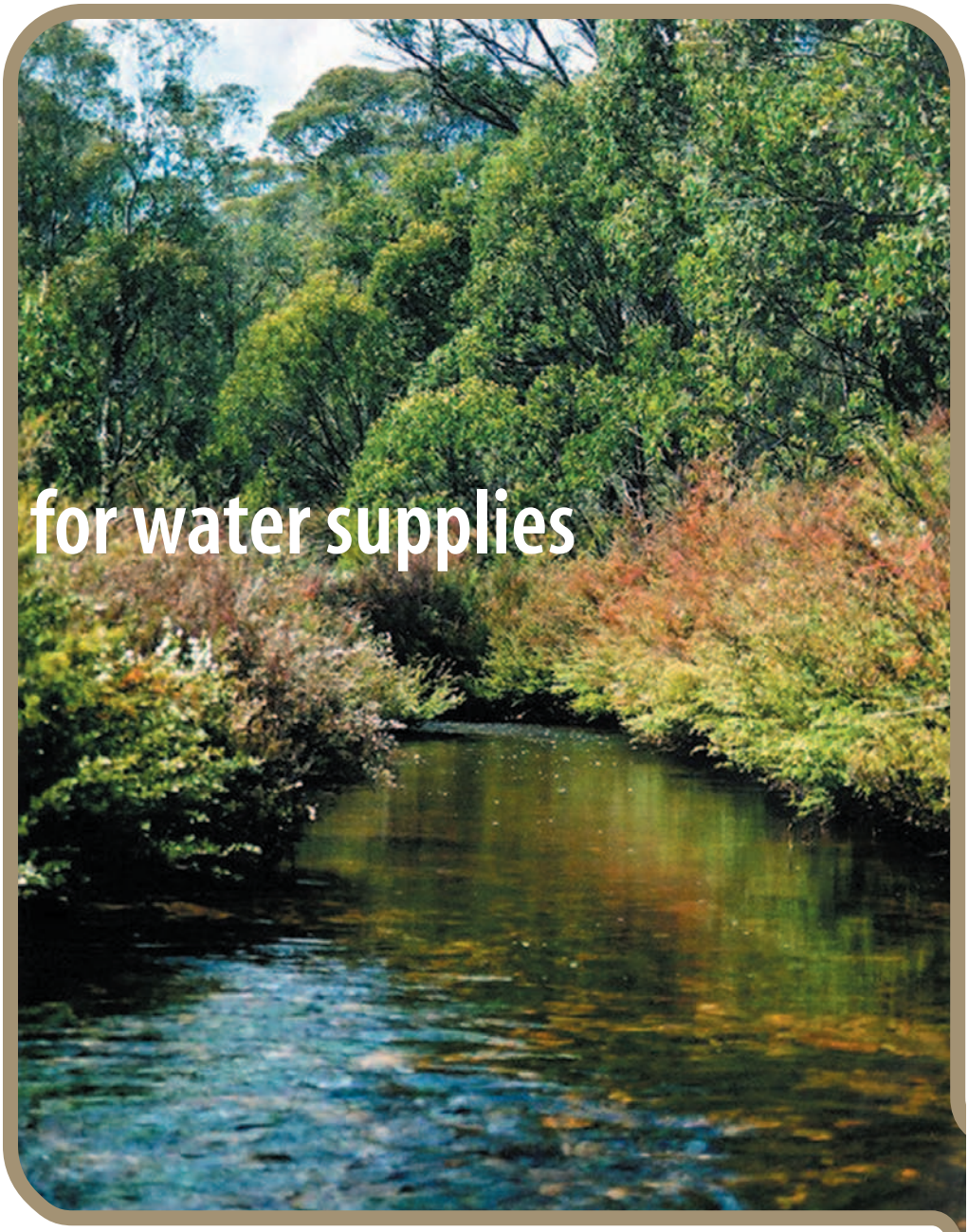
Progress

There were severe but little-known effects from recent bushfires on essential water catchments. **Steve Davidson** uncovers a concerning story of long-term damage and a lesson learned about the vulnerability of our urban water supplies.

Burning issues for water supplies



The pristine Cotter River before the 2003 fires and (below right) the same river after the fires.

Ecowise Environmental

Every time another wildfire rages through a forest in Australia, an opportunity arises to learn more about the interplay between fire, forests and catchment management. The unprecedented firestorm that tore through eucalypt forest, woodland, grassland and pine plantations, and into several Canberra suburbs in January 2003 has re-ignited debate on the best way to deal with fire in water-supply catchments. How does severe fire affect water-supply catchments? What happens to water yield and quality? Is commercial forestry a good idea in water catchments?

Impacts of the 2003 wildfires

Fires raged throughout the eastern states of Australia during the hot and dry summer of 2003. In all, blazes affected about 1.5 million hectares of south-eastern Australia. Nowhere was the devastation greater than in the ACT, where on January 8 several fires were caused by lightning strikes in the Brindabella Ranges, to the west of the ACT. At first the fires burnt slowly and remained small. However, on January 18, fanned by winds of up to 100 km per hour, and with hot dry weather, the fires spread with frightening speed and in one day burnt an area of 1649 square km.

Some 70% of the ACT was affected by fire, four lives and 500 homes were lost and 50 000 electricity customers and 7000 gas customers went without services. Water supply was lost for some hours and sewage treatment was disrupted for two days.

The horrendous fire, which came after six years of below-average rainfall and months of severe drought, blotted out the sun and caused several tornadoes. It burnt right across Canberra's main water supply, the Cotter catchment, containing the Bendora and Corin reservoirs. Before the fire, the Cotter supplied up to 96% of the water used by the 350 000 people in Canberra and nearby Queanbeyan. The near pristine, heavily timbered catchment provided some of the purest water in Australia, requiring minimal treatment. Now it's a different story.

After the fires, the blackened Cotter landscape, sitting right in the middle of the fire footprint, was a dismal sight. Although pockets of vegetation only experienced a slow burn, the fire burnt through all the undergrowth and 35% of the catchment suffered a 'very high-severity burn' that completely defoliated eucalypts and incinerated the understorey and probably most of the seed stores. The steep hill-slopes surrounding Bendora Reservoir experienced severe burning, as did riparian vegetation along the Cotter River.

Intense rain in March 2003 washed silt and debris into Bendora and authorities closed the Cotter supply and, until September, switched to the alternative water

Over most of the charred catchment, the ground cover and much of the leaf litter have been removed by fire.

supply, Googong Dam, in New South Wales. Googong has dropped to record low levels and water restrictions apply. The Cotter has also been shut off several times since and water drained from the bottom of Bendora to ease the build-up of sediments.

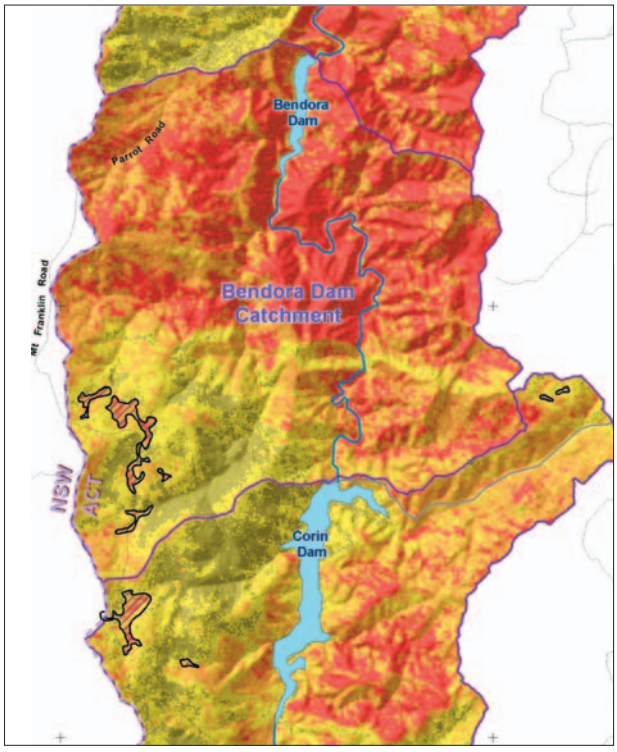
What were, and still are, the consequences of the fire in terms of water supply? Professor Bob Wasson, then at the ANU, Professor Paul Perkins of the ANU Centre for Resource and Environmental Studies (CRES), and Ross Knee and Tanya Whiteway, both with Ecowise Environmental, say we are witnessing what happens when the ecosystem services provided by natural vegetation in catchments are rudely and suddenly removed. The fire really amounts to a large-scale, unplanned and unwanted 'experiment' in which almost an entire water-supply catchment has been burnt in a natural catastrophe.

Ecosystem services sorely missed

Before the fire, the eucalypt forests, Ramsar Convention[1]-registered sphagnum swamps and tussock grasslands of the Cotter catchment provided services that included: water filtration, erosion protection, water storage (in sub-alpine swamps) and sequestering and storage of carbon and nutrients. Following removal of the vegetation, decline in water quality in the reservoirs has been dramatic and financial costs to the community immediate.

A new treatment plant is being constructed at considerable expense to counter the lower water quality. It is expected that recovery of ecosystem services and water quality to pre-fire levels will take at least 10 to 15 years.

The ACT State of the Environment Report, 2003, told of two post-fire thunderstorms that, in the absence of healthy protective vegetation, generated erosion over an area of 18 square km, mobilising a massive 1314 to 2354 tonnes of sediment per square km. Wasson and several colleagues found that in the six months following the bushfires, particulate organic carbon and sediment dumped into the upper Corin Reservoir were five to six times the long-term average annual loads. In that short time, two storm episodes deposited more than 2800 tonnes of sediment into Canberra's water storages.



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Landsat images were used to map the 2003 fire severity. Bendora, especially, was badly affected.

Over most of the charred catchment, the ground cover and much of the leaf litter have been removed by fire. Consequently, the magnitude of the erosion after just one rainfall event, on February 8–9 last year, exceeded anything experienced there for some 400 years. And the pain will continue.

'We know that there is a lot more sediment and organic matter temporarily stored along the main stream channels,' warns Wasson. 'This can be re-mobilised and dumped into the reservoirs each time heavy rain causes runoff and this will happen despite gradual revegetation of hill slopes and stream banks.'

Mr John Dymke, Chief Engineer Water Operations at ActewAGL, which operates and maintains the ACT's water and sewerage assets, says there is concern about the massive turbidity (cloudiness of water) and the elevated concentrations of iron and manganese that have been documented in the Cotter reservoirs. Elevated levels of iron and manganese can make water taste bad and cause staining of clothes during washing.

Another invisible but serious effect on water supply following fire is the moisture taken up by trees as they regenerate or grow from seeds. Young plants absorb and

1 The international Convention on Wetlands – formally entitled 'The Convention on Wetlands of International Importance, especially as Waterfowl Habitat' – was signed at an international conference in the Caspian seaside town of Ramsar, Iran, in 1971. The treaty has been known informally by the name RAMSAR ever since. The name should be written Ramsar Convention.


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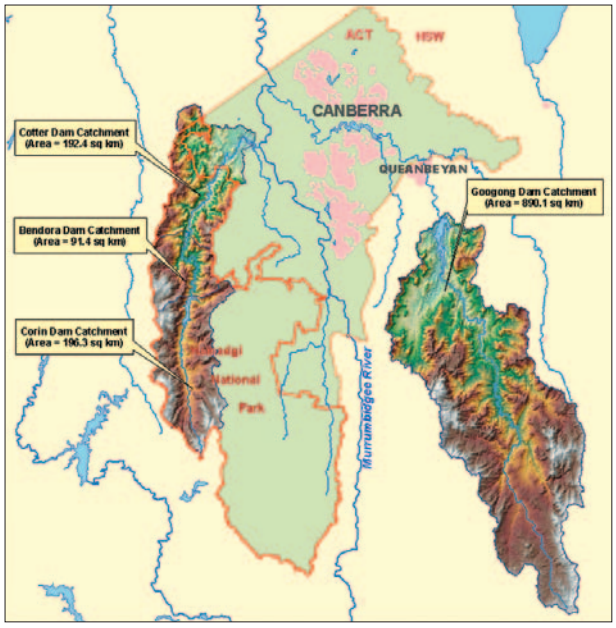
transpire large amounts of water during active growth, with this diminishing as growth plateaus in more mature trees. This has important ramifications for the hydrology of catchments because over large areas it means less groundwater flow to streams and dams. The growing trees effectively pinch more water than would a mature forest.

Consequences and costs

Mr Asoka Wijeratne, General Manager Water at ActewAGL, puts the cost of upgrading water treatment plants to cope with ongoing water quality problems at $50 million. The works are due to be completed by the end of this year. ACTEW Corporation is the owner and licensed operator of Canberra's water supply, including all water-supply dams, while Environment ACT administers water resources and has land management responsibility in Namadgi National Park, which includes most of the Cotter catchment.

Rehabilitation Project Manager at ActewAGL, Mr Peter Burgess, was unable to comment on the detail of fire management strategies in the catchment as the fires are the subject of various reviews and a Coronial Inquiry. However, he is concerned about the consequences of the fires.

'Sadly, for the moment, the catchment has become a net contributor rather than a barrier to water quality problems,' says Burgess. 'Due to the scale of the fire damage, we can't take much direct action to limit erosion. Water yield will also be significantly lessened during vegetation recovery over many years and this is a worry for the future water-supply security of the ACT.'



ActewAGL

Australian Capital Territory water supply catchments. Bendora, Corin and Cotter are collectively known as the Cotter River catchment.

Paul Perkins, and now an adviser to governments on water policy, argues that the fact that bushfire consumed the entire Cotter catchment suggests there is a real need for improvement in land management practices. Burgess says that fire management for a quality water supply is not always compatible with management for environmental or ecological values – something of a conundrum. The ACT Government is addressing these issues as a priority under its recently released Water Strategy.

Dr Peter Cullen, of the CRC for Freshwater Ecology and Chair of the ACT Natural Resource Management Committee, rejects the often-stated view that the 2003 fires would not have started or would have been less catastrophic had National Parks and other conservation areas been regularly grazed, periodically logged or frequently burned. He says there is no evidence to support this, and that the fires were an extreme event, probably a once-in-a-hundred-year occurrence. Indeed, the fires were so intense that even paddocks with virtually no grass carried flames.

'Future fire management strategies require careful balancing of a number of competing objectives and a concrete bunker approach to protection against fire would risk many every day values that we obtain from our natural resources,' says Cullen. 'Both wildfires and control burns affect runoff, erosion and other aspects of catchment hydrology, so managers need to be well informed to select appropriate fire regimes.'

It seems likely that land managers who have witnessed the extraordinary scale and intensity of the 2003 wildfires in south-eastern Australia will focus more on assessing the need for some degree of control burning to reduce fuel loads in water supply catchments.

In response to the fires, ACTEW and its partners have established a catchment rehabilitation taskforce with the job of collecting comprehensive data as well as catchment assessment and monitoring to assist in catchment remediation and disaster planning.


ActewAGL

The Cotter catchment about a month after the January 2003 fires, showing vegetation denuded of foliage and bare soil, and sediments dumped in a creek following rain.

Are the observed consequences of the Canberra firestorm typical of the impact that fire has on water-supply catchments? In response to numerous requests for information from land and water managers, the CRC for Catchment Hydrology updated its website following the 2003 fires and provides answers to a number of frequently asked questions about fire in catchments.

Hydrology of fire

Dr Emmett O'Loughlin, a former Director of the CRC, who updated the website, reminds us that although fires caused by lightning are a natural occurrence in Australia, and our resilient forests are accustomed to such events, in the short term, fire can have major consequences for water catchments. These result because fire causes:

- temporary loss of vegetation and litter cover
- release of nutrients into ash and nutrient loss to the atmosphere
- deposition of charcoal and ash on the forest floor
- changes to soil properties
- altered biological processes
- some permanent loss of mature trees
- vigorous forest regrowth.

Scientists at the CRC say that, strangely enough, because fire defoliates plants and so destroys the ability of vegetation to evaporate water drawn from the soil, streamflow (baseflow) usually *increases* immediately after fire, sometimes several-fold. This can happen even in the absence of rain. The water that would normally be used by the vegetation adds to moisture in the deeper soil layers and some passes beyond the rootzone and eventually into streams.

As long as evaporation from vegetation is suppressed, more and more water is stored in the soil during subsequent rainfall events, the soil's ability to act as a buffer during rainstorms diminishes and this means more runoff can be expected during storms. So loss of canopy cover can result in flood peaks several times greater than would occur in unburnt forest.

In the months (but not years) following wildfire, catchments generally become wetter than unburnt vegetated catchments until the foliage returns, and provide larger dry-weather flows and flood peaks until vegetation (total leaf area) recovers. Furthermore, due to changes to the soil surface, in the period shortly after fire, soils tend to shed water rapidly leading to increased runoff during the first rains.

Native forests or forestry in catchments?

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In pine plantations, salvage logging and replanting after fire are expensive and damaging activities. This is a view to a Mt Stromlo plantation.

Commercial forestry in catchments and how this relates to fire impacts and water supplies is a contentious issue.

Professor David Lindenmayer, of the ANU Centre for Resource and Environmental Studies, is a world authority on forest management. Living in Canberra, he experienced the fiery inferno of January 2003. Authorities in the ACT are replanting most of the territory's pine (*Pinus radiata*) plantations, which were incinerated in 2003, but is this the right way to go? Lindenmayer is adamant that it isn't and suggests we are repeating past mistakes.

'Commercial softwood plantation forestry and quality water catchments just don't mix,' he says. 'For a start, pines are killed outright by wildfires and do not regenerate, whereas native forests recover naturally. This means that, in the case of pines, after every wildfire – and there will inevitably be more – some or all of your forestry resource is wiped out. This is a huge financial loss. You also need to conduct costly salvage harvesting of the charred trees and then replant.'

Lindenmayer would much rather see native forests in water catchments, pointing to the water quality in Melbourne's pristine forested water catchment. The big plus is that native forests are fire adapted and recover after fire without need of human post-fire intervention. Fires devastate pines, but merely disturb native forests and this disturbance is actually beneficial to native forests, promoting habitat complexity, biodiversity, regeneration and productivity.

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Fire rages through catchment forests near Canberra.

The forestry industry argues that pine plantations are more productive and profitable than eucalypt plantations or forests and have recreational value. However, Lindenmayer suggests that the drawbacks should be taken into account.

Apart from the financial costs, salvage harvesting is detrimental to catchments because the roads and soil disturbance caused by machinery increase the risk of erosion and sediment movement into streams and dams. Lindenmayer and several overseas scientists recently wrote in the journal *Science*, that salvage harvesting activities, often undertaken as an urgent knee-jerk reaction, also undermine the benefits of fires, floods and other major natural disturbances in forests all over the world. Wildfires, for example, generate dead and downed trees, which provide habitat for many species, whereas these are depleted by forestry practices.

A case in point was the salvage logging after the 1939 fires in Victoria, which contributed to a shortage of tree cavities used by more than 40 species of vertebrates, including the highly endangered Leadbeater's possum. Recovery from this sort of setback can take up to 200 years.

More information:
Lindenmayer, DB, Foster, DR, Franklin, JF, Hunter, ML, Noss, RF, Schmiegelow, FA and Perry, D. (2004). Salvage harvesting policies after natural disturbance. *Science* 303: 1303.

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As evident in the Cotter catchment, these effects can be a mixed blessing because although the increased runoff during storms, for example, may bring more water into reservoirs, it also carries an undesirable cocktail of soil particles, clay, charcoal, ash, nutrients and dissolved organic matter.

What about the *longer term* changes in hydrology wrought by fire? There are two broad possibilities here.

Where forest trees are actually killed by fire (as in the case of many wet sclerophyll[2] tree species), water yield can be reduced for many years, even decades. Assisted by the pool of nutrients released by the fire in the ashbed, natural regeneration of the forest from seeds will lead to a young regrowth forest, with denser canopies than the mature forest. These intercept more rain and transpire more water than the old unburnt forest, less water reaches the streams, and so the water yield is less.

However, where the fire does not kill the trees outright, the pattern is different. Less-fire-sensitive forms of native forest usually recover their leaf area within three to five years. The water balance reverts pretty much to its pre-fire behaviour after that time. In catchments with a mix of these broad forest types, the long-term reduction in water yield will be proportional to the area of the former fire-sensitive forests.

S Davidson

Epicormic regrowth on eucalypts (foreground) contrasts with dead pines after bushfire.

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Double silt booms at the top end of Bendora Reservoir, part of Canberra's once-pristine water supply catchment.

Fortunately, the 2003 fires in south-eastern Australia occurred mostly in less-sensitive dry sclerophyll forests, and most of the trees survived. According to the CRC hydrologists, the water balance in most of the burnt catchments in south-east Australia should return to pre-fire conditions within about five years. In the Cotter, the fire-sensitive Alpine Ash forests, that occur in pockets only, are an exception and until mature forest returns, the regenerating tree stands will depress water yields, but only slightly due to their limited distribution. The severe drought is also a complicating factor making life difficult for recovering species and for water supply authorities.

Where fire reduces the long-term security of water supply, in terms of either quantity or quality, for various water allocations, there will be pressure to reduce releases of water for environmental flows and probably conflict between different user groups. This competition for water will be even greater in times of severe drought … and wildfire and drought often coincide.

Predictions of climate change (diminished rainfall and higher temperatures) and the continuing risk of wildfires in south-eastern Australia could combine to reduce water quality and availability over the next 25 years. The CRC for Catchment Hydrology warns that:

'Maintenance of water supplies … will require a sea change in the way that government devises contingency plans for future water supplies. This will probably require re-assessment of forest management policies in catchments, revision of water extraction licences from streams, and possibly new (and larger) expenditure on water storages. In conjunction with these measures, it is inevitable that future water demand in cities will need to be restricted.'

For water consumers, both urban and rural, the Golden Age of apparently boundless water supplies seems to be over. We should never again take water for granted. And living on a continent described as the most flammable on Earth, it is imperative that we learn more about the effects of fire on water-supply catchments and how to manage it wisely.

More information:

Wasson, R, Perkins, P, Knee, R and Whiteway, T. (2003). Canberra Wildfire 2003, US Geological Society of America, Wildfires and Watersheds Conference, Denver CO, USA, 2003.

Burgess, R, Dymke, J and Wade, A. (2004). Cotter Catchment remediation after the January 2003 fires. AWA Enviro04 Conference, Sydney, 2004

www.catchment.crc.org.au/bushfire/

2 Sclerophyll forests: a typically Australian vegetation type having plants with hard, short and often spiky leaves. They occur in a band around Australia from southern Queensland to the south-west of Western Australia. Wet Sclerophyll forests are taller than 30 metres, grow in higher rainfall areas and have a soft-leaved understorey, such as tree ferns.