Chapter 28

Structure and discharge test cases

28.1 Introduction

Three test case have been implemented to test the performance and applicability of the structures and discharges modules.

drythin Simulates the tidal flows around obstacles, either represented by a block of dry cells or a series of thin dams within an open channel.

weirbar A series of experiments are defined simulating the tidal flows over weirs and barriers within an open channel.

discharges The experiments are designed to test the various options of the discharge module.

28.2 Test case *drythin*

28.2.1 Model setup

The model domain consists of an open channel with open boundaries at either end and a uniform water depth of 10 m. The channel has a length of 10 km and a width of 5 km. A S_2-tidal flow is imposed at the western boundary with an amplitude of 2 m whereas a zero gradient Riemann condition is taken at the eastern boundary. Horizontal resolution is set to 100 m and 10 levels are taken in the vertical. Two types of obstacles are defined in the channel (see below). The simulations are performed for four tidal cycles.

28.2.2 Experiments and output parameters

Two experiments are defined

***A* :** A square block of dry cells with a size of 2km is defined in the middle of the channel (see Figure 28.1).

***B* :** A series of 7 thin dams is defined in the cross-channel direction. The dams have a length of 1 km and are separated at a distance of 1 km (see Figure 28.2).

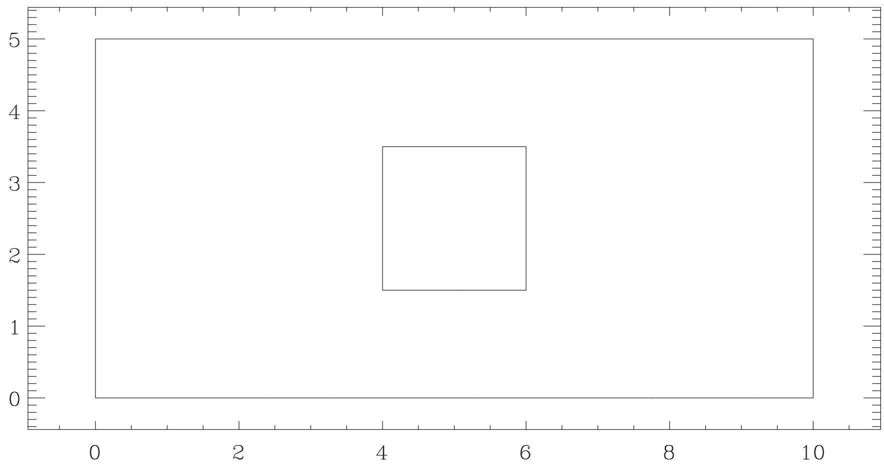

Figure 28.1: Test case ***drythin***. Model domain for the dry cells experiment.

The following output test parameters are defined:

ekin	Volume integrated kinetic energy (10^9J).
epot	Volume integrated potential energy (10^9J).
edissip	Volume integrated energy dissipation (10^3W).
enstr0d	Volume integrated energy enstrophy (m^3/s^2).

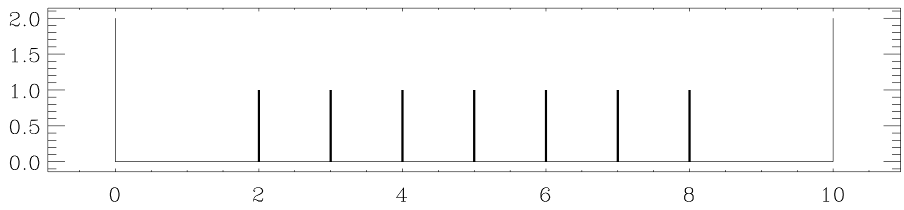

Figure 28.2: Test case ***drythin***. Model domain for the thin dams experiment.

uvelmax Maximum value of the u-current (cm/s).

uvelmin Minimum value of the u-current (cm/s).

vvelmax Maximum value of the v-current (cm/s).

vvelmin Minimum value of the v-current (cm/s).

wphysmax Maximum value of the physical vertical current (mm/s).

wphysmin Minimum value of the physical vertical current (mm/s).

28.2.3 Results

Figures 28.3 and 28.4 display the surface currents for the dry cells, respectively the thin dams experiments and the last tidal cycle. In the dry cells experiment ***A*** the flow converges along the alongchannel boundaries of the obstacle. This is compensated by a flow divergence at the donwstream cross-channel boundaries. In the thin dams experiment ***B*** the tidal current slightly

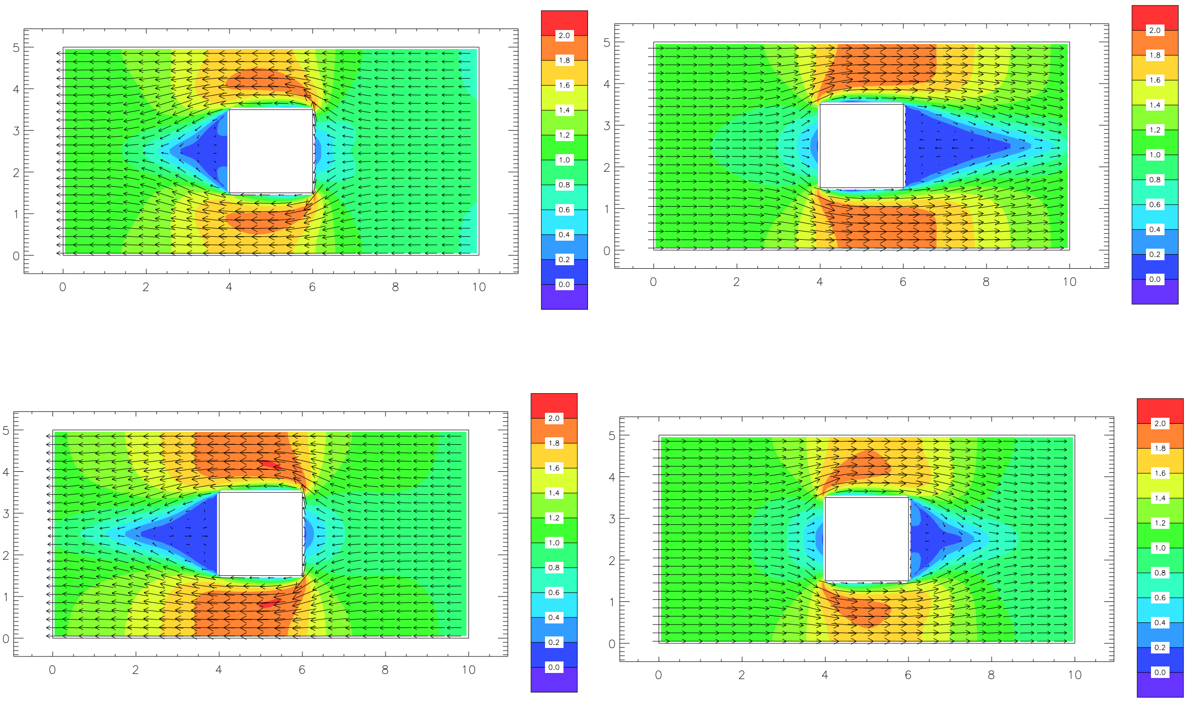

Figure 28.3: Test case ***drythin***. Time series (at 3 hours intervals) of the surface currents during the last tidal cycle and the dry cells experiment.

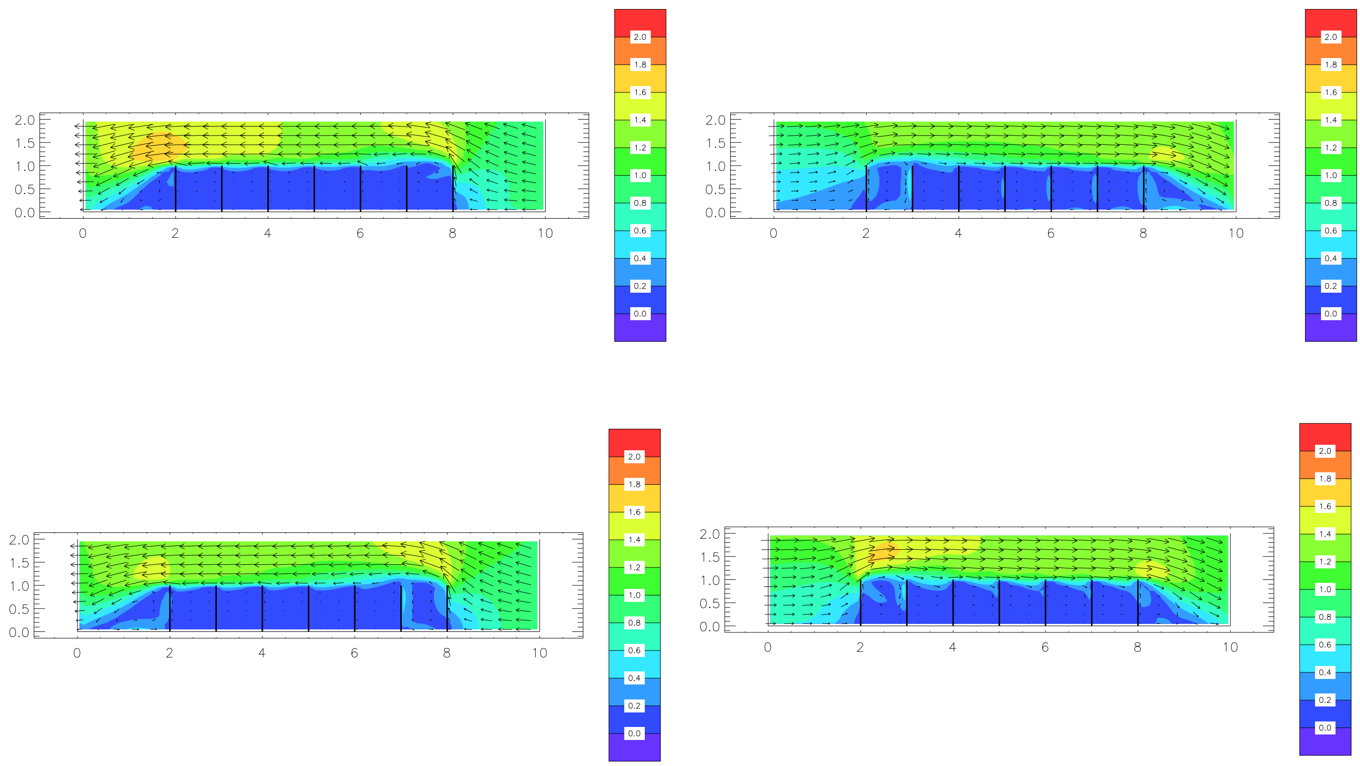

Figure 28.4: Test case ***drythin***. Time series (at 3 hours intervals) of the surface currents during the last tidal cycle and the thin dams experiment.

deflects into the area between the two most western dams during flood tide. The same occurs during ebb tide, now into the area between the two most eastern thin dams.

28.3 Test case *weirbar*

28.3.1 Model setup

Five experiments are conducted to demonstrate the implementation of weirs and barriers in COHERENS. Similar to the ***drythin*** test, the simulations are conducted in a open channel using the same tidal setup and bathymetry. Horizontal grid spacing is 100 m while 100 uniform levels are selected in the vertical. Simulations are performed for two tidal cycles.

28.3.2 Experiments and output parameters

The following experiments are defined:

A : Simulation is performed in 2DV (without cross-channel variation) and 2-D (depth-integrated) mode. A single weir of height $h_{cr} = 9$ m is defined in the centre of the channel.

B : As experiment ***A*** now in 3-D mode and $h_{cr} = 8$ m.

C : As experiment ***B*** now adding an orifice below the crest. Orifice width and sill height over the bed are set to $O_w = 2$ m and $O_h = 1$ m.

D : As experiment ***B*** with $h_{cr} = 15$ m (to prevent inundation of the weir crest), $O_w = 1$ m, $O_h = 8.5$ m.

E : A series of 7 parallel weirs are defined in the cross-channel direction with the heads located on the southern (solid) boundary. The weirs are separated at a disctance of 1 km and have a length of 500 m. The heights of the crests, from West to East, are given by 9, 8, 7, 6, 7, 8, 9 m. This run is conducted in full 3-D (including cross-channel variation).

Discharge coeeficient C_{st} for weirs, C_e for orifices and the modular limit m are set to respectively 0.9 and 0.04 $m^{1/2}$/s, and 0.7.

The following output test parameters are defined:

wdeptot Total water depth at each weir location (m).

wmean Depth-mean current at each weir location (m/s).

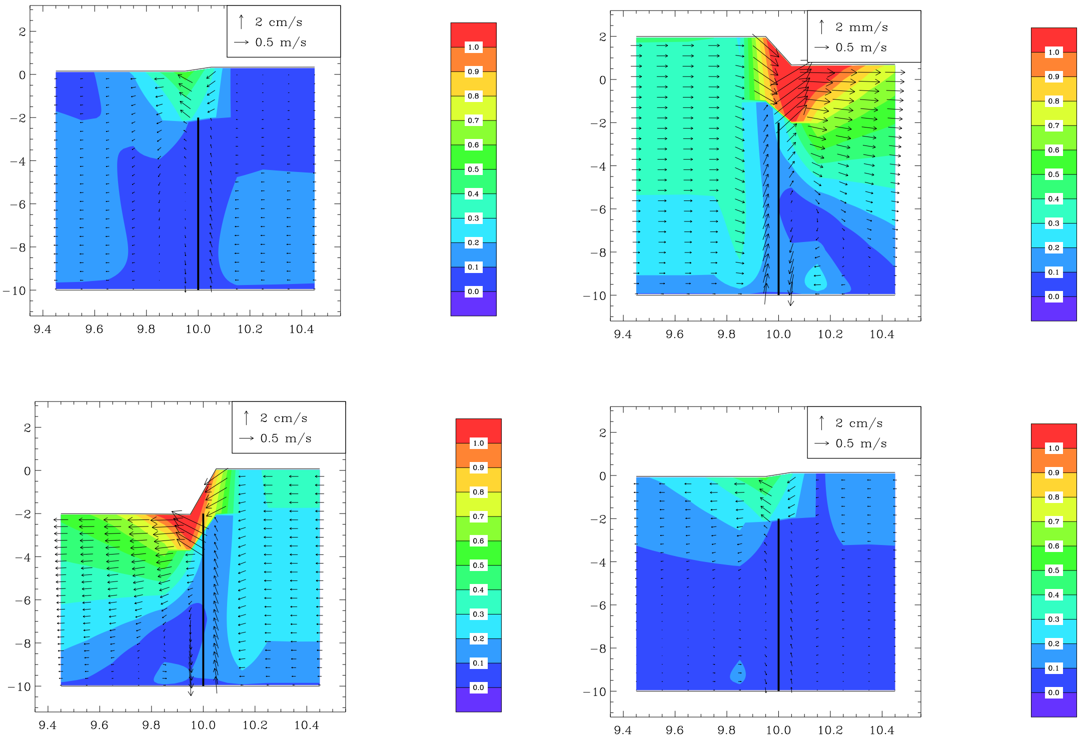

Figure 28.5: Test case ***weirbar***. Time series (at 3 hours intervals, counter-clockwise starting from the upper left) of the current field at a section in the middle of the channel during the last tidal cycle and experiment ***B***. Contours represent current magnitude.

eloss	Energy loss at each weir location (m^2/s^2).
uvelmax	Maximum value of the u-current (cm/s).
uvelmin	Minimum value of the u-current (cm/s).
vvelmax	Maximum value of the v-current (cm/s) for experiment ***E***.
vvelmin	Minimum value of the v-current (cm/s) for experiment ***E***.
wphysmax	Maximum value of the physical vertical current (mm/s).
wphysmin	Minimum value of the physical vertical current (mm/s).

28.3.3 Results

Time series of currents and current magnitude are shown in Figures 28.5)–28.8 for all experiments and a along channel transect. Surface distributions

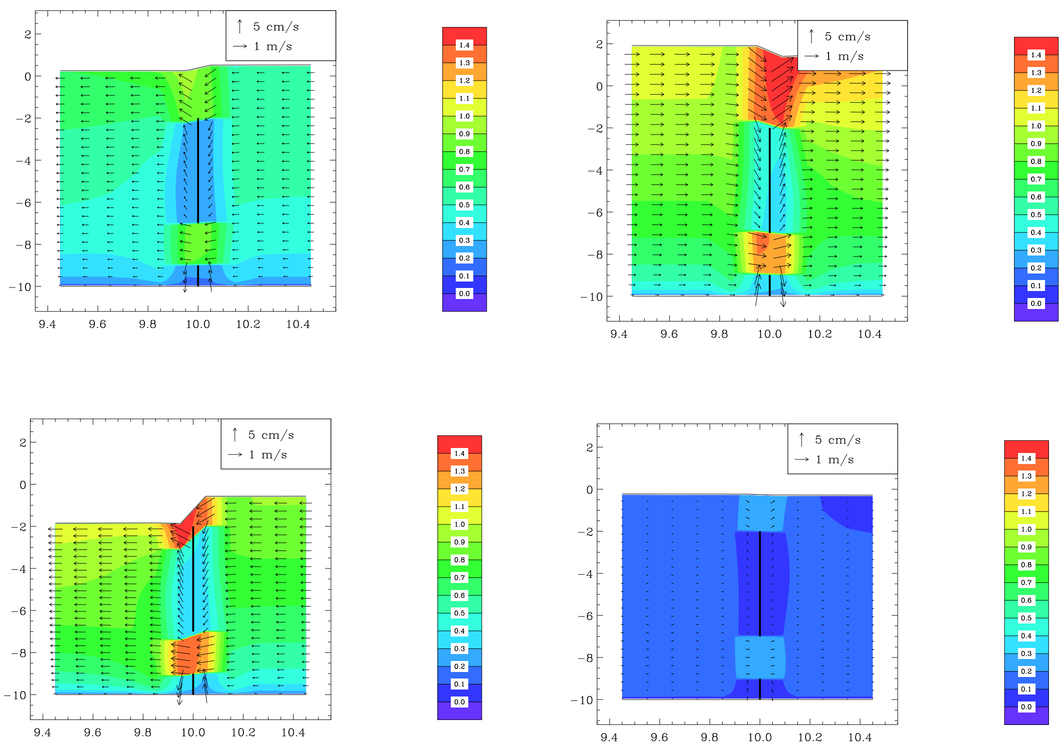

Figure 28.6: Test case ***weirbar***. Time series (at 3 hours intervals, counter-clockwise starting from the upper left) of the current field at a section in the middle of the channel during the last tidal cycle and experiment ***C***. Contours represent current magnitude.

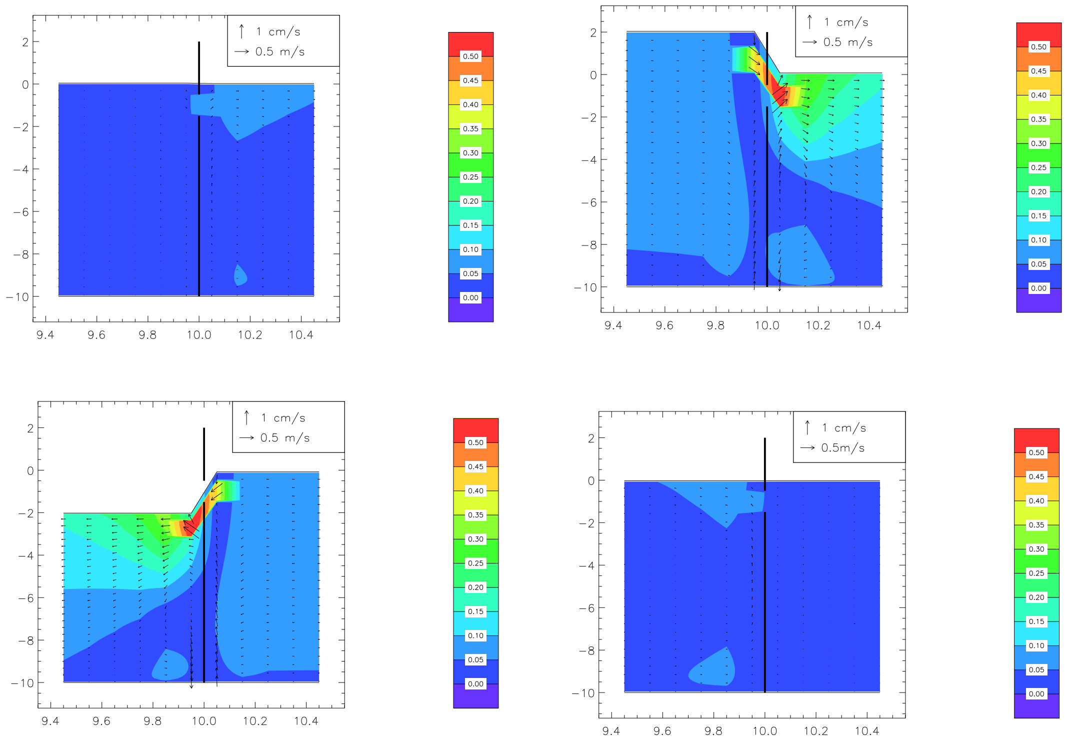

Figure 28.7: Test case ***weirbar***. Time series (at 3 hours intervals, counter-clockwise starting from the upper left) of the current field at a section in the middle of the channel during the last tidal cycle and experiment ***D***. Contours represent current magnitude.

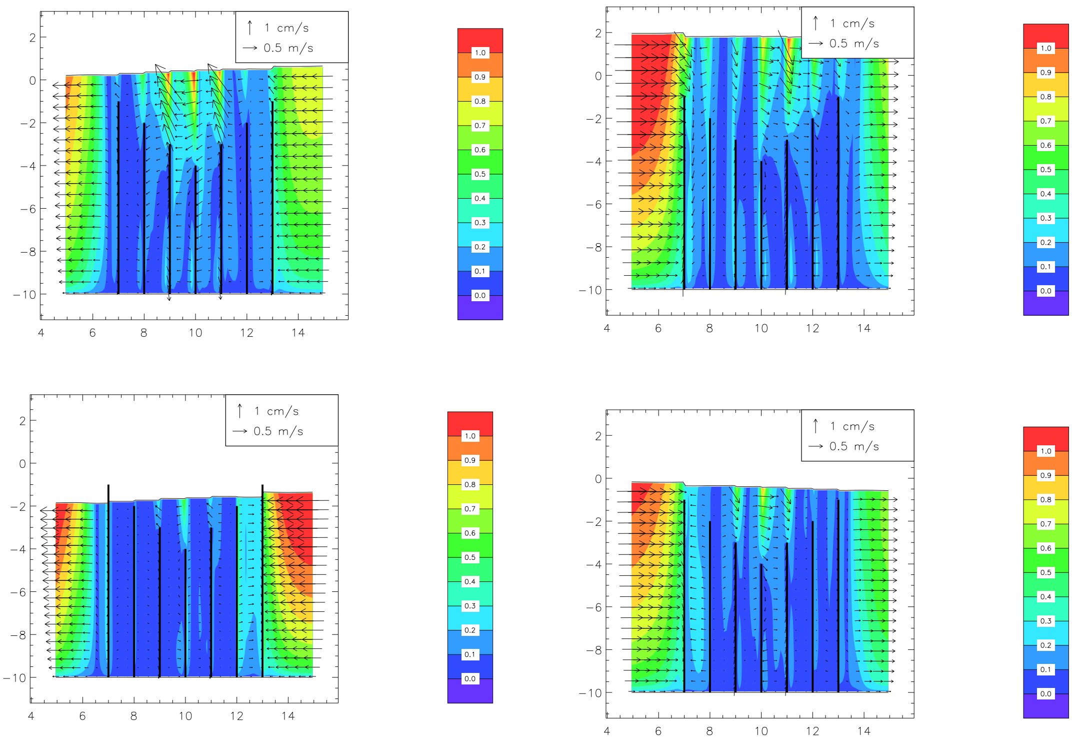

Figure 28.8: Test case ***weirbar***. Time series (at 3 hours intervals, counter-clockwise starting from the upper left) of the current field along a vertical transect in the alongshore direction at 250 m from the coast, during the last tidal cycle and experiment ***E***. Contours represent current magnitude.

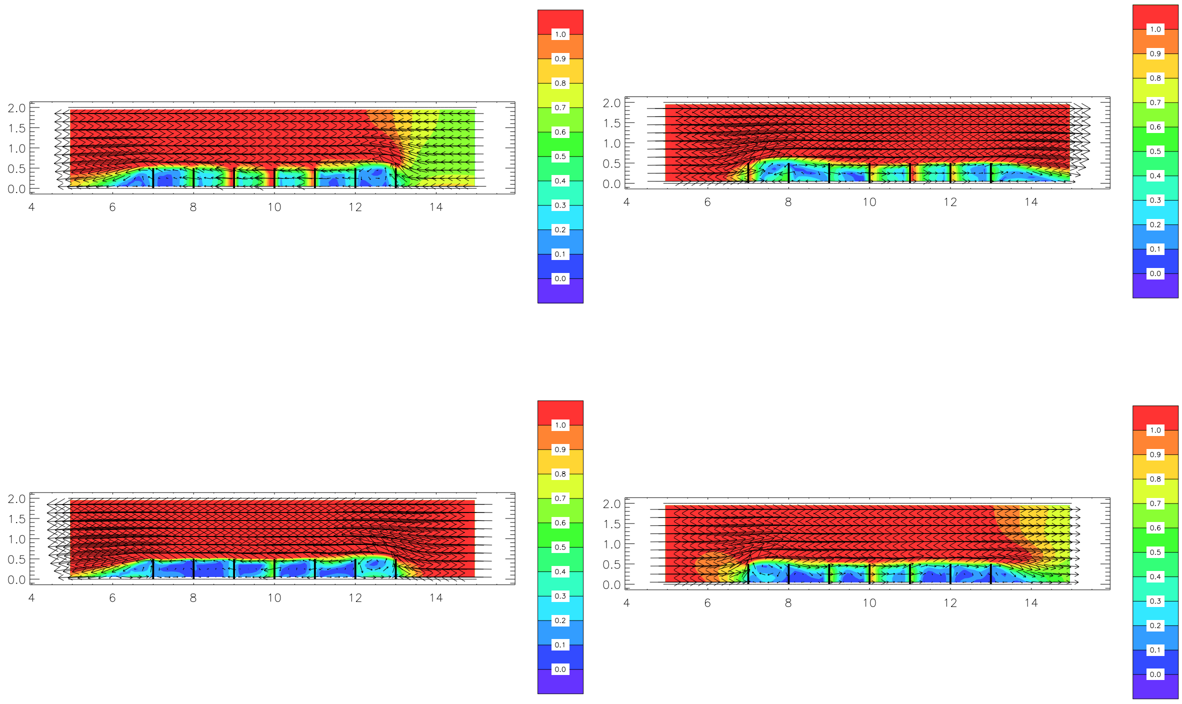

Figure 28.9: Test case ***weirbar***. Time series (at 3 hours intervals, counter-clockwise starting from the upper left) of the surface current field during the last tidal cycle and experiment ***E***. Contours represent current magnitude.

for experiment ***E*** are shown in Figure 28.9.

The following observations are made.

- Energy losses above the weir crest create a strong gradient of the current during slack tide when the tidal current is maximal. Blocking of the flow below the crest generates in turn downwelling at the upstream side and upwelling on the downstream side of the structure. Note also the strong downstream slope of the surface level above the crest which is created by energy loss and application of the upwind scheme 6.16 which determines the water depth at the weir location.

- A similar flow pattern is observed in case of an orifice flow in experiments ***C*** and ***D*** (see Figures 28.6 and 28.7).

- The multi-weir case of experiment ***E*** shows a more smoothened pattern both for the flow as for the surface slope. This indicates that the energy loss is now spread over the different weir crests. In the upper (northern) part of the channel the flow is no longer impeded by the structures, except near the weir tips where the flow deflects towards the zones between neighbouring weirs where it generates small vortex cells varying with the tide.

28.4 Test case *discharges*

28.4.1 Model setup

A simple test case has been designed to test the various options implemented in the discharge module. The model domain consists of a squared basin with a size of 10 km and closed boundaries. Four discharge points are defined in the middle part of the domain and taken sufficiently away from the domain boundaries (see Figure 28.10). A uniform water depth of 20 m is taken. The initial salinity field has a uniform value of 35.01 PSU. The experiments are set up without wind, tides or density flow so that the currents are only generated by the discharged water volume.

The model is run with 200 grid points (100 m resolution) in each horizontal direction and 20 (uniform) levels in the vertical, a 2-D time step of 2.5 s and for a period of 5 minutes.

28.4.2 Experiments and output parameters

The following experiments are defined:

A : A continous discharge of 100 m^3/s is taken at the four locations and uniformly spread over all horizontal directions so that there is no momentum discharge. Each location has a different discharge location (as indicated in Figure 28.10): uniform over the whole vertical, at the bottom cell, at the surface cell and at 5 m from the sea bed. The discharged water mass has the same salinity concentration as the ambient water.

B : The same as experiment ***A***, except that the discharge has an imposed direction (shown by the arrows in Figure 28.10). The area of discharge is set to 10 m^2.

C : The same as experiment ***B***, except that the discharge points move with a speed of 16.7 m/s in the same direction as the discharges and all discharges take place at the surface cell.

D : The same as experiment ***C***, except that discharge rate increases linearly from 50 m^3 initaially to 150 m^3 at the end of the simulation.

A series of output test parameters are defined:

dvolume	Fractional change of total water volume in %, defined as the ratio of the volume increase to the total initial volume of the basin multiplied by 100.
balance	Fractional difference between the water volume and the amount of discharged volume in %, defined as the ratio of the volume increase minus the discharged volume to the total initial volume multiplied by 100.
ekin	Volume integrated kinetic energy (10^3J).
epot	Volume integrated potential energy (10^3J).
zetad	Surface elevation (m) at each discharge location.
velmagd	Current magnitude (m/s) at each discharge location.
veldird	Current direction (degrees) at each discharge location.

28.4.3 Results

A discharge front is created at the initial time which spreads away from the source with the gravity speed $\sqrt{gh}$=14 m/s. The results, plotted in Figures 28.11–28.13, can be summarised as follows

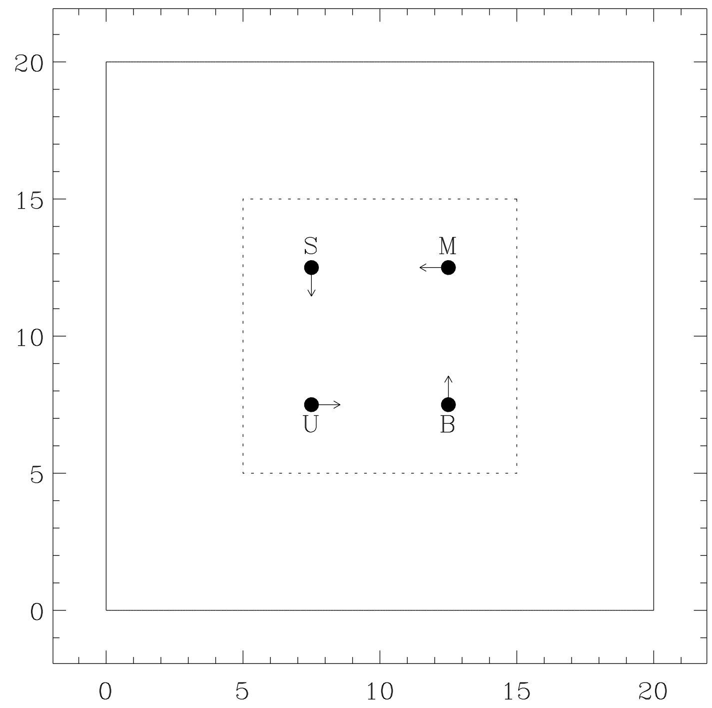

Figure 28.10: Test case ***discharges***. Model domain for the discharge experiments. Solid circles indicate the (initial) discharge positions. The letter deontes the vertical location for the first two experiments: uniform ('U'), bottom cell ('B'), surface cell ('S'), at 5 m above the sea bed ('M'). The arrows locate the direction of the discharge (except experiment ***A***) and the displacement direction of the discharges (experiments ***C*** and ***D***). The dashed lines delineate the area used in the time series plots.

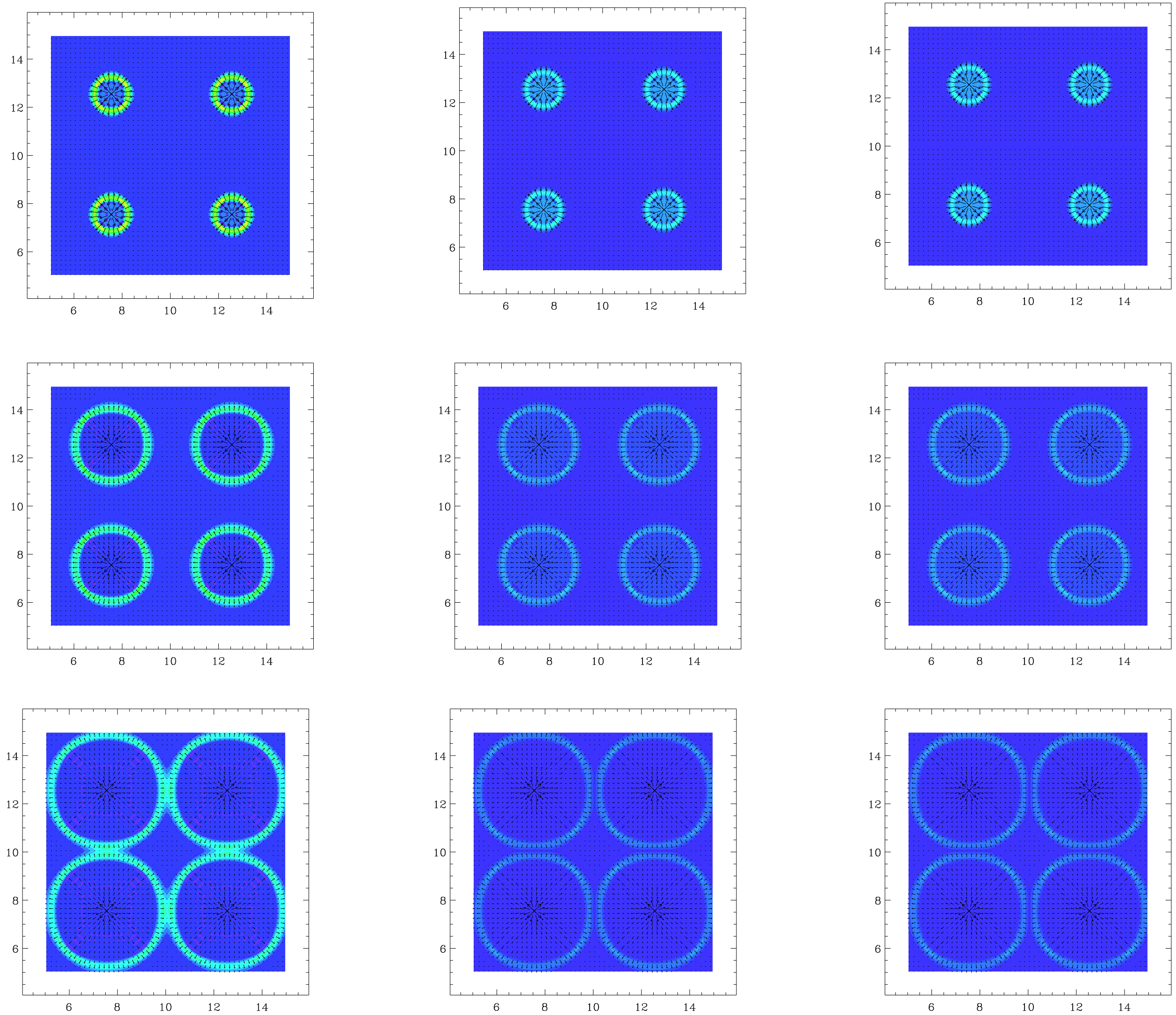

Figure 28.11: Test case ***discharges***. Time series of surface elevation, and depth mean, surface and bottom currents]. Test case ***discharges***. Horizontal distribution of depth mean current and surface elevation (left column), surface current and magnitude (middle column), bottom current and magnitude (right column) after 1 (upper row), 2 (middle row), 3 minutes (bottom row) of simulation.

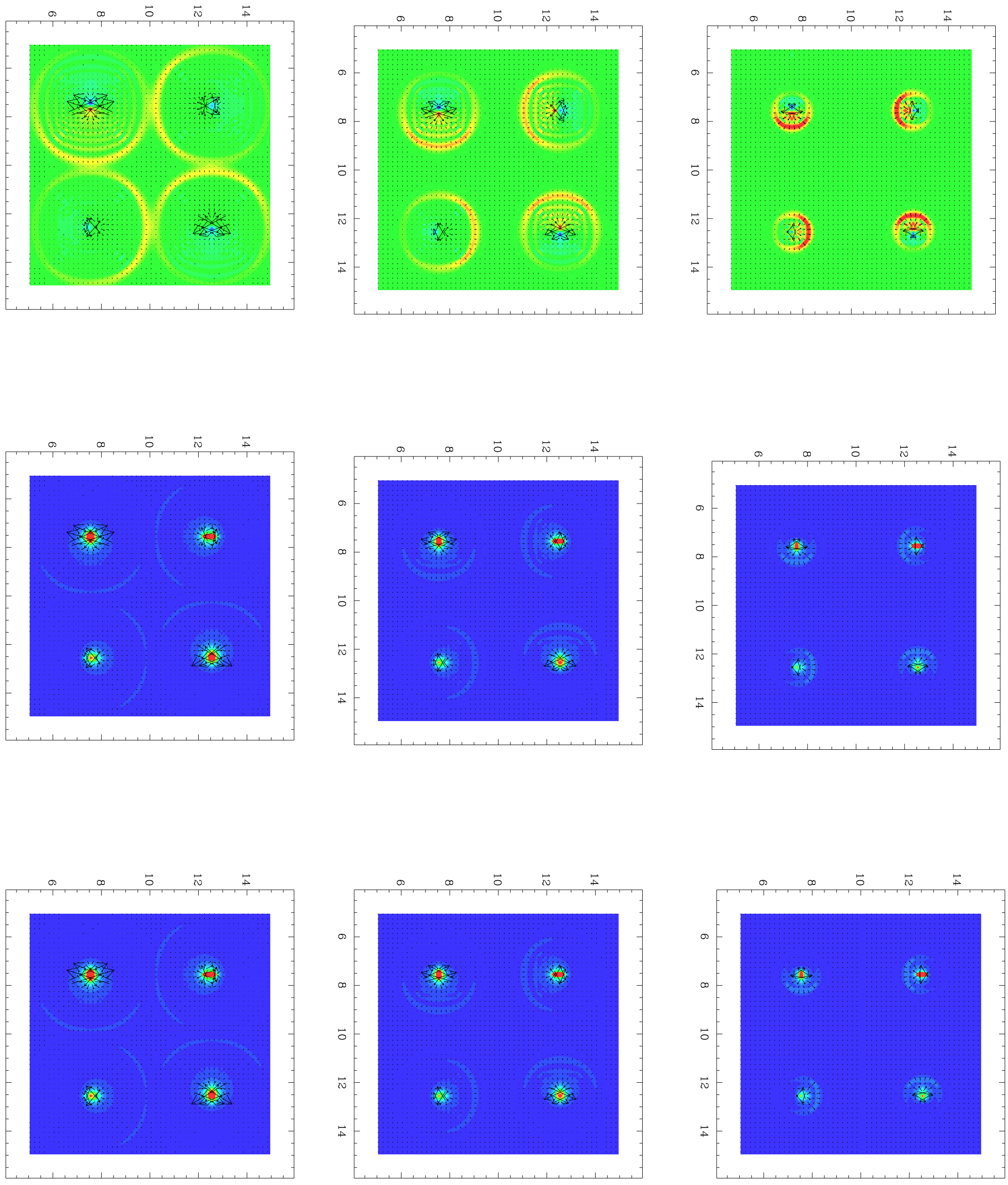

Figure 28.12: Test case ***discharges***. As Figure 28.11 now for experiment ***B***.

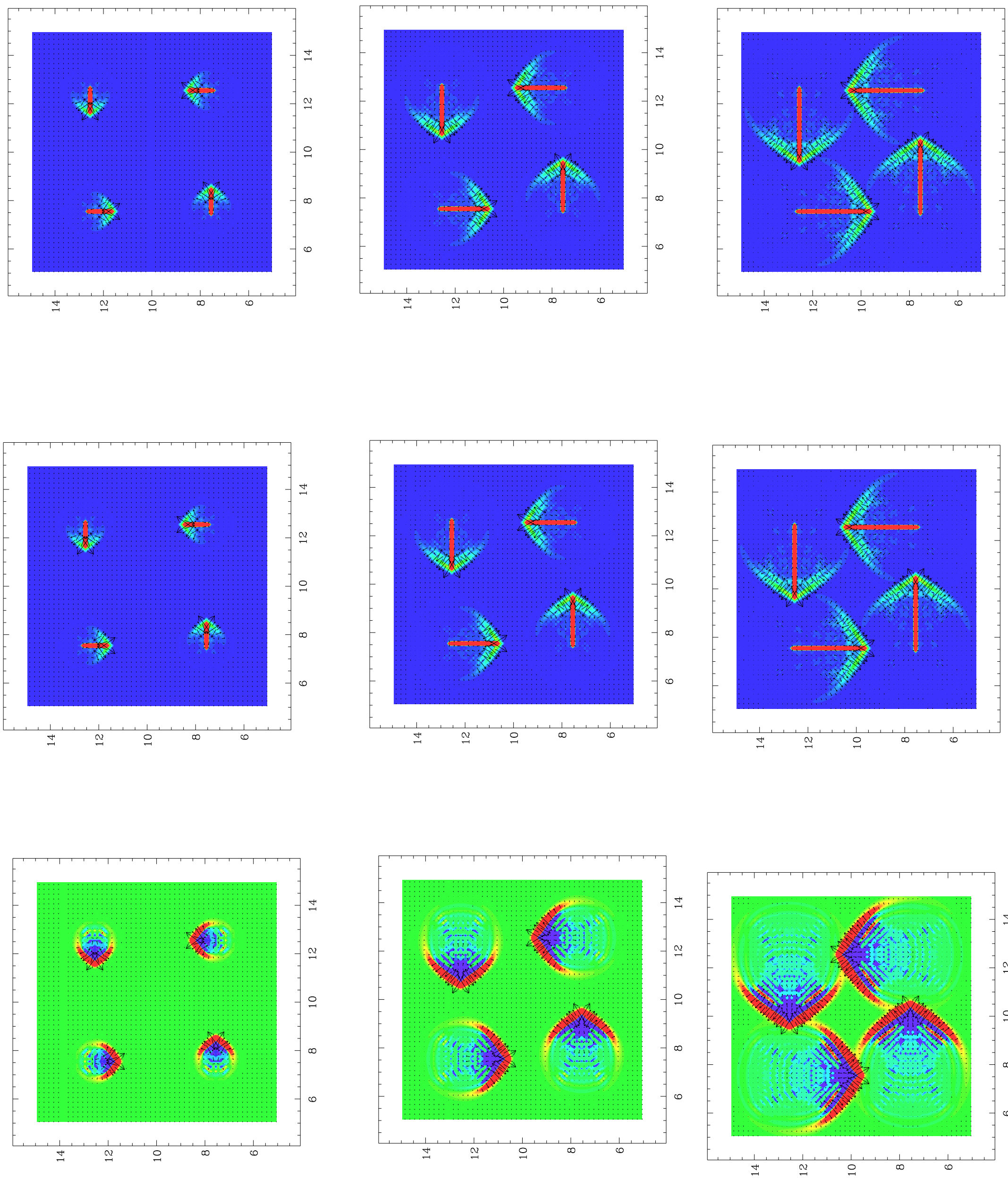

Figure 28.13: Test case ***discharges***. As Figure 28.11 now for experiment ***C***.

- Without directional discharge the wave front spreads radially outwards with an amplitude which decreases in time by volume conservation. This spreading takes place uniformly over all vertical levels.

- Even for a directional discharge, the front still expands radially with the same speed. Main difference is a higher surface current in the direction of the discharge and lower values on the opposite side. Contrary to the previous case currents are weaker for a discharge at the bottom due to bottom friction.

- When the discharge locations move in the direction of the discharge, a much different picture emerges. The upstream front now takes the from of two linearly shaped fronts located symmetrically along the line of displacement. Surface displacements along the upstream side of the front are much larger than previous which is compensated by a negative displacement behind the front edge due to mass convervation. Since there is no cross-stream advection, a uniform current is created along the track of the discharge locations.

- Results for experiment ***D*** (varying discharge) are not manifestly different from the previous case (experiment ***C***) and therefore not shown.