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Title:	Flow measurements in a two acre pond (pond 0106)		
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SIGNATURES

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EXECUTIVE SUMMARY

Flow velocity in one of IABR two acre ponds (pond 0106) was measured using a Vectrino-II flow profiler. Vectrino-II is a submersible probe which can measure velocity time-series along a 1.4'' vertical line in three different directions. Mean flow velocity components as well as the turbulence characteristics in all directions can then be extracted using the sampled time-series. In these experiments, the submersible probe was remotely traversed inside the pond using a cart and a telescopic pole. In order to accurately determine the flow velocity across the pond cross-section, data from 10 positions at each cross-section was collected.

For a nominal pond depth of 8.75'', the paddlewheel power consumption was measured to be 3.35 KW (4.5 horsepower). The average flow velocity over the entire data set is 19 cm/s. Based on these data, the paddlewheel efficiency is estimated to be 8.2%, which is consistent with our experiments at Las Cruces and predictions for these paddlewheels.

The results showed that there is a deadzone downstream of the distal end which extends for at least 100' downstream. The width of the deadzone immediately downstream of the U-turn is 18'. Based on these data, the deadzone area in the pond is estimated to be at least 2.9% of the pond total surface area.

PURPOSE

The purpose of this study is to estimate the paddlewheel efficiency as well as the deadzone area in a two acre pond. The estimate of the deadzone area can be utilized for the basic analysis of design and installation of flow guiding structures at the U-turns.

Figure 1. Measurement cart which carries the Vectrino-II and the probe.

BACKGROUND

Flow velocity in a 2 acre IABR pond with nominal flow depth of 8.75’’ was measured using a Vectrino-II flow profiler. The submersible probe of Vectrino-II can sample velocity signals in three different directions along a 1.4’’ vertical line with a frequency up to 100 Hz. In other words, the probe measures 3 time-series of instantaneous velocity components in the x-y-z directions. These time-series can then be utilized to extract mean flow velocity components as well as the turbulence characteristics in three different directions.

The probe was inserted into the pond using a measurement cart, which was designed and built at IABR. Figure 1 shows an image of the traversing cart when it is sampling velocity signals inside pond 0106. The cart was traversed across the pond remotely using a telescopic pole. The probe was used to sample velocity signals at 7 cross-sections (measurement stations) across the pond as depicted in Figure 2. At each measurement station, the flow velocity at 10 vertical positions across the pond cross-section was measured for a sampling period of 25 seconds. Figure 3 shows the measurement positions across the pond cross-section. Each measurement position is a 1.4’’ long vertical line at the middle of the pond depth as depicted in Figure 3.

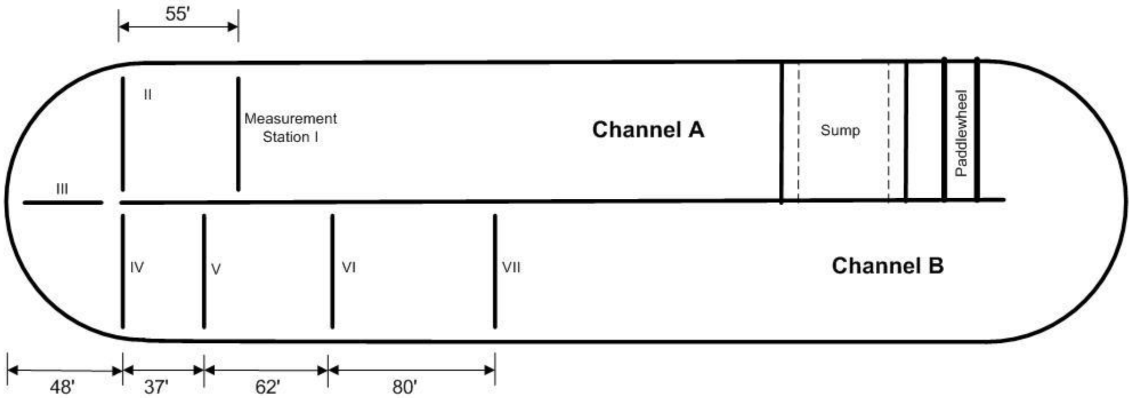

Figure 2. Layout of pond 0106 and the position of the measurement stations.

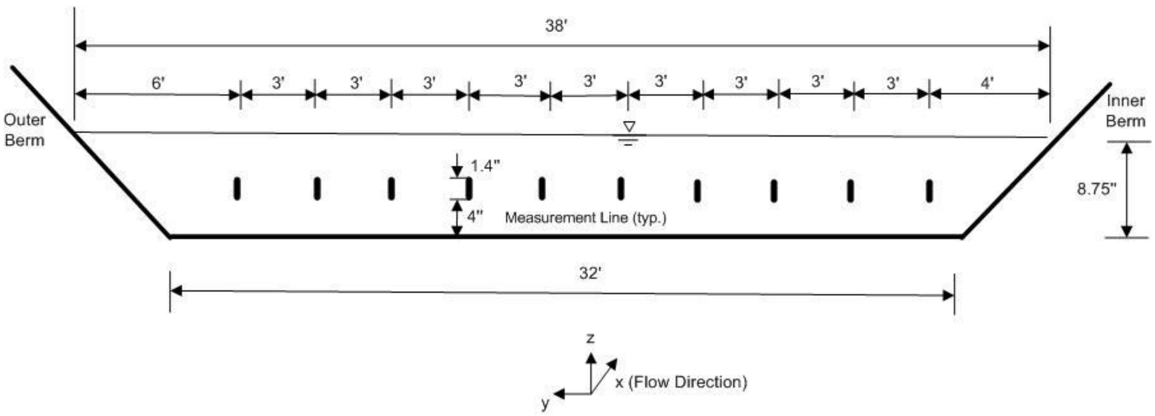

Figure 3. Layout of the pond’s cross-section and the position of the measurement stations.

RESULTS

In Figure 4 the layout of pond 0106 and the resultant velocity vectors across the measured cross-sections are shown. At each position, Vectrino-II was used to collect flow velocity signals at 35 points along a vertical 1.4’’ line. The positions of the measurement lines can be found in Figure 3. The velocity vectors shown in Figure 4 are the average velocity over all 35 vertical data points. Taking the average for all measured data points in all 7 cross-sections in Figure 4, the average velocity becomes 19 cm/s. In other words the average velocity along all cross sections and different downstream positions is 19 cm/s. The local flow velocity is variable depending on the position that we consider. In other words, it is significantly dependent on the position relative to the paddlewheel and berms as well as the distance from the pond bottom. For example, the maximum measured velocity was 35 cm/s while the minimum was -5 cm/s, which the latter was located inside the deadzone downstream of the distal end.

As Figure 4 clearly shows, the flow upstream of the distal end contains no deadzone. Downstream of the distal end the flow suffers from a major recirculating region along the inner berm. The width of the deadzone region immediately downstream of the distal end is about

18’. The width of the deadzone decreases downstream and about 140 ft downstream of station IV the deadzone disappears.

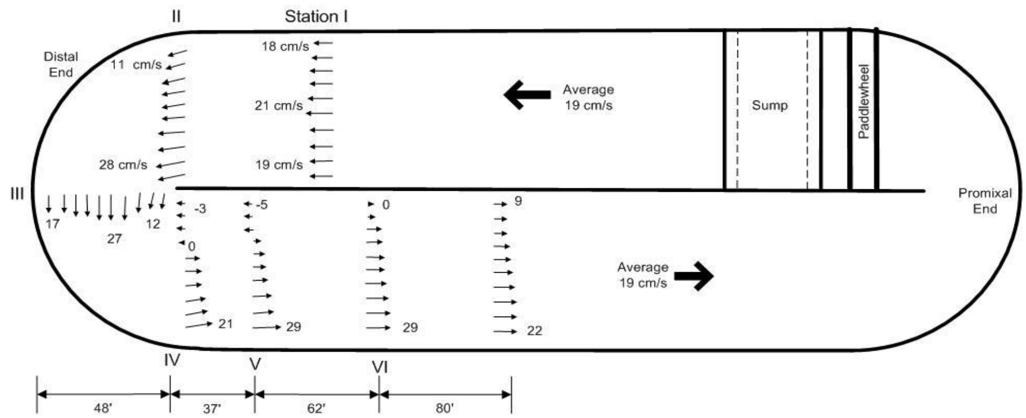

Figure 4. Layout of pond 0616 (2 acre) with the velocity vectors plotted at the measured stations. The pond is much longer and the length shown in this figure is not accurately scaled.

Comparing the velocity contours at cross-sections II, III, IV and VI (see Figure 2 for their location across the pond) we can better visualize the changes in flow uniformity across the pond width. These velocity contours are shown in Figures 5, 6, 7 and 8, respectively, where the flow direction is from the page outwards. The color shows the flow velocity in the channel direction. Figure 7 shows that the flow is significantly non-uniform immediately downstream of the U-turn, station IV, as there is a substantial negative flow direction along an 18 ft wide region adjacent to the inner berm. However, at position II, which is located immediately upstream of the distal end, there is no deadzone region, as can be seen in Figure 5. At position VI, Figure 8, the flow becomes more uniform and the negative flow region disappears and we estimate that it becomes fully uniform 300 ft downstream of position IV.

Considering a triangle with the base 18’ and length 140’ where the flow at the inner berm can have a velocity of at least 5 cm/s which means algae cells will not sediment by its weight, the surface area of the deadzone downstream of the U-turn is estimated to be 1250 ft^2. As a result, we estimate that the total area of the deadzone region to be 2.9% of the pond surface area. Paddlewheel power in these experiments was 3.4 KW. Our calculations show that the pond losses for a flow of 19 cm/s is about 60 mm. Based on these data, the paddlewheel efficiency is estimated to be 8.2%, which is consistent with our paddlewheel experiments conducted at Lac Cruces site.

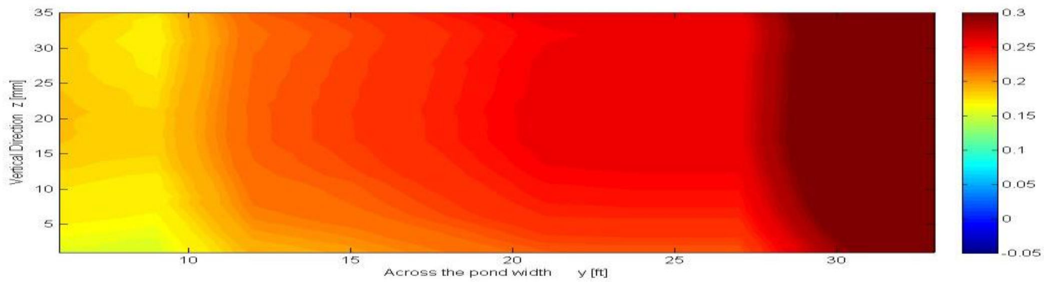

Figure 5. Velocity contour across the pond width at measurement station II where we look at it from downstream and flow direction is from the page towards us. The colorbar shows the velocity in m/s.

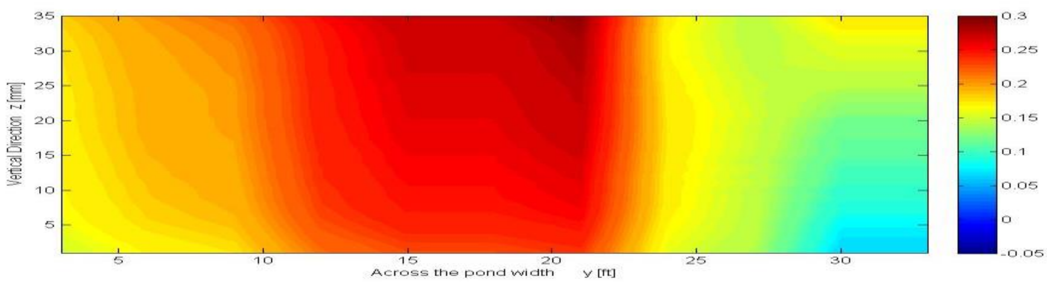

Figure 6. Velocity contour across the pond width at measurement station III.

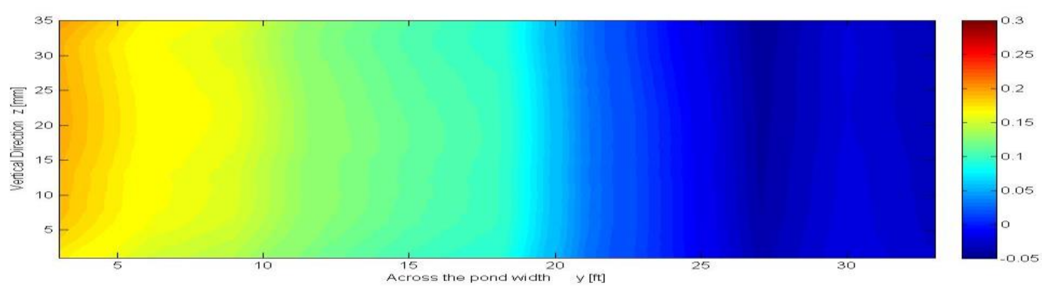

Figure 7. Velocity contour across the pond width at measurement station IV (immediately downstream of the U-turn).

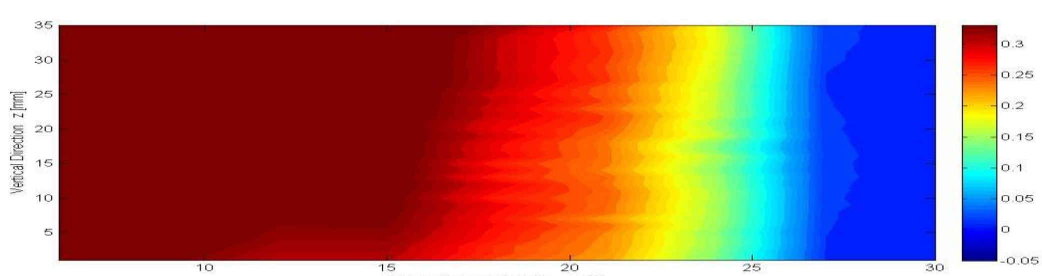

Figure 8. Velocity contour across the pond width at position VI (80 ft downstream of distal end)

CONCLUSIONS

Our experiments of flow measurements in a 2 acre pond with 8.75'' flow depth show that the flow velocity in the channel upstream of the distal end is reasonably uniform. Downstream of the U-turn the flow becomes non-uniform which is characterized by a substantial deadzone region along the inner berm. It takes almost 140 ft for the flow to travel downstream before the deadzone region disappears. In other words the negative flow velocity along the inner berm downstream of the U-turn turns to a positive velocity of 5 cm/s only after 140 ft downstream. In general, we can summarize the results of these experiments as following**:**

- For the flow depth of 8.75'' the paddlewheel efficiency was measured to be 8.2%. Since the paddlewheel efficiency decreases with decreasing flow depth it is expected that with shallower depths our flow velocity decreases
- The paddlewheel power consumption was measured to be 3.4 KW (4.6 HP)
- The average pond velocity was measured to be 19 cm/s
- The surface area of the deadzone is estimated to be 1250 ft^2 after each U-turn and totally 2.9% of the pond surface area