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Unsteady-Flow Velocity Variations in and near An Embayment

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All the three velocity components in unsteady flow inside and near an embayment, which was made on the flood plain of a compound channel, have been measured with electromagnetic probes. Unsteady flows were simulated by three hydrographs in a 25m long, 1m wide tilting flume. Shown here are the temporal variations of the depths, as well as the longitudinal velocity component's variations with time and water height. The circulating flow's evolution with time during a hydrograph is clearly demonstrated by the experimental results.

Keywords: *unsteady flow, embayment, compound channel, velocity variations, circulating flow*

1 Introduction

In natural rivers there exist often embayments along the river banks, usually located on the flood plains. These embayments may house a variety of fauna and flora, thus improve the natural environment. The flow in an embayment is strictly saying three dimensional. Though during most of the time the flow is in steady state, or may be treated as such, it becomes unsteady when a flood comes.

The importance of embayments and of unsteady flows have drawn the interests of many researchers. Jalil et al. (1993) investigated steady flows in an embayment. Tu and Graf (1993) and Nakagawa et al. (1993) studied unsteady open-channel flows. Tominaga et al. (1993) further conducted experiments in unsteady compound-channel flows. It is needless to say that it is important to investigate the flow structures in an embayment, under unsteady-flow conditions. This will not only help the practical engineers to design environmentally sound river fronts, but also improve our knowledge on pollutant and/or sediment transports in embayments, and provide a set of data for possible numerical modelling.

In the present study, the water depths as well as all the three velocity components during flood periods, in and near an embayment were measured, and part of the results are herein reported.

2 Unsteady-Flow Experiments

The experiments were conducted in a 25m long, 1m wide, tilting flume (Fig.1). More details about the flume are given in Jalil et al. (1993). Wooden plates were placed inside the flume to simulate half of a symmetric compound channel. On the flood plain, 13m from the flume entrance, an embayment of 30cm x 20cm x 5.18cm was made. The distance of 13m from the entrance guarantees a fully developed flow in and near the embayment. With a computer and relevant software specifically for generating unsteady flows in the flume, hydrographs (simulating unsteady flows) of desired shapes can be easily created by controlling the opening of the valve in the pipe system. In the present study, three hydrographs, designated HY.5, HY.7 and HY.8 (Fig.2), were repeatedly passed in the flume for the velocity and water depth measurements.

Both the water depths and all the three velocity components were measured at 11 positions in and near the embayment (see Fig.1 and the coordinates listed below). Water depth was measured using limnimeters, and the three velocity components were measured with two electromagnetic probes (manufactured by TKC), both having a diameter of 5mm. One is of I-type (SFT-200-05), which was used to measure the longitudinal and the streamwise velocity components; the other is of L-type (SFT-200-05L), which was used to measure the vertical velocity component. The flume's bottom slope was 1/1000 throughout this study.

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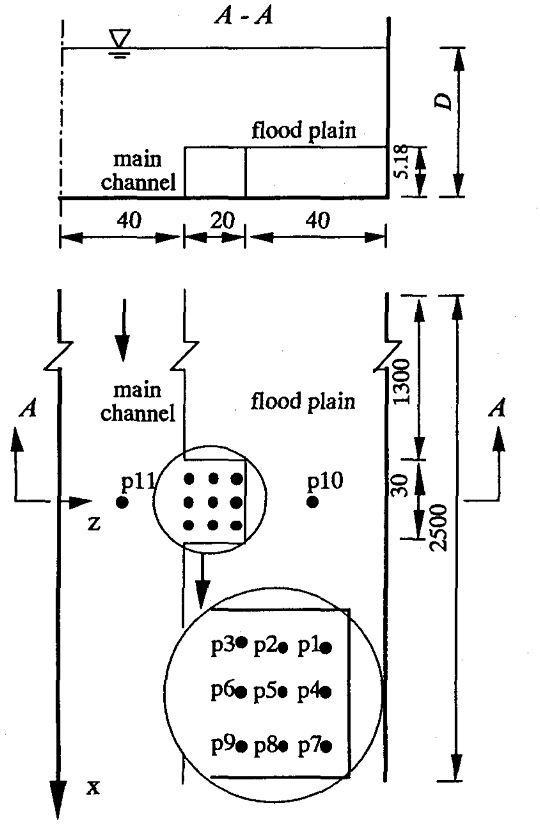

Coordinates of the measuring positions (x, z; in cm)											
	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11
x	-6.5	-6.5	-6.5	0	0	0	6.5	6.5	6.5	0	0
z	58	50	42	58	50	42	58	50	42	80	25

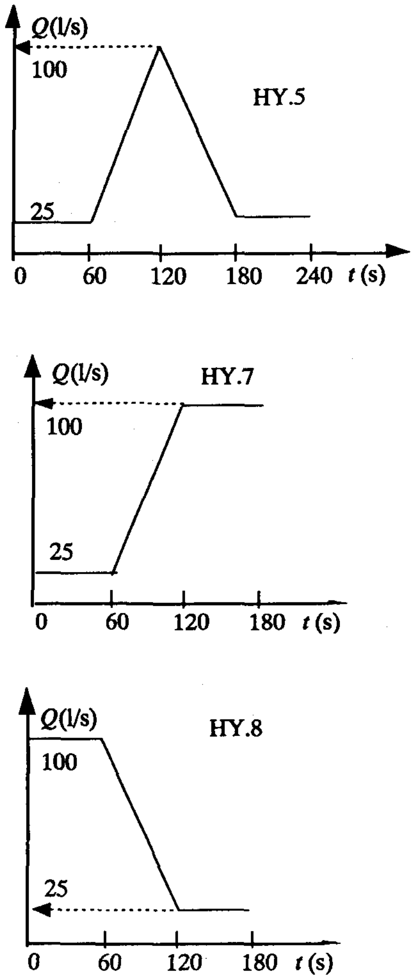

Fig. 1 Experimental setup; p1 to p11 indicate the positions where the velocities were measured

Fig. 2 Flow-discharge (at the flume entrance) variations for the simulated three hydrographs

At all the 11 positions (from p1 to p11 in Fig.1), the velocities were measured every 5mm, up to a maximum of 15 points in a vertical. During the passage of a hydrograph, velocity measurements were conducted at two different positions (at a certain water height) by using in parallel the two probes, which were then exchanged and the same procedures repeated. The sampling rate was 5Hz, and the five readings per second were averaged to render the time-mean velocities, though no information on the turbulent structure.

Theoretically, velocity measurements in unsteady flow at a given point in space should be carried out by repeating as many times as possible the same hydrograph. For the mean values, however, Tu and Graf (1993) reported that repeating more than five times hardly improve significantly the precision. What is more is that there were 11 positions (and in one position, there may be more than 10 water heights where the velocities were to be measured) in the present study. Since the flume is an outdoor facility, it was impossible to conduct the experiments every day due to the weather conditions. All these require that the experiments be finished as soon as possible. So the velocities at one point were measured by passing the hydrogrpah only once. The water depth measurements were carried out separately from the velocity measurements.

The signals from the electromagnetic probes or the limnimeters were recorded by another computer (in addition to the one generating the hydrograph) for later processing and analysis.

3 Data Presentation

3.1 Variations of the water depths

In Fig.3 are presented the temporal variations of the water depths measured in the embayment, in the main channel as well as on the flood plain, for all the three hydrographs. It shows a depth difference of about 5cm, which corresponds to the flood plain height (see Fig.1). Figure 4 indicates that the water depths in the embayment are relatively larger than the one in the main channel (measured at p11), being quite visible when the flood recedes (see the results of HY.5 and HY.8). In fact, when the hydrograph enters its receding stage, the water in the main channel flows relatively fast (see the following section) to the downstream, while it takes longer time for the water in the embayment to flow out. This leads to a depth difference.

3.2 Variations of the longitudinal velocity component

Due to space limit, only the variations of the longitudinal velocity component from HY.5 are presented here. Figure 5 shows the longitudinal velocity component's variations with time and water height (for clarity only data from three water heights were included here). And in Fig.6 are given the vertical velocity profiles for several selected time instants, which are sufficient to cover the whole duration of the hydrograph. Note that in both Fig.5 and Fig.6 the results are presented according to the relative positions of p1 to p9 (i.e., counter-clockwise, see also Fig.1), making it easier to observe the existing circulating flow in the embayment. Shown also are the velocity variations in the main channel (at p11) and on the flood plain (p10).

Figure 5 demonstrates that before the flood arrives (when the flow is steady), at all the three water heights (y=1cm, 5cm and 7cm): the longitudinal velocity component at p3, p6, p9 are positive; those at p2, p5, p8 are zero; while those at p1, p4 and p7 are negative. This shows clearly a circulating flow in the embayment. After the flood arrived, at y=1cm, the velocities throughout the embayment are decreased, with those at p1, p4 and p7 increasing somewhat in the receding stage. This means that near the channel bottom, the circulating flow is weakened as the flood comes and goes. Beyond y=5cm (i.e., a little lower than the flood plain's height), the circulating flow disappeared altogether during the flood.

In Fig.6 are given the evolutions of the vertical velocity distributions in and near the embayment. It shows how the vertical velocity profiles (e.x. at p5) evolves during the passage of the hydrograph. It also shows that, at the downstream corner of the embayment (p9), the longitudinal velocity component is all the time positive, while for y<3cm it remains negative at the inner corners (p1 and p7). The velocity in the main channel (p11), particularly for y<5cm (i.e., about the flood plain's height), is much larger that those in the embayment. Thus it flows much faster in the main channel, explaining partly the depth difference between the main channel and the flood plain (Fig.4).

4 Conclusion

The longitudinal velocity component's variations in unsteady flows in and near an embayment are shown in Figs.5 and 6, with the water depths given in Figs.3 and 4. During flood periods, the circulating flow in the lower part (near the bottom) of the embayment was weakened, and in the upper part it disappeared.

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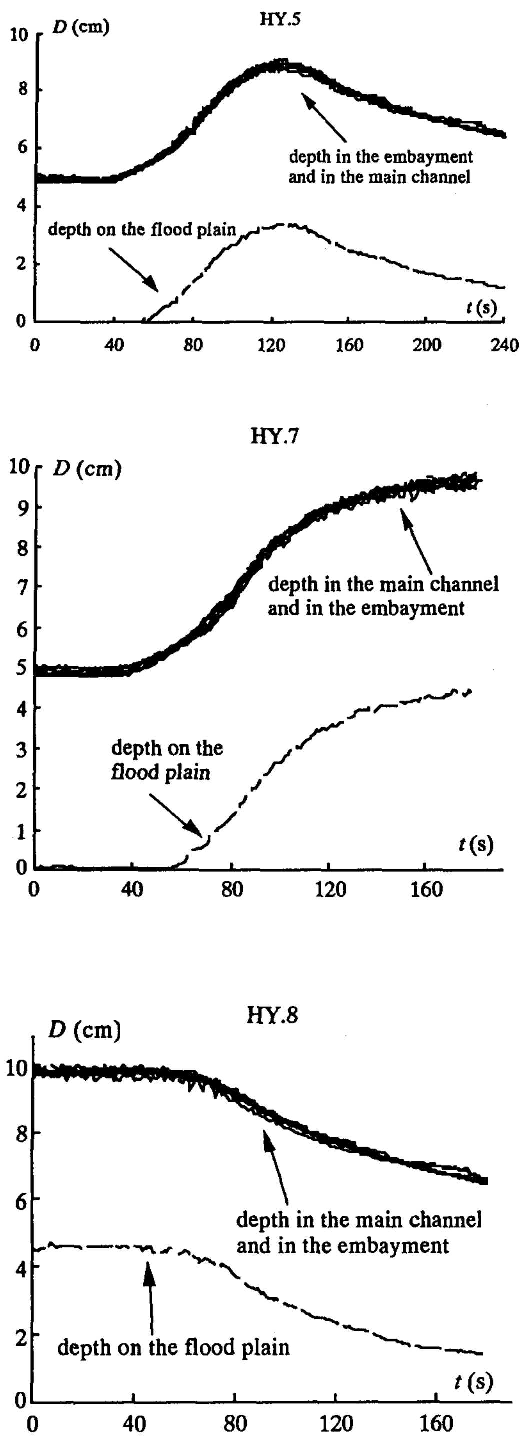

Fig.3 Depths in and near the embayment, as compared to the one on the flood plain

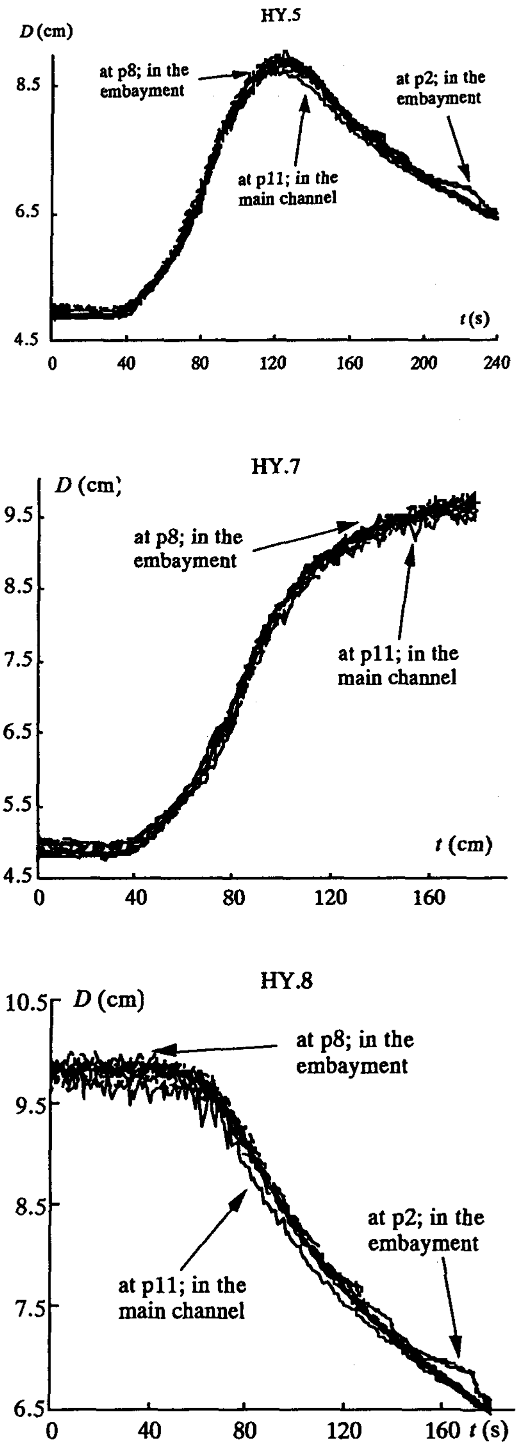

Fig.4 Depth in the embayment is larger than in the main channel, particularly during the receding stage

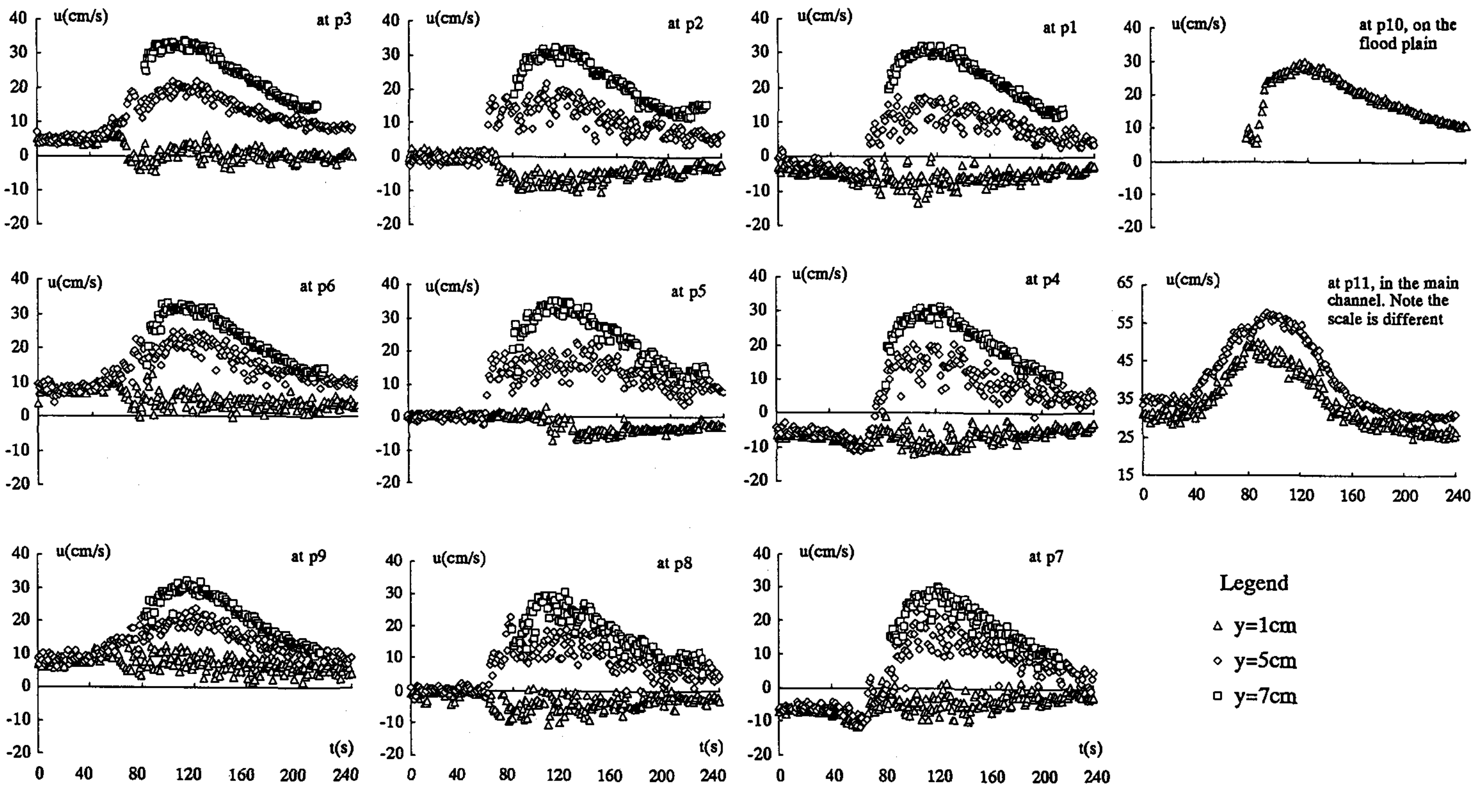

Fig.5 Longitudinal velocity component's variations with time and water height; for HY.5

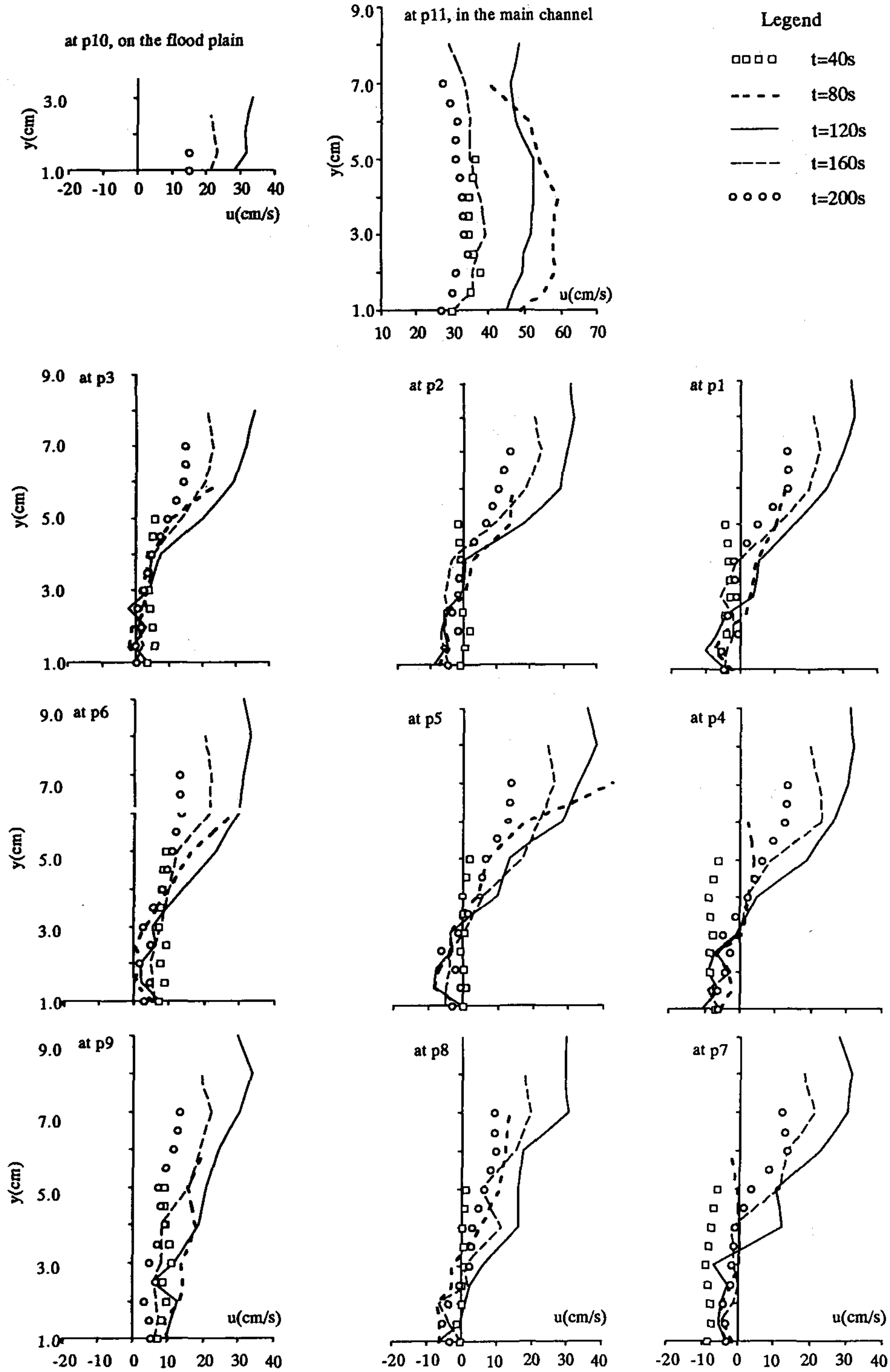

Fig.6 Vertical profiles of the longitudinal velocity component; for HY.5