Assessing storage reliability of farm dams

D Farmer

N Coles

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ASSESSING STORAGE RELIABILITY OF FARM DAMS

By Darren Farmer and Neil Coles

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Assessing storage reliability of farm dams

Darren Farmer and Neil Coles

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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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Introduction

During periods of low rainfall, dams with farmland catchments receive limited run-off. Dams with improved catchments normally receive minimal run-off. Any dam water then becomes a limited resource and needs to be managed effectively. Alternative water sources or management strategies will need to be considered before the water runs out.

This report provides information on a method to estimate the volume of water in a farm dam and to determine how long this water will last. It is intended to answer the question “roughly how long will it be before the water in this dam will no longer provide a reliable supply?”

Some of the important aspects to consider when calculating losses from farm dams under conditions of low rainfall are:

- due to sloping sides, the volume of water is less with each 1 m of depth, i.e. a dam at one quarter its maximum depth holds significantly less than one quarter of its total capacity;
- unless regularly maintained, farm dams generally accumulate sediments in the bottom 1.0-1.5 metres. This can cause a significant reduction in the expected volume of water stored in the dam;
- water quality generally decreases as dam depth decreases due to increased biological activity, evaporation and residual accumulation (e.g. salt concentration).

To estimate how long the water will last, data concerning demand and losses is required to begin water planning and budgeting. The most important facts to establish are:

(1) the volume of water in the dam;
(2) the expected demand on that water (i.e. rate of use) by livestock or domestic use; and
(3) critical losses (evaporation and leakage).

These methods are intended to provide the landholder with an indication of water supply over short periods only (i.e. in the order of 4-20 weeks). Should a more accurate estimate be required then the land owner should consult a hydrologist or Land Conservation Officer (LCO) at the Department of Agriculture.
1. Assessing remaining water supply

The first step in assessing the reliability of a water supply is to estimate the volume of water in the dam. Often, the depth has been reduced due to siltation. This means that you may not be able to guess the volume of a dam based on the constructed depth. This is particularly important during low rainfall years or periods where dam volumes are low. To calculate the volume and rate of loss, the geometry and dimensions of the dam are required.

1.1 Collecting information at the dam site

The following information should be collected (see Figure 1):

- length and width (rectangular dam) or diameter (circular dam) for the surface of the water contained in the dam;
- the depth of water to the top of the sediment (i.e. mud layer) in the bottom;
- the slope of the dam sides (batter slope) or batter.

Instructions on how to obtain these are contained in Appendix D.

Note: Where water quality is in doubt it may be necessary to collect a water sample in a clean plastic or glass bottle. Salinity and acidity measurements can be conducted at Department of Agriculture offices. For other water quality measurements contact the WA Chemistry Centre.

![Figure 1: Measurements needed related to dam (in addition to water depth)](image)

It is important to confirm that the water depth is measured as the distance between the surface of the water and the top of any sediment in the dam (see Appendix D).
This is because in most cases, water below 0.2 m cannot easily be accessed by stock or extracted by pumping, and is usually of poor quality.

It is recommended that the reader refer to the appendices (listed) in order to become familiar with measuring dam properties and obtaining the surface area and remaining water volume for a given depth.

**Calculating the surface area and volume**

The Department of Agriculture provides easy-to-use computer software that can estimate dam volumes from the basic information indicated in Figure 1. Alternatively, use the graphs in Appendix A, or the equations in Appendix B.

The most important information is the water surface area at measured depths and the change in volume with depth. A worksheet and explanation for manual calculation of these is in Appendix B.

When calculating values it is important to understand that as the water depth in the dam decreases, the length and width will decrease at a rate proportional to the batter slopes. The rate of reduction for a dam with a 1:3 batter is shown in Figure 2.

![Figure 2. Reduction in length with depth for a dam with batters of 1:3](image)

For example a farm dam has a length of 10 m when the water is 1.2 m deep. Locate 1.2 m and 10 m on the graph. Follow the lines across and upward to the point where they intersect. Follow along the closest diagonal line to this point to determine change in length as depth increases or decreases (e.g. at 0.6 m deep the length will be 6.4 m while 1.6 m deep would give a length of 12.4 m). The same can be done for width. Full size graphs for dams with 1:3 and 1:2 batters are in Appendix A.

Once the length has been resolved for a given depth, it is possible to determine the surface area at depth, and hence the volume. Figure 3 illustrates the change in surface area with depth. The ratio is important as it impacts upon the volume of water lost to evaporation. Figure 4 shows that volume will decrease more quickly as the depth of water in the dam decreases.
Figure 3. Decrease in surface area and stored volume with depth for a dam with water surface dimensions of 10 m x 8 m at 1.2 m depth (W=0.8 L) and 1:3 batters

Plotting volume versus depth clearly demonstrates the effect that changing depth has on the volume of available or stored water. For example, at a depth of 1.5 m the dam only stores a volume of 65 m$^3$. This is much less than half of the 432 m$^3$ when the dam is 3 m, or twice as deep (i.e. half the depth yet only 15% of the capacity).

These graphs give surface area and volumes for dams of a specific design. For accuracy in determining the surface area and volumes of other dams, run a series of calculations and compile a table (e.g. Table 1).

Table 1: Example dimensions for a rectangular dam with water surface 10 m x 8 m at 1.2 m deep and batter slopes of 1:3.

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Surface area (m$^2$)</th>
<th>Volume (m$^3$ or kL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>8.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.4</td>
<td>16.6</td>
<td>3.4</td>
</tr>
<tr>
<td>0.6</td>
<td>28.2</td>
<td>7.8</td>
</tr>
<tr>
<td>0.8</td>
<td>42.6</td>
<td>14.8</td>
</tr>
<tr>
<td>1.0</td>
<td>59.8</td>
<td>25.0</td>
</tr>
<tr>
<td>1.2</td>
<td>80.0</td>
<td>39.0</td>
</tr>
</tbody>
</table>

Due to the strong relationship between depth, slope, length, surface area and volume it is necessary to carry out all calculations, regardless of method. The long-hand or manual approach, and Dam Volume Calculator program are discussed in Appendices B and C.

Charts are provided for 1:3 and 1:2 batter slope dams in Appendix A. Information from these should be used with caution as some water below 0.2 m may be unavailable due to poor quality. Refer to Example 1 in Appendix B. The volume at a constructed depth of 1.2 m is 39 m$^3$. The volume of the low quality portion below 0.2 m is 1 m$^3$. This means that there is only an available volume of 38 m$^3$. 
2. Estimating demand volumes

To estimate demand, include all water that will be removed from a dam. This can include losses due to evaporation, leakage, livestock water use and water that is pumped for on-farm or domestic use.

2.1 Evaporation

Evaporation depends on temperature, humidity, wind, the surface area of water and orientation of the dam. Hot, dry, windy days will cause greater water loss than cold still days. Similarly, evaporation is usually much lower in the winter than that experienced during summer. Average monthly evaporation rates for various districts are included in Appendix E. This table should be used to obtain an average evaporation value for the nearest station to your location.

To calculate the evaporative loss use the following equation:

\[
\text{EVAP (m}^3\text{)} = \text{SurfAREA} \times \frac{\text{dEVAP}}{1000} \times n \text{ days}
\]

where:

SurfAREA is the surface area of the water in the dam in m²;

dEVAP is daily evaporation rate obtained from Appendix E and converted to mm/day by dividing by the days in the month; and

n days is the number of days over which the total evaporative loss is calculated.

Since evaporation is dependent upon various factors it is recommended that calculations be checked regularly against what is actually happening in terms of changes in depth of water in the dam over a seven day period.

2.2 Livestock water use

Livestock water use is discussed in detail by Luke (1988) and sheep drinking rates for various agricultural centres are included in Appendix F.

Livestock drinking rates are based on a dry sheep equivalent (DSE) which is defined as a 45 kg dry (i.e. non-lactating) sheep in forward store condition during summer on a maintenance diet of sub. clover or better pasture. Pigs (free range) and cattle/horses consume water at rates equivalent to 2 and 10 DSE respectively.

During a low rainfall year the lack of winter pasture often necessitates hand-feeding, or feeding alternative herbage. A minimum water requirement of 2 L/head/day is suggested for stock under these circumstances (Luke 1988).

Where water supplies have higher salt concentrations, or where stock are being sustained on alternative feed, such as saltbush, then water consumption has been found to be much higher (Table 2).
Table 2: Typical sheep drinking rates with increased salt content

<table>
<thead>
<tr>
<th>Total soluble salts (mg/L)</th>
<th>Consumption factor compared to tabulated DSE rates (sF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh water</td>
<td>1</td>
</tr>
<tr>
<td>3,500</td>
<td>1.2</td>
</tr>
<tr>
<td>7,000</td>
<td>1.4</td>
</tr>
<tr>
<td>10,500-14,000</td>
<td>1.7-2.8</td>
</tr>
</tbody>
</table>

To calculate livestock demand, first estimate the number of DSEs that have access to the water supply. Use the tables in Appendix F to estimate the expected water demand for sheep in your locality. Determine the potential salt concentration and read the correction factor from Table 2 or Appendix F.

\[
\text{Equation 2} \quad \text{STOCK (m}^3\text{)} = n\text{DSE}'s \times \frac{\text{dRATE}}{1000} \times sF \times \text{ndays}
\]

where:
- \(n\text{DSE}\) is dry sheep equivalent;
- \(\text{dRATE}\) is the value obtained from Appendix F (L/DSE/day);
- \(sF\) is the salt factor from Table 2 above; and
- \(\text{ndays}\) is the number of days over which the volume is being computed.

### 2.3 Domestic and other water use

Water extracted from farm dams for low quality domestic use, gardens or spraying is usually pumped from the dam. The rate at which this occurs is dependent on the system in use, the pump extraction rate and the length of time the pump operates. A best guess estimate is required for daily extraction volumes in kilolitres/day or cubic metres/day. As many people estimate water volumes in units other than m\(^3\) or kL a set of conversion factors is provided in Table 3.

Table 3: Conversion rates for various volume measures

<table>
<thead>
<tr>
<th>Volume unit</th>
<th>Conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic metre (m(^3))</td>
<td>1 m(^3) = 1 m(^3)</td>
</tr>
<tr>
<td>Litre (L)</td>
<td>1 L = 0.001 m(^3)</td>
</tr>
<tr>
<td>Kilolitre (kL)</td>
<td>1 kL = 1 m(^3)</td>
</tr>
<tr>
<td>Gallon</td>
<td>1 gal = 0.00454 m(^3)</td>
</tr>
<tr>
<td>Cubic yard</td>
<td>1 cu. yd = 0.76455 m(^3)</td>
</tr>
<tr>
<td>Cubic foot</td>
<td>1 cu. ft = 0.028316 m(^3)</td>
</tr>
</tbody>
</table>

If a pump is being used the volume consumed can be estimated by multiplying the pump rate by the time over which the pump is run.
Example 1. A 300 L/hr pump is run for 5 hours each day to top up an auxiliary house tank that is used for non-drinking purposes (e.g. toilet, shower, vegetable garden). Assume that this rate is applicable after head losses have been accounted for (refer to pump literature to assess head loss).

\[ 300 \text{ L/hr} \times 5 \text{ hrs} = 1500 \text{ L} \]

1 litre = 0.001 kL

Convert L to kL
\[ 1500 \times 0.001 = 1.5 \text{ kL} \]

Volume required for 30 days
\[ 30 \times 1.5 = 45 \text{ kL} \]

Example 2. A 600 kL/day pump is run for 6 hours to transfer water.

Calculate fraction (f) of day;
\[ 6 \text{ hours} = \frac{6}{24} \text{ hrs} = 0.25 \text{ day}, \]
Volume of water transferred is:
\[ = f\text{ day} \times \text{ pump rate} \]
\[ = 0.25 \times 600 = 150 \text{ kL/day} \]

When calculating the volume required it is best to list all the expected uses and then try to estimate how much water will be needed on each occasion. Once this has been established, simply multiply the single instance volume by the number of days that the volume of water might be required during the period of estimation.

The total external water demand is the sum of all water that is being extracted. Care must be taken to ensure that volumes are converted to the same units and the time period being considered. This will generally be per week or per month. To ensure consistency with dam storage all volumes should be converted to m$^3$. 
3. Determining reliability of supply

Total demand is simply the sum of all water requirements. In essence, if there is sufficient water in the dam to meet these requirements then the supply is termed reliable. If the demand is predicted to exceed the stored water capacity at any time the supply is termed unreliable and alternate measures will need to be taken such as reducing demand or carting water. The supply evaluation process is summarised in Figure 4.

Figure 4: Calculation process for determining the reliability of a farm dam over a period of 1-4 months (assuming no inflow during the period)
The steps involve those discussed in Sections 1 and 2: visiting the dam site; collecting the right measurements; determining the stored water volume; rating available water against expected demand for a designated period.

The reliability of the estimation will be influenced by the time frame over which the demand is calculated. At smaller periods (e.g. a week) the updating of surface area will tend to produce more realistic estimates of the evaporated volume. For many purposes however fortnightly or monthly computations are sufficient.

Example 3. The rectangular dam shown in Figure 1 (and referred to in Figures 2 and 3, and Table 1) is required to support 200 sheep and supply 3000 L of water per fortnight to the homestead. The dam is in the Lake Grace district and the month is May during a low rainfall year in which the dam has yet to receive substantial run-off.

Field inspection found the water surface was 10.0 m x 8.0 m and 1.2 m deep. The dam has a batter slope of 1:3.

Calculations to assess reliability of dam for May

(i) From Table 1 the volume of water available is 39 m$^3$ and surface area is 80 m$^2$ (see example in Appendix B).

(ii) From Appendix E evaporation from dams at Lake Grace in May is typically 69 mm/month or 69/31 = 2.2 mm/day.

\[
\text{EVAP (m}^3\text{)} = \text{SurfAREA} \times \frac{\text{dEVAP}}{1000} \times \text{n_days (Equation 1)}
\]

\[
80 \times \left(\frac{2.2}{1000}\right) \times 31\text{days} = 5.5 \text{m}^3/\text{month}
\]

(iii) Livestock use is 2 L/day/DSE due to hand feeding and there are 200 sheep. The water in the dam is slightly brackish (est. 2000 mg/L)

\[
\text{STOCK (m}^3\text{)} = n\text{DSEs} \times \frac{\text{dRATE}}{1000} \times s\text{F} \times \text{n_days (Equation 2)}
\]

\[
2 \times \left(\frac{200}{1000}\right) \times 1.1 \times 30 = 13.2 \text{m}^3/\text{mth}
\]

(iv) Domestic requirement is 3,000 L per fortnight or about 6 m$^3$/mth

(v) Total demand is therefore:

\[
5.5 + 13.2 + 6.0 = 24.7 \text{m}^3 \text{ during May}
\]

(vi) At the end of May therefore...

\[
\text{new Vol} = \text{old Vol} - \text{demand}
\]

\[
= 39 \text{ m}^3 - 24.7 \text{ m}^3 = 14.3 \text{ m}^3
\]

Looking up volume of 14.3 m$^3$ in Table 1 we find that this is associated with a depth of approx. 0.8 m (i.e. at the end of May the dam will have dropped by 0.4 m if there had been no inflow during that time).

Calculations to assess reliability of dam for month of June

(vi) The new surface area is approx. 43 m$^2$ and June evaporation is 43 mm (1.4 mm/day).

\[
\text{EVAP (m}^3\text{)} = \text{SurfAREA} \times \frac{\text{dEVAP}}{1000} \times \text{n_days (Equation 1)}
\]

\[
43 \times \left(\frac{1.4}{1000}\right) \times 30 \text{days} = 1.8 \text{m}^3/\text{mth}
\]

Assuming the stock demands remain the same:

\[
\text{Demand} = 1.8 + 13.2 + 6 = 21 \text{ m}^3/\text{mth}
\]

(vii) Since the demand volume exceeds the available volume (i.e. 21 >14.3), then it is likely that the dam will fail in the next month.
Even if 6 kL for the house supply is taken from another source the livestock and evaporation losses will still result in dam failure by the end of June.

It is probable that the water level will not drop to exactly 0.8 m. It may be more or it may be less. Hence it is important that actual water levels are monitored over the period. With regular monitoring of dam water levels it should be possible to refine water use and supply estimates.
4. Maximising limited water supplies and promoting efficient recovery

Excess run-off and recharge in agricultural areas are prime causes of waterlogging and salinity. In some cases, the same farms that are exposed to these problems also experience water shortages regularly.

In the eastern wheatbelt low rainfall periods can occur every three years, while in other agricultural areas there may only be one significant event per decade.

Water is an essential part of a farming enterprise. It makes sense to plan for low rainfall periods given their frequency. Some farms in Western Australia have a poorly designed infrastructure that does not allow the landholder to take advantage of water harvesting, storage and management techniques that will enable them to develop reliable water supplies. Through good design it is possible to generate and store run-off even in below average rainfall years.

These options exist for landholders that are regularly faced with water shortages:

- cater for existing demand by increasing on-farm storage;
- reduce demand through livestock reduction via sales or agistment;
- reduce home and garden use;
- maximise the harvesting of rainfall through improved catchments and diversion structures;
- develop a maintenance program for existing water supplies to ensure they are operating at optimum storage and collection capacities.

4.1 Increasing on-farm water storage

Increasing available storage on a property is the one step towards improved water supply reliability. Where existing dams fill regularly and excess run-off is not captured, various options exist to site a new dam below the existing dam (i.e. dams in series or double-dams). Effective options include siting a second dam off the drainage line and using the first to keep this dam topped up. Where the second dam is large, banks and roaded catchments can be used to increase the inflow.

Increases in storage should not be limited to earth dams. Efforts should be made to link rain tanks to all available roof areas for domestic or crop spray requirements. The RAINTANK™ calculator is a simple roof-run-off-storage evaluation program that enables the user to determine how effective their current system is and what size roof or tank is required to improve that system. The software is provided free by the Department of Agriculture and can be obtained from the DRAINWISE website (www.agric.wa.gov.au/drains). The calculator is Windows compatible and is designed to assist landholders in matching roof areas to tank sizes for the agricultural areas. Roof materials (e.g. corrugated iron, tiles etc) are capable of harvesting 70 to 80% of rainfall.
For example a 30 m x 10 m galvanised shed offers a catchment area of 300 m². During a 10 mm rainfall event this surface, if properly guttered, is capable of yielding 2.0 to 2.2 m³ (or 2,000 to 2,200 litres) of rainwater suitable for domestic use.

4.2 Maximising water harvesting

A major problem faced by property owners during low rainfall years is that many farm dams fail to fill. This is typically because a large portion of the initial rainfall simply soaks into the ground due to the dryness of the soil profile. Even in high run-off landscapes such as duplex soils and clays, up to 40 mm of rainfall may be required before the soil moisture deficits and detention storages are satisfied and run-off is generated. In deeper profiles and sandy soils this value can be significantly greater. Consequently, vital water supplies are lost and shortages may persist even after significant rainfall.

Roaded catchments

Roaded catchments, located above dams, are essentially compacted areas of hillslope, typically covering about 2 to 5 hectares (e.g. about 30-50 m wide and 70-200 m long), which have been surveyed and compacted to a design grade (0.5–1%). Experience in wheatbelt areas has shown that well maintained roaded catchments can deliver run-off volumes of 40,000-100,000 L from rainfall events as little as 10 mm. A well sited roaded catchment can deliver recharge volumes equivalent to meet one to two months of summer water demand for 1000 sheep from a single summer storm (based on 15-20 mm event and 2-5 ha catchment). The same rainfall event may not yield any significant inflow from a natural catchment.

The potential contribution of a roaded catchment to maintaining viable supplies of water can be assessed using the DAMCAT-3™ farm water supply design and assessment program. This software, developed by the Department of Agriculture, is used to match catchment areas to farm dam volumes for a given demand. Local rainfall records are used to assess the reliability of the catchment-dam combination for low rainfall years. DAMCAT-3 can be downloaded from the DRAINWISE website and was developed to run on most Windows platforms.

Roaded banks

An alternative to a roaded catchment is a roaded bank. These are essentially large broad flat-sectioned collector banks 8-20 m across running at grades of 0.5-1% similar in design to contour and level banks used for soil conservation, (which are typically 4-5 m across). The advantage is that, while acting as a collector bank for larger rainfall events, rainwater is also harvested during low rainfall events. In this respect roaded banks have been found to be more readily acceptable than having both water harvesting and soil conservation structures in the same paddock. This reduces the amount of area lost to production.

Opportunities exist to adopt dam designs that promote storage and minimise losses. These include above-ground circular earth or flat batter dams where deep dams are otherwise not possible, and the use of dam liners where local construction materials may be prone to leaking.
Recent research work funded by the Water and Rivers Commission, Department of Agriculture and the Office of Water Regulation has sought to reduce evaporation losses through the use of well sited shelter-belts, wind barriers and alternative dam construction techniques. These methods aim to minimise, or disrupt, water-surface-air interaction and therefore interfere with the uplift of water vapour. Information on windbreaks is available in Farmnote 80/2002.

4.3 Adopting a maintenance program

Combining the engineering concepts with proper design of water harvesting structures can often readily overcome many aspects of limited farm water supplies. However, if these structures are not properly maintained then they become less efficient, and the ability to effectively harvest water is compromised (i.e. the water supply is less reliable).

A regular maintenance program should be adopted for all the dams and roaded catchments on the property. Good design, such as silt traps and piped inlets for dams, can reduce the need for desilting of the main dam. Weed control and surface grading on the roaded catchment will help maintain its efficiency in low rainfall years.

Further information regarding the improvement and development of on-farm water supplies can be obtained by contacting your local Department of Agriculture or the Drainwise website.
References

Department of Agriculture. (In prep). DAMCAT-3 user documentation.

Department of Agriculture. (In prep). RAINTANK user documentation.


Appendix A
Charts and graphs for estimating dam storage dimension

Charts 1 & 2: Reduction in the length of the water surface with decreasing depth for farm dams with batter slopes of 1:3 and 1:2 respectively. To use this chart, first identify the current water surface length and depth. Find the closest diagonal line to where these intersect. Move up or down this diagonal line to estimate the increase or decrease in water surface length with increased or decreased depth.
Chart 3: Surface area for varying lengths (of a square dam) and diameters (for a circular dam) of the surface water level in farm dams. Inset shows enlarged section of the lower left of the chart. SQR line is for square dams (i.e. L = W), RND is for circular dams (i.e. L = diameter) and red shows various rectangular configurations (for example W = 0.8 L implies that a dam with L=20 m will have W = 16 m).
Charts 4, 5, 6 & 7: Length, depth and volume charts for square dams with batter slopes of 1:3 and 1:2.
Charts 8, 9, 10 & 11: Length, depth and volume charts for rectangular dams with batter slopes of 1:3 and 1:2 and L:W ratio of 0.75.
Charts 12, 13, 14 & 15: Length, depth and volume charts for circular dams with batter slopes of 1:3 and 1:2.
Appendix B
Computing dam volume and surface area

Dam volumes can be estimated using calculations applicable to the geometric shapes they most closely resemble. The simplest shapes are square, rectangular and circular. The cross-section of all three types is trapezoidal (see above). The valley dam or gully wall dam is not considered here.

For a trapezoid, knowing the length, depth and slope is sufficient to calculate any other dimension (see Appendix D for how to calculate depth, length and width). For dam volumes the base is the only remaining unknown.

If we express slope in the form 1 m rise for every $x$ m, then the term 1-in-3 (or 1:3) means that we have a 1 m rise for every 3 horizontal metres. A 1:3 ratio gives the value of 3 for slope, for the purposes of these calculations. See Appendix D for more.

To determine the length and width of the dam base:

$$\text{Base}_L = \text{Length} - 2 \times (\text{Depth} \times \text{Slope})$$

$$\text{Width}_L = \text{Width} - 2 \times (\text{Depth} \times \text{Slope})$$

Since the dam is assumed to be a regular shape (i.e. constant batter slope) then the following formula is used to calculate the volume.

$$VOL = \frac{D}{6} (AR_{\text{top}} + 4 \ AR_{\text{mid}} + AR_{\text{base}})$$

Where $AR_{\text{top}}$, $AR_{\text{mid}}$ and $AR_{\text{base}}$ are the surface areas of the top, middle and base of the dam, respectively.
This method requires three cross-section areas to be known - the surface, base and mid-sections. *Note that the mid-section area IS NOT simply the average of the surface and base.* The mid-length and width must each be computed:

\[
\text{Mid}_L = \text{Length} - 2 \times \left( \frac{\text{Depth}}{2} \times \text{Slope} \right)
\]

\[
\text{Mid}_W = \text{Width} - 2 \times \left( \frac{\text{Depth}}{2} \times \text{Slope} \right)
\]

Areas are calculated using the formulae:

*for square and rectangular dams:*

\[
\text{AREA} = \text{Length} \times \text{Width}
\]

*for circular dams:*

\[
\text{R} = \text{radius} = \text{diameter divided by 2}
\]

\[
\text{AREA} = \text{R} \times \text{R} \times 3.1415926
\]

**Example: Rectangular dam**

Dam water surface measures 10 m x 8 m, slope is found to be 1:3 and the water depth is 1.2 m. Compute the volume of water.

\[
\begin{align*}
\text{AR}_{\text{top}} &= \text{surface area} = 10 \times 8 = 80 \text{ m}^2 \\
\text{Base}_L &= 10 - (2 \times (1.2 \times 3)) = 2.8 \text{ m} \\
\text{Base}_W &= 8 - (2 \times (1.2 \times 3)) = 0.8 \text{ m} \\
\text{AR}_{\text{base}} &= 2.8 \times 0.8 = 2.24 \text{ m}^2 \\
\text{mid}_L &= (10+2.8)/2 = 6.4 \text{ m} \\
\text{mid}_W &= (8+0.8)/2 = 4.4 \text{ m} \\
\text{VOL} &= (1.2/6) \times (80 + (4 \times 28.2) + 2.24) \\
&= 39.0 \text{ m}^3
\end{align*}
\]

*Volume of water is 39.0 m$^3$*

**Example: Circular dam**

Diameter of dam at water surface measures 10 m (R=d/2 = 5 m). Slope is found to be 1:3 and water depth is 1.2 m. Compute the volume of water.

\[
\begin{align*}
\text{AR}_{\text{top}} &= \text{surface area} = \text{R} \times \text{R} \times 3.1415926 = 5^2 \times 3.14 = 79 \text{ m}^2 \\
\text{Base}_d &= 10 - (2 \times (1.2 \times 3)) = 2.8 \text{ m}; \quad \text{R} = d/2 = 2.8/2 = 1.4 \text{ m} \\
\text{AR}_{\text{base}} &= \text{R} \times \text{R} \times 3.1415926 = 1.4^2 \times 3.14 = 6.2 \text{ m}^2 \\
\text{Mid}_d &= 10 - (1.2 \times 3) = 6.4 \text{ m}; \quad \text{R} = d/2 = 6.4/2 = 3.2 \text{ m} \\
\text{AR}_{\text{mid}} &= 3.2^2 \times 3.14 = 32.2 \text{ m}^2 \\
\text{VOL} &= D/6(\text{AR}_{\text{top}} + 4\text{AR}_{\text{mid}} + \text{AR}_{\text{base}}) = 1.2 \text{ m}/6 (79 + 4(32.2) + 62)\text{m}^2 \\
&= 42.8 \text{ m}^3
\end{align*}
\]

*Volume of water is 42.8 m$^3$*
Appendix C

Using the Dam Volume Calculator to assess water supply reliability of a farm dam

The Dam Volume Calculator computes volumes and unknown dimensions for regularly-shaped farm dams. It allows a range of questions relating to the design of new dams and the water supply assessment of existing dams to be answered.

Data required (should be in metres)

The first step is to obtain the data required to assess the dam. For an existing dam, such as that shown above, it is necessary to know the length and width of the water surface, the depth of the water and the slope of the batters. A summary of methods used to obtain these can be found in Appendix D.

Setting up the Dam Volume Calculator

Run the Dam Volume Calculator, and select the appropriate dam geometry (square, rectangular or circular). For existing dams it is necessary to select the ‘solve for bottom dimensions’ mode (since slope, depth and surface dimensions are known).

Enter the field measurements in the appropriate boxes. If the depth measurement penetrated the bottom sediment enter the sediment thickness otherwise use the default value. The actual water depth and maximum depth should both be the same for the first run. Enter an appropriate value for daily evaporation (see Appendix E) and select the desired volume units.

Check that the data has been entered correctly and then press COMPUTE. The dimensions of the base have now been computed. If the water depth is set the same as the dam depth then the data in the lower part of the output screen will correspond to the current water surface.

The base dimensions should be recorded on a sheet of paper because to calculate the capacity or volume above the current depth it will be necessary to change to the mode to ‘Solve Top’.
Assessing volumes as water levels fall

After completing the initial calculation it is only necessary to change the water depth value to calculate the remaining volume as the storage declines. After entering a new depth press **COMPUTE** to calculate the new volume.

**Water budgeting**

The Dam Volume Calculator can assist in determining whether the current volume of water in a dam is sufficient to meet expected demand.

First run the Dam Volume Calculator as described for the current water surface level. Record the **volume**, **surface area** and **evaporation losses** on a sheet of paper.

Next determine the total amount of water that is required for the period of interest (i.e. week or month). This should include all water for livestock, farm and domestic use. Ensure this value is in the same units as those set for the Dam Volume Calculator (e.g. M$^3$).

The computed evaporation loss is for one week. If the period of interest is greater than a week then the value must be multiplied appropriately (e.g. if the period of interest is one month then multiply by 4 to obtain a close approximation).

Enter the figures from the Dam Volume Calculator and what has been determined to be the demand into the following equations:

\[
\text{Total Demand} = \text{VOL water needed} + \text{VOL evaporated}
\]

\[
\text{New Dam VOL} = \text{Current Dam VOL} – \text{Total Demand}
\]

**If the total demand exceeds the current volume then the dam will fail within the time period assessed if no rainfall occurs.**

As it is not possible to directly compute the new depth with the calculator, the best approach is to create a table of depths and volumes at 0.1-0.2 m intervals from the current depth down to 0.2 m (similar to Table 1). Once the ‘**New Dam Vol**’ has been determined look up the corresponding depth value in the table, enter this new depth in the water depth box and press **COMPUTE**. Repeat the process for the next period.

**N.B. Evaporation reduces as the dam water level drops. Hence it is advisable not to exceed time periods of one month for each iteration.**
Appendix D

Obtaining storage volume information for a farm dam

When determining the dam reliability it is important that the dam be inspected and measured. Visually estimating water volume is not good enough to obtain a reliable assessment of the projected dam performance. To obtain the best estimate of the existing dam volume it is necessary to determine the following dimensions:

Square or rectangular dam: Length, Width, Depth, Batter slope
Circular dam: Diameter, Depth, Batter slope

Note: To use the information in this report all measurements should be in metres.

1. Measuring the current water surface area

For dams with rectangular or square shapes it is simply a case of measuring the length and width as shown in Figure 1.

Surface area = Length x Width

For circular dams it is necessary to measure the diameter. The radius is half of the diameter. The surface area is then calculated using:

Radius = Diameter divided by 2

Surface area = Radius x Radius x 3.1416

2. Determining dam depth

When determining the water supply capability in dams with low water volumes it is essential the dam depth be physically measured. Depth boards should not be assumed to be zeroed to the base of the dam as sediment may have accumulated in the dam. However once calibrated (i.e. compared to actual measurements) they can provide a valuable role for monitoring.
The easiest way to measure dam depth is to use a weighted wooden or aluminium pole. Hold the pole vertically near the centre of the dam using a rope and move it around till the average water level is determined (Figure D2).

![Figure D2: A simple ‘dam dipper’ can be used to measure water depth. To move the pole, simply pull the rope tight to raise it off the dam floor. A rope with a weight attached and ribboned sections can be used as an alternative to the pole.](image)

### 3. Making a dipper

A simple method of measuring this depth without physically entering the dam is to make a dam dipper. Attach a weight (e.g. a sock or plastic bag filled with sand) to the bottom of the pole. Tie a rope around a wooden pole longer than the expected water depth about half way up. Stand on each side of the dam and, keeping the rope tight, pull the pole out into the middle of the dam.

Keeping the pole upright lower the pole until it rests on the bottom — do not allow it to lie over. Again pull the rope tight (this will raise the pole off the bottom) and carefully drag it to the bank. The water level will be visible on the pole and can be measured using a tape measure. Alternative approaches include using coloured tape (e.g. electrical tape) or paint placed at 0.25 m intervals on the pole so that it can be read while in the water, and using a weighted rope in place of the pole.

**WARNING:** When measuring depth avoid sinking the base of the pole into the sediment. Water below this mark is not accessible to livestock or pumps and should not be considered. Where sediment is a major problem it may be necessary to attach a flat base plate to the pole.

### 4. Estimating the dam batter slope

The dam batter slope is needed to determine the rate at which the surface area and volume decreases with depth. This is important since the dam will hold less water per metre of depth as the dam depth decreases or dries out (see Figure D3 below).

![Figure D3: Reduction in storage volume with depth due to sloping dam sides. The width of A is greater than B](image)
The slope can be measured using a builders spirit level, a wooden stake (longer than 1m) and wooden or metal pole more than 2m long. Hammer the stake into the ground at the water’s edge. Place one end of the pole UPSLOPE of the stake and raise the pole until it is level (check using the builders spirit level). Use a tape measure to measure the distance ALONG THE LEVEL POLE from the upslope end to the stake (this is the Horizontal Distance). Measure the height of the pole off the ground (the Vertical Distance). See Figure D4.

![Diagram of slope measurement](stake_horiz_dist_vert_dist)

*Figure D4: Using a stake, pole and builder’s spirit level it is possible to compute the batter slope of a farm dam. Measure the horizontal distance (between the end of the pole and the stake) and the vertical distance (from the pole to the ground at the stake)*

Use this information to compute the slope:

\[ \text{slope} = \frac{\text{horiz. distance}}{\text{vert. distance}} \]

This formula computes the slope in terms of X metres required to rise 1 m (i.e. 1 in X).

**Example:**

*The slope method is used and the horizontal distance from the end of the pole to the stake is measured at 1.7m. The vertical distance up the stake was measured to be 0.6m.*

\[ \text{slope} = \frac{1.7\text{m}}{0.6\text{m}} = 2.833 \quad \text{i.e. 1 in 2.8.} \]
5. Determining the profile of irregular dam shapes

Farm dams which do not have a regular geometrical shape must be surveyed. This should be carried out on a grid or cross-sectional basis, ideally using a level or a theodolite. To obtain a rough estimate, sections can be measured by stretching a rope marked at 1 or 2 metre intervals (e.g. using cloth strips or ribbons) and using either a pole or dam dipper to obtain depth readings at each mark on the rope.

![Diagram of irregular dam shape]

The depths are then plotted on graph paper, contoured or gridded using a suitable computer package. Refer to a surveying text-book for information on calculating volumes using cross-section, grid data or contour data.

6. Computing the volume

The Department of Agriculture has developed a computer program that can be used with Length, Width, Depth and Slope to compute the dam volume, surface area and base dimensions automatically. Once solved the software will also allow varying depths and sediment thicknesses to be considered. This program can be obtained from the DRAINWISE website (www.agric.wa.gov.au/drains) or by contacting the Water Resource Group at Department of Agriculture, South Perth.

Manual methods of calculating surface area and volume are discussed in Appendix B.
### Appendix E

**Estimated monthly and annual evaporation loss from dams in South-West Agricultural Area (mm*)**

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**ASSESSING STORAGE RELIABILITY OF FARM DAMS**

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*Tabulated values are mm/month. To obtain daily values, divide by the number of days in the month*

**Ed/Ep is dam evaporation (Ed) divided by Class A pan evaporation (Ep)**

*From: Luke et al. 1988*
Livestock drinking rates

Livestock drinking rates are based on a dry sheep equivalent (DSE) which is defined as a 45 kg dry (i.e. not lactating) sheep in forward store condition during summer on a maintenance diet of sub. clover or better pasture. Pigs and cattle/horses consume water at rates equivalent to 2 and 10 DSE respectively.

During a drought year the lack of winter pasture often necessitates hand-feeding and therefore a minimum water requirement of 2 L/head per day was imposed on the sheep drinking rates (Luke 1988). Although this value is too high for most years, design criteria must consider worst case conditions. Greater than normal sheep drinking rates during winter incorporates a safety factor into water supply designs.

N.B. The concept of livestock water used here is highly simplified. Actual water use is highly variable due to seasonal conditions, feed type and water quality. Higher use rates occur as salt content increases.

Table F1. Livestock drinking rates (L/DSE/day) using a minimum of 2.0

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### Table F2. Peak water demand estimates per DSE [L/head/day] for water supply designs with corrected rates for water quality

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</table>


1 Daily drinking allocation has been modified by accounting for average maximum daily temperature and waste (20%) factors. Particular attention should be given to different tolerance of water quality by different classes of stock (Luke 1988).

2 To convert mS/m to mg/L TSS multiply by 5.5; to convert mS/m to gr/gl TSS multiply by 0.385.
### Maximum daily DSE drinking rates in January/February (Factored drinking rates)

<table>
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<th>Locality</th>
<th>Water EC² (mS/m)</th>
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