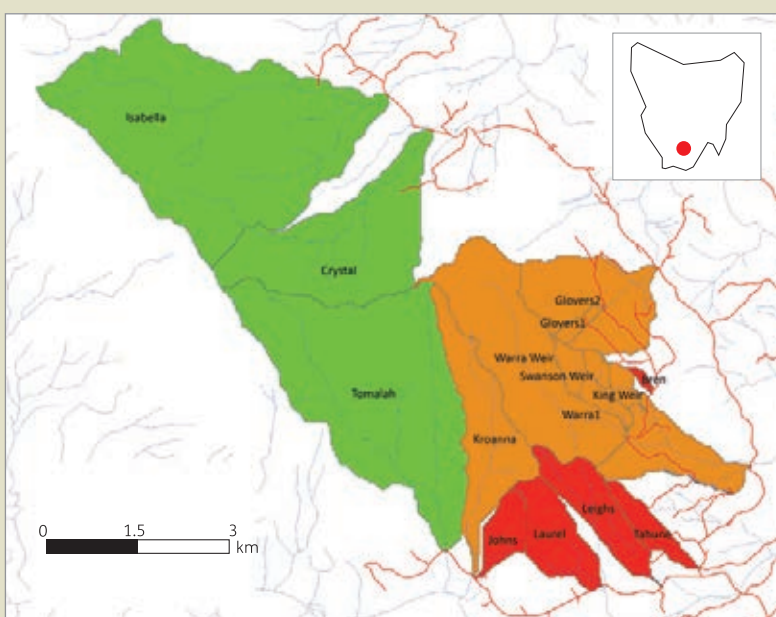


Figure 4.2: Sampled catchments in the Warra Long-Term Ecological Research site coloured by mean turbidity and water colour

- Catchments of low turbidity and low colour
- Catchments of medium turbidity and high colour
- Catchments of high turbidity and medium colour



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