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Drought Resistant Farm Dams for New England Tablelands

R.A. PATTERSON
Lecturer, Department of Resource Engineering, University of New England
and
S.J. PERRENS
Senior Lecturer, Department of Resource Engineering, University of New England

SUMMARY The 1980-83 drought on the New England Tablelands highlighted the need for a conscious appraisal of incorporating farm dam design and catchment management strategies in the overall development of a drought resistant pastoral industry. Variables such as soil type, vegetative cover and composition, catchment areas, slopes and mainstream lengths together with specific water storage dimensions were measured for two types of dams - those which had failed during the three year drought - those which had been able to maintain a stock water supply. Failure to apply management strategies to farm dam design was highlighted by a failure rate of up to 90% depending upon subdivisional area. Gully storages performed better because of the greater capacity to route the interflow and groundwater components of runoff. Lack of planning adequate catchment area on suitable soil types and poor design for depth indicated the most consistent errors in farm dam design.

1 INTRODUCTION

1.1 Background

The drought continuing through 1982 followed two previous years of below average rainfall, brought with it not only a "pasture drought" but also a "water drought". Pasture droughts have been reasonably common on the New England Tablelands following prolonged dry periods and severe winters. Water droughts have been rare, occurring only three times this century (1902, 1939, 1966). Changes in land use brought about by technological advances in land clearing (bulldozer, chainsaw) fertilizers (superphosphate and aerial broadcasting) and improved perennial and leguminous pastures lead to a reduction in paddock size, increase in stocking rates and increase in improved pastures. Banens (1981) illustrated the changes since 1950 in the graph reproduced in Figure 1 below. The 40% change from native pasture (pasture dominated by native species) to improved native and improved pasture (pasture dominated by introduced grass species and legumes) resulted in the altered soil moisture regime. The extended growth period of improved pastures, higher evapotranspiration rates and higher plant densities cause a more rapid depletion of the soil moisture storage. Runoff, according to Boughton (1965) occurs after this storage is replenished, however, compared to native pasture a smaller percentage of runoff is produced from the improved pasture. This reduced runoff becomes one variable not recognised in farm dam design.

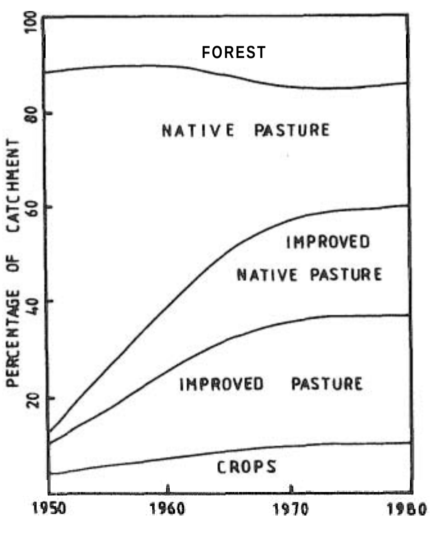

Figure 1 Severn Valley land use (after Banens 1981)

A survey in the Armidale area by Patterson (1982) highlighted the high density of farm dams in the closer settled areas. Landowners repeated that the need to supply adequate stock water in each paddock was of paramount importance. This resuloted in a strategy of "one paddock - one dam" for properties where natural water courses or groundwater resources (springs) were not available. On this basis dams were planned on fence lines rather than on natural catchments. High failure rates were inevitable. Finally economics dictate that many dams must be small dams, which invariably are shallow.

Thus at the commencement of the 1979-83 drought pastoralists were relying upon a small dam in each paddock to provide essential stock water facilities.

1.2 Description of Study Area

Armidale, on the New England Tablelands is situated at an altitude of 1000 metres. The surrounding district ranges from 700 metres in the west to 1500 metres on the edge of the eastern escarpment. The rainfall varies similarly from 650 mm to 1400 mm while Armidale averages 800 mm per annum. Rainfall is relatively evenly distributed on a monthly basis but with a pronounced summer dominance. The summer rainfalls are high intensity short duration events, giving rise to high percentage runoffs. The average annual rainfalls for the period since 1963 are given in Figure 2 based upon unpublished University of New England data (Laureldale Experimental Station). The 1979-83 drought is obvious when a three year moving average is employed to show the variation.

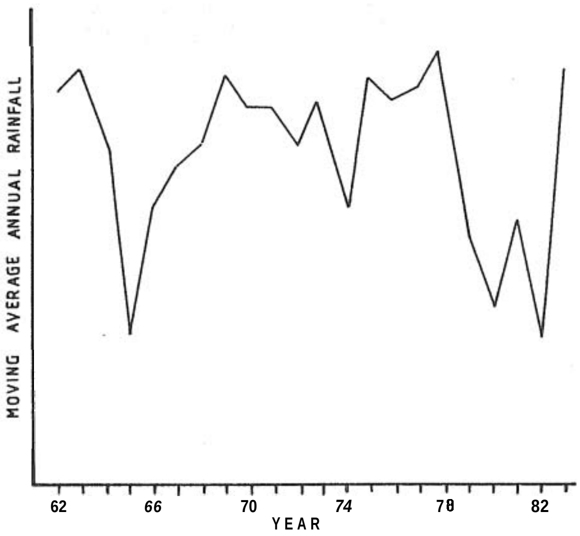

Figure 2 Moving average rainfall for Armidale

The farms surveyed varied from 'hobby' farm size of 5–40 ha to viable agricultural holdings of 600 ha. The hobby farms were in close proximity to Armidale city and were considered representative of peri–urban development generally.

1.3 Study Objectives

Initially the study aimed at identifying parameters based on catchment specifications, soil type, soil cover and land use management options which could be manipulated to maximise runoff. The maximisation of runoff was to be achieved while maintaining a high level of pasture production and an economic stocking rate. These variables from the U.S. Soil Conservation Service Curve Number Method were considered the most applicable to model broad farm dam catchment studies and the variables as described by Eastgate et al. (1979) were used for the study. Following drought breaking rains shortly after the commencement of the project as shown by the 1983 rainfall value, the objectives were altered to:

(a) identify those farm dams which had maintained a reliable stock water source during the 1979–83 drought; and

(b) identify the catchment and storage parameters which assisted in achieving this reliability.

Since a comparison of dam reliability over the period of the drought was the aim of the project, quantification of rainfall variables such as intensity/duration, individual rainfall events, antecedent moisture conditions or evaporation were not necessary for the success of the project.

2. SURVEY METHODS

2.1 Sample Selection

Photointerpretation of low level aerial photographs followed by a ground reconnaissance method was used to identify suitable dams such that a sample of catchment sizes, soil types and storage volumes was representative of the area. Together with 100% sample data collected from hobby farm subdivisions, selection was made for more intensive parameter measurements. Parameters were measured on dams which fulfilled specific criteria such that the soil types and cover were similar for the whole catchment. Prediction of runoff from mixed soil type catchments was beyond the initial scope of this project to estimate.

2.2 Aerial Surveys

The aerial photographs used in this study were those obtained by Nugent (1982) during development of a Single Lens Reflex camera mounted on a modified door of a Cessna 172 aircraft. At altitudes of 3500 metres high resolution photographs were obtained using black and white aerial film. While geometrical precision was less than commercial aerial photography the low cost of the results for the degree of accuracy necessary for this project compensated for any losses.

Figure 3 is an example of the quality of photography produced by Nugent and illustrates the ease with which farm dams storages can be identified.

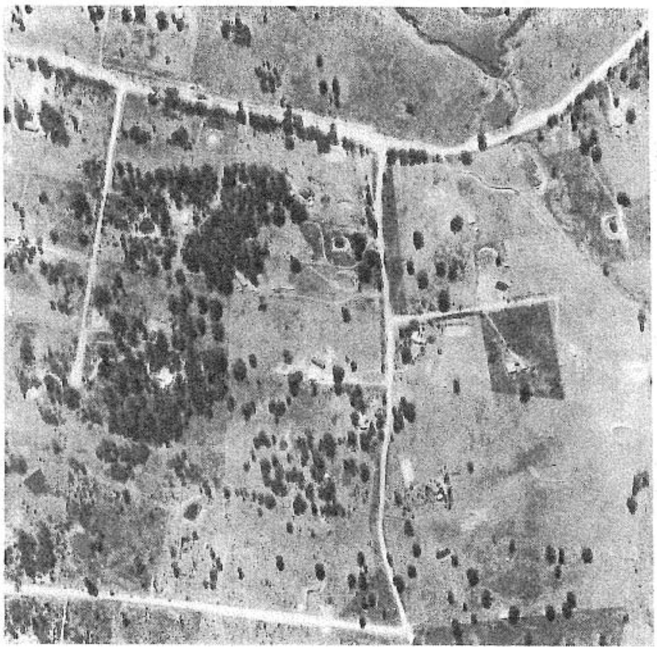

Figure 3 Low Altitude Aerial Photograph for survey work

Measurements made on stereoscopic pairs of photographs were used to calculate the surface area of the dam and the estimated embankment volumes. Where dams were checked by ground surveying the accuracy was to within 10%, acceptable for the purposes of this study.

2.3 Storage Volume Measurement

The drought breaking rainfalls of April and May 1983 resulted in 95% of all dams on the New England Tablelands being full. April recording was 137 mm compared with long term average of 45.3 mm, similarly May had 137 mm compared to 44.6 mm. Those dams below maximum capacity indicated a major design fault, either in catchment area or catchment/storage ratio. In four cases observed the location of the storages in relation to the direction of overland flow from the catchments were poorly co–ordinated.

Construction of simple control banks would have corrected the fault and allowed maximum inflow.

Measurement of the stored water volume was carried out using a device similar to that used for stream gauging. An endless rope was slung across the dam to resemble a "flying fox". Supported from this rope was a brass ring, through which a light weight cord with plumb-bob attached was lowered into the water. Depth measurements were made from the shore by recording the interval of cord passing a marker while allowing the plumb-bob to travel from the water surface to the dam floor. A 'feel' for the latter position was quickly acquired. A cross section showing the layout of the device is illustrated in Figure 4. A dryland evaluation of the method resulted in a 95% accuracy of depth up to 5 metres over horizontal distances to 80 metres. Movement of the supporting ring across the dam, and relocation of the endless rope allowed a 5 x 5 metre grid pattern measurement, over the whole dam. Depths were recorded at each intersection and contours constructed of the storage. Volumes were estimated from these contours and depth/storage curves constructed for each dam.

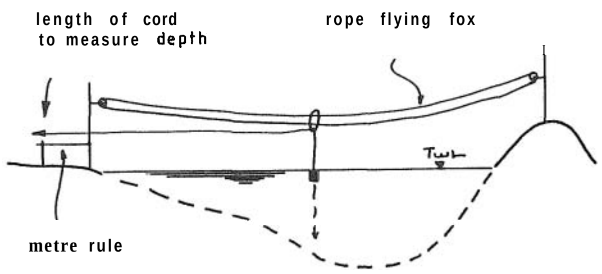

Figure 4 Cross section measurements of depths

2.4 Catchment parameters

A ground survey, supplemented with information derived from the low level aerial photographs and standard series topographic maps was conducted to evaluate the following:

(a) soil survey map of the catchment only to the level of Great Soil Groups;

(b) catchment cover according to percentage cover and species composition;

(c) catchment shape, average slope, mainstream length;

(d) discussion with landowner relating to catchment management, reservoir performance and leakage rates.

3 RESULTS

3.1 Reliability

Hydrologic failure of a farm storage is a serious problem aggravated only by the time period of the drought over which the storage is empty. Many combinations of emptiness and degree of fill can be recorded to identify the reliability, however, this study was confined to identifying those storages which failed at least once during 1979-83. The dams were categorised according to both construction type and topographic location. Hillside dams are typically structures designed for landscape positions other than gully lines. Excavation ratios are in the order to up to 1.5 to 1 depending upon natural ground surface slope. These dams were more popular in hobby farm areas where block size and shape precluded maximising catchment parameters. Gully storages were classified according to the length of embankment namely wide or narrow gully. These storages empounded volumes up to 5 times that excavated and in relation to hillside dams are more economical to construct. Gully storages were also categorised on sources of water. Sixty percent of all gully storages were fed by some groundwater, either within the storage area or from upslope within the catchment. Table I below outlines the proportion of each type of dam surveyed during the project. These figures do not necessarily reflect the averages for New England because their selection was not statistically based. In regions dissected by numerous small streams, a greater reliance is placed upon natural storage within the creek lines. No information was collected on proportion of properties served only by constructed storages.

TABLE I
COMPOSITION OF DAMS SURVEYED

TYPE	PERCENTAGE FAILED	RELIABLE	TOTAL
Hillside	72	28	67
Narrow Gully	40	60	11
Narrow + Spring	10	90	7
Wide Gully	32	68	5
Wide + Spring	12	88	10
Total	34	66	100

It can be seen from Table I that while there was an overall failure of 34% of all dams surveyed, 72% of all hilside dams failed, inflicting drought conditions in those areas where the construction of gully storages was not possible. Of the dams surveyed 71% had been constructed since 1976 while many had been commenced after 1979, the beginning of the current drought period (1979-83). While storages were empty, 60% were cleaned of sediments, enlarged, while the addition of catch banks was not uncommon.

3.2 Hillside Storages

Typically hillside storages were confined to small area holdings where catchments were usually less than 10 hectares. Hobby farms were ,dominated by this type where subdivisional boundaries dictated location rather than on sound hydrologic criteria, the failure rate of 72% verifies this situation. Table II below gives the average data for these dams, however stored volumes and depths were often from landowners' estimates.

TABLE II
AVERAGE HILLSIDE STORAGE FEATURES

	Stored Volume <500 m^3	500-700 m^3	>700 m^3
Average Depths	2.1 m	2.3 m	2.5 m
Water stored in top 0.5 m	56%	45%	45%
Water stored in top 1.0 m	76%	71%	71%
Average catchment area (ha)	2-4	3-6	3-6
Domestic use	10%	30%	30%
Stock water only	90%	70%	70%

The shallow storages, given by the volume of water stored in top 1.0 metre of storage contributed greatly to the failure of the reservoir. Where domestic use (gardening) was made of the stored volume the dam failed early in the drought period and small runoff events were quickly used in rewetting the internal surfnce, and not available for use.

3.3 Gully Storages

A reliability of 76% for the gully storages reflects the better use of catchment hydrology in siting the structures. This was evident also in relation to the larger catchments available. Areas averaging 40 ha were typical, while 50% of all gully dams had been located to maximise groundwater resources such as soakages or springs. The higher reliability rate afforded by non-surface runoff during periods of droughts was highlighted in this study. However, the utility of these storage volumes was only possible by 'gate opening' methods, that is, properties were opened internally to allow animal access to gully dams, often the only source of water during this period. Details of the gully dams given in Table III below indicate the larger volumes and deeper storages able to surviye a 'water' drought. Gully storages up to 8000 m^3 were not uncommon on the larger properties but were often designed for minor irrigation purposes as well as stock watering. This study selectively omitted irrigation storages.

TABLE III
TYPICAL GULLY STORAGE DIMENSIONS

	2000 m^3	2-4000 m^3	4000 m^3
Average depths	2.8	3.5	4.0
Water Stored in top 0.5 m	26%	44%	30%
Water stored in top 1.0 m	57%	73%	51%
Average catchment area (ha)	20-30	20-30	40+
Domestic use	10%	10%	10%

The extended period of the 1979-83 drought took toll on shallow storages. On average, storages over 2 metres in depth survived the drought but a condition of reliability was soil type of catchment.

3.4 Catchment by Soil Type

The best correlation related to reliability was soil type of catchment. Two basic soil types are common on New England Tablelands. Duplex soils derived from palaeozoic sediments and Jurassic granites and uniform fine soils derived from tertiary basalts. Duplex catchments responded better to the intermittent high rainfall events during 1979-83, producing runboff from smaller events than required to produce runoff from basaltic soils. Seasonal cracking of the heavy clay soils allowed surface detention of small events while the more productive pasture depleted soil moisture storage. In two dams on chocolate soils, monitored for the period of the drought, runoff over the three years did little more than rewet the internal storage surface, however an adjacent dam on a Lateritic Podzolic of similar catchment area maintained a reliable supply. The hard setting surface of the latter benefited runoff production. Failure rate of dams on chocolate soils was 85% while podzolic failure average 40% where catchment parameters matched storage.

3.5 Catchment Characteristics

Other characteristics which indicated an advantage to runoff production during the drought were native pastures and roaded catchments. Native pasture catchments on average produced twice the volume of runoff on similar soils and catchment areas to improved or semi improved pasture. Runoff from native pasture was estimated at 14% on two homogenous soil type (duplex) native catchments while a similar sized catchment on improved pasture was estimated at 6% of rainfall over a similar 6 month period. An estimate of runoff from chocolate soils from both pasture types was not possible however an improved pasture on chocolate soils returned 3% for the 1982 year. Runoff in normal years has not been shown to be significantly different except where "partial areas'' contribute proportionally higher amounts on the duplex soils.

Roaded catchments are considered sound methods of runoff production from low rainfall events. Diverting runoff from roadside tabledrains improved reliability where employed. Eleven dams considered failures based on other criteria had all performed well during the drought, six had provided additional domestic water for maintaining gardens. The construction of simple banks from the public road easement to route runoff into a small storage is a viable means of providing runoff from small events. It often provides a reliable method of controlling roadside runoff through property boundaries.

3.6 Leakage and Evaporation

Loss of stored water by surface evaporation is inevitable at any time of the year and often cannot be reduced from potential open pan evaporation rates, however, the loss through leakage can be avoided by pre-construction inspections of foundation materials. Leakage from recently constructed dams was common in both duplex and uniform soils following initial filling in April/May 1983. The heavy clay dams sealed within the first 6 months but many dams on the duplex soils were still leaking some 18 months later. Ironstone layers, pervious shales and fractured rocks aggravated leakage in both hillside and gully storages. Where it was possible to estimate losses, podzolic soils lost up to 25 mm per day. The situation was often not easily rectified because of absence of suitable clay material in close proximity.

Leakage losses were repaorted in the majority of dams (68%) which had been cleaned during the drought. A loss of biological slime on the water/soil interface is expected as the cause of the induced loss. Except where cleaning had exposed a porous substrate, this type of seepage ceased within 6 months after filling.

There was no evidence that dams had been built in sheltered locations to reduce loss of water by surface evaporation nor of maximising water use before annual evaporation removed the largest volume. In all cases 50% of stored water would be lost within one year of drought condtions. The 1979-83 drought period resulted in a net evaporation loss of 2.4 metres. Excluding seepage loss and aggravated evaporation all hillside dams surveyed could be expected to fail within a three year drought. However other factors such as catch banks and catchment management reduce this failure rate.

4 DISCUSSION

The survey highlighted several oversights in the planning phase of farm water storage construction. Because of the principle of "one paddock - one dam" sound hydrologic principles relating to runoff, land use, soil type and soil cover are often ignored. Where dams were located in positions which fulfilled many of the criteria, reliability was high. Although most dams failed at least once during the drought, recovery of the latter was speedier and assured, The addition of roaded catchments into the farm catchment provided additional runoff but was not seriously pursued in all possible cases.

Dams were more often placed where it was thought they were the most useful for stock water and/or domestic purposes (inclusive of aesthetic reasons) rather than for reasons of hydrologic principles. Hobby farm owners, in particular, were culprits of this, however, irrespective of hydrologic variables many dams on small holdings were shown to be of little use except in above average rainfall years. On one new small area subdivision five 500 m^3 dams were constructed each having a catchment of less than 1 ha. The purpose of construction was reported as being for aesthetic reasons, a fact too easily proven in these types of subdivision.

Lack of sufficient depth to counter evaporation losses during extended drier years was the major factor contributing to farm dam failure. Leakage losses were significant only on ironstone or fractured shale country, areas which could be avoided by strategic subdivision.

Reticulation from dams was perceived by landowners as creating more problems than it solved. Where reticulation was used it was shown to be superior to a complex of smaller storages, however, the hydrologic requirements for the particular supplying storage had in all cases been well implemented.

Selection of soil types for farm catchments is often beyond the physical attributes within the property boundaries while the mix of native and improved pasture will depend upon soil types, topography and level of commercial enterprise. Thus the selection of these variables to maximise runoff can only be performed where the natural features permit. Hobby farms do not fall into this category hence methods such as roaded catchments, contour banking, and maximising catchment topography must be employed rather than rule of thumb or aesthetic measures.

5 CONCLUSIONS

Drought proofing farm water storages on the New England Tablelands must consider two levels of need - the commercial farming enterprise occupying areas in excess of 100 ha hence able to select appropriate dam sites; and small area landowners (hobby ,farmers) who must accept less than ideal physical constraints. However both purposes must aim to maximise runoff collection by choice of:

(a) an adequate volume of water stored at a depth greater than 2 metres to combat evaporation loss;

(b) selection of sites indicating high water holding qualities or having suitable resources for providing an artificial seal against leakage;

(c) avoiding small volume (< 1000 m^3) hillside storages on uniform soils unless complemented by roaded catchments or contoured catchments;

(d) siting of dams according to sound hydrologic principles not on subdivisional boundaries or aesthetic value.

(e) construction of reticulation systems to supply water from most ideally positioned reservoirs, located by (d) above.

6 ACKNOWLEDGEMENTS

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