4 INLET DESIGN

What about the inlet? What effect will its position and design have on the efficiency of the pond?

4.1 Introduction

Existing design manuals give little information on the importance of the position and design of an inlet in a waste stabilisation pond. In this chapter, previous work is briefly reviewed and new ideas presented on how inlet position and design affect pond hydraulics.

4.2 Previous Work

Recent research suggests that the inlet position and its relation to the outlet are more important than previously thought. Pearson *et al*., (1995) concluded "…the positioning and depths of the inlet and outlets may have a greater beneficial impact on treatment efficiency than pond shape." (pg 137).

Wood (1997); Persson (2000); and Shilton (2001) all noted that the position and design of the inlet does indeed have a significant impact on the hydraulic efficiency of a pond. However, little practical guidance exists on the design and positioning of inlets.

Inlet position and type has a significant impact on treatment efficiency in ponds.

4.3 New Thinking

4.3.1 Introduction

There has been uncertainty in the literature regarding the flow patterns that exist within waste stabilisation ponds. A number of researchers have assumed that fluid moves reasonably directly from the inlet towards the outlet. However, it has been found that horizontal inlets can drive the pond contents to circulate in large cells at velocities much faster than if the flow was simply moving from the inlet to the outlet in a 'plug flow' manner.

It is useful to think of the inlet as a small drive on a large flywheel where, in the case of the pond, the flywheel is the bulk volume. Although the jetting effect from an inlet pipe is quite localised, it provides a consistent source of momentum inputted in a fixed direction at a fixed point. This momentum is transferred into the bulk volume and thereby drives the main circulation.

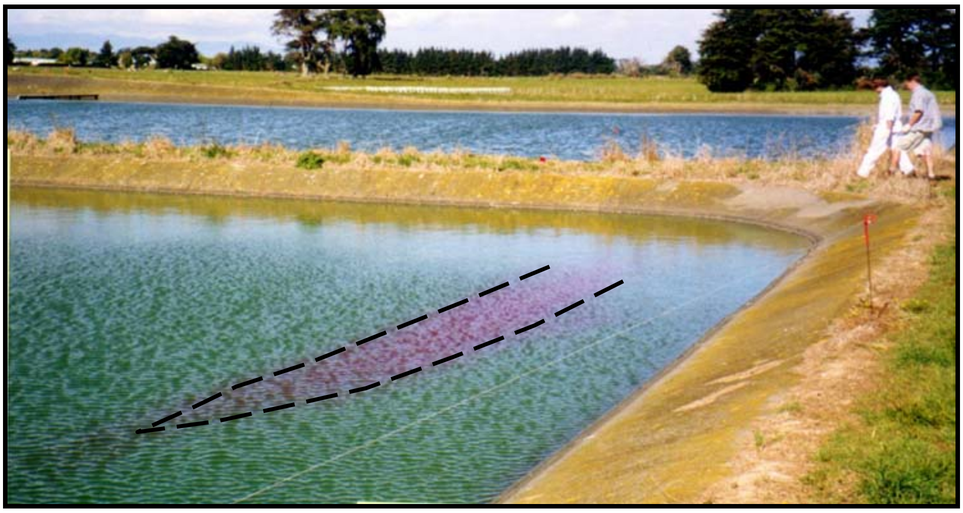


Figure 4-1 'Jetting' effect of the inlet as seen in a tracer study on a field pond

Laboratory experiments, computer modelling and fieldwork have all repeatedly highlighted the ‘jetting’ effect that a horizontal inlet creates in a pond. The picture in Figure 4-1 above of a tracer study performed on a field pond shows this jetting effect as wastewater flows from a primary pond into a secondary pond via a pipe in the embankment.

The inlet jet is relatively localised but provides a momentum source that drives circulation of the main flow pattern.

This effect is similar to a small drive on a large flywheel.

4.3.2 Use of Large Horizontal Inlets

In order to reduce the jetting effect associated with horizontal inlet pipes, laboratory experiments and computer modelling work were undertaken to assess the effect of increasing the cross-sectional area of the inlet, thereby slowing its velocity. Large pipe diameters and a large inlet channel were tested.

While the larger inlets did indeed decrease the velocity of the main flow circulation, the overall pattern of wastewater swirling around past the outlet at the opposite end of the pond was just the same. Short-circuiting was indeed delayed but the net effect, in terms of improving treatment efficiency, was not particularly significant.

While a larger inlet will slow the pond circulation and provide some delay in short-circuiting the improvement is not significant.

Rather than increasing inlet size it can also be important to use a smaller pipe to maintain inlet momentum, mixing and flow control. This is discussed further in section 4.3.8.

4.3.3 The Jet Attachment Technique

Rather than seeking to reduce the jetting effect created by a horizontal inlet pipe, this technique seeks to utilise it for flow control. The idea is simply an alternative to directing a horizontal pipe straight out into the main body of the pond. Instead, the inlet is kept close in against a sidewall. When this is done the inflow will tend to 'cling' to the side.

This is known as 'jet attachment'. The fluid from an inlet pipe creates localised inlet jetting. An inlet jet acts to suck in and entrain fluid from the surrounding water body. However, if a jet is positioned close to a sidewall it tends to suck into and attach on to this wall.

Previously it was noted that a common problem with pond hydraulics was that the influent swirled too quickly around from the inlet to an outlet located at the opposite end of the pond. So why would we want to use an inlet that encourages this effect?

If we wish to control the flow pattern in the pond in order to optimise the hydraulics, then this could be a useful tool. For example, in the following section we discuss locating an outlet in the centre of a pond. In this case we want to keep the influent around the edge and have it slowly spiral into the centre.

Another application is that used in the case study discussed in Appendix One at the rear of these guidelines. By adding a right angle bend and swirling the influent around the edge of the pond, the end wall then essentially acted as a baffle to contain and slow the inflow. The flow then circulated around, and into a short baffle located on the opposite side of the pond as shown in the following diagram.

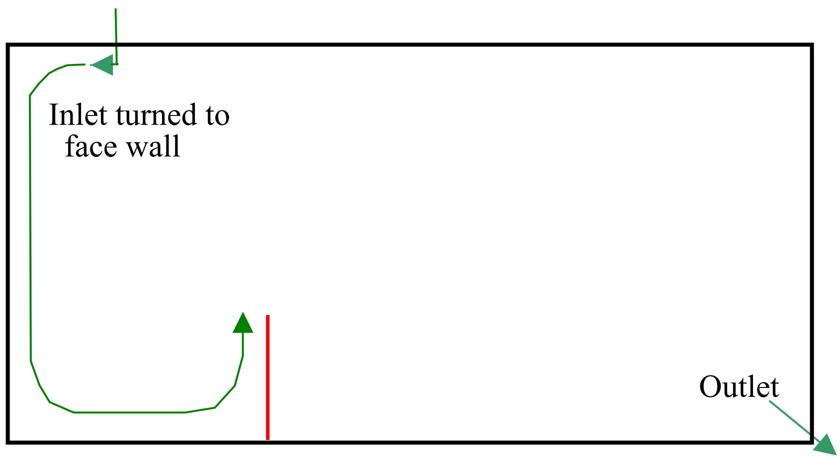


Figure 4-2 Pond with modified inlet and stub baffle

It is possible to control the inlet flow by 'attaching' the inlet jet along the edge of a pond.

While this alone won't necessarily reduce short-circuiting, it can be an effective tool when used in conjunction with other design improvements.

4.3.4 Vertical Inlet

If a horizontal inlet causes short-circuiting problems then a relatively cheap method of avoiding this would seem to be simply changing it to discharge vertically.

In initial laboratory testing it was found that the use of the vertical inlet provided a significant improvement. Further work on a different laboratory model again showed it to work very well. Given the ease and simplicity of installing a vertical bend to an existing horizontal pipe, this approach appeared very promising.

However, when a vertical inlet was computer modelled and tested on a full-scale pond (of somewhat different configuration to the laboratory experiments), it was not found to give any significant improvement over a horizontal inlet pipe. It had been assumed that the tracer would be discharged and then slowly spread out evenly across the pond. However, in this case the tracer appeared to move out in two plumes along either adjacent wall.

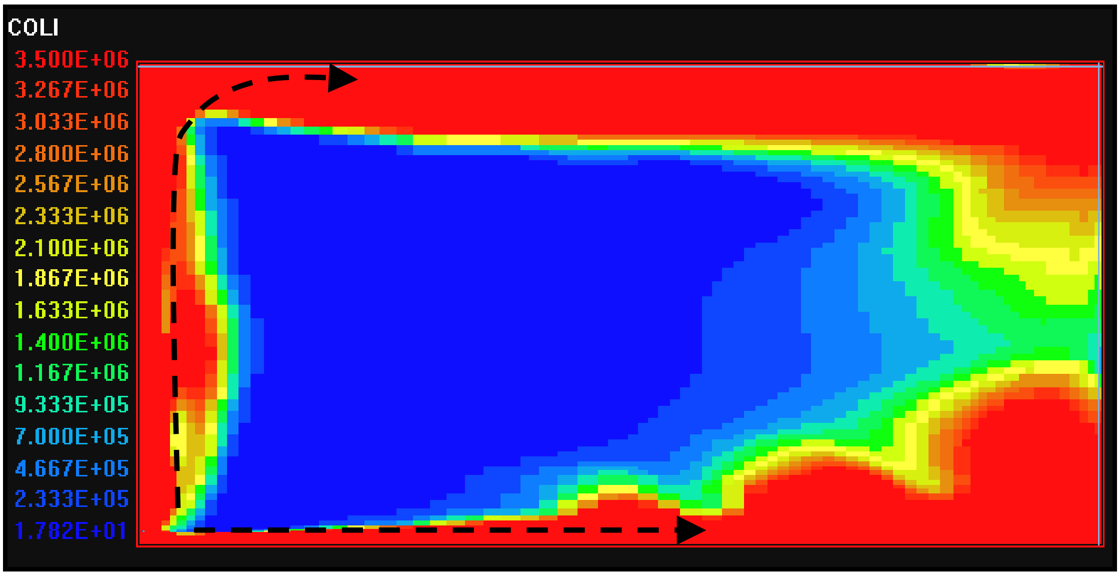


Figure 4-3 Flow pattern and direction from a vertical inlet

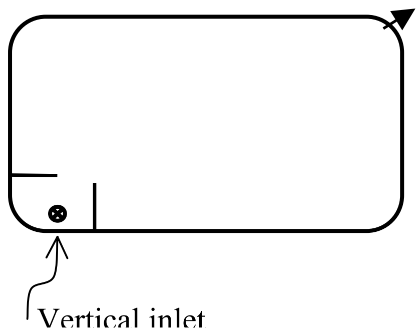
This finding is similar to a result found when modelling a water storage reservoir where again the inflow from a vertical inlet moved out around the walls of the tank.

It is not clear why this inlet design works well in some cases but not in others. While this type of inlet deserves further research, until we have a better understanding of this behaviour we need to be cautious before using this design approach.

Used alone, vertical inlets have variable performance and may not always offer an improvement over a horizontal inlet.

4.3.5 Vertical Inlet with Stub Baffles

This idea again involved using a vertical inlet but now with short baffles placed on either adjacent wall to block the circulation around the edges that had been seen previously.



This approach was tested in both the laboratory and in computer modelling of the full-scale pond. Both cases gave excellent results. The tracer was rapidly mixed within the baffled inlet area and then moved uniformly out into the main body of the pond through the gap between the two baffles. The following photo shows the tracer in a laboratory test moving out of the baffled corner.

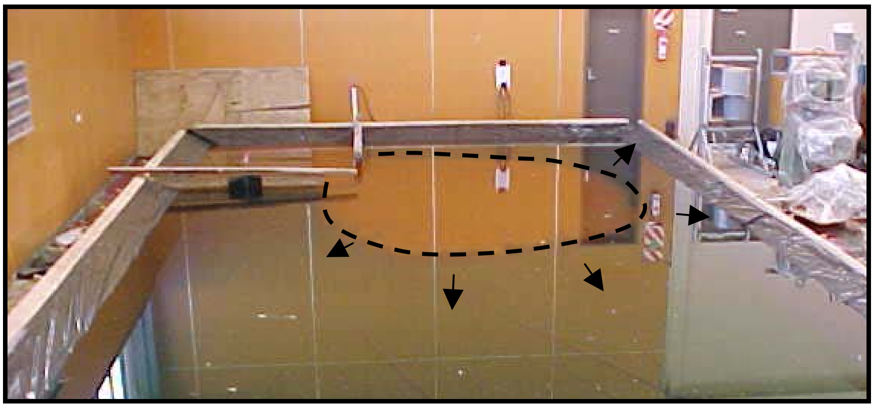


Figure 4-4 Dye movement in pond with vertical inlet and adjacent stub baffles

The addition of the stub baffles appears to have made the performance of the vertical inlet more effective and reliable than in the testing using vertical inlets alone.

Addition of stub baffles adjacent to a vertical inlet improved its reliability.

However, before considering this application consideration must be given to the effect of the loading in the inlet zone. This is discussed further in section 4.3.8.

4.3.6 Diffuse (Manifold) Inlet

Previous researchers have indicated that diffuse or manifold inlets offer potential as an inlet improvement option (Mangelson *et al.*, 1973; Fares *et al.,* 1996; Persson 2000).

A manifold inlet was tested in the laboratory. This consisted of an inlet pipe running the width of the pond, containing eight equally spaced small diffuser holes facing downward towards the base of the pond. As can be see in the photo below these had the effect of creating an even distribution of the tracer that then spread down the length of the pond. Surprisingly, however, the tracer still moved relatively steadily.

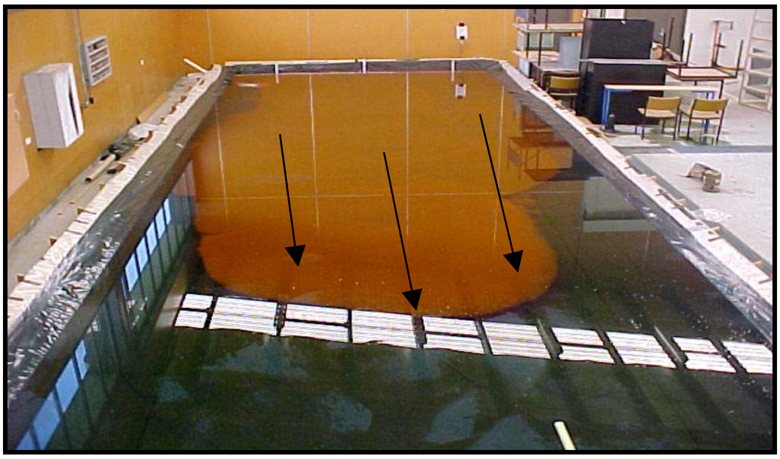


Figure 4-5 Dye movement down laboratory model due to diffuse (manifold) inlet

Although this gave an improvement over simply having a horizontal inlet pipe, this pond configuration was one of the cases mentioned previously where a simple vertical inlet gave far better results.

Based on this result, and the comments of previous researchers, the manifold inlet option clearly has some potential. However, installing and maintaining this sort of inlet on a large full-scale pond may not always be practical or cost effective compared to other options.

Diffuse (manifold) inlets can reduce short-circuiting, but may not always be practical or cost-effective.

4.3.7 Inflow Dropping from a Horizontal Pipe

Many ponds are currently fitted with a horizontal inlet pipe that discharges a short distance above the pond surface. So is this working like a horizontal inlet or a vertical inlet?

As the water plunges down into the pond it will certainly pick up a significant vertical velocity. However, even though the water drops rapidly down and appears vertical, the horizontal component of momentum still remains after discharge.

Figure 4-6 Field pond with inflow dropping from a horizontal pipe

Testing undertaken on a laboratory model confirmed the strong influence of the horizontal momentum. Even though the water seemed to be almost vertical when it impacted the pond surface it did in fact set up a rapidly circulating flow pattern, as was the case with a horizontal inlet. Tracer testing confirmed that for this type of inlet the influent swirled around to the outlet in a time very similar to that for the submerged horizontal inlet.

Dropping inlets from horizontal pipes above the water surface have similar behaviour as submerged horizontal inlets.

4.3.8 Inlet Type – Overall Recommendation

There is a range of alternative inlet designs, however, most of these are simply methods for avoiding/minimising the jetting effect that results from using a horizontal inlet pipe.

In the previous section we highlighted the need to consider organic and solids loading. While from a purely hydraulic viewpoint it may be useful to dissipate the inlet momentum, in so doing we lose the useful effect that this momentum has in rapidly distributing the organic and solids loading out into the main body of the pond. This is not, however, an issue for maturation ponds where organic and solids loads have already been significantly reduced by prior treatment.

A second practical consideration is wind. If the inlet design acts to dissipate the driving force of the inlet then it is more likely that, on a windy day, the wind will determine the flow pattern in a pond. In certain cases this may drive the influent rapidly towards the outlet again leading to short-circuiting problems and poor hydraulic efficiency.

Every case will have its own considerations for the design engineer to take into account, but as a general guide the following recommendations are proposed:

- For ponds receiving wastewater which has a significant organic and/or solids loading it is preferable to use a horizontal inlet pipe to ensure good distribution and mixing of the influent out into the pond. However, attention must be given to prevent the inflow swirling quickly around past the outlet. This could be achieved by careful consideration of the outlet position and the use of baffles (discussed further in Sections 5 & 6).

- For ponds receiving pre-treated wastewater with low organics and/or solids loadings consider alternatives such as a manifold or vertical inlets with adjacent stub baffles, but only after due consideration of the potential influence of wind.

For high load wastewaters: horizontal inlets may be needed to mix wastewater into the pond. Consider baffles and outlet positioning to avoid short- circuiting problems!

For low load wastewaters: consider a manifold or baffled vertical inlet but only after consideration of wind influences!

4.3.9 Inlet Position

Since the inlet is an important driving force on the main pond circulation, engineers need to assess the broad flow pattern that will result from inlet positioning as part of the design process. The ideal approach is to model this on a computer but, at the time of writing, this is still a relatively specialist application that many practitioners do not have access to and is not cheap to commission.

The alternative is simple. Use a plan diagram to sketch the circulation pattern that the inlet will set up. Consider a horizontal jet to be a source of momentum that will then drive the larger bulk circulation around the pond just like a small mixer would.

In our work we have observed that ponds that are roughly 1:1 to 1:2 in terms of their length to width ratio tend to circulate in a single large cell typically with small counter-current circulations tucked in the corners (back-eddies).

Also recall that the jet attachment technique, discussed in Section 4.3.3, can also be used to improve the predictability of the flow path. What gets harder to assess, is when multiple circulation cells will be established in longer/narrower ponds - this is discussed further in section 6.3.6.

In the past it has been very common for engineers to set the inlet and outlet positions with little or no consideration of their effect on the resulting flow pattern within the pond. While drawing a simple sketch prediction of the flow pattern is certainly not ‘rocket science’ the fact that the designer is giving due consideration to the inlet positioning is certainly a significant step forward. The next steps to be considered in this process are the application of baffles and finally the positioning of the outlet. These issues are considered in more detail in Sections 5 and 6.

Inlet positioning has a major influence on the flow pattern.

Designers need to consider the effect of inlet position in conjunction with outlet position and pond shape/baffles.

4.3.10 Effect of Varying Flowrate

In practice, the flow entering a pond system is constantly changing both through a daily cycle and more extremely during periods of wet weather. Will this cause problems when trying to design a pond for improved hydraulic performance?

Runs undertaken at different flowrates were compared and found to have similar flow patterns. This is a similar finding as discussed in Section 4.3.2 for larger inlets and is not surprising since in both cases we are simply discussing a change in momentum input.

This is good news for the designers as it would be difficult to optimise pond hydraulics if the flow pattern changed at different flowrates. The only time that this may not hold is when wind effects are able to dominate, which is more likely when inlet momentum is reduced. This aspect is discussed further in Section 7.

A pond should maintain a similar and reasonably well-defined flow pattern through a range of different flowrates.

Figure 4-7 An inlet manifold used on a surface flow wetland system