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Monitoring Small Farm Dams for Better Drought Planning

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ABSTRACT

Small catchment dams are an integral part of the farming landscape in many parts of Australia. They provide water for stock, crop spraying, domestic household use, and are increasingly recognised for their amenity and recreational value. The susceptibility of small dams to extended dry periods will vary depending on geography and climate, and also the design and use of the small dam itself. This susceptibility to drought will then influence on-farm planning, along with land and water use decisions.

This project will see the rollout of instrumentation across 12 Victorian farms to monitor and establish the rainfall, runoff and yield characteristics of rural catchments and small dams subject to various land use types. Once data is collected, the project will develop water balance models that will provide insight into what runoff can be typically expected from different types of rainfall and rural catchments. Insights are particularly expected into catchment coefficients and losses, time of travel, and how these might change across the year and antecedent conditions. Further insights may be revealed around the reliability of dams and their performance under an increasingly drying and variable climate.

A user friendly spatial tool will be developed to allow the rapid calculation of the likely runoff for different rainfall, to assist farmers prepare, manage, and recover from drought. An interactive calculator like this does not yet exist.

This paper will describe the dams and their monitoring arrangements to be used as the case studies to inform the broader research program. The paper will then further describe the planned work around water balance monitoring, catchment characterisation, and development of the spatial tool for improved on-farm planning.

INTRODUCTION AND BACKGROUND

Dams are found on farming properties across many parts of Australia, and form an important and quintessential part of the rural landscape. For the purpose of this paper, small farm dams are artificial water impoundments typically in the range of 1 to 5 ML in volume, and source their water from an upstream catchment. They are used for a range of water supply purposes including stock watering, domestic household use, crop spraying, and are also used to enhance the recreational and livabillity functions of regional and rural areas (Nathan and Lowe 2012).

Dams have long been used to supplement water supply on farms, and their proliferation in use has been noticed in recent decades (Peña-Arancibia, Malerba et al. 2023, Robertson, Zheng et al. 2023), particularly on lifestyle properties. They remain critical to the farming economy wherever alternative water supplies are not available (Gordon, Finlayson and Falkenmark 2010, Fowler, Morden et al. 2011, Nathan and Lowe 2012). Because the functioning of dams are rainfall dependent, they are susceptible to drought periods where, with sufficient duration, they may become unreliable (Malerba, Wright and Macreadie 2022). Dam performance during drought periods can influence on-farm planning decisions, such as stocking rates.

The focus of this paper it to describe the monitoring for a number of dams in Victoria, Australia, to better understand their unique hydrology. Whilst small and hillslope catchment hydrology is a well-studied field, there has not been widespread dam-scale investigations within Australia, beyond looking at the impact of dams on larger catchment processes (Morden, Horne et al. 2022). This current work will inform the development of a web-based drought planning tool where users can simulate seasonal outlooks to update their on-farm activities over their chosen forecast period. A key component of that tool will be a well-functioning water balance model which incorporates seasonal outlooks.

CASE STUDY SITES

Monitoring sites have been established across 4 geographic areas within Victoria, Australia (Figure 1): 4 dams South of Ballarat, 3 dams West of Bendigo, 1 dam south of Leongatha, and 4 dams West of Wangaratta. The selection of dams was based on a mix of considerations around cooperating land owners and ease of access, advice from the partner farming groups (Southern Farming Systems, Birchip Cropping Group, Riverine Plains and Food and Fibre Gippsland), and relatively idealistic conditions including land use that was relatively stable across the monitoring period, no groundwater contributions and off waterways. All dams were located within catchments used for grazing or cropping, with some lightly or partially timbered.

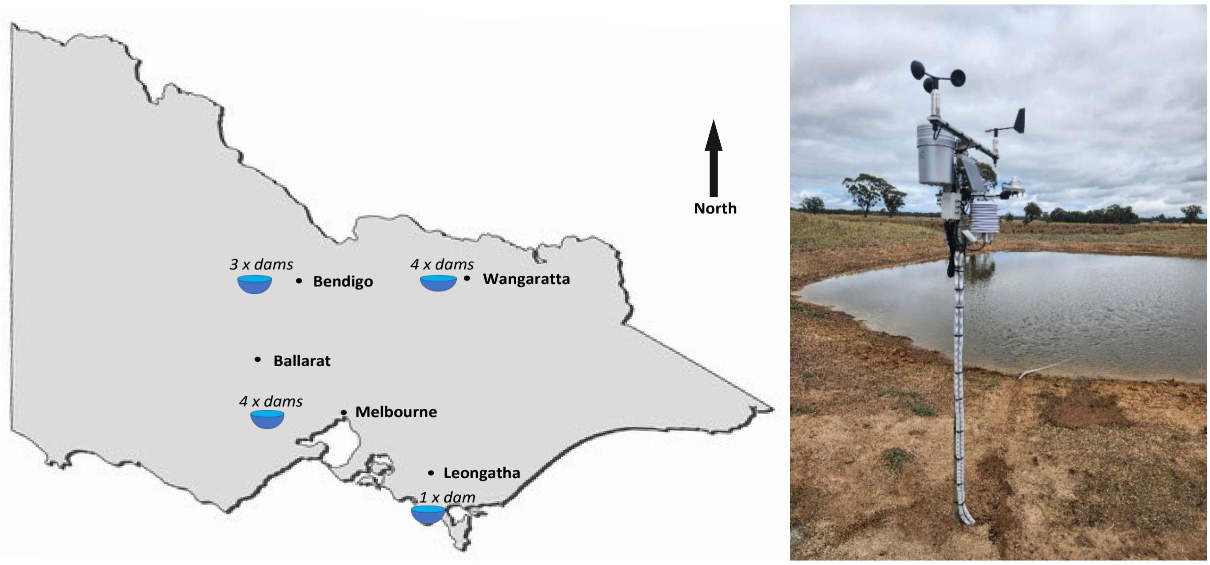

Figure 1: General location of dams across Victoria, and typical farm dam monitoring.

MONITORING ARRANGEMENTS

The monitoring at each farm dam consists of a fully automatic weather station, water level sensor, a soil moisture probe, along with RTU and data logger with solar charging. Details of the monitoring instruments are outlined in Table 1 with a typical farm dam and installation shown in Figure 1. Where the dam is subject to cattle or sheep access, fencing has been provided for protection. Where the catchment is subject to cropping, all cabling has been buried and sensors placed on fencelines or out of the way of farm machinery.

Table 1: Details of monitoring equipment.

Sensor and Specifications	Comment
PT20 SDI-12 hydrostatic water level sensor.	0-5m range, 0.1mm resolution and +/-0.25% accuracy. Installed to sit at the bottom of dam.
TBSHTP06 SDI-12 air sensor, installed within a RK95-01 multi-plate radiation shield.	Air temperature (0.2°C resolution, 0-90°C range), relative humidity (+/-2% accuracy, 0-100% range), barometric pressure (+/-0.5hPa accuracy, 300-1250hPa range). Installed within a radiation shield.
ADCON Wind sensor set vento1.	Wind speed (+/-0.3m/s accuracy, +/-0.1 m/s resolution, 0.4-55.56 m/s range) and direction (+/-2° accuracy, +/-1° resolution).
Rika RK200-04 solar radiation sensor.	Measuring a spectral range of 300~1100nm wavelength (0-1500 W/m^2 range, 1W/m^2 resolution).
EnviroPro ssoil moisture probe, EP100GL-08.	8 sensors at 10 cm intervals and temperature enabled (0.01% resolution, +/-2% accuracy)
RG1 Raingauge	200 cm^2 orifice, double tipping buckets at 0.2 mm resolution (+/-1% accuracy at up to 50mm/hr).
ADCON Series 6 A764 RTU	Compact data logger with integrated 4G modem.
Accessories include 2.4W solar panel, junction box (TBS04 8 Port SDI-12) and cabling (SDI12 7 pin M9)	Junction box to connect all sensors with the SDI-12 port of the data logger. Solar set charges a 2 AHr battery.

CONCEPTUAL WATER BALANCE MODEL

Monitoring arrangements have been designed to allow for the establishment of water balance models at each farm dam location. A water balance can be conceptualised as follows:

$$\Delta S = I - O$$

Where the change in farm dam storage, ΔS, is governed by the volume of water entering the dam ($I = Inflow$), and the volume leaving ($0 = Outflows$). This can be further broken down into several key water balance components, where:

$$\Delta S = Rain - Evaporation + Inflow - Consumption - Losses.$$

Monitoring will enable the direct measurement of rain (precipitation directly on the dam), an estimate of evaporation (from the water surface of the dam), an estimate of catchment inflows (volumes derived from the catchment), with any water consumed (by stock, domestic use or pumped in/out) needing to be estimated or measured elsewhere, and losses due to seepage and other unaccounted for volumes needing to be derived.

CATCHMENT CHARACTERISATION

Soil characterisation was undertaken for each catchment to help inform the rainfall-runoff relationships derived for each catchment. Soil profiles were described for the upper, middle and lower sections of each dam catchment according to the Australian standard methodsm (National Committee on Soil and

Terrain 2009), and included profile descriptions for each soil series in the catchment if more than one was present. The descriptions included physical and chemical properties required for hydropedological characterisation, including infiltration testing using ring infiltrometers. The data is used to characterise the soil hydrology (infiltration, throughflow and interflow) in each catchment. Terrain and physiographic characteristics were derived from high resolution digital elevation models derived from the available Lidar survey data.

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BIOGRAPHY

Andrew Barton is a Professor in Water Resources Engineering and has worked for over 20 years in industry and academia in strategic water resource planning, impacts of climate change to water supply, streamflow and water quality monitoring, entitlement and allocation frameworks, and has direct operational experience of managing water resources through the extremes of droughts and floods. Andrew is the research lead for the small farm dam's project.

Peter Dahlhuas has a career spanning 40 years in engineering geology, environmental geology and hydrogeology working in private and public sectors. He has been influential in applying his scientific knowledge to direct policy on salinity, soils and catchment management. Peter is well-known as a science communicator by his students and community groups, and as an independent advisor to Catchment Management Authorities, Water Corporations and Local Government. Peter's current research focuses on spatial data interoperability and visualisation to ensure that environmental data, information and knowledge are globally and publicly available.

Matt Burns is a hydrologist and engineer who works mainly in urban areas. He has significant experience in the monitoring and modelling of blue-green infrastructure at the household scale. A major component of his PhD research was the monitoring and modelling of 12 rainwater tank systems. Matt has worked as an environmental drainage engineer for local government, a role which involved the design and construction supervision of several blue-green infrastructure projects. He also co-leads the teaching of Water Sensitive Urban Design at the University of Melbourne and has previously taught urban water to undergraduate students.

Lloyd Chua is an Associate Professor in Civil Engineering at Deakin University, Australia where he teaches subjects related to hydraulics and hydrology, and conducts research into water quality monitoring, modelling and management, and flood modelling He collaborates extensively with universities and organisations internationally. Prior to Deakin, he held positions at Nanyang Technological University, Singapore, Brandenburg Technical University, Germany and at the Technical University of Denmark. He is the recipient the 2005 Hilgard Hydraulic Prize (ASCE) and has won best paper awards in 2003, 2013 and 2014. He is reviewer for international journals and has published >150 papers in refereed journals and conferences and has. He has supervised about 20 PhD students, 7 post-docs and has been involved in projects internationally worth over A$10M related to stormwater management.

Tim Fletcher is a hydrologist and ARC Industry Laureate Fellow, whose work is principally on stormwater management, including the development of real-time control algorithms to simultaneously enhance water supply, reduce flood risk and provide flow regimes aimed at protecting ecosystem health of waterways. Tim is based, with Matt, at the University of Melbourne, but was previously based at Monash University, and at INSA Lyon, France.