CRITICAL APPRAISAL OF VARIOUS APPROACHES TO PREDICT FLOW IN COMPOUND CHANNEL HAVING CONVERGING AND DIVERGING FLOODPLAINS

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ABSTRACT

Each river in the world is idiosyncratic in its geometry. Some are gently curve, others meander, and some others are relatively straight, converging, diverging or skewed. But at the time of flood they forget their boundaries and inundate their surroundings. The size of river geometry changes from section to section longitudinally due to different hydraulic and surface conditions called non-prismatic compound channel. Non-prismatic compound channel generally categorizes into three types-converging, diverging and skewed. There are various methods exist which are generally meant for prismatic compound channel cases but very few methods exist for non-prismatic cases. There has also been significant progress of work in meandering channels. But an area which has been somewhat neglected is that of non-prismatic compound channels. As discharge prediction is a vital issue in flood risk management and more important for a river in changed geometry. Therefore, a critical appraisal of the various techniques developed by various researchers across the globe for the past few decades to predict the stage-discharge relationship of a non-prismatic compound channel has been performed. The most widely used methods for non-prismatic compound channels are Modified Lateral Distribution method (MLDM), Ex-tended lateral distribution method (Ex-LDM), and Exchange Discharge model (EDM) and Independent Subsection method (ISM). The advantages and disadvantages of all the aforementioned have been discussed in this paper. The most suitable method for different flow conditions has been proposed as it will facilitate the researchers to focus on the area of river hydraulics and that may lead to solve other related objectives.

Keywords: *Compound channels, converging, diverging floodplains, LDM, EDM, ISM*

1. INTRODUCTION:

Today, more than half the world's population live within 65 km of the coast, and most of the major cities are also located on main river systems. Open channel can be said to be as the deep hollow surface having usually the top surface open to atmosphere. Open channel flow can be said to be as the flow of fluid (water) over the deep hollow surface (channel) with the cover of atmosphere on the top. Open Channels are classified as: prismatic open channels, non prismatic channels. The open channels in which shape, size of cross section and slope of the bed remain constant are said to be as the prismatic channels. Opposite of these channels are non-prismatic channels. Natural channels are the example of non-prismatic channels while manmade open channels are the example of prismatic channels. Some examples are flow through culverts, flow through bridge piers, high flow through bridge pier and obstruction, channel junction etc. It is seen that, the river generally exhibit a two stage geometry (deeper main channel and shallow floodplain called compound section) having either prismatic or non-prismatic geometry (geometry changes longitudinally). Due to the rapidly growing population, and to the consequent demand for food and accommodation, more and more land on such areas has been used for agriculture and settlement. Therefore, due to improper estimation of floods, it has led to an increase in the loss of life, and properties. The modelling of such flows is of primary importance when seeking to identify flooded areas and for flood risk management studies etc. To face those modelling, the critical appraisal to study various techniques used for flow modelling in both prismatic and non-prismatic compound open channel flow are useful. Even for a prismatic compound channel, there lies difference in hydraulic and geometric conditions between the main channel and floodplain components, causing strong interactions (figure 1) between the sub-sections (e.g.1 and 2).

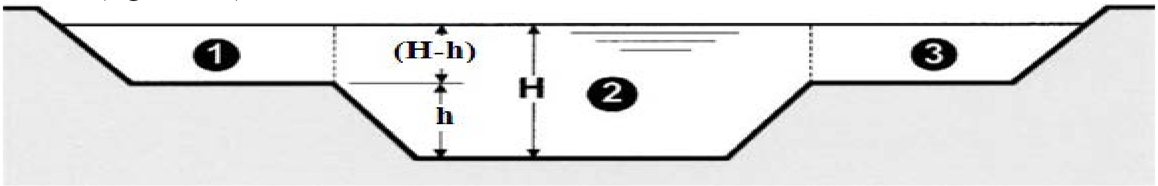

Figure 1. Cross section of compound channel

In non-prismatic compound channels with converging/diverging floodplains (Fig. 2), due to further continuous change in floodplain geometry along the flow path, the resulting interactions and momentum exchanges is further increased (Bousmar, 2002 and Proust 2005). This extra momentum exchange is very important parameter and should be taken into account in the overall flow modelling of a spatially varied river flow.

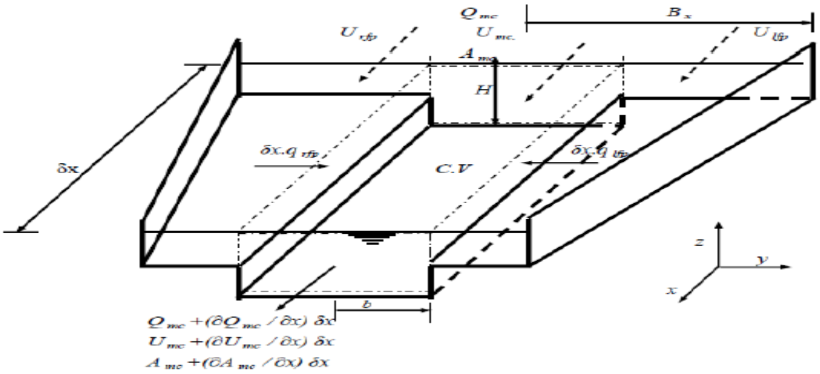

Figure 2. Perspective view of control volume in compound channels with non-prismatic floodplains whole cross section

In this paper, we are considering four methods Modified Lateral Distribution method (MLDM), Extended lateral distribution method (Ex-LDM), and Exchange Discharge model (EDM) and Independent Subsection method (ISM) for compound channel having converging and diverging floodplains.

2. Lateral distribution Method- Previous work

LDM equation: The Lateral Distribution Method (LDM) is derived from the depth-averaging of the Navier-Stokes momentum-conservation equation in the stream-wise direction [Rodi 1980]:

$$\rho\left(\frac{\partial\bar{u}}{\partial t}+\frac{\bar{u}(\partial\bar{u})}{\partial x}+\frac{\bar{v}(\partial\bar{u})}{\partial y}+\frac{\bar{w}(\partial\bar{u})}{\partial z}\right)=\rho F_x-\frac{\partial\bar{p}}{\partial x}+\mu\Delta\bar{u}-\rho\left(\frac{\partial\overline{u'u'}}{\partial x}+\frac{\partial\overline{u'v'}}{\partial y}+\frac{\partial\overline{u'w'}}{\partial z}\right) \qquad (1)$$

where ($\bar{u}$,$\bar{v}$, $\bar{w}$) are Reynolds averaged local velocity components in the *x*- (stream-wise, parallel to the bed), *y*- (lateral) and *z*- (normal to bed) directions respectively (Fig. 4); ρ is the density of water; $F_x$is the *x*-wise component of gravitational forces which equals the longitudinal bed slope S_0time the gravity constant g; pis the pressure; μ is the dynamic viscosity; and ($\overline{u'u'}$, $\overline{u'v'}$, $\overline{u'w'}$)are the Reynolds turbulent shear stresses. This equation (1) is also known as Reynolds-averaged Navier-Stokes (RANS) equation because of the use of Reynolds decomposition technique. This technique mathematically separates the average and fluctuating parts of a fluid flow quantity used in Navier-Stokes momentum-conservation equation (Rodi,1980).

$$\rho\left[\frac{\partial\bar{u}\bar{v}}{\partial y}+\frac{\partial\bar{u}\bar{w}}{\partial z}\right]=\rho g S_0+\frac{\partial}{\partial y}\left(-\rho\overline{u'v'}\right)+\frac{\partial}{\partial z}\left(-\rho\overline{u'w'}\right) \qquad (2)$$

where u′, v′ and w′ are the fluctuation of the velocity components. Here the over bar represents a time averaged parameters. The simplification of (2) is done in LDM method. In equation (2) the first term is the secondary flow term consisting of lateral and vertical components of the velocity. The second term represents the weight component of water. The third and fourth term account for the apparent shear and Reynolds shear stresses in vertical and horizontal planes respectively.

Considering the mean velocity component is very negligible in z direction, $\bar{w}$ is equal to zero and $\tau_{yx} = -\rho\overline{u'v'}$, $\tau_{zx} = -\rho\overline{u'w'}$. Integrating equation (2) in the normal direction z over the total flow depth H, we have

$$\rho g H S_0 + \frac{\partial}{\partial y} H\tau_{xy} - \tau_b\sqrt{1+S_{0y}^2} = \frac{\partial}{\partial y}\int_0^H \rho\bar{u}\bar{v}dz \quad (3)$$

where $\tau_b = \rho U_*^2$ is bed shear stress, U_* is the shear velocity, S_{0y}=lateral slope or transverse bed slope across the channel

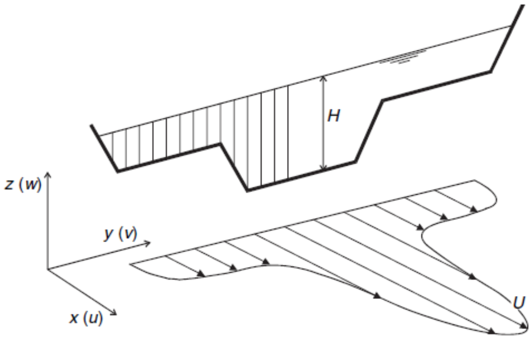

Figure 3. Compound channel cross section and reference definition (Bousmar and Zech,2004)

Knight et al.(1989) assumed that: (1) the eddy viscosity $\vartheta_t = \lambda H U_*$, is proportional to the flow depth H and the shear velocityU_*,, where $\lambda$is the dimensionless eddy viscosity; (2) the bed shear stress$\tau_b$can be evaluated using the Darcy–Weisbach friction factor f; and (3) the secondary-current term is negligible. The LDM equation is then

$$\rho g H S_{0x} + \frac{\partial}{\partial y}\left(\rho\lambda H^2\sqrt{\frac{f}{8}}U\frac{\partial U}{\partial y}\right) - \rho\frac{f}{8}U^2\sqrt{1+S_{0y}^2} = 0 \quad (4)$$

where U is the depth averaged velocity. Details of derivation are presented in Bousmar (2002). Equation (4) can be solved by both numerically and analytically. Using dimensionless eddy viscosity range $\lambda = 0.2 - 0.3$ for a natural river test case, Knight et al. (1989) found good estimates of longitudinal velocity distribution and total discharge.

2.1 Secondary current term modelling

Despite of the aforesaid results, none of the methods accurately predicted both the depth averaged velocity and boundary shear stress simultaneously. As in the above methods secondary current term is neglected, the bed friction factor is to be adapted to include its effect, and this jeopardized the actual relation between the computed velocities and boundary shear stresses. A secondary current model was proposed in Ervine et al.(2000), that assumes a linear variation of the depth averaged velocity product in equation (13)for the y-direction. This linearity assumption was verified using FCF data. The secondary current term was expressed as a constant Γ.

$$\rho g H S_{0x} + \frac{\partial}{\partial y}\left(\rho\lambda H^2\sqrt{\frac{f}{8}}U\frac{\partial U}{\partial y}\right) - \rho\frac{f}{8}U^2\sqrt{1+S_{0y}^2} = \Gamma \quad (5)$$

This constant Γ has distinct value in each subsection. This analytical solution method of this LDM version of equation is known as the Shiono Knight Method (SKM).Reynolds shear stress tensor τ_{xy} is significant within shear layer regions but it can be neglected outside the lateral shear layers as suggested in Abril and Knight(1996). The same observations are incorporates for non-prismatic compound channel Rezaei(2006). Thus the secondary current term varies with average lateral shear layer per panel τ_{avg} and $\rho g H S_e$ as

$$\rho g H S_e - \tau_{avg} = \frac{\partial}{\partial y}[H(\rho U V)_d] = \Gamma \quad (6)$$

$$\rho g H S_e\left(1 - \frac{\tau_{avg}}{\rho g H S_e}\right) = \Gamma \quad (7)$$

The details of secondary current is described in Rezaei(2006).

3. Modified Shiono-Knight Method

In prismatic channel cases, the flow generally remains uniform. But in non-prismatic channel the flow is non-uniform i.e., the depth of water varies along the length of the channel. Due to this variation of depth in non-prismatic channel, the role of friction slope or energy slope (S_e) comes into account in place of bed slope in equation (5). So the modified version of the LDM equation becomes

$$\rho g H S_e + \frac{\partial}{\partial y}\left(\rho\lambda H^2\sqrt{\frac{f}{8}}U\frac{\partial U}{\partial y}\right) - \rho\frac{f}{8}U^2\sqrt{1+S_{0y}^2} = \Gamma \qquad (9$$

It is known as Modified SKM (Rezaei, 2006). Using the Manning's roughness coefficient *n* in Modified SKM, the energy slope can be estimated. As the energy slope S_e and the average flow velocity *U (=Q/A)* are unknown so to calculate those variables, an iteration method is used as below.

$$S_e \approx \left(\frac{n^2U^2}{R^{4/3}}\right) \qquad (10)$$

where Q= total discharge, A = cross-sectional area, and R = hydraulic radius =(Area/wetted perimeter).

4. Extended lateral distribution method

The 2D Saint-Venant stream-wise momentum equation results from Reynolds averaging and depth integration of the Navier–Stokes equation (1), replacing the local velocities by $\bar{u} = U + (\bar{u} - U)$as presented by (Bousmar and Zech 2001, 2002 and Yulistianto et al. 1998)

$$\rho H\left(\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + g\frac{\partial U}{\partial x} + V\frac{\partial V}{\partial y}\right) = \rho g H S_{0x} - \rho g H S_f - \frac{\partial}{\partial x}HT_{xx} + \frac{\partial}{\partial y}HT_{xy} - \rho\frac{\partial}{\partial x}\int_o^H(\bar{u} - U)^2 dz - \rho\frac{\partial}{\partial y}\int_o^H(\bar{u} - U)(\bar{v} - V)dz \qquad (11)$$

where S_f is the friction slope, and where the viscous shearstresses are neglected. The two last terms are the so-called dispersion terms. They result from the depth-averaging of the velocity products $\bar{u}\bar{u}$ and $\bar{u}\bar{v}$ in equation (11), as the local velocities are not constant along the flow depth.
Assuming a steady and uniform flow, equation (11) reduces to

$$\rho g H S_{0x} - \rho g H S_f + \frac{\partial}{\partial y}HT_{xy} = \rho\frac{\partial}{\partial y}\int_o^H(\bar{u} - U)(\bar{v} - V)dz + \rho V H\frac{\partial U}{\partial y} \qquad (12)$$

The first term of the right-hand side of equation (12) is the dispersion term. It corresponds to the SKM secondary-current term Γ. The second term should formally vanish as the transverse velocity *V* is supposed to be null in uniform flow, although $\bar{v}$ is not zero due to secondary currents. It partly corresponds to Ervine et al.(2000) secondary-current term in equation (6), developed for meandering channels. Using equation (12) for non-prismatic flows seems a rather crude assumption, as some other left terms of equation (11) are no longer negligible. The acceleration term and the pressure term should be taken into account, while the stream-wise turbulent friction and dispersion terms could be expected to remain small for gradually varied flow. The acceleration and pressure terms, together with the bottom slope, define the energy slope S_e

$$S_e = S_{0x} - \frac{\partial H}{\partial x} - \frac{U}{g}\frac{\partial U}{\partial x} \qquad (13)$$

Neglecting the stream-wise turbulent friction and dispersion terms and using this definition of the energy slope, equation (12) reduces to the proposed extended form of the LDM (ELDM)

$$\rho g H S_e - \rho g H S_f + \frac{\partial}{\partial y}HT_{xy} = \rho\frac{\partial}{\partial y}\int_o^H(\bar{u} - U)(\bar{v} - V)dz + \rho V H\frac{\partial U}{\partial y} \qquad (14)$$

This new expression basically differs from equation (12) in that the bottom slope has been replaced by the actual energy slope, which is no longer equal to the bed slope in the non-uniform flow case. This extension of the LDM is similar to the usual one-dimensional modelling assumption that the head loss in a gradually varied flow equals the head loss in an equivalent uniform flow by Lyness et al(2001).

For practical computation of equation (14), the following assumptions are used: (1) the energy slope Se is estimated in a first stage from one-dimensional measurements, its value is noted, S_{e1D}; (2) the turbulent shear stress is modelled using the Boussinesq assumption, with an eddy viscosity proportional to the shear velocity, U_*; (3) the friction slope is derived from the Manning formulation; (4) the dispersion term is estimated using Shiono and Knight's Γ, although the latter is expected to be negligible in non-prismatic flows, where a strong mass transfer occurs between subsection and restrains the helical secondary current development on the floodplains; and (5) the ratio $\kappa=V/U$ between transverse and longitudinal velocity components is taken as a constant, depending on the channel geometry. The ELDM is finally given by

$$\rho g H S_e + \frac{\partial}{\partial y}\left(\rho\lambda H^2\sqrt{\frac{gn^2}{H^{1/3}}}U\frac{\partial U}{\partial y}\right) - \frac{\rho g n^2}{H^{1/3}}U^2\sqrt{1+S_{0y}^2} = \Gamma + \rho\kappa H U\frac{\partial U}{\partial y} \qquad (15)$$

The last term of this equation corresponds to the mass-transfer currents. It differs from Ervine et al (2000) expression in equation (15), as dispersion and mass-transfer effects have been separated: the parameter κ is now outside the derivative, and its value is expected to be explicitly linked to the non-prismatic channel geometry presented by Bousmar and Zech (2002).

5. Exchange discharge method (EDM)

The exchange discharge model (EDM)(Bousmar and Zech 1999) models flow in a compound channel by taking into account the momentum transfer at the interface between the main channel and floodplains due to both turbulent exchanges in a prismatic channel and mass transfer generated by geometrical changes in a non-prismatic channel (Fig. 4)

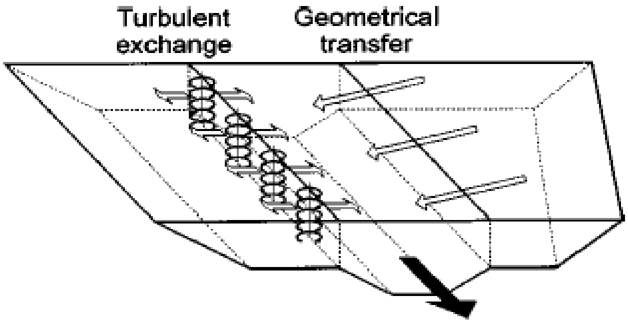

Figure **4.** Exchange discharge model, flow exchanges at the interfaces between main channel and floodplains

The momentum transfer is estimated as the product of the lateral discharge through the interface by the velocity difference between the subsections. For computational purposes, the momentum transfer is then converted in an additional head loss to be added to the usual frictional losses, and the total discharge is obtained by summation of the so-corrected sub-sectional discharges. Governing equations of EDM are summarized here, as they are used for subsequent analysis. The momentum equation for a subsection of the compound channel may be demonstrated to be (Bousmar and Zech 1999)

$$\frac{d}{dt}(\rho A U) + \frac{d}{dt}(\rho A U^2) + \rho g A\frac{dH}{dx} = \rho g A(S_0 - S_f) + \rho q_{in}u_l - \rho q_{out}U \qquad (16)$$

where ρ=density of water; g=gravity constant; A=cross-section area; U=Q/A=mean velocity with Q =discharge; H=flow depth; qin and qout=lateral inflow and outflow per unit length, respectively; ul=velocity component of the lateral inflow in the main-flow direction; and S0 and Sf=bottom and friction slopes, respectively. The friction slope Sf is derived from Manning's equation, using the classical assumption that the head loss for a specific reach is equal to the head loss in the reach for a uniform flow having the same hydraulic radius and averaged velocity (French 1985)

$$S_f = \left(\frac{Q}{AR^{2/3}/n}\right)^2 = \left(\frac{Q}{K}\right)^2 \qquad (17)$$

where R=cross-sectional hydraulic radius; K=cross-sectional conveyance; and n=roughness coefficient. In the momentum equation (16) inflow and outflow convey different momentum since their initial velocities are different.

For steady flow, the total head loss per unit length Se is obtained from Eq. (17) associated to the continuity equation

$$S_e = -\frac{d}{dx}\left(z + \frac{U^2}{2g}\right) = S_f + \frac{q_{in}(U-u_l)}{gA} = S_f + S_a = S_f(1+\chi) \qquad (18)$$

where the slope Sa is defined as the additional head loss due to the exchange discharges at the interface, to be added to the friction slope; and $\chi = S_a/S_f$ is the ratio of this additional loss and the friction loss, depending only on geometrical parameters. In a compound channel, an additional loss ratio χ_i and a friction slope S_{fi} are defined in each subsection *i*, while the total energy slope S_e is the same in all subsections for a one-dimensional model. Bousmar and Zech (1999) developed a set of equations to evaluate the χ_i ratio and the total additional loss for the entire compound cross section. The exchange discharge q was subdivided into two parts: (1) q^t related to turbulent momentum flux; and (2) q^g associated to the mass transfer due to geometrical changes. The turbulent exchange discharge was estimated by a turbulence model analogous to a mixing-length model in the horizontal plane

$$q_{cf}^t = q_{fc}^t = \overline{|u'|}(\mathrm{H} - \mathrm{h_f}) = \psi^t \left|U_c - U_f\right| (\mathrm{H} - \mathrm{h_f}) \qquad (19)$$

where q_{cf}^t and q_{fc}^t =lateral inflows from the main channel to a floodplain and from this floodplain to the main channel, respectively; u'=fluctuating part of transverse velocity; h_f=bank level above the main-channel bottom(Fig. 1); U_c and U_f=longitudinal velocity in the main channel and floodplains, respectively; and ψ^t=proportionality factor. This proportionality factor was calibrated as ψ^t=0.16 using the available experimental data (Bousmar and Zech 1999!)

The geometrical transfer discharge q^g was estimated by considering conveyance change in the floodplain subsection. For decreasing floodplain conveyance

$$q_{fc}^g = -\psi^g \frac{dQ_f}{dx} = -\psi^g \frac{dK_f}{dx} S_{ff}^{1/2} \text{and } q_{cf}^g = 0 \qquad (20)$$

where the friction slope variation $\frac{dS_{ff}}{dx}$ was neglected against $\frac{dK_f}{dx}$. The geometrical transfer discharge was then multiplied by a proportionality factor ψ^g to adjust the momentum transfer. A preliminary calibration, using the Elliott and Sellin (1990) data resulted in ψ^g=0.5 (Bousmar and Zech 1999). The details of the method Exchange Discharge Model are given in Bousmar (2002).

6. Independent Subsection Method

6.1 Flow equations

The flow dynamics in the main channel and the floodplains can be separated by writing a 1D momentum equation in each subsection. These equations are linked together by lateral mass discharges and momentum exchange terms acting at the interface between two adjacent subsections. An additional equation ensures the mass conservation on the overall cross-section area. The compound channel considered here consists of rectangular main channel and floodplains whose width can vary. Subscripts “mc”, “lfp”, and “rfp” are used for mean values of hydraulic parameters in the main channel, the left flood plain and the right flood plain, respectively. Moreover, water level *H* across the compound channel is supposed constant, as $H_{mc} = H_{rfp} = H_{lfp}$.

For such a compound channel, the 1D momentum equations can be simplified for the three subsections(Proust 2005) as:

$$\frac{dh_l}{dx}\left(1 - \frac{U_l^2}{gh_l}\right) = S_0 - S_{fl} + \frac{U_l^2}{gB_l}\frac{dB_l}{dx} + \frac{\tau_{lm} \cdot h_l}{\rho g A_l} + \frac{q_{lm}(2U_l - U_{int.l})}{gA_l} \qquad (21)$$

$$\frac{dh_r}{dx}\left(1 - \frac{U_r^2}{gh_r}\right) = S_0 - S_{fr} + \frac{U_r^2}{gB_r}\frac{dB_r}{dx} + \frac{\tau_{rm} \cdot h_r}{\rho g A_r} + \frac{q_{rm}(2U_r - U_{int.r})}{gA_r} \qquad (22)$$

$$\frac{dh_m}{dx}\left(1 - \frac{U_m^2}{gh_m}\right) = S_0 - S_{fm} + \frac{U_m^2}{gB_m}\frac{dB_m}{dx} - \frac{\tau_{lm} \cdot h_l}{\rho g A_l} - \frac{\tau_{rm} \cdot h_m}{\rho g A_m} - \frac{q_{lm}(2U_m - U_{int.l})}{gA_m} - \frac{q_{rm}(2U_m - U_{int.r})}{gA_m} \qquad (23)$$

where *x*=longitudinal direction; *h*=subsection flow depth; *U* =subsection mean velocity; U_{int} =longitudinal velocity at the interface; *B*=subsection width; *A*=subsection area; S_o =bed slope; S_f =subsection friction slope; τ =shear stress at the interface in the *x* direction. Besides, q_{rfm} (resp. q_{lfm}) is the lateral mass discharge per unit longitudinal length between the right floodplain (resp. the left floodplain) and the main channel, being positive from a floodplain to the main channel. The friction slope S_f is calculated with classical Manning’s formula applied to a subsection. The continuity equations in both floodplains are:

$$\frac{dQ_l}{dx} = -q_{lm} \text{ and } \frac{dQ_r}{dx} = -q_{rm} \qquad (24)$$

and the mass conservation on the overall cross-section area writes:

$$\frac{dQ_m}{dx} = q_{lm} + q_{rm} \qquad (25)$$

where the sum of the subsection discharges, Q_{mc}, Q_{frm} and Q_{flm} is the total discharge Q. The Independent Subsections Method consists thus in solving the set of equations (21), (22), (23), (24) and (25), with closure equations defining the interface shear stress τ and velocity U_{int} .

6.2 Momentum transfer modelling
6.2.1 Turbulent transfers

Yen (1985) proposed to relate the interfacial side shear stress τ to the velocity gradient in the lateral direction y across the channel, assuming a constant eddy viscosity ν_t. But Wilson et al. (2002) showed that this assumption leads to overestimate turbulent diffusion and therefore to reduce the velocity difference between flows in the main channel and the floodplains. Other authors preferred to evaluate the interfacial shear on the subsection boundary by using a mixing length model in the horizontal plane. This model was validated by Ervine&Baird (1982) from experimental data collected byMyers (1978), Rajaratnam &Ahmadi (1981), Ghosh & Jena (1971) and Sellin (1964), by Lambert & Sellin (1996) and by Bousmar (2002). Finally, the mixing length model included in the Exchange Discharge Model was retained (Bousmar & Zech 1999). The side shear stress τ on the two interfaces are modelled by:

$$|\tau_{lm}| = \rho\psi^t(U_m - U_l)^2$$

$$|\tau_{rm}| = \rho\psi^t(U_m - U_r)^2 \qquad (26)$$

where ψ^t=a constant coefficient of turbulent exchange. The ψ^t value is taken as 0.2 as taken by proust (2006).

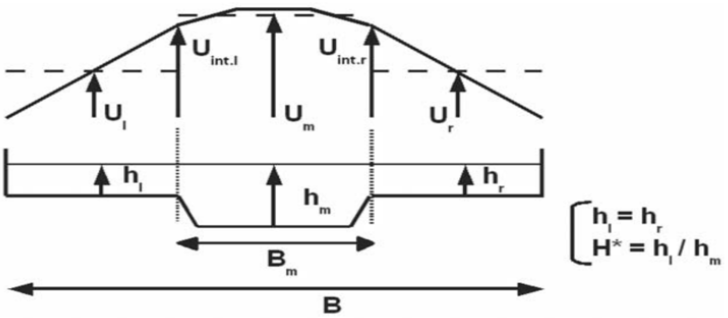

Figure 5. Notation for geometric and hydraulic parameter (Proust, 2009)

6.2.2 Mass transfers

In Equation (1), (2) and (3), $U_{int.lfp}$ is the x-component velocity of lateral mass discharge q_{lfm} (left interface) and $U_{int.rfp}$ is related to q_{rfm} (right interface). Consequently, the momentum transfer due to mass exchange strongly depends on the interfacial velocities values. Determination of these velocities relies on experimental observations. For flows in compound channels with floodplain(s)-width decrease, the longitudinal velocity of water entering the main channel is very close to the floodplain mean velocity, as observed for symmetrical narrowing floodplains (Bousmar et al.2004) and abrupt floodplain contraction (Proust et al. 2006). In that case, interfacial velocities can be modelled by:

$$U_{int.l} = \varphi_l U_l + (1-\varphi_l)U_m \text{ and } U_{int.r} = \varphi_r U_r + (1-\varphi_r)U_m \qquad (27)$$

where φ_l and φ_r are weighting coefficients depending on the geometry.

Accordingly, the interfacial velocities in ISM are modelled depending on the mass transfer direction for each interface. The details of ISM and to solve the system of equation is well described in Proust (2005)

7. SOURCES OF DATASETS

For this research work we consider the data of converging compound channels from Université Catholique de Louvain flume (UCLF) (Rezaei,2006) .

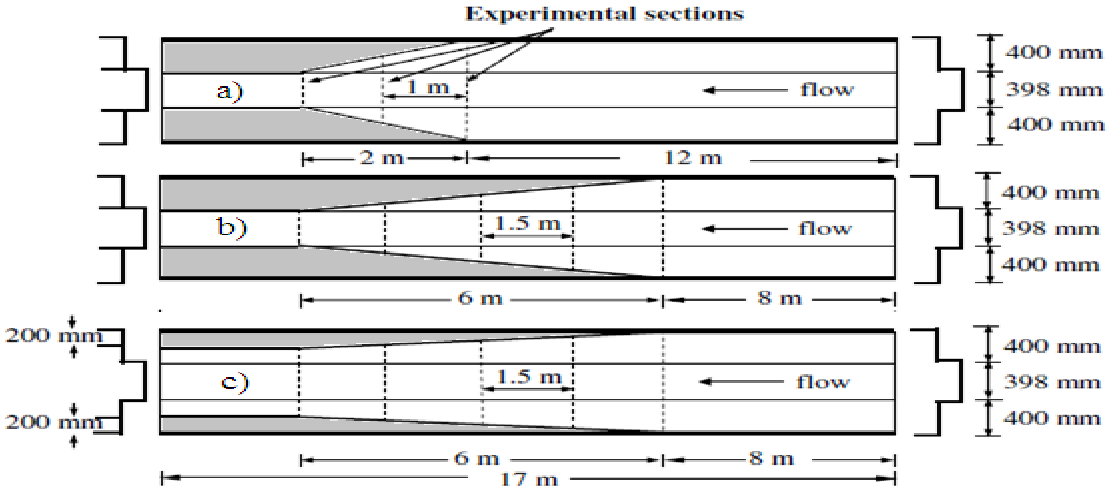

Figure 6. Plan view of compound channels with converging floodplains, (a) Cv2/UCLF (b) Cv6/UCLF, (c) Cv6-200/UCLF

Converging Compound channel datasets-The dimension of the experimental flume is shown in Fig 5.There are three converging compound channels (a) Cv2, flood plain width converges from 400mm to 0mm along a 2m length, θ=11.31°, (b) Cv6, flood plain width converges from 400mm to 0mm along a 6m length, θ=3.81° and (c) Cv6-200, flood plain width converges from 400mm to 200mm along a 6m length, θ=1.91°. Total width (B) of the channel is 1.198m and the bed slope (S0) is 0.002003. The channel geometry for converging compound channels symbolize as Cv2, Cv6 and Cv6-200 where Cv stands for Converging and the numbers i.e., 2 and 6 represent the converging floodplain length and 200 is the floodplain width.

8. RESULTS AND DISCUSSIONS

The four numerical methods Modified Lateral Distribution method (MLDM), Ex-tended lateral distribution method (ExLDM), and Exchange Discharge model (EDM) and Independent Subsection method (ISM) are applied to compound channel having converging and diverging floodplains and the error in discharge computation is shown in Figures 7 and 8. The discharge value in different sections of converging compound channel Cv6/UCLF for relative depth 0.5 has been presented in Table 1. All the methods are overestimated the discharge value for higher relative depth 0.5. It has been observed from the Table 1 that all methods except EDM give good results at different sections but at the end of the converging portion all are providing good results because the floodplain converges to main channel making the whole compound section to a simple channel. By EDM the computed discharge value increases from beginning to the middle of the converging portion and gradually decreases towards the end of the converging part. Similarly the discharge value in different sections of a diverging compound channel Dv6/UTF for relative depth 0.35 has been presented in Table 2. All the methods are overestimated the discharge value for higher relative depth 0.5. It has been observed from the Table 2 that all methods except EDM give good results at different sections but at the end of the diverging portion all are providing good results because at the end of the diverging portion it tends to prismatic compound channel. By EDM the computed discharge values follows a same trend as in converging compound channel case.

Table 1. Computed discharges from various approaches for five different sections of converging compound channel (Cv6/UCLF) for 0.5 relative depth

Various approaches / Sections	ExLDM Q (m^3/s)	EDM Q (m^3/s)	MSKM Q (m^3/s)	ISM Q (m^3/s)
X=8m	0.02571	0.02938	0.02572	0.02534
X=9.5m	0.02558	0.03251	0.02579	0.02519
X=11m	0.02535	0.03719	0.02523	0.02530
X=11.5m	0.02567	0.03322	0.02556	0.02534
X=13m	0.02574	0.02603	0.02569	0.02529
Experimental discharge is 0.0249m^3/s for relative depth Dr=0.5				

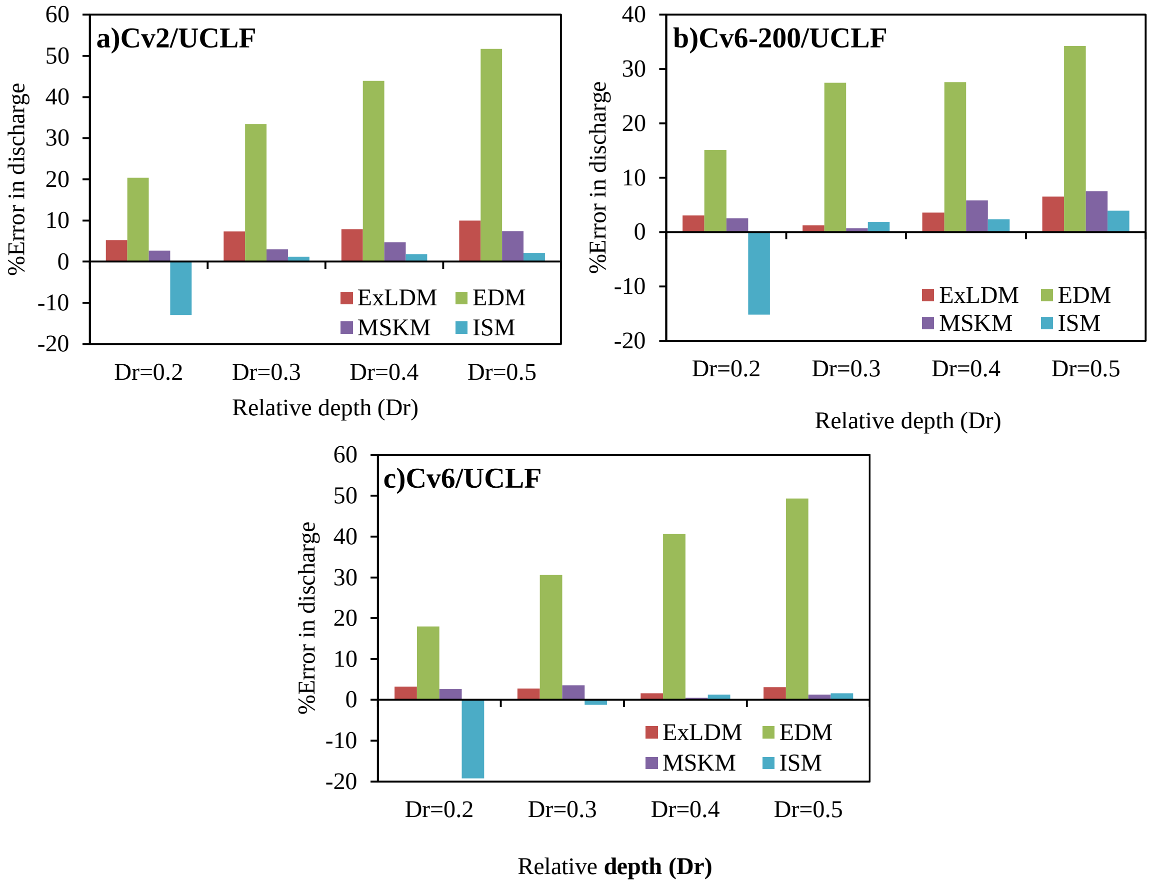

Figure 8. Error in discharge computed by various method (a), (b), and (c) for converging compound channel cases

Converging compound channel- The Figures 8(a), 8(b) and 8(c) show the error in discharge computation by four method ExLDM ,EDM, MSKM and ISM for four different relative depths Dr= 0.2, 0.3, 0.4 and 0.5. EDM overestimated the discharge value and give high error in discharge prediction for different relative depth compared to other three models. It is because of not considering proper discharge distributions in the main channel and flood plain. ExLDM overestimated the discharge value for all relative depth and the error increases with increase in relative depth and it provides good discharge value having discharge error below 10%. MSKM it provides very good results for higher relative depth 0.5 for Cv6-200 i.e. 1.91°. For low and medium relative depth it gives good discharge value for higher angle 3.81° and 11.31°. For low relative depth 0.2 the ISM underestimated 12%, 17% and 19.6% for Cv2, Cv6 and Cv6-200 respectively and for medium and high relative depth it provides better results as compare to other model as it overestimate discharge value but the error in discharge prediction is below 5%.

9. CONCLUSIONS

Four numerical and analytical methods Modified Lateral Distribution method (MLDM), Ex-tended lateral distribution method (ExLDM), and Exchange Discharge model (EDM) and Independent Subsection method (ISM) are successfully applied to compound channel having converging and diverging floodplains and the following conclusions are drawn

- For converging compound channel case MSKM better results for low relative depth and for medium and high relative depth ISM is the best among the four methods with percentage error in discharge below 5%.

- For a constant relative depth all methods give nearly same results for different sections of converging part except Exchange Discharge model.
- The results from MSKM get improved with decreases in converges angle from 11.31° to 1.91°.
- The EDM highly overestimated the discharge value with increase in relative depth for converging compound channel.

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