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Repairing Australia's rivers

Last year CSIRO produced for the Government a report on Australia's rivers. Two centuries of abuse have caused enormous damage, the report reveals. But there is hope that with a national strategy, supported by the community, our rivers can be repaired.

Australia's rivers have changed dramatically in the past two centuries. They've been disrupted by damming, draining and land clearing, invaded by exotic plants and animals and polluted with agricultural, industrial and urban waste.

Most of those changes are irrevocable, but not irreparable. Reparation is needed because a continent as dry as Australia must have reliable, healthy rivers to survive. These precious lifelines, however, are often treated like sewers. Sewage and industrial or agricultural chemicals overload rivers with nutrients, promoting eutrophication and weed growth, and heightening the risk of blooms of toxic blue-green algae (see 'What can be done about toxic algal blooms?', *Ecos* 72). Underground water tables are affected by water pumped from rivers for irrigation. This can cause salinisation which destroys the habitats of plants and animals and also washes back in the rivers (see 'A direct approach to salinity control', *Ecos* 67).

This article is based on a discussion paper, *Towards Healthier Rivers*, issued in December, 1992, by the Commonwealth Environment Protection Agency (CEPA). The paper summarises a technical report produced earlier in the year by CSIRO's Division of Water Resources.

Poor management of rivers causes short- and long-term damage to riparian ecosystems. This, in turn, affects the health of Australia's 17 million human inhabitants. Also important is the economic argument that Australian produce will be less attractive in export markets if the water on which it is raised is of questionable quality. This is a matter of consumer perception, not fact.

What has changed?

Land-use changes have radically altered the water balance of Australia's catchments and rivers. Even small changes to seasonal variations in flow can produce effects — such as changes in salinity and bank erosion — that have impacts further downstream. Fortunately, most of these changes can be detected easily and action can then be taken to remedy them.

contribution of groundwater to stream flow is therefore greater, often bringing highly saline waters and nutrients to streams. Irrigation also reduces stream flow. This is because 80-90% of the water diverted from streams for irrigation is lost through evaporation.

Where groundwater is saline (most of arid and sub-humid Australia), irrigation increases the total salt load because of reduced stream flows from irrigation diversion and increased groundwater flows. As well as salt, irrigated pastures can yield large quantities of nutrients to rivers and estuaries.

Dams and weirs: Seventy per cent of Australia is arid, characterised by unpredictable and highly variable rainfall (see 'Understanding arid Australia', *Ecos* 73). Native plants and animals have adapted to this by timing their reproduction to take advantage of rain-

have low temperatures, low oxygen, low pH — making them relatively acidic — and high levels of sulphide and manganese. These characteristics affect aquatic ecosystems and make life difficult for human users. For example, the pH and bicarbonate content of water released from the Burdekin Dam in Queensland has blocked irrigation equipment.

Erosion: Increased runoff, following land clearing for agriculture and forestry, has exacerbated erosion on the banks of most Australian rivers. Regulation of river flows also causes erosion. For example, the banks of the Murray River near Albury/Wodonga, are fretted and eroded at the height at which flows are held during the summer irrigation period. Enlarging and straightening natural channels also erodes river banks and stream beds.

Salinity: The clearing of forests for shallow-rooted crops and pastures has meant that in many areas the annual recharge of groundwater systems has increased dramatically. Because the discharging groundwater may be highly saline, the total quantity of salt discharged also increases. As saline water tables approach the surface and invade the root zone, salt-intolerant plants die, erosion increases and the soil ceases to support plant and animal life. The pattern of water movement through a catchment also changes, generally leading to increased runoff. Higher peak runoff rates lead to increased sheet erosion and greater peak stream flows. Streams cut their banks and beds to accommodate the new flows.

The situation is worsened by irrigation. Irrigation increases the average water content of the soil, meaning more deep drainage to groundwater. The proportion of rainfall contributing to both runoff and deep drainage also rises. The

fall where and when it occurs. Humans, on the other hand, must time their economic and other activities according to the needs of markets, so they have built dams, weirs, diversions and channels to ensure a regular, adequate water supply.

The Ord River, in the tropical north of Western Australia, normally has a peak flow of about 108 gigalitres an hour in the wet (summer) season and stops flowing altogether in 'the dry'. The Ord Dam holds 15 000 GL, but has a spillway capacity of only 0.025 GL/hour. As a result, all peak flows downstream have effectively ceased, and most sediment is trapped in the dam. This means nutrients are no longer flowing into the system in the way they used to. Also, sediment-deficient discharges over the spillway are scouring the river bed immediately downstream.

Dams also affect water quality and temperature. Most releases from reservoirs are from deep water, and typically

The Avon River in Western Australia was 'trained' in this way. Dead trees, logs and debris were removed, and the bed was ripped to scour a deeper channel. The aim was to prevent flooding of towns built, unwisely, on the floodplain. Instead, huge volumes of water, travelling faster than under natural conditions, sedimented the deep pools inhabited by native fish and worsened the flooding.

Fortunately, the Western Australian Government has not taken matters to the extremes demonstrated by the US Army Corps of Engineers, which has surrounded towns and cities on the floodplains of the Mississippi and Atchafalaya Rivers with concrete levees. One levee, around Morgan City, Louisiana, is almost seven metres high!

To create and maintain a healthy river, it must be understood what needs to be controlled. Let us compare mining and agriculture. Olympic Dam mine is in South Australia. The mine site

Making our water fit to drink

'Australia's rivers should one day be fit to drink most of the time.'

This goal was the basis of recommendations made in last year's report by CSIRO's Division of Water Resources into the state of Australia's rivers. The report was commissioned by the Commonwealth Environment Protection Agency on behalf of the Federal Government.

The report recognised that ultimately, communities would set their own water quality standards, and these may be affected by economic, environmental or social considerations. For the purpose of the report, however, 'drinkability' was considered a broadly-acceptable standard.

To achieve this goal, the development of a water-quality index was advocated. The index, incorporating key indicators of water purity, could be used to detect trends and show when action was required. Where possible, the indicators should have universal applicability. For example, dissolved-oxygen concentration defines the habitability of all waters.

The report also advocated establishing a national water-quality policy. This policy, incorporating water-quality goals developed in consultation with the community, would be the basis of a water management strategy. State and territory governments and the Federal Government are already working together through the Australian and New Zealand Environment and Conservation Council, the Agriculture and Resource Management Council of Australia and New Zealand and the National Health and Medical Research Council to develop a National Water Quality Management Strategy.

A range of issues relevant to the development of a water-quality management strategy were considered in the *Towards Healthier Rivers* report. The following is a summary of the points made in relation to each.

Ecosystem management: Many of our river systems have changed since European Settlement and ecosystems can never be restored to their 'natural' condition. The aim should be remediation: the return of structures and functions similar to those that previously existed.

Floods: Rivers must be allowed, where practical, to flow naturally. No other feature of river systems is as important in maintaining ecosystem diversity as the timing and extent of floods. Floods move sediment and nutrients into long-term stores, disperse the next generation of animals and plants and provide nutrients for animals living in billabongs and wetlands. They are only a problem when people build on floodplains. Extensive community consultation is needed to bring about changes to land-use zoning and building approvals in these areas.

Flow management: Sympathetic river-flow management is an important part of river reclamation. Slight changes to water scheduling and more efficient water allocation can help to achieve more 'natural' flows during irrigation periods.

Blue-green algae: Reduction of nutrient sources in catchments and streams is a long-term goal which should lead to improvements in water quality and fewer blooms of blue-green algae (cyanobacteria). In some weir pools, siphoning water over the top of wier walls, rather than discharging it underneath can reduce the blooms of algae in weir pools. Another possibility is to physically manipulate water storages so that algae are prevented form floating on the surface where they are exposed to light, the energy source for their vigorous growth. Also, keeping enough water flowing in rivers keeps the water turbulent and algae do not multiply as fast as in still or low-velocity water.

The river-bank zone: The impact of livestock on the river-band (riparian) zone needs to be minimised. The benefits would be greater vegetation and bank stability, less sediment and nutrient loss to rivers, less direct defacation into rivers, more protection for native animals and more attractive scenery. Restoring river-bank vegetation requires less grazing pressure and active replanting where spontaneous regeneration is insufficient. Community commitment is essential if livestock management and the restoration of river-bank vegetation is to be successful.

Fish for biomanipulation: Biomanipulation is a management tool involving the removal of fish that prey on algae-eating organisms, that stimulate algae growth, or that facilitate the transport of nutrients from sediment to water. The application of biomanipulation, though not easy, may be helpful in Australian rivers. For example, an experimental program involving the removal of European carp, linked with replanting of vegetation might, with community support, be worth attempting.

Total catchment management: The links between the land and the water make total catchment management (TCM) essential if our rivers and their catchments are to become healthier. Replacement of wooded and shrubland catchments by cropped and grazed lands has increased the delivery of sediment and nutrients to rivers. A principle goal of TCM should be to reduce these loads.

Effective planning tools are needed to help implement TCM. This is a major technical issue to be resolved. It needs to be approached using large-scale catchment modelling and tracers of phosphorus and sediment.

Financial and economic methods: There is no direct economic incentive to moderate pollutant discharges in Australia. River use could be charged for, but property rights and pricing mechanisms can never be solved by market forces alone. For example, it is difficult to estimate the recreational value of a river.

Access charges could be used, however, to restrict the use of particularly environmentally sensitive areas. These could help ration the available resource and finance rehabilitation. Some kind of natural resource accounting (which brings together economic data about production and consumption characteristics of a region or catchment with resource and environmental data) is needed to work on these issues.

Catchment-wide strategies for water allocation, including flows for environmental purposes, need to be developed. Issues of structural adjustment in agriculture are involved, but they are issues which for economic, social and environmental reasons must be resolved. Water re-allocation may be possible through demand reduction caused by full cost-pricing. The concept of 'capacity sharing', where commercial users must bid against environmental users (possibly represented by government) for part of the available regulated river capacity, might be worth trying. Also, grants to farmers in economically stressful times should not support bad irrigation practices.

Research in the United Kingdom has shown that when a system of 'discharge pricing' is used, industries will invest in pollution-abating equipment. There is an urgent need to assess the applicability of the 'polluter pays' principle to the discharge of nutrients in Australia from sources such as intensive rural industries, processing industries and sewerage works.

When operating complex river systems, managers and stakeholders need computer models and information systems. Computer-based decision-support systems, providing information to decision makers, can help. Such systems are being developed, but much time is needed to collect all the basic information about each part of a management problem. Also, the organisation of information management systems, particularly those for integrated catchment management, is at present unsophisticated.

itself is carefully planned and controlled, yet to reach the mine, one must drive through degraded rangelands. Environmental regulation of broadacre farming is low compared with that affecting mining. Inconsistent policies such as these need to be addressed.

Nutrients: Phosphorus and nitrogen are vital to life, but they are also responsible for eutrophication, a serious water quality problem. Eutrophication is the excessive fertilisation of aquatic plant growth and algae.

Phosphorus is normally in equilibrium within a forested catchment, with roughly equal amounts entering the system from the atmosphere and the soil and returning to storage in soil, plants and animals. When catchments are cleared for agriculture, however, and sewage is pumped into rivers with little or no treatment, this equilibrim is upset. Phosphorus loss from the soil-plant-animal system to rivers, lakes, wetlands and reservoirs amounts to about 25 000 tonnes a year. Biological imbalances like massive algal blooms caused by excessive phosphorus concentrations can damage water quality.

Less is known about the effect of nitrogen on rivers, partly because it is such a volatile element. Sixteen per cent of the nitrogen fed into agricultural land

Research giving new life to rivers

The CSIRO has underway many research projects that are contributing to the restoration and maintenance of healthy rivers. Here are some of them.

Water quality monitoring: Water quality monitoring has become highly sophisticated with the development of AQUALAB. This is a remote water quality monitoring system which provides a continuous, instantaneous readout of a number of physical and biological parameters crucial to water quality.

The CSIRO divisions of Entomology and Water Resources and the Water Resources Corporation of Victoria are jointly investigating the use of sensitive organisms (such as as chironomids) which may give the first indications of the presence of toxic substances in water. *Moina* (a type of *Daphnia* or water flea) is another indicator organism being researched.

Aquatic plants can also be used as indicators of both the quantity and quality of water available in a river system. The Division of Plant Industry is working with the Division of Water Resources on biological monitoring of pesticides in water, by the use of immunoassays.

Flow requirements: Work is underway to build up the necessary data for quantification of optimum flow requirements for the impact on breeding of birds and fish; riparian vegetation; management of algal blooms and other biological consequences.

When these flow requirements are in conflict with the needs of other users, political and social solutions will have to be negotiated. The CSIRO Social Science Research Unit is producing world-class research on successful methods of conflict management in the area of natural resources.

Nutrient control: The recently-formulated Algal Research Program coordinates the work of several CSIRO divisions in an effort to overcome this major threat to the health of our rivers. Several other projects are contributing to our knowledge of algal blooms, but the program concentrates on the following areas:

- Determining the factors which influence the growth and distribution of algae in weir pools, and then developing models of circulation and mixing.
- Using AQUALAB at three sites across southern Australia to provide monitoring strategies and protocols relevant to bloom prediction.
- Clarifying the interactions of nutrient sources and trigger mechanisms for algal blooms on the Swan Canning Estuary in Western Australia.
- Investigating the chemical characterisation of novel toxins produced by *Anabaena* and *Mycrocystis* spp., then establishing their chemical and biological suitability in surface waters.
- Developing a conceptual model of freshwater algal dynamics, in consultation with management and research experts.

Riparian zone: Studies at Chowilla, on the Murray River, have revealed some of the complexities of interactions among the floodplain, the river and the riparian zone trees. Carp are under investigation for their role in digging up sediment and disturbing the ecosystem. Also under scrutiny is the role macrophytes and emergent vegetation play in protecting against this disturbance.

Research begun in 1992, involving staff from CSIRO Division of Water Resources, concerns the health of black box woodland on the River Murray floodplain at Chowilla in South Australia. This work will show how shallow and saline groundwater, flood frequency and soil type influence woodland condition. Such knowledge is essential for river and floodplain management.

Less well known is the problem of river bank erosion. Work at the Murray-Darling Freshwater Research Centre has established that much erosion of River Murray banks is related to continual high summer flows on bare, unvegetated banks.

Current research is aimed at developing techniques and guidelines for erosion control using the common native reed *Phragmites australis*.

Control of release of sediment: A CSIRO Land and Water Care Program-funded project on sources of turbidity in the Murrumbidgee River has thrown up some challenging results because it has attempted to estimate the relative significance of all sources of fine clays.

Using a combination of turbidity and suspended sediment monitoring along with radioactive and magnetic tracers, it has been shown that the upland part of the catchment (such as upstream of the large irrigation reservoirs, Burrinjuck and Blowering) supplies essentially no turbidity to the lower river. The key source area lies between Gundagai and Wagga Wagga where there is extensive cultivation and grazing.

The tracers have shown that surface-derived soil (such as topsoil) has reached the river, and possibly is the dominant source. Work in a 1000km^2 subcatchment has shown that the amount of sediment that reaches the main river is less than 10% of the total eroded soil. The rest is simply redistributed in the catchment.

Various lines of evidence show that the eroded banks of the main river are a relatively small source of sediment. Although this erosion is of ecological significance to the riparian zone, as shown in the Murray River, it is not the major sediment villain. The project has demonstrated the value of a holistic approach to sourcing sediment.

through fertilisers leaches into river catchments. Such large inputs of any element are thought likely to have some effect.

Pesticides: Pesticide analysis by conventional methods is expensive and new compounds are constantly being introduced. We need to assess the status of our rivers and implement agricultural practices to minimise pollution.

Mining: Acids and toxic metals from mine spoil and tailings dumps can cause long-term damage to aquatic life. Near Canberra, long-lasting heavy-metal pollution of the Molonglo River was caused by erosion and leaching of mine waste at Captain's Flat. Despite efforts to clean up the mine site, reduced diversity and abundance of invertebrates, and an absence of fish for 40 km downstream of the mine, have persisted for more than 20 years.

Human health: More must be learned about the health of the Australian environment — especially our rivers — if the effects of water quality on human health are to be monitored effectively. Recent research in Britain indicates that herbicide residues are more dangerous for human drinking water than pesticides and insecticides, especially in water for towns downstream of farming land. It is not known how serious this problem might be in Australia.

Plants and animals: Interference with Australia's river systems has damaged the habitats of native plants and animals. Aquatic animals are adapted to natural, irregular river flows: not to dams, channels and billabongs controlled by pumps and weirs. Clearing of riverbank vegetation, increased sedimentation, competition from exotic species and salinity have also contibuted to the decline of natural habitats.

More about the topic

For more about the Commonwealth Environment Protection Agency's *Towards Healthier Rivers* report, contact: Pollution Avoidance Section, CEPA, PO Box E305, Queen Victoria Terrace, ACT 2600, or Ms Margaret Bryant, CSIRO Division of Water Resources, Private Bag, PO Wembley, WA 6014.

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What is a healthy river?

Proper management of Australia's rivers involves balancing people's needs with those of native fauna and flora. To achieve this, the features of a healthy river must first be identified. A healthy river:

- Is unpolluted by wastes such as oils, litter, dyes and foam. It is unpolluted by sewage (which feeds potentially dangerous coliform bacteria, as well as other bacteria and viruses). It is fit to drink most of the time.
- Contains levels of poisons such as pesticides, metals and organic compounds too low to affect plants and animals.
- Contains enough water of suitable quality for recreational activities such as fishing and boating.
- Is brackish only during low flows that result from evaporation or drought, or from groundwater input.
- Receives and stores sub-critical amounts of nutrients such as phosphorus and nitrates, so that the growth of algae and weeds is kept to a minimum.
- Receives enough organic matter to keep aquatic ecosystems functioning, neither starving them of essential nutrients nor overloading them and keeping biological oxygen demands at a level where fish and invertebrates can survive.
- Carries low levels of suspended sediment (which means efficient catchment management), minimising siltation and the transport of nutrients and keeping toxin- and odour-producing algae in check.
- Is shaded by trees or fringed by appropriate amounts of vegetation, and is characterised by a natural variety of snags, pools, rapids, riffles and bars (which help keep water aerated), and water plants.
- Contains a minimum of exotic plants and animals.
- If controlled, only has the minimum number of structures (such as dams or weirs) necessary to regulate flow for human safety and agricultural needs. A healthy river retains essential elements of flow such as seasonal variation and does not prevent fish migrating.
- Receives water from reservoirs that are themselves managed so they are neither too warm or too cold for the season, and that do not contain excessive amounts of sulphide and manganese.
- Is managed so that its biological resources (for example, fish or crustaceans) are not over-exploited.
- Has banks that are protected from erosion by (mainly native) vegetation.
- Contains viable communities of plants and animals.
- Is managed so that flooding is recognised as vital and revitalising events rather than 'disasters', and is unregulated wherever possible. A healthy river's floodplains and channels receive flood-borne nutrients and sediments; its wetlands are supplied with appropriate amounts of water to protect ecosystems and to support bird and other animal populations; and floodwaters are not obstructed by structures on floodplains.
- Is managed to ensure that it contributes to the beauty of the landscape: is not 'channelised', is valued for its healthy plants and animals, and is regarded as an asset rather than as a drain or a water-supply canal.
- Is regularly monitored to ensure its health.
- Has adequate legislative and financial resources committed to the attainment and maintenance of a healthy state.

It is immediately obvious that some of these characteristics are contradictory: a river is a complex entity, and what is appropriate in one section or reach (or, in one kind of river) is not necessarily appropriate in others. A healthy river has features that suit its region and its intended use, and that support its physical and biological diversity.