Department of Sustainability and Environment

Action Statement

Flora and Fauna Guarantee Act 1988 No. 122

Increase in sediment input to rivers and streams due to human activities

Description

Rivers and stream systems provide habitat for countless native plant and animal species. The continued survival and evolutionary development of these species depends on the 'quality' of this in-stream habitat. A large number of factors influence in-stream habitat quality - water quality (e.g. temperature, dissolved oxygen, pH, presence of toxins), water volume (amount and seasonality) and the stream bed and bank characteristics (e.g. presence of large woody debris).

The amount and distribution of sediment in streams and rivers is one important factor contributing to habitat quality. All aquatic species have evolved within environments containing varying amounts of sediment from natural sources. However, the deleterious effects on the biological resources of streams of an increase in sediment over natural levels has been recognised throughout the world for some time (e.g. Cordone and Kelly 1961, Chutter 1969, Hynes 1970).

Sediment in rivers and streams comes from either erosion processes delivering soil to the stream system from the catchment via overland flows, in-stream bed and bank scouring, or re-suspension of material previously eroded or scoured.

Erosion and in-stream scouring are natural processes in all catchments. Within catchments relatively undisturbed by human activity, the baseline input of sediment is relatively low (Olive and Rieger 1987) but naturally varies with geology, rainfall and landform. However, flushes of high concentrations of sediment result naturally from the consequences of extreme weather/climate variability (eg. wildfire, floods, landslips, land denudation during drought).

Human activities have modified many ecosystems. A substantial number of these modifications have resulted in increased erosion rates and levels of sediment delivered to streams.

Aboriginals initiated catchment modification by burning land (Barr and Cary 1992). Later, Europeans wrought even greater change by clearing, stocking and cropping (Walker 1986). A variety of land uses have been shown, or are believed, to substantially increase the accession of sediment to streams (Mitchell 1990).

Sediment movement induced by human activity is widespread across nearly all of Victoria's catchments. This is documented in Ministry for Conservation (1983), OCE (1988), DWR (1989), Mitchell (1990), Government of Victoria (1992) and OCE (1992). It is a major cause of ecological degradation in Australian upland (Lake and Marchant 1990) and lowland streams (Mitchell 1990).

Increased erosion processes on land

The major sources of increased sediment are generally those activities occurring in proximity to the stream channel. Primarily, these activities involve disturbing the protective catchment vegetation layer (thus increasing opportunities for erosion) and/or compaction of riparian soils (leading to greater overland flow to the stream). In terms of volume of sediment generated and geographical distribution, the activities of most concern in Victoria are:

- stream bank degradation through stock access;
- riparian zone degradation through clearing or grazing; and
- run-off from roads, tracks and other infrastructure.

One or more of these three activities have occurred or are occurring throughout almost all areas of the state. However, the activity of most concern will vary from catchment to catchment, and even at different points within a catchment.

Less widespread activities that can add to the process include run-off from construction sites, forest harvesting, urban run-off, frontage cultivation or burning, recreation and draining swamplands and wetlands. While not so widespread, these activities may be locally significant.

Increased in-stream scouring

Increased in-stream scouring can result from hydrological changes to the stream system.

Catchment changes in vegetation type and abundance, soil exposure, soil disturbance, soil compaction and hard surfaced cover (sealed roads and roofs) can significantly increase flows in streams and put additional erosional stress on stream systems (Broughton 1970). Subsequent gully erosion (particularly where streambanks are degraded through stock access) can supply large volumes of sediment directly to stream systems.

Construction and operation of dams also alter the hydrological and scouring regime in streams. Rapid increases or decreases in flow after releases (e.g. hydroelectric generation, irrigation flows) can lead to additional bank erosion by slumping.

Many in-stream works such as construction of road and pipeline crossings, straightening meanders, removal of wood debris to 'rejuvenate' streams, lead to increased in-stream erosion.

Many river and stream ecosystems have been made geomorphically as well as biologically unstable as a result of the magnitude of these changes. Thus, restoration of catchments to a condition that would provide pristine water quality may involve processes operating on a geological rather than a human scale (Walker 1986).

Status of threat

The increase in sediment input to rivers and streams due to human activity is listed as a potentially threatening process under the **Flora and Fauna Guarantee Act 1988**. Increased sediment is a significant cause of loss of fish habitat and breeding grounds (OCE 1988) and has been identified as a major threat to Victorian native freshwater fish (Koehn and O'Connor 1990) and cause for decline in the range and abundance of native fish species (Cadwallader 1978). Several studies have shown the serious effect that additional sediment has on aquatic macroinvertebrate communities (e.g. Blyth *et al.* 1984, Doeg *et al.* 1987), reducing the abundance and diversity or substantially changing the composition of these communities. Additional sediment has been shown to adversely affect the development of tadpoles of the endangered Spotted Tree Frog *Litoria spenceri* which breeds exclusively in streams (Gillespie 1997). Oviposition habitats of this and other lotic frog species are also likely to be adversely affected by increased sediment loads.

In its final recommendation the Scientific Advisory Committee (SAC 1991) has determined that the increase in sediment input to rivers and streams due to human activities is a potentially threatening process, as in the absence of appropriate management it:

- poses a significant threat to the survival of a range of flora and fauna; and
- poses a significant threat to the survival of two or more taxa; and
- poses a significant threat to the evolutionary development of two or more taxa.

Major Conservation Objectives

Long term objectives:

- to reduce the delivery of sediment into streams and the instream generation of sediment to levels which do not compromise the viability of stream biota;
- to reverse declines in the conservation status of many individual species or ecological communities.

Short term objectives:

- to manage sediment input at acceptable levels in waterways supporting populations of susceptible threatened taxa and communities;
- to eliminate or reduce sediment input from priority point sources;
- to protect and restore riparian vegetation in priority catchments;
- to increase awareness amongst land and water managers and the community of the threat posed by increased sediment input to biodiversity, and the most effective management responses.

Management Issues

Manipulation of catchment vegetation, soils and riparian condition has caused significant instability in the vegetative and hydrologic equilibrium of many catchment ecosystems. Erosion above natural levels is a physical manifestation of this instability and can ultimately only be successfully controlled by dealing with primary causes.

Ecological issues

Sediments in a stream system can be found in three distinct phases: suspended (particles in the water column), deposited (particles lying on the stream-bed) and hyporheic (particles within the matrix of the stream bottom). Increase in sediment accession to streams has a variety of adverse effects on the biological resources of the streams, often dependent on the phases of the sediment.

Higher than normal levels of suspended sediment have been found in overseas studies to cause direct fatality, reduced growth rates, reduced feeding, altered diet, increased stress, increased incidence of disease, altered behaviour and in displacement of fish (Lloyd 1987). Other potential or reported effects include a reduction in oxygen uptake by the coating or clogging of gills by fine particles and a reduction in feeding efficiency for visual predators (DWR 1989). Increased deposited sediments have been shown to reduce in growth and development of tadpoles of at least one native lotic frog species presumably by reduction in feeding efficiency (Gillespie 1997). Native Australian fish species are likely to also display these effects (ENRC 1994).

Suspended sediments reduce light transmission, thus adversely affecting photosynthetic activity (Lloyd 1987, DWR 1989).

Higher than normal levels of deposited sediment also have direct and indirect effects on stream biota (Cadwallader 1978). Possibly the major effect is the blanketing of the substrate and the filling of scour holes.

This smothering and filling reduces the total useable habitat areas for fish and tadpoles of lotic frog species. Deposited sediment also fills the spaces between surface substrate elements which are used as sites for deposition of eggs and as habitat, shelter and rearing areas by juvenile fish and other small faunal species (Cadwallader and Backhouse 1983, Koehn and O'Connor 1990). Lotic frog species also use these microhabitats for egg deposition and shelter from predators, and are likely to be similarly adversely affected (Gillespie 1997). The coating of eggs already in place reduces gas exchange which can prevent egg development (DWR 1989).

Many aquatic invertebrate species spend large parts of their life cycle (particularly during the larval phase) on the river-bed (Williams 1980) or on wood debris (Bennison and Suter 1990). Some taxa, such as Simuliidae (Diptera) have a demonstrated need for clean surfaces on which to attach (Williams 1980). Grazing animals (e.g. many mayfly nymphs) may be adversely effected by the smothering of their algal food source (which, of course, also represents a direct effect on the algal species). This smothering also reduces habitat diversity, a key factor in determining and maintaining the diversity of macroinvertebrate communities in streams and rivers (Hynes 1970). Deposited sediment may also smother accumulations of leaves on the bottom of the stream, interrupting litter decomposition and reducing the habitat for specialised leaf pack fauna (Bunn 1980).

Victorian native fish feed mainly on benthic invertebrates, thus factors affecting invertebrates will indirectly affect the fish fauna (Jackson 1986).

The amount of hyporheic sediment within the river-bed itself is also of concern. The bed of a stream is generally composed of a matrix of inorganic particles of differing sizes. Between these particles are free areas known as interstitial spaces. These spaces serve as important habitats for many species (Marchant 1988). The introduction of sediment to a stream fills or reduces the available interstitial spaces with inorganic material (Beschta and Jackson 1979), reducing the potential use of this zone.

Once deposited in a stream, sediment can travel downstream in successive flood events, progressively damaging the stream communities (e.g. Doeg and Koehn 1994). This mobility can cause difficulties in locating the source of sediment, as well as potentially disturbing stream communities a long way from the source. Once allowed in, sediment cannot naturally 'disappear' from the system, nor is it feasible to physically remove it; which makes the need for prevention of further inputs more imperative.

Additionally, sediment eroded into streams also can carry nutrients. Phosphorus readily adsorbs to soil particles and erosion moves the enriched soil particles into waterways. In the water, nutrients can become detached from the soil and become available to support algal blooms.

To manage sediment input effectively, additional knowledge is required in several other areas, including:

- ecosystem processes which contribute to geomorphic stability.
- erosion processes and the relative importance of different erosion sources, both instream and catchment generated. For example, the relative inputs from ephemeral streams versus permanent streams has not been determined.
- influence of sediment on different biota.

- the lower limits of sediment input which compromise particular stream ecosystems.
- monitoring systems which are capable of following changes in the level of sediment input, as well as detecting changes in the ecosystem which result from changes to sediment input.
- recovery time for streams following discharges of sediment.

Wider conservation issues

The magnitude of catchment changes over the past 100 years and the consequential changes to stream systems suggest that a concerted effort is needed to move steadily towards the major conservation objectives. Development of the Catchment Management Authorities (CMAs) under the **Catchment and Land Protection Act 1994** provides a solid basis for improving land and water management and for implementing this Action Statement and meeting the conservation objectives.

The Victorian Government recognises the importance of improving land management in catchment areas for a range of ecological, economic and social reasons. Accelerated erosion is a consequence of resource misuse and rundown. It is an end-point indicator of poor land-use and land degradation.

Protection, maintenance and enhancement of the natural resource is seen as a key requirement for economic and social health of the community. The primary goal of CMAs, the Department of Natural Resources and Environment and other bodies such as the Environment Protection Authority is to protect the soil and water resource through targeted activities including soil conservation and erosion control. It is through such programs that the objectives of this Action Statement will be realised.

Management of this threatening process is an integral part of achieving quality catchment management and ecologically sustainable development. Carbon, nutrient, water cycling and sediment movement all need to be balanced for maintenance of a sustainable system. Any significant reduction in sediment input to stream systems can only be achieved if there is balance between land management and ecological processes.

Previous Management Action

Early Victorian legislators saw the importance of water (quality and quantity) to the economic well-being of the state and thus prohibited alienation of streamsides, ensuring that the crown retained ownership of the frontages to rivers and streams for all land alienated after 1881 and closing Melbourne's water supply areas to outside uses.

Many recent approaches, initiatives and actions have been targeted at improved water and land management and biodiversity protection. These have worked, often indirectly, to reduce sedimentation or now offer opportunities to do so.

In June 1997, ten CMAs were established under the **Catchment and Land Management Act 1994**, replacing the Catchment and Land Protection Boards (Catchment Management Structures Working Party 1997). The role of the CMAs is to ensure the sustainable development of natural resource based industries, the protection of land and water resources and the conservation of natural and cultural heritage.

Each CMA is responsible for waterway management, water quality management, floodplain management, rural drainage management, Crown Frontage management and management of Heritage Rivers outside National Parks. Each CMA has produced a Regional Catchment Strategy for their area outlining actions to achieve these goals. These include new initiatives that will benefit streams by reducing sedimentation.

Additionally, CMAs are now responsible for all existing programs and plans that have benefits in reducing sedimentation to Victorian streams, including:

- Waterway Management Programs,
- Water Quality Plans,
- Regional Vegetation Plans,
- Salinity Management Plans.

In addition to plans under the auspices of the CMAs, the following are all examples of important programs, activities and guidelines currently operating which can also effectively target reduced sediment input into streams:

- The Nutrient Management Strategy for Victorian Inland Waters (Victorian Blue-Green Algae Project Team 1995);
- Forest Management Plans and Code of Forest Practices (e.g. NRE 1996);
- Planning guidelines for road construction and maintenance in forest areas (e.g. DCE 1991);
- Guidelines for Environmental Management of Road Construction Activities (VicRoads in prep.);
- Environmental Guidelines for River Management Works (CFL 1990);
- Construction techniques for sediment pollution control (EPA 1987);

- Guidelines for Stabilising Waterways (RWC 1991);
- VicRoads Environment Strategy (VicRoads 1995);
- Heritage River Management Plans;
- Local Conservation Strategies (e.g. Cardinia Shire Sites of Significance Program);
- Declaration and management of National Parks and reserves;
- NRE Sustainable Agriculture Program;
- EPA State Environment Protection Policies;
- Special Area Plans under the CALP Act;
- Water use efficiency programs in cropping areas;
- Victoria's Landcare Program;
- Corridors of Green;
- Waterwatch;
- Tree planting programs;
- Tree Victoria Action Plan;
- Property Management Planning Program;
- Rabbit control programs.
- NRE's membership of the Co-operative Research Centre for Catchment Hydrology;
- CMA Nutrient Management Strategies.

Flora and fauna values are increasingly taken into account in the ongoing development of these programs (e.g. they are now one of three key Landcare criteria). Most have not been specifically designed for biodiversity benefits, but rather aim to broadly improve management of the soil and water resources of which flora and fauna values are one part. At best, specific programs have been aimed directly at protection of threatened species. For example, extended stream buffer widths and other measures aimed at minimising the risk of sedimentation are provided for the protection of the Spotted Tree Frog *Litoria spenceri*, Barred Galaxias *Galaxias fuscus* and Stirling Stonefly *Thaumatoperla flaveola* and restoration of riparian vegetation for protection of Variegated Pigmy-perch *Nannoperca variegata*.

Research programs such as that conducted by the Cooperative Research Centre for Catchment Hydrology (CRCCH 1997) and the Land and Water Resources program on riparian vegetation restoration and management also provide significant information for managing sediment movement.

Intended Management Action

Given the range and inter-dependence of the changes required, the intended management actions will be undertaken by a range of agencies. These include all Government and semi-government agencies associated with water, resource and land use management responsibilities, ie. CMAs (and associated Implementation Committees), NRE, VicRoads, EPA, and local government.

Specific intentions to minimise sediment production are:

- avoid concentration of surface flows (especially roads and drains);
- protect/rehabilitate riparian vegetation;
- improve disposal of 'unavoidable' concentrations of surface flows;
- control rates of disturbance of vegetation and soil in waterway areas (including bridges, culverts, dams);
- control of direct stock access to waterway areas;
- maximise vegetative cover of catchments, banks and river margins;
- contain development of hard-surfaced areas;
- maximise the proportion of rain intercepted by vegetation and mulch;
- maximise rate of rain infiltration into soil;
- increase rate of water use by vegetation;
- minimise rate of overland flow.

The intended management actions to achieve these intentions are as follows:

In-stream and Riparian program

1. Develop an in-stream and riparian program following the guidelines of Victoria's Biodiversity Strategy aimed at protecting and restoring riparian vegetation communities along waterways. Facilitate incorporation of this program into business plans, strategies and so on produced by land and water managers, and acceptance by landholders through such programs as Landcare and Land for Wildlife.

   Responsibility: DSE (Biodiversity and Natural Resources Division)

Planning and Co-ordination

2. Ensure that all authorities with land or water management responsibilities include, as part of their business plans or strategies, objectives

and targets to minimise sedimentation of waterways. Authorities include, but are not restricted to, CMAs, DSE Businesses, bodies responsible for road construction and maintenance, Roadsides Conservation Advisory Committee, Local Councils. Strategies should indicate targets, set standards, and priorities, indicate co-ordination arrangements and proposed monitoring. Priorities should include the protection of threatened species and communities, and the management of key point sources of sediment.

Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division, Regions), Catchment Management Authorities

3. Use reduction of sediment input into streams as one of the priority criteria for assessing grants under the Land Protection Incentive Scheme and Natural Heritage Trust.

   Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division, Regions), Catchment Management Authorities

4. Provide input on riparian vegetation management to CMAs for use when reviewing grazing licences on river frontages.

   Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division, Regions)

Production of guidelines, legislation

5. Where appropriate, develop guidelines, including Codes of Practice, and legislative requirements, such as State Environment Protection Policies (prepared by the Environment Protection Authority), to clearly specify criteria for those activities which can contribute sediment to stream systems, viz: roading, stream crossings, in stream activities, specification of protection/filter zones.

   Responsibility: DSE (Land and Catchments Division, Water Sector Group), Environment Protection Authority

Education and extension

6. Provide information to all authorities with land or water management responsibilities on sediment impacts on stream habitat and aquatic biota for use in setting priorities and recommending management actions for catchment and river works.

   Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division, Regions), Catchment Management Authorities

7. Identify and promote best practice examples to river management authorities, road managers, landholders and other relevant agencies.

   Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division, Regions), Catchment Management Authorities

8. Develop an education and extension program on the effects of sedimentation and control measures for landholders and other strategic groups (e.g. recreational fishers, teachers). This should include production and distribution of education and extension material explaining the ecological and economic problems of erosion and production of guidelines and technical information for landholders describing appropriate land management techniques to achieve soil conservation. Much of this information already exists, but needs to be consolidated. Add information at established demonstration sites at popular sites to illustrate the nature and effects of sedimentation.

   Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division, Regions), Catchment Management Authorities

Research

9. Undertake, as funding becomes available, technical research in priority areas:

- evaluating actions to measure their effectiveness in stopping sediment input;
- establishing standards or criteria for instream sediment levels, particularly deposited and hyporheic;
- identifying areas of critical stream habitat requiring priority attention;
- identifying stream management methods which will minimise the production or mobilisation of sediment.

Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division)

10. Undertake baseline social research into public knowledge and attitude towards sedimentation and its control.

    Responsibility: DSE (Land and Catchments Division, Water Sector Group)

11. Undertake, where appropriate, economic research into the cost effectiveness of different control measures, and into the possible application of incentives and other economic instruments which may contribute to solutions.

Responsibility: DSE (Land and Catchments Division, Water Sector Group)

Resource assessment and monitoring

12. Develop appropriate performance indicators for this threatening process to assist land and water management authorities in environmental audit and condition of catchment requirements.

    Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division)

13. Develop an appropriate monitoring and assessment program for this threatening process which will measure changes in catchment and instream erosion and impacts on the aquatic ecosystem. Monitoring will also help evaluate the actions which deliver the most benefit for the least cost.

    Responsibility: DSE (Land and Catchments Division, Water Sector Group, Biodiversity and Natural Resources Division)

References

Barr, N. & Cary, J. (1992) *Greening a Brown Land* Macmillan Education, Australia.

Bennison, G. & Suter, P. (1990) Macroinvertebrates. *in* Mackay, N. and Eastburn, D. (eds) *The Murray*. Murray-Darling basin Commission, Canberra. pp: 287-302.

Beschta, R.L. & Jackson, W.L. (1979) The intrusion of fine sediments into a stable gravel bed. *Journal Fisheries Research Board of Canada* **36**: 204-10.

Blyth, J.D., Doeg, T.J. & St. Clair, R.M. (1984) Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria to the construction and operation of the Dartmouth Dam. 1. Construction and the initial filling period. *Occ. Pap. Mus. Vic.* **1:** 83-100

Broughton, W.C. (1970) Effects of Land Management on the Quantity and Quality of Available Water. *Australian Water Resources Council Report No.* **120**.

Bunn, S.W. (1988) Processing of leaf litter in two northern jarrah streams, Western Australia: II. The role of macroinvertebrates and the influence of soluble polyphenols and inorganic sediment. *Hydrobiologia* **162**: 211-23.

Cadwallader, P.L. (1978) Some causes of the decline in the range and abundance of native fish in the Murray Darling River system. *Proc. R. Soc. Vict.* **90:** 211-24.

Cadwallader, P.L. & Backhouse, G.N. (1983) *A Guide to the Freshwater Fish of Victoria*. Government Printer, Melbourne.

Campbell, I.C. (1980) Diurnal variations in the activity of *Mirawara purpurea* Riek (Ephemeroptera: Siphlonuridae) in the Aberfeldy River, Victoria, Australia, *in* Flannagan, J.F. & Marshall, K.E. (eds.) *Advances in Ephemeroptera Biology*. Plenum, New York. pp: 297-308.

Catchment Management Structures Working Party (1997) Review of Catchment Management Structures in Victoria. Report to the Minister of Agriculture and Resources and Minister for Conservation and Land Management.

CFL (1990) *Environmental Guidelines for River Management Works*. Office of Water Resources and Department of Conservation Forests and Lands, Government Printer, Melbourne.

Chisholm, A.H. & Dumsday, R.G. (1987) *Land degradation: problems and policies*. Cambridge University Press, Cambridge.

Chutter, F.M. (1969) The effects of silt and sand on the invertebrate fauna of streams and rivers. *Hydrobiologia* **34**: 57-76.

Coleman, M.S. & Hynes, H.B.N. (1970) The vertical distribution of the invertebrate fauna in the bed of a stream. *Limnology and Oceanography* **15**: 31-40.

Cordone, A.J. & Kelly, D.W. (1961) The influences of inorganic sediment on the aquatic life of streams. *California Fish and Game* **47**: 189-228.

CRCCH (1997) *Controlling sediment and nutrient movement within catchments: Industry Report 97/9*. Cooperative Research Centre for Catchment Hydrology, Melbourne.

DCE (1991) *Standard roading prescriptions for timber production in the Central Highlands ash and mixed species forests.* Department of Conservation and Environment, Melbourne. (unpublished).

DWR (1989) *Water Victoria: An Environmental Handbook.* Government Printer, Melbourne.

Doeg, T.J., Davey, G.W. & Blyth, J.D. (1987) Response of the aquatic macroinvertebrate community to dam construction on the Thompson River, south-eastern Australia. *Regulated Rivers* **1(1):** 195-209.

Doeg, T.J. & Koehn, J.D. (1994) Effects of draining and de-silting a small weir on downstream fish and macroinvertebrates. *Regulated Rivers* **9**: 263-77.

ENRC (1994) *Environment and Natural Resources Committee Report on Eductor Dredging in Victoria.* Government Printer, Melbourne.

EPA (1987) *Control of Erosion on Construction Sites.* Environment Protection Authority, Melbourne.

Gillespie, G. R. (1997) The Biology of the Spotted Tree Frog (*Litoria spenceri*) and examination of factors responsible for population declines. Unpublished report to Environment Australia, Biodiversity Group, Canberra.

Government of Victoria (1992) *Victoria's Decade of Landcare Plan.*

Government of Victoria (1993) *Victoria's Regional Landcare Plans.* (9 documents).

Hynes, H.B.N. (1970) *The Ecology of Running Water.* Liverpool University Press, Liverpool.

Hynes, H.B.N. (1974) Further studies on the distribution of stream animals within substratum. *Limnology and Oceanography* **19**: 92-9.

Jackson, P.D. (1986) Fish Habitat for River Management Works, in *River Management Foremans Workshop: Workshop Proceedings.* Department of Water Resources, Melbourne.

Koehn, J.D. & O'Connor, W.G. (1990) Threats to Victorian native freshwater fish. *Vict. Nat.* **107(1)**: 5-12.

Lake, P.S. & Marchant, R. (1990) Australian upland streams: ecological degradation and possible restoration. *Proceedings of the Ecological Society of Australia* **16**: 79-91.

Lloyd, D.S. (1987) Turbidity as a water quality standard for salmonid habitats in Alaska. *North American Journal of Fisheries Management* **7**: 34-45.

Marchant, R. (1988) Vertical distribution of benthic invertebrates in the bed of the Thomson River, Victoria. *Australian Journal of Marine and Freshwater Research* **39**: 775-84.

Mitchell, P.A. (1990) *The Environmental Condition of Victorian Streams.* Department of Water Resources. Melbourne.

Ministry for Conservation (1983), *The State of the Rivers.* Government Printer, Melbourne.

NRE (1996) *Code of Forest Practices for Timber Production. Revision No. 2.* Department of Natural Resources and Environment, Melbourne.

NSW Department of Land and Water Conservation (1995) Managing the Water Resources of New South Wales: A survey of landholder and community attitudes. NSW Department of Land and Water Conservation, Sydney.

OCE (1988) *Victoria's Inland Waters. State of the Environment Report.* Victorian Government Printing Office, Melbourne.

OCE (1991) *Victoria's Agricultural Lands. State of the Environment Report.* Victorian Government Printing Office.

Olive, L.J. & Rieger, W.A. (1987) Eden catchment project: sediment transport and catchment disturbance. 1977-1983. *Monograph Series* **1.** Department of Geography and Oceanography, Aust. Defence Forces Academy, Canberra.

RWC (1991) Guidelines for Stabilising Waterways. Rural Water Commission, Melbourne.

SAC (1991) Final Recommendation on a nomination for listing - Potentially Threatening Process - *Increase in sediment input to rivers and streams due to human activities* (Nomination No. **181**). Department of Conservation and Natural Resources, Melbourne.

Singh, G., Kershaw, A.P. & Clark, R. (1980) Quaternary vegetation and fire history in Australia, in *Fire and Australian Biota*, A.M. Gill, R.A.. Groves & I.R. Noble (eds). Australian Academy of Science, Canberra.

Standing Committee on Rivers and Catchments (1990) *Environmental Guidelines for River Management Works.* DCE, Melbourne.

VicRoads (1995) *Environment Strategy.* VicRoads, Melbourne.

Victorian Blue-Green Algae Project Team (1995) *Nutrient Management Strategy for Victorian Inland Waters.* Government of Victoria, Melbourne.

Walker, P.H. (1986) The impact of civilisation on the major ecosystems of the Australian continent: 2. the temperate South-east In *Australian Soils: the Human Impact,* J.S. Russell & R.F. Isabel (eds), University of Qld. Press, St Luca.

Williams, W.D. (1980) *Australian Freshwater Life.* MacMillan Books, Melbourne.

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Further information can be obtained from Department of Sustainability and Environment Customer Service Centre on 136 186.

Flora and Fauna Guarantee Action Statements are available from the Department of Sustainability and Environment website: http://www.dse.vic.gov.au

This Action Statement has been prepared under section 19 of the Flora and Fauna Guarantee Act 1988 under delegation from Chloe Munro, Secretary, Department of Natural Resources and Environment, June 2001.

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This Action Statement was approved in 2001 and remains current. This version has been prepared for web publication. It retains the original text of the action statement, although some details, such as the names of organisations, may have been updated.

Published by the Department of Sustainability and Environment, Victoria. 8 Nicholson Street, East Melbourne, Victoria 3002 Australia

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ISSN 1448-9902