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HYDRODYNAMICS OF LAKES AND RESERVOIRS

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1. INTRODUCTION: One of the earliest application of Navier-Stokes equations using numerical solution procedure for simulating wind driven water level fluctuations and currents is given by Hansen(1962). Since then, a large number of mathematical models on the same subject have been developed. The present model is also an attempt in that direction. The model equations are obtained by averaging the three-dimensional equations over the water depth. The model equations are represented into finite difference form using explicit scheme and alternating direction implicit(ADI) scheme. The results from the later scheme are used to compare the results obtained from the first scheme to evaluate the accuracy of both methods and vice versa.

2. MODEL EQUATIONS: A two-dimensional horizontal motion in a homogeneous and incompressible fluid of a test reservoir shown in Fig.1 (size 80*24m) is considered. The maximum water depth in the reservoir is 12.0m and is constant. When undisturbed, the surface is horizontal. Also there is no inflow and outflow of the reservoir. The rigid lid approximation (w=0 at z=0) is considered at surface. The model equations are:

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

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}(uM)+\frac{\partial}{\partial y}(vM)-fN+g(h+\eta)\frac{\partial \eta}{\partial x}+\frac{1}{\rho}[\tau_x^b-\tau_x^s]=0 \qquad (2)$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}(uN)+\frac{\partial}{\partial y}(vN)+fM+g(h+\eta)\frac{\partial \eta}{\partial y}+\frac{1}{\rho}[\tau_y^{(b)}-\tau_y^{(s)}]=0 \qquad (3)$$

The interpretation of the variables used in the eqns.(1)-(3) and finite difference representation of eqns.(1)-(3) into the used two schemes are available in details from Garg(1988).

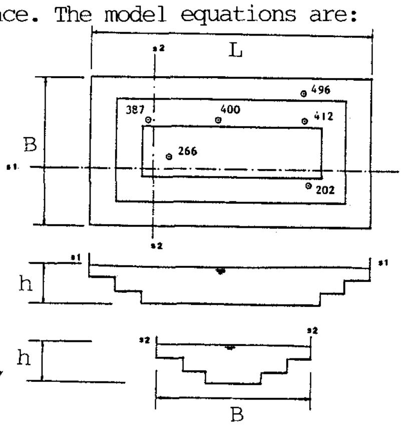

Fig.1 Test reservoir

3. DISCUSSION OF SIMULATION RESULTS AND CONCLUSIONS: The wind driven flows caused by a constant spatially uniform wind of 3m/s suddenly imposed on an initially calm non-stratified test reservoir from W45°S is discussed. Wind blows for 48 hrs. over the surface of test reservoir. The surface elevation(seiches) and velocities versus time at selected locations in the test reservoir are shown in Fig.2 in view of the both explicit and alternating direction implicit(ADI) scheme. Fig.2 shows that the amplitude and time period of surface fluctuations from the model in the explicit scheme compared well with the ADI scheme. Periods of surface oscillation in the longitudinal direction is about 255 min. which agrees well with the Merian formula(1928). It verifies that the computed results from both the methods are correct The general flow patterns generated by this wind in this test reservoir is discussed in Figs.3-4. Fig.3 shows that the flow pattern obtained from the model in the explicit scheme at 2,10 and 48 hrs. after the start of the wind, whereas Fig.4 shows from the model in ADI scheme. It can be seen in Figs.3-4 that the flow pattern obtained from both the methods in this test reservoir also agrees well with each other at any instant of time. From Figs.3-4 and from additional results of the calculations, it is concluded that the steady state reached almost at the same time in both the schemes. Figs.3-4 shows that at about 3 hrs. after the start of the wind, the mass flow in the deeper central region of the test reservoir begins to reverse its direction, while the mass flow in the shallow water region is still in the direction of the wind. The highest velocities on the surface occure near the boundaries and are in the downwind direction. Mass transport due to this wind in this reservoir at different sections are shown in Fig.5. Fig.5 shows that at the extreme left and right ends of the reservoir, the mass transport in the x-direction is zero and all the mass is transporting in the y-direction, whereas in the central portion the mass transport in the y-direction is

zero and all the mass transport is in the x-direction. It match very well with the flow pattern in the reservoir shown in Figs.3-4. The effect of convective terms in the momentum equations on this forced flow patterns are relatively minor at this wind velocity as indicated in Fig.6.

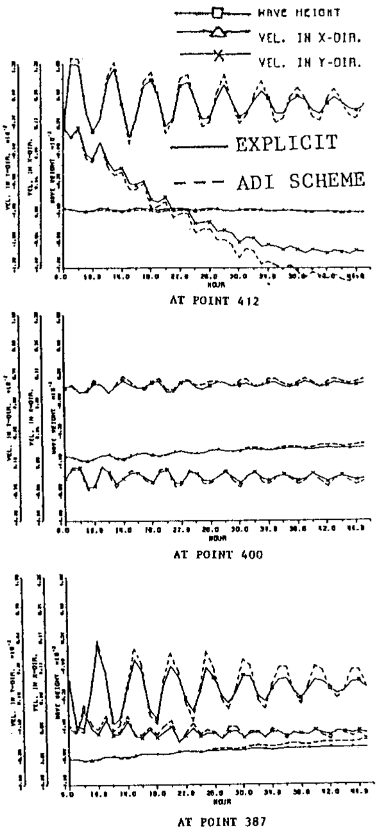

Fig.2 Wave height and velocities at different points in reservoirs

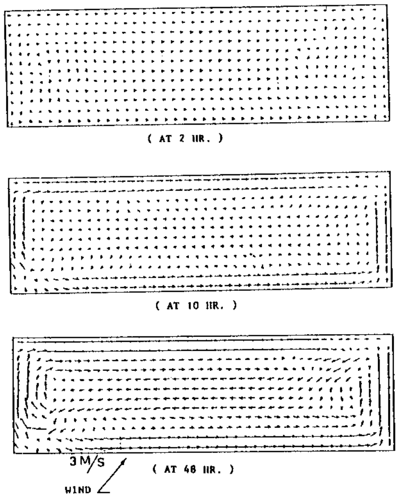

Fig.4 Velocity pattern in ADI scheme

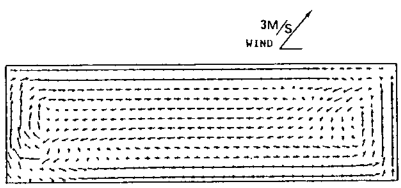

Fig.6 Velocity pattern without convective term in momentum equations in ADI scheme at 48 hrs.

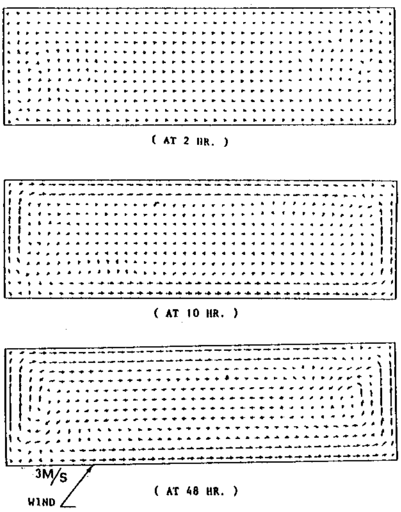

Fig.3 Velocity pattern in explicit scheme

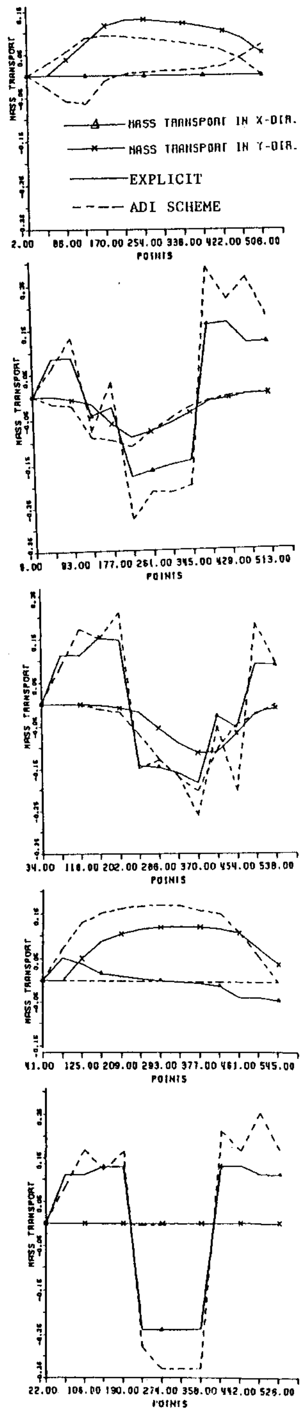

Fig.5 Mass transport

4. REFERENCES:

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