Rural Domestic Water Consumption Rates and Associated Catchment Storage Combinations

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A copy of the paper presented to

Hydrology and Water Resources Symposium 1985

Held at Sydney, 94-16 May, 1985

Organised by:

National Committee on Hydrology and Water Resources

Institution of Engineers, Australia

National Conference Publication No, 85/2

Pages 39 - 42

Hydrology and Water
Resources Symposium,
1985, Sydney, 14-16 May

Rural Domestic Water Consumption Rates and Associated Catchment Storage Combinations

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SUMMARY The quantification of domestic water consumption rates is essential to the planning of both reticulated water services and the need for correlating roof catchments with rainwater storage systems. Household consumption rates have been in the past estimated for metropolitan areas by various government agencies. These values have then been implied to rural domestic consumers. This study aimed at gauging long-term total household consumption rates for three rural consumer types: those reliant wholly on rainwater collection and storage; those with additional water resources available; and those connected to a reticulated water supply. Data were collected from a representative sample of small area rural households ("hobby farms") surrounding Armidale, New South Wales. This data included volume of total water use over 12 months of drought conditions, domestic water using appliances, additional water purchased to overcome shortages, roof area and rainwater storage facilities. Consumption of water was estimated to average 126-165 litres per person per day when totally dependent upon rainwater storage. Individuals required up to 350 litres per person per day in occasional circumstances. However, 71% of all residents surveyed confined daily consumption to between 100 and 200 litres. Reticulated water consumption was estimated as 565 litres per person per day, three and a half times the requirements for households dependent totally on rainwater. The combination of roof catchment and storage volume required to provide a reliable supply of rainwater was inadequate in most households surveyed. The necessity of a critical storage period of 120 days had been highlighted over three years of drought. Sixty-nine percent of all storages calculated on this value were more than 20% under requirement. However, in 61% of cases the roof catchment areas approximated the areas required. Thus, there exists a unique set of conditions relating rural domestic water consumption with the combination of roof area and storage to provide a reliable water supply.

1 INTRODUCTION

1.1 Background

The study evolved from a need to provide more accurate data for use in planning domestic water requirements for small area holdings (less than 40 ha) on subdivisions outside the reach of reticulated urban water supplies. The continuing subdivision of land around major towns on the Northern Tablelands of M.S.W. has placed Local Government Councils under financial pressure due to the difficulty of extending the town reticulated water supply into these areas. Often the location of the subdivision poses hydraulic problems because of elevation differences or long supply routes while complicated economically by low user-density and poor "willingness-to-pay". The value derived from the latter was shown to be substantially less than the expected increase in market value of the land following connection to a reticulated supply.

Provision of adequate rainwater collection and storage facilities together with a conservative policy for household use of rainwater remains an option which has low commitment of public resources (Council funds) while maximising "user pay" theory. The lack of guidelines for household rainwater collection and storage, based upon predicted usage and annual rainfall, prevents Councils from incorporating minimum standards into local building regulations. This study aimed at the provision of basic guidelines for New England Tablelands.

1.2 Existing data

Household water consumption rates for Melbourne's metropolitan area are documented in Heeps (1977). The proportional usage by household activities were considered applicable to this study with the exception that leakage would be negligible from households reliant upon rainwater. Thus, in Table 1 below, Column C has been recalculated on the total volume without the leakage. This project confirmed the approximate percentages used in each element, where the larger volumes were used for toilet flushing and laundry purposes.

TABLE I

DOMESTIC WATER CONSUMPTION FOR MELBOURNE DURING WINTER 1975 (after Heeps, 1977)

Water Use	l/p/d (a)	Average percentage (b)	percentage (c)
Dishwashing	17	9	11
Clothes washing	33	18	22
Toilet flushing	37	20	24
Shower	34	19	22
Bath/handbasin	20	11	13
Drinking/cooking	8	4	5
Carwashing	4	3	3
Leakage	32	16	omitted
	185	100	100

Although the values given by Heeps in Table 1 are for metropolitan Melbourne during winter 1975, a figure quoted for annual average daily usage was 290 litres per person per day (l/p/d) during a period of restriction on sprinkler use. Such a period would indicate a high proportion of internally used water, a value more akin to rainwater usage.

Perrens (1975) quoted approximate values of water consumption for rural Armidale at 200 litres per person per day. He applied this value to a computer model to calculate a combination of tank size and roof area for a probability of failure of once per year. It was-considered that cost of cartage of one 5000 litre load of water was an economic proposition in relation to cost of providing additional catchment and storage of the same volume. From the model, Perrens defined a critical storage period of 120 days for a failure rate of once per year based upon average annual rainfall. This critical value was applied to analysis for the present study.

No other water consumption details were found in the literature other than rule of thumb estimates relating to previous decades when standards of living (based upon water consumption) were less than those acceptable today. Modern appliances such as automatic washing machines and dishwashers increase internal water use, while the flush toilet is now a requirement under local health regulations.

2 STUDY OBJECTIVES

The estimation of water usage was based upon the following variables in domestic water consumption and collection/storage ratios:

(a) Daily average domestic water consumption rates calculated for rural households where:

 (i) supply was wholly rainwater catchment/storage;
 (ii) the source was an unrestricted reticulated supply.

(b) Calculated roof catchment and storage volume based on average annual rainfall which would provide:

 (i) 120 days critical storage; and
 (ii) failure rate of once per year.

The study aimed at comparing the use of water under both conservative (rainwater storage systems) and non-conservative (reticulated supply) household policies. The severe drought conditions which applied at the time of the survey suited a matched comparison since both household types had ceased to use water externally. The gardens in both were beyond recovery and watering on even a weekly basis was of little value. The greater proportion of all water used was "domestic" water, that is, water used within the household for drinking, washing, cooking and toilet flushing. Since many households purchased tanker loads of water (5000 litres per load) it was possible to accurately gauge total water consumption over a 12 months period.

3 STUDY AREA

Armidale is situated on the New England Tablelands in North Eastern New South Wales at an altitude of 1000 metres. The city is fringed within 6 kilometres radius by hundreds of 2-40 ha allotments, the majority of which are dependent wholly on rainwater systems for domestic water supplies. Sixty-two percent of occupied dwellings within the study area were surveyed.

Average climatic variables are shown in Table II,however during the period covered by the survey data, 420 mm of rainfall were recorded in the previous 12 months (November 1981-October 1982).

TABLE II
CLIMATIC DATA FOR ARMIDALE
(after Bureau Meteorology, 1977)

	Rainfall	Evaporation	Temperature
Mean annual	800	1120	
Lowest	420	na	-10°C
Highest	1507	na	39.7

4 METHOD OF DATA COLLECTION

A house to house survey method was used to collect the information for the period of the 12 months August 1981 to September 1982. The data were based on rainwater collection area, storage volume, volume of water purchased by tanker load, number of household occupants and the water consuming devices in use. The latter included washing machines by type, and toilet flushing systems by volume flush.

The drought of 1979-82 had ensured that the estimates of rainwater use were almost wholly "domestic". An assessment was made of gardens and lawns to estimate the proportion of rainwater used externally. However, in 96% of households only bath or laundry water was used externally for aesthetic purposes. Further, no surveyed households had overflowing tanks at any time within the study period, thus all water falling upon the catchment was consumed.

For each dwelling surveyed, the estimated daily consumption rate, estimated critical storage volume and minimum roof area requirements were calculated. Households supplemented from groundwater or surface runoff storages were compared with "rainwater only" dwellings. This was carried out to gauge the percentage reduction of water consumption possible when lower quality water was used for purposes such as laundry and toilet flushing facilities. The results of these are discussed in detail later.

5 RESULTS

5.1 Surveyed households

The summary of dwellings surveyed is given below in Table III. The townwater users were geographically favoured by the physical aspects of a reticulated supply. There were several instances where householders had invested up to $10 000 at 1978 values to obtain townwater by providing their own supply pipelines over distances not normally regarded as economically viable.

The high proportion of dwellings (40%) supplemented by other resources such as underground or stored surface water, was indicative of attempts by householders to raise the standard of living and the external aesthetic appearance of the dwellings by the availability of excess water for gardening and landscaping.

TABLE III
SUMMARY OF HOUSEHOLD WATER SUPPLY SYSTEMS

	Townwater	Rainwater only	Rainwater + other	Other	Total
Households	22	21	34	8	85
Percentages	26	25	40	9	100

5.2 Consumption rates of water

Various criteria were used to calculate the consumption rates for domestic water. As the study was an averaged estimate, loss of water by initial wetting of roof catchment, splash beyond roof edge and gutter overflow by high intensity rainfall events were neglected. Loss through underdesigned guttering sizes was indicated as a cause of failure in many instances. While these losses are not regarded as insignificant, their estimation was beyond the requirements for accuracy in this project.

Given that the storages could have been either full, partly full or empty at the commencement of the 12 month measuring period, calculations were based on both full and empty storages. Thus respective maximum and minimum rates were calculated. The rainfall value used was the actual value of 620 mm for the previous 12 calendar months. Equation 1 relates the measured data to the consumption rate in litres per person per day.

$$\text{Per capita consumption (l/p/d)} = \frac{R \times AR \times V_c \times V_p}{365 \times N} \qquad \text{Equation 1}$$

where R is the roof area catchment in square metres, AR is the annual rainfall in millimetres, V_t and V_p are the volumes of the tank and tanker water purchased respectively and N is the number of residents.

Rates varied from 73 litres to 350 litres per person per day. The average was 165 litres, however, the spread of consumption rates is given in Table IV below, shown as percentates for four categories. A lower value of 126 litres was calculated based upon storage empty at the commencement of the measuring period.

TABLE IV
CONSUMPTION RATES FOR VARIOUS DOMESTIC WATER SYSTEMS

	per capita daily consumption			
Group averaged	100L	100-200L	200L	500L
All groups	5%	71%	24%	nil
Solely rainwater	6%	56%	38%	nil
Townwater only	nil	nil	nil	100%

It should be noted that the consumption of rainwater increased when other sources were also available. This indicates the change to a non-conservative attitude of the household, a theory supported by personal comments 'from residents. Reticulated water consumption was estimated at 565 litres per day, three and a half times the usage of households totally dependent on rainwater. Again, this reflected a poor attitude to conservation and perhaps a low monetary value per unit of water.

5.3 Minimum planning requirements

Calculated storage volumes and roof areas for each residence were correlated against the consumption rate of the household for a critical storage period of 120 days. Rainwater supply systems which had not failed more than once indicated that a critical storage period of 120 days was adequate, while 150 days would have avoided failure during the period of drought in most cases. The economic pricing of the extra 30 days storage (approximately 30 kL per household) had to be weighed against the purchase price of carted water. The latter was cheaper in the short term but dependent upon annual rainfall variability for long term assessment.

The ratio of the estimated roof area to the actual roof area was calculated for each dwelling. The results tabulated below indicate that 56% of the households were within 10% of the actual area for the number of residents in each household. Only two dwellings had roof areas in excess of requirements, however each had three or fewer residents. The average occupancy rate for the study area was 4 persons per dwelling. An increase in residency by one person would have placed the dwellings into a failure category in all cases.

TABLE V
ESTIMATED ROOF AREA IN RELATION TO CALCULATED MINIMUM REQUIREMENT

	Under estimated area				Over estimated area			
Roof Area	70-40%	30%	20%	10%	0	10%	20%	30%
Percentages	14%	17%	8%	19%	22%	14%	3%	3%

The ratio of the estimated storage volume calculated on a 120 day critical storage period is tabled below (Table VI). Sixty-nine percent of households were supplied with inadequate storage facilities, that is, more than 20% under required volume for a failure of once per year.

TABLE VI
ESTIMATED STORAGE IN RELATION TO CALCULATED REQUIREMENT

	Under estimated				Over estimated	
	200%+	50-100%	20-50%	+10%	20-50%	50%
Percentage	17%	25%	27%	14%	14%	3%

The combination of the two ratios into graphical form indicates the distribution of poor catchment and poor storage combinations for the households surveyed. All positions lying above the 1.0 catchment ratio line (estimated area to actual area) had catchments under the minimum requirement for the number of residents in the dwelling. All positions to the right of the 1.0 storage ratio (estimated storage to actual storage) had storages below minimum required for the number of occupants. It can be seen from Figure 1 that only four households had both catchments and storages above the calculated minimum.

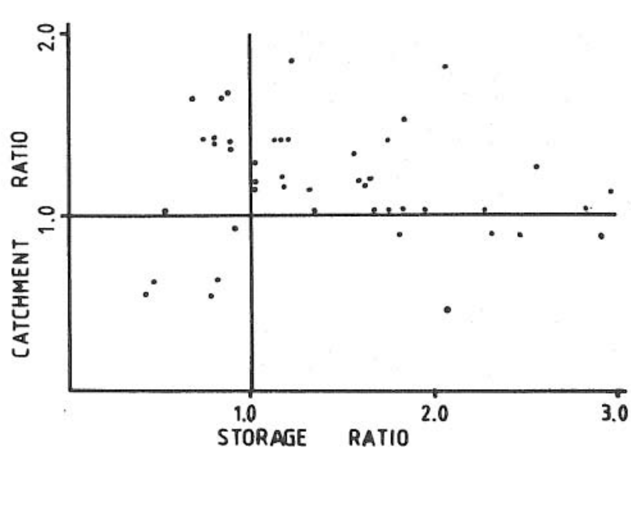

Figure 1 Storage ratio graphed with catchment

6 DISCUSSION

A unique set of conditions applies to each household in relation to its drought resistance. Conservation policy for restricted water use and a choice of low water use appliances was considered paramount to a reduction in usage. The economic benefits to be derived from these were evidenced in greater system reliability and reduced storage volume and catchment area requirements. The need to conserve water was dictated by circumstances in households having a "rainwater only" system. Average daily consumption rates of 126–165 litres per person per day for reticulated households illustrate the issues of conservation. Higher operating pressures of the latter increase the consumption rate. A 30% reduction in system pressure would reduce domestic consumption by 20% as an independent study by the author has verified.

Little information is available to the builder, plumber or potential house owner to advise on suitable combinations of roof area and storage volume. The results indicate the high failure rate of most rainwater systems, verification of the success rate for guessing. While much can be done to educate the residents in the use and availability of water conserving devices the roof catchment/storage volume to resident ratio is the most easily implemented. Through Local Government Councils' building regulations, local codes can be adopted and enforced during the planning and application stages of the development. Such guidelines for New England should be based up to a minimum household of 5 persons, having a roof catchment of 290 square metres and 70 000 litres of storage. This assessment is based on a need for 120 days of storage estimated at a consumption rate of 160 litres per person per day.

Maximum limits for other areas of the state can be based upon local average rainfall conditions by firstly estimating the roof area capable of collecting the annual water requirement for the household. A 5 member household uses 290 ML per annum if consumed at a rate of 160 litres per person per day. At a rate of 250 litres, a volume of 460 ML would be required.

The economics of "rural habitation" based solely upon rainwater for domestic purposes dictate, for the majority, a conservative water use policy. The strategy must be implemented at the construction phase by the choice of low volume flush toilets, selection of pressure systems and associated pipe sizes. The conservative approach leads to a reduction in the total roof catchment area which reduces total cost. The average New England price for additional roof catchment (medium sized machinery shed) is approximately $5000 per 100 square metres, which provides for one additional resident only. Storage economies impose further on the cost of the total system.

7 CONCLUSION

The inclusion of basic roof catchment/storage volume ratios in Local Government Councils' building regulations will have two major community effects:

(1) Improve on-site collection and storage of rainwater to provide a reliable domestic supply of water; and

(2) Reduce likelihood of social and political pressure being imposed on local authorities for the extension of reticulated water into small rural subdivisions.

The estimation of numerical values for the codes needs to be based upon a minimum average household occupancy rate, average rainfall, estimated water usage rate and 120 days storage capacity. Under these constraints the failure of domestic rainwater systems will be decreased.

9 ACKNOWLEDGEMENTS

Special thanks are offered to Dr. S.J. Perrens of the Department of Resource Engineering, University of New England for guidance during the study.

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