6 BAFFLES & SHAPE

Baffles are known to improve pond performance. Here, the efficient use of baffling is discussed. How many? What length? What position?

6.1 Introduction

Baffles are commonly proposed for improving the hydraulic and treatment efficiency of ponds. There are numerous ways in which baffles can be built. Obviously it is easier to build baffles as part of the original design, in which case a concrete block or earthen wall is typically used. Retrofitting a baffle into an existing pond is, however, still relatively straightforward. An example of a baffle retrofit using a heavy anchor chain, surface floats and flexible sheeting is detailed in Appendix One. Regardless of the design, it is important to ensure that the baffle is well sealed and doesn't leak effluent from one side to the other to avoid any short-circuiting.

6.2 Previous Work

Watters *et al*., (1973) undertook an in-depth study on baffles and the following sections on horizontal, vertical and longitudinal baffling are derived from this work.

6.2.1 Horizontal Baffling (Transverse)

Three different lengths of baffles were tested: 50%, 70% and 90% of the width of the pond. Each length was tested using 2, 4, 6 and 8 evenly spaced baffles. The following figure illustrates the configurations tested for the 50% width baffles.

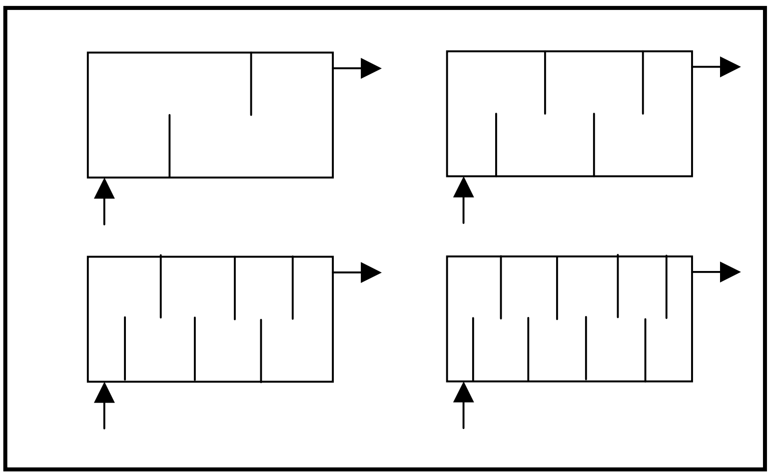


Figure 6-1 Experimental set-ups for 50% width baffles tested by Watters *et al*., (1973)

For the 50% width baffles, short-circuiting problems actually increased in the pond when more baffles were used. As can be seen in Figure 6-2, the flow tracked directly down the middle of the pond and, in effect, the baffle 'cells' create hydraulic dead space.

Increasing to 90% width baffles was found to give a lower hydraulic efficiency than was seen for the 70% width baffles. Watters, *et al*., (1973) believed that this was due to the narrow channel created at the end of the baffles that increased the velocity of the fluid in this area. The effect of channelling within baffled systems is explored further in Section 6.3.2.

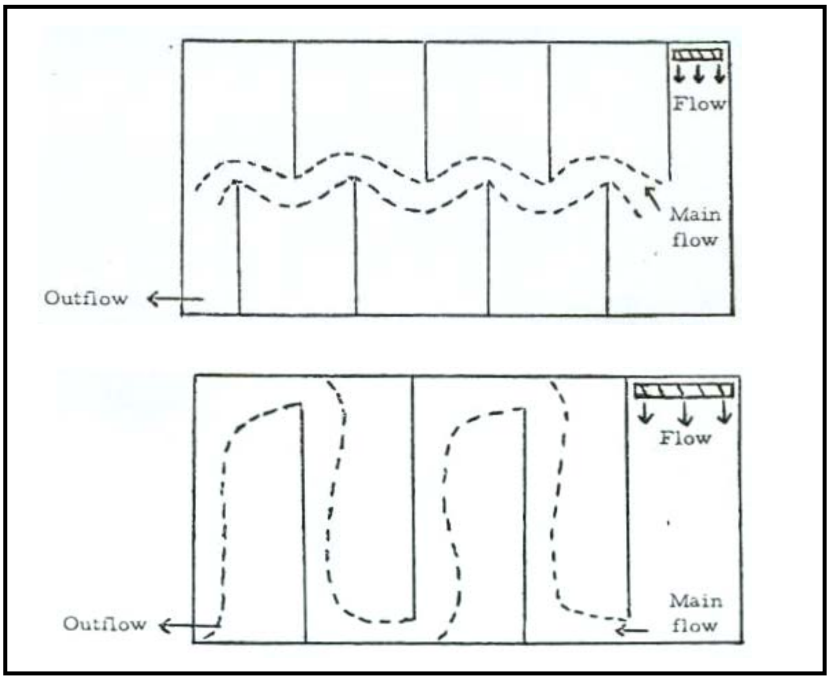


Figure 6-2 Flow patterns produced in the 50% & 90% width baffle runs

(Watters *et al.*, 1973, pg. 49)

The conclusion was made that the 70% width baffles were the most hydraulically efficient option out of the three lengths tested.

Long, evenly spaced baffles improve pond efficiency.

Baffles of 70% width gave superior performance compared to 50% and 90% baffle widths.

6.2.2 Vertical Baffling

Vertical baffles were tested as shown in the following diagram.

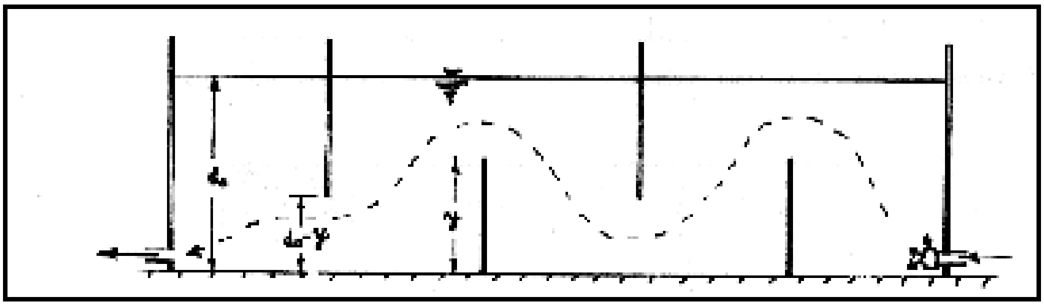


Figure 6-3 Experimental set-up for vertical baffle runs (Watters *et al.*, 1973, pg. 50)

Four experiments were performed: two with four baffles and two with six baffles. Surprisingly, the 4-baffle cases proved to be more efficient than the 6-baffle cases. Again this was attributed to channelling effects. However, when the results were compared against the horizontal baffle experiments, for a comparable amount of baffling it was found that the horizontal configuration was more efficient.

Horizontal baffles were found to be more efficient than vertical baffles.

6.2.3 Longitudinal versus Transverse Baffling

Longitudinal baffles are horizontal baffles that extend along the length of the pond, instead of across the width as shown in the following diagram from Watters *et al*., (1973).

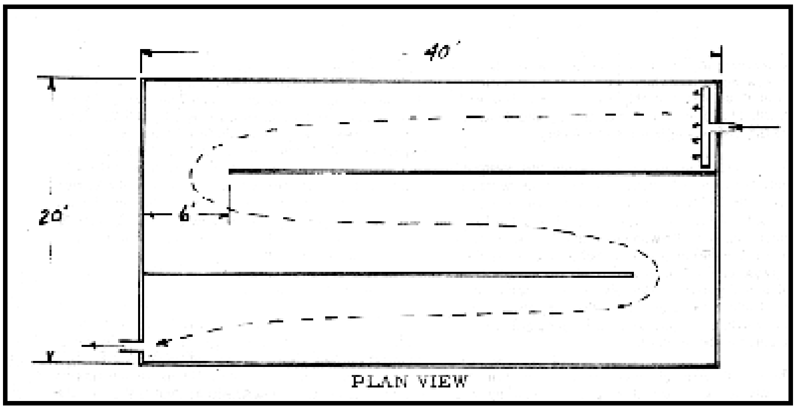


Figure 6-4 Experimental set-up for longitudinal baffle (Watters *et al*., 1973, pg. 50)

It was found that for a comparable length of baffling, essentially the same result was achieved as for transverse baffling across the pond width.

Longitudinal baffling was found to be no more efficient than transverse baffling.

It is noted, however, that this experiment used a manifold inlet. If a simple horizontal inlet was used then it could be expected that transverse baffling might be more effective.

6.2.4 Interactions of Baffles and Inlets

Persson (2000) investigated the use of sub-surface berms or islands (in effect, baffles) located close to the inlet. He found that these resulted in a reduction in short-circuiting. This will have been due to the dissipation and redirection of the inlet jet. Similar work was done using baffles located close to the inlet in this study and this is reviewed later.

Shilton (2001) tested the effect of installing a single baffle (67% of the pond width) located halfway down the length of a laboratory model. The baffle was tested with three different inlets. In the first two tests horizontal inlets were used. It was found that after baffle addition the time taken for tracer to reach the outlet was lengthened considerably. However, in the final comparison using a vertical inlet, the baffle addition gave no further improvement over the un-baffled case.

While generally effective on ponds with horizontal inlets, traditional full-length baffles may not always further improve the efficiency in ponds with other inlet types.

6.3 New Thinking

The length, number and positioning of baffles has been extensively researched during the development of these guidelines. The majority of the research has been carried out using computer modelling, however, laboratory and field testing was also undertaken.

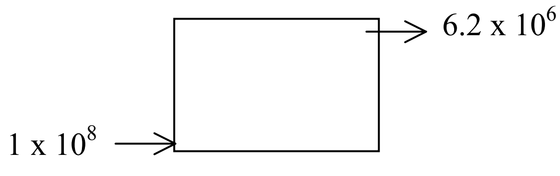
The computer modelling was undertaken in two broad stages. Initially a 'typical' primary facultative pond was sized according to a modern design manual (Mara & Pearson, 1998) and then simulated by computer modelling. The second stage of the computing modelling work was then based on the upgrade of an existing field pond. The details of this second stage work are presented in the appendices as a case study.

In both stages a range of baffle modifications were tested to assess their impact on hydraulic and treatment efficiency. The general flow pattern was studied and the treatment efficiency was quantified by integrating first order bacterial decay kinetics within the computer model.

The configurations shown in this current section come from the initial testing on the 'typical' primary facultative pond.

NOTE: For a benchmark, an inlet coliform concentration of 1x10^{8} cfu/100ml was used and the resultant efficiencies were calculated. This does not mean that any pond with a similar configuration will achieve the same concentration. In practice this will depend on the influent concentration, retention time, temperature and a host of other variables. The values presented here are only intended to be used to compare and contrast the <u>relative</u> improvements in efficiency between the different pond configurations.

The standard case of the pond without baffles was simulated first to provide a basis against which the baffled designs could be evaluated.

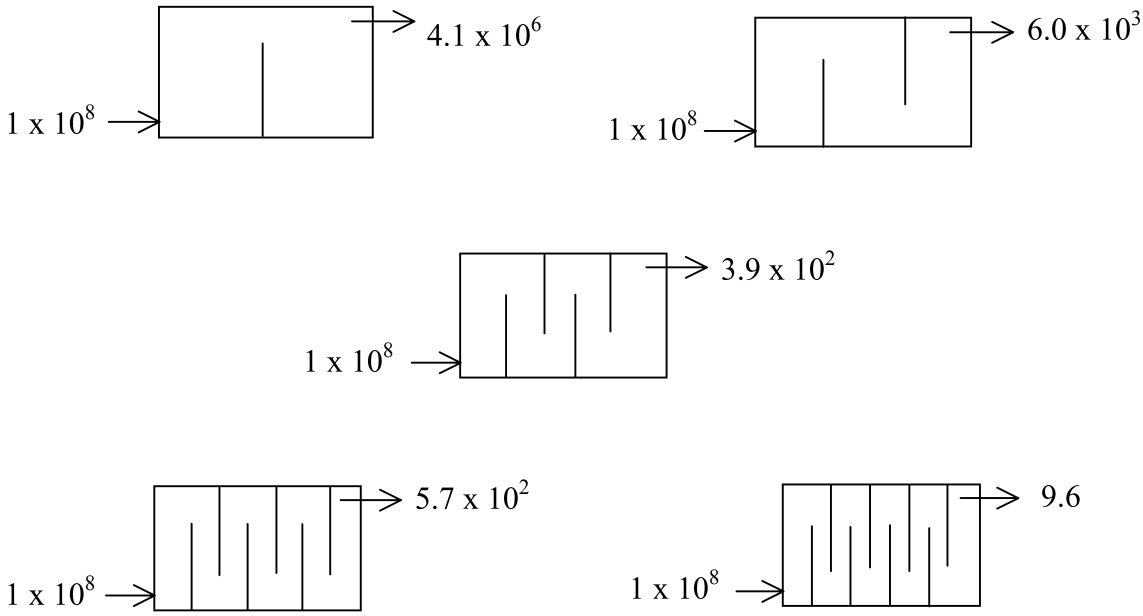


The flow pattern produced in the un-baffled pond was a large circular swirl. Despite the inlet and outlet being in opposite corners the bulk flow moved straight from the inlet around past the outlet, thereby allowing some influent to escape very quickly (short-circuiting) and impacting on the treatment efficiency.

6.3.1 Number of Baffles

Typically baffles tend to be 'long' extending across most of the width of the pond. A number of previous studies have, not unsurprisingly, concluded that using more baffles gives better hydraulic efficiency. But with cost in mind we need to better understand the effect of baffle number on treatment efficiency.

In this project a series of models were tested using evenly spaced, 70% width baffles. These configurations are illustrated below and their results are plotted in Figure 6-7.



A single baffle does give an improvement over an un-baffled case, but clearly stepping up to a two-baffle system was far superior. The study showed a further, but smaller, improvement was achieved by increasing to four baffles and where a high efficiency is trying to be achieved this may be warranted. However, the use of six baffles offered no further improvement and the extra gain provided by using eight baffles might not seem to warrant the extra cost in most applications.

A further argument against the use of too many baffles is discussed in Section 3. Unless the pond has a low organic and solids load (ie it is a maturation pond), then excessive baffles will create much higher localised loading near the inlet as compared to the outlet.

It is believed that lack of improvement between the 4 and 6 baffle cases is due to a change in the flow behaviour that exists between the baffle cells. This is discussed further in the following section.

A minimum of 2 baffles is recommended.

A further improvement was achieved using 4 baffles and this extra cost may be warranted in some cases.

Based on the results of this study, the use of more than 4 baffles would not be recommended.

6.3.2 Channelling versus Mixing within Baffle Cells

Previous work by Watters *et al*., (1973) mentioned a channelling effect on flow by baffles that were 90% of the pond width. A distinct pattern was observed and flow seemed to speed up around the end of the baffles.

The first two cells of the 6-baffle case tested in the laboratory work undertaken in support of these guidelines are shown in Figure 6-5.

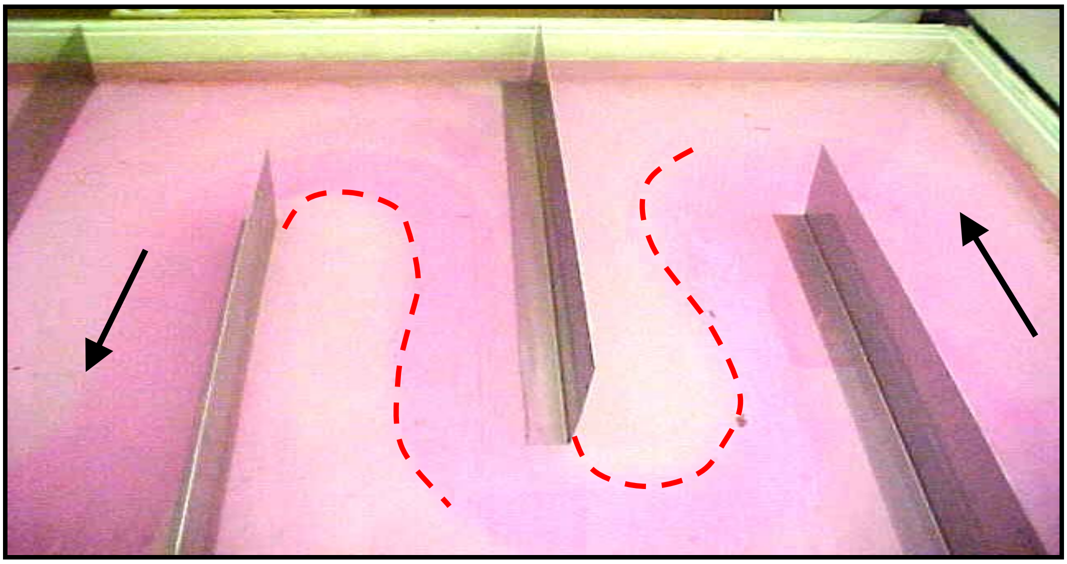


Figure 6-5 Channelling due to baffles

Figure 6-6, over the page, is a diagram produced by Watters *et al*., (1973) showing their observations.

Clearly these flow patterns are very similar but in Figure 6-5, this type of flow behaviour was seen when 70% width baffles were used.

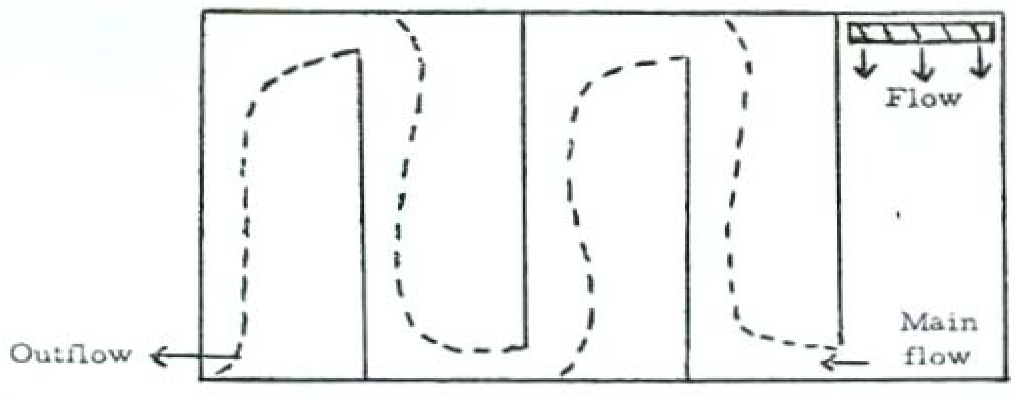


Figure 6-6 Channelling due to 90%width baffles (Watters *et al.*, 1973)

In the initial computer-modelling work, and in subsequent laboratory testing, the two-baffle case did not exhibit this characteristic. It showed a well-mixed circulation pattern in each cell. These observations have led to the conclusion that this channelling effect is not related to the baffle length, but instead is related to the spacing between the baffles/walls.

Occurrence of channelling between baffles is dependent on baffle spacing.

From the results obtained in the computer modelling work described in Section 6.3.1, a plot of treatment efficiency versus the number of baffles was made as shown in Figure 6-7.

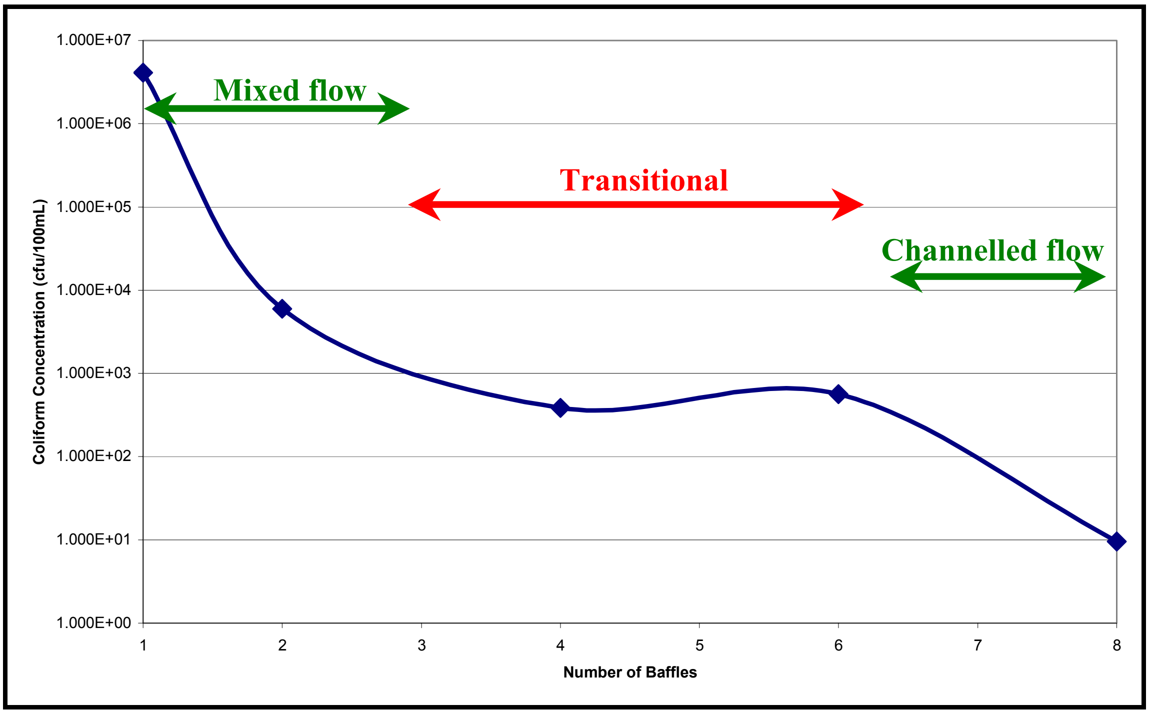


Figure 6-7 Plot of baffle number versus treatment

The treatment provided in the four and six baffle cases is very similar. During the research it was observed that in these cases, the cells near the inlet still had more of a mixed, circulating flow pattern with the channelled behaviour then dominating in the latter cells. This indicates a transition from mixed circulating flow through to channelled flow. This behaviour is discussed further in the following section.

6.3.3 Length to Width Ratio and the Invisible Baffle Effect

There is a general belief that increasing the length to width ratio of a pond helps force its hydraulic behaviour towards plug flow. As seen in the previous section where six to eight baffles were installed (giving length to width ratios approaching 20) this might be true but at lower ratios the picture is less clear-cut.

From our experiences with both laboratory and field ponds we have observed that at low ratios of 1:1 to 1:2, the flow tends to circulate right around the circumference of the pond if a horizontal inlet is positioned in a corner so as to discharge down the longer length.

However in laboratory testing on a pond with a ratio of 1:3 it was found that when the inlet was aligned to discharge along the shorter width, the behaviour changed dramatically. The flow moved across the width and around the corner, but then instead of travelling to the far end, it travelled about one third of the pond length and then turned quite sharply back into the middle of the pond. It appeared as if an 'invisible' baffle was in place!

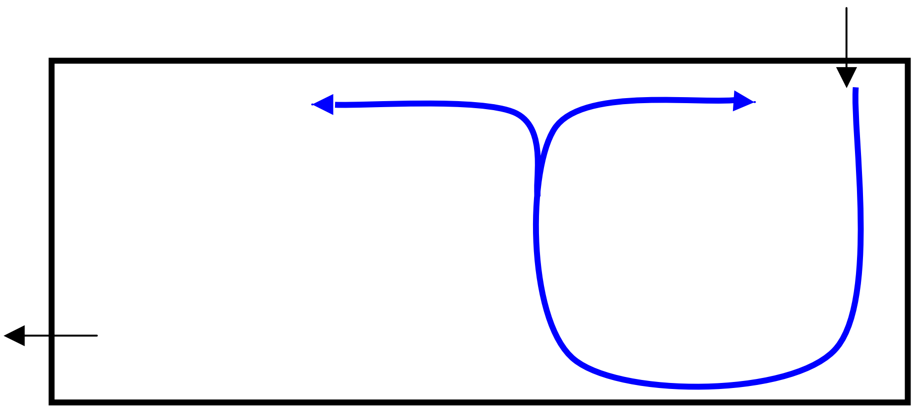


Figure 6-8 Illustration of the 'invisible baffle' effect

The reason for this phenomenon was actually quite obvious in retrospect. As the pond becomes narrower then it is possible to set up a series of counter-current, circulation cells that are roughly the diameter of the pond width. This is what may be happening in the transition zone discussed in the previous section. Circulating cells are established near the inlet end, but as the momentum decreases along the length these die out and channel flow starts to dominate.

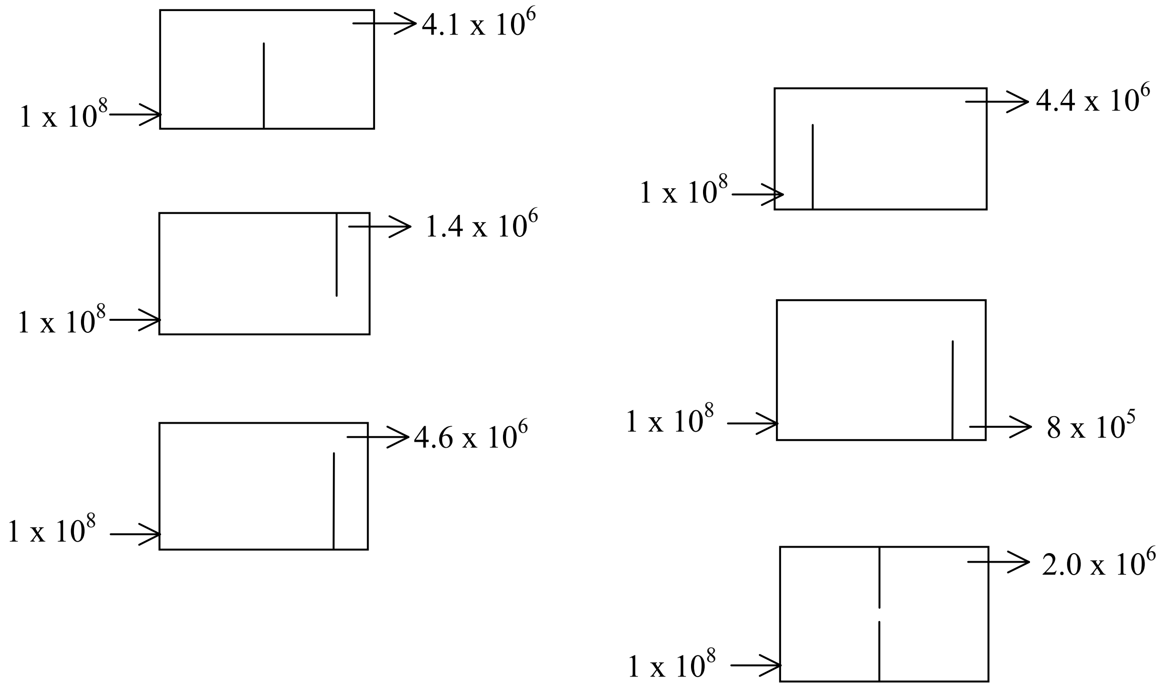
A series of these circulation cells could actually work very effectively, but further research is needed to better define this effect before it can be recommended for general application. What is very clear, however, is that the traditional thinking that in a long narrow pond, the influent simply flows slowly, in a plug flow manner, from one end to the other is not necessarily correct except at very high length to width ratios.

Traditional thinking that in a long narrow pond the influent simply flows slowly from one end to the other is not necessarily correct except at very high length to width ratios.

6.3.4 Alternative Single Baffle Positioning

As discussed previously, while a single baffle can produce an improvement in efficiency, two or more baffles are really far more effective. However, with the important consideration of cost in mind, it still seemed that single baffles warranted further investigation, particularly, if alternative placement options were considered.

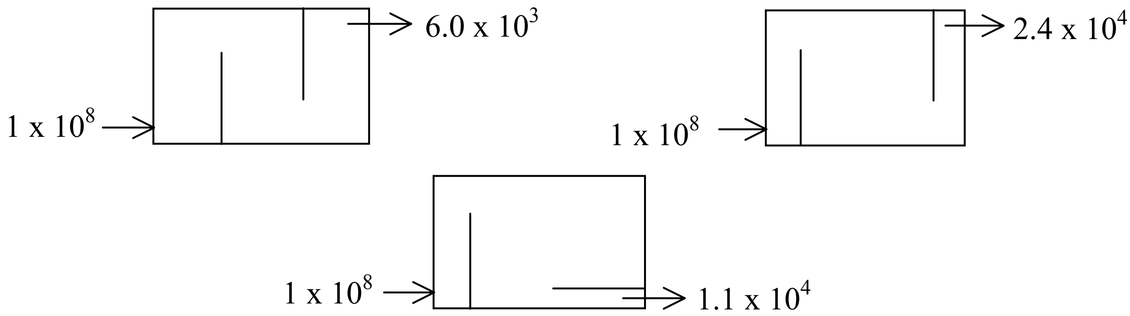
The following configurations were tested by mathematical modelling, however as can be seen, none of these designs came close to the results achieved by the use of two baffles.



Even with consideration of alternative designs, the use of two baffles gives far better performance than a single baffled pond.

6.3.5 Alternative Twin Baffle Positioning

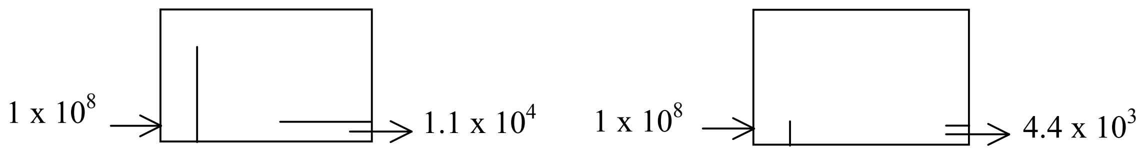
Usually long baffles are evenly spaced along the length of the pond. However, possibilities for alternative, baffle layouts have not been previously investigated. The second two of the three cases shown below modelled alternative baffling placement, but as can be seen these gave no improvement over the standard even spacing of the first case.



Normal, even baffle spacing across the pond is most effective.

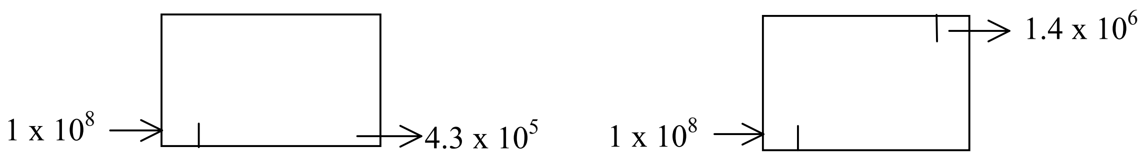
6.3.6 The Stub Baffle

It was felt that after a baffle has worked to ‘turn the flow’ it might not need to extend right across the pond. The cases below compare two standard ‘long baffles’ (70% width) against two much shorter ‘stub’ baffles (15% width).



Upon testing these designs by computer modelling and in the laboratory, it was found that the stub baffling performed extremely well. The stub baffle set up a tight circulation localised in the inlet corner. This appeared to mix and help disperse the flow evenly out into the larger main pond area. While the longer baffles obviously had benefits at blocking the flow, the tight circulation pattern was not set up and instead the flow was forced up along the channel.

Both configurations had similar treatment efficiency (as determined by computer modelling) and similar times to short-circuiting (as confirmed in the laboratory). Clearly for this particular configuration, the shorter and cheaper stub baffle could be just as effectively used. However, testing undertaken on the application of the stub baffles in the different configurations as seen below, didn’t produce the same level of treatment efficiency as their long baffle counterparts did (see Sections 6.3.4 and 0).



Clearly while the stub baffle can work extremely well in some cases, its performance is sensitive to changes in pond configuration. This finding was also reinforced in the later work on the case study as discussed in Appendix One.

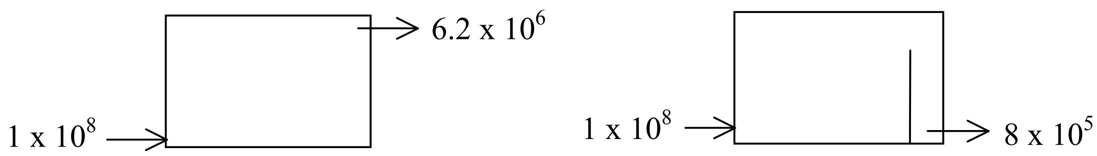
We have discussed previously how stub baffles have been successfully used to improve a vertical inlet and in the following section we note their effectiveness for shielding an outlet. However for traditional baffling applications we recommend that while stub baffles have a lot of potential they can not yet be considered a substitute to long baffles in general application. Clearly this is an area deserving of more research.

Stub baffles have the potential to provide similar treatment improvements as longer baffles but this performance is inconsistent on different pond configurations.

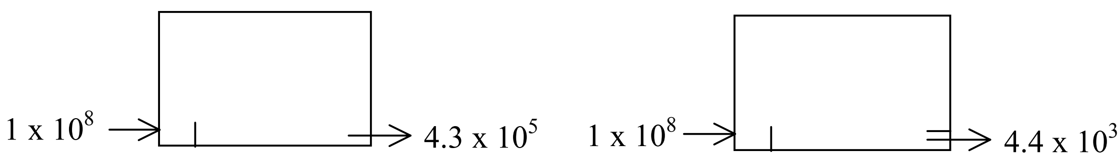
6.3.7 Baffles as an Outlet Shield

As shown previously in Section 6.3.4, the addition of a single baffle placed in front of the outlet, improved treatment efficiency from 6.2×10^6 to 1.4×10^6 cfu/100mL. However, this arrangement wasn't ideal as the entrance to the outlet channel was in a direct line with the inlet jet.

One possibility would be to move or redirect the inlet. The other, as shown below, is to position the baffle to block the 'swirl' from the inlet and then relocate the outlet so that it is shielded behind the baffle. As seen below, this achieved a result of 8×10^5 cfu/100mL, which represents almost another order of magnitude in improvement.



Another example of using a baffle to shield the outlet can be seen in comparison of two of the stub baffle cases from the previous section. As seen below, for this particular pond design, even a small stub baffle worked effectively to shield the outlet.



Baffles that 'shield' the outlet are beneficial.