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Impacts of the January 2003 Wildfires on ACT Water Supply Catchments

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EXECUTIVE SUMMARY

In January 2003, major bushfires burnt out the ACT‘s drinking water catchments on the Cotter River. The upper catchment storages were normally pristine sources of excellent quality water. This paper describes the impacts on catchment water yields and dam water quality as well as the works, monitoring and studies being undertaken to better understand and manage the catchment response to fire. To date there has been no significant change in annual upper catchment yield following the 2003 fires, in stark contrast to the 1983 fires when yield increased in burnt out portions of the upper catchment for at least two years. Analysis of dam water quality data in the upper catchment since 1968 showed only infrequent problems at the end of droughts, after very intense rainfalls, or during the annual turnover of dams. Prior to the fires, turbidity, iron and manganese levels at the bottom of the reservoirs peaked in late autumn each year due to depletion of oxygen in bottom waters and sediments. In the lower Cotter, our analysis confirmed previous studies that identified continuing water quality problems from changed land use and pine forestry. The 2003 fires caused unprecedented increases in turbidity, iron and manganese, by up to thirty times previous events in the catchment dams. To handle the deterioration in water quality due to the large sediment and ash loads in runoff from the denuded catchment, a water filtration treatment plant was designed and constructed in 18 months. Natural revegetation in the upper catchment has returned dam water quality to almost pre-fire conditions within 24 months, but water quality in the lower Cotter continues to deteriorate. Remediation works to improve water quality in the degraded lower Cotter catchment are also described.

INTRODUCTION

Landscape-scale bushfires in eastern Australia occur during prolonged periods of very high daily temperatures, high mean wind velocities very low relative humidities, very small litter and soil moisture contents and corresponding very low base flows in streams. Usually these extreme conditions are associated with ENSO and Pacific Decadal Oscillation (PDO) related droughts (Verdon *et al.,* 2004). These fires can destroy lives, dwellings, infrastructure and farmlands and can devastate native forested water supply catchments, such as the 1939 fires in Melbourne water supply catchments (Langford, 1976). Rainfalls on unprotected catchment soils following fires can deposit large quantities of sediment, organic matter, ash and dissolved materials in streams and reservoirs (Brown 1972; Good 1973; Leitch et al*.* 1983; Chessman 1986). Dramatic and long-term catchment yield decreases have been reported in burnt-out, Victorian mountain ash forested catchments as trees re-establish (Langford, 1976; Kuczera, 1987). In other native-vegetated catchments yield responses appear less dramatic (Daniell and Kulik, 1987) and in some, yield initially increases (Brown, 1972; Langford, 1976; Kuczera, 1998) due to reduced interception and evapotranspiration.

The potential to reduce landscape-scale fire hazard in native forested catchments appears limited so planning for adaptation responses to major fires is necessary. Such plans can be assisted by analysis of the impact of major bushfires on water supply catchments. In this paper we present analyses of impacts from the January 2003 ACT mixed severity bushfires that burnt out 98% of the Cotter catchment, Canberra's main water supply catchment, and destroyed 500 houses in western Canberra. These fires raised four questions for water supply management: What are the impacts on catchment water yield? What are the impacts on water quality? Will they persist? What management strategies can be used to reduce the impacts? This paper addresses those questions. Since it is only three years since the fires, identification of long-term impacts or responses to management interventions is limited.

THE COTTER CATCHMENT AND BUSHFIRES

The 480 km^2 Cotter catchment lies almost completely within the western and southern boundaries of the Australian Capital Territory, ACT (Fig. 1). It has an extensive array of rain gauges, stream flow gauges and weather stations. Some data goes back to 1910 and dam water quality has been measured since 1968. Annual average rainfall in the upper Cotter, which is in Namadgi National Park, is around 935 mm compared with about 780 mm in the lower Cotter. Evaporation and seepage losses in the upper catchment are of the order of 630 mm. The characteristics of the three dams on the Cotter River (Fig. 1) are given in Table 1. Potable water is supplied to Canberra and Queanbeyan from only the two storage dams on the upper Cotter River, Bendora and Corin, and from Googong on the Queanbeyan River.

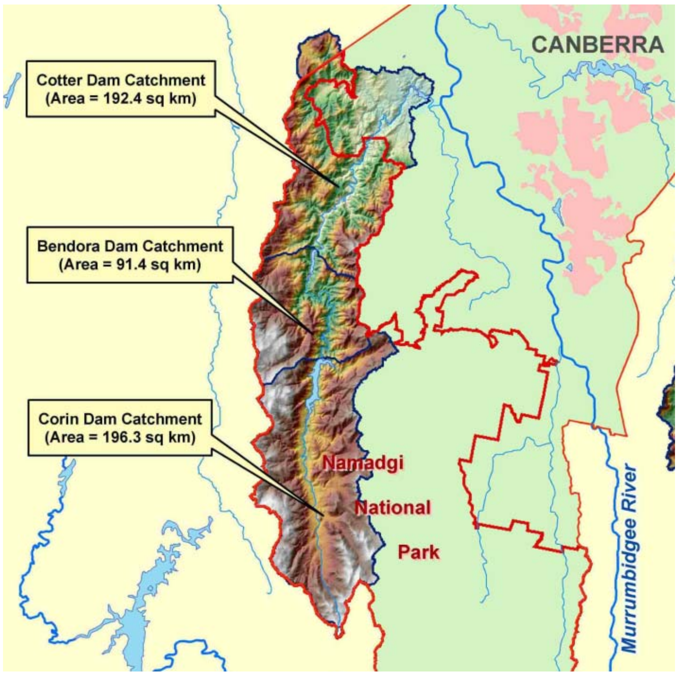

Figure 1 The Cotter catchment, ACT, its three water supply Dams and its relation to Namadgi National Park.

The Lower Cotter Dam has a high dynamic yield but water quality has been poor for 70 years due to pine forestry practices in the lower Cotter (Department of Works, 1965).
Cotter Dam was "mothballed" following the completion of the upper Cotter dams until very recently. Prior to January 2003, the middle and upper reaches were almost pristine and supplied water of exceptional quality, with low dissolved solids and turbidity and almost no taste or odour problems. Only minimal water treatment, disinfection, fluoridation and minor pH adjustment, was required with no need for filtration.

Over the last 100 years, major bushfires (>5,000 ha burnt) occurred in the Cotter in the summers of 1920, 1926, 1939, 1983 and 2003. These fires generally correspond to El

Niño droughts when the Southern Oscillation Index (SOI) is negative and when the Pacific Decadal Oscillation (PDO) is positive (Verdon *et al.,* 2004, White *et al.,* 2006). The summer leading up to the 1939 fire was the driest since 1918. Daily temperatures exceeded 38ºC, relative humidity was around 20%, litter moisture contents had dropped to oven dry levels and mean wind velocities were over 40 km/h and gusting to 72 km/h (Department of Forestry, 1973). The 2000-3 drought had similarly dried out the entire catchment dramatically reducing stream flows to almost historic low levels. In January 2003 bushfires, started by lightning strikes west of the ACT and fanned by strong dry winds, burnt out more than 47,500 ha of the Cotter catchment. The fires removed ground cover vegetation, litter and riparian vegetation and produced large amounts of charred organic debris (Wasson et al*.,* 2003). Fire severity was more severe in the mid- and lower catchment and on west facing slopes. Thunderstorms in February and March 2003 mobilised sediment and organic matter and deposited them in all Cotter storages.

Table 1 Characteristics of the Cotter River water supply dams and sub-catchments

Dam	Year of Completion	Catchment Area (km^2)	Capacity (GL)	Mean annual runoff (GL/yr)
Corin	1968	196.2	70.9	76
Bendora	1961	91.4	11.5	34
Lower Cotter	1917[†]	192.4	3.9[‡]	36

[†] The dam wall was raised in 1951. [‡] Decreased from 4.7 GL estimated in the 1960's due to sedimentation.

IMPACT OF THE FIRES ON CATCHMENT YIELD

The 1939 bushfires in Melbourne's water supply catchments halved yield 30 years after the fires, due to increased evapotranspiration of rapidly growing mountain ash trees (*Eucalyptus regnans*) as forests re-established (Langford, 1976; Kuczera, 1987; Cornish and Vertessy, 2001). A January 1983 fire in mixed eucalypt forests in the Licking Hole Creek sub-catchment (area 20.6 km^2) of the upper Cotter has also been examined (Kulik and Daniell, 1986; Kuczera, 1998). Although, streamflow monitoring in this sub-catchment started several months after the fire, Kuczera (1998) was able to identify an increased yield for about 36 months after the 1983 fire, but no significant long-term change in yield was evident after that. The initial increase in yield was attributed to interception and evapotranspiration reductions due to vegetation loss as a result of the fire. Mature trees in the mixed eucalypt forests survived the fire and regenerated rapidly by lignotuberous and epicormic growth, apparently resulting in no significant long-term yield reduction.

The January 2003 fire was severe in the Licking Hole Creek sub-catchment. It is instructive to compare impacts of both the 1983 and 2003 fires on annual catchment yield for Licking Hole. Fig. 2 shows the specific discharges for 1983 and 1984 were higher than other years with similar rainfalls, consistent with Kuczera's findings. However the yields for the three years following the 2003 fire are indistinguishable from non-fire years, confirming findings by White *et al.* (2006) for the larger Gingera catchment (catchment area 148 km^2), which includes the Licking Hole sub-catchment. They found no significant changes in annual yield at Gingera following either the 1983 fire, which burnt one seventh of the catchment, or after the 2003 fires that burnt the whole catchment. Fig. 3 compares the response of both catchments to the fires using the relative difference in cumulative yield ([cumulative yield Licking Hole-cumulative yield Gingera]/[cumulative yield Gingera]). The major differences in catchment response to the 1983 fire that persisted until September 1983 followed by a slow decline in the difference that appears to have persisted until 1998.

After that, the catchment yields respond similarly with the long-term yield at Licking Hole being 1.06 times that at Gingera. It is not yet clear why the yield of Licking Hole catchment responded so differently to two fires of similar magnitude, or why both sub-catchments showed no significant yield change following the 2003 fires. A difference in the timing of intense drought breaking rains after the two fires may be involved. What is clear is that the behaviour of fire sensitive mountain ash forested catchments is not a guide for determining impact of major bushfires on yield in mixed eucalyptus forested catchments.

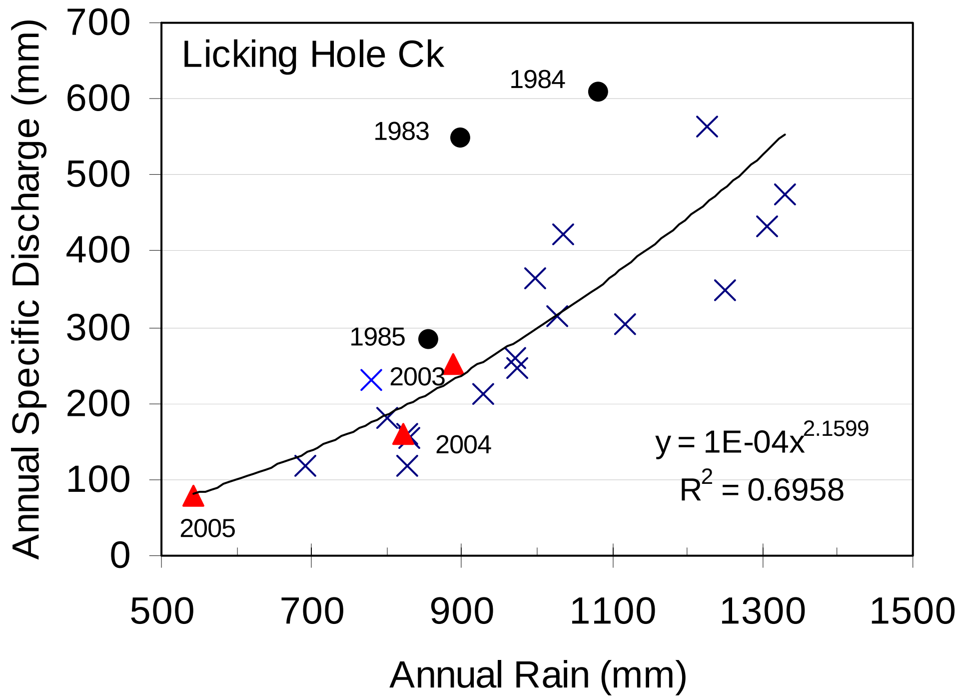

Figure 2. Annual specific discharge for the Licking Hole Creek sub-catchment for the period 1983-2005 as a function of annual rainfall. Solid circles show the three years following the January 1983 fire, solid triangles show the three years following the January 2003 fires.

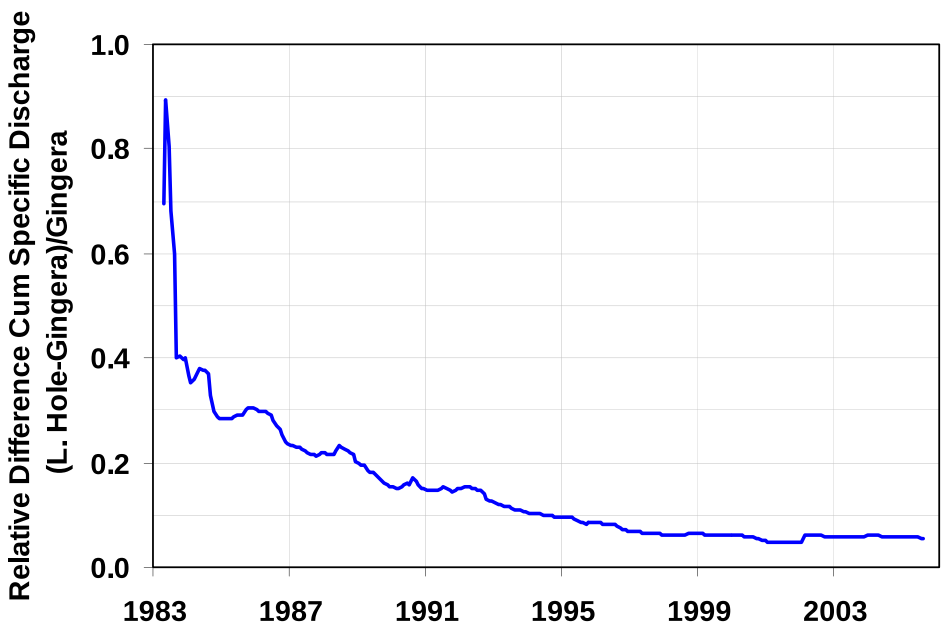

Figure 3 Relative difference in the cumulative specific yield between Licking Hole Creek and Gingera sub-catchments relative to the cumulative specific yield of Gingera.

IMPACT OF THE FIRES ON DAM WATER QUALITY

Dam water quality data collected in the upper Cotter since 1968 revealed only rare water quality problems before the 2003 fires, usually in the form of increased turbidity, iron and manganese. These problems were either associated with the initial filling of dams, intense rains or with the annual turnover of the dams when bottom waters are mixed throughout the dam (White *et al.*, 2006). After the fires, major decreases in water quality occurred. Fig. 4 contrasts the turbidity in the surface layers (0, 3 and 6 m) at Bendora and Cotter Dam off takes since 1968. The poorer water quality in the lower Cotter before the 2003 fires is evident. Also apparent are generally higher turbidities in Bendora Dam during the wet period in the 1970's. The rapid rise in turbidity following the 2003 fires in both dams is clear, as is the rapid return of Bendora, but not the Lower Cotter Dam, to pre-fire levels.

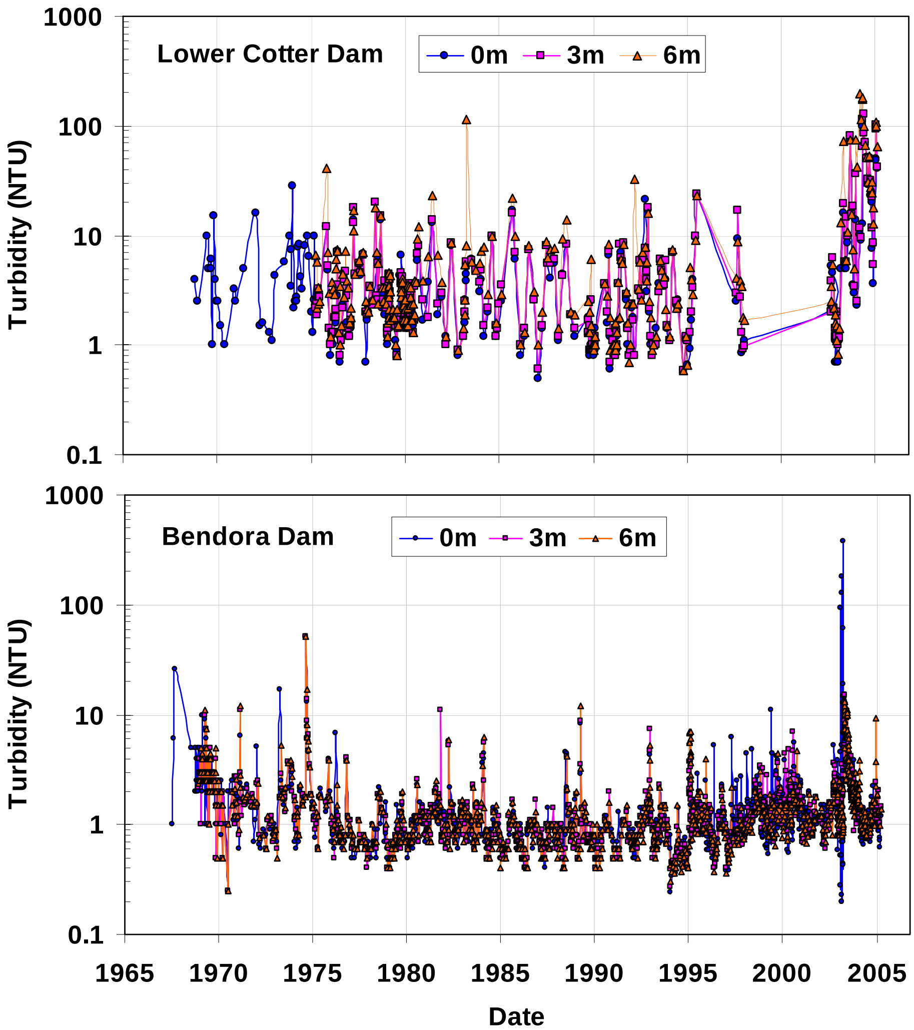

Figure 4 Turbidity of the surface layers of Lower Cotter and Bendora Dams at the offtakes since 1968.

Fig. 5 compares the percent exceedance of the NHMRC (1996) guideline for turbidity (5 NTU) for the three Cotter dams at four depths for pre-fire, and two twelve month post-fire periods. Fig. 5 shows that by the period January 2004-2005, Corin Dam turbidity levels had returned to pre-fire levels of exceedance. This is also the case for three shallow depths in Bendora Dam, although at its bottom, exceedance is still higher than the pre-fire period but lower than the immediate post-fire January 2003-2004 period. The Lower Cotter Dam has responded quite differently. Its poorer pre-fire water quality is evident.

Exceedance levels increased in January 2004-2005 over the immediate post-fire January 2003-2004. The results for total iron and manganese mirror the turbidity records.

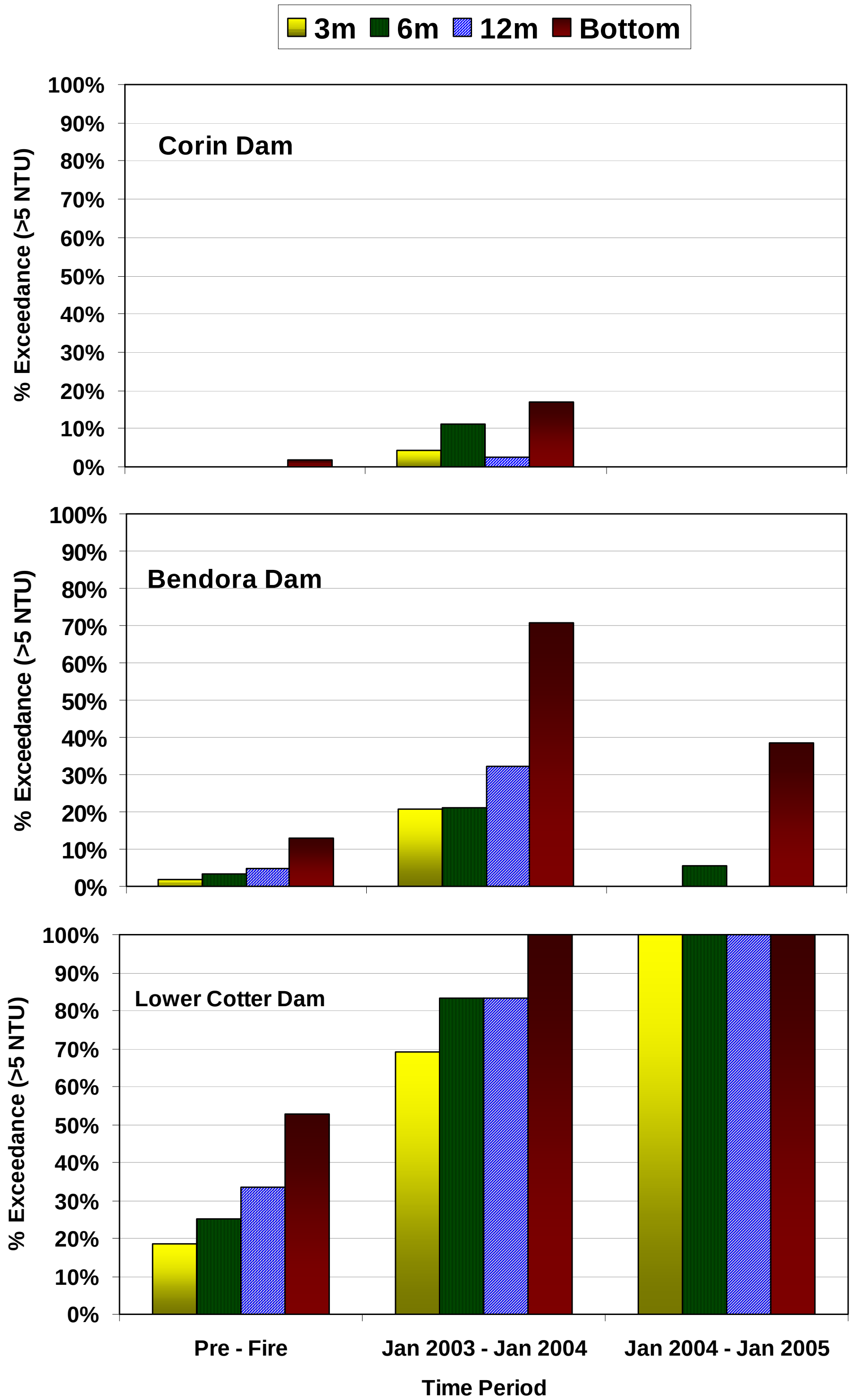

Figure 5 Comparison of the percent exceedance of the NHMRC guideline for turbidity (5 NTU) at four water depths in the three Cotter dams for the pre-fire, January 2003-January 2004 and January 2004-January 2005 periods.

Previous reports have concluded that continuing water quality problems in the Lower Cotter were due to pine plantation forestry land management practices such as the construction of roads and fire breaks (Department of Works, 1965). After the fires in the Lower Cotter, a number of forestry interventions were undertaken, including felling,

windrowing down slope and burning of pines killed by the fire, herbicide spraying and deep ripping prior to replanting. These have worsened runoff water quality
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MITIGATION STRATEGIES

Sediment and organic matter deposited in the dams immediately following the fires made the stored Cotter water unsuitable for reticulation because of excessive turbidity and iron and manganese loads. This forced the ACT to rely solely on Googong Dam, whose treatment plant was unable to supply peak summer demand for the region. The voluntary water restrictions in place because of the drought become stricter mandatory restrictions because of the limited capacity to supply potable water. Silt curtain booms were placed in the dams to retain suspended material. About 750 ML of turbid bottom waters were released from the bottom scour valve of Bendora Dam in June 2003. It was recognised that, irrespective of the rate of recovery of the dam water and catchment, the ability to fully treat Cotter water was necessary as a safeguard. A full treatment plant for the Cotter was recommended in 1987, following the 1983 fire. The new $35 M treatment plant was designed, constructed and operational within 18 months and is capable of treating around 200 ML/day of water with turbidity as high as 15 NTU. In addition, the treatment plant at Googong Dam was expanded to be capable of treating 270 ML/day. Modifications to the existing reticulation system were carried out in 2005 to allow the interbasin transfer of treated, higher yielding Lower Cotter Dam water to Googong Dam in the lower yielding Queanbeyan River.

Although these responses addressed immediate water quality problems in the upper Cotter catchment, they did not address the cause of continuing production of turbid water in the Lower Cotter Dam. Rehabilitation works have commenced in the lower Cotter. These include the decommissioning of some forestry roads, strategic placement of significant numbers of drainage culverts and gabion protection works, the construction of wetlands and settling basins and the replanting of riparian zones and steep slopes to native vegetation rather than pines. Pines, however, have been replanted in large areas of the lower Cotter. This has involved the felling, windrowing and burning of killed trees, sometimes on steep slopes with severe local erosion, removal of regenerating native vegetation, deep ripping and herbicide spraying of an area of 220 ha close to streams in preparation for pine replanting. Pines were planted not only to replace the commercial stock of previously existing pines, but also because there was insufficient local genetic stock of native plants because of the 2003 fires and the bare soil needed vegetative cover. Subsequently, the ACT Government has stopped planting pines until a review was undertaken into options in the catchment. The Government is currently developing a long-term strategy for the lower Cotter catchment, with water quality as the primary focus.

CONCLUSIONS

There has been no significant change in the short-term measured yield of the upper Cotter catchment in the two years following the 2003 fires, in contrast to the yield increase in Licking Hole Creek sub-catchment found following the 1983 fire. The difference in response to the two fires may be due to a difference in the arrival time of intense drought breaking rains following the two fires. Whatever the reason, the long-term yield reductions by fires in Mountain Ash forests do not seem applicable to mixed eucalypt forests able to regenerate by epicormic growth. Before the fires, water quality in the upper Cotter Dams was superior to that in the Lower Cotter. Immediately after the fires, water quality in all dams catastrophically decreased. However, in only two years after the fire, following native forest regeneration, the upper 12 metres of both dams on the upper Cotter have returned to the excellent prefire water quality conditions. It has been estimated that it will take up to

10 years for the vegetation in the upper Cotter to fully recover (Ingwersen and Wade, 2004). The upper Cotter is in sharp contrast to the lower Cotter catchment where water quality continues to deteriorate due to ongoing pine-forestry operations. It is too soon to assess the efficacy of remediation works or long term yield trends. This study demonstrates the value of long-term catchment hydrologic and water quality data sets for assessing abrupt natural changes and land use impacts in catchments.

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