

Numerical Simulation on Flooding Flows over Mangrove Swamps

Dept. of Ocean Civil Eng., Kagoshima University
 Dept. of Ocean Civil Eng., Kagoshima University
 Inst. of Oce., Univ. College Terengganu, Malaysia

Shahbudin Saad
 Toshiyuki Asano
 Mohd. Lokman Husain

1. INTRODUCTION

Flooding and draining flows of tidal waters over mangrove swamps are very complicated. This is due to the morphology of mangroves that usually comprised of narrow and branched creeks and thickly vegetated swamps (Asano, et al., 2000). This complicate water flows are primarily important in governing other activities such as biological, chemical and sedimentation processes. In this study, a numerical simulation has been conducted to reproduce a tidal flow in an existing mangrove swamp of the Kemaman mangroves estuary in Malaysia (Figure 1).

2. MATHEMATICAL MODEL

The two-dimensional finite difference model based upon a Leapfrog scheme was used in this study. The basic equations are non-linear shallow water equations as follows:

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0 \quad (1)$$

$$\frac{\partial M}{\partial t} + \frac{\partial M^2}{\partial x D} + \frac{\partial MN}{\partial y D} + gD \frac{\partial \eta}{\partial x} - f \frac{MQ}{D^2} - A_h \left(\frac{\partial^2 M}{\partial x^2} + \frac{\partial^2 M}{\partial y^2} \right) = 0 \quad (2)$$

$$\frac{\partial N}{\partial t} + \frac{\partial MN}{\partial x D} + \frac{\partial N^2}{\partial y D} + gD \frac{\partial \eta}{\partial y} - f \frac{NQ}{D^2} - A_h \left(\frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial y^2} \right) = 0 \quad (3)$$

A_h is the horizontal mixing coefficient, of which value is used here as $1.0 \text{ m}^2/\text{s}$. The friction factor f is considered to be comprised of the bottom friction f_b and the drag resistance due to the mangrove roots f_{roots} (Asano, 1999) as follows:

$$f = f_b + f_{roots}, \quad f_{roots} = \frac{1}{2} C_D \int_0^D d_0(z) N(z) dz \quad (4)$$

Substituting equation (4) into the friction terms of equation (2) and (3) and integrating over the bottom area, we find

$$\rho \iint f \frac{MQ}{D^2} dx dy = \tau_{b,x} + \frac{\rho}{2} C_D A(z) u \sqrt{u^2 + v^2} \quad (5)$$

$$\rho \iint f \frac{NQ}{D^2} dx dy = \tau_{b,y} + \frac{\rho}{2} C_D A(z) v \sqrt{u^2 + v^2} \quad (6)$$

3. RESULT AND DISCUSSION

Figure 2 clearly shows the phase lag among the creeks (at cross-section J110 in Figure 1) because the total distance from the estuary mouth varies for each creek. The water level at the right creek rises up faster than that of the left at $t=18\text{hr}$. An overflow from the right side to the left can be observed at that time. The water flooding continues until the water level start to recede. It is noted from the curves at $t=20\text{hr}$ that the water level in the right creek recedes faster than the left one.

Figure 3 elucidates the horizontal velocity distribution at point E, which is situated almost at the middle of estuary, approximately 1.5km from river mouth. The small velocity at this point is due to the friction at the shallow water in this area that caused a diminution in the tidal range and flow velocity.

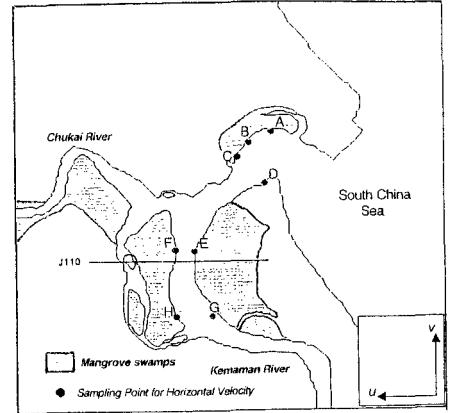


Figure 1: Sampling Points

where, $D = h + \eta$ is the total depth (h : still water depth, η : water surface elevation), $(M, N) = (Du, Dv)$ and $Q = \sqrt{M^2 + N^2}$ are the mass fluxes.

where, C_D is the drag coefficient, d_0 is the projected diameter of a mangrove root, N is the number of roots per unit bottom area and $A(z)$ is sum of the projected area of mangrove roots against the flow.

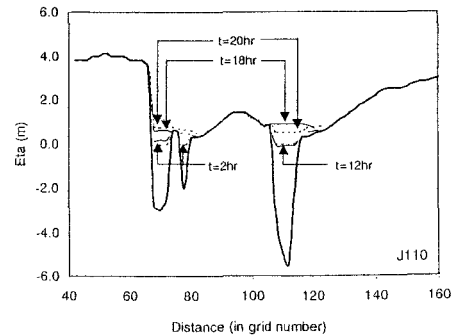


Figure 2 (a): Surface Water Level Variation at Cross-section J110

Horizontal u -velocity is less than v -velocity, there. As illustrated in Figure 3, the maximum u -velocity during flood tide and ebb tide is just about 0.1m/s and 0.22m/s respectively. Meanwhile, the maximum v -velocity during flood tide and ebb tide is about 0.25m/s and 0.15m/s, respectively.

A flooding flow over a mangrove swamp is subject to the drag resistance by mangrove prop roots, pneumatophors and their fallen branches, seedlings and leaves etc. Generated low velocity region over the swamp will retard the adjacent velocity in the creek region by the lateral mixing effect. Figure 4 illustrates velocity variation for u and v , at the central point of the transect J110. The figures indicate that the peak values for the case including mangrove roughness take greater values, even though the differences are small. This is the contrary result to that was expected from the resistance function by the mangrove roots system.

In order to look into the cause, the flooding situations for both calculations including and excluding mangrove drag resistance are investigated. The calculation shows that the flooding water (at 18hr 40min) enters deeper inside the swamp near the estuary mouth if the flood plain is assumed to be no resistance except the bed friction. This large expansion of the flooding will cause a reduction of water mass entering into the midstream creek region. This volume reduction effect will exceed the resistance effects by the mangrove roots, and this is the reason that the results of including roughness yield the greater velocities.

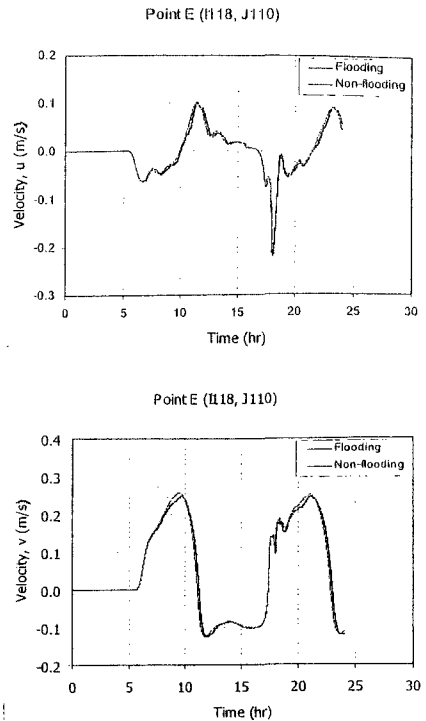


Figure 3: Horizontal Velocity Profiles at Point E for Flooding and Non-flooding Cases

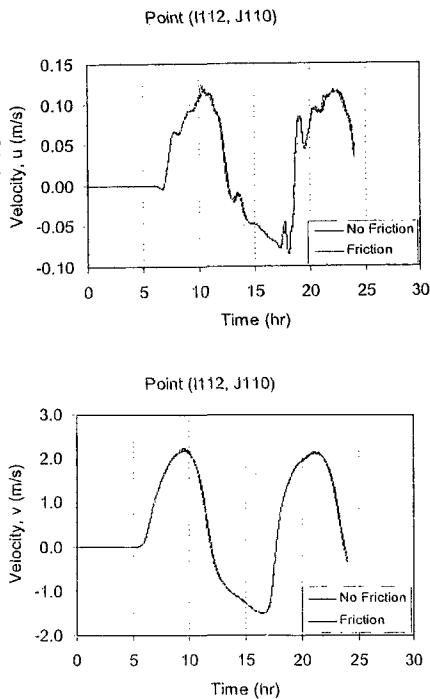


Figure 4: u and v -velocity Variation at Point (I112, J110)

4. CONCLUSIONS

The estimated drag resistance in terms of Manning rough coefficient is found to be consistent with that suggested by the existing knowledge of open channel flow for vegetated flood plains. The peak values of velocity fluctuations are reduced by an occurrence of flooding, and the temporal fluctuations are slightly skewed to lean backward. The unexpected result is observed on the study of drag resistance effects on the water level and velocity fluctuations. The retarding effects on the creek velocity does not appear, even on the contrary, the peak velocity including the mangrove drag resistance becomes slightly greater than that no drag resistance assumed. The reason is that more water intrusion flooding over the swamp occurs near the estuary mouth when the mangrove drag resistance is ignored.

REFERENCES

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