*Journal of Civil Engineering and Urbanism*

**Volume 3, Issue 6: 357-361 (2013)** ISSN-2252-0430

# Floodplain Vegetation Contribution to Velocity Distribution in Compound Channels

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ORIGINAL ARTICLE
Received 27 Aug. 2013
Accepted 03 Nov. 2013

**ABSTRACT:** The flow in compound open-channel is characterized by a complex flow structure due to the interaction between the main channel and floodplain which is often home to a lot of kinds of vegetation. This paper describes the results of an experimental study on the influence of floodplain vegetation on velocity distribution in compound channels. For vegetation on the floodplain, rigid cylindrical rods 1 cm in diameter are used. The local flow velocities for different densities of vegetation were measured using a 3D acoustic Doppler velocimeter. The results showed that that after implanting the vegetation over the floodplain, the depth averaged velocity over the floodplain increases whereas it increases in the main channel. Also, the depth averaged velocity decreases in both the main channel and floodplain with an increase in the vegetation density. The maximum value of the streamwise velocity was found to decreases with vegetation density. While it was found that a major vortex forms in the main channel for smooth floodplain, two distinct vortexes (free surface and bottom vortexes) were observed for the tests with vegetated floodplain.

**Keywords:** Compound channel, Vegetation, Floodplain, Velocity distribution, Secondary currents

## INTRODUCTION

Rivers and floodplains are main natural resources to both human society and wild life and serve as sources of water for irrigation, drinking and industrial usage. The velocity distribution of river flows is essential information for channel design, channel stabilization, flood control and restoration projects. In addition, transport of sediments and pollutants are affected by the flow structure (Bousmar, 2002).

In many practical situations the natural cross section is irregular in shape, e.g., a river channel with flood plain. Under these circumstances the primary flow field is significantly modified by the lateral and vertical momentum transfer between regions of different depth (Knight and Demetriou, 1983; Huthoff et al. 2008; Martín-Vide et al. 2008; Proust et al., 2010; Al-Khatib et al., 2012). A schematic of the velocity distribution in a symmetric compound channel is shown in Figure 1.

Recently, research into the understanding of the physical processes controlling flow in compound channels has been intensified. Traditional uniform flow equations have proved inadequate in modeling the carrying capacity of compound cross sections. If the compound channel is considered as a single entity, the carrying capacity is underestimated, while if the more usual method of dividing the channel into deep section and floodplains is used, the resulting discharge is an overestimation of the actual capacity (Myers et al., 2001; Cassells et al., 2001; Seckin, 2004; Atabay, 2006). Many experimental investigations have been carried out to clarify the distributions of mean velocity in compound channel flows (Shiono and Knight, 1991; Tomionaga and Nezu, 1991; Wang et al., 1998; Huang et al., 2002; Yang et al., 2005; Li et al., 2005). While in natural rivers, floodplains are often home to many kinds of vegetation, the effect of vegetation on velocity distribution in compound channels has not been understood well yet.

In the past, vegetation in open-channels was removed to increase the flow capacity during floods. However, vegetation plays an important role in the chemistry and biology of water systems. Through the direct uptake of nutrients and heavy metals (Kadlec and Knight, 1996), the capture of suspended sediment (Palmer et al., 2004) and the production of oxygen, vegetation can considerably enhance water quality. Despite the influence of vegetation on both the hydrodynamics and ecological function of aquatic systems, the structure of vegetated aquatic flows is not studied completely yet.

It is recognized that vegetation generally increases the flow resistance and affects the discharge capacity and sediment transport rate (Yang et al., 2007). Huang et al. (2002) studied the velocity distribution in a compound channel and found that velocity in the main channel increased significantly after the floodplains were covered in vegetation. The impact of vegetation growth on flow resistance and flood capacity in compound channels has been investigated by Darby and Thorne (1996). The experimental results of Thornton et al. (2000) showed that the apparent shear stress on the interface between the main river channel and vegetated and non-vegetated floodplains differs significantly. In this paper, the effect of floodplain vegetation on streamwise velocity distribution in an asymmetric compound channel is investigated experimentally.

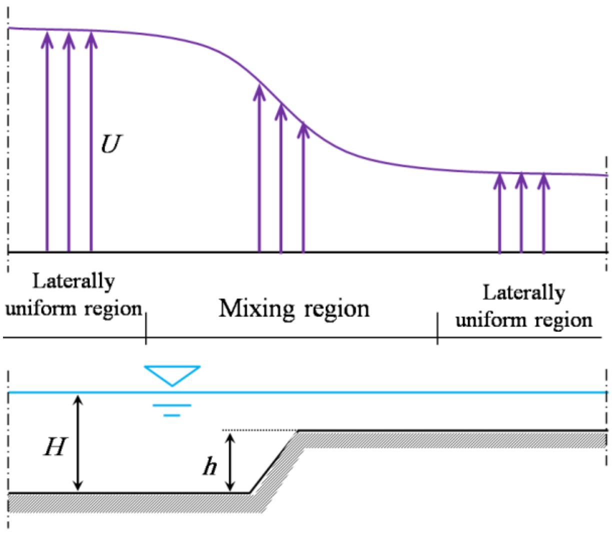


**Figure 1.** Velocity distribution in a compound channel

## MATERIALS AND METHODS

The experiments were undertaken in a fixed bed rectangular flume 18 m long and 0.6 m high and 0.9 m wide comprising a 0.45 m wide, 0.14 m deep main channel and a rigid 0.45 m wide floodplain, forming an asymmetric compound channel. The slope of the flume bed was $8.8 \times 10^{-4}$. A calibrated rectangular sharp crested weir was used for discharge measurement. For a given discharge, the tailgate at the downstream end of the flume was adjusted to form uniform flow conditions in the flume. Water surface elevations were measured directly using some point gauges as well as manometers installed in 1m intervals along the flume. A schematic sketch of the experimental setup is shown in Figure 2.

Three-dimensional instantaneous velocities were measured using a sideways-looking Nortek Vectrino$^+$ Acoustic Doppler Velocimeter (ADV) with a sample frequency rate of 200 Hz and sampling duration of 120 s (Figure 3).

In all the experiments, the relative depth, $D_r$, was kept at fixed value of 0.25. Velocity measurements were taken 11m downstream from the beginning of the flume. Velocity readings were taken at 14 and 19 verticals across the main channel and flood plain, respectively. For the tests with vegetated flood plain, velocity measurements were carried out at 57 verticals, including 4 parallel sections across the flume width, to obtain average flow condition through vegetation. The velocity data were filtered using WinADV software based on criteria of signal to noise ratio (SNR) greater than 15 and correlation score (COR) greater than 70. Also, the velocity data were filtered using the phase-space threshold despiking filter suggested by Goring and Nikora (2002).

In the first experiment, the flood plain was smooth whereas in the rest of the tests, vegetation elements were installed over the floodplain. Rigid PVC cylindrical elements, 1cm in diameter and 15 cm high, were used for simulation of vegetation as previously used by many researchers for flow-vegetation interaction studies (for example: Stone and Shen, 2002; Musleh, 2003; Liu, 2008; McNaughton, 2009). The dowels were attached to a PVC sheet bolted to the bottom of the flood plain in a parallel (tandem) arrangement. The spacing of the dowels varies from 5-20 cm in both lateral and streamwise directions forming stem density of 33-400 stems per m$^2$, equals to 0.26-3.14% (Table 1). Figure 4 shows the vegetation array and the velocity measuring system during data collection.

**Table 1.** Summary of the experiments

| Code | *H* (m) | *h* (m) | $D_r$ (-) | *Q*(m3/s) | *φ* (%) |
|---|---|---|---|---|---|
| 0.25-N | 0.187 | 0.047 | 0.2513 | 0.0432 | - |
| 0.25-L | 0.187 | 0.047 | 0.2513 | 0.0394 | 0.26 |
| 0.25-M | 0.187 | 0.047 | 0.2513 | 0.0354 | 0.88 |
| 0.25-H | 0.187 | 0.047 | 0.2513 | 0.0307 | 3.14 |

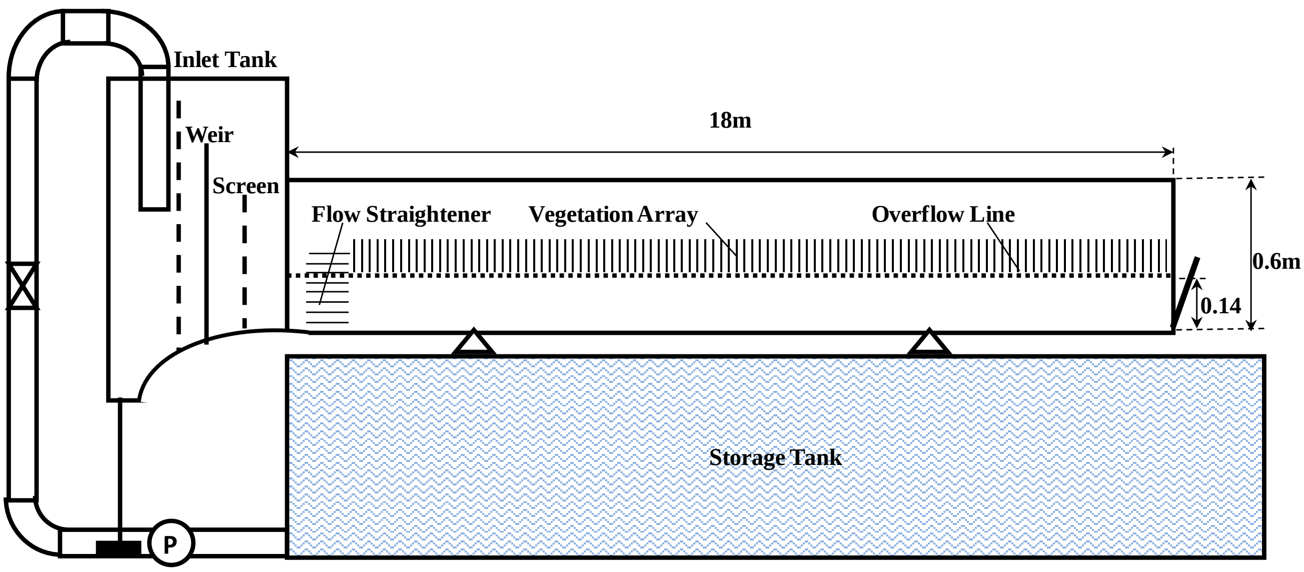


**Figure 2.** Schematic of the experimental setup

To cite this paper: Hamidifar H. and Omid M.H. 2013. Floodplain Vegetation Contribution to Velocity Distribution in Compound Channels. *J. Civil Eng. Urban.* 3(6): 357-361.
Journal homepage http://www.ojceu.ir/main/

**Figure 3.** Acoustic Doppler Velocimeter (ADV): a pulse is transmitted from the centre transducer, and the Doppler shift introduced by the reflections from particles suspended in the water, is picked up by the four receivers.

**Figure 4.** Vegetation array and ADV during data collection

## RESULTS AND DISCUSSION

The sampling time of point velocity measurement with an ADV is very important to ensuring the collection of sufficient data to accurately determine the mean point. Where SNR and COR values are low, a longer sampling duration is helpful, as it increases the number of data points that may meet whatever filter criteria are being used and therefore be available for use in calculating the mean velocity and variation in instantaneous velocity. Prior to beginning data collection, the use of a variable sampling duration was explored. Data were collected at various distances above the main channel bed at the vertical located at 12 cm to the main channel side fall. The resulting velocity analysis, shown in Table 2, confirmed that the mean streamwise velocity takes less than two minutes to become relatively constant. Hence, a constant sampling time of 2 minutes was used for this research.

In order to find the width of the momentum extension zone in the main channel and over the floodplain, relation proposed by Hu et al. (2010) was used. Table 3 shows the momentum transfer width calculated by the mentioned method. It is seen that in the main channel a width of 17.5 cm from the interface is affected by momentum transfer whereas over the floodplain it increases to a longer width (23.5 cm). As the width of each of the main channel or floodplain is 45 cm, the channel width is enough for complete extension of the momentum transfer zone.

**Table 2.** Deviation of the measured velocity at different sampling time from the six minutes recording

| ***z* (cm)** | **Sampling time (s)** | | |
|---|---|---|---|
| | **60** | **120** | **180** |
| 0.6 | -0.18 | -0.01 | 0.17 |
| 1 | -0.37 | -0.19 | 0.08 |
| 1.5 | 0.41 | 0.37 | -0.27 |
| 2 | -0.20 | -0.17 | -0.18 |
| 2.5 | 0.00 | 0.45 | -0.23 |
| 4 | 0.00 | 0.10 | -0.18 |
| 6 | 0.52 | 0.25 | 0.11 |
| 8 | 0.34 | 0.23 | 0.10 |
| 10 | -0.30 | -0.10 | -0.11 |
| 12 | -0.27 | -0.09 | -0.09 |
| 13.4 | 0.15 | 0.07 | -0.07 |

**Table 3.** Momentum transfer width in the main channel and floodplain

| ***H* (cm)** | ***H-h* (cm)** | **$D_r$ (-)** | **$b_m$ (cm)** | **$b_f$ (cm)** |
|---|---|---|---|---|
| 18.67 | 4.67 | 0.25 | 17.5 | 23.4 |

Figure 5 shows the lateral profiles of the depth averaged velocity, Ud, nondimensionalized with the average cross sectional velocity, Uave, for both smooth and vegetated floodplain conditions. It is seen that after implanting the vegetation over the floodplain, the depth averaged velocity over the floodplain increases whereas it increases in the main channel. Also, as the vegetation density, *φ*, increases, the depth averaged velocity decreases in both the main channel and floodplain. It is interesting to note that the velocity distribution over the floodplain becomes more uniform after implanting the vegetation.

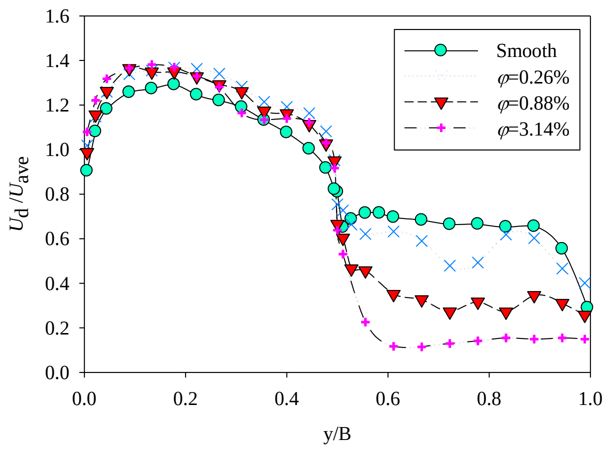


**Figure 5.** Lateral profiles of the depth averaged velocity

Also, it is seen in Figure 4 that the velocity behind each vegetation element decreases suddenly whereas it has a local maximum between two adjacent elements. While the velocity increases continuously from the floodplain toward the main channel, a sudden decrease in the velocity profile is observed for the test with smooth floodplain. Near the floodplain sidewall, velocity profile has high gradient for the smooth floodplain whereas the gradient has been decreased after implanting the vegetation over the floodplain.

Point velocity data was collected throughout the cross sectional area. This data was used to create contour plots of longitudinal velocity (Figures 6 a-d). It is seen from Figures 6a-6d that the core of the maximum streamwise velocity occurs near the outer sidewall of the main channel. Also, for all the tests, the velocity in the main channel is significantly higher than that over the floodplain. The effect of the different densities of floodplain vegetation on the velocity distribution is also very obvious.

As vegetation reduces the channel conveyance capacity (Table 1), it is seen that the maximum value of the streamwise velocity decreases with vegetation density. Whereas the velocity contours show high vertical gradient in the streamwise velocity over the floodplain, Figures 6b-6d show that it is reduced due to the presence of vegetation over the floodplain.

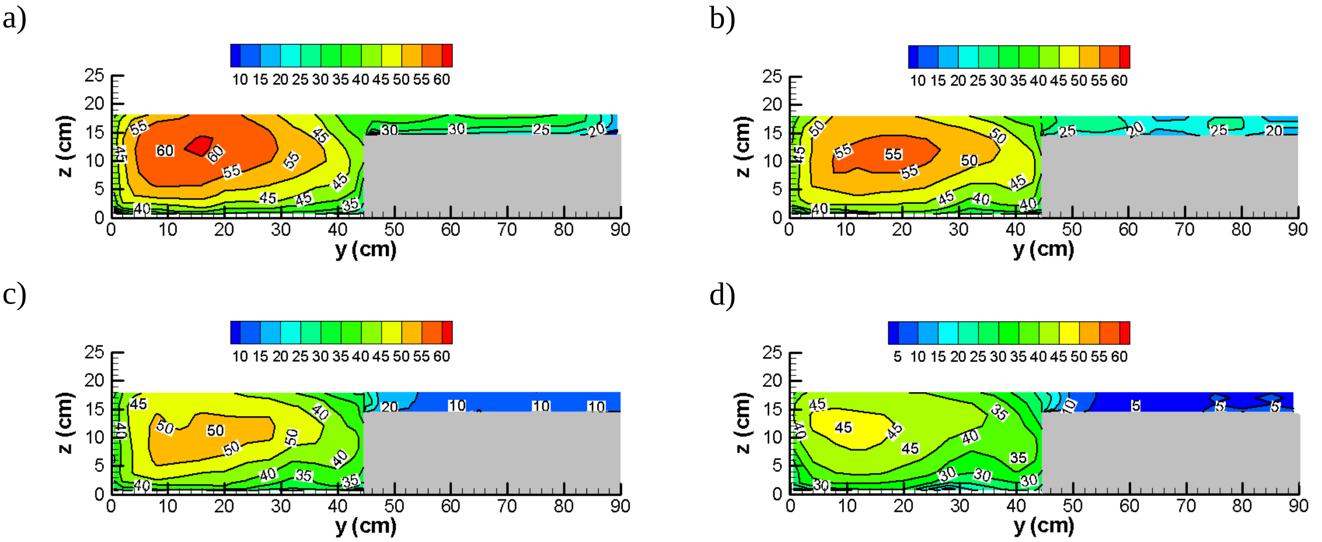


**Figure 6.** Contour plots of streamwise velocity (cm/s) for a) smooth floodplain, b) $\varphi$=0.26%, c) $\varphi$=0.88% and d) $\varphi$=3.14%

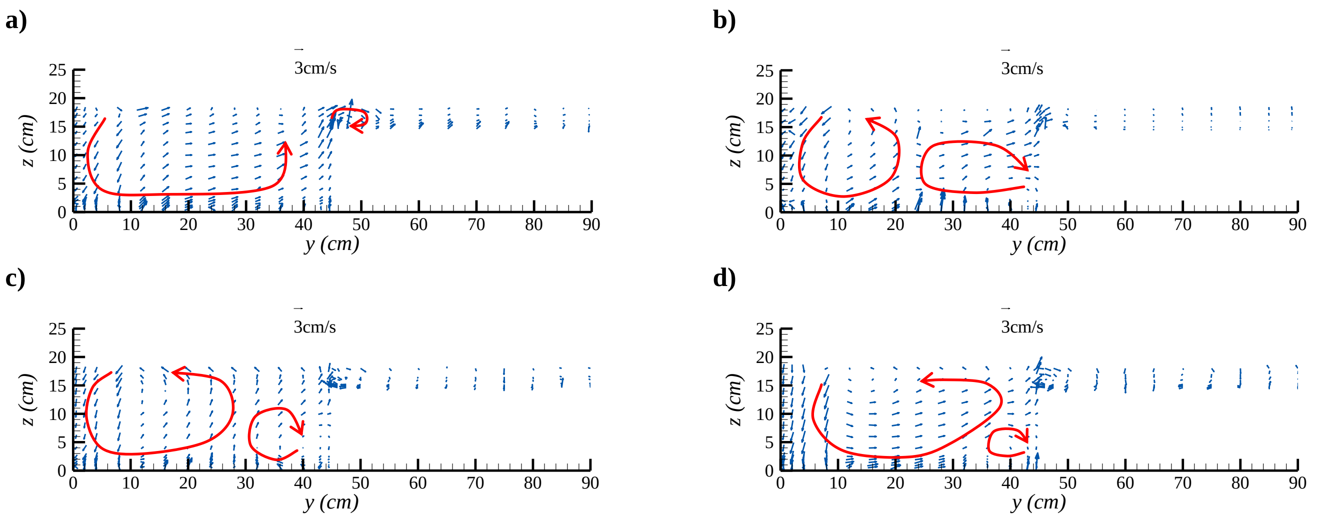


**Figure 7.** Vector plots of secondary currents for a) smooth floodplain, b) φ=0.26%, c) φ=0.88% and d) φ=3.14%

Secondary current vectors for different runs are depicted in Figures 7a-7d. It is seen in Figure 7a (smooth floodplain) that a major vortex forms in the main channel (called as the free surface vortex) whereas a weaker vortex can be observed at the interface. The free surface vortex was observed by Tominaga and Nezu (1991) in their experiments. They reported that this vortex is generated due to the anisotropy of turbulence across the flume. After the floodplain is roughened with vegetation at low density (Figure 7b), the major vortex in the main channel is broken into two smaller vortexes rotating in opposite directions. These vortexes are more or less of the same order of magnitude. However, the strength of the left vortex increases with the vegetation density whereas the right vortex (or bottom vortex) is weakened (Figures 7c and 7d). It is interesting to note that vegetation has weakened the strength of the secondary currents over the floodplain.

## CONCLUSION

In the present study, the influence of floodplain vegetation on velocity distribution in a compound channel was investigated experimentally. Rigid cylindrical dowels were used as vegetation elements. The experiments were carried out in an asymmetric compound channel under constant relative depth and for different roughness conditions over the floodplain including one smooth and three different vegetation densities. It was found that that after implanting the vegetation over the floodplain, the depth averaged velocity over the floodplain increases whereas it increases in the main channel. As the vegetation density increases, the depth averaged velocity decreases in both the main channel and floodplain. Also, the maximum value of the streamwise velocity decreases with vegetation density. Secondary current vectors showed that for smooth floodplain, a major vortex forms in the main channel. For the vegetated floodplain tests, two distinct vortexes (free surface and bottom vortexes) were observed.

## REFERENCES


1. Al-Khatib A and Gogus M (2012). Evaluation of separate channel methods for discharge computation in asymmetric compound channels. Flow Measurement and Instrumentation. 24: 19–25.
2. Atabay S and Knight DW (2006). 1-D modelling of conveyance, boundary shear and sediment transport in overbank flow. Journal of Hydraulic Research 44: 739–754.
3. Bousmar D (2002). Flow modelling in compound channels. Momentum transfer between main channel and prismatic or non-prismatic floodplains. PhD thesis. Universite´ catholique de Louvain. Louvainla- Neuve. Belgium.
4. Cassells JBC, Lambert MF, Myers RWC (2001). Discharge prediction in straight mobile bed compound channels. Proceedings of the Institution of Civil Engineers, Water & Maritime Engineering. 148:177–188.
5. Darby SE and Thorne CR (1996). Predicting stage-discharge curves in channels with bank vegetation. Journal of Hydraulic Engineering. 122: 583–586.
6. Goring DG, Nikora VI (2002). Despiking Acoustic Doppler Velocimeter Data. Journal of Hydraulic Engineering. 128: 117-126.
7. Huang B, Lai G and Qin J (2002). Hydraulics of compound channel with vegetated floodplains. Journal of Hydrodynamics. Series B. 14: 23–8.
8. Huthoff F, Roos PC, Augustijn DCM and Hulscher S (2008). Interacting divided channel method for compound channel flow. Journal of Hydraulic Engineering. 134: 1158–1165.
9. Kadlec RH and Knight RL (1996). Treatment Wetlands. Lewis Publishers. Boca Raton. FL.
10. Knight DW and Demetriou JD (1983). Flood plain and main channel flow interaction. Journal of Hydraulic Engineering. 109: 1073–1092.
11. Li B, Hu X, Xu and L (2005). Review of research work of overbank distribution of flow velocity in compound channel. Journal of Waterway and Harbor. 26: 228–32.
12. Liu D. (2008). Flow through Rigid Vegetation Hydrodynamics. MSc thesis. Virginia Polytechnic Institute. USA.
13. Martín-Vide JP, Moreta JPM and López-Querol S (2008). Improved 1-D modelling in compound meandering channels with vegetated floodplains. Journal of Hydraulic Research. 46: 265–276.
14. McNaughton J (2009). Laboratory modeling of open channel flow past emergent vegetation. MSc. Thesis. University of Manchester. Manchester. UK.
15. Musleh FA and Cruise JF (2006). Functional relationships of resistance in wide flood plains with rigid unsubmerged vegetation. Journal of Hydraulic Engineering. 132: 163–171.
16. Myers WRC, Lyness JF and Cassells J (2001). Influence of boundary roughness on velocity and discharge in compound river channels. Journal of Hydraulic Research. 39: 311–319.
17. Palmer M, Nepf H, Petterson T and Ackerman J (2004). Observations of particle capture on a cylindrical collector: Implications for particle accumulation and removal in aquatic systems. Limnology and Oceanography. 49: 76–85.
18. Proust S, Bousmar D, Riviere N and Zech Y (2010). Energy losses in compound open channels. Advances in Water Resources. 33: 1–16.
19. Seckin G (2004). A comparison of one-dimensional methods for estimating discharge capacity of straight compound channels. Canadaian Journal of Civil Engineering. 31: 619–631
20. Shiono K and Knight DW (1991). Turbulent open-channel flows with variable depth across the channel. Journal of Fluid Mechanics. 222: 617–646.
21. Stone B and Shen HT (2002). Hydraulic resistance of flow in channels with cylindrical roughness. Journal of Hydraulic Engineering. 128: 500–506
22. Thornton CI, Abt SR, Morris CE and Fischenich JC (2000). Calculating shear stress at channel-overbank interfaces in straight channels with vegetated floodplains. Journal of Hydraulic Engineering. 126: 929–936.
23. Tominaga A and Nezu I (1991). Turbulent structure in compound open channel flows. Journal of Hydraulic Engineering. 117: 21–41.
24. Wang W, Cai J and Xu W (1998). Discharge distribution in straight compound channels. Journal of Hydrodynamics. Series B. 10: 31–36.
25. Yang K, Cao S and Knight DW (2007). Flow patterns in compound channels with vegetated floodplains. Journal of Hydraulic Engineering. 133: 148–59.
26. Yang K, Cao S and Liu X (2005). Research on system dynamics model of conveyance capacity in symmetric compound channels. Journal of Hydrodynamics. Series B. 17: 295–300.