2.6 Effluent storage requirement

Most of the dairy industry is located in regions with a strong seasonal soil moisture deficit, so the opportunity for effluent to be applied to land must be considered in the design of an effluent storage system. The term ‘storage period’ is used to identify the length of time during which effluent distribution is not appropriate, as indicated by historical climatic data.

Although state authority guidelines should be followed for specific requirements, ‘a generally accepted standard is to design any system to cope with the wettest year in ten’ (ARMCANZ & ANZECC 1996). For ‘environmentally sensitive’ sites (for example, where an overflow will result in pollution of waters or cross property boundaries), use a lower frequency of occurrence or other means of mitigating impacts.

Developing a water budget

Modelling the volume of effluent held in storage (with regular and event-driven inflows), the simultaneous loss via evaporation from a variable pond surface area and evapotranspiration from the reuse area is a relatively complex undertaking, so models such as MEDLI, RUSTIC and ERIM have been developed to help. However, simple spreadsheets using monthly precipitation and evaporation data are appropriate if developed to the following criteria. Indeed, modelling based on monthly data is typically more conservative than daily time-step models (Department of Environment and Conservation NSW 2004) and may offer more robustness and flexibility to system operators.

90th percentile rainfall (and evaporation)

Water budgets to determine storage requirements should be based on the 90th percentile rainfall rather than on mean rainfall. Two approaches to generating the 90th percentile data are valid: the 90th percentile wet year and the adjusted 90th percentile monthly rainfall.

90th percentile wet year: Actual rainfall (and evaporation) recorded during the year where the annual total (YR^{90}) is the wettest in 10 years is used as the basis for design. This is the simplest approach but there may be some irregularities, particularly where heavy rain contributing to the annual total falls in months outside the storage period (e.g. in northern NSW and Queensland with summer-dominant rainfall patterns).

Adjusted 90th percentile monthly rainfall: The 90th percentile rainfall, MR^{90}, is determined for each calendar month and totalled ($\sum MR^{90}$). As the total of individual 90th percentile months is much larger than YR^{90} (the chances of recording 12 consecutive 90th percentile months are low), MR^{90} must therefore be adjusted so that $\sum MR^{90}_{adj}$ equals YR^{90}:

$$MR^{90}_{adj} = \frac{YR^{90}}{\sum MR^{90}} \times MR^{90} \qquad (1)$$

This method smooths the monthly rainfall to better reflect the seasonal patterns than does using the 90th percentile ‘wet year’. It may result in a slightly lower annual rainfall than the 90th percentile wet year as, under that method, the year with an annual total ranked one position larger than YR^{90} is used. For example, in Table 1, the adopted 90th percentile wet year (1978) has a total rainfall of 655 mm. By comparison, the 90th percentile annual total (YR^{90}) is 633 mm. In addition, as the ratio of 90th percentile to mean monthly rainfall is greater in summer than in winter, the adjustment tends to increase the proportion of rainfall received in summer months at the expense of winter (storage period) months.

When using the adjusted 90th percentile month method, use 10th percentile evaporation data (ER^{10}_{adj}).

Table 1. Example calculation of YR^{90} and MR^{90}_{adj} (BOM Station 081125—Shepparton).

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1977	40.4	45.9	17.9	37.4	56	66.6	23.1	13.1	35.7	18.7	16.3	5.3	376
1978	**54**	**3.5**	**81.9**	**46.4**	**75.9**	**57.2**	**75**	**43.6**	**67.9**	**29.4**	**80.1**	**39.6**	**655**
1979	31	0.1	5.6	30.2	50.4	25.9	12.5	82.4	88.2	62.9	45.2	1.8	436
1980	25.4	0.1	19.3	73.5	25.5	52	47.6	37.2	26.5	58.5	22.5	51.3	439
1981	57.4	32.2	40.4	5.1	54.2	104.5	96.4	117.4	30.4	12.6	34.4	7.9	593
1982	44.4	1.6	41.7	18.4	27.4	23.1	11.1	5.2	22.7	11.3	4	4.6	216
1983	10.5	3.7	51.9	64.9	82.2	36.5	102.9	62.1	75.9	26.6	31.3	21.5	570
1984	104.7	12.7	33.2	39.5	8.4	12.1	68.8	81.3	37.8	41.9	15.3	1.7	457
1985	4.1	1.1	14.4	27.9	56.9	21.6	21.5	86.6	31.7	61	73.1	93.6	494
1986	1.2	10.4	0	44.2	71.5	18.9	100.9	60.9	58.8	81.3	8	39.3	495
1987	22.4	27.3	12.8	34.8	28.2	79.3	60.9	27.2	31.8	25.4	25.1	32.8	408
1988	39.2	10.7	36.7	62.2	78.1	69	54.6	19.5	63.6	23	75.4	85.1	617
1989	27.5	8.5	123.8	70.9	67.4	63.7	41.6	97.7	24.2	59.8	23.4	22.6	631
1990	7.8	52	11.9	53	38.1	48.3	89.4	67.1	22.3	30.4	9.5	15.2	445
1991	84.4	0.4	6.9	19.9	3.9	144.2	66.9	55.7	69.1	0.2	5.4	46.6	504
1992	8.2	16.7	41.3	21.9	80.8	33.6	33.3	71.1	100.6	109.2	82.7	121.4	721
1993	98.4	40	46.1	2	37	25.2	83.6	46.4	117.4	148.6	32.7	67.8	745
1994	9.7	90.3	33.1	6.1	17.5	58.5	21.7	11.2	22.2	15.4	21.2	4.5	311
1995	80.7	12.8	0.3	41.8	105.9	81.5	126.4	19.2	32.3	67.3	36.2	2.7	607
1996	55.5	48.4	37.1	36.4	4.7	94.2	78.4	39.1	55.5	25.6	25.7	20.6	521
1997	39.9	10	3.1	1.5	55.3	26.2	8.1	51.7	71.2	18	58	4.3	347
1998	15.7	37.7	3.1	71.4	9.4	31.1	54	64.1	47.9	49.1	102.3	4.9	491
1999	4.1	2.6	65.6	45.8	65.8	42.6	33.3	95.6	25.3	28.8	59	65.2	534
2000	8.8	43	24.7	54.2	58.3	43.4	50.8	44.5	50.6	55.6	84.1	6.6	525
2001	48.5	75.7	26.6	25.4	8.6	35.5	31.3	40.8	32.9	77.1	22.4	7.1	432
2002	8.7	51.4	15.3	6.5	17.6	37.5	13.7	11.6	27.7	9	11	4.7	215
2003	30.8	31.8	0.3	84	54.5	50.5	75.2	69.7	27	57.3	23.9	84.4	589
2004	4.3	3.2	3.9	7.3	33.9	45.4	35.1	44.1	74.8	18.6	70.4	40	381
2005	13.7	97.2	2.5	25	2.2	74.9	29.5	80.2	40.5	82.3	59.3	32.9	540
2006	28.7	17.5	3	20	17.2	16.1	32.6	12.6	22.6	0.4	7.6	6.3	185
Mean	34	26	27	36	43	51	53	52	48	44	39	31	483
YR90													633
MR90	81	54	53	71	78	83	97	88	77	81	80	84	929
$MR90_{adj}$	**55**	**37**	**36**	**48**	**53**	**56**	**66**	**60**	**53**	**56**	**55**	**58**	**633**

Note that rainfall is rarely 100% effective(in terms of being available for infiltration by soil), as some is lost via runoff, interception and evaporation or percolation below the root zone. Procedures are available to allow for this loss, using effective rainfall instead (Environment Protection Authority 1991), but have not been used here. Unless site-specific limitations warrant further refinement of the storage requirement, use a conservative volume and actual rainfall to provide the farmer with more flexibility in timing distributions.

Evaporation and evapotranspiration data

Evapotranspiration is the transfer of water from the landscape to the atmosphere, and is a combination of evaporation and plant transpiration. Hydrologists and irrigators often use measured Class A pan evaporation (E_{pan}) and pan coefficients (k_p) to estimate reference crop (potential) evapotranspiration (ET_o). Alternatively, ET_o can be calculated directly from meteorological data using methods described in FAO (1988).

Both E_{pan} and ET_o data can be provided by the Bureau of Meteorology. If the nearest weather station is not likely to yield representative data for the site, the Queensland Government's Natural Resources and Water website can provide a synthetic dataset for any location in Australia, interpolated from surrounding stations (http://www.nrw.qld.gov.au/silo/datadrill/).

Specific crop evapotranspiration (ET_c) from a disease-free, well fertilised crop grown in large fields under optimum soil water conditions and achieving full production is calculated by using experimentally determined ratios of ET_c/ET_o, called crop coefficients (k_c), where:

$$ET_c = k_c \times ET_o \tag{2}$$

Tables of crop coefficients for common pasture species and crops can be sourced from state departments of primary industries, or more generally from FAO (1988). Crop evapotranspiration under non-standard conditions can be calculated where stresses and environmental constraints may reduce ET_c (FAO (1988).

Irrigation deficit

Any month when the irrigation deficit is less than the minimum depth of application achievable by the irrigation system should be considered part of the 'storage period'. For example, a 6-mm deficit (Table 2) in early spring does not provide an opportunity for reuse, as the minimum depth of application by most pressurised irrigation systems (and certainly flood irrigation) is greater. The storage period for the example shown in Table 2 should therefore be based on a minimum of 4 but preferably 5 months (May to September inclusive). Note that a deficit of 100 mm is equivalent to 1 $ML{\cdot}ha^{-1}$.

Hydraulic balance

The concept of hydraulic balance can be expressed by the following equation:

$$\text{Change in volume} = V_{effluent} + V_{runoff} + (V_{precipitation} - V_{evaporation}) \tag{3}$$

where $V_{effluent}$ = the volume of effluent determined by the water audit (see chapter 1.2 'Characteristics of effluent and manure')

$V_{runoff} = MR^{90}{}_{adj} \times A_{catchment} \times C_x$

$V_{precipitation} = MR^{90}{}_{adj} \times A_{pond}$

$V_{evaporation} = ER^{10}{}_{adj} \times A_{water\ surface}$

C_x = appropriate runoff coefficient (see next section)

$A_{catchment}$ = area of surfaces generating contaminated runoff

A_{pond} = pond area to centreline of embankment

$A_{water\ surface}$ = surface area from which evaporation occurs.

Because the surface area from which evaporation occurs fluctuates with the volume in storage, it is difficult to model using the spreadsheet approach. For that reason, the liquid surface area at mid-depth is generally assumed as a fixed evaporative surface area. Parker *et al.* (1999) found that evaporation from week-old effluent could be closely approximated by Class A pan evaporation. For any pond with a substantial crust, the evaporation component can be ignored.

2.4 Effluent storage requirement

Table 2. Example water balance (BOM Station 081125—Shepparton).

90th percentile water budget—adjusted monthly															Maximum storage volume
Climate data		J	F	M	A	M	J	J	A	S	O	N	D	Total	
Precipitation	mm	55	37	36	48	53	56	66	60	53	56	55	58	633	
ET_o	mm	229	183	156	90	46	28	32	47	73	111	169	195	1360	
k_c		0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.8	0.9	0.9	0.9		
ET_c	mm	207	165	140	72	37	20	22	33	58	100	152	176	1182	
Deficit	mm	151	128	104	24	0	0	0	0	6	45	97	118	672	
Effluent volumes															
Volume of effluent	m^3	194	175	194	188	194	188	194	194	188	194	188	194	2281	
Volume of runoff	m^3	75	51	50	66	73	77	90	81	72	76	75	79	864	
Net pond surface flux (precip – evap)	m^3	–149	–137	–104	9	77	106	125	90	41	–1	–74	–100	–117	
Change in storage	m^3	121	89	139	262	343	370	409	365	300	269	188	172	3029	
Reuse & storage requirement															
Irrigation volume required	m^3	9073	7679	6241	1412	0	0	0	0	335	2689	5826	7085	40340	
Distribution event occurs?		*n*	*n*	*n*	y	*n*	*n*	*n*	*n*	*n*	y	*n*	*n*		
Cumulative storage	m^3	481	570	710	0	343	713	1122	1488	1788	0	188	361		1788
Distributed volume	m^3	0	0	0	972	0	0	0	0	0	2057	0	0	3029	
Distribution depth	mm	0	0	0	16	0	0	0	0	0	34	0	0	50	
											Warning				

Assumed data for worked example:
Effluent volume = 6250 $L \cdot day^{-1}$
Runoff area impervious = 750-m^2 concrete feedpad + 650-m^2 concrete yard = 1400 m^2 total impervious
Runoff area pervious = 3000-m^2 loafing pad
Pond catchment area = 2500 m^2
Evaporation area = 1250 m^2
Reuse area = 6 ha
‘Warning’ flags a distribution depth exceeding a site-specific limit (in this example, 25 $mm \cdot month^{-1}$).

Calculation of runoff coefficients

Australian Rainfall & Runoff (IEAust 1987) provides a method for determining an appropriate runoff coefficient. Figure 1 relates the runoff coefficient C_{10} for a 10-year average recurrence interval (ARI) event to the pervious and impervious fractions of the catchment, and to the 10-year ARI 1-h rainfall intensity (${}^{10}I_1$). Where ${}^{10}I_1$ is between 25 and 70 mm·h^{-1}, a line can be interpolated as:

$$C_{10} = 0.9 \times f + C^1_{10}(1 - f) \tag{4}$$

where f = fraction impervious (0.0–1.0)

C^1_{10} = pervious area coefficient:

$$C^1_{10} = 0.1 + 0.0133({}^{10}I_1 - 25) \tag{5}$$

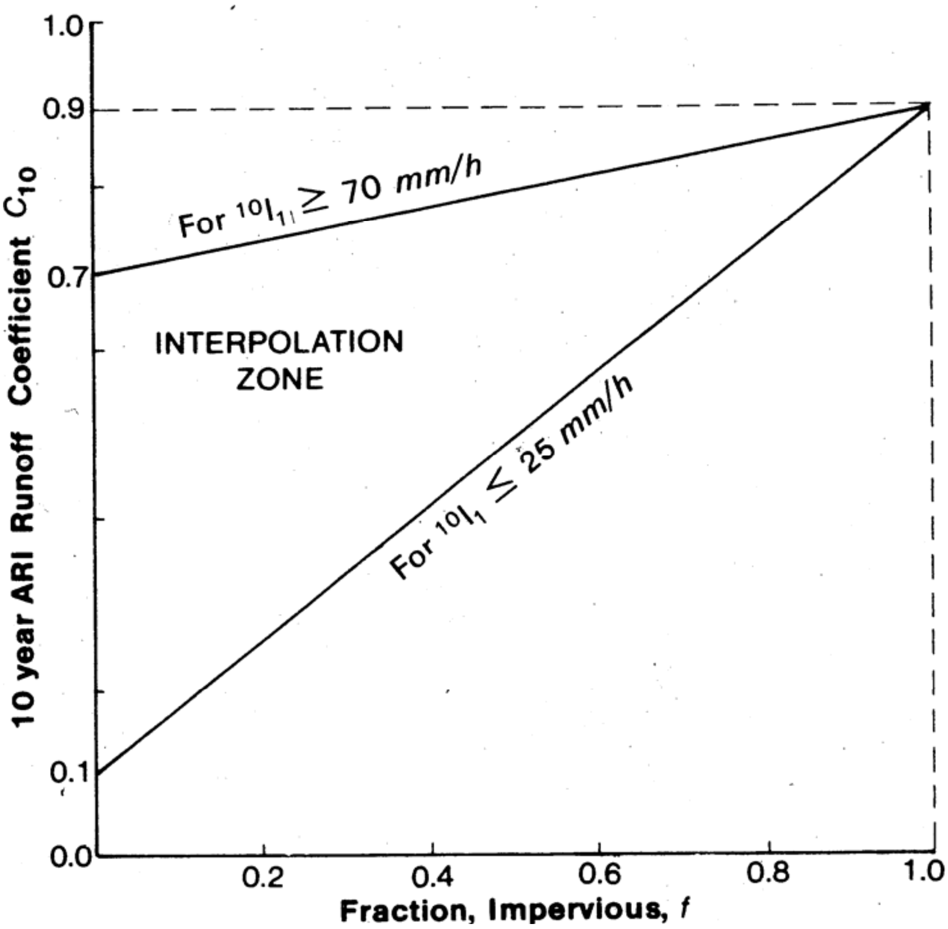

Figure 1. Calculation of runoff coefficient C_{10} (IEAust 1987).

For a balance using 90th percentile rainfall data, it is appropriate to use the 1-year ARI coefficient (C_1):

$$C_1 = 0.8 \times C_{10} \tag{6}$$

Worked example

Data come from Table 2.

2.6 Effluent storage requirement

Effluent volume	6250 L·day^{-1}
Runoff area impervious	750-m^2 concrete feedpad + 650-m^2 concrete yard = 1400 m^2
Runoff area pervious	3000-m^2 loafing pad
10-year 1-h rainfall intensity $^{10}I_1$	29 mm·h^{-1}
Fraction impervious f	1400 / (1400 + 3000) = 0.32
Pervious area coefficient C^1_{10}	0.1 + 0.0133 × (29 – 25) = 0.15
10-year ARI runoff coefficient C_{10}	0.9 × 0.32 + 0.15 × (1 – 0.32) = 0.39
Annual runoff coefficient C_1	0.8 × 0.38 = 0.31

Maximum cumulative storage volume

The spreadsheet should identify the maximum cumulative storage volume needed to avoid a spill or a distribution event during the storage period. For the worked example in Table 2, the storage volume required was 1788 m^3 (excluding freeboard).

Residual volumes

The preceding section identifies how the ‘active’ storage volume is determined. In addition to that volume, an allowance needs to be made for any effluent remaining following drawdown and for a treatment volume where a floodwash system uses water from the storage pond.

Allowance for residual volume

The allowance for residual volume should generally be the larger of either:

- a minimum depth of 300 mm to prevent desiccation and cracking of the pond liner; or
- at least 2.5 times the suction inlet (or ~4 times the diameter of the suction pipe) to avoid air entrainment, as the storage pond is likely to be emptied by a pump (APMA 2001). Also see chapter 1.5 ‘Sump design’.

Storages providing treated effluent for floodwash

Effluent is often recycled from the storage pond to supply a floodwash system for yard and feedpad wash. Sufficient volume should be retained following drawdown to provide a nominal residence time of 20 to 30 days before reuse for aerobic or facultative treatment processes. When applicable, this volume is likely to exceed the volume required for suction submergence or liner protection and becomes the residual volume.

Managing the effluent storage

Depth marker

A properly sized effluent storage is a good start, but it must be managed (drawn down when appropriate) to provide the required storage capacity. A depth marker is a handy device and should be installed with markings showing at least:

- the full supply level (600 mm below top of bank)
- the level at which the ‘active’ storage volume remains—the water level must be drawn down to this point at the start of the storage period.

It is useful to have additional level marks at increments of 200 to 500 mm to track cumulative volume over the course of the storage period.

Painted level marks can be obscured by discoloration and a build-up of bacterial slime. Use V-shaped notches 25 mm deep instead.

Stormwater diversion and reducing storage requirements

All dairies should:

- collect and use roof runoff by directing gutters to the tank supplying platecooler or washdown water
- reuse platecooler discharge for washdown
- prevent runoff from entering the yards or effluent systems from upslope.

Diverting clean stormwater from the holding yard, however, requires more consideration. Diverting 'clean' runoff from the washed holding yard will reduce the storage volume requirement, pumping costs and the risk of overtopping. On the other hand, farms in dry climates may be required to add fresh water just to dilute pond salinity levels (see Chapter 2.3 'Anaerobic, aerobic and facultative ponds') and would benefit from the addition of clean stormwater. In addition, a storage designed to accommodate stormwater avoids the risk of unintentional diversion of effluent (if the diverter is not reset to 'collect' mode before the yard is washed) and contaminated stormwater. The SA EPA (Environment Protection Authority 2003) suggests that even washed yards may generate contaminated runoff. Therefore, if site constraints allow, capturing stormwater is preferable, and the storage volume should be calculated on that basis. However, farms that practise seasonal milking are usually able to safely divert runoff from cleaned yards over their non-milking periods.

In high-rainfall areas, any or all of the following stormwater minimisation options may be considered:

- Install guttering so that roof runoff is directed to the washdown tank and any overflow is diverted away from the effluent system.
- Reuse platecooler discharge for washdown and divert any excess away from the effluent system.
- Divert runoff from clean holding yards (using a washdown pump cut-out or high-visibility reminder to signal when the diversion is in use).
- Roof the holding yard (which may also help control heat stress in summer).
- Minimise unnecessary accumulation of manure (e.g. by holding cows after milking).
- Install a trafficable solids separation trap to reduce the sludge allowance for the pond and therefore the pond surface area.
- Minimise pond surface area by using a single pond or increasing depth.
- Recycle effluent for yard floodwashing.
- Cover the pond (see chapter 8.1 'Production and beneficial use of methane').

Reuse scheduling

Plan effluent distributions, taking into account the volume in storage, current soil moisture deficits and crop conditions and, where available, 4- to 7-day weather forecasts. See chapter 3.9 'Hydraulic application rate and scheduling'.

Sizing collection and diversion structures for storms

With increasing numbers of uncovered feedpads contributing contaminated runoff from larger catchment areas, it is necessary to consider the rate of runoff that must be dealt with during storms. Intense storms may generate larger volumes of runoff than traditional collection pipes and pumps can handle, causing effluent to overflow the collection system.

National guidelines for beef feedlots require that collection and diversion structures (diversion banks, catch drains, sedimentation basins etc.) be designed to carry the peak flow rate resulting from a design storm event with an ARI of 20 years (ARMCANZ 1997). The design storm has a duration equal to the time of concentration, that is, the time taken for runoff to travel from the most remote point in the catchment to the point of interest (IEAust 1987) both by overland flow and in any drain or pipe.

Owing to the limited extent of most collected surfaces around a dairy, it may be preferable in all but the largest operations to adopt a conservative time of concentration; that is, a time of concentration of 5 min will give the highest-intensity rainfall event. Check the capacity of all structures to ensure that they can handle the expected peak flows.

The rate of runoff (Q, $m^3 \cdot s^{-1}$) is given by:

$$Q = \frac{C\,i\,A}{3.6x10^6} \tag{7}$$

where C = runoff coefficient (see ‘Developing a water budget’ above); $C_{20} = 1.05 \times C_{10}$

i = intensity ($mm \cdot h^{-1}$)

A = catchment area (m^2).

Local storm intensities can be obtained from the Bureau of Meteorology (http://www.bom.gov.au/hydro/has/ifd.shtml).

Worked example

A 150-mm pipe is proposed for both the effluent collection pipe and stormwater diversion device for the 650-m^2 yard (above). The 5-min storm intensity in this worked example was determined to be 125 $mm \cdot h^{-1}$ (IEAust 1987).

Fraction impervious f	= 1.0
10-year ARI runoff coefficient, C_{10}	= 0.9 × 1.0 = 0.9
20-year ARI runoff coefficient, C_{20}	= 1.05 × 0.9 = 0.95
Runoff, Q	= (0.95 × 125 × 650) / 3 600 000
	= 0.02 $m^3 \cdot s^{-1}$ (20 $L \cdot s^{-1}$).

At a grade of 1 in 60, a 150-mm (ID) pipe will convey approximately 30 $L \cdot s^{-1}$. Therefore, the proposal is adequate.

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