Department for
Water Resources

Impact of farm dams on streamflow in the Mount Lofty Ranges: a literature review

Report DWR 2001/003

Government
of South Australia

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Department for Water Resources

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FOREWORD

South Australia's water resources are fundamental to the economic and social wellbeing of the State. Water resources are an integral part of our natural resources. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of surface and groundwater resources changes the natural balance and causes degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Degradation may also be very gradual and take some years to become apparent, imparting a false sense of security.

Management of water resources requires a sound understanding of key factors such as physical extent (quantity), quality, availability, and constraints to development. The role of the Resource Assessment Division of the Department for Water Resources is to maintain an effective knowledge base on the State's water resources, including environmental and other factors likely to influence sustainable use and development, and to provide timely and relevant management advice.

Bryan Harris
Director, Resource Assessment Division
Department for Water Resources

ABBREVIATIONS

General

d	day
EPA	Environmental Protection Agency, Department for Environment and Heritage
GIS	geographic information systems
HYDSYS	a suite of hydrological and water resources management software packages employed as part of the South Australian State water data archive.
m.	month
TEDI	'Tool for Estimation of Dam Impact', water balance simulation model designed to examine the impact of farm dams on streamflow.
WaterCress	water balance computer model for designing and testing trial layouts of water systems using multiple sources of water.
XP-AQUALM	integrated hydrological and water quality management computer package (from XP software company).
yr	year

Measurement

Units of measurement used in this volume are those of the International System of Units (SI) and are not included here.

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INTRODUCTION

This literature review summarises the findings of studies conducted on the impact of farm dam development on streamflow in the Mount Lofty Ranges over the last 10 years. The review is intended to illustrate recent advances in the understanding of the hydrological impact of farm dams on streamflow, summarise the current level of knowledge and highlight areas for future work.

Due to the paucity of documented studies in the Mount Lofty Ranges, the review includes personal communications and draws heavily on work undertaken in the Barossa Valley and Marne River catchments.

IMPACT OF FARM DAMS ON STREAMFLOW IN THE MOUNT LOFTY RANGES

The state of water resources in the Mount Lofty Ranges has been the subject of discussion for at least 10 years (Cresswell and Verhoff, 1991). As early as 1989, it was suggested that controls were necessary to restrict the development of specific activities where it could be justified that the risk to surface water should be minimised (Mount Lofty Ranges Review, 1989). Concerns regarding water availability have risen recently due to increased water use associated with changes in land use, towards intensive agricultural practices and smaller land holdings (Billington, 1999; Billington and Barnett, 2001; McMicheal and Scholefield, 2000). Similar concerns eventually led to the proclamation of prescribed water resource areas over portions of the Barossa and Clare Valleys in the early to mid 1990s.

Farm dam capture and watercourse abstractions have their greatest effect on the surface water resources of the Mount Lofty Ranges in three ways:

- competing with SA Water by capturing water that would otherwise be collected by metropolitan reservoirs
- affecting the integrity of aquatic ecosystems through reduced flow volumes and altered streamflow regimes
- competing with other downstream farm dams or watercourse abstractions.

These issues are attracting greater attention due to recent increases in the rate of farm dam development (Pikusa, 1999c). In the Mount Lofty Ranges Watershed alone dam construction approvals continue at rates in excess of 1 GL/yr (J. Lenz, DWR

Resources Management Mount Barker, pers. comm., 2000b). Many of the larger farm dam developments have been constructed in the eastern sections of the Mount Lofty Ranges where surface water resources are modest, irrigation demands tend to be higher than in wetter areas and the consequent potential for conflict is greatest (McMurray, 1996; Billington, 2000).

Estimates of total farm dam storage in the Mount Lofty Ranges tend to differ but indicate that while total storage represents a modest percentage of mean annual runoff, some catchments have farm dam capacities that exceed their total runoff during dry years (Cresswell, 1991; McMurray, 1996; and data from Champion et al., 1999). Such levels of development tend to deprive downstream access to water during times when it is most needed, with the potential to stop streamflow from at least some sections of catchments for several years (Cresswell, 1991).

Mean annual streamflow reduction may vary from 10 to 50% depending on the area and level of development. During summer or prolonged dry periods the reduction may be as high as 70 to 80% (Cresswell, 1991; Good, 1992; Tonkin and Associates, 1998; Nathan et al., 1999; Champion et al., 1999).

Beyond the reduction in total volume, farm dams alter ecologically significant streamflow regimes. Ephemeral streams, common in the Mount Lofty Ranges, are characterised by extended periods of low or no flow. Pools contract during prolonged dry periods forming refuges for biota which are maintained by small volumes of runoff or baseflow. Ecosystems then respond to the onset of early season flows during late autumn and early winter.

Low flows derived from groundwater and erratic summer rainfall that provide pool maintenance and connection, show the greatest percentage reduction in streamflow under intensive farm dam development, compromising the ability of aquatic ecosystems to survive dry periods (Champion et al., 1999; Cresswell, 1991). In these cases, the number of no-flow periods and their duration increases. Sustaining low flows are severely reduced in number and duration, and in cases of heavy dam development removed (Champion et al., 1999; Cresswell, 1991).

In addition, late autumn and early winter flows are greatly reduced or removed (Philpott et al., 1999; Pikusa, 2000). Their duration is shortened and their onset may be delayed by up to a month depending on the degree of development, disrupting the migration patterns of some species of fish (Cresswell, 1991; Philpott et al., 1999; Pikusa, 2000). Moderate flows that maintain the river environment are also reduced in number and duration, causing a loss of habitat, habitat diversity and obstruction of free passage through the stream (Philpott et al., 1999; Champion et al., 1999). Farm dams have little effect on very large over-bank flows.

Much of the above draws on research conducted in areas outside the Mount Lofty Ranges, in the Gawler and Marne River catchments. The only work of comparable detail completed entirely within the Mount Lofty Ranges Watershed is that of Champion et al., (1999), which focused on the small Inverbrackie Creek Sub-catchment of the upper Onkaparinga River. Work of a similar quality and scope to that of Cresswell (1991) and Philpott et al., (1999) is recommended in the Mount Lofty Ranges to support and enhance current water resources management and future management options.

AVAILABLE REFERENCES

MOUNT LOFTY RANGES

Mount Lofty Ranges Review investigations report (Mount Lofty Ranges Review, 1989)

Scope

To enable the formulation of a comprehensive regional management strategy which would provide a statement of policies for the region having regard to competing land use interests and which would provide, as far as possible, for their orderly co-existence (p. 3).

Summary

- Seven physiographic character units were defined in the Mount Lofty Ranges Region (p. 1). The Western Range Character Unit was the Mount Lofty Ranges Watershed as described in the First Schedule to Regulations under the *Waterworks Act 1932–1974* (p. 14) and mentioned in the *Water Resources Act 1997*. The Central and Eastern Range Character Units were regions that may experience development pressure should the Watershed be subject to tighter regulation of water use.
- Major water resources issues were identified under 'Regional Objectives: Riparian vegetation' (objectives 18, 22 'water quality'; objective 23, p. 12), protection of the Watershed against contamination such as from increased pollution from intensified agriculture and sub-division (objectives 36 and 37, p. 14).
- Water resources were divided into three groups (p. 77): Mount Lofty Ranges Watershed, surface water resources outside the Watershed and groundwater resources throughout the region. Main concerns were regarding water quality decline (section 8.3, p. 83).
- Issues inside the Watershed included:
  - alternatives to SA Water infrastructure were too expensive and assets too valuable to abandon (p. 78)
  - major water quality threats were outbreaks of cyano-bacteria due to elevated nutrient loads, principally a result of phosphorous bearing sediments being washed into creeks (p. 78)
  - water quality decline was associated with agricultural development over preceding 40 years, particularly the late 1940s through to the 1950s (p. 79); slight increases in pollution were likely during the 1960s and 1970s mitigated by improved sewerage, agricultural practices and awareness.
- Issues outside the Watershed included:
  - largely ephemeral streams with less plentiful surface resources (p. 79)
  - some areas affected by localised pollution (p. 79); many sources of pollution had been removed (such as tanneries and mines), but problems were still arising, particularly during periods of high flow, when contaminants were washed into watercourses from a wide area (p. 79)
  - increasing numbers of farm dams constructed as irrigation and hobby farm developments had diminished downstream flows, causing conflicts between landowners, degradation of stream environments and a reduction of the water's ability to assimilate pollutants (p. 79)
  - decreased streamflows were also flagged as significant in wetlands and downstream areas of environmental significance (p. 79)
  - modifications of stream beds and clearing riparian vegetation had led to increased erosion, siltation and degradation of the stream environment

(p. 80); in severe cases intense gully formation had reduced farm land productivity.

- Management options to cope with water quality decline concentrated on the metropolitan supply (section 8.3, p. 83). Options for catchment management were discussed concluding:
  - more intensive land uses were more likely to result in pollution than broad-scale agricultural activities (section 8.3.2, p. 84)
  - controls were justified to restrict the development of such activities as market gardening, dairying, horse keeping, and urban development in specific areas where it could be justified that the risk to surface water should be minimised; the prohibition of certain activities which generate, accumulate or store large quantities of waste could also be justified in sensitive areas such as the Watershed (section 8.3.2, p. 85).
  - maintaining river health was identified as an important factor in determining water quality; in particular key stream habitats and morphology (pools, riffles, bars) and flow regimes; the latter represented by at least a base flow over the period a stream would naturally flow (section 8.3.2, p. 86).
- In section 8.5, land management issues were identified in relation to water quality and relevant reports cited (pp. 87–92). Runoff water quality and land use were discussed in section 8.5.3, p. 88.

The control of farm dam development in the Mount Lofty Ranges

(Cresswell and Verhoff, 1991)

Scope

The Engineering and Water Supply Department Scientific Services' Group became concerned with the construction of large farm dams in the Mount Lofty Ranges as development patterns appeared to be following those in the Barossa Valley over which a moratorium had been declared (p. 1). The scope was to review all associated issues, the majority of which the discussions focus on the Mount Lofty Ranges Watershed.

Summary

- Farm dams reduced streamflow by less than 10% and their impact was considered small (p. 2).
- A 50:50 rule recommended: 'Maximum capacity of dams not to exceed 50% of runoff expected from the property owned' (p. 2).
- Prior to 1991, controls were insufficient to effectively regulate farm dam construction. During this time demand for surface water increased for reasons which included (pp. 3, 6):
  - intensified agriculture
  - poor-quality – high-cost groundwater compared to surface resources in many areas
  - restrictions on water resources in adjacent areas
  - increased population and rural living
  - an increase in the construction of larger dams (up to 250 ML) in the headwaters of some catchments.
- Significant increase in farm dam development in the Onkaparinga River catchment since 1970 (fig. 1, p. 4)
- Based on Onkaparinga levels of development, farm dam storage in the Watershed was ~25 GL (p. 4)
- Farm dam issues included (p. 5):
  - loss to metropolitan supply, offset by increased pumping costs

  - large dams reduced streamflow so that ecosystems suffered under reduced flood frequency, flow duration and contraction of pools
  - impacts on downstream users, especially those with riparian rights.
- Potential for environmental damage was greatest in drier catchments where runoff was more sporadic, and the major source areas for runoff concentrated in smaller, wetter catchments (p. 5).

Farm dam storage assessment in the Mount Lofty Ranges

(McMurray, 1996)

Scope

To estimate farm dam storage in the Mount Lofty Ranges using aerial photography and surface area to volume relationships.

Summary

- The study used 1:40 000 false-colour infra-red aerial photography, flown between 20 December 1995 to 12 January 1996, within a two-hour time frame after midday Central Standard Time (p. 2).
- The study area included the region from North Para River to southern Fleurieu Peninsula, upland regions east of Adelaide, the region from Onkaparinga to the sea, and upper Marne, Eastern Hills, Bremer, Angas, Finnis, Currency Creek and Hindmarsh Catchments (map 1, p. 21).
- Volumes were estimated from surface areas using relationships developed from bathymetric surveys of 26 farm dams carried out by SA Water in 1986 (p. 5).
- Only 9% (1109 out of 13 000) of all farm dams had capacities >5 ML, but these contained 69% of the total storage capacity (22 out of 32 GL; p. 6).
- Total storage volumes formed a small proportion of mean annual catchment yield but a large proportion of 'minimum catchment yield' as extracted from the *HYDSYS* database over a 20 to 30 year period to 1995 (p. 7):
  - farm dam storage exceeded minimum annual flows in Angas, Bremer, Marne North Para River, South Para River and River Torrens catchment (fig. 3, p. 15)
  - such rates of development had the capacity to extend dry periods and change conditions normally observed during low-flow periods to those that resemble drought (Cresswell, 1991; Champion et al., 1999).

The management of farm dams and their environmental impact in the Mount Lofty Ranges (Good and McMurray, 1998)

Scope

The extent of farm dam development in the Mount Lofty Ranges is uncertain and the impact 'may be interpreted' to be as great as SA Water reservoirs. The scope was to estimate farm dam distribution and volumes from which impacts may be implied using GIS techniques. (*See also* McMurray, 1996).

Summary

- Only 9% of all farm dams had capacities >5 ML but these contained 69% of the total storage capacity
- The total storage capacity of farm dams in many Mount Lofty Ranges catchments exceeded the minimum annual catchment yield. The catchments identified were:
  - Angas, Bremer, Marne, North Para River (to Turretfield), South Para River (Barossa offtake) and Torrens (Gorge Weir; fig. 2)
  - minimum annual catchment yield was not defined; estimates of minimum flow were taken from gauging stations but the techniques used were not

documented (D. McMurray, Department for Environment, Heritage and Aboriginal Affairs, pers. comm., 31 August 2000).

- SA Water reservoirs have severely impacted the lower reaches of their catchments, but farm dams affect a far greater length of riparian and stream environment upstream of the reservoirs.

Torrens Catchment land and water use change, 1993–98 (Billington, 1999)

Scope

To evaluate land change using available GIS coverage and indicate where water for irrigation was sourced.

Summary

- Land use change between 1993 and 1998 GIS data sets was considerable, comprising a fragmentation of pasture and the establishment of intensive horticulture. While different land use categorisations made direct comparisons between the data sets difficult, the author noted (table 2, p. 3):
  - significant decreases in dairy farming and grazing
  - significant increases in irrigated pasture, horse keeping, horticulture, intensive vegetables and viticulture
  - an estimated increase in water use from 15 000 to 23 000 ML/yr (p. 3).

The state of health of the Mount Lofty Ranges Catchments from a water quality perspective (Environment Protection Agency, 1999)

Scope

The report describes water quality issues of the Mount Lofty Ranges against a background of rising concerns regarding pesticides, *Cryptosporidium*, *Giardia* and cyano-bacteria triggered by elevated levels of nutrients.

Summary

- Major impacts on streamflow included (p. 14):
  - farm dam development
  - reservoirs
  - inter-basin water transfers, land clearing, agricultural development and stormwater runoff
  - disruption of natural waterways through use as aqueducts during inter-basin transfers and for discharge of treated effluent.
- Major impacts of altered streamflow on water quality were (p. 14):
  - reduced flow inhibits the stream's ability to flush out pollutants, intensifying their adverse effect on aquatic environments
  - reservoirs trap sediments and pollutants which accumulate and degrade water quality
  - farm dams hold flow that would otherwise form part of the natural regime of the stream.

The impact of farm dams on streamflow in a rural catchment (Champion et al., 1999)

Scope

To review the 50% runoff policy guideline to limiting construction of farm dams through a study of Inverbrackie Creek catchment.

Summary

- In 1996 there were ~13 000 farm dams in the Mount Lofty Ranges Watershed with storage capacity of 32 GL (p. 2, cited as: J. Lenz, DWR Resources Management Mount Barker, pers. comm., 2000b).
- Inverbrackie Creek catchment contained 73 dams with a total volume of 518 ML (apps B, C):
    - dam volumes were estimated from surface areas taken from 1997 aerial photography
    - ~50% of the dams were >2 ML (i.e. dams likely to be used for irrigation (J. Lenz, DWR Resources Management Mount Barker, pers. comm. 6 September, 2000a) and accounted for 90% of the total storage (data from app. C).
- Using a *WaterCress* model over 98 years and assuming the 1997 level of development, farm dams could be expected to reduce annual streamflow volumes by an average of 44%. The results reflected what would have occurred if the Inverbrackie catchment was developed at modern agricultural levels over the past century, including:
    - maximum reductions of 84% in February to April representing runoff only generated by the uncontrolled portion of the catchment (table 7-2, p. 74)
    - minimum reduction of 33% in September (table 7-2, p. 74)
    - averages calculated in this way tended to present the reductions in streamflow as greater than indicated by total volumes for the same period; total reduction in streamflow volumes were 33%; maximum reductions in runoff of 84% during the period February to April, and minimum reductions were 20% in September (table 7-2, p. 74).
    - although the greatest percentage of streamflow was trapped by farm dams during summer, the greatest volumes were trapped during winter (fig. 7-2, p. 75).
- The exceedance probability of larger flow events (50 ML/d) was reduced by 1%, smaller flows were reduced by 4% (5 ML/d; p. 76).
- Daily flow band analysis revealed (p. 77, table 7-3):
    - Zone 0 (0 ML/d) number of no flow days increased by 10%
    - Zone 1 (<1 ML/d) number of low flows to sustain riffles and pools reduced by 9%
    - Zone 2 (1–28 ML/d) number of normal river maintenance flows reduced by 23%
    - Zone 3 (28–60 ML/d) number of higher river maintenance flows reduced by 35%
    - Zone 4 (>60 ML/d) number of channel flushing and riparian zone maintenance flows reduced by 35%.
- The reduction in the number of smaller events and increase in no flow days are highly significant and were directly attributed to farm dam development.
- A 50:50 Rule simulation gave similar results to those currently seen in the Inverbrackie catchment. The river was probably close to its limit of development under this rule (pp. 78–79). The interpretation of the 50:50 Rule presented in the report was different to the working application of the 50:50 Rule in farm dam development by DWR (formerly Environmental Protection Agency, EPA). The DWR policy is such that the total permissible volume of farm dams on any property within the Mount Lofty Ranges Watershed can be no greater than 50% of the median annual runoff from that property. Champion et al. (1999) interpreted the rule to equate the permitted maximum volume of farm dams to 50% of the long term modelled runoff. [Note: Farm dam development under the

EPA 50:50 Rule would probably be incapable of reducing the long-term runoff by 50%. Figures indicating reductions in runoff of 44% (see below) may indicate the catchment is developed above the EPA 50:50 Rule].

- A 70:30 rule simulation produced a total reduction in annual streamflow volume of 21% over the 98-year simulation (average reduction 30%; tables 7-8, 7-9, p. 81):
  - a notable decrease in the number of flow events occurred at development levels greater than specified by the 70:30 rule (table 7-10, p. 82; figs 7-4, 7-5, p. 84)
  - the Champion et al. (1999) 50:50 Rule probably removed too much water to provide desirable flow regimes (p. 79 and points above).
- A 44% reduction in streamflow complied with the Champion et al. (1999) 50:50 rule but may not represent an environmentally appropriate level of development (p. 90). The 70:30 rule appeared to have a far smaller impact on the number of flow events and streamflow volumes.

Review of residual pesticide use in the Mount Lofty Ranges Watershed, including the implications of avoiding such use (McMicheal and Scholefield, 2000)

Scope

The report compared 1993 and 1999 land use GIS as part of a review of pesticide use.

Summary

- Changes in land use for the Torrens catchment were (table 3, p. 20):
  - grazing decreased from 60 to 55%
  - intensive vegetable farming reduced from 4.5 to 2.5%
  - rural living increased from 2 to 5%
  - area under vines increased from 1 to 3%.
- Karla Billington (Environment Protection Agency, pers. comm., 2000) noted that the data probably reflected the different categories used in the two land use GIS data sets rather than providing an unambiguous indication of development trends.

Southern Fleurieu Water Resources Forum: water resource assessments (Billington and Barnett, 2001)

Scope

The report was prepared in response to community concerns regarding the development of water resources on the Fleurieu Peninsula and was released at the Southern Fleurieu Water Resources Forum on 4 August 2000. The findings from a surface water perspective were qualitative.

Summary

Four main issues were identified:

- Regional water resources — According to information currently available, surface and groundwater resources were not over-committed on a regional scale. As in other parts of the State, fluctuations in groundwater levels were causing concern in the southern Fleurieu Peninsula. These fluctuations were considered to be largely due to natural variation in annual rainfall.
- Local water development 'hot spots' — In some catchment areas, the availability of useful quantities of good quality water for irrigation could lead to rapid development of local water resources, potentially causing water sharing issues to

arise (e.g. as in the Hindmarsh Tiers groundwater area). The rate of development and the implications for sustainable use of these water resources needed to be carefully monitored.

- Sustainable development — There was limited availability of land suitable for irrigation development in some areas, particularly in the coastal catchments. Changes in land use merit careful consideration in the development assessment process, largely implemented by local government.
- Monitoring requirements — Continued monitoring of land use (especially land under irrigation), water use and water resources was required. The Department for Water Resources will be reviewing its monitoring procedures within the region as part of the Mount Lofty Region monitoring review.

Personal communication 1 (K.M. Billington, Environment Protection Agency, pers. comm., 2000)

Scope

Issues associated with farm dam development in the Mount Lofty Ranges were discussed.

Summary

Only a select number of points have been highlighted:

- Issues caused greatest concern in drier, fringing catchments of the Mount Lofty Ranges. Irrigation practices applied in wetter parts of the region were also maintained in drier areas, requiring greater volumes of water and larger farm dams.
- Implications of Notice of Restriction:
  - SA Water — marginal improvement in security of supply to their reservoirs, outweighed by natural, seasonal variations in rainfall, as reflected by historic pumping costs.
  - Irrigators — increased security of supply, particularly in drier fringes of Mount Lofty Ranges.
  - Ecosystems — prevention of further degradation due to farm dam induced changes in streamflow.

Personal communication 2 (J. Lenz, DWR Resources Management Mount Barker, pers. comm. 6 September, 2000a)

Scope

Farm dam development issues were discussed during a meeting at the Department for Water Resources office, Mount Barker.

Summary

- Stock and domestic dams were generally up to 2 ML in size. Dams 5 ML in size were generally used for irrigation.

Personal communication 3 (J. Lenz, DWR Resources Management Mount Barker, pers. comm., 2000a)

Scope

The communication was based on a conversation with Jim Lenz to check the veracity of the estimate of total farm dam volumes in the Mount Lofty Ranges Watershed presented by Champion et al. (1999).

Summary

- In 1996 there were ~13 000 farm dams in the Mount Lofty Ranges Watershed with storage capacity of 32 GL (data presented by Champion et al. (1999) was taken from McMurray (1996)).
- From the beginning of 1998 to 12 September 2000, Jim Lenz approved 189 dams for 1258 ML, in the Mount Lofty Ranges Watershed.

The data suggests the current volume of dams in the entire Mount Lofty Ranges Region, (including the southern Fleurieu Peninsula and South Para River Catchments) may be in the vicinity of 35 GL. The lack of a comprehensive survey of farm dams is a significant information gap for decision making and management of the Mount Lofty Ranges surface water resource.

Torrens catchment modelling technical report (Tonkin Engineering Science, 2000)

Scope

To develop an effective model of the Torrens catchment to assess surface water resources; evaluate the impact of SA Water and private developments (including farm dams); provide data to investigate environmental flows, and evaluate water quality and the effects of land use change on pollution load.

Summary

- The *XP-AQUALM* (v 2.1) rainfall runoff package was run on a daily time step:
  - urban and rural catchments were modelled separately, and sub-catchments were delineated on points of hydrological interest such as reservoirs, wetlands, major drains, gauging stations, etc. (~80 nodes)
  - farm dams were captured from 1999 infra-red aerial photography and volumes were estimated from surface area and depth relationships after McMurray (1996, p. 5).
- Farm dam volumes totalled 8464 ML, 19% of the average annual discharge from upper Torrens catchment (p. 20).

- Streamflow modelling results were presented in terms of mean annual and monthly 'catchment yield' flow regimes. Frequency, duration and seasonal variability were not discussed:
  - reductions in mean annual yield (cited in table 6.1) due to farm dam development were equated to the total farm dam volume in each sub-catchment, rather than the difference between the 'no farm dam' and 'existing farm dam' modelled scenarios
  - reductions in mean annual catchment yield due to farm dam development ranged between 2 and 26% (based on data extracted from table 6.1)
  - catchments with farm dam volumes totalling 20% their mean annual 'no dams' catchment yield, suffered a reduction in catchment yield of 10% under the 'existing dams' scenario (based on data from table 6.1).
- Kangaroo Creek and Millbrook Reservoirs have reduced the 'no dams' mean annual catchment yield in the Torrens main channel at Hope Valley by 54% (p. 20).
- Greatest reductions in 'no dam' monthly catchment yield were noticed during dry months. During average and wet months, the effect was noted in the early onset of the season (p. 20). Further conclusions were based on data presented in appendix C:
  - highest flow volumes were evident between May and October for most sub-catchments
  - the effect of farm dams on catchment yield was lowest during wet years (90th percentile flow)
  - during average years, farm dams caused a notable decrease in monthly catchment yield in May, June and July. Yields seemed to recover in September and through October.
  - during dry years (10th percentile flow) the flow season contracted and the effect of farm dams was to severely decrease monthly catchment yield in August and in some catchments in September.
- Use of the Torrens as an aqueduct has reversed natural seasonal flow regimes around discharge points and has probably contributed to channel scouring (p. 20).
- Pre-European catchment yield was modelled using parameters taken from Sixth Creek (p. 16). [Sixth Creek is a high-yielding catchment and may not give an accurate reflection of the pre-European Torrens catchment yield]. Comparisons between current and estimated pre-European conditions included:
  - land clearing, agriculture and urban development has led to an increase in runoff from pre-European times of 16% in some sections of the catchment (p. 20). Data from table 6.1 would indicate that the increase in sub-catchment yield since pre-European times with existing farm dams varies between 10 and 40%
  - urban development may have reduced the deficit in catchment yield caused by urban reservoirs (p. 20), [however the observation was made without mention of the disruption of flow regimes, frequency, duration or seasonality].
- Water quality modelling indicated that (pp. 21–22):
  - no single sub-catchment could be identified in the upper Torrens catchment as a major pollution source
  - water quality of the Torrens at the river's junction with Kersbrook Creek (Millbrook Confluence) was heavily influenced by inter-basin transfers from the Mannum–Adelaide Pipeline
  - increasing the amount of land under perennial horticulture would not produce great changes in pollutant loads

- the establishment of buffer strips and wetlands would produce significant reductions in the pollutant load entering Gulf St Vincent.

BAROSSA VALLEY

Integrated management of farm dams in the Barossa Valley (Cresswell, 1991)

Scope

The study provided data on the status and rate of farm dam development within the Barossa Valley Moratorium Area proclaimed in November 1990 (p. 1).

Summary

- There was a ten-fold increase in farm dam development since 1970 due to increases in irrigated viticulture in upland areas.
- Farm dam development reduced mean annual streamflow at Yaldara and in the Flaxman Valley by an average of 20%, during dry years the reduction may be as much as 60 to 70% (see pp. 1, 28). Streamflow volumes normally expected during dry years may be reduced to those experienced during periods of drought (p. 30). Although surface water resources may appear plentiful in average or wet years, unacceptable effects were emerging during drier periods (pp. 1,30).
- Farm dams caused reduction in flow duration. Two major effects of reduced duration on streamflow were (pp. 31–32):
  - length of the season when flow passes downstream was shortened (see Philpott et al. (1999) for timing of fish migrations)
  - periods of no flow increased.
- Recharge to the aquifer system was reduced by 17% (p. 1). Salinity of surface recharge water increased by 25% (p. 1). Increased salinity was considered due to (p. 33):
  - concentration as a result of a reduction in good-quality runoff contributing to baseflow
  - rising watertables due to irrigation and seepage around farm dams.
- Direct stream abstractions were limited by natural variability of streamflow and baseflow. Reductions to streamflow by farm dams or large upstream abstractions had potential to infringe on (common law) rights of established users downstream (pp. 8–9).
- Small stock and domestic dams formed a significant proportion of the storage in all farm dams (p. 21).
- On-stream farm dam designs were not conducive to sharing as they block all flow until full. This also produced a markedly different flow regime downstream that had significant ecological implications (p. 28).
- Strategic location of farm dams was important in controlling runoff in catchments (p. 30). Some farm dams required more than the mean annual runoff to fill. Streamflow from such sub-catchments may be stopped for several years (p. 31).

Determination of environmental water requirements for the Gawler River system (Philpott et al., 1999)

Scope

Gawler River scientific panel assessment of environmental streamflow requirements.

Summary

- Pool habitats were important summer refuges for aquatic biota (p. 38).
- Threats to fish (nominated as stream-health indicators) that might result in a reduction or failure in reproductive capacity included (p. 39):
  - fluctuating water levels due to irrigation dams

- modification of flooding patterns and water temperature caused by dam construction.
- Threats to the biotic integrity of fish included (p. 40):
  - alteration of streamflow regimes
  - loss of habitat and habitat diversity
  - obstruction of free passage through streams.
- Results of the fish survey found (p. 40):
  - most fish expected to be found in the North Para River system were present but showed limited distributions
  - reduction in connective flows may have contributed to the absence of two species of lamprey in the North Para River system.
- Results of the macroinvertebrate survey (p. 41) indicated that several species with limited or unusual distributions were living in pool environments. These environments were identified as significant and warranted specific protection and consideration in water management due to their role in maintaining biodiversity.
- Changes in the natural hydrograph in the Flaxman Valley included (p. 78):
  - pool connection flows delayed by four weeks in 1990
  - freshet and pool connection flows not achieved in 1993; base flow duration was reduced by three weeks
  - duration of flows reduced by approximately three weeks in 1997
  - total volume of flow for all years reduced.
- Streamflow was not generated evenly across the catchment (p. 71). Remaining high runoff areas not heavily regulated required protection to ensure adequate environmental flows (p. 80; see also level of development in Barossa catchments in Pikusa (1999b, p. 6)).

Ecological water provisions in the Barossa Valley (Pikusa, 1999a)

Scope

The report describes the methodology by which the environmental water requirements for the Gawler River were determined.

Summary

See comments made under Pikusa (2000) (p. 21).

Surface and watercourse irrigation water demands in the Barossa Prescribed Water Resources Area (Pikusa, 1999b)

Scope

The scope was to report on water use from farm dams and watercourse abstractions to assist in the preparation of the Barossa Water Allocation Plan.

Summary

- licensed irrigation farm dam volume, 3712 ML
- licensed irrigation area using farm dams by application rate, 1994 ML
- licensed irrigation area using watercourse abstractions by application rate, 799 ML
- licensed irrigation area using volumetric watercourse abstractions, 58 ML

- stock and domestic farm dam capacity, 3245 ML
- stock and domestic use, 108 ML.

Farm dams in Greenock Creek, a preliminary investigation (Pikusa, 1999c)

Scope

Concerns regarding farm dam development in the Greenock Creek Catchment adjacent to the Barossa Prescribed Area were investigated on behalf of the Northern Adelaide and Barossa Catchment Water Management Board.

Summary

Results of the investigation are summarised below:

- Runoff was estimated at 31.7 mm or 2.05 GL/yr.
- Total volume of farm dams was 956.8 ML.
- Most dam development was in eastern sections directly adjacent to the Barossa Prescribed Area.
- According to 50:50 rule applied in the Mount Lofty Ranges Watershed the catchment area was over developed in 30% of sub-catchments.
- A moratorium was proclaimed because (E.R.Pikusa, Department for Environment, Heritage and Environmental Affairs, pers. comm., 1999):
    - ~30% of the catchment yield appeared committed
    - aerial photos used to estimate farm dam volumes were two years old
    - the rate of farm dam development was increasing.
- After further modelling in the Barossa Valley, figures were revised using data from a BOM streamflow gauge on Salt Creek at She-oak Log with approximately three years of record. Tanh curves were constructed and a model run on an annual time-step. Runoff was subsequently estimated at ~5 mm or 325 ML (E.R. Pikusa, Department for Environment, Heritage and Environmental Affairs, pers. comm., 5 September 2000).

Draft water allocation plan Barossa Prescribed Water Resources Area

(Northern Adelaide and Barossa Catchment Water Management Board, 1999)

Scope

To prepare a water allocation plan for the Barossa Prescribed Water Resources Area, as required under the Water Resources Act.

Summary

- Reductions in streamflow due to farm dams as reported in Cresswell (1991) and possibly Philpott et al. (1999, p. 5).
- Ecological consequences of farm dams and watercourse abstractions are described on page 8 and include:
    - volume of extractions was significant, but timing and duration of abstractions may have an equally adverse affect on ecology
    - permanent deep pools (often fed by groundwater and act as refuges during summer) may be reduced by abstractions and reduction in recharge due to constricted flow duration caused by farm dams
    - riparian issues as identified in Philpott et al. (1999).

Environmental water provisions in the Gawler River catchment

(Pikusa, 2000)

Scope

The report describes the methodology by which the environmental water requirements for the Gawler River were determined (see Philpott et al., 1999).

Summary

- Streamflow in the North Para River was reduced by 10–20% due to farm dams (p. 4)
- Flaxman Valley was the most heavily developed catchment in the Barossa Valley Prescribed Area. *WaterCress* modelling found (table 3-4, pp. 6–7):
  - reduction in flow volume — annual flow reduced by 22%
autumn low flows absent
early winter flows heavily abstracted up to 54%
spring flows reduced by 8–10%.
  - reduction in frequency — pool connection flows decreased by 30%
in-channel flows decreased by 24%.
  - reduction in duration — pool connection flows reduced by 19%
in-channel flows decreased by 21%.
  - large overbank flows were unaffected by farm dams.
- Seasonality of flows was as significant as volumetric analysis. Fish migrations, known to occur in early autumn and spring when flows permit, were threatened by reduction of early season flows.

MARNE RIVER CATCHMENT

The impact of development on streamflow in the Marne River

(Good, 1992)

Scope

To assess the impact of farm development on surface water resources in the Marne River catchment.

Summary

- Storage increased from 600 ML in 1973 to 1600 ML in 1991 — a three-fold increase since 1970 (p. 16). Increase was not as prominent as in the Barossa Valley and Onkaparinga catchments.
- A tendency to construct larger dams was noted. The average dam size in 1973 was 1.7 ML, the average between 1973 and 1991 was 6 ML (p. 16).
- Percentage of runoff captured by farm dams fluctuated greatly with normal climate variability. Volume trapped ranged from 5% in wet years and up to 35% in dry years (p. 28), assuming 1991 levels of development, the average proportion was estimated at ~20% (p. 33). For the 16-year period 1973–88, streamflow was reduced by 10% (p. 28):
  - consecutive dry years were thought to have had a significant impact; during dry spells of up to seven years, farm dams were estimated to have trapped 30% of total runoff (p. 28).
- Farm dams reduced flow duration (pp. 32–33):
  - by reducing the recharge to groundwater through direct hydraulic connection in the streambed by ~5%
  - while no increase in salinity was detected, groundwater fed wetlands in the lower Marne were likely to be affected by a decrease in available water.

Impact of water use in the Marne catchment on water resources for the River Murray Catchment Water Management Board (BC Tonkin & Associates, 1998)

Scope

To evaluate water resources in the Marne catchment and the impacts of surface water resource use on other users and the environment.

Summary

- Farm dam volumes:
  - trend towards larger dams in higher rainfall western areas, primarily for the irrigation of vines (pp. 5, 7)
  - 1998 farm dam inventory — 619 dams for 2558 ML (p. 7)
  - a sharp increase in total farm dam storage was noted after 1996 (fig. 3.6), most of this development occurred in the headwaters of the Marne Catchment (fig. 3.7); Eden Valley has been under similar levels of development since 1991 (fig. 3.7)
  - sub-catchments with the greatest proportion of area controlled by farm dams were in areas with the highest rainfall (fig. 3.9, p. 8)
  - a significant proportion of new dams were greater than 10 ML in size and many exceeded 50 ML (p. 7).
- Increasing farm dam development was reducing streamflow 'during dry or average years' (fig. 4.14, p. 12):

    - streamflow had been reduced, by ~20% at Cambrai gauging station, 'in an average year' (p. i)
    - 'during dry years' the reduction in streamflow was up to 50% (p. 12); further development could result in reductions of up to 60% in dry years
    - the reduction in streamflow was <10% in wet years (fig. 4.14, p. 12).
- Recharge to the lower Marne aquifer was associated with large flows and subsequently not greatly reduced by farm dam development, although base flow from springs between Black Hill and Wongulla wetlands had been observed to be decreasing (p. 15).
- Ecological effects included (p. 18):
    - delayed onset of high flows upon which aquatic ecosystems depend
    - constriction of range and diversity of aquatic life forms due to reduction in volume and duration of streamflow (more details on p. 20).
- Salinity had potential to increase due to the decrease in surface flows that dilute baseflow (p. 18)
- Areas with high ecological conservation value had different flow requirements (p. i):
    - Marne Gorge — depended on maintaining flow duration, quantity was a secondary issue
    - the lower Marne depended on large flood events to recharge aquifers and maintain baseflow into the stream below Black Hill.
- Current levels of development were considered sustainable but pressures for development had increased over the last two years and were expected to increase further.

Inventory of dams in the Marne River catchment, South Australia

(Billington and Kotz, 1999)

Scope

To prepare an inventory of farm dams in response to community concerns regarding the construction of dams in the upper Marne and subsequent downstream impacts.

Summary

- Trends in farm dam development:
    - 1973, ~600 ML (Good, 1992)
    - 1983, ~1200 ML (Good, 1992)
    - 1991, 480 dams for 1656 ML
    - 1996, 603 dams for 1837 ML
    - 1998, 613 dams for 2159 ML.
- Concerns of downstream landholders were supported.
- Viticultural irrigation developments in the upper Marne had increased pressure on water resources adjacent to the Barossa Prescribed Area; the trend has been towards constructing larger irrigation dams rather than small stock and domestic dams:
    - 1991–96, 123 dams constructed for 2.6 ML, averaging <1.5 ML
    - 1996–98, 10 dams constructed for 337 ML, averaging 33.7 ML.
- Most dams were located high in the catchment. The likelihood of the dams spilling was small, due to the limited area of harvest. Downstream users and the environment in general were consequently deprived of water.
- Highly variable rainfall in the area had resulted in a string of dry years, during which the impacts on downstream users were even greater.

The impact of farm dams on streamflows in the Marne River catchment

(Nathan et al., 1999)

Scope

To assess the impact of farm dams on streamflow in the Marne River Catchment. Trends in streamflow were examined, without the effects of climatic variability and the streamflow was then modelled to determine how much of this trend was attributable to farm dams.

Summary

- The method by which the effects of climatic variability were removed from the streamflow data was highly involved. Time constraints did not permit a thorough review of the trend analysis technique used and conclusions from the study are presented without reference to its applicability.
- An average annual decrease in streamflow of 44 ML/yr was identified, independent of climatic variability (p. 6%):
  - ~1% (0.6) reduction every year between 1973–89
  - statistically significant at the 5% level.
- Low flows (below monthly median; less than 13 ML/m.) reduced by 2.9 ML each year on average, i.e. low flows reduced by 10% on average each year between 1973–89 (p. 6):
  - statistically significant at the 5% level.
- Water balance simulation (*TEDI*) suggested the reduction could be wholly explained by increased farm dam development (p. 6):
  - de-trended streamflow data input to *TEDI* produced average reductions of 48 ML/yr for all flows and 2.8 ML/yr for low flows, specifically.
- Previous work suggested that the impact of farm dam development was greatest at rates of >1.5%/yr of mean annual flow, while no impacts could be detected at development rates of less than 0.3%/yr (p. 7). The statistically significant results at only 0.6% indicated that catchments may be more sensitive than previously reported:
  - especially in catchments that display pronounced seasonality in their streamflow regimes
  - volume of annual farm dam increase may be small compared to mean annual flow, but sizeable compared to mean summer flows.

OUTSIDE SOUTH AUSTRALIA

Farm dam development: a review of potential impacts (Beavis, 1996)

Scope

The report reviews Australian and international farm dam literature on the environmental impacts of farm dams.

Summary

- General effects of farm dams were to slow water movement through the landscape and divert it to evaporative and groundwater pathways (p. 7)
- The effects of farm dams on streamflow included (p. 8):
  - reduction in streamflow volumes
  - alteration of flow duration, frequency and timing
  - increased evaporation.
- Reductions in annual streamflow were greatest during dry periods (p. 11):
  - 20% in wet years and 50% in dry years (Cresswell, 1991; Good, 1992).
- Meigh's (1995) studies in Botswana indicated (p. 11):
  - farm dams with a total capacity of 10% of the mean annual runoff reduced streamflow by 8–10%
  - 'a small number of large dams had less impact than a large number of small dams of the same total capacity'; Meigh suggested that large dams reduced evaporation as a result of the smaller surface to volume ratios.
  - for the same total capacity, greater downstream impacts were felt if farm dams were located in lower regions of the catchment; in-stream and evaporative losses were cited as an explanation; [however, the cause may be more heavily influenced by the proportions of the catchment controlled by the dams]
  - these points underline the importance of farm dam location and the part of the catchment under the influence of the dams.
- Streamflow regime (p. 13) — a reduction was noted in duration of entire period of streamflow (cited Cresswell, 1991).
- Seepage, due to build up of hydrostatic head behind wall (p. 17):
  - was usually small in farm dams
  - was prone to higher salinity than normal runoff due to exposure of deeper unleached strata (p. 18)
  - caused localised rising watertables, waterlogging and salinity (p. 18)
  - caused recharge reductions (Cresswell, 1991).

The impact of farm dam development on water resources due to catchment yield (Beavis and Lewis, 1999)

Scope

The report provides rule-of-thumb techniques for sustainable harvesting of runoff using farm dams in Victorian catchments.

Summary

Farm dam issues were discussed and techniques used in the control of farm dam capacities based on percentages of rainfall developed. Impacts on streamflow were not within the scope of the work.

Impacts and implications of farm dams on catchment yield (Sinclair Knight Merz, 1999)

Scope

To comprehensively review farm dam issues based on studies in the Murray–Darling Basin.

Summary

- Changes in land use produced changes in streamflow. The most significant reductions in streamflow were due to farm dams (pp. 15–16, references cited)
- The most pronounced effects were during periods of low rainfall (p. 16)
- Farm dam development was tracked in different catchments around Tamworth New South Wales:
  - the number of farm dams continued to increase (tables 2.1–2.4, pp. 18–25), the rate of increase was prominent in recent times (tables 2.1, 2.3, pp. 18, 23)
  - tendency to build larger dams during the 1990s (pp. 19, 21).
- Land use changes were evaluated as residuals from rainfall-runoff modelling in two catchments: the Yass (NSW, highly developed) and Jamieson Rivers (Victoria, lightly developed). Changes were evident in Yass Catchment associated with farm dam construction (p. 61). Twelve catchments were considered with the results summarised on page 75:
  - magnitude of reductions in streamflow was greater than the increase in farm dam development for some catchments. This suggested the impact of farm dams on streamflow may be greater than their total storage volume, such as increased evaporation and additional impacts associated with farm dam development.
- Conclusions (p. 98):
  - catchments with increases in total farm dam capacities greater than 1.5% of the mean annual streamflow showed significant reductions in streamflow
  - trend analysis gave reductions in streamflow consistently larger than the total farm dam capacity over the same period. This suggested that the effects of farm dam development were not restricted to the direct detention of water but also by associated land use changes such as seepage, evaporation and agricultural consumption
  - findings were supported by *TEDI*, which estimated up to 50% of detected streamflow reductions were likely to be a direct result of farm dam construction, while the remainder were due to other land use changes in the catchment.

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