Journal of Geographical Research
https://ojs.bilpublishing.com/index.php/jgr

ARTICLE

Development of River Meander Model

Levent Yilmaz*

Nisantasi University, 1453 Neocampus, Civil Engineering Department, Hydraulic Division, 80626, Maslak, Istanbul, Turkey

ARTICLE INFO

Article history
Received: 28 December 2020
Accepted: 9 May 2020
Published Online: 31 May 2020

Keywords:
Meander
Flow
Model
Boundary layer
Sediment

ABSTRACT

In the studies of open-channel flow with suspended sediments, used a constant of Von Karman κ in a model for velocity profile. The augmentation parameters have been added by various researchers in more recent development of the boundary-layer theory of meander development. In this research new parameters will be included because of the existence of the turbulent flow region in meandering channels because of boundary-layer theory.

1. Introduction

A functional relationship was attempt for the lower flow regime discharge to which the sediment rate may be related as [1]:

$$U/ U_*'' = F(\psi') \quad (1)$$

where U is the mean velocity and U_*'' is the shear velocity and ψ' is the intensity of shear on representative particles and is given by [1]

$$\psi'_{35} = \frac{(\rho s - \rho) d35}{\rho R' s}. \quad (2)$$

where ψ'_{35} is the intensity of shear on the particle with a diameter 35 mm. sieve probe,

ρs = Sediment density and

ρ = Water density

R' = Hydraulic radius of meandering boundary layer

S = Slope of the meandering boundary layer which is given in the Form resistance relationship of the 2nd equation.

2. Method

Another research works with the divided slope approach by assuming that the skin friction is due primarily to expansion losses associated with flow separation downstream of dune crest in meandering boundary layer [1].

The magnitude of the expansion head loss H'' may be estimated from the formula [1],

$$\Delta H'' = \alpha \frac{(U1 - U2)^{**}2}{2g} \quad (3)$$

**Corresponding Author:*
Levent Yilmaz,
Nisantasi University, 1453 Neocampus, Civil Engineering Department, Hydraulic Division, 80626, Maslak, Istanbul, Turkey;
Email: levent.yilmaz@nisantasi.edu.tr

  DOI: https://doi.org/10.30564/jgr.v3i1.1845

where α is the loss coefficient, U_1 is the mean velocity above the crest, and U_2 is the mean velocity over the trough. If the bed form height is given as h and the mean depth is given as D, then the 3rd relationship becomes [1]

$$\Delta H'' = \frac{\alpha}{2g}\left[\frac{q}{D-\left(\frac{1}{2}\right)h} - \frac{q}{D+\left(\frac{1}{2}\right)h}\right]A^2 \cong \frac{U^2}{2g}\left[\frac{h}{D}\right]A^2 \qquad (4)$$

where q is the discharge per unit channel width and U = q/D is the mean velocity and A =unit.

The energy gradient S'' is the head loss H'' divided by the distance of one wavelength at the bed formation in meandering channels [1],

$$S'' = \frac{\Delta H''}{\lambda} = \frac{\alpha}{2}\frac{h1^2}{\lambda D}F1^2 \qquad (5)$$

and substituting the above equation into Eq. 5 yields [1],

$$S = S' + S'' \qquad (6)$$

where the depth D is replaced by the hydraulic radius R.

Multiplying both sides by $\gamma R(\gamma_s - \gamma)$ gives,

$$\frac{\gamma RS}{(\gamma s-\gamma)d} = \frac{\gamma RS'}{(\gamma s-\gamma)d} + \frac{\alpha}{2}\frac{\gamma h1^2}{(\gamma s-\gamma)\lambda d} \qquad (7)$$

3. Mathematical Model

In research of this model the vertical component of velocity is negligible, and the pressure is assumed as hydrostatic. The two-dimensional equations for water depth and depth-averaged velocities is given accoding to [14].

$$\frac{\delta(uh)}{\delta s} + \frac{1}{r}\frac{\delta(rvh)}{\delta n} = 0 \qquad (8)$$

$$\frac{\delta u}{\delta s}u + \frac{\delta u}{\delta n}v + \frac{uv}{r} = -\frac{1}{\rho}\frac{\delta p}{\delta s} - \frac{\tau 1_s}{\rho h} + 2\frac{\delta}{\delta s}\left[\in\frac{\delta u}{\delta s}\right] + \frac{\delta}{\delta n}\left[\in\frac{\delta u}{\delta n}\right] \qquad (9)$$

$$\frac{\delta u}{\delta s}u + \frac{\delta u}{\delta n}v - \frac{u1^2}{r} = -\frac{1}{\rho}\frac{\delta p}{\delta s} - \frac{\tau n_s}{\rho h} + 2\frac{\delta}{\delta n}\left[\in\frac{\delta v}{\delta n}\right] + \frac{\delta}{\delta s}\left[\in\frac{\delta v}{\delta s}\right] \qquad (10)$$

where u, v, is the s- and n- components of the depth-averaged flow velocity, respectively, is the depth of water, r is the radius of curvature of meandering boundary layer at (s,n); ρ is the specific density of fluid; p = ρ g (h+z); z = bed elevation; τ_s ; τ_n = s- and n- components of bed shear stress; respectively; and ϵ = Diffusion coefficient.

In the model prediction the continuity equation for two-dimensional bed-load sedimentation equation is predicted [14],

$$\frac{\delta z}{\delta t} + \frac{1}{1-\lambda}\left[\frac{\delta q1_{BS}}{\delta s} + \frac{1}{r}\frac{\delta(rq1_{Bn})}{\delta n}\right] = 0 \qquad (11)$$

where t is the duration; λ is the porosity of bed material, and q_{Bs}, q_{Bn} = s- and n- components of the volume rate of bed-load transport per unit width of the bed, respectively. For calculation of bed-load transport equation the Meyer-Peter-Müller Formula is used [1].

4. Equations with Empirical Background

Meander expansion is a significant sediment transport problem in river navigation which is well-researched by [2]. Many investigations have been made for the so-called regime theory [3-7], which are given for empirical relationships. They are used for primarily designing the stable, straight channels. All the theories generally are given for predicting the value of meander formation that the channel width must be less than six-to-ten times depth in order for the channel remaining unchanged. Most river meanders have a width-depth ratio larger than six to ten, and their planform is variable. It consists of meanders that usually expanded by both downstream translation and lateral expansion. Most empirical equations cannot give rate and direction of expansion. Some expansion equations are given in the form of measured correlations between rates of bank retreat and width or width-radius ratio [8-12].

Another theory is obtained by perturbation theory of river meandering boundary layer [13]. Perturbations are permitted into the system of observing the discharge which shows variation on channel planform migration by calculating the rate of growth of the oscillation at the boundary layer. The gain for river planform protection is that the perturbation – stability analysis enables river discharge characteristics in future basic flow conditions at the boundary layer. One –dimensional, straight-channel resistance formulas are given by [14,15] where the perturbation analyses generally give some new models including those of sedimentation, and the description of flow and boundary layer formation in the channel in two different conditions. Two different stability formulations are given as:

(1) Bend formation theory which gives expansion of meandering features,

(2) Bar formation theory which gives alternating bar formation in straight channel.

New bend formation theories are given by[15]. It gives theories about river erosion conditions with centrifugally induced secondary flow rates which influenced the river boundary layer topography and primary flow distributions. It is assumed that the bank erosion rate is proportional to the secondary current phase [15]. It is assumed that the transverse bed slope has negligible impact on river boundary layer stability [15]. In other research the secondary circulation is influenced by an external stress conditions which is controlled by different basic flow conditions.

5. Meandering Boundary Layers

A mandering flow model is searched to predict the symmetric and asymmetric meander loops. Results overlapping with experiments are given. Observations of the prediction to the development of meso-scale bed configuration in straight channels are also shown. The model predictions are conducted for three types of bed formations: alternating bars, braided bars, and no bars, according to the regime criteria of meso-scale bed formations [14]. The migration velocity of bars in expanding boundary layers is also predicted.

In river management, it is the first condition to predict water surface height, water path and erosion and deposition of alluvial channels with sedimentation under different regime theories. Mathematical and physical models can be used in designing or planning for navigation use of river channels and hydraulic structures. Several researches have been conducted to evaluate flow and bed variation in expanding channels in nature [1,4]. In meandering boundary layers the erosion and the deposition also shorthly bed variation is computed by the continuity equation for sedimentation and discharge. Typical boundary layer formations and discharge with alternating bars and braided bars are predicted firstly in straight channels, and thus the formation and migration of bars are enabling prediction the boundary layer formations quantitatively.

6. Conclusions

Through an iteration process by prediction new finite difference method on a computational grid a result for steady-state condition is determined [1]. The relationsips for discharge are given implicitly, while the continuity equation is given explicitly. The ratio of mean discharge is given as the square root of the mean energy gradient which is given by Manning [1].

$$\frac{Q+\Delta Q}{Q} \approx [\frac{Ie+\Delta Ie}{Ie}]1^{1/2} \approx \frac{1}{2}\frac{\Delta Ie}{Ie} \quad (12)$$

in which Q = the discharge; and Ie=energy slope is equal to the cross-sectional averge water surface gradient. If v =0 and a slip velocity u_w is emphasized as,

$$\frac{\tau 1_w}{\rho} = \in \frac{du}{dn} = C1_d u1_{w1^2} \quad (13)$$

where τ_w is the shear stres at the boundary layer and C_d is the friction coefficient at boundary. The coefficient ϵ of the diffusion gives permission to compute the slip velocity u where v=0 and z is the location at the upstream end. If the flow is superctitical, the boundary conditions are given as p at the upstrea end and u,v are given at the downstream end.

7. Results

The results of model observations were carried out fort he same conditions as the mathemtical model at the Technical University of Berlin, Institute of Water Constructions and Water Resources, continued with a boundary layer without any gradient at contiuous discharge conditions. Then the boundary layers were solidified, and precise measurement of the boundary layer formations and the new velocity conditions were attempted. It is observed [14]:

(1) The depth-averaged computational precise investigation was used to show equilibrium with natural observations at the symmetrical and asymmetrical meander loops.

(2) The simulation with experimentation models and prototypes show good overlapping with this model.

(3) The objective was to investigate a simple numerical relationship for prediction the variation of bed topography in prototypes.

In alluvial planforms, the relationships between hydraulic behaviour and plan geometries result in various of boundary layer formations which are dependent on migration bars and meandering river dunes.

Selected Readings

Hey, R.D., Bathurst, J.C., Thorne, C.R.. Gravel Bed Rivers. John Wiley, new York, 1982.

References

[1] Yilmaz, L.. Meandering River Sediment Distribution Determination. Nisantasi University, 1453 Neocampus, Maslak, Istanbul, Turkey, 2019. (unpublished source).

[2] U.S. Army Corps of Engineers. The Streambank Erosion Control Evaluation and Demonstration. Act of 1974, section 32, Public Law 93-251. Final report to Congress, Waterways Experiment Station, Vicksburg, Miss, 1981.

[3] Yen, B. C.. Spiral motion of developed flow in wide

  DOI: https://doi.org/10.30564/jgr.v3i1.1845

curved open channels. Sedimentation, H. W. Shen, ed., Fort Collins, Colo., 1972, 22.
[4] Zimmermann, C., Kennedy, J.F.. Transverse bed slopes in curved alluvial streams, J. Hydr. Div., ASCE, 1978, 104 (1): 33-48.
[5] Odgaard, A. J.. Meander flow model. I: Development, J. Hydr. Div., ASCE, 1986a, 112(12): 1117-1136.
[6] Odgaard, A. J.. Meander flow model. II: Applications, J. Hydr. Div., ASCE, 1986b, 112(12): 1137-1150.
[7] Odgaard, A. J.. Streambank erosion along two rivers in Iowa. Water Resources Research, 1987, 23(7): 1225-1236.
[8] Odgaard, A. J.. River-Meander model. II: Applications, J. Hydr. Engrg. Div., ASCE, 1989, 115(11): 1451-1464.
[9] Odgaard, A. J., Bergs, M. A.. Flow processes in a curved alluvial channel. Water Resources Research, 1988, 24 (1): 45-56.
[10] Parker, G., Andrews, E.D.. Sorting of bed load sediment by flow in meander bends. Water Resources Research, 1985, 21 (9): 1361-1373.
[11] Rozovskii, I. L.. Flow of water in bends of open channels. Academy of Sciences of the Ukrainian SSR, Kiev, USSR (in Russian),1957. (English Translation, Israel Program for Scientific Translation, Jerusalem, Israel, 1961).
[12] Simons, D.B., Senturk, F.. Sediment transport technology, Water Resources Publications, Fort Collins, Colo., 1977.
[13] Zeller, J.. Meandering channels in Switzerland, International Association of Scientific Hydrology, Symp. On River Morphology, Bern, Switzerland, 1967, 75: 174-186.
[14] Yilmaz, L.. Sedimentation in different rough boundary layers, Nisantasi University, 1453 Neocampus, Maslak, Istanbul, Turkey, 2019. (unpublished resource).
[15] Yilmaz L.. Irrigation and Drainage Management Studium Press.P.O. Box 772200, HOUSTON.TEXAS 77072 USA, 2012.