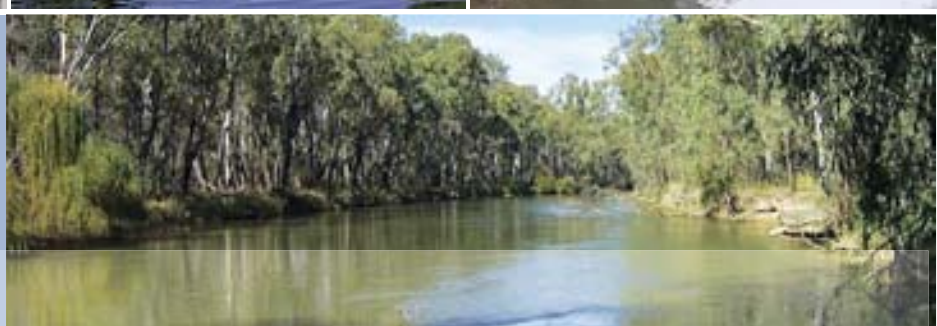
THREAT ABATEMENT PLAN

Removal of large woody debris from NSW rivers and streams



NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Threat abatement plan - Removal of large woody debris from NSW rivers and streams

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Prepared in accordance with the threatened species provisions of the NSW *Fisheries Management Act 1994.*

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Background

The ‘removal of large woody debris from NSW rivers and streams’ is listed as a key threatening process under the NSW *Fisheries Management Act 1994*. Large woody debris includes trees, trunks, branches, tree heads or root masses that have fallen, been washed or placed into rivers or streams, and were previously referred to as “snags”.

Removal of large woody debris – or 'de-snagging' – has been widely practiced since at least the mid-1800s, initially to clear river channels for navigation and later continued with the aim of increasing channel capacity, reducing flood risk, removing safety hazards, protecting infrastructure and preventing bank erosion. Recent research has shown that many of the justifications for removing large woody debris were unfounded and that large woody debris has a critical ecological function in rivers and estuaries. Removal of large woody debris threatens several vulnerable and endangered species, populations and ecological communities.

This plan has been developed in accordance with the requirements of the *Fisheries Management Act 1994* to reduce or eliminate threats associated with the removal of large woody debris from NSW rivers and streams. The plan proposes a combination of new initiatives and coordination of existing efforts. The document provides guidance to Ministers and public authorities on the actions required to eliminate, manage or mitigate the threat posed by the removal of large woody debris from NSW watercourses. Ministers and public authorities must take appropriate actions to implement the measures in the plan for which they are responsible, and ensure that they do not make decisions that are inconsistent with the provisions of the plan without consulting the NSW Minister for Primary Industries.

Threat abatement objectives and actions

This threat abatement plan contains 10 strategies to be achieved in 3 action areas:

- Research and information activities;
- Compliance and regulation activities; and
- Management activities

The objective of this threat abatement plan is to abate, ameliorate or eliminate the adverse effects from the removal of large woody debris on threatened species, populations and ecological communities listed on the schedules of the NSW *Fisheries Management Act 1994.* The criteria for assessing achievement of the objective will be the de-listing of the removal of large woody debris as a key threatening process in NSW.

Implementing the plan

The NSW Department of Primary Industries is responsible for developing and leading implementation of threat abatement plans for key threatening processes listed under the NSW *Fisheries Management Act 1994*. However, successful threat abatement is contingent on the assistance, cooperation and involvement of agencies, public authorities, local councils, research institutions and the community. Implementation of some threat abatement actions will be contingent on the availability of funding from grant programs.

1. Introduction

1.1 Legislative context

The conservation of threatened species of fish, aquatic invertebrates and marine vegetation in NSW is covered by Part 7A of the *Fisheries Management Act 1994*; administered by the NSW Department of Primary Industries (NSW DPI). Part 7A deals with the protection and recovery of threatened species, populations and ecological communities, the listing of key threatening processes, the preparation of recovery and threat abatement plans and development of the Priorities Action Statement.

Following consideration by the Fisheries Scientific Committee, 'the removal of large woody debris from NSW rivers and streams' was listed as a key threatening process in November 2001. To be eligible for listing, a key threatening process must adversely affect threatened species, populations or ecological communities, or possibly cause others that are not currently threatened to become threatened. Table 1 shows species, populations and ecological communities listed under the NSW *Fisheries Management Act 1994* (as at July 2007) adversely impacted by the removal of large woody debris.

Table 1 – Threatened species, populations and ecological communities impacted by the 'removal of large woody debris from NSW rivers and streams'.

Endangered species	Endangered populations	Endangered ecological communities	Vulnerable species
Eastern freshwater cod	Purple-spotted gudgeon (western population)	Lower Murray River catchment	Macquarie perch
Trout cod	Olive perchlet (western population)	Lowland catchment of the Darling River	Silver perch
River snail		Lowland catchment of the Lachlan River	Southern pygmy perch

1.2 Preparation of threat abatement plans

The NSW DPI may prepare threat abatement plans to abate, ameliorate or eliminate adverse effects of key threatening processes. The NSW DPI is also required to set out the strategies to manage key threatening processes in a Priorities Action Statement. Approved threat abatement plans are statutory documents. Ministers and public authorities need to take appropriate actions to implement the measures in the plan for which they are responsible, and to ensure their decisions are not inconsistent with the provisions of the plan without consulting the NSW Minister for Primary Industries. The NSW *Fisheries Management Act 1994* also requires public authorities (other than local councils) with identified responsibilities in a threat abatement plan to report on implementation actions in their annual report to Parliament. Local councils must report on actions for which they are responsible in annual State of the Environment reports.

1.3 Environmental planning and assessment

The NSW *Fisheries Management Act 1994* integrates the conservation of threatened species into development control processes established by the NSW *Environmental Planning and Assessment Act 1979*. As part of the development assessment process, consent authorities are required to assess development impacts on threatened species, and to consider if activities are of a class of development recognised as a threatening process. Threat abatement plans must also be considered by determining, consent and concurrence

authorities for activities and developments under Parts 4 and 5 of the *Environmental Planning and Assessment Act 1979.*

Activities and developments that do not require approval under the *Environmental Planning and Assessment Act 1979* may require licensing under the *Fisheries Management Act 1994* if they cause damage to any habitat or critical habitat of a threatened species, population or ecological community. This includes activities such as the removal of large woody debris from an area that is habitat for a threatened species, population or ecological community.

1.4 Threat abatement plan implementation

The NSW DPI is the lead agency responsible for coordinating the implementation of the plan however the success of the plan and achievement of its objectives will require action by all levels of government, organisations and the community. The NSW DPI has a statutory obligation to encourage the conservation of threatened species by the adoption of measures involving co-operative management.

Other agencies with responsibility for implementing actions contained in this plan include the NSW Department of Environment and Climate Change (DECC), NSW Maritime Authority, Catchment Management Authorities (CMAs) and local councils. In addition, a range of other organisations will need to be involved including the Murray Darling Basin Commission (MDBC), Fisheries Scientific Committee, universities and research institutions, Rural Lands Protection Boards, and the NSW Department of Water and Energy (DWE), community organisations such as Landcare groups and fishing clubs also have an important role in ensuring the successful implementation of the plan.

1.5 Linkages to other recovery and threat abatement plans

1.5.1 New South Wales

Recovery plans may be prepared for threatened species, populations and ecological communities listed on the Schedules of the *Fisheries Management Act 1994*. In addition, a Priorities Action Statement must be prepared in accordance with section 220ZVA of the *Fisheries Management Act 1994*. The Priorities Action Statement sets out the strategies and relative priorities for promoting the recovery of threatened species, populations and ecological communities and for managing key threatening processes. There will be links between this threat abatement plan, the Priorities Action Statement and other recovery plans for threatened species, populations and ecological communities.

In addition, the ‘degradation of native riparian vegetation along NSW water courses' is listed as a key threatening process. Since native riparian vegetation is the major source of large woody debris in NSW rivers and streams, its removal has a significant effect on the amount of large woody debris entering aquatic ecosystems. The Priorities Action Statement and any threat abatement strategies addressing the degradation of native riparian vegetation should contribute to mitigating the impacts of large woody debris removal.

1.5.2 Victoria

‘Removal of wood debris from Victorian streams’ has been listed as a potentially threatening process under the Victorian *Flora and Fauna Guarantee Act 1998* (SAC 1991).

1.5.3 Other jurisdictions

The removal of woody debris is not listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. However, the Commonwealth has several native fish species that rely on woody debris for habitat listed as endangered or vulnerable. These include the Murray cod, eastern freshwater cod, trout cod and Macquarie perch. Removal of woody debris has also been identified as a threat to silver perch, which are listed as an endangered species in the Australian Capital Territory. The NSW DPI is involved in various interagency teams to coordinate a national approach to the recovery of these species.

2. Large woody debris and the aquatic environment

2.1 What is large woody debris?

Large woody debris – also commonly referred to as 'snags' – consists of whole trees, limbs or root masses that have fallen or been washed into a waterway and have become partly or wholly submerged by water. Large woody debris may consist of full trees, trunks, branches, tree heads or root masses. The debris may have fallen directly from riverbanks to lie *in situ*, or been transported during high flows to accumulate in masses (often termed log jams or debris dams) further downstream. This threat abatement plan applies to large woody debris that is partially, totally or intermittently covered with water and includes large woody debris on floodplains and in tidal rivers.

The amount of large woody debris in streams under natural conditions depends on a range of factors, including the type and age of riparian vegetation. Many native eucalypts lose limbs in hot dry weather because of water stress (Lloyd et al. 1991), and native timbers tend to be dense, long lasting, and can remain in-stream for periods up to several thousand years before decomposing (Nanson et al. 1995). These factors result in naturally high large woody debris loadings in many Australian rivers and streams. Conversely, willows and many other introduced species that commonly grow along NSW rivers and streams have soft timbers that decompose rapidly and have limited value in providing large woody debris compared to native species.

Large-scale disturbances including landslides and bank erosion can increase the input of large woody debris to streams. Similarly, floods carry in and deposit large woody debris from tributaries and floodplains (Harmon et al. 1986; Treadwell et al. 1999).

Despite the naturally high loads and persistent nature of large woody debris in NSW watercourses, extensive de-snagging programs and clearing of riparian vegetation have greatly reduced large woody debris loadings from their natural state.

2.2 Importance of large woody debris

Large woody debris plays a crucial role in riverine processes; forms an important structural component of rivers; influences many ecological processes; provides essential habitat for aquatic and terrestrial organisms; and influences stream morphology and stability. Large woody debris has clear ecological and geomorphic benefits by providing:

- Shelter to aquatic organisms from fast flowing water and direct sunlight, and cover to hide from predators and ambush prey;
- Solid stable surfaces for micro-organisms, plants and invertebrates to colonise;

- A food source for aquatic borers;
- Feeding areas, spawning sites on which to lay eggs, nursery areas for fish larvae and juveniles, and territory markers for some species;
- Drought refuge for invertebrates during dry periods;
- Physical habitat complexity for fish species, including varying in-stream flow velocities, and provision of flow refuges;
- A source of dissolved and solid organic carbon;
- Increased oxygenation of water and reduced stream stagnation resulting from eddying;
- Stabilisation of channels, protection of stream banks and reduction of erosion;
- Promotion of different habitat elements including scour pools, bars, islands, and side-channels; and
- Development of scour pools that provide drought refuge for aquatic organisms.

Figure 1: Large woody debris includes root masses, whole trees, and limbs that may be partially, wholly, or intermittently covered with water (Photo: A Vey NSW DPI)

Many native fish prefer to live in and around large woody debris, and their numbers can often be directly correlated with the amount of large woody debris habitat available (Treadwell et al. 1999). For example, species such as trout cod, Murray cod, two-spined blackfish, eastern freshwater cod, golden perch and Macquarie perch show a very close association with large woody debris habitat and are adversely affected by its removal. At least 23 native freshwater fish species found in NSW use large woody debris as a major habitat component and/or for spawning at some point in their life cycle (Appendix 1). This figure includes six threatened species and populations, as well as species that have declined in range and abundance such as Murray cod, freshwater catfish, and river blackfish. Since the habitat requirements of all species have not been well studied, the number of native fish species that rely on large woody debris may be higher.

2.2.1 Habitat values of large woody debris

Large woody debris is most effective as habitat when it has a complex structure with various sized spaces and surfaces at different levels above and below the water surface, thus meeting the habitat requirements of different species (Treadwell 1999). A complex surface structure containing grooves, splits, and hollows provides a greater surface area for colonisation by invertebrates, microbes and algae (O'Connor 1991). Large woody debris is found at a range of depths and locations in rivers and streams, creating habitat variability that is utilised by different species. For example, trout cod prefer wood in higher flows in the middle of channels or downstream of bends, Murray cod tend to be found around snags in slower-flowing waters near the edges, and golden perch prefer wood that extends higher into the water column (Nicol et al. 2002).

The value of large woody debris as habitat also depends on the type of wood. Willows and other introduced tree species seem to be of less value than native trees, supporting a less diverse invertebrate community (Treadwell 1999) and degrading more rapidly. Further, most species of willows are recognised as environmental weeds and can propagate vegetatively from branches and other woody material that washes or falls into rivers and streams.

2.2.2 Microbes & large woody debris

Submerged wood provides a suitable surface for colonisation by a range of microbes, including fungi, bacteria and algae, commonly known as 'biofilm' (Willoughby & Archer 1973; Aumen et al. 1983; Sinsabaugh et al. 1991; Scholz & Boon 1993). In rivers with shifting substrates (silt or sand), large woody debris may provide the only stable surface for such biofilms to develop (Treadwell et al. 1999).

Microbes play a vital role in generating and recycling organic carbon and other nutrients in the aquatic ecosystem, and are grazed upon by other organisms such as invertebrates.

Species composition of the biofilm depends on factors such as the depth of the wood in the water, the amount of light penetration (shallower, well-lit areas favour algae) and whether the water is flowing or still (bacterial biofilms tend to dominate in flowing waters). Research has shown a greater biomass of biofilm organisms on woody substrates than other inert substances such as glass (Sinsabaugh et al. 1991). The loss of bacterial biofilms has been implicated in the decline of the endangered river snail.

2.2.3 Invertebrates & large woody debris

Woody debris also provides important habitat for a range of invertebrate species, including insects, crustaceans and sponges (e.g. McKie & Cranston 1988; Boulton & Lloyd 1991; Lloyd et al. 1991). Compared to the benthos, large woody debris generally supports a greater diversity of invertebrate species (O'Connor 1991). In rivers with unstable sandy substrates, large woody debris may provide the only stable surface for invertebrate colonisation, particularly during high flows (Beesley 1996; Treadwell et al. 1999). Large woody debris can also provide a refuge for invertebrates during dry periods (Boulton 1989).

Many invertebrates graze on the biofilm and other fine organic material that occurs on the surface of submerged timber (O'Connor 1991). Other invertebrates including freshwater hydras, sponges, blackfly larvae (Simuliidae) and net-spinning caddis (Hydropsychidae) attach onto the wood in order to filter-feed (Tsyrlin 1994). Others, such as borers, feed directly on the wood and play an important role in decomposing and modifying the surface, thus promoting further colonisation (McKie & Cranston 1988; Flint 1996). In

turn, these invertebrates are consumed by many fish species, providing an important link in the food chain.

Research into species-habitat complexity has shown different species groups colonising various micro-habitats on large woody debris (O'Connor 1991). Species richness seems to be linked to the complexity of the wood surface, with more complex surfaces providing greater surface area for colonisation (O'Connor 1991).

2.2.4 Fish & large woody debris

Large woody debris forms one of the most important in-stream habitat components for native fish, particularly in lowland streams with sand or silt substrates. Many native fish prefer to live in and around large woody debris, and their numbers can often be directly correlated with the amount of such habitat available (Treadwell et al. 1999). Koehn (1995) found 80% of Murray cod within 1 metre of large woody debris, and fish appeared to show a preference for snagged areas (particularly those with snag piles) over areas devoid of snags.

Large woody debris provides a range of benefits for native fish. Woody structures obstruct currents and create eddies, producing both relatively still areas and zones of increased flow velocities. The variety of water velocities and depths suits fish of different sizes and with different swimming abilities. Large woody debris can allow fish to conserve energy by providing 'flow refuges' – places to rest out of the main current flow to avoid high velocities.

Figure 2: Large woody debris provides important fish habitat (Photo: M Doering NSW DPI)

Large woody debris also provides shelter and cover, enabling fish to hide from predators and avoid direct sunlight. Some smaller fish species use woody debris as shelter from predators. Species such as olive perchlet, Australian smelt, Duboulay's rainbow fish and estuary perchlet can often be found shoaling around fallen trees and branches. Predatory species such as short-finned eels often favour log-jams as a place from which to ambush prey (Koehn et al. 1994).

Migratory species such as Murray cod and golden perch, may use woody habitat as markers to identify territorial boundaries. For example, radio-tracking of Murray cod has shown they may stay in close proximity to particular snags for months at a time, migrate up to several hundred kilometres during spawning, and then exhibit a 'homing response' by returning to the same 'home snag' (Koehn 1995; J. Koehn unpubl. data cited in Treadwell et al. 1999).

Large woody debris also plays an essential role in the breeding cycle of many native fishes, such as purple-spotted gudgeons, Murray cod and river blackfish, by providing spawning sites on which to lay eggs (Cadwallader & Backhouse 1983). For example, river blackfish lay a fairly small number of eggs in the safety of hollow logs (Jackson 1978), while other species deposit adhesive eggs onto log surfaces or among woody debris.

During flooding, the availability of large woody debris habitat to fish can increase dramatically because of increased water in side channels, anabranches, effluent streams and the floodplain. This may increase the availability of spawning sites and shelter for larvae, in turn influencing recruitment (Treadwell et al. 1999).

2.2.5 Carbon and nutrient processing

Large woody debris has an important role in carbon and nutrient processing (Treadwell 1999). Bacterial and fungal biofilms that develop on large woody debris help to decompose the wood, hence providing a supply of dissolved and solid organic carbon that is consumed by invertebrates and fish. The decomposition of large woody debris also increases the availability of other important nutrients such as nitrogen and phosphorus (Aumen et al. 1990). Algal biofilms can produce a large amount of carbon through photosynthesis, and are eaten by species higher in the food chain. These processes are particularly important in areas with limited inputs of carbon from the floodplain resulting from clearing or river regulation (Treadwell 1999).

Accumulations of large woody debris (debris dams) in headwater tributaries are important components of small stream ecosystems because they trap organic matter until it decomposes into smaller fragments, rather than allowing it to be immediately washed downstream (Bilby & Likens 1980). Water flowing over snags in lowland rivers can also help to re-oxygenate the water and prevent stagnation (Treadwell 1999).

2.2.6 Role in habitat formation

As well as providing direct habitat, large woody debris can increase physical habitat complexity streams by affecting the formation of different in-stream habitat types. Large woody debris can help to stabilise the channel and prevent erosion by holding sediment in place and protecting banks (e.g. Webb & Erskine 1999a), as well as inducing localised bank scour immediately downstream. The process of inducing small-scale erosion and sedimentation pockets helps to give river channels structural variability; providing niche environments for a diverse array of aquatic species that require different levels of flow, sunlight, shade, water depth, and substrate coarseness to survive.

Depending on the size and orientation of the woody structures and the strength of water flow, large woody debris can promote the development and maintenance of scour pools, bars, islands and side-channels as shown in Table 2 (Keller & Swanson 1979; Montgomery et al. 1995, Abbe & Montgomery 1996, Richmond & Fausch 1995, Wallace et al. 1995).

Table 2: Habitat development as determined by snag orientation (from Treadwell et al. 1999)

Orientation to flow	Upstream habitat formed	Downstream habitat formed
Parallel	Scour pool	Bar or island
Angled	Combination pool and bar	Combination pool and bar
Perpendicular: on bed	Depositional zone	Scour pool
Perpendicular: above bed	Scour pool	Scour pool

Scour pools formed by snags are particularly important in providing refuges for aquatic organisms when flows slow or dry up over summer. These pools also provide a source of new recruitment once flows are restored (Treadwell et al. 1999).

Variable flow speeds around large woody debris create localised variations in substrate, with fine silts settling in still areas and all but the larger gravels scoured out where currents are strongest. This produces a range of different habitats for benthic (bottom-dwelling) organisms.

Figure 3: Large woody debris reinstated as part of a habitat restoration program (Photo: A Vey NSW DPI).

Research has been conducted in the Williams River (NSW) on the effectiveness of re-snagging on channel stability and habitat variability. Preliminary findings (Brooks et al. in press) showed increased pool and riffle area, pool depth, and complexity of substrate material coupled with significant ecological associations including an increase in fish species diversity and abundance.

2.3 History of large woody debris removal in NSW

Historical records (particularly from the Murray-Darling river system) indicate that most large rivers had high loadings of large woody debris (Treadwell et al. 1999). The amount of large woody debris in NSW rivers and streams has been reduced by de-snagging programs and clearing of riparian vegetation which reduces the supply of large woody debris falling into the river.

The removal of large woody debris from NSW rivers began in the mid-1800s to facilitate navigation, and continued as part of 'river improvement' programs which frequently included bank clearing and revetment, dredging, artificial cut-offs and other structural works. These practices usually resulted in extensive physical disturbance of the channel bed and banks (Gregory & Pressey 1982; Erskine 2001). Preventative work such as felling undermined trees onto the bank was also carried out (Erskine & Webb 2003). The aim of these programs included removing navigation hazards to allow free passage of boats; reducing damage to in-stream structures such as weirs, jetties and bridges; reducing bank erosion; and increasing channel capacity to improve irrigation flows and reduce flooding (Strom 1962; Gregory & Pressey 1982; Shields & Nunnally 1984; Gippel et al. 1992; Gippel 1995; Gippel et al. 1996a). While the benefits of de-snagging for navigation are clear, the justifications for removing large woody debris have been increasingly called into question in recent years.

Historically the removal of large woody debris, vegetation clearing and planting of exotics was supported by legislation, government funding and institutional arrangements (Erskine & Webb 2003), with de-snagging commonly carried out under the authority of State government agencies. Extensive de-snagging programs continued to be carried out in NSW until at least 1995 (Erskine & Webb 2003).

2.4 Impacts of large woody debris removal

The effects of removing large woody debris are often confounded with other human impacts on river systems, however it appears that the removal of large woody debris has had major impacts on aquatic organisms (Zelman 1977; Johnson 1978; Gregory & Pressey 1982; Hortle & Lake 1983), and it has been widely recognised as a threat to native freshwater fish (Cadwallader 1978; Koehn & Morison 1990; Wager & Jackson 1993; Morris et al. 2001). Some of the reasons for the decline of fish populations in river reaches affected by de-snagging and vegetation clearing include:

- Loss of general habitat for snag-dependent species such as trout cod and Murray cod;
- Reduction in pool habitat formed by scouring and debris dams. Pool development, particularly in rivers that have experienced channel enlargement, is instead restricted to river bends (Erskine & Webb 2003);
- Loss of spawning sites - hollow woody debris is used as spawning sites by some fish species, particularly river blackfish;
- Increases in water temperatures resulting from removal of riparian vegetation (Erskine & Webb 2003) - some species (e.g. river blackfish) may be excluded from rivers with high summer water temperatures (WG O'Connor pers. comm. in Erskine & Webb 2003);
- Reduction in invertebrate numbers and species diversity – macro invertebrate biodiversity is low in rivers with shifting sand substrates but is much greater in rivers with large woody debris (O'Connor & Lake 1994). Removal of large woody debris has been documented as causing greater sand mobility and supply in the streambed (Erskine 1999), which could lead to a loss of invertebrate biodiversity. De-snagging has been identified as a threat to at least four species of freshwater crayfish found in lowland rivers throughout Australia (Horwitz 1994).

The removal of large woody debris can also contribute to:

- Increased flow velocities and associated bank and bed erosion, leading to riverbed degradation, channel enlargement and straightening, and loss of fish habitat (Erskine

& Webb 2003; Drummond 1972; Bird 1980; Brookes 1985; Erskine 1990; Shields & Gippel 1995).

There is little evidence to suggest that removing large woody debris improves the hydraulic capacity of rivers or reduces potential impacts of flooding. Gippel et al. (1992), in a study that estimated the hydraulic impact of snags in the Murrumbidgee and Tumut Rivers found that in many cases the removal of snags could not be justified on hydraulic grounds alone. Similarly, Young (1991) reported that large woody debris occurring in the lowland rivers of south-eastern Australia seldom caused significant effects on flood levels. In general a river channel needs to be substantially blocked by large woody debris before there is a significant effect on the movement of floodwaters (Treadwell 1999).

2.5 Current situation

The focus of river management has changed over the past decade due to research highlighting the beneficial values of large woody debris and native riparian vegetation. Many of the arguments for large woody debris removal have been discounted. Growing awareness of the values of large woody debris and native riparian vegetation have led to new initiatives including research into more appropriate management practices, development of river rehabilitation guidelines (Raine & Gardiner 1995; Erskine & Webb 1999, 2003; Webb & Erskine 1999b; Rutherfurd et al. 2000; Nicol et al. 2002) and trials to investigate options for re-instating woody debris into rivers ('re-snagging').

As a result, large woody debris removal has become less common in recent years, and there are basic legislative controls in place to regulate the removal of woody debris in NSW. The practice of routinely removing large woody debris to maintain channel capacity is no longer widely supported by natural resource management agencies, and relocation, realignment or lopping are more frequently practiced as alternatives to removal. For example, annual river works programs undertaken by the NSW Department of Environment and Climate Change (DECC; formerly the Department of Natural Resources) in the Murray River downstream of Hume Dam, and in the Tumut River downstream of Blowering Dam, are designed to maintain channel capacity to cater for peak downstream irrigation demands and prevent the development of effluent creeks and bank erosion. Large woody debris management as part of river works is now restricted to specific cases where debris is causing localised bank erosion.

Despite improved management there is still concern that in some areas the practice is continuing unnecessarily and to the detriment of stream health. Removal of large woody debris still occurs for a range of purposes by State government departments, road authorities, catchment management organisations, local councils, Landcare groups, boating clubs and private landholders. In some cases there is a valid need such as reducing specific boating, swimming, or traffic hazards, but in other cases large woody debris removal is continuing as part of misdirected efforts to mitigate flood risks, maintain channel capacity and control erosion. Depending on the nature of the works, persons require a permit issued under the NSW *Rivers and Foreshores Improvement Act 1948*, or approval under the NSW *Native Vegetation Act 2003* before removing large woody debris from rivers or their banks. Under Fish Habitat Protection Plan No.1 (gazetted under the NSW *Fisheries Management Act 1994*) public authorities must notify the NSW Minister for Primary Industries before proposing to remove or relocate snags (including large boulders and woody debris) whether or not they propose to undertake the work or to authorise it under legislation. However, anecdotal reports suggest that unauthorised removal of large woody debris continues to occur.

There are limited data on the current extent of large woody debris removal and management in NSW and current large woody debris loads in NSW rivers. Most of the available data relate to rivers that have been de-snagged, or to rivers that flow through cleared riparian land. Recently, large woody debris in the lower Murray River in NSW has been found to occur at densities reaching 14 objects per 100 metres of bank, but in degraded regions of the river can fall below 3 objects per 100 metres (FSC 2001).

The availability of large woody debris is affected by rates of removal and replenishment. Mature native trees within the riparian zone are the primary source of woody debris accumulations in streams, and the widespread degradation and loss of this vegetation means few streams have a natural supply of mature native trees for conversion to in-stream woody debris. Thus in the long term, riparian vegetation rehabilitation is essential to ensure future supplies of large woody debris. Given that very large woody debris makes a significant contribution to the total loading, it will be a long time (>100 years) before natural levels of large woody debris recruitment can be reinstated (Erskine & Webb 2003).

The removal of large woody debris from banks and levees for firewood and agricultural purposes (FSC 2001) exacerbates the problem by further reducing the volume of debris available for incorporation into the stream. Private native forestry activities in riparian vegetation communities such as river red gum forests also have the potential to reduce the amount of large woody debris recruitment material.

3. Protection and management of large woody debris in NSW

3.1 Legislation

Legislative arrangements in respect of large woody debris management and removal are complex. Several public authorities and government agencies administer legislation that influences large woody debris management, including the ability to permit its destruction or removal. Despite multiple legislative controls over large woody debris, approval to remove or destroy large woody debris is generally only required from a single public authority. Removal of large woody debris may be approved directly, such as to remove a specific navigation hazard, or may be ancillary to other developments such as dredging, reclamation, revetment works, bridge and road construction, pump installations etc. In some cases, such as “cleaning up” woody debris from floodplains for cultivation, is not regulated and may not require approval.

A summary of relevant legislation is contained in Table 3. Additional information is presented in Appendix 2.

The complex nature of the legislative frameworks related to large woody debris highlight the importance of interagency consultation when exercising consent or approval functions that may result in removal of large woody debris from NSW rivers and streams.

Table 3 – NSW legislation affecting management and removal of large woody debris

Title of Act	Responsible Agency
Native Vegetation Conservation Act 1997	Department of Environment and Climate Change
Native Vegetation Act 2003	Department of Environment and Climate Change
Rivers and Foreshores Improvement Act 1948	Department of Water and Energy
Water Management Act 2000	Department of Water and Energy
Fisheries Management Act 1994	Department of Primary Industries
Environmental Planning and Assessment Act 1979	Department of Planning
Navigation Act 1901	NSW Maritime Authority
Maritime Services Act 1935	NSW Maritime Authority
Marine Safety Act 1998	NSW Maritime Authority

3.2 Policies and strategies

The NSW Government and the Murray Darling Basin Commission have developed numerous policies and strategies to deal with the management of river and floodplain habitats, including large woody debris. Key policies and strategies are shown in Table 4 and further detailed in Appendix 2.

Table 4 - Key policies and strategies related to large woody debris management in NSW

Policy/Strategy	Responsible agency
NSW Fisheries Policy and Guidelines (1999)	NSW Department of Primary Industries
NSW State Rivers and Estuaries Policy (1991)	NSW Government
NSW Wetlands Management Policy (1996)	NSW Government
Native Fish Strategy for the Murray-Darling Basin 2003-2013	Murray-Darling Basin Commission
NSW Flood Prone Land Policy and NSW Floodplain Management Manual (2001)	NSW Government
Regional Forest Agreements and Integrated Forest Operations Approvals.	NSW Government

3.3 Other programs and initiatives

Recognition of the ecological, geomorphic and other values of large woody debris has resulted in several recommendations to restore large woody debris to Australian streams (Lloyd & Walker 1988; Gippel & White 2000; Gippel et al. 1996a, 1996b). Various state and national programs and initiatives aim to protect and restore the aquatic habitat of NSW rivers, including large woody debris. This may occur either as specific reintroduction programs; in conjunction with other river rehabilitation works; as part of research programs; or in conjunction with broad-scale integrated natural resource management programs.

3.3.1 NSW DPI Aquatic Habitat Rehabilitation Program

The NSW DPI manages a large program to rehabilitate aquatic habitats by addressing barriers to the free movement of fish and by coordinating and/or implementing aquatic habitat rehabilitation projects. The primary objective of this program is to increase the rate of fish habitat repair in NSW.

The program goals are to (by 2008):

- Double the area of wetlands under repair,

- Triple the length of river in which fish have free passage,
- Increase by four times the area of riparian zone fenced or replanted,
- Implement a state-wide re-snagging program,
- Secure agreements on the delivery of environmental water for fish, allocated under Water Sharing Plans in all catchments.

In addition, the program will demonstrate substantial delivery on the threat abatement plans for the removal of large woody debris, degradation of native riparian vegetation along NSW watercourses and the installation and operation of in-stream structures and other mechanisms that alter natural flow regimes of rivers and streams.

3.3.2 Catchment Management Authorities & Catchment Action Plans

Catchment Management Authorities (CMAs) are statutory regional natural resource management authorities established by the *Catchment Management Authorities Act 2003*. The CMAs will develop catchment action plans using processes that comply with the State-wide natural resource management standard and to promote the achievement of State-wide natural resource management targets set by the Natural Resources Commission. Catchment action plans are statutory, non-regulatory documents that will be the primary drivers of regional natural resource investment and management in NSW.

Actions contained within these plans will be implemented in accordance with annual implementation programs through external funding sources and through on-ground works by government agencies, local councils, CMAs and the community. Catchment action plans are expected to result in improvements to large woody debris management.

3.3.3 Land & Water Australia Technical Guidelines & Rehabilitation Manual

Land and Water Australia has produced a set of technical guidelines and a rehabilitation manual dealing specifically with riparian zone and large woody debris management. These are a useful resource for authorities or members of the public undertaking large woody debris management activities. The *Riparian Land Management Technical Guidelines* deal with in-stream management principles, on-ground management tools and techniques, and guidelines for the management of large woody debris to improve ecosystem health.

The *Rehabilitation Manual for Australian Streams* (Rutherford et al. 2000) covers general concepts in stream rehabilitation as well as notes on planning rehabilitation in relation to particular issues including large woody debris (Gippel & White 2000).

3.3.4 Landcare programs

State and Commonwealth governments support the Landcare movement through the Natural Heritage Trust, to encourage individuals and community groups to undertake conservation and resource management works. There are currently more than 1600 Landcare groups in NSW conducting a wide range of activities including on-ground works, research, monitoring, education and community awareness. Landcare groups are involved in sustainable management, rehabilitation and conservation of rivers; river planning; erosion and sediment control; riverine corridor revegetation; constructed wetlands; and nutrient control. The Landcare movement is likely to play an active role in the successful management and restoration of large woody debris.

3.3.5 Large woody debris reinstatement programs

Re-introduction of large woody debris has become one of the most common techniques for river rehabilitation to improve fish habitat and to compensate for other forms of habitat degradation (Kauffman et al. 1997; Cowx & Welcomme 1998; Ronni & Quinn 2001).

Large woody debris reinstatement has commenced in a number of areas, including sites in the Broken River catchment in Victoria (Tennant et al. 1996), the Murray River, and the Williams and Upper Hunter Rivers in NSW. Most of these reinstatement programs are part of trials to test the most effective means of undertaking restoration works and the impacts on fish populations that result from the works.

3.3.6 Research programs

There are numerous research programs underway at state and national level looking at the effectiveness of reinstating large woody debris, river rehabilitation works, and fish use of riverine habitats including woody structures. These programs include initiatives of the Living Murray program, the National Riparian Lands Research and Development Program, and work by State agencies including NSW DPI, the NSW Department of Environment and Climate Change, and the Victorian Department of Natural Resources and Environment. These programs are investigating:

- The feasibility and effectiveness of reintroducing large woody debris to large lowland rivers, including native fish response (Koehn et al. 2000; Nicol et al. 2002);
- Whether reintroduction of large woody debris can restore habitat complexity and increase aquatic biodiversity; and
- Response by different fish and invertebrate species to the reintroduction of woody structures, and testing different locations and configurations of large woody debris.

3.3.7 Funding initiatives

Funding initiatives available at national and state level that apply to large woody debris rehabilitation programs include the Catchment Management Authority investment strategies, Envirofund, Threatened Species Network Community Grants, Recreational Freshwater Fishing Trust Fund, Land and Water Australia, and the Environmental Trust (NSW).

4. Threat abatement objectives, actions, and performance criteria

The objective of this threat abatement plan is to abate, ameliorate or eliminate the adverse effects from the removal of large woody debris on threatened species, populations and ecological communities listed on the schedules of the NSW *Fisheries Management Act 1994*. The plan sets out a range of strategies to achieve this objective. The criteria for assessing achievement of the objective will be the de-listing of the removal of large woody debris as a key threatening process in NSW.

4.1 Research & Investigation Activities (RIA)

Strategy 1:	**Increase knowledge of the distribution and abundance of large woody debris**
RIA 1:	Develop and implement a targeted investigation program to quantify the historical and current abundance and distribution of large woody debris in NSW rivers, focusing on key knowledge gaps, endangered ecological communities and catchments containing habitat for listed threatened species/populations.
RIA 2:	Disseminate information and mapping products to stakeholders regarding the historical and current distribution of large woody debris including degraded areas to assist targeting habitat rehabilitation projects.
Responsibility:	RIA 1 & 2: NSW DPI
Partners:	DECC, FSC, CMAs, water utilities, DWE, universities and research institutions, MDBC
Timeframe:	RIA 1 & 2: Ongoing

Strategy 2:	**Increase knowledge of the ecological interactions between large woody debris and threatened species, populations, and ecological communities**
RIA 3:	Develop and implement research programs to address key knowledge gaps of the ecological interactions between large woody debris and threatened species, populations and ecological communities.
RIA 4:	Incorporate knowledge gathered from large woody debris research programs into recovery and threat abatement actions for threatened species, populations, and ecological communities.
Responsibility:	RIA 3 & 4: NSW DPI
Partners:	FSC, DECC, CMAs, water utilities, DWE, universities and research institutions, MDBC
Timeframe:	RIA 3 & 4: Ongoing

Strategy 3:	**Identify reasons for, and current rates of, large woody debris removal**
RIA 5:	Review reports and investigations of illegal large woody debris removal, and consult with relevant public authorities and local councils to determine the extent, rates and reasons for large woody debris removal authorised by relevant NSW legislation.
RIA 6:	Establish and maintain a database of large woody debris management approvals in consultation with relevant public authorities.
Responsibility:	RIA 5 & 6: NSW DPI
Partners:	NSW Maritime Authority, local councils, DWE, DECC
Timeframe:	RIA 5 & 6: Year 3

Strategy 4:	Increase knowledge of the use of large woody debris in rehabilitation programs
RIA 7:	Support and assist large woody debris research and investigation activities, and prepare guidelines for the reinstatement of large woody debris.
RIA 8:	Investigate, and report on sources of large woody debris for use in rehabilitation programs and record in the NSW DPI Aquatic Habitat Rehab. Program database.
Responsibility:	RIA 7 & 8: NSW DPI
Partners:	DECC, DWE, CMAs universities & research institutions
Timeframe:	RIA 7: Ongoing RIA 8: Year 1 & ongoing

4.2 Compliance and Regulatory Activities (CRA)

Strategy 5:	Increase protection of large woody debris in NSW rivers
CRA 1:	Review existing statutory frameworks affecting large woody debris. Identify anomalies and deficiencies, and amend statutory frameworks where required to increase protection for large woody debris.
CRA 2:	Ensure the development, administration and implementation of legislative and policy frameworks to protect riparian vegetation and maintain future supply of large woody debris. This includes development consents, State Environmental Planning Policies, property vegetation plans, private native forestry codes of practice, native vegetation regulations, integrated forest operations approvals, and forest operating procedures.
CRA 3:	Review environmental impact assessment processes and procedures used by consent and determining authorities when considering developments or activities that have the potential to impact on large woody debris. Identify anomalies, inconsistencies or deficiencies and modify processes as required.
CRA 4:	Identify options to utilise regulatory and voluntary incentive based mechanisms to protect large woody debris in priority areas known to support threatened species, populations or ecological communities and implement as appropriate.
Responsibility:	CRA 1: NSW DPI CRA 2 - 4: NSW DPI, local councils, NSW Maritime Authority, DECC
Partners:	CMAs, DECC, local councils, DWE
Timeframe:	CRA: 1 & 3: Year 3 CRA 2 & 4: Ongoing

Strategy 6:	Increase the capacity of consent and determining authorities to provide for and protect large woody debris
CRA 5:	Provide local councils, agencies and CMAs with resource materials (impact assessment guidelines, mitigating prescriptions, offsets, and generic consent conditions) regarding large woody debris to support planning, determination, impact assessment and concurrence decision making processes.
CRA 6:	Promote the existence and implications of legislative mechanisms that protect large woody debris to consent, determining, and constructing authorities.
Responsibility:	CRA 5 & 6: NSW DPI
Partners:	CMAs, DECC, local councils, NSW Maritime Authority
Timeframe:	CRA 5: Yr 3 & Ongoing CRA 6: Ongoing

4.3 Management Activities (MA)

Strategy 7:	**Undertake rehabilitation and restoration of large woody debris habitat**
MA 1:	Review existing literature and integrate research and investigation results to develop best practice guidelines for re-snagging activities.
MA 2:	Develop and implement a large woody debris reinstatement program for NSW rivers involving the NSW DPI Aquatic Habitat Rehabilitation Program. Program to integrate with national and state initiatives where possible and to give consideration to priority areas identified through research and information actions, and have regard to threatened species, populations and ecological communities.
MA 3:	Actively seek funding for reinstatement programs in priority and degraded areas having regard to other recovery and threat abatement plans.
MA 4:	Encourage and provide technical support to CMAs, community groups, relevant natural resource management agencies, local councils, landholders and other land managers to protect and rehabilitate riparian vegetation and in-stream habitats along key river stretches, particularly where threatened species, populations or ecological communities occur.
Responsibility:	MA 1: NSW DPI MA 2 – 4: NSW DPI
Partners:	CMAs, DECC, local councils, Landcare groups, MDBC, RLPBs
Timeframe:	MA 1, 3 & 4 : Year 1 & ongoing MA 2: Year 2 & ongoing

Strategy 8:	**Increase community awareness of the role and value of large woody debris**
MA 5:	Develop and disseminate educational, technical and promotional materials regarding large woody debris through the media, NSW DPI website, community networks, extension officers, CMAs and local councils.
MA 6:	Support and assist extension officers and community information providers with technical information on appropriate management of large woody debris.
MA 7:	Publicly promote rehabilitation programs to raise awareness of the role and importance of large woody debris in the broader community, and levels of community interest.
Responsibility:	MA 5 – 7: NSW DPI
Partners:	CMAs, NSW Maritime Authority, DECC, DWE
Timeframe:	MA 5 – 7: Ongoing

Strategy 9:	**Prioritise threat abatement actions and monitor their effectiveness to inform adaptive management**
MA 8:	Prioritise threat abatement actions for implementation to ensure targeted and efficient use of resources.
MA 9:	Monitor the response of aquatic ecological communities to large woody debris reinstatement programs.
MA 10:	Review and amend threat abatement actions in response to monitoring results that indicate management actions are inappropriate or ineffective at achieving plan objectives.
MA 11:	Review information on the rates of large woody debris removal after 5 years to evaluate the effectiveness of threat abatement actions.
Responsibility:	MA 8 – 11: NSW DPI
Partners:	CMAs, universities and research institutions, funding providers, MDBC
Timeframe:	MA 8: Year 1 MA 9: Year 3

	MA 10: Ongoing MA 11: Year 6

Strategy 10:	**Evaluate and report on plan effectiveness and implementation.**
MA 12:	Review and report on the status and effectiveness of threat abatement actions in achieving the plans objectives against the performance criteria, and report this information in threat statements on a three yearly basis.
Responsibility:	MA 12: NSW DPI
Partners:	DECC, CMAs, local councils, universities and research institutions, MDBC, NSW Maritime Authority, DWE
Timeframe:	Action 12: Years 3, 6, and 9

Acronyms	
NSW DPI	Department of Primary Industries
DWE	Department of Water and Energy
FSC	Fisheries Scientific Committee
DECC	Department of Environment and Climate Change
CMAs	Catchment Management Authorities
RLPBs	Rural Lands Protection Boards
MDBC	Murray Darling Basin Commission
RIA	Research and Information Action
CRA	Compliance and Regulatory Action
MA	Management Action

5. Social, economic and cultural issues

The following section identifies potential social and economic consequences that may result from the implementation of this plan and describes methods to minimise or ameliorate them.

The threat abatement plan will not directly affect the rights of landholders or other individuals, as the plan only has direct statutory implications for public authorities such as government agencies and councils. The implementation of the plan may involve some changes in the way public authorities carry out large woody debris management or approve works by individuals, which may result in some changes to the activities of landholders and others.

The objectives and actions of the plan have been developed with the aim of minimising potential adverse social and economic impacts. For example, the plan recognises that large woody debris management is still required in some circumstances, such as where there is a hazard to navigation or public safety.

The implementation of the threat abatement plan will also have some positive consequences for local communities by improving aquatic habitats utilised by native fish species. Over the longer-term this may contribute to increased opportunities for recreational anglers, with subsequent benefits to associated industries such as tourism.

5.1 Implementation Costs

Threat abatement plans must state the estimated costs of the measures included in the plan. Costs are shown in Appendix 3. Due to the state-wide operation of this key threatening process, the broad nature of the recovery activities and the wide range of organisations with implementation responsibilities, the costs shown in Appendix 3 are estimates only. Actual implementation costs will depend on a range of factors including the availability of resources for implementation, the final nature and extent of threat abatement activities including research and large woody debris reinstatement programs. Implementation of some threat abatement actions will be contingent on the availability of funding from grant programs. Threat abatement activities will be linked to existing government or community programs wherever possible to prevent duplication and to promote cost efficiencies. The costs shown in Appendix 3 include estimates of expenditure by public authorities with implementation responsibilities, and estimates of external funding for large woody debris reinstatement programs. Costs have been averaged over the 10 year life of the plan.

5.2 Navigation

The NSW DPI will not agree to removal of large woody debris for the purposes of improving or enhancing navigability of streams for individuals. The Department may, however, agree to proposals that aim to maintain navigation in those areas where there is an established history of boating use, or where there is a public safety hazard. In these instances, the realignment and relocation must be investigated as an alternative to large woody debris removal, and the impact on large woody debris dependent threatened species will need to be considered.

The implementation of reinstatement programs for large woody debris will need to give consideration to issues of navigation and public safety. These activities will be conducted in consultation with public authorities and stakeholder groups to ensure impacts on recreational and commercial users are minimised. A range of mitigating measures is available when conducting reinstatement programs including securing woody structures in-stream to prevent movement and locating woody structures adjacent to banks out of main navigation channels.

5.3 Flood mitigation and asset protection

Large woody debris removal is often carried out with the aim of reducing flood risk or for asset protection. Large woody debris may hinder water flow and exacerbate flooding in some situations such as when large debris dams are formed. However, in most cases large woody debris removal results in minimal improvement in channel capacity and reduction of flooding in lowland rivers. For this reason, large woody debris management proposals aimed at improving or enhancing the hydraulic capacity of streams or reducing flood risk will not be supported.

Some landholders may feel that their property and assets are at greater risk of flooding due to the presence of large woody debris. At times, large woody debris may contribute to localised bank erosion, deflect flows, or threaten infrastructure such as pump foot valves. The NSW DPI policy in relation to these issues is sufficiently flexible to resolve these issues in most instances. Mitigating measures to reduce social and economic impacts in these situations can include lopping, realignment, relocation or in some instances removal of the large woody debris. Cases involving the removal or management of large woody debris are assessed on an individual basis.

Information on the importance of large woody debris for stream geomorphology and the lack of demonstrated benefits of large woody debris removal will be disseminated to stakeholders and the general public. A collaborative approach to the management of large woody debris in the future is critical for the successful implementation of this plan.

Flood mitigation is also an important issue in urban areas, and situations can arise where removal of large woody debris may be required to prevent damage to urban stormwater systems and associated infrastructure. In many cases this will form part of planned routine maintenance activities. In these cases a variety of mechanisms exist for the appropriate environmental impact assessment and approval of large woody debris removal. The NSW *Native Vegetation Act 2003* controls the clearing or removal of dead and exotic vegetation from prescribed streams in certain urban areas, and consent is required from the Department of Environment and Climate Change to clear living or dead, native or exotic vegetation on these lands. In certain circumstances however, removal or realignment of large woody debris may be approved, or require concurrence under other statutes including the *Rivers and Foreshores Improvement Act 1948, Water Act 2000, Roads Act 1993* or the *Fisheries Management Act 1994*.

In the case of emergency situations during actual or imminent flood events large woody debris may be removed under the authority of the *State Emergency and Rescue Management Act 1989* in relation to an emergency within the meaning of that Act.

5.4 Agriculture and other land uses

Large woody debris in the riparian zone is sometimes removed for firewood, agricultural purposes (such as stock access to water) and other activities. This threat abatement plan, together with Fish Habitat Protection Plan No.1 and the NSW DPI' Policy and Guidelines, aims to encourage retention of large woody debris wherever possible, and only supports removal in limited circumstances (where it can be justified on the grounds of public safety or another clear public good). In general, the NSW DPI will seek the cooperation of public authorities and private landholders to achieve adherence to these guidelines for large woody debris management, and when required will assess proposals regarding removal or management of large woody debris on a case-by-case basis. Mitigating measures to reduce social and economic impacts can include lopping, realignment or relocation of large woody debris.

5.5 Cultural issues

Riverine environments are highly significant to the indigenous people of Australia. Rivers and the associated riparian zone are important for many traditional and contemporary uses. These include:

- Hunting and fishing activities;
- Recreational uses;
- Ceremonial activities;
- Food preparation;
- Movement and trade corridors;
- Source of materials for tools, implements and shelter; and
- Burials

Large woody debris plays a significant role in providing habitat for many species of fish that have cultural significance to Aboriginal people.

Consultation with indigenous communities will be undertaken during development and implementation of this plan. The NSW DPI will endeavour to cooperate and support activities in regional areas that engage and involve Aboriginal communities in active management of the natural resources of the riparian zone.

6. Reporting and Review

Progress in implementing this threat abatement plan will be reported in annual reports to reports to Parliament and triennially in the PAS review. Summary information will include details of implementation activities, investment, program outcomes, and review against the performance criteria. This information will be made available to all parties contributing to the implementation of the plan, and the public. Summary information will be included in the NSW DPI Annual Report.

This threat abatement plan will be subject to major review within ten years of the date of publication.

7. Further Information

Copies of the threat abatement plan and additional information can be obtained from:

NSW Department of Primary Industries
Threatened Species Unit
Port Stephens Fisheries Centre
Locked Bag 1
Nelson Bay NSW 2315
Ph: (02) 4982 1232

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Appendix 1 - NSW fish that utilise LWD in their life cycle

Species	Scientific Name	NSW Status	NSW Distribution	Details - References
Eastern freshwater cod	*Maccullochella ikei*	Endangered	Clarence and Richmond rivers, north coast NSW	Riparian vegetation, large boulders and woody debris provide a complex array of habitats for each stage of its life cycle (Morris et al. 2001).
Trout cod	*Maccullochella macquariensis*	Endangered	Southern part of Murray-Darling Basin	Murray River habitat includes various substrates and abundant in-stream cover of snags and woody debris (McDowall 1996). Trout cod congregate around large woody debris and as a result of de-snagging, their habitat is now patchily distributed and limited in availability (Morris et al. 2001).
Macquarie perch	*Macquaria australasica*	Vulnerable	Upper reaches of the Hawkesbury-Nepean, Shoalhaven, Lachlan, Murrumbidgee & Murray Rivers	Causes of decline in Macquarie perch populations include de-snagging (Morris et al. 2001).
Silver perch	*Bidyanus bidyanus*	Vulnerable	Murray-Darling Basin	Species inhabits both warm, sluggish, standing waters with cover provided by woody debris and reeds (phragmites), as well as fast-flowing turbid waters (Koehn & O'Connor 1990). Removal of LWD could impact on silver perch because it normally provides refuge (Morris et al. 2001).
Olive perchlet	*Ambassis agassizii*	Endangered population	Western population – Murray-Darling Basin	Small to large congregations are common among log snags and aquatic vegetation (McDowall 1996). Removal of LWD has contributed to their decline in southern half of the Basin (Morris et al. 2001).
Purple spotted gudgeon	*Mogurnda adspersa*	Endangered population	Western population – Murray-Darling Basin	Found amongst benthic structures such as rocks and snags, and amongst vegetation (Morris et al. 2001). Eggs are deposited on rocks, logs or other solid debris (Allen et al. 2002).
Freshwater catfish	*Tandanus tandanus*	Considerable decline western populations	Western populations – Murray-Darling Basin, Eastern populations – coastal rivers north of Manning River	Large woody debris may provide refuge (Clunie & Koehn 2000).
Murray cod	*Maccullochella peelii peelii*	Vulnerable (EPBC Act)	Murray-Darling Basin	Prefers habitats containing cover such as rocks, fallen trees, stumps, clay banks or over-hanging vegetation (McDowall 1996). Eggs shed in hollow objects, under fallen timber and on substratum. Relative numbers have been found to be proportional to the abundance of snags (Morris et al. 2001).
River blackfish	*Gadopsis marmoratus*	Range and abundance considerably reduced	Upper parts of many Murray-Darling tributaries	Sedentary and apparently non-migratory, with home range of about 20m. Prefer streams with abundant cover such as snags and boulders. Spawning takes place in hollow logs (McDowall 1996). Habitat degradation, including clearing of timber from within streams has restricted their abundance (Morris et al. 2001).
Two-spined blackfish	*Gadopsis bispinosus*	Abundant in many streams across its range	Upper Murray (above Lake Hume) and upper Murrumbidgee catchments	Juveniles are often found in large numbers sheltering and feeding around leaf litter and wood debris (McDowall 1996). Abundance has dramatically increased where boulders and woody debris have been added to otherwise uniform substrates.
Climbing galaxias	*Galaxias brevipinnis*	Fragmented distribution.	Coastal drainages from Sydney to south coast	Generally dwell amongst rocks or woody debris (O'Connor 1994; Allen et al. 2002).

Species	Scientific Name	NSW Status	NSW Distribution	Details - References
Mountain galaxias	*Galaxias olidus*	Fragmented distribution; small isolated populations	Moderate and high elevation streams in both coastal and inland (Murray-Darling) draining catchments	Usually found in clear pools of small, flowing streams around rocks and logs (Allen et al. 2002). Egg masses may be found drifting, lodged in the substrate or attached to in-stream debris (Morris et al. 2001).
Australian smelt	*Retropinna semoni*	Common	Coastal NSW and tributaries of Murray-Darling Basin	Most common in slow-flowing streams and still waters, shoaling near the surface or around the cover of aquatic plants and woody debris (Allen et al. 2002).Eggs when dispersed attach to vegetation, debris or sediment (McDowall 1996).
Duboulay's rainbowfish	*Melanotaenia duboulayi*	Relatively common	Coastal catchments from Macleay River north into Qld	Congregates in schools around log snags and other debris (McDowall 1996).
Estuary perchlet	*Ambassis marianus*	Generally abundant	Coastal catchments from Narooma north into southern Qld	Small to large aggregations are common among mangrove roots, log snags and aquatic vegetation (McDowall 1996).
Congolli	*Pseudaphritis urvillii*	Abundant through its range	Coastal catchments south of Bega.	Favoured habitat is on the beds of slow-flowing streams in leaf litter, where it often remains partly buried, among rocks and under sunken logs and overhanging banks (McDowall 1996).
Golden perch	*Macquaria ambigua*	Common in Murray Darling Basin	Throughout the Murray-Darling Basin except at high altitudes	Often found in deep pools containing cover such as dead trees or fallen timber, undercut banks or rocky ledges (Battaglene 1987).
Murray River rainbowfish	*Melanotaenia fluviatilis*	Reasonably common, esp. in lower Murray	Murray-Darling Basin	Often congregates along grassy banks or around submerged logs and branches (Allen et al. 2002).
Ornate rainbowfish	*Rhadinocentrus ornatus*	Locally common but restricted distribution	Coastal areas from Coffs Harbour north into QLD	Prefers the cover of submerged logs and branches, grassy banks, reeds and water lily roots (Allen et al. 2002).
Bullrout	*Notesthes robusta*	Common	Coastal areas from Clyde River north to QLD border.	Usually found near aquatic vegetation or woody debris (Allen et al. 2002).
Empire gudgeon	*Hypseleotris compressa*	Common	Coastal	Most common in the lower reaches of rivers (also found further upstream) in flowing or still water around aquatic plants and fallen tree branches (Allen et al. 2002).
Firetail gudgeon	*Hypseleotris galii*	Common	Coastal	Eggs are laid underneath rock ledges, logs or leaves (Allen et al. 2002).
Flathead gudgeon	*Philypnodon grandiceps*	Common	Coast and Murray-Darling Basin	Females lay a clutch of eggs on a hard surface such as a rock or piece of wood (Allen et al. 2002).

Appendix 2 – Legislation affecting large woody debris management

Fisheries Management Act 1994 – Part 7

Currently under Part 7 of the *Fisheries Management Act 1994* large woody debris is protected by controls over dredging and reclamation activities that are harmful to fish habitat (under Division 3 of the Act). Dredging activities may include the wholesale removal of large woody debris from rivers and thus, depending on the method of removal and scale of the activity, may require a permit under Part 7 of the Act. However, these provisions do not allow the NSW DPI to control other potential impacts on aquatic habitats including the removal of large woody debris and damage to spawning and nursery habitats of native fish by activities other than dredging and reclamation. Amendments to the Act are currently underway to improve spawning site protection for native freshwater fish, which will include the requirement for a permit to damage spawning sites, including large woody debris.

A public authority (other than a local government authority) planning to carry out or authorise any dredging or reclamation work must first give the Minister for Primary Industries written notice of the proposed work, consider any matters raised by the Minister regarding the work, and notify the Minister if it intends to carry out or authorise the work despite any matters raised.

Local government authorities and individuals must obtain a permit from the Minister for Primary Industries before carrying out any dredging or reclamation work (unless the work is authorised under the *Crown Lands Act 1989* or authorised by another relevant public authority. However, in these cases the public authority is required to give the Minister written notice of the proposed work, and consider any matters raised by the Minister before authorising the dredging or reclamation work.

Section 193 – Fish Habitat Protection Plans

Under the NSW DPI Fish Habitat Protection Plan No. 1 (developed in accordance with s193, Part 7 of the *Fisheries Management Act 1994*), local councils and other public authorities are required to notify the NSW DPI of any proposed works that involve the lopping, realignment, relocation or removal of large woody debris (NSWF 1995).

The NSW DPI will consider the proposal and, if potential problems are evident, contact the proponent in order to seek a modification. The habitat protection plan makes a concession in the case of urgent works by stating that “where a snag is causing a hazard to navigation or public safety, and needs to be removed or relocated as a matter of urgency, a public authority may do so without complying with the notification period, but must promptly inform the Minister of the work undertaken and the reasons for it”.

However, there are no penalties for failing to comply with a habitat protection plan, and not all public authorities are currently complying with the requirement to notify the DPI of works involving large woody debris management.

Native Vegetation Act 2003

The removal of large woody debris may require approval under the *Native Vegetation Act 2003*. Clause 4 of Schedule 3 of the *Native Vegetation Act 2003* provides that the provisions of the *Native Vegetation Conservation Act 1997* continue to have effect (despite its repeal) to State Protected Land in relation to dead trees.

The *Native Vegetation Conservation Act 1997* includes State Protected Land and provides that nobody shall ringbark, cut down, fell, poison, top, lop, remove, or otherwise destroy or injure any tree or cause such to be done on any State Protected Land except in accordance with an authority. A tree for this purpose includes a sapling, shrub or scrub; native and non-indigenous trees; and dead trees whether standing or fallen. State Protected Land is defined as land within, or within 20 metres of, the bed and bank of a prescribed stream and may include a river, stream, lake, lagoon or wetland.

The lopping, topping, removal or destruction of large woody debris in/on prescribed streams either requires development consent from the Department of Environment and Climate Change issued in accordance with the *Native Vegetation Act 2003* and *Environmental Planning and Assessment Act 1979,* or through an approved Property Vegetation Plan negotiated with a Catchment Management Authority in accordance with the Environmental Outcomes Assessment Methodology.

However, under Section 25 (i) and (j) which outlines clearing excluded from the operation of the Act, states that the *Native Vegetation Act 2003* does not apply to:

(i) any clearing authorised to be carried out under Division 3 or 4 of Part 7 of the *Fisheries Management Act 1994*.

(j) any clearing authorised under a licence issued under Division 6 of Part 7A of the *Fisheries Management Act 1994*.

Rivers & Foreshores Improvement Act 1948

The Department Water and Energy is responsible for administering the *Rivers and Foreshores Improvement Act 1948* that provides for Part 3A permits to excavate or remove material from the bank, shore or bed of any river, estuary or lake, or land that is not more than 40 metres from the top of the bank or shore of protected waters, on private property. 'Protected waters' as defined under section 22A of the *Rivers and Foreshores Improvement Act 1948* means a river, lake into or from which a river flows, coastal lake or lagoon (including any permanent or temporary channel between a coastal lake or lagoon and the sea). Large woody debris management is not specifically mentioned under the *Rivers and Foreshores Improvement Act 1948* unless it is part of material being excavated from protected lands.

Activities that do not require a Part 3A permit include works:

- That are entirely on Crown Land and have a lawful approval under the Crown Lands Act 1989,
- Undertaken by a council or a public authority (not including business ventures such as state-owned corporations or commercial undertakings),
- Are authorised under any Act relating to mining.

However, all works still need to comply with State government policy, and if deemed to degrade protected waters, the Department of Water and Energy can require works to cease and issue a remediation notice to repair any damage. When assessing developments that require a Part 3A permit under the *Rivers and Foreshores Improvement Act 1948,* the Department of Water and Energy considers whether the proposal is consistent with State government policy, including the NSW State Rivers and Estuaries Policy.

The *Rivers and Foreshores Improvement Act 1948* is due to be repealed upon the whole commencement of Schedule 7 of the *Water Management Act 2000*.

Water Management Act 2000

The *Water Management Act 2000* provides the principal legislative control of water management across NSW, and is administered by the Department of Water and Energy.

With the commencement of relevant parts (Chapter 3, Part 3) of the *Water Management Act 2000*, a controlled activity approval will replace a Part 3A permit under the *Rivers and Foreshores Improvement Act 1948*. A controlled activity approval will be required for any 'controlled activity' on waterfront land (i.e. the bed and banks – generally to within 40m – of rivers, lakes and estuaries). Controlled activities requiring an approval may be specified in a water management plan, but include erection of buildings, other works, removal of material or vegetation, deposition of material, and any other activity which affects the quantity or flow of water in a water source. This could include the removal of large woody debris.

The implementation of controlled activity approvals under the *Water Management Act 2000* will be staged over time. Existing exemptions (under the *Rivers and Foreshores Improvement Act 1948*) for local councils and Crown land are not likely to be carried over into the *Water Management Act 2000*, or will be modified to some extent in consultation with local government.

Environmental Planning and Assessment Act 1979

The Department of Planning administers the *Environmental Planning and Assessment Act 1979* which is the primary land use planning legislation in NSW and provides for the creation of environmental planning instruments at various levels of government to control land use and planning.

Part 3 of the *Environmental Planning and Assessment Act 1979* deals with the plan making process (State environmental planning policies, regional environmental plans, and local environmental plans. Parts 4 and 5 of the Act deal with assessment of applications for development consent or activity approvals.

Determining and consent authorities under Part 4 and 5 of the *Environmental Planning and Assessment Act 1979* must decide whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats when exercising their approval functions. This includes considering whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process. Similarly, threat abatement plans must be considered as part of this process.

Navigation Act 1901

The *Navigation Act 1901* consolidated previous Acts relating to navigation, and is administered by the NSW Maritime Authority. The *Navigation Act 1901* applies to all navigable waters, defined as any port, harbour, haven, roadstead, channel, navigable river or creek, or arm of the sea within the jurisdiction. The *Navigation Act 1901* establishes offences for constructing unauthorised works in navigable waters and allows the Minister to serve notices requiring the removal of unauthorised works. In the event that the unauthorised works are not removed within 21 days, the Minister may authorise the removal of the works and recover costs. The *Navigation Act 1901* also requires the removal of any tree felled on the bank of any navigable waters so that any part of such tree is in or over the water.

Maritime Services Act 1935

The *Maritime Services Act 1935* provides for the improvement of navigable waters, and includes provisions to undertake works and activities to maintain or improve navigation. The Act vests control of areas with the "Board" and provides a broad suite of powers to undertake works in these areas. In areas not vested with the "Board", prior consent and approval of the person in whom that area is vested and of all proper authorities having jurisdiction or control over that area is required. Waterways management functions vested with the "Board" have subsequently been transferred to the NSW Maritime Authority and Port Authorities by the *Ports Corporatisation and Waterways Management Act 1995*.

Marine Safety Act 1998

The *Marine Safety Act 1998* will consolidate the *Maritime Services Act 1935* and the *Navigation Act 1901* upon commencement of Part 1 of Schedule 2. The *Marine Safety Act 1998* aims to ensure safe operation of vessels in ports and other waterways, and promotes responsible operation of vessels in so as to protect the safety and amenity of the waters and the amenity of adjoining land. The Act defines navigable waters as all waters that are from time to time capable of navigation and are open to or used by the public for navigation. Section 16 of Act provides the Minster with powers to direct owners or persons responsible for obstructions to navigation to remove the obstruction within specified time frames. The Act also grants powers for the Minister to remove or authorise the removal of obstructions.

Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* is administered through the Commonwealth Department of Environment and Water Resources and provides a framework for environmental assessment and approval of actions that have, will have, or are likely to have a significant impact on matters of 'national environmental significance'.

There are six matters of national environmental significance that are triggers for Commonwealth assessment and approval. These include World Heritage properties, Ramsar listed wetlands of international importance, nationally threatened species and communities (note that these species may not be the same as those listed under State legislation), and migratory species protected under international agreements.

Under the *Environment Protection and Biodiversity Conservation Act 1999* a person must not take an action that has, will have or is likely to have a significant impact any of these matters of national environmental significance without approval from the Commonwealth Environment Minister. There are penalties for taking such an action without approval.

Regional Forest Agreements

The NSW Government's Forestry Policy commits to detailed Comprehensive Regional Assessments and joint State/Commonwealth Regional Forest Agreements. Regional Forest Agreements (RFAs) are 20-year agreements between the Commonwealth and State governments that allocate forestry resources to industry and establish a variety of mechanisms for ecologically sustainable forest management (ESFM). These include establishment of a comprehensive, adequate and representative reserve system, and complementary off-reserve initiatives such as codes of practice and management plans.

The RFA process for State forests and other Crown timber land includes the granting of 'integrated forest operations approvals' to regulate forestry operations in each region.

These approvals are granted jointly by the Ministers for Natural Resources, Environment and Primary Industries, and include a range of licence conditions. For example, licence conditions under Part 7A of the *Fisheries Management Act 1994* contain general aquatic habitat protection conditions as well as conditions relating to threatened species.

Conditions on these licenses include establishment of exclusion zones and buffer zones around all aquatic habitats where forestry operations may impact on threatened species or their habitat. There may also be specific provisions relating to the management of large woody debris, such as prohibiting realignment or relocation of woody debris except in certain conditions, and requiring all large woody debris management decisions to be documented by State Forests.

Appendix 3 – Implementation costs

Table 4 – Estimated costs of implementing large woody debris threat abatement strategies

No.	Strategy	Estimated cost/yr										Total cost
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	
4.1	**Research and investigation**											
1	Increase knowledge of the distribution and abundance of large woody debris	17 500	17 500	17 500	17 500	17 500	17 500	17 500	17 500	17 500	17 500	175 000
2	Increase knowledge of the ecological interactions between large woody debris and threatened species, populations, and ecological communities	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	100 000
3	Identify reasons for, and current rates of, large woody debris removal			7 500								7 500
4	Increase knowledge of the use of large woody debris in rehabilitation programs	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	50 000
4.2	**Compliance and regulation**											
5	Increase protection of large woody debris in NSW rivers	7 500	7 500	22 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	90 000
6	Increase the capacity of consent and determining authorities to provide for and protect large woody debris	2 500	2 500	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	45 000
4.3	**Management**											
7	Undertake rehabilitation and restoration of large woody debris habitat	17 500	42 500	42 500	42 500	42 500	42 500	42 500	42 500	42 500	42 500	400 000
8	Increase community awareness of the role and value of large woody debris	6 500	6 500	6 500	6 500	6 500	6 500	6 500	6 500	6 500	6 500	65 000
9	Prioritise threat abatement actions and monitor their effectiveness to inform adaptive management	7 500	5 000	10 000	5 000	5 000	10 000	5 000	5 000	5 000	5 000	62 500
10	Evaluate and report on plan effectiveness and implementation.			7 500			7 500			7 500		22 500
	Totals	74 000	96 500	134 000	99 000	99 000	111 500	99 000	99 000	106 500	99 000	1 017 500

Note: Costs have been averaged and are indicative estimates only as discussed in Section 5.1.