1.4 Floodwash systems

Floodwash or flush systems offer large savings in the labour required to clean yards, feedpads and flush alleys (cow movement lanes in freestall sheds). Adopting suitable design criteria is essential to ensuring a thorough cleaning action and avoiding unnecessary water use.

Design criteria

Following a technical assistance program on the NSW Mid-North Coast, Bullock (2002) reported typical yard cleaning rates of 7 to 10 $m^2 \cdot s^{-1}$ for floodwash systems, compared to 0.3 to 0.4 $m^2 \cdot s^{-1}$ for manual hosing and 2 $m^2 \cdot s^{-1}$ for hydrant systems. Therefore, as a labour-saving option, floodwash systems are very attractive and have been adopted widely in new dairy developments.

However, for a floodwash system to effectively clean the surface without scraping, the design criteria selected must reflect the nature of the material to be removed: there is a considerable difference in the flush velocity required to dislodge and transport organic matter compared with sand and stones, or freshly excreted manure compared with dry manure. Wedel (2000) reports that a flush velocity over 0.3 $m \cdot s^{-1}$ is sufficient to scour most organic material, but that 1.5 $m \cdot s^{-1}$ is needed to move sand particles of up to 5 mm diameter.

Where a floodwash system is being considered for cleaning a feedpad, bear in mind that dry manure adheres strongly to any concrete surface, and that it is impractical to expect that water alone will dislodge it. Mechanical scraping will be required to assist floodwashing in such situations.

Target depth and velocity

The design depth of flow ranges from 25 to 100 mm. Depths of 75 to 100 mm are generally used in freestall flush alleys where manure build-up is heavy. Depths of 25 to 50 mm are typically used for holding yards in Australia.

Table 1. Minimum floodwash criteria.

Situation	Minimum depth (mm)	Minimum velocity ($m \cdot s^{-1}$)
Some mechanical assistance may be necessary	25	1.0
Recommended for most yards	50	1.0
Sand-laden manure and freestalls	75	1.5

Manning's equation (1) is commonly used to check that the required flush velocity will be achieved at the target flow depth. It is apparent that yard slope and surface roughness are important determinants of the flush velocity.

$$v = \frac{R^{0.67}\ S^{0.5}}{n} \qquad (1)$$

where v = velocity ($m \cdot s^{-1}$)

R = hydraulic radius (m) (see Equation 2)

S = slope ($m \cdot m^{-1}$)

n = roughness coefficient.

Values of Manning's *n* range typically from 0.015 to 0.02 for concrete yards and channels: the rougher the surface, the larger the number.

For rectangular channels and yards, the hydraulic radius is calculated by:

$$R = \frac{WD}{W + 2D} \qquad (2)$$

where *W* = width (m)

D = depth of flow (m).

Flow rate required to achieve target depth and velocity

Once the flush depth and velocity are known, the flow rate required to generate those characteristics can be simply determined by Equation 3:

$$Q = A\,v \qquad (3)$$

where *Q* = flow rate ($m^3 \cdot s^{-1}$)

A = area (m^2)

v = velocity ($m \cdot s^{-1}$).

Figure 1 shows the flow rate required to flush a 12-m-wide yard with a minimum flush velocity of 1 $m \cdot s^{-1}$ and a target depth of 50 mm. A yard slope of 2% (or 1 in 50) achieves the minimum flow rate required (650 $L \cdot s^{-1}$); flatter slopes will require a larger flush depth to achieve the 1 $m \cdot s^{-1}$ flush velocity; steeper slopes will produce higher flush velocities. Both increase the required flow rate.

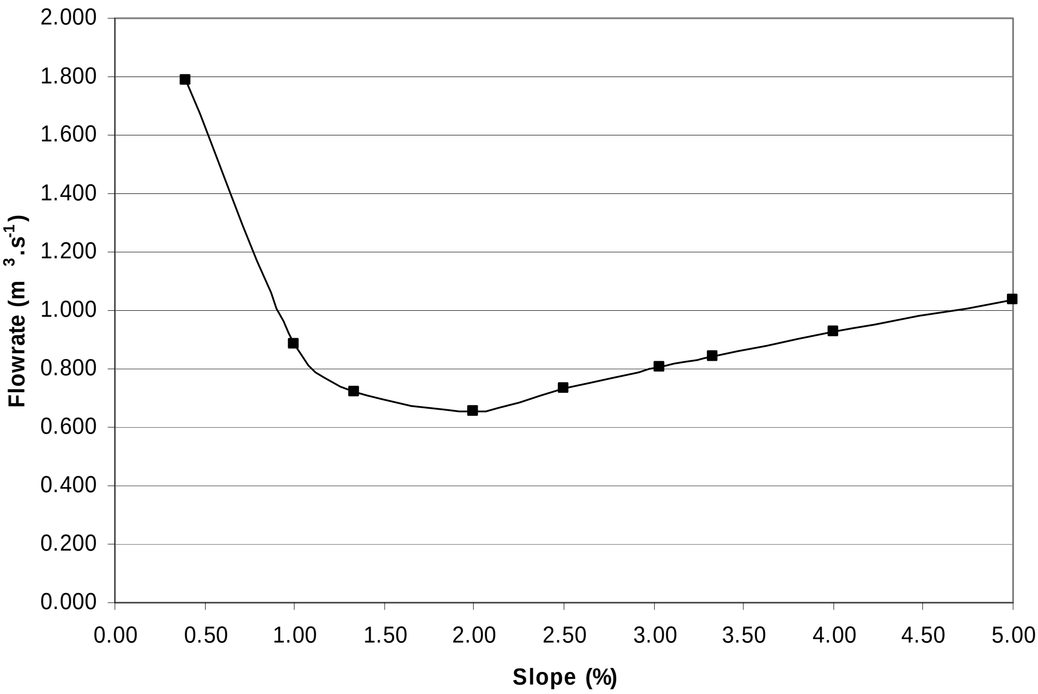

Figure 1. Flow rate required to flush a 12-m-wide yard (*v* = 1.0 $m \cdot s^{-1}$, *D* = 50 mm, *n* = 0.0175).

Tables of required flow rates can be produced for a range of yard slopes and widths. Table 2 shows an example for a flush velocity of 1.0 $m \cdot s^{-1}$ and depth of 50 mm (with Manning's *n* = 0.0175).

Table 2. Flow rate (Q, $m^3 \cdot s^{-1}$) for various yard widths and slopes (v = 1.0 $m \cdot s^{-1}$, D = 50 mm, n = 0.0175).

	Width (m)								
Slope (%)	4	6	8	10	12	14	16	18	20
1.00	0.304	0.450	0.602	0.738	0.887	1.036	1.185	1.334	1.483
1.33	0.245	0.359	0.481	0.602	0.723	0.833	0.939	1.057	1.175
2.00	0.216	0.325	0.435	0.545	0.654	0.764	0.874	0.983	1.093
2.50	0.241	0.364	0.486	0.609	0.732	0.854	0.977	1.100	1.222
3.00	0.264	0.399	0.533	0.668	0.802	0.936	1.071	1.205	1.339
3.33	0.279	0.420	0.562	0.703	0.845	0.986	1.128	1.270	1.411
4.00	0.305	0.460	0.615	0.770	0.926	1.081	1.236	1.391	1.546
5.00	0.341	0.515	0.688	0.861	1.035	1.208	1.382	1.555	1.728

Use 'volume per metre width' as a check, not a design criterion

The volume of water required for floodwashing is typically reported as 500 to 1500 L per metre width of yard in Australian references and is based on easily measurable parameters (i.e. water use and yard width) from successful systems. Previously, these recommendations have been used to determine the required flush duration. Instead, it is recommended that designers adopt US procedures for determining the flush duration. Fulhage and Pfost (1993) state that the flush duration must either:

- achieve a minimum contact time of 10 s (suitable for yards and short alleys); or
- maintain the flow rate for sufficient time for the wave front to traverse at least one-third of the alley length (suitable for freestall alleys).

At 1 $m \cdot s^{-1}$, the criterion adopted changes from contact time to the one-third travel time if the yard length exceeds 30 m. That is, the flush duration will be at least 10 s for yards up to 30 m, and the length divided by three times the velocity after 30 m. For a flush velocity of 1.5 $m \cdot s^{-1}$, the critical yard length is 45 m.

Cleaning the 12-m-wide yard examined in Figure 1 would require a minimum flush duration of 10 s if the yard is 30 m long and a volume of 6500 L. Equivalent to a volume of 540 L per metre of width, this falls within the range of reported volumes. It is important to remember, however, that 540 $L \cdot m^{-1}$ is the result of applying the depth–velocity–duration criteria and that, although the volume–width rule of thumb can be used as a check, it is not the starting point for design.

Floodwash system configurations

Once the required flow rate has been determined, the delivery system, including tank, head and pipe configuration, can be designed. The range of floodwash systems includes both pre-fabricated and custom-made installations, but all fall into one of two categories: 'above the surface' delivery and 'buried main and riser'. Large-volume irrigation pumps (axial or mixed flow) are an alternative to using a tank to supply the required flow rate for either delivery configuration.

Above-the-surface delivery

A tank with one or more outlet valves and short delivery pipes is located beside the upper end of the yard. The outlets are oriented to spread water across the yard width or are fitted with a manual direction-control vane. Tanks should be mounted at least 2 m above the yard elevation. Specialist floodwash tanks and used petrochemical storage tanks, which may range from 4 to 8 m in height, can be mounted on a slab at yard level.

Buried main and risers

A main delivery pipe, usually HDPE of 300 mm diameter or greater, with approx. 150 mm risers on 2- to-3 m centres, is fabricated on site and bedded into place before the yard is concreted. The bedding is critical to prevent movement during use, and all junctions require thrust blocks (see Water Service Association of Australia (2002) or similar for thrust block details). Grates or hinged lids must be fitted onto risers to prevent cows stepping into open risers. Tanks may be mounted on a stand or slab to achieve sufficient head.

Buried main and pipe systems are more expensive than above-the-surface delivery systems, but they offer the advantage of uniform delivery of water and cleaning. Additionally, more risers may be located in areas of higher activity, where extra flushing is required. They are suited to wide yards or where the location of the tanks and pipes for an above-the-surface delivery system is restricted; that is, in freestall alleys.

Figure 1. Floodwash tanks and above-the-surface delivery for feedpad flushing.

Where less than the full volume of the tank is used for each flush, a pressure relief or vacuum release valve may be required on the delivery pipe to prevent damage upon valve closure. Gear-operated, air-actuated or electric valves are preferred over lever-type valves, as they can prevent the valve from being opened or closed too quickly and causing water hammer. In the case of air-actuated valves, two-way actuators provide the most flexibility, as they can be set up to control the speed of opening and closing, unlike one-way actuators, which have spring-operated return-to-close valves.

Hydraulic design procedure

Tools are available to help designers size pipes and valves for floodwash delivery. Skerman (2004) provides a spreadsheet that enables such calculations to be performed, including the response of flow rate to decreasing available head.

If a manual calculation is necessary, the procedure can be summarised as follows:

- Select appropriate flow criteria (depth and velocity) from Table 2.
- Using the target flow depth, calculate the flush velocity using Equations 1 and 2.
- If the velocity is less than required, increase the depth and recalculate until the target velocity is achieved.
- Calculate the flow rate using Equation 3.
- Determine the tank and discharge pipe and valve configuration (or pump–pipe arrangement for direct pumping) and select appropriate friction and local losses.
- Solve the continuity equation (see standard hydraulic texts) for pipeline velocity (by trial and error) according to the head available from the tank.
- If the target flow rate cannot be achieved for the head available, select a larger pipe diameter or alternative (higher or larger) tank arrangement.
- Calculate the flush duration to deliver the larger volume determined by adopting a contact time of 10 s or maintaining the target flow depth and velocity over at least one-third of the alley length.
- Determine the flush volume and confirm that the tank provides sufficient head for the flush duration.

Floodwash systems and the effluent system

Adopting a floodwash system will have implications for the remainder of the effluent management system. There are several implications:

- A larger volume of water is required than for any other yard cleaning system. McDonald (2005) reports that the average volume for floodwash tanks in Victoria in a 2005 audit was 17 000 L, and that most farms used the full capacity in flushing. The reported volume used in floodwashing yards ranged from 8000 to 60 000 L·day^{-1}. Fortunately, floodwashing systems can use treated effluent drawn from the terminal pond in a multiple pond system to minimise the use of clean water. However, solids separation traps and pumps will have to be sized larger than otherwise required to cope with the increased throughput.
- A solids separation trap or large-capacity gutter should be used to collect the flush at the lower end of the yard. Solids separation traps must be sized to accommodate the volume of the floodwash tank in addition to the volume of sludge built up between cleaning events (see chapter 2.1 'Solid–liquid separation systems'). Gutters conveying floodwash away from yards to traps or ponds must be designed to convey the maximum flow rate without backing water onto the yard.
- There is potential for salt build-up in systems using recycled effluent. A reduction in clean water input to the effluent system, in conjunction with the additional pond surface and evaporation from the multiple pond systems required, will increase

the salinity of the effluent, potentially compromising anaerobic pond function and exacerbating salinity problems following land application (see chapter 2.3 'Anaerobic, aerobic and facultative ponds').

- Struvite (a build-up of the salt magnesium ammonium phosphate) may become a problem where the ratio of recycled effluent to clean water entering the effluent system is high. The presence of struvite can be an indication that TDS levels are too high and that additional clean water needs to be added to the system. See Hopkins (2002) for further information on struvite and its control.
- Some farms draw effluent from sumps or solids traps to supply the floodwash, rather than from the terminal pond in a treatment system. Although anecdotal evidence suggests that this reduces odours, this approach also causes algal growth and slippery yard surfaces.

There are implications for yard design as well:

- Nib walls or kerbs must be a minimum of 200 mm high to contain the wave produced.
- The flush should discharge from the end of the yard into the gutter or solids separation trap. However, if there is no alternative to a side discharge arrangement, yards may have a cross fall (<25 mm at the upper end, increasing at the lower end), but be aware that the high side will not clean well. Cross-drains are an alternative but may allow some solids to drop out of suspension where the flush slows to change direction.
- Valves and outlet rudders for above-the-surface delivery must be guarded to prevent injury to cows on the yard. Outlets must be positioned so that they do not reduce good cow flow.

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