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A review of four on-farm water supply demonstration farms

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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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1. Summary

In March 1982, the Western Australian Government allocated $100,000 to the Department of Agriculture to demonstrate appropriate, reliable, on-farm water conservation technology on four farms in the north-eastern wheat belt. The Government grant was matched dollar for dollar with the farmers funds with a maximum of $25,000 grant to any one farm. The demonstrations used existing techniques, such as dams and roaded catchments, to establish permanent drought-proof water supplies.
The farm water supply improvements were designed and constructed in the period November 1982 to December 1985.

Seven years after the water supply improvements were completed; all four farmers have stated they believe that the demonstration farm water supplies are highly successful. In response to the increased water supplies all four farmers have increased their water demand. Gardens are flourishing, and until the 1991/92 summers none had carted water for livestock since the project began. Two of the four fanners still cart water for their domestic supply, although they are both aware that supply reliability could be improved by fixing guttering and ensuring that more existing roof area drains to tanks.

All four farms now carry sheep numbers close to the optimum for the region. Feed supply is now the major factor limiting sheep numbers.

The new dams and catchments on the four farms were designed using the DAMCAT (1976) water supply design model. However, according to the more conservative estimates of the updated DAMCAT II (1988) water supply design model, the four water supply systems were designed to a standard less reliable than was originally intended. If the farmers continue to over-use these water supply systems it is very likely that supplies will fail in years of low rainfall. Through 1991, and in the summer of 1991/92, the rainfall was the lowest for many years. Surface water supplies in the north-eastern wheat belt were put to a severe test. The performance of the four demonstration farms during this period was of great importance since those farms were solely reliant on surface supplies. In the summer of 1991/92 one farmer of the four carted 250 kL of water for garden and livestock use over a six-week period, and another carted water for domestic use only.

The reasons for the water carting were mainly related to the following factors:

1) Not all works were implemented as designed: e.g. some small dams were originally proposed to be larger, some dams with only farmland catchments were originally proposed to roaded catchments or other improved catchments, and some roof areas required guttering to divert runoff to storage tanks; and
2) Some roaded catchments were not maintained and weed growth limited runoff into dams.

There is a clear need to extend the demonstration results to other farms. The concept of whole-farm water supply improvement must be emphasised rather than looking at individual designs of catchments or dams. Farmers must be encouraged to develop long-term plans with consequent long-term financial benefits if water supply self-sufficiency is to be achieved.

2. Introduction

2.1 Aims

The aim was to demonstrate that reliable water supplies could be established on farms in the north-eastern wheat belt using existing technology. This was to be achieved by planning and implementing permanent water supplies with adequate distribution to provide farm water requirements in years of low rainfall and thus reduce the dependence on water carting.

The report describes the original water supplies on the farms, the improvements made and the new supplies constructed during the course of the project. A profile of the farm operations and farmers' attitudes to water supply are described both before the project began and seven years later.

2.2 Background

In 1981, the Federal Government advised that no financial support would be available to assist with the construction of the North Eastern Agricultural Water Supply (Agaton Project), and the State Government subsequently announced that the State could not afford to construct the project alone.

The cost-benefit study of the Agaton Project and the on-farm water supply alternative (Agaton Cost-Benefit Study Group, 1981) indicated an unfavourable benefit-cost ratio for the piped water scheme, and a favourable ratio for the on-farm alternative.

Following discussions with the Department of Agriculture, the State Government allocated $100,000 to be used to demonstrate reliable on-farm water supply technology.

One farm in each of four shires in the north-eastern wheat belt was selected by the respective Shire Council, and a water supply improvement program was designed and implemented by the Department of Agriculture in conjunction with each farmer and experienced construction contractors.

The area has an average annual rainfall of between 275 mm and 325 mm, an average annual Class A pan evaporation of 2.9 metres, and an average annual dam evaporation of 2.1 m (Luke et al. 1987). Several years of below average rainfall in the late 1970s and early 1980s drew attention to the vulnerability of farm water supplies in the district. Typical problems associated with water supplies were:

- difficulty in siting dams;
- leaky dams;
- inadequate catchments; and
- limited groundwater of livestock drinking quality.

Distribution of the water around the farm was an important feature of the water supply improvement plan. Although distribution does not increase the quantity of water in storage, the ability to reticulate water to paddocks where dam sites are hard to find improves the prospects of securing a satisfactory water supply on most north-eastern wheat belt farms.

2.3 Farm water situation prior to project implementation

The farms which were selected are listed below with brief notes regarding the nature and degree of water supply shortage on each farm before the water supply improvement program.

Farm 1

A property 10 km west of Kalannie in the Shire of Dalwallinu.

Although sheep numbers were reduced over summer, the farmer carted nine kL on average once a week for three months from the Kalannie standpipe, a 20 km round trip. Re-cycled laundry water was used to water a small garden. Water was not carted for the garden.

Farm 2

A property eight km north of Cleary in the Shire of Mt Marshall.

Sheep and pig numbers were severely restricted by lack of water and water carting was a continual chore, although the Cleary Rocks standpipe was less than five km from the property. There was no water allowance for the garden.

Farm 3

A property 10 km from Bonnie Rock, in the Shire of Mukinbudin.

When water deficiencies occurred before 1983, the farmer destocked the farm rather than cart water for livestock. However, water was carted for domestic use. Over three months of summer, the average amount carted was five kL per day for five days per week. Water was carted from the Bonnie Rock standpipe 10 km away, the Karloning tank or the Beringbooding Rock.

Farm 4

A property 40 km north of Koorda, in the Shire of Koorda.
Before 1983, the farmer supplemented his water supply by restricting demand and by carting water 12 km from the Kulja dam.

3. Method

3.1 Demonstration projects

Within the north-eastern wheat belt, four Shire Councils (Dalwallinu, Koorda, Mt Marshall and Mukinbudin) were asked to nominate farms with severe difficulty in obtaining water. One farm in each Shire was chosen to participate in the project. The farmers and the Department of Agriculture shared the costs equally, up to a total of $50,000 for each farm. Additional costs were met by the farmers. A locality map of the four farms is shown in Figure 1. Planning, design and investigation of the water supply improvements was commenced in 1982.

In planning the water supply improvements the water supply design model DAMCAT (Frith, 1976) was used. The model simulates a flock of sheep drinking water from a dam equipped with a roaded catchment. It allocates a dry sheep equivalent (DSE)* rating to each dam indicating the number of sheep that may be watered continuously through a 25 year simulation period without the dam going dry.

The farmers' preferences for a secure water supply were also incorporated into the farm water plan. Some of these works were not considered necessary for drought proofing but were installed to provide better water supply distribution.

3.2 Review of demonstration projects

The farms were visited between January 1990 and October 1990. The following measurements were taken:

- dam size;
- roaded catchment size;
- dam construction material;
- total depth;
- batter slope;
- volume and depth at time of measurement;
- seepage from the dam;
- presence of a piped inlet;
- freeboard;
- salinity of water; and
- pH of water.

The farmers were interviewed to find if the works performed to their expectations. They were asked questions relating to their present demand for water, their future demands and whether the present system would cater for their plans. Questions regarding the use and reliability of domestic supply were also asked.

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*See Appendix I.
**See Appendix II.

An updated farm water supply design model, DAMCAT II (Denby and Hauck 1988), is now in use in the Department of Agriculture. DAMCAT II** is regarded as a more appropriate design tool than the original DAMCAT (1976) due to changes to some of the design parameters in the model.

DAMCAT II was used to rate the carrying capacity of the dams in this review, and it was generally found to allocate fewer DSE's to a particular dam than the original design. Also, a water supply design model, RAINTANK (Laing et al. 1988; Laing, 1990), which was not available when the project commenced, was used to evaluate the reliability of domestic water supplies based on demand, tank volume and roof area.

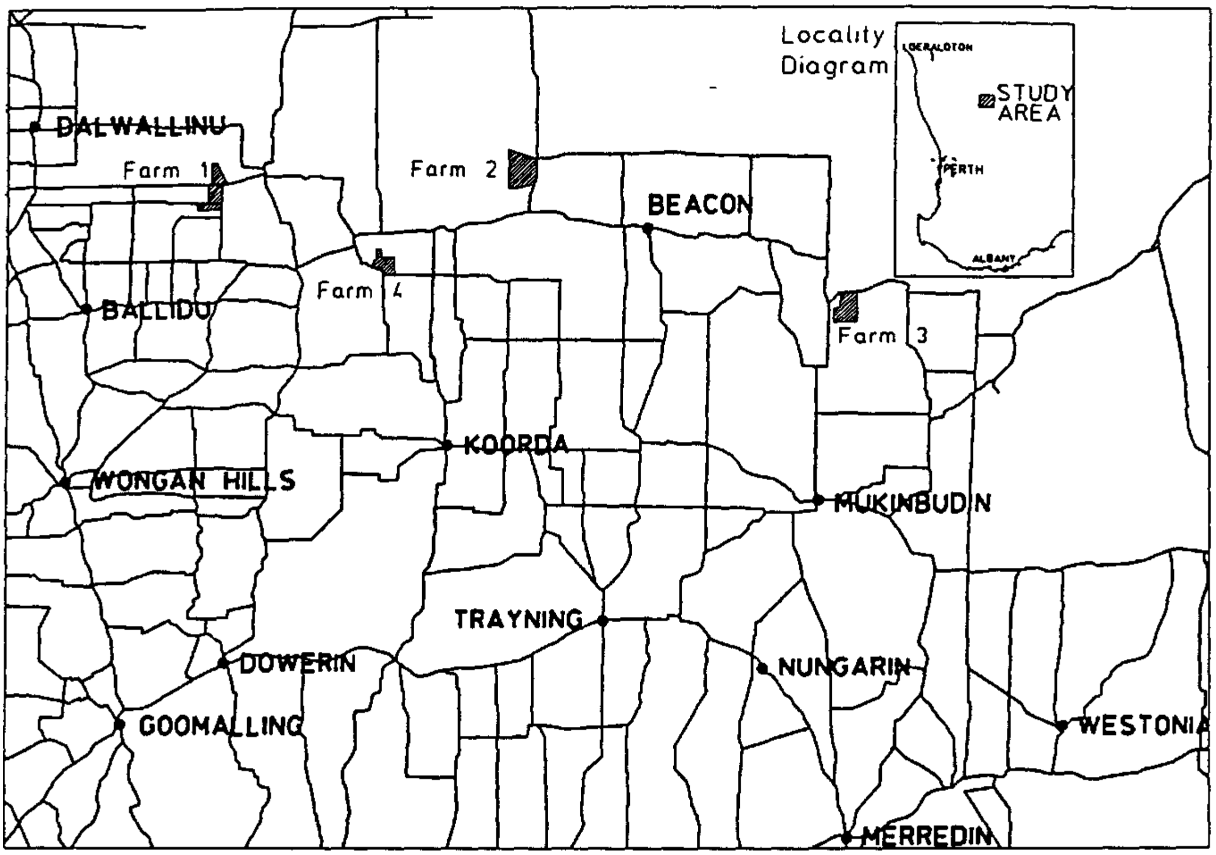


Figure 1. Locality map.

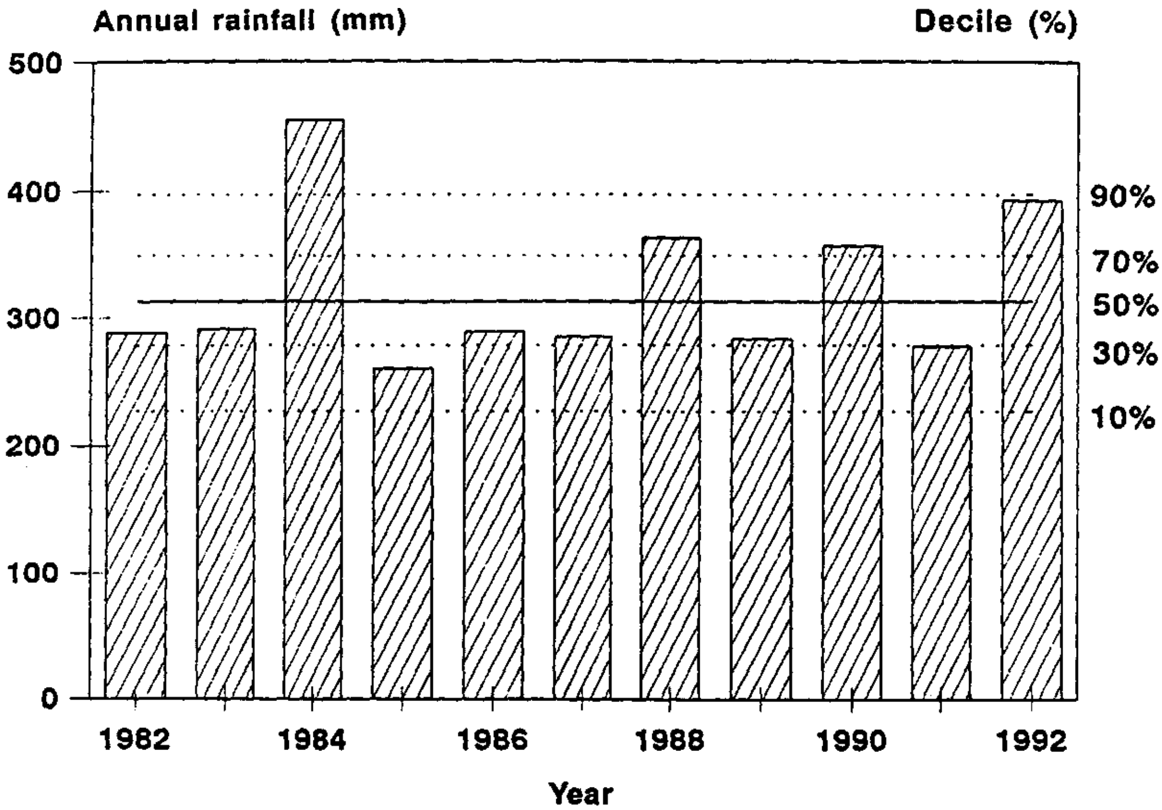
The present demand was estimated and with the calculated supply figure, a deficiency or excess water supply was determined. This indicated whether the water supplies were being over-used.
The new dams constructed on the four farms during the project were all built by one contractor using a 210 kilowatt Komatsu bulldozer.
The new roaded catchments were all constructed with a road grader, at a time when soil moisture content was sufficient to allow effective soil compaction. Compaction was applied more or less continuously during catchment formation. At least two passes of the finished catchment surface were made with a static (non-vibrating) roller.

Two types of rollers were used on different farms - a self-propelled vibrating steel drum roller, and a rubber-tyred roller.

A second review of water supplies on each farm occurred in March 1992 as a result of the particularly low rainfall recorded in the region from mid-1990 to March 1992. A review at this time was regarded as a valuable opportunity to evaluate the project following a critical period.

To illustrate the annual rainfall pattern for the duration of the project and the period of the review, annual rainfall data for Beacon from 1982 to 1992 is presented in Figure 2.

Monthly rainfall data for the four farms are presented in Table 1 and in Figure 3, for the critical water supply period July 1990 to August 1992.



Average annual rainfall of 313mm

Figure 2. Beacon annual rainfall 1982-1992 (Station 010264).

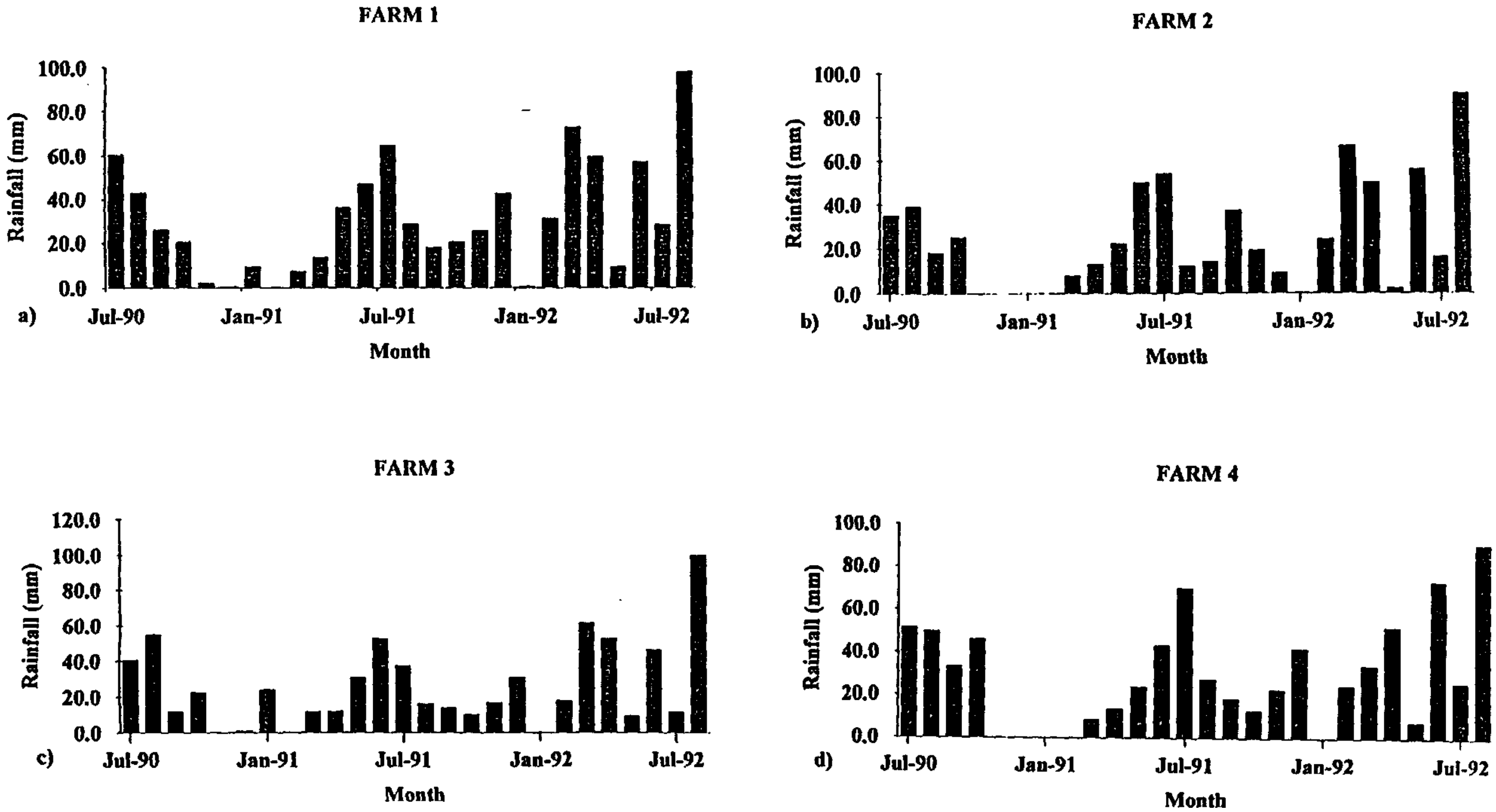


Figure 3. Monthly rainfall for the demonstration farms from July 1990 to August 1992; a) Farm 1, b) Farm 2, c) Farm 3 and d) Farm 4.

Table 1. Monthly rainfall data for the four demonstration farms, for the period July 1990 to August 1992

	Farm 1 (mm)	Farm 2 (mm)	Farm 3 (mm)	Farm 4 (mm)
July 1990	60.5	35	40.6	51.5
August	43	39	55	49.8
September	26	18	11.6	33.3
October	20.5	25	22.2	46
November	2	0	0	0
December	0.5	0	1	0
January 1991	9.5	0	23.8	0
February	0	0	0	0
March	7.5	8	11.6	8.3
April	13.5	13	11.8	13.5
May	36	22	30.8	23.8
June	47	50	52.8	43.3
July	64.5	54	37.6	70
August	28.5	12	16	27.3
September	18	14	13.8	18.5
October	20.5	37	10.2	12.8
November	25.5	19	17	22.5
December	42.5	9	31.2	42
January 1992	0.5	0	0	0
February	31	24	18	24.5
March	73	67	62	34
April	59.5	50	53	52
May	9.5	2	9.4	7.5
June	57	56	46.6	73.5
July	28	16	11.8	26
August	98	91	94	91

4. Results

A detailed review of the water supply of each of the four farms is described below.

4.1 Farm 1

Farm 1 consists of two blocks covering 2,223 ha, of which 2,170 ha are cleared. About 60 per cent of the cleared area is cropped each year to wheat, lupins and barley. The average annual rainfall is 309 mm.
A farm plan, including the new dams, is shown in Figure 4.

4.1.1 Situation before the project began (1983)

The demand for, and supply of water on Farm 1, before the project began in 1983, are presented in Table 2.

Table 2. Demand and supply of water on Farm 1, before the project began in 1983

Demand	DSE		kL/year
House garden	0		0
Sheep	2,000		1,800
Pigs	3,000		2,700
Total demand	5,000		4,500
Supply	**Capacity**	**Comment**	**DSE rating***
Dam A (m3)	4,500	Previously Leaked	0
Dam I (m3)	4,000	leaked	0
BoreJ(klVd)	20	Salty (900 mS/m)	2,000
Total supply			2,000

* DAMCAT(1976).

4.1.2 Demand projected in 1983

The water demand projected in 1983, for Farm 1, is presented in Table 3.

Table 3. Water demand projected in 1983, Farm 1

Demand	DSE	kL/year
House garden	1,500	1,300
Sheep	3,000	2,700
Pigs	3,000	2,700
Total demand	7,500	6,700

4.1.3 Works planned in 1983

The plan was to supply water for 9,500 DSE by the following works:

- A roaded catchment was to be added to both existing dams, bringing their combined capacity to 1,200 DSE. One of the dams was to supply the house and piggery.
- Two new dams, one of 12,500 cubic metres with a 5.4 ha roaded catchment, the other of 4,500 cubic metres and collecting runoff from a granite outcrop, were to be constructed to supply the house and piggery. Their combined capacity was designed to supply 3,800 DSE.
- Five small dams ranging from 1,000 to 3,300 cubic metres were to be constructed at points spaced around the farm. Three were to have roaded catchments, one to collect water from a granite outcrop, and the other from a farm track. Between them, they were to provide for 2,300 DSE.
- The well supply was to be re-directed to the southern extremity of the farm.
- Dams A and I both leaked rapidly before the project began. Both dams were sealed successfully by blending soils found adjacent to the site and placing the soil in layers and paying particular attention to thorough compaction of the placed soil layers using bulldozer tracks on the moist soil (Frith 1985).

4.1.4 Works done

The previous works (see supply in Table 2) and new works are listed in Table 4.

Table 4. Water supply works, Farm 1

Supply	Capacity (m3)	Comments	DSE rating*
Dam A	5,100	Reliable. Runoff is from 3.5 ha of roaded catchment.	1,000
B	9,000	Reliable. Runoff is from 4.3 ha of roaded catchment and 1 ha of gravel road.	1,900
C	3,300	Reliable. Runoff is from 5.0 ha of rock catchment.	800
D	1,400	Reliable. Runoff is from 2.1 ha or roaded catchment and road.	400
E	1,000	Unreliable. Dam too shallow. Goes dry quickly.	0
F	2,900	Reliable. Runoff is from 1.1 ha of roaded catchment and 500 m of farm track.	300
G	1,000	Unreliable. Dam too shallow.	0
H	1,500	Reliable. Runoff is from 2.5 ha of roaded catchment.	400
I	4,700	Reliable. Runoff is from 3.5 ha of roaded catchment.	1,000
M	2,500	Reliable. Runoff is from 100 ha of natural catchment and rock outcrop.	200
BoreJ	20 kL/day	Reliable. Not used much as salinity level of 900 mS/m limits use to adult sheep.	2,000
K	0	Unreliable.	0
L	9 kL/day	Unreliable. High salinity levels limit use.	0
		Total livestock and garden supply	8,000

* DAMCATII(1988).

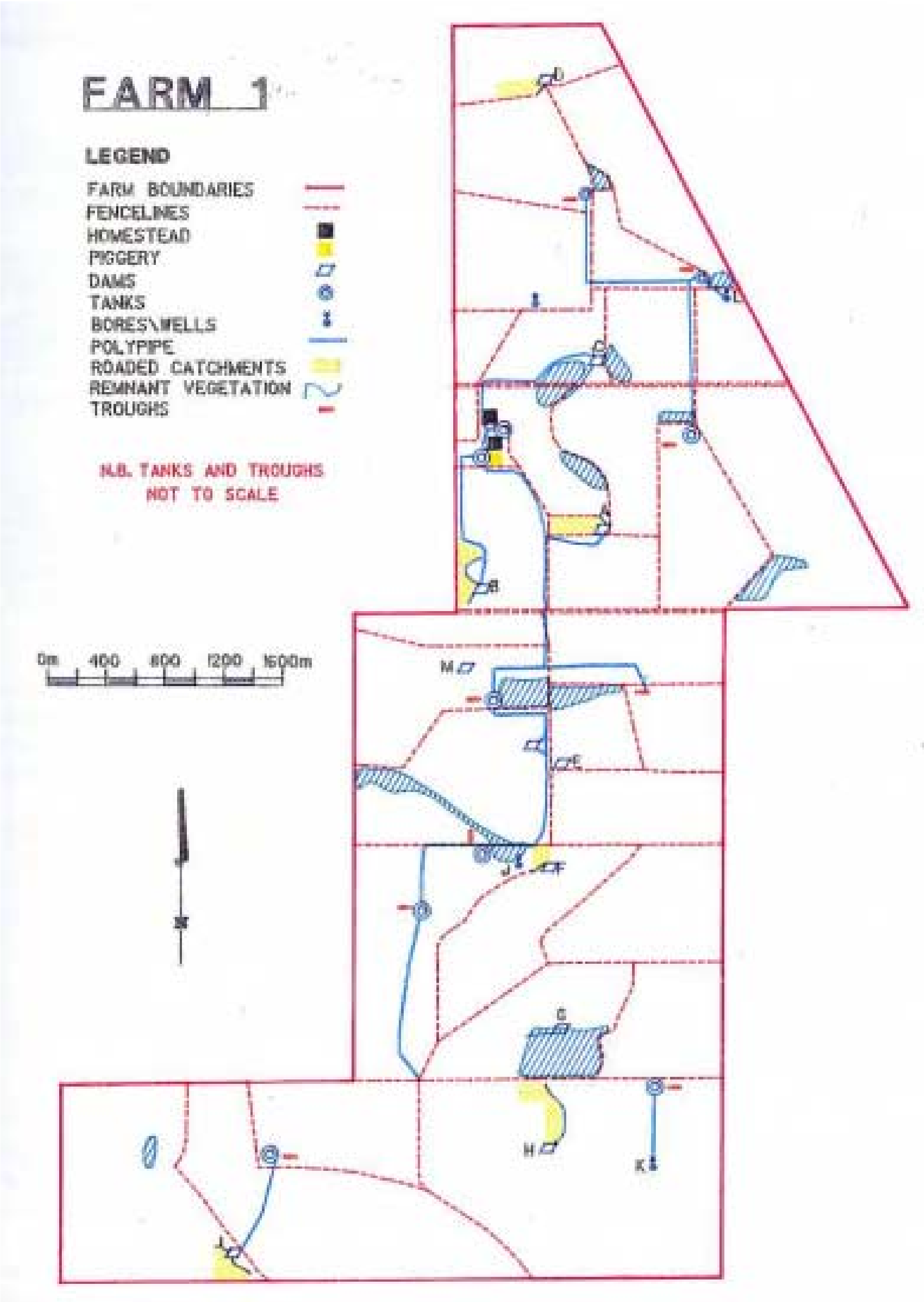


Figure 4. Farm 1 - Farm Plan.

The following aspects of the project require special comment. One proposed roaded catchment was not constructed (on Dam M), thereby limiting supply; and the smaller dams with no improved catchments (in particular, Dams E, G and M) can only cater for a small demand.

A degree of earthworks instability is evident on two dams.

On one of these a side bank has eroded and collapsed, although damage is only slight.

On Dam B a side bank is also actively eroding. This dam should be inspected regularly and a maintenance plan devised. Continuing erosion during rapid inflow will increase the risk of the side bank collapsing.

Initially weeds on the catchments were sprayed regularly with glyphosate which proved quite effective.

Some characteristics of the dams are listed in Appendix HI, roaded catchment specifications are listed in Appendix IV, and some further details in Appendix V.

4.1.5 Cost

The total cost of the project for Farm 1 was $50,000: $32,000 for the dams and roaded catchments and $18,000 for reticulation and troughs. These are 1983 figures.

4.1.6 Situation report - January to July 1990

The farmer stated that the improvements were a good investment. Water has not been carted since the project began. However, he has increased his demand for water to greater than was projected in 1983. The farm water demand in 1990 (summarised in Table 5) was 10,100 DSE.

The amount of water used on the garden was underestimated and the introduction of goats to the farm was not foreseen. However, sheep numbers have stayed constant.

The farmer is so confident he has drought-proofed his farm, he has sold his water-carting truck. He is happy with the way the dams and roaded catchments are performing. Minor erosion and weed growth on roaded catchments and the occasional blocked piped inlet to a dam are viewed as manageable. He has not sprayed the roaded catchments for weeds for some years in case the chemical killed the marron and koonacs in the dams but he intends to spray in the future to prevent the weeds from getting out of control and limiting runoff.

Table 5. Water demand for Farm 1 in 1990

Demand	Numbers	DSE	kL/year
House gardens	2	1,800	1,600
Sheep - Ewes	1,300		
- Wethers	100		
-. Lambs	1,000		
- Ewe hoggets	480		
- Rams	24		
Total sheep	**2,904**	3,000	2,700
Pigs - Sows	50		
- Growers	400		
-			
Total pigs	**450**	5,000	4,500
Goats	**150**	300	270
Total demand		10,100	9,070

The farmer is convinced that water does not limit sheep numbers. He believes that the limitation to increased sheep numbers is the amount and quality of pastures and stubbles. His sheep numbers however, have increased by 1,000 since 1983. Lamb numbers are unchanged.

The pigs, which are housed in sheds, have increased from 30 sows in 1985 to 50 sows in August 1990, an increase of nearly 70 per cent. Total pig numbers for August 1990 were 450 which included 400 growers. Presently, they use on average 4,500 kL of water per year (or 12.3 kL per day) in the piggery. The ratio of pig drinking water to washdown water is about 1:11.

Goats were not run on the farm before the new water supplies were installed. Numbers are not expected to increase.

House

There are two houses on the farm. One house has on average three adults in full-time residence, while the second house has two adults and three children. All domestic water supplies come from rainwater collected off the roofs of the houses and sheds.

Each house has a flush toilet, a shower and an automatic washing machine. The total amount of water used per annum in the two houses is 260 kL.

All possible house and shed roofs are connected to storage tanks with a total volume of 302 kL. One new tank and shed roof have been connected since the project was completed. The tanks are interconnected with pipes. Total roof area connected for domestic supply is 1,420 m^2.

RAINTANK (Laing et al. 1988) Indicates that there should be greater than 98 per cent reliability for the domestic water supply if the daily demand averages 800 L for the houses (Figure 5). When the domestic water is in short supply, dam water is used in the toilet and for the shower. The dam water is treated with lime to settle suspended clay before it is pumped from a 90 kL tank which normally stores dam water for the garden.

Garden

Each house has a reticulated lawn with a total area of approximately 100 m2. One house also has a few fruit trees, and a number of native trees and shrubs. There is a small shade house for pot plants and a vegetable garden. The second house also has native trees and shrubs and a small vegetable garden. The owners may expand the garden.

The two houses combined use an average of 1,600 kL per year for garden watering. However, in the first year of operation the water from the house dam was cloudy, indicating a high level of suspended clay, and the lawn died off after watering. Although nothing was done to treat the problem it has not recurred, and it seems likely that the new dam and catchment earthworks resulted in higher levels of turbidity than have been experienced in subsequent years.

Water for the garden is pumped from Dam B initially, followed by Dam A and then C (Figure 4).

4.1.7 Situation Report - March 1992

Although the water level in the "key" supply (Dam B in Figure 4) was low, sufficient water for more than four weeks supply remained at mid-March, when widespread storms caused significant runoff and replenished the water source in all dams. No water has been carted since 1983.

Projected demand

Future water demands for Farm 1 are presented in Table 6.

Table 6. Projected demand for Farm 1, in 1990

Demand	**DSE**	**kL/year**
House gardens	2,000	1,800
Sheep	3,000	2,700
Pigs	6,000	5,400
Goats	300	270
Total demand	11,300	10,170

The farmer considers that sheep and goat numbers will not be increased but more pigs may be carried if extra sheds are built. The garden size may also be increased.

Comprehensive water scheme

Presently, there is a proposal to extend the Comprehensive Water Scheme past the house providing the farmer pays installation and labour costs. He believes his current water supply is sufficient and more economical and he will not need the pipeline.

Farm 1 – Demand 800 L/day

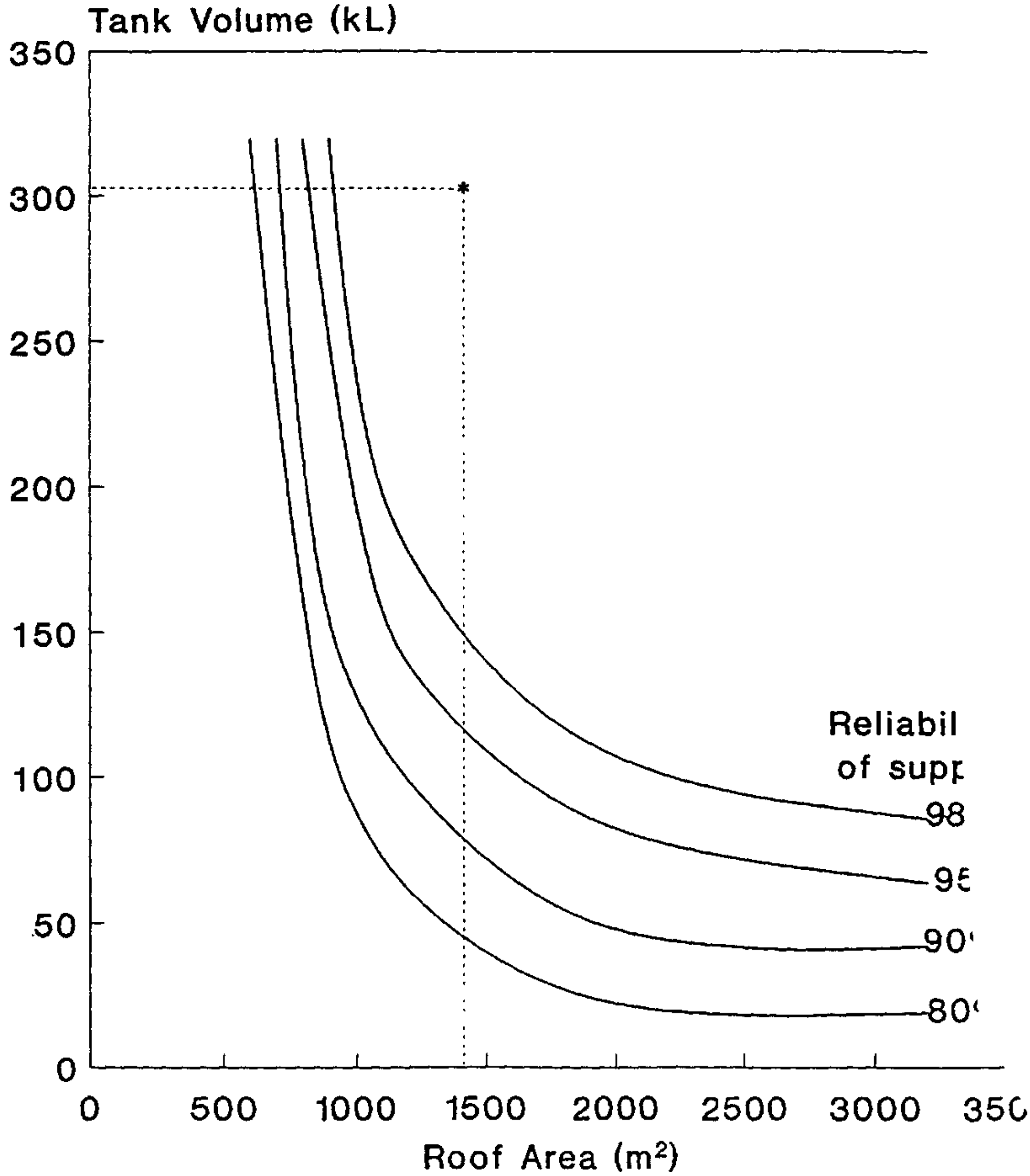


Figure 5. Raintank curves - Farm 1.

4.2 Farm 2

Farm 2 consists of three blocks totaling 5,000 ha. Only 80 ha are uncleared. About 50 per cent of the cleared area is cropped each year to a combination of wheat, barley, oats and lupins. The average annual rainfall is 300 mm.

A plan of the farm is presented in Figure 6.

4.2.1 Situation before the project began, 1983

The demand for and supply of water on Farm 2, before the project began in 1983, are presented in Table 7.

Table 7. Demand and supply of water on Farm 2, before the project began in 1983

Demand	**DSE**		**kL/year**
House garden Sheep Pigs (600) Total demand	0 3,000 3,000 6,000		0 2,700 2,700 5,400
Supply	**Capacity**	**Comment**	**DSE rating***
DamF DamG DamH Bore A BoreB BoreC BoreD	1,000m3 1,000 m3 700m3 20 kL/day 10 kL/day 4 kL/day 3 kL/day	Dam too shallow Dam goes dry Dam goes dry Good supply Good supply Unreliable supply Unreliable supply	0 0 0 1,000 1,000 0 0
Total supply			2,000

* DAMCAT(1976).

4.2.2 Demand projected in 1983

The water demand projected in 1983, for Farm 2, is presented in Table 8.

Table 8. Water demand projected in 1983, Farm 2

Demand	**DSE**	**kL/year**
House Gardens Sheep Pigs (800) Total demand	2,000 3,000 4,000 9,000	1,800 2,700 3,600 8,100

4.2.3 Works planned in 1983

The deficiency amounted to 7,000 DSE. The plan was to improve the supply to provide an additional 8,300 DSE by:

- Constructing a 6,800 cubic metre dam with a small roaded catchment to supplement some good natural catchment of rock outcrop and farm tracks. This dam was to supply two homesteads and the piggery by siphoning and gravity.
- Constructing a dam of 6,300 cubic metres with four hectares of roaded catchment and to collect runoff from public roads and a farm track. Water was to be pumped by windmill to one homestead and the piggery.
- Constructing a 4,400 cubic metre dam with four hectares of roaded catchment and equipping it with a windmill to supply several surrounding paddocks.
- Distributing four smaller dams varying in size from 500 to 1,500 cubic metres at strategic points around the main farm block. Two of these dams were not designed to be permanent supplies, but were to be supplemented from the larger dams.
- Building one dam of between 2,000 and 3,000 cubic metres.
- On the northern margin of the property building two dams, each of about 2,500 cubic metres with two hectares of roaded catchment on each.

The works were completed in 1984, although the sizes of structures built varied from the planned sizes.

4.2.4 Works done

The previous works (see supply in Table 7) and new works are listed in Table 9.

Table 9. Water supply works, Farm 2

Supply	**Capacity (m3)**	**Comments**	**DSE rating***
Dam A	6,100	Reliable. Runoff is from 4.5 ha of roaded catchment and public road.	1,300
B	9,700	Reliable. Water runs from 5.6 ha of roaded catchment and rock outcrop.	2,100
C	800	Unreliable. Dam is shallow and dries up quickly.	0
D	1,700	Unreliable. Only relies on natural catchment to fill. It is also shallow.	0
E	2,600	Unreliable. Dries up without regular rainfall. Runoff is from 100 ha of farmland and a track.	0
F	1,400	Unreliable. Dam is too shallow to remain a permanent supply.	0
G	2,600	Unreliable. Dam leaks and insufficient natural catchment.	0
H	1,500	Unreliable. Dam is too shallow and dries up quickly.	0
I	7,700	Reliable. Runoff is from 3.8 ha of roaded catchment and a public road.	1,300
J	2,000	Reliable. Catchment includes 1 km of Shire road and 100 ha farmland.	200
K	900	Unreliable. Dam is too shallow.	0
L	3,400	Reliable. Runoff is from 2.8 ha of roaded catchment.	900
M	1,800	Unreliable. Dam is shallow and it leaks.	0
N	5,500	Reliable. Runoff is from 1.9 ha of roaded catchment.	300
Bore A	10 kL/day	Only used for old ewes. Water is too salty for lambs and weaners.	800
B	}	Not in use: pipes are rusted or water is salty.	0
C			0
D			0
		Total livestock and garden supply	6,900 DSE

DAMCATII (1988).

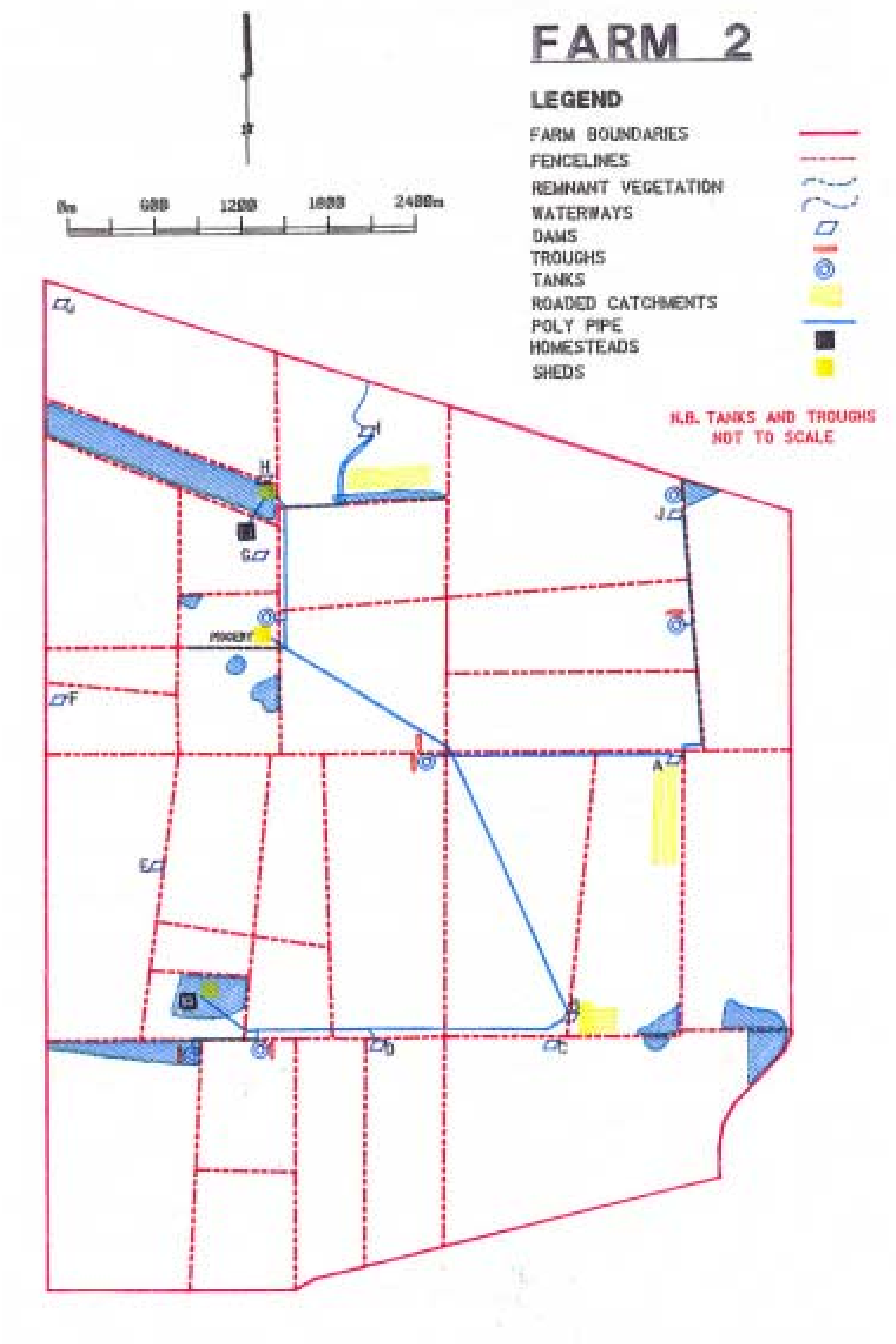


Figure 6. FARM 2 - Farm Plan.

The catchments have each been sprayed once, about two years after construction. A mixture of simazine, atrazine and Sprayseed(r) was used with good results. This was handsprayed from the back of a vehicle. However, the farmer considers he will not spray again, especially since the dams are now filled with yabbies. He feels that on the catchments that were not fenced off, the sheep kept the weeds to a minimum. The manure did not seem to promote weed growth and the problem of dam pollution was minimised with a piped inlet.

Some characteristics of the dams are listed in Appendix VIE and the roaded catchment specifications in Appendix IV.

No new supplies have been built since the demonstration works were constructed. However, another dam was sited hi 1989 on the Cleary block. Contractors excavated approximately 700 cubic metres but hit hard rock and the dam was abandoned.

Extra piping to redistribute water from dams other than A, B or I as originally planned have also occurred. Dam J is now connected by pipe to Dam A. This reticulates another two paddocks on the way. When the water level in Dam J becomes low, water is pumped from Dam A.

4.2.5 Cost

The total cost of water supply construction was $54,000 (1985): $42,000 for dams and roaded catchments, $12,000 for pipes, mills and tanks.

4.2.6 Situation report - January 1990

The demand for water on Farm 2 in 1990 is summarised in Table 10.

Table 10. Water demand for Farm 2 in 1990

Demand	Numbers	DSE	kL/year
House gardens	1	250	210
Sheep - Ewes	1,900		
- Wethers	1,000		
- Lambs	700		
- Weaners	2,300		
- Rams	40		
Total sheep	**5,940**	6,000	5,400
Pigs - Sows	80		
- Growers	850		
Total pigs	**930**	5,400	4,800
Total demand		11,650	10,410

Demand has increased from 6,000 DSE to 11,650 DSE, a rise of nearly 100 per cent since 1983 and a 30 per cent rise beyond projections made in 1983. This implies a deficiency of 4,750 DSE, however the farmer has not needed to cart water for livestock since the works were completed. Since 1984 sheep numbers have been limited by the amount and quality of available pasture.

Before 1984, no more than 600 pigs were run because of the lack of water. The pigs were free roaming but at the time the new supplies were being planned, a pig shed was built. Demand for water was based on estimates for the new intensive piggery - including a large allocation for washdown water. Pig numbers have increased from 600, before 1984, to 930 in 1990.

Piggery washdown and drinking water, used in a ratio of 12:1, totals 4,800 kL annually or 13.2 kL per day. This water is pumped from dams B and A (Figure 6). The farmer believes that because of his increased water supply, he could house up to 1,000 pigs.

Domestic water use and supply

Two families live on the farm in separate houses and their domestic water requirements are supplied from rainwater tanks and water carted from a Water Authority standpipe.

House 1 is occupied by two adults and three children, and their domestic water requirements consist of all in-house uses, plus a swimming pool and a shade-house.

Total annual domestic water use for House 1 is estimated to be 480 kL, of which 190 kL is carted from an off-farm source, and 290 kL is supplied from rainwater tanks.

House 2 is occupied by two adults, and their domestic water requirements consist of all normal in-house water uses.

From the RAINTANK model it can be estimated that the existing system for House 1, consisting of tank capacity of 162 kL and roof area of 1642 m2, should be capable of supplying a continuous demand of 875 litres per day with a reliability of 98 per cent.

Similarly, the existing system for House 2, consisting of 108 kL of tank capacity and 330 m2 of roof area is estimated to be capable of supplying a continuous demand of 150 litres per day with a reliability of 98 per cent.

The RAINTANK systems for House 1 and House 2, considered together, should be able to cater for a combined total demand of 1025 litres per day, which is equivalent to 375 kLper annum.

The above estimates assume that all roof runoff is diverted to storage, but it is known that guttering in both systems requires maintenance and is currently resulting in significant loss from the system.

Another 508 m2 of roof area is available for water harvesting, and if connected to a tank of 54 kL capacity, the system could supply an extra 350 litres per day with a reliability of 98 per cent (equivalent to an extra 125 kL per annum).

Garden

The main homestead has a reticulated lawn covering about 10 m2, and the whole garden, which includes four fruit trees, is about 20 m2. The garden is mostly native trees and shrubs. Water is pumped to the garden from either Dam A, B or I.

Water use is estimated to be one kL per day during the three months of summer and 0.36 kL per day during the three months of winter. Annual water use on the garden is approximately 200 kL. The second house does not have a garden but dam water is still pumped to the house for car washing, etc. Annual water use is about 10 kL.

The water is of good quality with the trees and lawn thriving. No flocculants are used to settle suspended clay in the water. Because the ferns in the shadehouse are susceptible to the slightly cloudy water, rainwater is used.

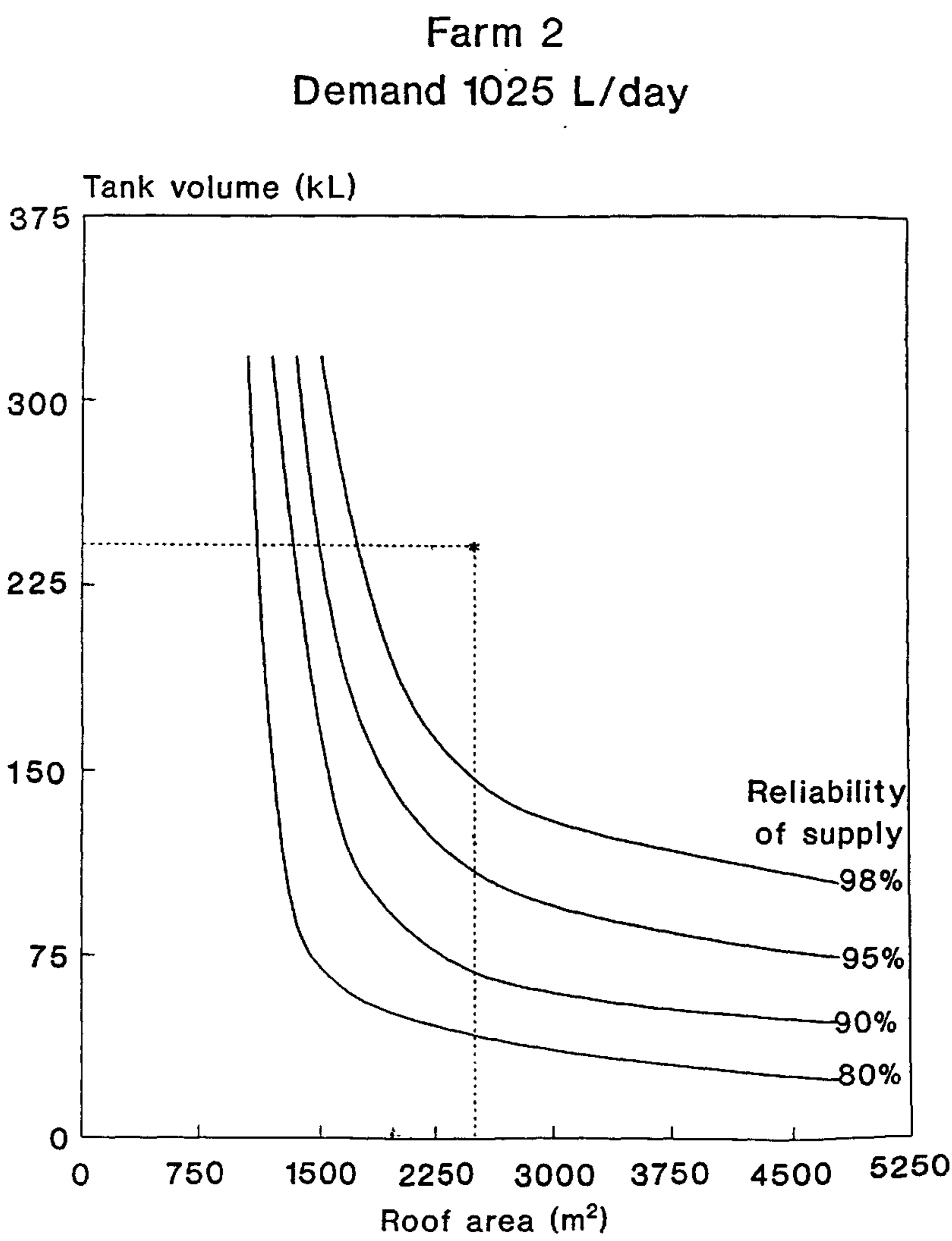


Figure 7. RAINTANK curve - Farm 2.

Water carting

Water is still carted for domestic use but not for livestock. The need for carting is not due to improper design but largely through the need to replace roof gutters.

About 180 kL of domestic water is carted for the main house for four months during summer from a standpipe less than five km from the property. Another 13.5 kL is carted during the rest of the year.

For the second house, 90 kL is carted during the four months of summer. A total of 280 kL of domestic water is carted to the farm throughout the year.

4.2.7 Situation report - March 1992

Prior to Christmas 1991, two of the three major dams on the home block were dry, although no water had been carted from any outside source. Rainfall at Christmas relieved the situation and the system has operated satisfactorily since then.

Projected demand

The farmer believes his sheep-stocking rate is as high as it will ever be, because now feed is the limiting factor. Therefore water demand is likely to be increased only if pig numbers rise or if more water is used in the gardens.

The projected water demand for Farm 2 is presented in Table 11.

Table 11. Projected water demand for Farm 2 in 1990

Demand	DSE	kL/year
House gardens	500	450
Sheep	6,000	5,400
Pigs (1,000)	6,000	5,400
Total demand	12,500	11,250

Proposed extension of Government piped water supply

A proposal to extend a Water Authority (WAWA) pipeline past the farmer's house to Cleary Rocks was first mooted in 1988, and was subsequently constructed in 1991. The farmer believes this will not benefit the livestock but will benefit the domestic situation considerably.

In retrospect, there are a few changes the farmer would make to the demonstration project. Most of the small dams would be made bigger. He would also look for a dam site on the very south of the property where there are no reliable supplies but where there is good runoff potential. The farmer is confident he has drought-proofed his farm for livestock water by way of dams and groundwater. He is, however, conscious of his domestic water problem and intends to rectify it.

4.3 Farm 3

Farm 3 has a total area of 2,064 ha of which 1,560 ha are cleared. About 60 per cent of the cleared area is cropped to cereals and lupins each year. The average annual rainfall is 300 mm.

A farm plan is shown in Figure 8.

4.3.1 Situation before the project began

The demand for, and supply of water on Farm 3, before the project began in 1983, are presented in Table 12.

Table 12. Demand and supply of water on Farm 3, before the project began in 1983

Demand	**DSE**		**kL/year**
House garden	500		450
Sheep	2,000		1,800
Total demand	2,500		2,250
Supply	**Capacity**	**Comment**	**DSE rating***
Dam A	6,200	Reliable	500
DamB	2,000	Dam too shallow	0
DamC	1,700	Dam leaked	0
DamD	4,210	Reliable	500
DamE	4,000	Reliable	200
Total supply			1,200

* DAMCAT (1976).

4.3.2 Demand projected in 1983

The water demand projected in 1983, for Farm 3, is presented in Table 13.

Table 13. Water demand projected in 1983, for Farm 3

House garden	1,500	1,350
Sheep	2,000	1,800
Other uses	500	1,800
Total demand	4,000	3,600

4.3.3 Works planned

Improvements planned in 1983 were:

- Three roaded catchments totalling 15 ha were to be added to three of the dams. One of these dams in leaky pallid zone was to be deepened and clay-lined. The combined rating of all dams was to be increased from 1,200 to 5,000 DSE.

- Two new dams of 7,500 and 9,500 cubic metres were to be constructed, both with large natural catchments. One of the dams was to collect runoff from an airstrip and the other was to have four hectares of roaded catchment added. Together, these dams were to provide for 2,500 DSE.
- A distribution network was to be installed, comprising six 55 kL tanks, seven kilometres of 50 mm polythene pipe and three pumping units to convey water to the homestead and to all parts of the farm not directly served by a dam.

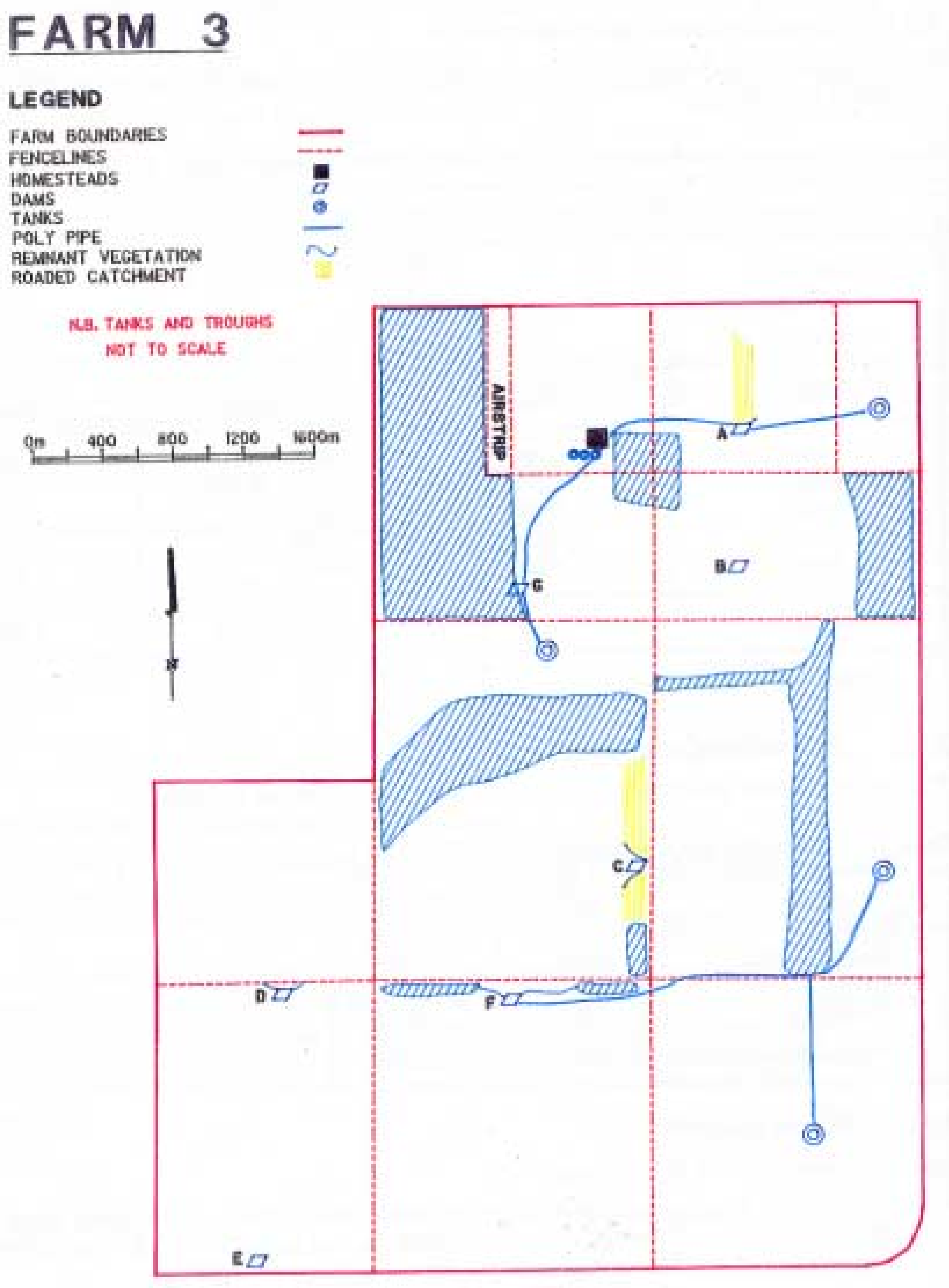


Figure 8. FARM3 - Farm Plan.

4.3.4 Works done

The previous works (see supply in Table 12) and new works are listed in Table 14.

Table 14. Water supply works, Farm 3

Supply	Capacity (m3)	Comments	DSE rating*
Dam A	5,900	Reliable. Runoff is from 3.2 ha of roaded catchment and 500m of road.	1,200
B	1,700	Unreliable. Dam is too shallow.	0
C	2,300	Reliable. Runoff is from 5 ha of roaded catchment.	600
D	3,300	Reliable. Runoff is from 120 ha of farmland catchment including 10 ha of rock outcrop and breakaway.	300
E	3,600	Unreliable. Dam is too shallow.	0
F	10,600	Reliable. Runoff is from 200 ha of natural catchment, 200 m of track and the overflow from Dam C.	2,000
G	6,600	Reliable. Water comes from runoff from an airstrip (1 ha), a large farmland catchment of 300 ha, and the overflow from Dam B.	800
		Total livestock and garden supply	4,900

* DAMCATII(1988).

Erosion in the collecting channels of the roaded catchments is significant. The erosion is due to the dispersive nature of the material and the steepness of the slopes. Piles of rocks have been dumped in the collecting channels to stem the problem but with little success. Reconstruction of the channels may offer a means of managing the problem, by ensuring that water flows are wider and shallower, with some concrete drop-structures to reduce the gradient in the earth channels.

The farmer is concerned about the erosion of the two roaded catchments. He feels that in his location, roaded catchments do not work as effectively as they are claimed to. The farmer claims the granite outcrops around his property could shed enough water to fill the dams, without the need for roaded catchments. Consequently, he has not installed two other proposed roaded catchments.

A problem with the piped inlets the farmer feels strongly about is the need to cap the pipes once the dam is full. He feels it is a messy (and cold) situation fitting the caps on when the water is up to one metre deep. He would like to see his own design, consisting of flexible coupling and extended pipes which can be pulled out of the water, implemented in the future.

Nothing has been done to control the spread of weeds on the roaded catchments. As all chemicals are banned on the farm, an alternative being considered is grading and then recompacting the roads.

Some characteristics of the dams are given in Appendix IX, and specifications for the roaded catchments in Appendix IV.

4.3.5 Cost

The total cost of the improvements in 1985 was $56,000. About $26,000 was spent on dams and roaded catchments, and $30,000 on the distribution system.

4.3.6 Situation report - January 1990

No water has been carted onto the farm since the project was completed. The supply of water for 4,900 DSE outweighs the farm's demand of 4,030 DSE (Table 15) by only 870 DSE. The increase in demand from 1983 to 1990 (1,530 DSE) is mainly due to the increase in garden water use. Sheep demand has not increased.

Table 15. Water demand for Farm 3 in 1990

Demand	Numbers	DSE	kL/year
House garden	1	2,100	1,890
Sheep - Ewes	800		
- Wethers, hoggets and lambs	1,070		
- Rams	30		
Total sheep	**1,900**	1,900	1,710
Horses	**3**	30	30
Total demand		4,030	3,630

In 1983 the new water supplies were estimated to cater for 7,700 DSE, however this did not eventuate, mainly because only two of the proposed four roaded catchments were constructed.

Slightly less sheep were stocked on the property in 1990 than in 1983, mainly due to the limitation of feed. The farmer does not intend to run more than 2,000 sheep on the property. The sheep-stocking rate is about 0.75 DSE per hectare of cleared land.

House

There are eight permanent residents in the only house on the property. All domestic water used is rainwater, collected from shed roofs. Items in the house using most of the water are the toilet, shower and automatic washing machine. However, to save water during the summer months, the wastewater is drained from the washing machine onto the garden. It would also be possible to use clarified dam water for toilet flushing.

Average annual domestic water use is about 260 kL. Previously, about 150 kL was used per year. This was supplemented with water carted from Bonnie Rock, Karloning and Beringbooding, and with dam water treated with aluminium sulphate to settle suspended clay.

Presently 1,190 m2 of roof area is connected to tanks to collect rainwater. Total tank volume is about 164 kL. Using the RAINTANK computer simulation model for a demand of 800 L per day, the domestic water supply should be 97 per cent reliable (Figure 9). However, since the new water supplies were implemented, the farmer has not had to cart water for domestic use.

Garden

Before the water supply was improved, there was virtually no lawn and only a few trees. Now there is about 1,000 m2 of garden with 500 ntf of lawn. A few fruit trees, including stone fruit, have been established while the area of native shrubs and trees has expanded. A small vegetable garden also exists.

Farm 3 – Demand 800 L/day

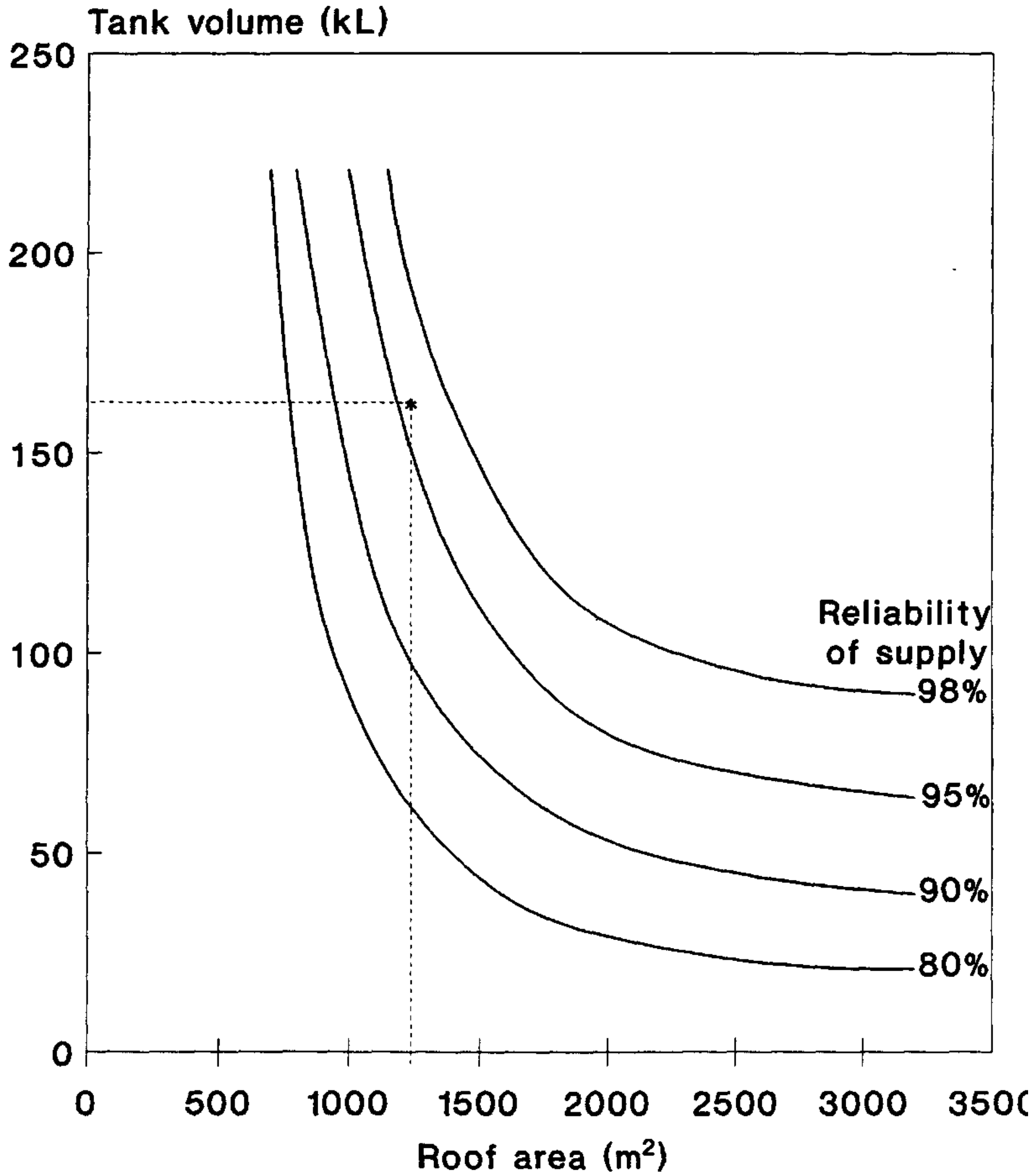


Figure 9. Rain tank curve – Farm 3.

Aluminium sulphate is always added when refilling the tanks to reduce turbidity to an acceptable level. For a few weeks in the summer of 1989/90, the quality of water being pumped from Dam A (Figure 7) deteriorated to such an extent that the lawn grass was dying and the leaves were falling off the trees. This may have been due to sediments in the dam being stirred up after heavy rain in December and January, or the runoff from these rains may have brought a lot of sediment into the dam. In the meantime Dam G was used as an alternative supply. This water quality problem subsequently disappeared.

The average annual water use on the garden is 1,800 kL and is pumped from Dams A and G. Water is applied throughout the year with a peak daily water use in December, January, February and March of 22 kL per day, and a minimum daily water use of 0.5 kL per day in the winter.

4.3.7 Situation report - March 1992

The livestock water supply system is operating well. A small amount (20 kL) of water was carted for the house in February 1992.

Projected demand

As sheep numbers are considered by the farmer to be the highest possible with the present pasture status, the only increase in water demand likely is for the garden. The projected demand for water on Farm 3 is presented in Table 16.

Table 16. Projected demand for Farm 3, in 1990

Demand	DSE	kL/year
House garden	2,500	2,250
Sheep	2,000	1,800
Horses	30	30
Total demand	4,530	4,087

The farmer considers that the $56,000 for dams, catchments and distribution was well spent. An alternative approach to achieving a drought-proof supply at less cost would have been to construct larger roaded catchments on three existing dams. For reasons of personal preference and perceived management convenience, the farmer chose the approach that was adopted.

4.4 Farm 4

Farm 4 consists of two blocks covering 1,266 ha of which 1,166 ha is cleared. About 30 per cent of the cleared area is cropped each year. Average annual rainfall is 313 mm.

A farm plan is shown in Figure 10.

4.4.1 Situation before the project began

The demand for and supply of water for Farm 4, before the project began in 1982, is presented in Table 17.

Table 17. Demand and supply of water on Farm 4, before the project began in 1982

Demand	**DSE**		**kL/year**
House garden Sheep Horses Total demand	200 1,200 100 1,500		180 1,080 90 1,350
Supply	**Capacity**	**Comment**	**DSE rating***
Dam A	7,500	Reliable	500
DamB	2,500	Reliable	200
DamC	4,000	Dam leaks	0
DamD	1,000	Dam leaks	0
Dam E	1,000	Dam too shallow	0
DamF	1,000	Dam too shallow	0
Total supply			700

* DAMCAT(1976).

4.4.2 Demand projected in 1983

The water demand projected in 1983, for Farm 4, is presented in Table 18.

Table 18. Water demand projected in 1983, for Farm 4

Demand	**DSE**	**kL/year**
House garden	1,200	1,080
Sheep	2,000	1,800
Horses (and other uses)	300	270
Total demand	3,500	3,150

4.4.3 Works planned

The water supply planned for Farm 4 was to provide 8,100 DSE and comprised the following:

- The construction of 6 ha of roaded catchment on the existing 7,500 m cubic metre dam, to increase its rating from 500 to 2,400 DSE.
- Two of the small dams were to be deepened and one which overlies pallid zone was to be clay-lined. Their combined capacity would be increased to 1,000 DSE.
- A new 8,500 cubic metre dam with 9 ha of roaded catchment was to provide water to the house and that half of the farm which had no permanent water supply. Its rating was 3,800 DSE.
- A new 3,300 cubic metre dam with 3 ha of roaded catchment was to supply 700 DSE.

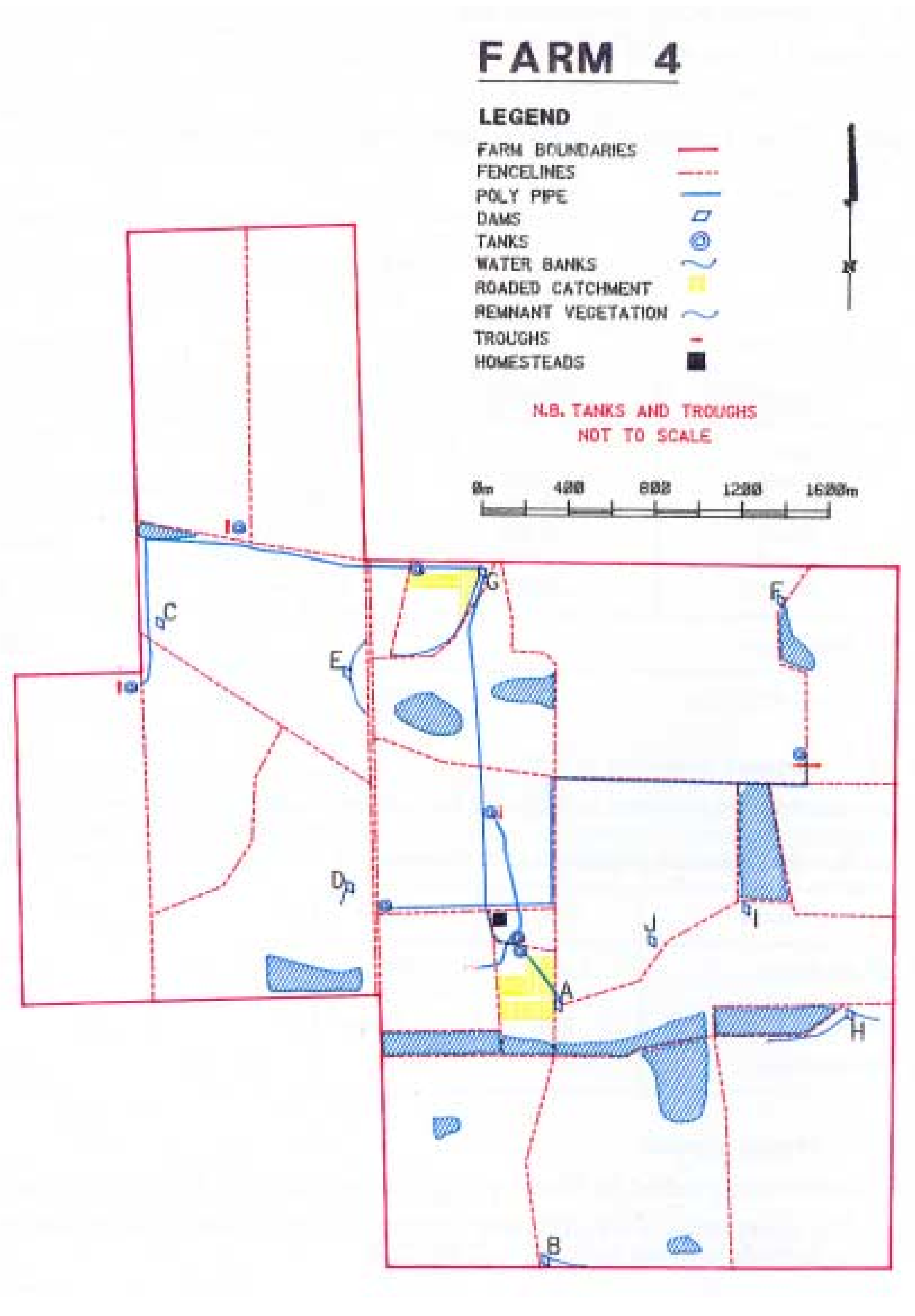


Figure 10. FARM 4 - Farm Plan.

4.4.4 Works done

The previous works (see supply in Table 17) and new works are listed in Table 19.

Table 19. Water supply works, Farm 4

Supply	Capacity (m3)	Comments	DSE rating*
Dam A	7,400	Reliable. Runoff is from 5.4 ha of roaded catchment.	1,400
B	2,600	Reliable. Water runs from 100 ha of crop and 2 ha of public road.	300
C	5,700	Unreliable. Dam leaks.	0
D	2,000	Reliable. Runoff is from 700 m of Shire road and 100 ha of farmland catchment.	200
E	1,100	Unreliable. Dries out quickly due to its small size. Dam leaks.	0
F	3,200	Reliable. Runoff is from 50 ha of farmland.	150
G	5,200	Reliable. Runoff is from 10.6 ha of roaded catchment	3,000
H	2,800	Reliable. Grade banks collect runoff from 50 ha of farmland catchment.	150
I	600	Unreliable. Dam is extremely small and most water is lost by evaporation.	0
J	1,300	Unreliable. Dam is shallow and supplies dry up quickly. Total livestock and garden supply	0 5,200

* DAMCATII(1988).

No new supplies have been constructed since 1984 but a new dam is planned on the eastern block, as well as enlargement of two existing dams and addition of a roaded catchment to Dam H. The catchment was in the initial plans but was never constructed.

Some characteristics of the dams are given in Appendix X and roaded catchment specifications in Appendix IV.

4.4.5 Cost

The total cost of the work was $28,000 in 1983, including $18,500 for the dams and roaded catchments, and $9,500 for the distribution system, tank storages and reticulated irrigation in the garden.

4.4.6 Situation report - January 1990

Of the four demonstration farms, Farm 4 appears to have the best water supply. The farm's present demand is 2,035 DSE while the supply is 5,200 DSE, a surplus of 3,165 DSE. The demand for Farm 4 is presented in Table 20.

Table 20. Water demand for Farm 4 in 1990

Demand	Numbers	DSE	kL/year
House garden	1	800	710
Sheep - Ewes	360		
- Wethers	300		
- Lambs	250		
- Hoggets	250		
- Rams	75		
Total sheep	1,235	1,235	1,130
Total demand		2,035	1,840

From 1983, the farm's supply has increased 750 per cent while the demand has increased by almost 60 per cent, most of which has been due to increased garden and house water use, since sheep numbers have not increased.

Yet the farmer still carts water for domestic use. Also, the roaded catchments have never been maintained and weed growth on them may be limiting runoff. Because of the presence of "poison" bushes, sheep cannot be run on the catchments. Burning of the catchments may spread the bush more. The fanner is aware of the urgent need for maintenance.

Stocking rate is one DSE per hectare of cleared land. Sheep numbers have not increased since 1983 when the water supply works commenced on the farm.

There are no records to show the sheep flock composition hi 1983, but the farmer has stated the flock composition was similar in 1983 to the present.

Horses are no longer run on the property.

House

The main house is occupied by the farmer, his wife and their two small children. Rainwater is used for all domestic use, including washing and toilet flushing and an automatic washing machine. Total average annual domestic water use is approximately 215 kL.

The total roof area connected to tanks to collect rainwater for in-house use is 600 m2. Tank volume is 28.3 kL. With the demand being 600 L per day, RAINTANK indicates less than 80 per cent reliability of supply (Figure 11). This is supported by the fact that the farmer carts water nearly every year in the summer months.

If all available roof areas were guttered and connected to tanks, total area would be I,010m2. To have 98 per cent reliability of supply, tank volume must be at least 100 kL.

Garden

Before the new water supplies were established, the garden comprised native trees and shrubs and a small area of lawn which was watered with dam water.

The homestead now has a reticulated lawn, a few fruit trees, pot plants in an outdoor greenery and native trees and shrubs. The garden covers about 80 m2, of which lawn is 70 per cent.

On average, the estimated garden use is 700 kL per year. Peak summer requirement reaches 5 kL per day but the average use during December, January and February is 3 kL per day. During the three months of winter, about 3 kL is used weekly on the garden.

Farm 4 Demand – 600 L/day

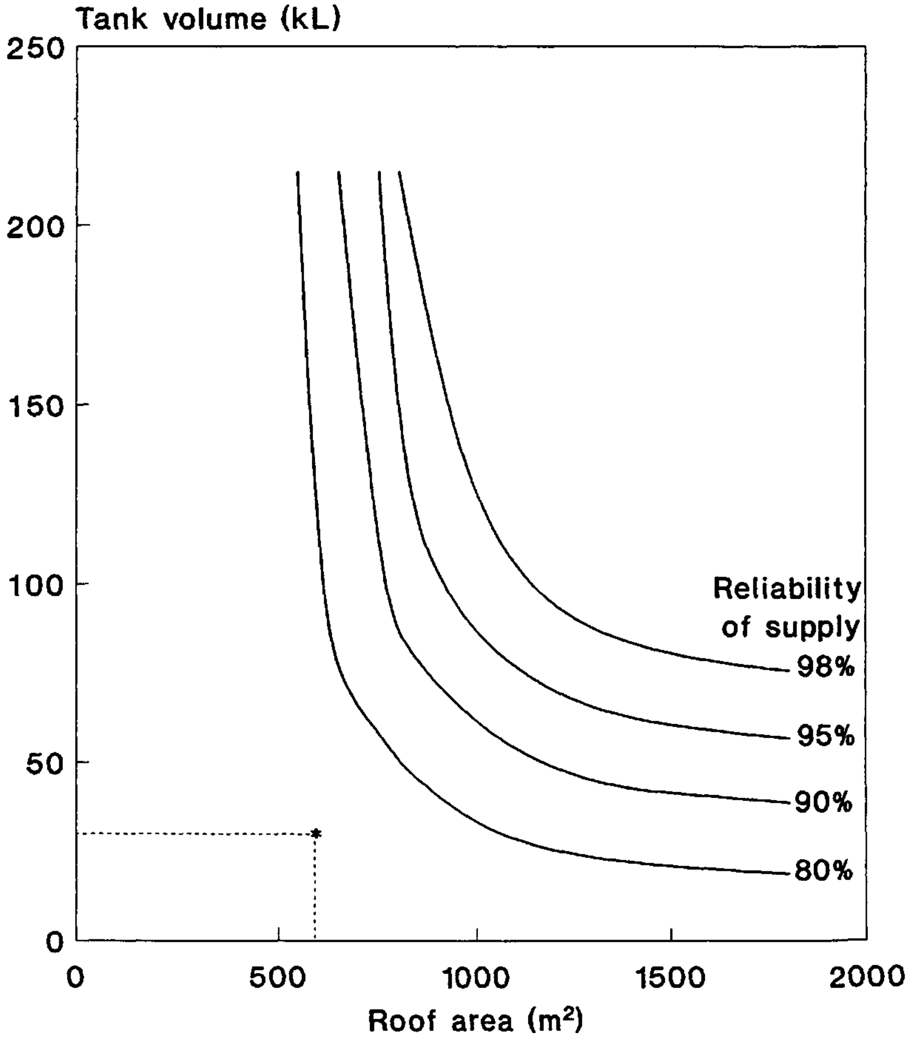


Figure 11. RAINTANK curve - Farm 4.

The dam water is not treated before being used on the garden. However, where the water from the reticulation system falls on the fruit trees, the leaves have died indicating that the fruit trees are highly sensitive to turbid water. It seems likely that clay suspended in irrigation water can clog the pores of the leaves, not allowing them to transpire. The dam water does not seem to affect the lawn or pot plants. Water for the garden is pumped from Dams A and G (Figure 10), usually from Dam A first.

Water carting

Water is still carted for domestic use only in the summer of each year. The water has to be carted because there are too few tanks to collect rainwater and more roof area needs to be used. In December and January of 1989/90,63 kL was carted at an average of one load (6.3 kL) per week for 10 weeks. The farmer is aware of the problem and the solution.

4.4.7 Situation report - March 1992

Dam G (Figure 9), which normally supplies more than 60 per cent of the livestock and garden water requirements of the farm, went dry in January 1992. Little runoff occurred from the roaded catchment from mid 1990 to March 1992 due to the combined effects of low rainfall and vigorous native vegetation regrowth on the catchment.

Approximately 250 kilolitres of water was carted over a six-week period, for livestock and garden use.

The domestic (in-house) water supply has not been a problem, mainly because the in-house water demand has been less than originally anticipated.

Water carting for livestock and garden use commenced in late January and ceased in mid-March 1992 following widespread storms.

Due to the farmer's preference for not using chemical weed control methods, the control of weeds on the catchments on this farm has been given a lower priority than was appropriate. Since the problem was clearly identified in March 1992, the native vegetation regrowth has been mechanically removed with a road grader and the quality of the roaded catchment surface restored.

Projected demand

The estimated future demand for water in Farm 4 is presented in Table 21.

Table 21. Projected water demand for Farm 4 in 1990

Demand	DSE	kL/year
House gardens	2,000	1,800
Sheep	2,000	1,800
Goats (30)	30	30
Total demand	4,030	3,630

The projected demand for water is within the design limits of existing water supplies. Feed is presently the limiting factor but pastures are being improved which should allow sheep numbers to increase to 2,000.

Comprehensive water scheme

There is a proposal for an extension of the Comprehensive Water Scheme near Mollerin. The farmer may have the opportunity to tap into this if he is prepared to pay. He doubts this would be of any benefit to his property other than for domestic water.

5. Discussion

Demand and supply of water

All four farms have significantly increased their demand for water since the new supplies were implemented. The situation is summarised in Table 22. The average increased demand is 79 per cent, with Farm 1 experiencing the greatest increase, 102 per cent, and Farm 4 the least, 57 per cent.

Table 22. Summary of water supply and demand for the four demonstration farms

	Farm 1 DSE	Farm 2 DSE	Farm 3 DSE	Farm 4 DSE	Average DSE
Demand prior to 1982	5,000	6,000	2,500	1,300	3,700
Supply prior to 1982	2,000	2,000	1,200	700	1,480
Present demand	10,100	11,650	4,030	2,035	6,955
Estimated safe supply	8,000	6,900	4,900	5,200	6,250
Excess capacity	-2,100	-4,750	+870	+3,165	-705
Increased capacity	6,000	4,900	3,700	4,500	4,775

Three of the four farmers reported that sheep numbers have not increased over the past seven years. The extra demand for water has been created by increased pig numbers on two farms, and by increased garden watering on all four farms.

As DAMCAT (1976) allocated a higher DSE rating to dams than DAMCATII (1988) (Figure 12), a review of the four demonstration farms based on DAMCAT n (1988) will inevitably indicate a design short-fall. Farm 1 and Farm 2 are now classed as potentially water deficient because their present demand is greater than the present supply. However, water for livestock use was carted onto only one of the four farms (Farm 4) for a six-week period in the nine-year period from 1983 to 1992.

In using DAMCAT II (1988), the assumption is that future seasons will not present more severe droughts than were encountered in the recorded rainfall periods of the past 25 years. However it is likely that a drought more severe than the worse one in that 25-year record will occur. It may occur next year, in five years or in 50 years time. The fact that two farms are over-using their water supplies could disadvantage them in times of low rainfall, when supplies may be limiting.

Figure 12 shows how DAMCAT (1976) and DAMCAT II (1988) compare. As an example, dam sizes and associated roaded catchments for Farm 1 were plotted in the DAMCAT n (1988) graph (Figure 13). The number of DSE's the dam can cater for without going dry can be estimated from the set demand levels on the graph.

Many of the dams with roaded catchments on Farm 1 can only supply demands below 500 DSE. A demand in excess of estimated safe supply could jeopardise the supply.

Some farmers seem prepared to take a risk when using water supplies and DAMCAT II (1988) gives them a guide as to the kind of risk they run. There is a trade off between reliability of a dam, the amount of roaded catchment constructed and the number of livestock watered. If the farmer puts in less roaded catchment than is suggested by DAMCAT II (1988), then there is a greater chance of the dam failing. In times of economic hardship, farmers may elect to do this. Estimates obtained from DAMCAT II (1988) were considered conservative by the manager of

Farm 3 who would run more sheep on the water supply than DAMCAT n (1988) recommends. However, DAMCAT n (1988) bases its recommendation on the dam not failing in a 25-year period for a set-stocking rate. The farmer takes a greater risk by running more sheep even though he may consider the 25-year period too conservative.

A seven to nine year period has elapsed since the works were put in place. The period from June 1990 to March 1992 was a potentially critical period for surface water supplies in the north-eastern wheat belt, and although the water supply on one farm failed in that period, the duration of the failure was for only one month. This failure rate can be expressed as occurring 1 year in 32 years of total water supply years; or with a duration of 1 month in 384 water supply months.

Water quality

Water quality samples from every dam on the four properties indicate good quality water with salinity levels less than 50 mS/m. This compares to 80 mS/m for scheme water. The water from two bores (both of which are rarely used nowadays) on Farm 1 tested as 624 and 737 mS/m - relatively good stock quality water.

Livestock

The fact that sheep numbers have not increased in response to increased water availability on all farms indicates that some of the demonstration farms may be operating at their maximum potential livestock numbers. The increase and subsequent decrease in sheep numbers over the last seven years is due to fluctuations in the market, and was not due to a lack of water. The unanimous opinion from the farmers involved is that the availability of feed is now the factor limiting sheep numbers on all four farms.

Probably the greatest water demand that was underestimated in planning the works, was for pig use. Water had been the limiting factor on the two farms with piggeries. With the new water supplies, pig numbers on both farms were increased substantially - by 50 per cent on Farm 1 and 100 per cent on Farm 2. The original plans did not anticipate such large changes to pig numbers.

House

In this demonstration, the source of domestic water on all farms is rainwater collected in tanks. Average annual water use for each house is 230 kL.

While two farms have a domestic water supply, which is more than 97 per cent reliable, Farm 4's supply is less than 80 per cent reliable and Farm 2 is rated below 95 per cent. Water is carted every summer for domestic use on Farms 2 and 4. Their ratings would be increased if all roofs were connected to tanks, and the tank volumes were increased. Farm 4 also needs new guttering.

It appears that individual farmers put different priorities on water, even where domestic use is involved.

Garden

The homestead gardens had improvements made that were not contemplated before the new supplies were implemented. All have reticulated lawns and healthy trees and shrubs, which cover large areas and use more water than expected. Suspended clay in water from farm dams was found to cause leaf damage to some plants when the wetting pattern of overhead sprinklers covered some of the foliage. This problem can be avoided by careful planning of the irrigation system, and planting pattern, and by water treatment to reduce the suspended clay (Platell, 1986).

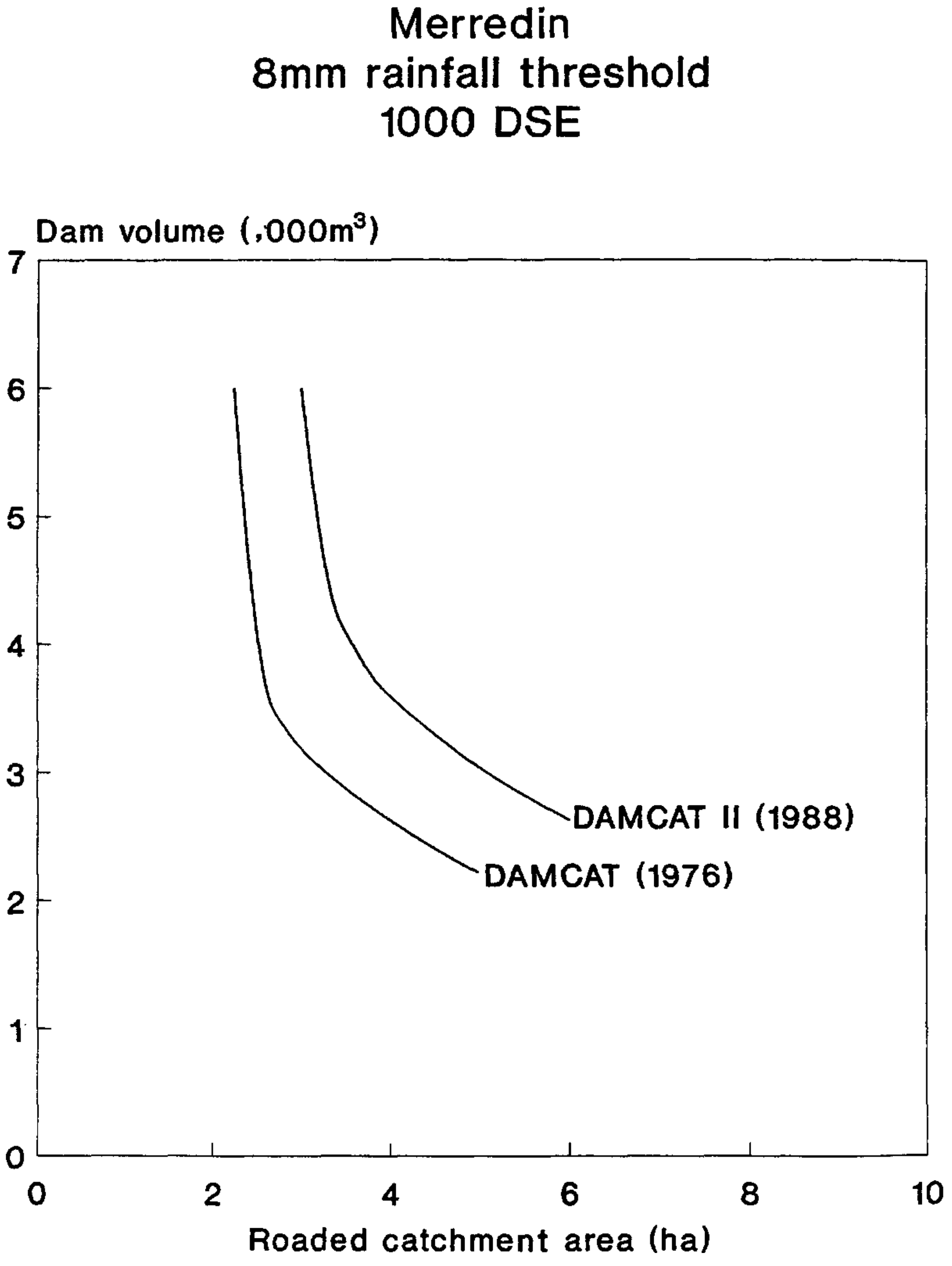


Figure 12. Relationship between DAMCAT (1976) and DAMCATII (1988).

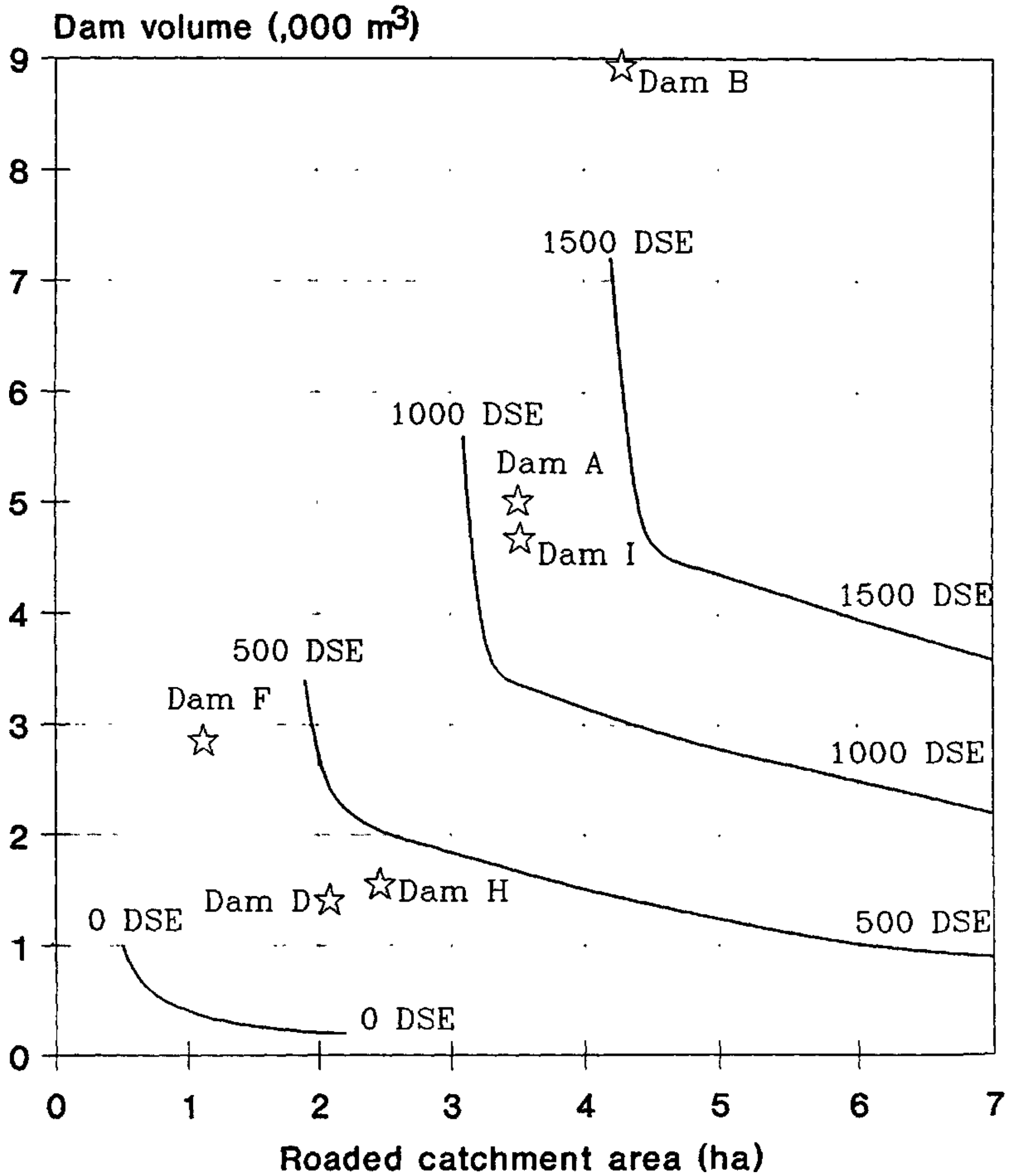


Figure 13. DSE values of dams and roaded catchments on Farm 1.

Groundwater

Although the occurrence of good quality groundwater is not common in this area, it is surprising that there is only one usable bore on the four farms. Farm water supply surveys by the Australian Bureau of Statistics and the Department of Agriculture indicate that on average, there are 1.6 bores in use per farm in the district. The difference may be due to all the demonstration farms occupying relatively high positions in the landscape compared to most properties in the area. Farms were also selected on the need to establish reliable water supplies.

Dam design

The major new dams built for the project are all four walled dams with piped inlets to minimise inlet erosion and thereby preserve the storage volume and depth. The design also includes a temporary storage by pushing out 'wings' from the front of the dam, to minimise bypass loss when there is rapid inflow to the dam. In most cases, three pipes of 150 mm diameter were used as the inlet. On one farm, single 225 mm pipes were used. A recent study (Cameron, 1990) has shown that the optimal combination of pipe size and number of pipes required where a large volume of temporary storage exists on farm dams up to about 5,000 m3, is two 90 mm pipes.

An important factor to consider in the design of a dam (especially a four walled dam) is that there is sufficient freeboard. As a rule, one metre freeboard is the minimum recommended. Appendices III, VIII, IX and X list the freeboards for all dams on the four farms. Many of the smaller (and often older) dams have not been designed to cope with heavy inflows.

This was evident in Dam D on Farm 1, where a one metre wide section of a side bank has been over-topped and washed away by the force of the water. This part may initially have been weaker but heavy flows eroded it further. In some dams freeboard on the back wall was less than 0.5 m.

The data in Appendices HI, VIE, IX and X show that much more attention should be paid to freeboard than is commonly done for farm dams. Failure to do so may mean loss of valuable water supplies and possibly loss of the dam.

Also there must be an adequate spillway to carry overflow safely to a waterway or diversion bank. If the catchment of a dam is improved by contours, grade banks or a roaded catchment, it is very likely that the dam will overflow in average and above average rainfall years.

Surplus water must be able to flow out of a dam as fast as it comes in. A restricted spillway will mean that heavy inflows to a full dam may overtop the standard one metre freeboard. If the water is brought to the dam by two collecting drains, the spillway must have the capacity to cope with the peak flow from both at once.

In the two years following construction, two dams required repairs to breached walls. In both cases, wall failures occurred along the alignment of the pipe inlet, during a storm event, which caused rapid filling. The failure of the piped inlets was due to inadequate compaction of soil along the length of the pipes, allowing water to flow through the embankment causing subsequent failure of the wall. It appears that in both cases, insufficient attention was paid to the design and construction of pipe inlets, temporary storage areas, spillways, and front walls.

A well-designed, wide, flat spillway can safely direct dam overflow to a nearby creek or other safe disposal area. The design of a safe spillway is relatively simple in the north-eastern wheat belt due to the generally low surface slopes. The maximum peak flow for all catchments on the four farms is 3.2 m3/s for a 1 in 20 year event and an average of 0.78 m3/s, so the individual spillways must be able to accommodate these flows. Determining factors will be the slope of the bank leading to the spillway and the amount of freeboard on this bank. While the 'standard' one metre freeboard is designed for a 1 in 50 year event, 0.5m freeboard should be reasonably safe for a 1 in 20 year rainfall event. However, some of the banks in this project had freeboard of less than 0.2 m, and in one case the bank had breached downstream from the designed spillway. A lot of potentially stored water was lost.

Roaded catchment design

Roaded catchments on the demonstration farms commonly have the roads running straight downhill. These can erode if the natural slopes, and therefore the roads, are too steep. Plan views of two dam and catchment combinations are presented in Figures 14 and 15, as examples of roaded catchment layout. One roaded catchment on Farm 3 has suffered serious erosion due to the combined effects of steep channel slopes (up to 3 per cent), and dispersive soils. The overall gradient on the roaded catchment is 1.1 per cent, for 500 m. The gradient is steepest at the end of the roaded catchment furthest from the dam.

Attempts to reduce the serious erosion have been unsuccessful. Measures used to reduce the erosion include: a) diversion channels, which cut across the steep road channels and are surveyed on lower gradients (- 0.6 per cent), have not stopped the erosion, but merely slowed the rate of water flow; and b) the runoff water has flowed around the loose rocks which were dumped in random heaps in the gullied Vee-drains and collecting drains, and the gullies have continued to erode.

In the future, the farmer plans to terrace the channels to make the channels wider with flatter bottoms to lessen the flow rate and the erosive force of the runoff. Concrete drop-structures or flumes may provide the only long-term solution to the problem.

The other roaded catchments constructed for the project have experienced very little erosion even though the average gradients along the road channels are in some cases greater than those in the case referred to above (Appendix IV). Some erosion is evident at the top of the catchments where the slope is generally steepest.

Weed control on roaded catchments

Maintenance of roaded catchments has been given relatively little priority. Only one farmer sprays the catchments regularly. Another knows of the need to, but has yet to do so. The roads should be kept bare because plant growth slows down the movement of water and allows it greater time to soak in or evaporate. Plant growth also tends to break up the compacted surface, which induces a higher infiltration rate.

All the demonstration catchments have weeds on them including those that are regularly sprayed. Most have less than 50 per cent cover (Appendix IV).

Two farmers do not spray for personal or environmental reasons. One of these farmers is worried the spray may contaminate the dam water and kill the koonacs and marron living in the dam. The other farm manages without using chemicals. An option for them to get rid of the weeds is to scrape the catchments with a grader at approximately two yearly intervals, and to re-compact the surface soil following the grading.

Costs

Table 23 summarises the costs involved in the project for the year of expenditure, and in 1991 dollar values. The average total cost of works in 1991 dollars was $74,710 per farm.

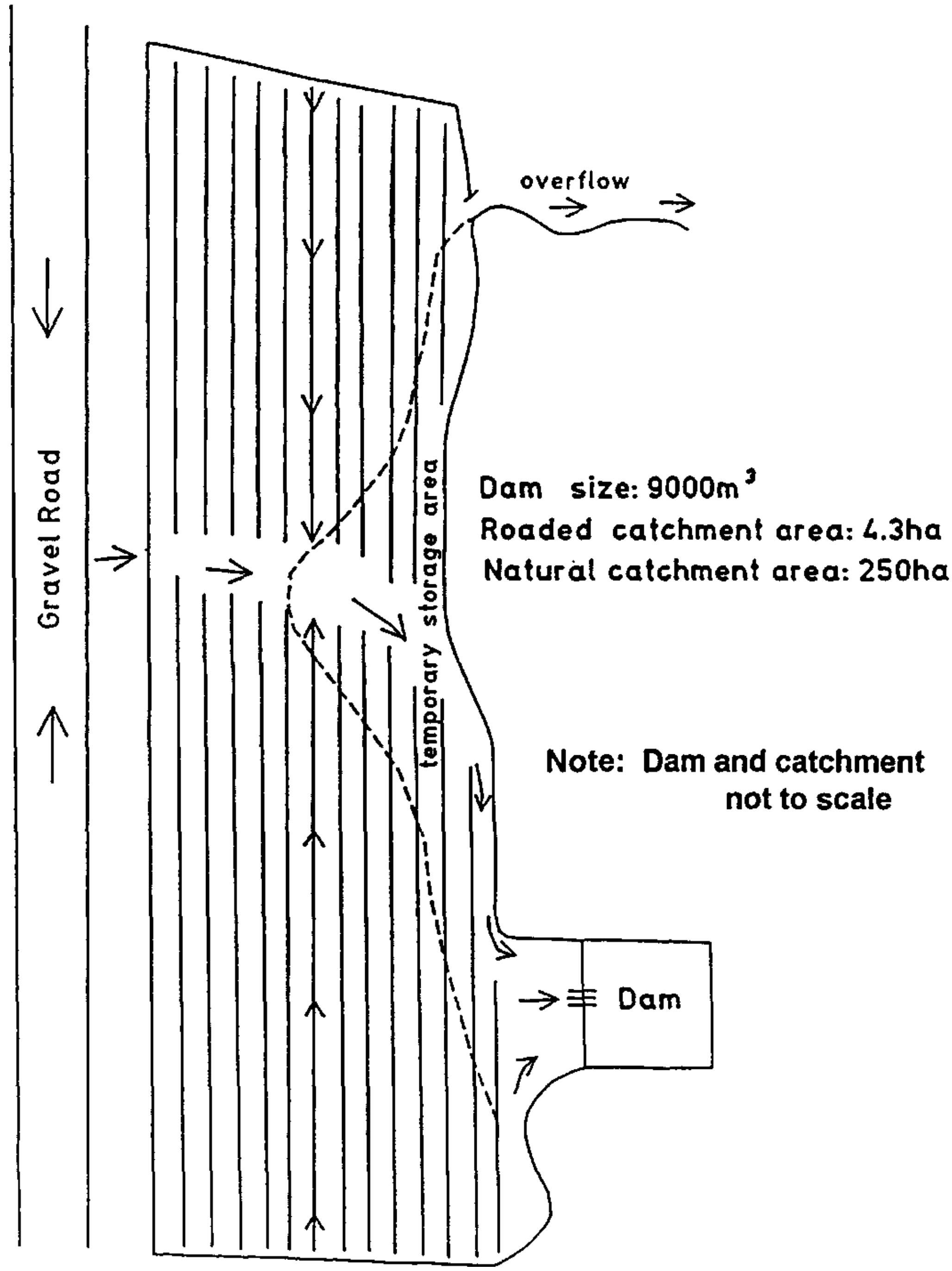


Figure 14. Plan review of a dam and roaded catchment design (Farm 1).

Dam   size: 6100m
Roaded catchment area: £.5ha
Natural catchment area: 130ha
Note: Dam and catchment not to scale

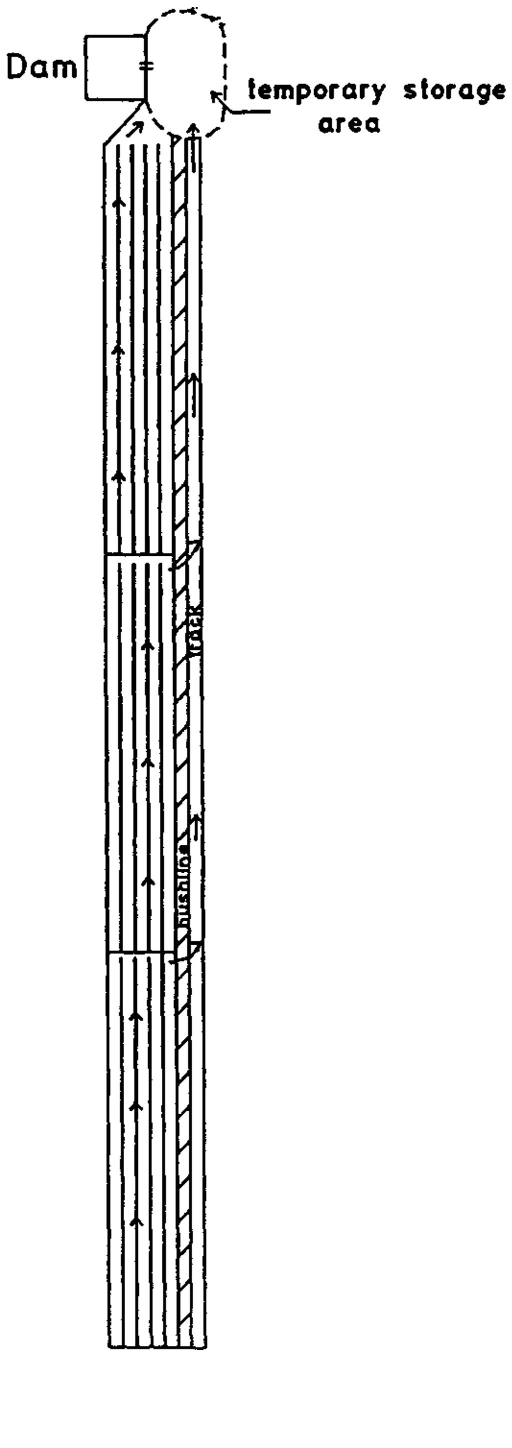


Figure 15. Plan view of a dam and roaded catchment design (Farm 2).

Table 23. Total costs of drought proofing the four demonstration farms

Costs	Farm 1	Farm 2	Farm3	Farm 4	Average
Dams and catchments	$32,500	$42,000	$26,000	$18,500	$29,600
Water distribution	$18,000	$12,000	$30,000	$9,500	$17,400
Total cost in year of expenditure	$50,000	$54,000	$56,000	$28,000	$47,000
Cleared farm area (ha)	2,170	4,920	1,560	1,166	2,454
Expenditure Year	1983	1985	1985	1983	
Inflation factor to convert to 1991 $	1.73	1.49	1.49	1.73	
Total - 1991 $	$86,500	$80,460	$83,440	$48,440	$74,710
Cost per ha (1991$)	$39.90	$16.40	$53.50	$41.50	$30.40
1991 $ per DSE of supply increase	$14.40	$16.40	$22.60	$10.80	$15.60

More than one third of the cost of the project, or $27,700 per farm was associated with the distribution of the water, compared with $47,000 per farm for dams and roaded catchments (Table 23). The inflation indices applied to the original expenditure amounts are shown in Table 23. These indices were derived from ABS Commodity Statistical Bulletin (1991) by taking an average of the indices given for farm plant and equipment, and farm labour.

Although the Government subsidised the water supply improvement projects on the four farms on a dollar for dollar basis, the final decision regarding the proportional expenditure on dams, catchments and distribution systems was made by the farmer in each case. Thus, large differences can be seen in the cost of the project for each farm. In terms of the cost of the extra DSE catered for, the minimum amount spent was $10.80 per DSE increase on Farm 4, and the greatest was $22.60 per DSE increase on Farm 3. It is likely that other farms in the north-east wheat belt could be drought-proofed for less because:

1. the four demonstration farms are probably representative of the most water-deficient farms, rather than the "average" case; and
2. the significant level of subsidy applied is believed to have afforded, and possibly encouraged, a certain degree of preferred investment - especially in water supply distribution.

6. Conclusions

In the seven to nine year period since the new works were constructed, the water supplies on the four demonstration farms have catered for the livestock water demand for the whole period except for six weeks on one farm. Two farmers are still carting for domestic water because of leaky gutters and inadequate tank storage.

On two of the farms, the demand for water has been significantly more than the original design demand, and the reasons that these systems have not failed to supply are the favourable seasonal conditions and conservative design standards.

Experience from this project indicates a need for the development of appropriate construction practice for construction of piped inlets and temporary storage areas on farm dams.

Roaded catchments in this project have generally given good results. The weed control problems on catchments were no different from other districts and the choice of which control method to use depends more on farmer attitude to use of chemicals than on any weed agronomy issue.
One roaded catchment in the project was located on a steep (three per cent) slope and on a highly dispersive subsoil. Although at the tune of site selection it was known that the site was relatively steep, the degree of instability was under-estimated. With hindsight, this site should have been avoided.

The average cost in 1991 dollars of the water supply improvements on the four farms was $74,710 per farm, or $30.40 per hectare.

7. Acknowledgments

We are very grateful to the farming community in the four shires of Dalwallinu, Koorda, Mount Marshall and Mukinbudin for their interest in the project; and in particular we acknowledge the personal contribution of the four farmers and their families upon whose properties the demonstration water supply works were constructed.

The contribution of dam-building contractor Mr Joe Pavlinovich, is gratefully acknowledged. His high level of expertise in earthworks construction and dam-site selection in cemented sub-soils (hardpan), and many years of experience in the Study Area, were key factors in the success of the project.

Similarly, the dedicated contributions in the design, site evaluation, supervision, and coordination of the project by two Department of Agriculture officers - Mr Jim Frith, Agricultural Adviser, and Mr Jim Prince, Technical Officer - are also acknowledged.

The planning and implementation of the project required a cooperative approach and the outcome is evidence that such cooperation occurred. The review of the project was made easier as a result of the combined efforts of all those involved in the project from its inception, and we appreciate their assistance.

We acknowledge the assistance of Brian Hillman in editing this report, David Quinlan for providing recent supplementary information, and Ed Hauck and Allan Herbert for their comments on the manuscript.

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9. Appendix i

Definition of the Dry Sheep Equivalent (DSE)

Demand for water may be rated in a number of different ways. To equate demand and supply sources it is simplest and convenient to express them in common units. The most useful of these on wheat belt farms is the "dry sheep equivalent" (DSE) which is the drinking rate of a dry sheep of 45 kg liveweight in forward store condition grazing annual pasture. The actual drinking rate in litres per day varies from zero during the growing season and when green feed is available, to 5.0 L per day during the summer, when the feed is dry and temperatures are high.

The relationship between drinking rate and the average daily maximum temperature can be described by the following equation developed by Luke (1987):

DR = 0.19 T - 2.88.
DR = Drinking Rate (L/DSE/day).
T = Average daily maximum temperature (°C).

The average daily maximum temperature in the Study Area is 28°C (Bureau of Meteorology, 1975), and the estimated average drinking rate is 2.5 L/DSE/day.

To calculate the annual demand of water by sheep, the average daily rate of 2.5 L/DSE/day was used. This was multiplied by 365 days and by the number of sheep e.g. a flock of 2,000 sheep would drink 1,830 kL per year.

(2,000 sheep x 365 days x 2.5 L/DSE/day = 1,830 kL/year.)

The DAM CAT II (1988) model has a dam evaporation rate (developed from the Class A pan evaporation data) built into it, so the DSE rating it gives incorporates the loss expected from evaporation in that area.

Since a ewe and a lamb will together drink about twice as much as a wether, each over-summering sheep can be counted as 1 DSE. The following equivalents of drinking by other classes of livestock are suggested

1 beast or horse = 10 DSE.
1 pig (free roaming) = 2 DSE.
1 goat = 1 DSE.

Garden demand tends to have the same pattern of seasonal variation as grazing stock. To find the present DSE demand for the garden, the annual use in kilolitres was used (this figure was obtained from the farmer and assumed to be accurate). The amount of annual use was converted to a daily rate then divided by the average daily sheep-drinking rate to express garden water use in DSE's.

$$\frac{1{,}000 \text{ kL}}{365 \text{ days} \times 2.5 \text{ L/DSE/day}} = 1{,}096 \text{ DSE.}$$

10. Appendix ii

Water supply design models - DAMCAT (1976) and DAMCATII (1988)

Two water supply design models have been used to simulate the performance of dams and roaded catchments supplying water to sheep in the Western Australian wheat belt.

The earliest version of DAMCAT (Frith, 1976) consisted of dam and catchment substitution curves for 21 centres in the State. The graphs represented combinations of dam and roaded catchment, which would have provided continuously for 1,000 sheep at any one of the 21 centres over the whole period of available daily rainfall record.

DAMCAT II (Denby and Hauck, 1988) is a personal computer-based program and database, which contains a water balance model. Developed in 1988, to replace DAMCAT (1976), it produces water supply design substitution curves, allows operational characteristics of proposed or existing water supplies to be assessed, identifies the least-cost reliable design, and presents rainfall and estimated runoff summaries for 50 locations in the south-west agricultural districts of Western Australia. The model uses a 25-year simulation period and bases sizing recommendations on a no-failure condition.

The reliability of a dam/catchment combination is measured by the number of sheep (DSE) able to be supplied continuously. The amount of water consumed by a DSE varies throughout the year, ranging from zero during winter to approximately 5 litres per day when the maximum temperature reaches 40°C. However, water conservation design must be based on a worst-case scenario. As such, the design parameter files in the DAMCAT II (1988) database impose a minimum livestock-drinking rate of 2.0 L/DSE per day to account for water consumption of livestock on dry feed during times of drought.

In both DAMCAT (1976) and DAMCAT II, (1988) certain constraining assumptions have been made:
a) Sheep are assumed to have an average liveweight of 45 kg, to be dry (i.e. not lactating) and during summer to be in a forward store condition.

b) A catchment "threshold" can be nominated and applied. This is the average amount of a daily fall of rain which does not reach the dam.

c) The only source of inflow to the dam is from the area of roaded catchment and from rain falling directly over the dam.

d) No leakage from the dam.

DAMCAT II (1988) is more conservative in DSE estimations than the earlier model DAMCAT (1976). To cater for a particular demand the predicted dam sizes do not differ greatly between DAMCAT II (1988) and DAMCAT (1976), but predicted catchment sizes from DAMCAT II (1988) are approximately 1.2 ha greater than from DAMCAT (1976). Figure 12 illustrates these differences.

11. Appendix iii Farm 1, dam specifications

Dam I.D.	Dam* type	Capacity (m3)	Depth When Full (m)	Batter slope	Volume Of Water Held At '4/1/90' (m3)	Depth at '4/1/90' (m)	Is seepage significant?	Is a Piped Inlet present?	Free Board (m)	Area of Roaded Catch-ment (ha)	Water B.C. At 4/1/90 (mS/m)	PH At 4/1/90	Is the dam equipped to pump?	DSE rating
A	P/PZ	5100	4.5	3.7:1	700	1.5	NO	YES	0.58	3.5	27.5	7.9	YES	1000
B	HP/P	9000	6.6	3.8:1	4100	4.9	NO	YES	0.69	4.3	16.0	7.7	NO	1900
C	GR	3300	3.9	3.2:1	1000	2.0	YES	NO	0.82	0.0	30.8	7.0	YES	800
D	P/CG	1400	3.1	3.0:1	400	1.5	NO	YES	1.07	2.1	16.4	7.4	NO	400
E	GR	1000	3.1	3.0:1	1000	3.1	YES	NO	1.29	0.0	32.0	N/A	NO	0
F	HP	2900	4.7	3.2:1	1500	3.5	NO	YES	0.33	1.1	46.8	7.6	NO	300
G	GR	1100	3.3	3.2:1	500	2.4	YES	NO	0.10	0.0	N/A	N/A	NO	0
H	HP	1500	3.6	2.9:1	200	1.7	NO	YES	0.79	2.5	42.5	7.9	NO	400
I	PZ	4700	3.9	3.4:1	2200	2.5	NO	NO	0.39	3.5	16.2	7.0	YES	1000
M	HP	2500	3.8	3.1:1	800	2.2	NO	YES	0.10	0.0	N/A	N/A	NO	200

* See Appendix VI.

12. Appendix iv Roaded catchment specifications

Roaded catchment identification	Area (ha)	Average length of roads (m)	Average depth of cut(m)	Width of cut (m)	Slope of batter	Average gradient along channel (%)	Weed rating*
Farm 1							
A	3.5	310	0.43	4.0	1:4.7	1.0	4
B	4.3	250	0.60	10.0	1:8.3	1.5	2
D	2.1	420	0.24	12.6	1:26.3	1.6	2
F	1.1	140	0.50	10.0	1:10.0	0.9	1
H	2.5	140	0.40	8.0	1:10.0	1.0	2
I	3.5	260	1.20	13.0	1:10.8	1.0	1
Farm 2							
A	4.5	900	0.40	9.0	1:11.3	1.4	1
B	5.6	200	0.46	10.0	1:10.9	1.2	2
I	3.8	625	0.40	10.0	1:12.5	0.5	2
L	2.8	250	0.40	10.0	1:12.5	1.1	4
N	1.9	375	0.34	8.5	1:12.6	1.2	4
Farm 3							
A	3.2	500	0.23	8.0	1:17.5	1.1	2
C	5.4	210	0.29	9.6	1:16.6	1.0	2
Farm 4							
A	5.4	150	0.44	10.8	1:12.5	1.4	5
G	10.6	200	0.47	8.9	1:9.5	1.2	3

See Appendix VII.

13. Appendix v

Demonstration dam/catchment combinations

Farm 1

Dam/Catchment A

This pallid zone dam was present on the farm initially. The farm plans included adding a 3.5 ha roaded catchment to increase the DSE rating. The dam previously leaked at 7 mm per day but has slowed down to a negligible rate. Water quality is excellent. A piped inlet consisting of two 375 mm concrete pipes was In place before the project began. The dam has a DSE rating of 1,000.

The dam/catchment combination works effectively with little erosion evident on the roaded catchment. This may be due to about 40 per cent of the area covered in grass. There is very little siltation in the storage area in front of the piped inlet and the pipes rarely block up. The average slope for the roads is 1.0 per cent, with the steepest section from 150 m to 200 m being 1.3 per cent. The length of the 12 roads averages 310 m. The roads are narrow (average 4m) and the depth is about 400 mm.

Natural catchment contributing to the runoff includes 200 m gravel road, 30 ha pasture and 5ha bush.

Dam/Catchment B

Dam B and its associated roaded catchment was part of the demonstration project. It is the largest single water supply on the farm being 9,000 m3 in size with 4.3 ha of roaded catchment and provides for 1,900 DSE. The farmer considers the DSE rating to be 4,500.

A plan view of this water source is presented in Figure 14.

The dam has a piped inlet consisting of 3 x 150 mm storm water pipes. The storage area holds back a lot of fast flowing water evident by the erosion occurring in this area. The inner walls of the dam are also eroding and this has silted up the dam to a depth of 40 cm. The channel slope averages 1.5 per cent over 300 m, with the greatest slope occurring in the first 50 m (2.3 per cent). The large slope may account for the erosion in the storage area. This drops to 1.1 per cent in the last 50 m. The roads were built deeper and wider than catchment A.

Water from this dam is mostly used in the piggery, which includes washdown and drinking water. It is also pumped to the houses for garden use and to the ram paddocks. When the water level in the dam drops below a certain point pumping resumes from Dam A, and in low rainfall years Dam C might be used as well. Salinity levels of the water are very low. The roaded catchment is overgrown with broadleaf weeds and some shrubs up to 1 m high. If these were cleared, more water would get to the dam.

Also contributing to the runoff for this dam is 1 km of gravel road and 200 m of farm track as well as 30 ha of pasture.

Dam/Catchment C

Although Dam C has no roaded catchment as such, it was strategically placed to catch the runoff from a rock outcrop close by. The area covered by the rock approximates 5 ha and banks direct the water into the dam. The inlet on this three wall dam has eroded badly and silted up the dam. Twenty-five hectare of pasture also contributes to the runoff.

The dam has gone dry once since it was constructed, mainly due to over-use, although the farmer suggests it could leak. Water is pumped to the piggery and gardens and is of good quality.

Dam/Catchment D

This 1,400 m3 dam and 2.1 ha roaded catchment combination may not work as effectively as it should due to a hole in the bank, opposite the inlet. This occurred in June 1989 after a heavy rainstorm. The hole has continued to erode and now has a 1 m diameter. It is situated at the high water mark, restricting the dam's potential.

The roaded catchment contains very few weeds, most of which occur 100 m up from the dam. All channels have sand deposition in them up to 3 cm thick.

A piped inlet is made of 3 x 150 mm PVC pipes and inset with rocks into the dam wall. It still is extremely stable considering the large volumes of water it handles.

Natural catchment comes from 2 ha of gravel road and approximately 20 ha of farmland. This is a wide but shallow roaded catchment with the average width of the roads being 12.6 m and the depth 0.24 m. The average slope over 420 m is 1.6 per cent with the steepest part in the first 50 m (2.8 per cent).

Dam/Catchment F

Dam F is 2,900 m3 with 1.1 ha of roaded catchment attached. This is classified as a hardpan dam and seems to have a good water holding capacity. The roaded catchment works effectively, evident by the fact that it has never gone dry.

Very few weeds exist on the catchment and only a small amount of siltation has occurred in the channels.

The piped inlet consists of 3 x 150 mm PVC pipes. The problem of blocking rarely occurs. Water quality is very good (EC = 46.8 mS/m).

A lot of natural runoff comes from 500 m of well-used track and about 50 ha of farmland.

The roaded catchment was built on a slight grade (0.9 per cent average) and the length of the roads is 140 m. The road channels were made 0.5 m deep to get to the clay layer suitable for construction.

Dam/Catchment H

This clay dam is relatively small (1,500 m3) but with enough roaded catchment to stop it going dry throughout the year.

The catchment has roads running east-west and also north-south, a total of 2.5 ha. Silting occurs in the downstream end of the catchment, with deposition about 50 mm deep. Weed cover approximates 20 per cent of the total area, mostly being short grasses and broadleaf weed varieties. Spraying the weeds would increase the catchment potential to harvest water.

Like most of the other piped inlets in the demonstration dams on this farm, it consists of 3 x 150 mm PVC pipes. The farmer does not have a problem with pipes blocking up. Water quality is excellent.

The length of the roads of the catchment range from 120 m to 160 m. The slope on the east-west section averages 1.2 per cent, while the north-south section is 0.9 per cent.

Dam/Catchment I

Dam I was on the farm originally but the demonstration plans involved adding another 1.8 ha of roaded catchment to the existing 1.2 ha. The dam previously leaked at 10-12 mm/day (1983) but has since taken up.

Water is pumped from this dam to a tank and trough in a neighbouring paddock. The salinity level of the water is very low.

The roaded catchment is characterised by wide and deep roads (13 m wide by 1.2 m deep). Although the channels are not steep (average 1.0 per cent), a lot of sand has accumulated at the bottom of the roads (maximum 150 mm depth). No grasses or broadleaf weeds exist but about 2 per cent of the area is covered in bushes up to 0.5 m high. No piped inlet exists.

Farm 2

Dam/Catchment A

Dam A (6,100 m3) is located east of the home block and is a typical example of a hardpan dam. Adjoining it is 4.5 ha of roaded catchment. From the top of the slope to the dam is 900 m, with the average slope being 1.4 per cent. The steepest part is between the first 200 m and 300 m. The slope here measures 2.5 per cent, but decreases thereafter to a minimum of 0.8 per cent for the last 100 m.
Due to the elongated catchment layout, the designers decided against making all roads this long because of the threat of erosion at the bottom. Instead, they opted to

divide the length of the catchment into thirds with cross channels taking the water to the drainage channel on the far side of the catchment.

A plan view of this water source is presented in Figure 15.

Water is also being diverted to the adjoining bushland, running down a track where it is causing extensive erosion before it reaches the dam. A grade bank running from the Shire road across the paddock also delivers water to this track, adding to the problem. Much of the material washed down the track is ending up at the dam, silting up the area in front of the piped inlet.

The piped inlet consists of 1 x 230 mm Spyrex pipe that easily blocks up with material from the paddock and track such as branches, sticks, weeds and sediment.

The roaded catchment has very few weeds on it, due to the fact that it is fenced off from sheep.

Dam/Catchment B

Being the largest dam on the property (9,700 m3), this dam is used constantly for watering the pigs and the homestead garden. With the large roaded catchment (5.6 ha), this dam has never been dry and copes well with the demand placed upon it. A piped inlet with 1 x 680 mm Spyrex pipe allows water to be stored outside the dam, further increasing its capacity. Occasionally the pipe gets blocked with sticks or " paddy" melons and water banks up outside the dam before someone cleans them out.

The roaded catchment has about 40 per cent of the area covered in broad leafed weeds, and 30 mm of silt has built up at the piped inlet but this is not causing any major problems. This also indicated that the roads are not eroding. The slopes range from 1.8 per cent to 0.5 per cent and are 200 m in length.

This roaded catchment was increased by the addition of approximately 2 ha of flat graded area some years after the works were completed. Also contributing to runoff is an area (10 ha) of granite outcrop above the catchment.

Water is gravitated about 1 km to the piggery and both homesteads and the water quality is excellent. No treatments are needed to improve the water.

Dam/Catchment I

This dam and roaded catchment combination provide a constant supply of water evident by the fact the dam has never been dry in its 6 year history. Initially, 6 ha of roaded catchment were planned, but only 3.8 ha has actually been implemented. The dam is a classical hardpan dam with a piped inlet at the front and a volume of 7,700 m3. The inlet consists of a 1 x 230 mm Spyrex pipe.

The length of the roads of the catchment are up to 625 m long. The slopes are very low with the average being 0.5 per cent. The greatest per centage slope occurs in the first 100 m of the roaded catchment at the top end.

Shrubs under 1.5 m tall cover 15 per cent of the area while broad leafed weeds cover about 40 per cent. The catchment needs weed maintenance to make it more effective in running water.

Dam/Catchment L

Dam L is a granite rock dam with a roaded catchment of 2.8 ha and a piped inlet consisting of 3 x 150 mm PVC pipes. At the time of inspection in January 1990 and again in July, only one pipe was visible and functioning. The other two were blocked up with grass and sticks.

The roaded catchment shows little sign of erosion on a slope averaging 1.1 per cent with roads 400 m to 600 m long. About 40 per cent of the area is covered in broad leafed weeds and about 5 per cent in 1 m tall bushes.

Dam/Catchment N

Dam N is the only reliable surface water source on the Cleary block of the property. It is a hardpan dam with a light land roaded catchment adjoining. The piped inlet contains a 1 x 230 mm Spyrex pipe which, at the time of inspection, was concealed by a thick layer (200 mm) of silt and clay washed down from the roaded catchment. Although nearly three-quarters full, it is a wonder how any water can get into the dam while the pipes are blocked.

This dam's storage capacity could be greatly enhanced by cleaning out the storage area in front of the dam and by keeping the catchment weed free. Weeds are the biggest problem where the water banks up onto the catchment before flowing into the dam.

The average slope of the roaded catchment decreases from 2 per cent for the first 100 m to 0.32 per cent for the last 75 m, with the total length being 375 m.

Farm 3

Dam/Catchment A

Dam A and its associated roaded catchment provide for 1,200 DSE. The dam volume is 5,900 m3 with 3.2 ha of roaded catchment. The dam existed prior to the new supplies being constructed but the catchment was added in 1983 to increase the DSE rating. No piped inlet is present.

The roaded catchment is 500 m long, but split into thirds by collecting channels which run across the roads and direct the water into waterways running beside the catchment. This drainage arrangement has resulted in nearly all the water from the roads flowing down the one waterway channel, and causing serious erosion. The farmer has piled rocks in this channel to reduce the rate of erosion but this has helped very little. The gully is now 0.5 m deep, with most of the sediment ending up in the dam. The average slope of the roads is 1.1 per cent.

Water is pumped from this dam to the house for garden use, a distance of about 1 km. It is also pumped across the road to another property.

Weeds and grasses cover about 40 per cent of the roaded catchment, but since the farmer does not allow chemicals onto his property, spraying is not an option to get rid of them. Weed control options combine either grazing or burning to remove rank growth followed by skimming the road surfaces with a road grader.

Dam/Catchment C

This dam was on the property before the new supplies were implemented. In 1983 it was clay lined to stop seepage and 5.0 ha of roaded catchment added to increase the DSE to 600. Three 15 cm PVC pipes make up the piped inlet. However, two of these are blocked making only one operational.

There are two sections of roaded catchment, one on either side of the dam. The northern section has an average slope of 2.3 per cent while the southern side is lower at 1 per cent. With the roads being 500 m long on the northern section, again it was decided (as in dam A) to have collecting drains dividing the catchment into fifths, though not of equal length. The water is directed into the major drain running down beside the roaded catchment, which is causing major erosion problems. Mounds of rocks every 50 m in the channel have not helped the problem.

The weeds, although covering 20 per cent of the catchment, are not of concern to the fanner but he is prepared to grade the roads (as an alternative to spraying) if they do become a problem.

Farm 4

Dam/Catchment A

Roaded catchment (5.4 ha) was added to this existing dam to provide a reliable water source for 1,400 DSE.

The dam is a four wall dam with an opening in one bank for inflow. No piped inlet is present for slowing the water down and letting the sediment settle. This may have been the problem in a heavy downpour some years ago, when a part of the far bank gave way. It has not been reconstructed but does not limit the dam's capacity hi any way. Instead it acts as the overflow and a bank has been built to take this water downstream.

Even though 5.4 ha of roaded catchment exists, not all of this is effective in promoting runoff. Much of it (80 per cent) is covered in thick bushes including Broombush (Eremophila scoparid), as well as grasses and broadleaf weeds. The average slope of the roads is 1.4 per cent with the longest being 200 m and the shortest 100 m.

Natural catchment includes a 300 m track and 100 ha of farmland.

Dam/Catchment G

The dam was constructed of granite clay with a 3 x 150 mm PVC piped inlet. It leaked after completion but has since taken up. The water quality is very good.

10.6 ha of roaded catchment accompanies this 5,200 m3 dam, giving a DSE rating of 3,000. While the average slope is 1.2 per cent, scouring has occurred in many channels in areas furthest upstream from the dam. This may be due to the length of some roads - up to 360 m long.

Grasses are thick at the stilling area in front of the inlet.

The water from this dam is pumped to the house for garden use and to the piggery. It is regarded as the most reliable water source on the farm.

14. APPENDIX VI

Reference code to dam construction materials - Appendices III, VIII, IX and X

CG	=	cemented gravel
GC	=	granite clay
GR	=	granite rock
HP	=	hardpan
L	=	lined
P	=	plastic
PZ	=	pallid zone.

For more information on dam materials refer to "Dam Site Selection in the North-Eastern Wheatbelt" by J.L. Frith in Journal of Agriculture, Western Australia, Vol. 26, No. 3,1985.

15. APPENDIX VII

Weed ratings on catchments

The cover of weeds on the roaded catchments of all four farms were rated using the following rating scores.

The ratings are from 0 to 5 and are as follows:

Rating scores	Weed cover	Most common plant types
0	0- 5%	broad leaf weeds
1	5- 20%	broad leaf weeds and small shrubs
2	20- 40%	
3	40- 60%	
4	60- 80%	
5	80-100%	tall shrubs up to 2 m high

16. Appendix VIII Farm 2, dam specifications

Dam I.D.	Dam* type	Capacity (m3)	Depth When Full (m)	Batter slope	Volume Of Water Held '23/1/90' (m3)	Depth At 23/1/90 (m)	Is Seepage significant?	Is a piped inlet present?	Freeboard (m)	Area of roaded catch-ment	Water E.C. at 23/1/90 (mS/m)	PH At 23/1/90	Is the Dam Equipped to pump?	DSE rating
A	HP	6100	5.3	3.0:1	2700	3.5	NO	YES	0.81	4.5	31.7	7.6	YES	1300
B	GC	9700	6.4	4.7:1	2900	4.1	NO	YES	0.39	5.1	13.1	7.0	YES	2100
C	GR	800	2.4	4.8:1	200	1.2	NO	NO	0.24	0	23.2	6.8	NO	0
D	CG	1700	3.8	2.9:1	200	1.2	YES	YES	0.12	0	21.2	6.5	YES	0
E	HP	2600	2.7	3.5:1	500	0.9	NO	YES	0.23	0	38.7	7.3	NO	0
F	GC	1400	1.8	7.8:1	700	1.3	NO	NO	0.12	0	31.8	7.4	NO	0
G	P	2600	2.5	3.1:1	500	0.7	YES	NO	0.12	0	58.6	6.7	NO	0
H	P	1500	2.4	3.7:1	200	0.6	NO	NO	0.34	0	15.6	7.3	NO	0
I	HP/P	7700	6.5	3.6:1	4300	5.2	NO	YES	0.41	3.8	9.1	7.2	YES	1300
J	HP	2000	4.0	3.3:1	1400	2.3	NO	YES	0.44	0	10.4	7.0	YES	200
K	HP	900	2.3	3.0:1	300	1.2	NO	NO	1.10	0	13.3	6.9	NO	0
L	GR	3400	5.1	3.3:1	1300	3.5	NO	YES	0.34	2.8	13.5	6.6	NO	900
M	P	1800	3.2	3.7:1	50	0.4	YES	NO	1.30	0	14.8	6.9	NO	0
N	HP	5500	5.5	3.0:1	2400	3.7	NO	YES	0.35	1.9	23.6	7.4	NO	300

* See Appendix VI.

17. Appendix IX Farm 3, dam specifications

Dam I.D.	Dam* type	Capacity (m3)	Depth when full (m)	Batter slope	Volume of water held at '4/1/90' (m3)	Depth at '4/1/90' (m)	Is seepage significant?	Is a piped inlet present?	Freeboard (m)	Area of roaded catchment (ha)	Water E.C. (mS/m)	PH	Is the dam equipped to pump?	DSE rating
A	PZ	5900	2.4	5.7:1	1100	0.8	NO	NO	1.0	3.2	17.6	7.6	YES	1200
B	HP	1700	2.4	4.3:1	700	1.5	NO	NO	1.3	0.0	15.4	7.7	NO	0
C	L/PZ	2300	3.0	3.6:1	1000	1.9	NO	YES	1.0	5.0	34.8	8.2	NO	600
D	GC	3300	2.9	4.0:1	1400	1.7	NO	NO	1.4	0.0	18.6	7.2	NO	300
E	HP	3600	2.7	4.6:1	1300	1.4	NO	NO	1.2	0.0	8.6	7.8	NO	0
F	GC	10600	8.3	4.0:1	8300	6.5	NO	YES	N/A	0.0	11.7	7.3	YES	2000
G	GC	6600	5.7	3.9:1	4500	4.9	NO	YES	0.8	0.0	27.8	8.0	YES	800

* See Appendix VI.

18. Appendix X Farm 4, dam specifications

Dam I.D.	Dam* type	Capacity (m3)	Depth when full (m)	Batter slope	Volume of water held at '4/1/90' (m3)	Depth at '4/1/90' (m)	Is seepage significant?	Is a piped inlet present?	Freeboard (m)	Area of roaded catchment (ha)	Water E.C (mS/m)	pH	Is the dam equipped to pump?	DSE rating
A	P	7400	4.8	3.6:1	3900	3.4	NO	NO	1.36	5.4	N/A	N/A	YES	1400
B	GC	2600	3.0	4.2:1	900	1.7	NO	NO	1.10	0.0	N/A	N/A	NO	300
C	P/PZ	5700	3.7	3.1	0	0.0	YES	NO	0.26	0.0	24.2	7.6	NO	0
D	P	2000	3.5	3.3:1	300	1.3	NO	YES	0.33	0.0	18.4	7.6	NO	200
E	P	1100	2.6	2.4:1	0	0.0	YES	NO	1.02	0.0	29.2	8.1	NO	0
F	GC	3200	2.3	3.0:1	1500	1.3	NO	NO	1.30	0.0	38.1	7.4	NO	150
G	GC	5200	5.3	3.5:1	3200	4.3	NO	YES	0.25	10.6	21.3	7.3	YES	3000
H	HP/GC	2800	4.5	3.0:1	600	3.1	NO	YES	0.47	0.0	14.6	8.0	NO	150
I	GC	600	1.8	3.6:1	200	0.9	NO	NO	0.28	0.0	40.6	7.7	NO	0
J	P	1300	1.5	3.4:1	300	0.5	NO	NO	0.12	0.0	73.9	7.9	NO	0

* See Appendix VI