Nile Basin Capacity Building Network

River morphology Research Cluster

Specialized Training Course On Modelling For River Engineering

Applications On : SSIIM Program

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Outline of Presentation
Grid Generation

1. General
2. Grid terms.
3. Classification.
4. Structured Grid Generation (SSIIM1).
5. Unstructured Grid Generation (SSIIM2).
6. Transient Grid Changes.
7. Changes in Grid Cell Shapes.
8. Nested Grids.
9. Grid Accuracy
10. Advice On How To Shape The Cells.

1. General

One of the main concepts behind CFD is to divide the water geometry into small cells. Equations for velocity, turbulence, water quality, sediment concentration etc. are then solved for each cell.

The cells are obtained by dividing the water body into a grid. The composition and quality of the grid is important for the accuracy and stability of the solution of the equations.

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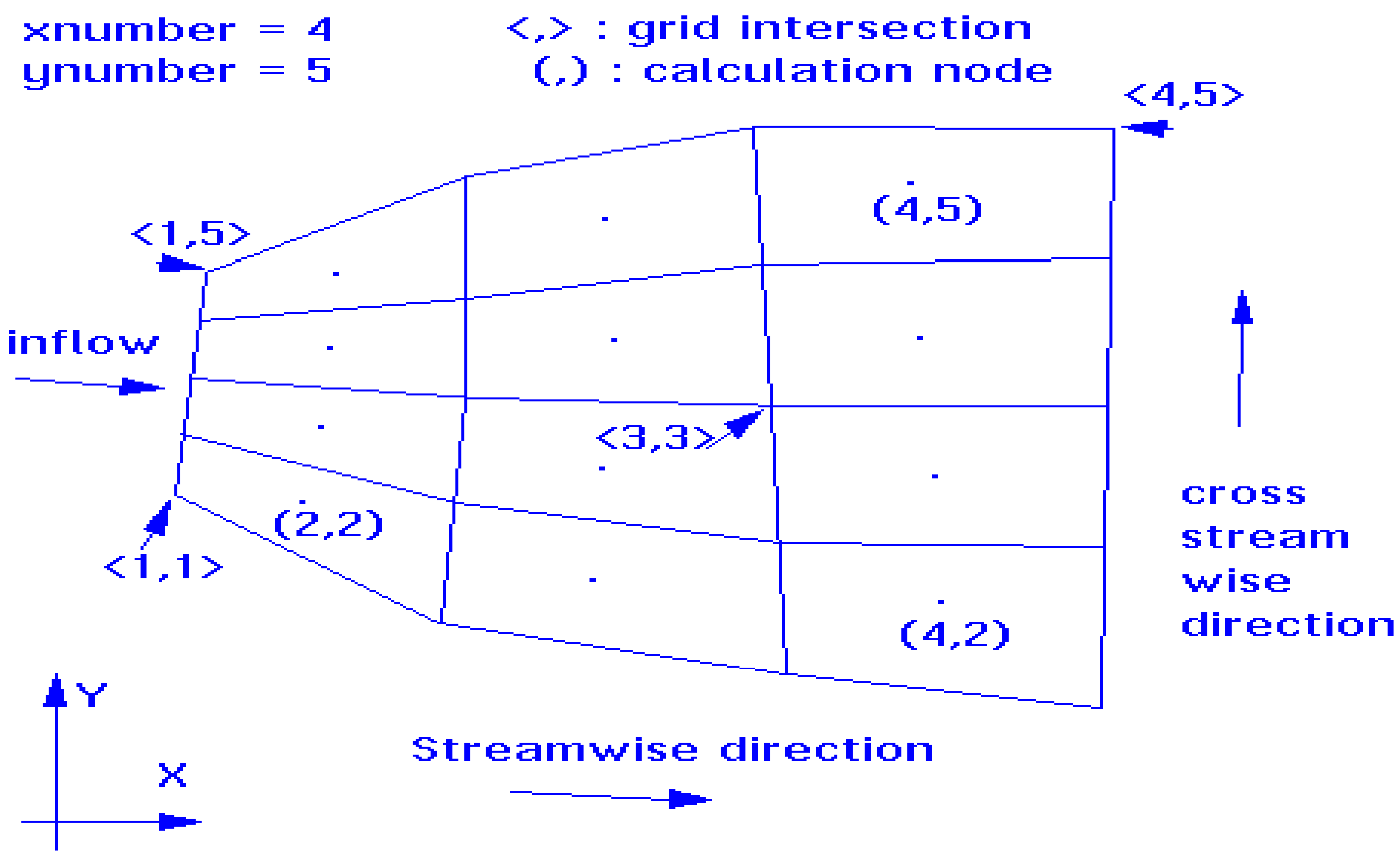
2. Grid Terms



xnumber = 4
ynumber = 5
<,> : grid intersection
(,) : calculation node
<4,5>
(4,5)
<1,5>
inflow
<3,3>
(2,2)
<1,1>
(4,2)
cross
stream
wise
direction
Y
X
Streamwise direction

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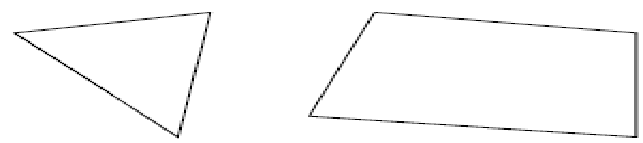
3. Classifications

Grids can be classified according to several characteristics:

1- Shape
2- Orthogonality
3- Structure
4- Blocks
5- Position of variable
6- Grid movements(staggered)

3.1. Shape

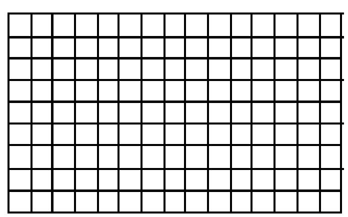
The shape of the cells is usually triangular or quadrilateral in 2D.



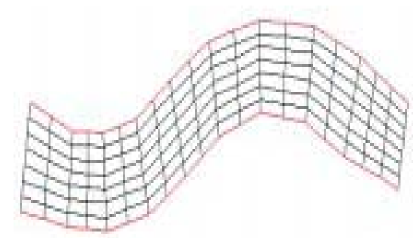
In 3D, the cells are tetrahedral (four sides) or hexahedral(six sides).

3.2.The Orthognality

The orthogonality of the grid is determined by the angle between crossing grid lines. If the angle is 90 degrees, the grid is orthogonal. If it is different from 90 degrees, the grid is non-orthogonal.



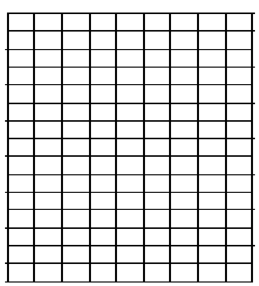
Orthogonal grid



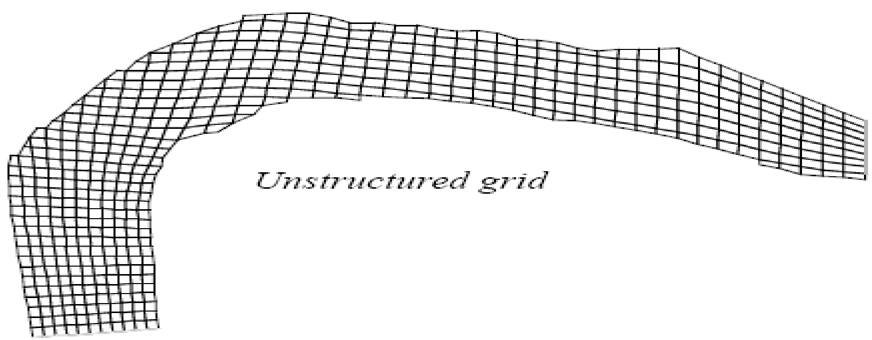
Non-orthogonal grid

3.3. Structure

Often a structured grid is used in finite volume methods and an unstructured grid is used in finite element method. In a structured grid it is possible to make a two-dimensional array indexing the grid cells. If this is not possible, the grid is unstructured.



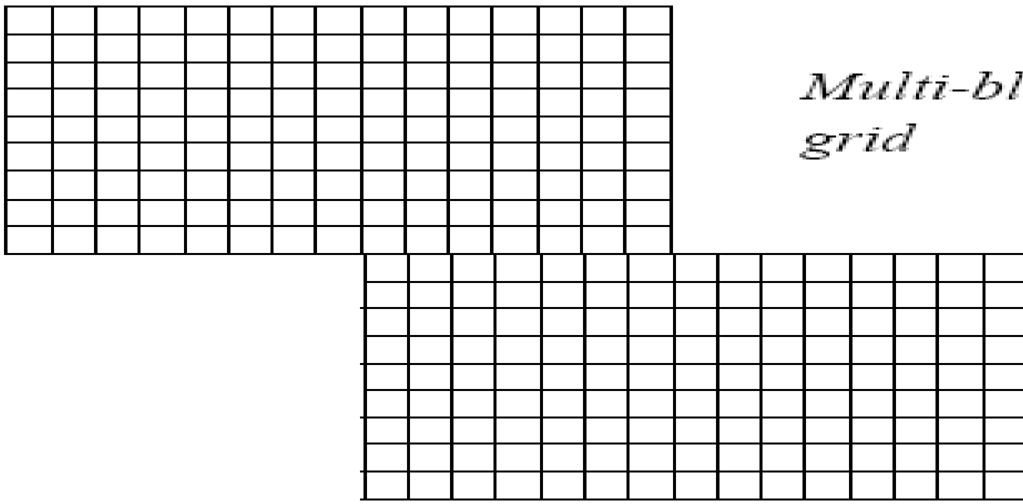
Structured grid



Unstructured grid

3.4.Blocks

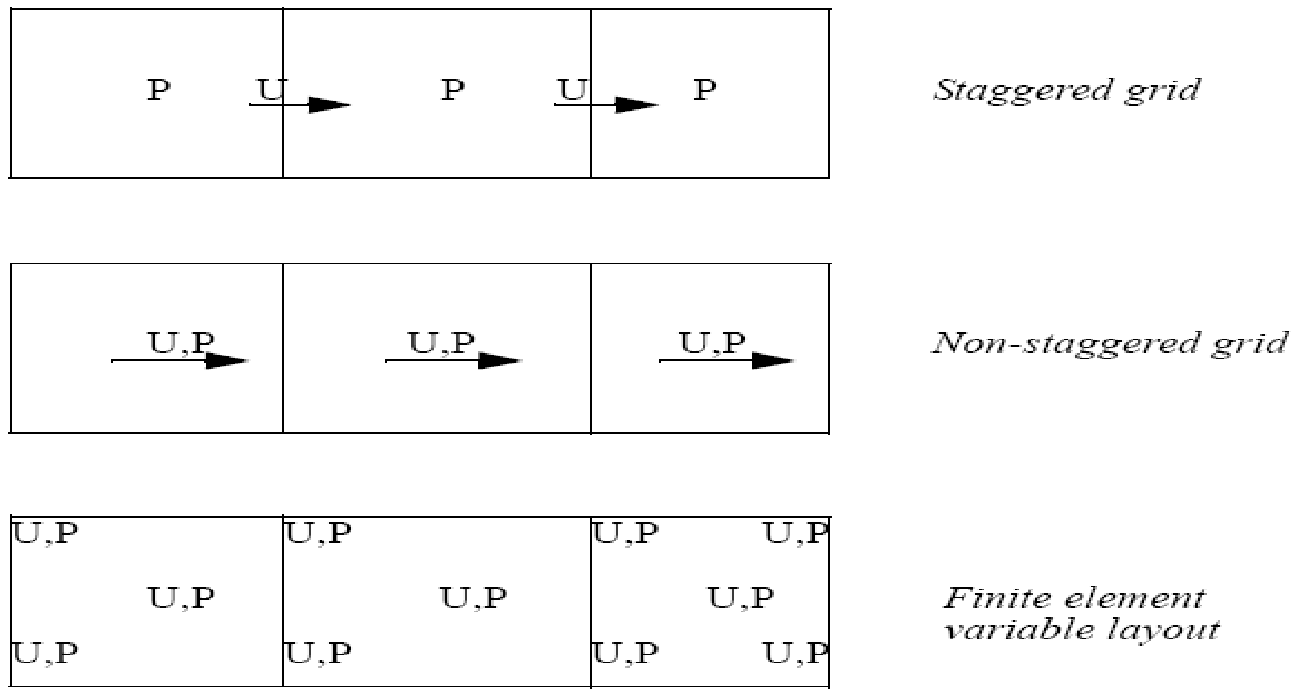
A multi-block grid is made from several structured grids as shown below.



Multi-block grid

3.5. Position of variables:

A non-staggered grid is used when all variables are calculated in the same location,most often the centre of each cell.



3.5. Grid movement:

An adaptive grid moves according to the calculated flow field or the physics of the problem. When the water surface or the bed moves during a time step, it is possible to make the grid move accordingly, to calculate the situation for the new geometry. Thereby time-dependent calculations of bed changes and water levels can be done.

An adaptive grid is used to model bed changes in for example sediment deposition, reservoir flushing or local scour. It is also used to model changes in the water surface when for example calculating a flood wave.

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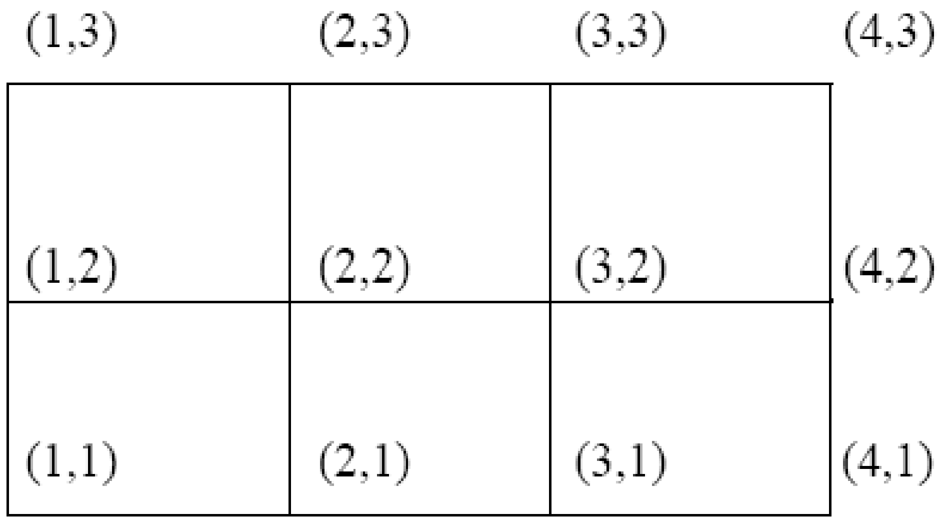
4. Structured Grid Generation (SSIIM1).

1. Structured grid numbering

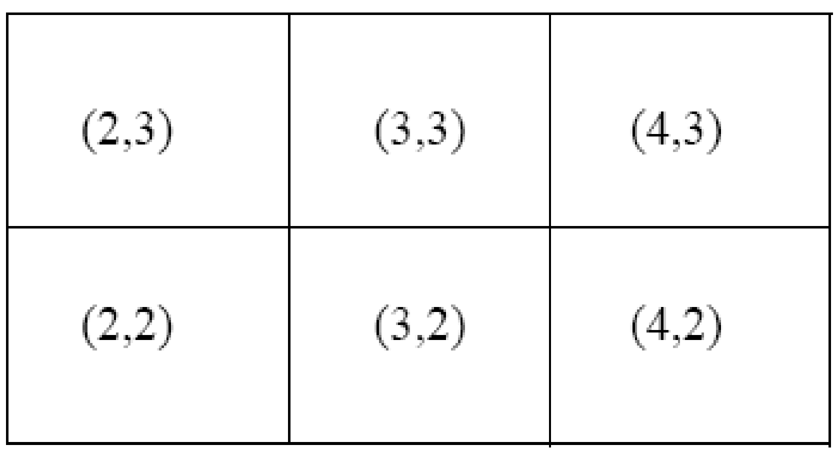
There are several ways to identify cell and grid lines in a structured grid. When using some CFD programs, it is important to know the numbering system for each particular program in order to identify the regions of inflow/outflow and outblocking procedures.

The numbering system described in the following is used by the SSIIM program. In a structured grid, there will always be one more grid line than grid cells in any given direction.

Because boundary conditions are also needed, there will be a grid cell with zero thickness at the walls. The number of this cell is1. The number of the first cell inside the grid is therefore 2.



Grid line numbering

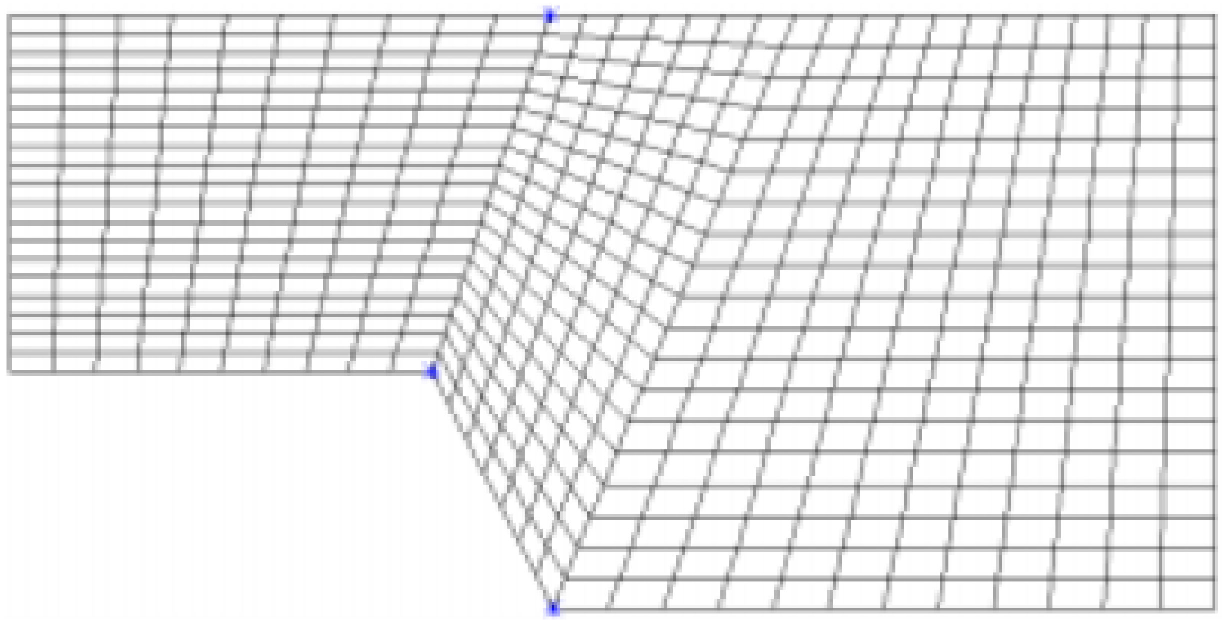


Grid cell numbering

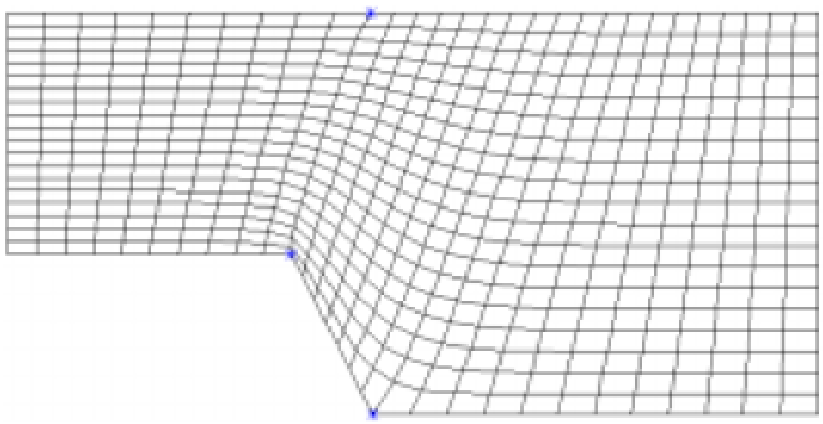
2. Transfinite and elliptic grid generation

Further there are a number of ways to create the internal points in a structured grid. The most used are: Transfinite interpolation and elliptic grid generation

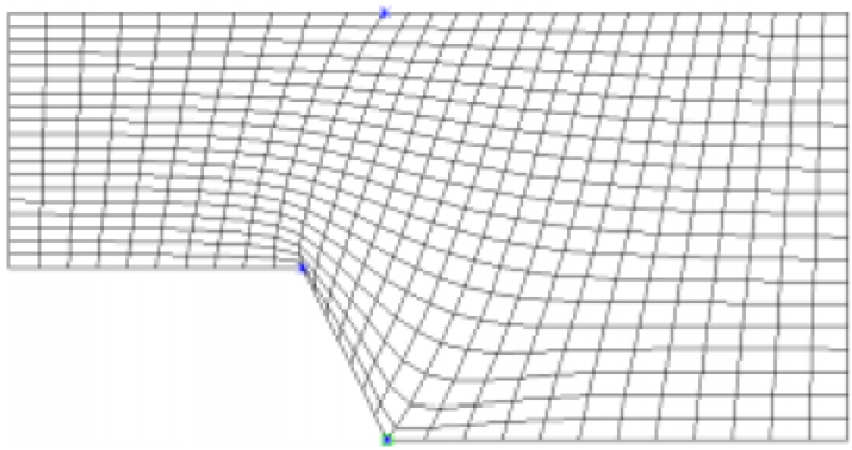
Transfinite interpolation generates straight lines in one of the grid directions



Elliptic grid generation distributes the points more smoothly



Grid obtained using elliptic generation with no attraction



Grid obtained using elliptic generation with attraction to the bottom boundary

3. Generation of structured non-orthogonal grid

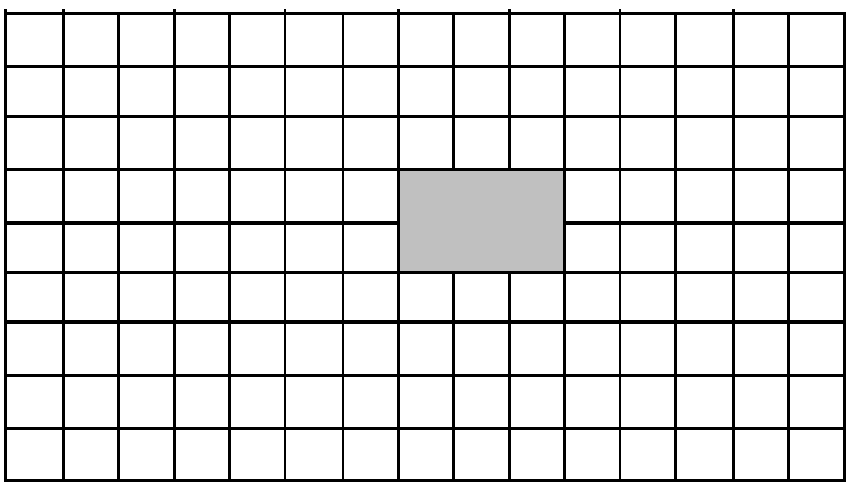
Making a good grid is a considerable part of the work for CFD calculations for complex geometries. Experience seems to be very important for this task, so the first advice is to practice making grids.

Before starting to make the grid, some information is necessary:

1. How many grid cells are available for the grid? This can be calculated from the capacity of the computer and the expected computational time.

2. Drawings of the geometry are important, where boundaries and the inflow/outflow regions are shown together with possible islands or other **outblocked** regions.

An **outblocked** region is a part of the grid where water is not allowed to flow. It can be used for making islands or obstacles in the flow. An example is given below with flow around a square obstacle:



Grid with an outblocked region of 3x2 cells

Do the rest in the class2 note if there is time

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5. Unstructured Grid Generation (SSIIM2).

In the approach used by SSIIM 2, the user generates blocks of structured grids graphically, and connects these afterwards. The process is relatively fast, and a complex grid can be generated in a couple of hours. An automatically generated unstructured grid will usually have lower qualities, so the extra work by the user is often justified.

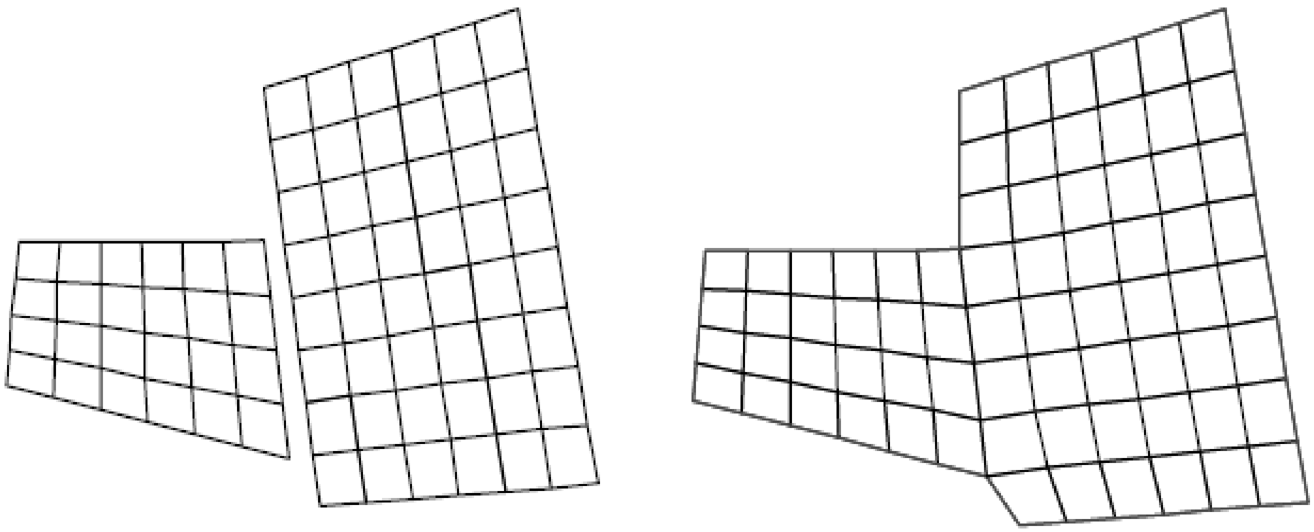
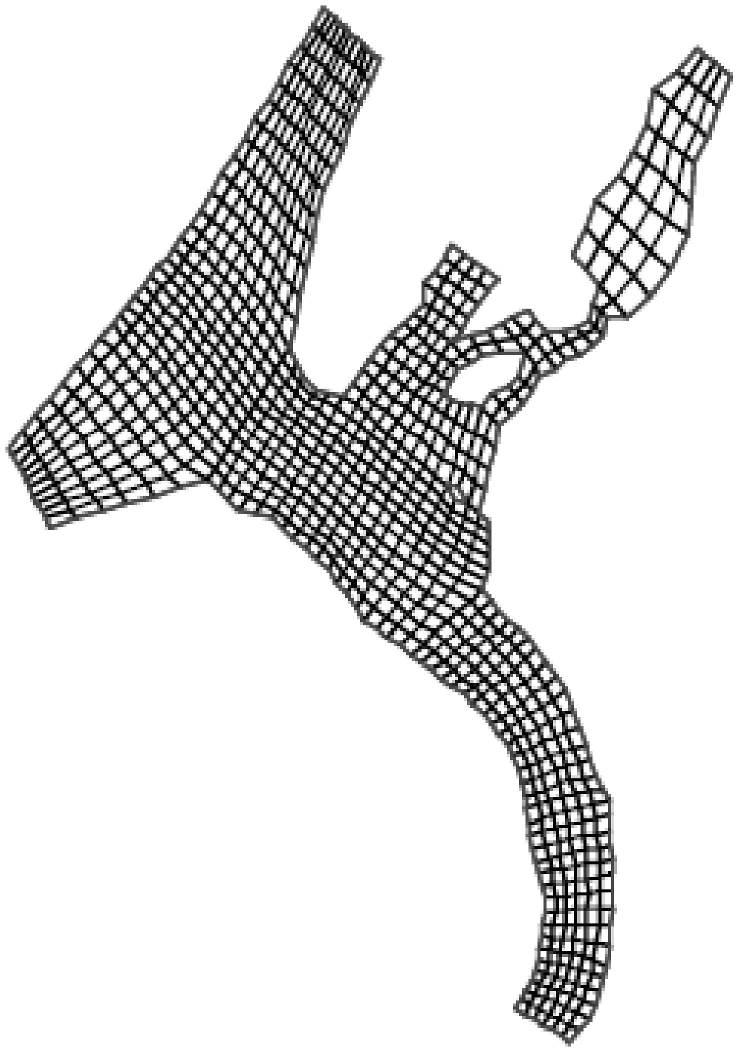


Figure 2.3.1 The left figure shows two structured blocks. These are connected on the right figure to form an unstructured grid.

Using several blocks, a relatively complex geometry can be made. An example is given below:



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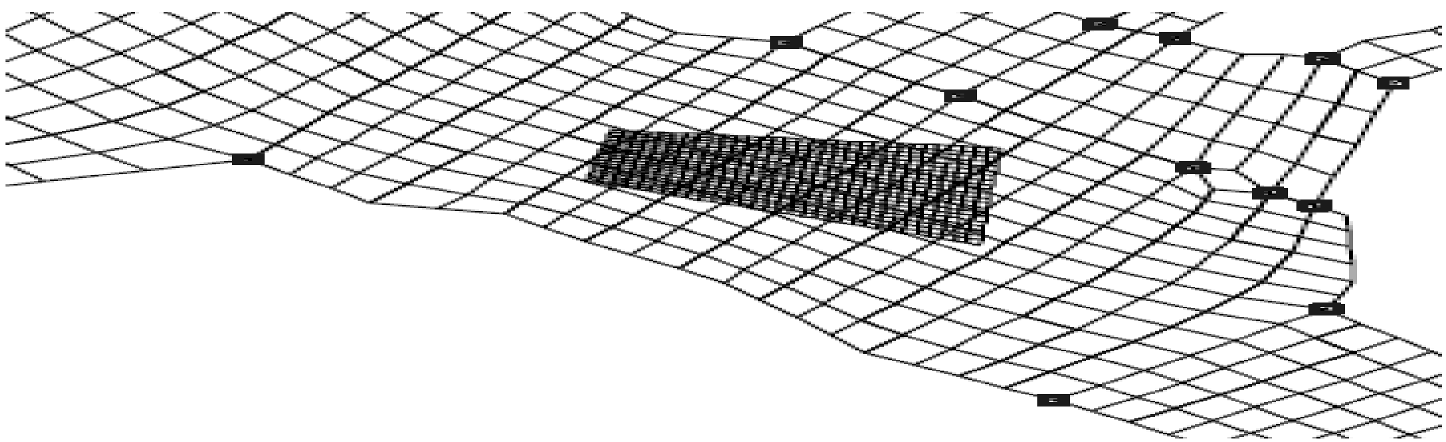
6. Nested grids

Many hydraulic phenomena involves processes at different scales. One example is pollution from point-source into a lake. The lake may have dimensions of kilometers, while the plume of the pollution may be in the orders of meters wide.

The grid of the lake may have cell sizes of the order of hundreds of meters, and can not resolve the concentration profile of the pollution. A solution is then to use a nested grid.



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7. Grid Accuracy

The accuracy and convergence of finite volume calculation depends on the quality of the grid, three grid characteristeristics are important:

(1) **Aspect ratio**

(2) **Expansions ratio**

(3) **The non-orthogonality**

9.1 Aspect Ratio

The aspect ratio and expansion ratio is described in the figure (3.4) below: The figure shows two grid cells, *A* and *B*. The lengths of the cells are Δx_A and Δx_B.

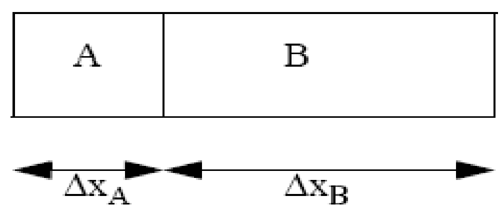

Figure (3.4) Expansion/aspect ratio

The **aspect ratio** of the grid at cell A is $\Delta x_A / \Delta y_A$.

9.2 Expansions ratio

The expansion ratio of the grid at these cells is $\Delta x_A/\Delta x_B$. The expansion ratio and the aspect ratio of a grid should not be too great, in order to avoid convergence problems and inaccuracies.

Aspect ratios of 2-3 should not be a problem if the flow direction is parallel to the longest side of the cell

9.3 The non-orthognality

The non-orthogonality of the grid line intersections is the deviation from 90 degrees. If the grid line intersection is below 45 degrees or over 135 degrees, the grid is said to be very non-orthogonal.

This is a situation one should avoid. Low non-orthogonality of the grid leads to more rapid convergence, and in some cases better accuracy.

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8. Advice On How To Shape The Cells.

1. Make the grid line intersections as perpendicular as possible. It is not advisable to have intersections with an angle of less than 45 degrees. Non-orthogonality in the grid will make the convergence slower.
2. Try to align the grid lines in the stream wise direction parallel to the velocity vectors. This will decrease false diffusion.
3. The distortion ratio should not be too great. The distortion ratio is the dimension of the grid in one direction divided by the dimension in another direction.
4. The size of a grid cell should not be too much larger than its neighbors'.

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9. The Grid Editor.

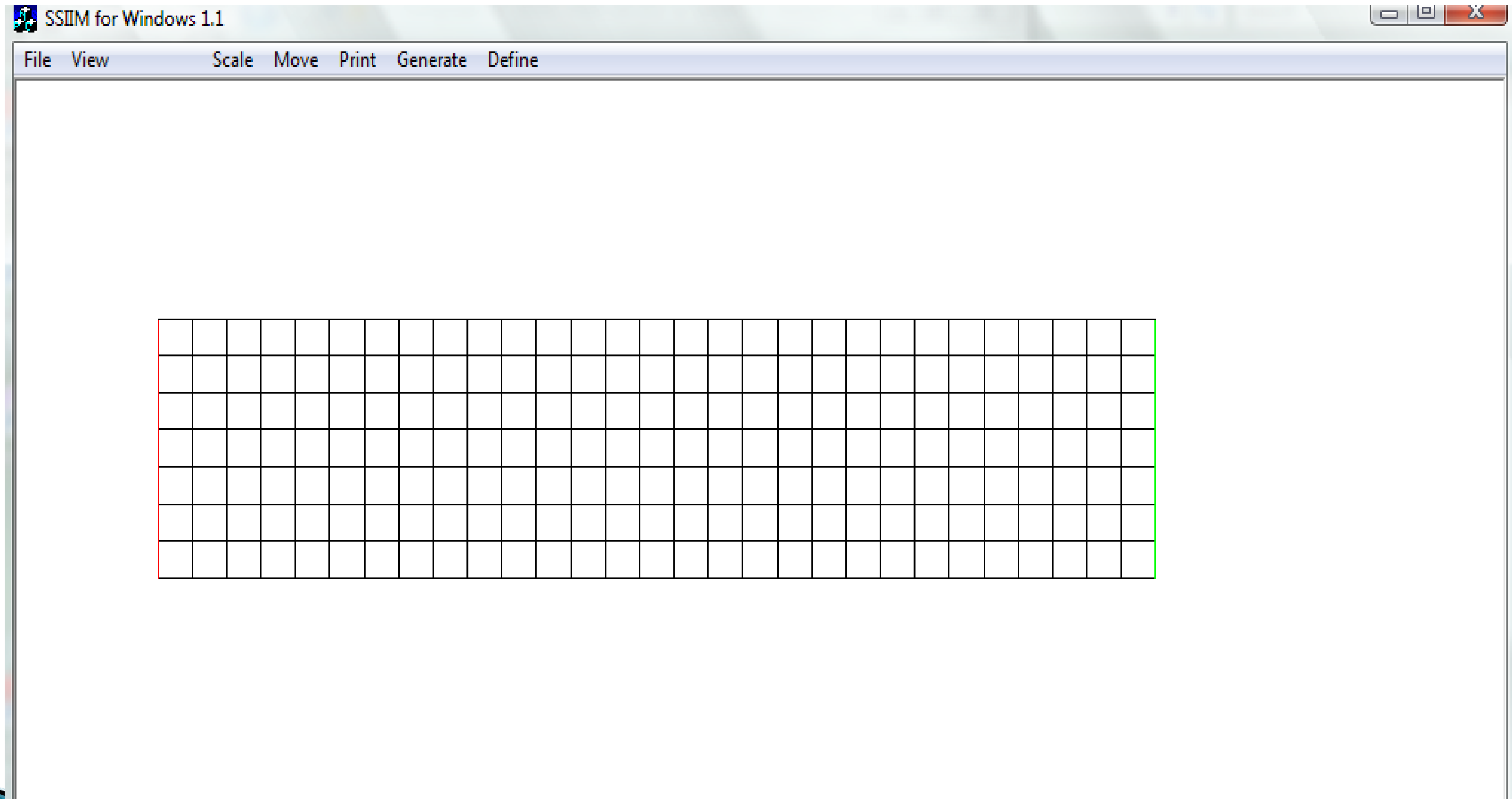
In windows version of SSIIM the Grid Editor is invoked from the View option in the main menu. The grid is seen from above.

In SSIIM 1, a structured grid is used. When starting the Grid Editor without reading a previously generated grid, a rectangular grid is shown as default. The left side of this rectangular grid is the default water inflow. The right side is the default water outflow. In the Windows version of SSIIM 1, the default inflow side is coloured red. And the default outflow side is coloured green.

When generating a grid for a natural geometry using geodata points, the inflow of water is often not on the left side, and the outflow not often on the right side. The grid therefore has to 30 be rotated initially. This is most easily done by moving the corners first, and then using the menu options Sides and Transfinite I.

The grid editor menu

The main menu of the grid editor is made up of several options with corresponding submenus.The structure of the menu depend on which version of SSIIM - OS/2 or Windows, and version 1 or 2.



View

In the Windows versions of SSIIM1, the *View option has many sub options. The Geodata points sub-option is used for displaying* the points in the *geodata file on the grid plot. The points are shown with a circle, and the* different colour indicate different vertical levels. Note that the points are read from the file, and this may take some time if the file is large.

Move/Scale

The option *Move is used to move the plot upwards, downwards or sideways. The arrow keys* can be used instead of the menu. The option *Scale is used to enlarge, shrink or distort the plot.*The keys *<Page Up> and <Page Down> can be used for scaling.*

Define

This option is used for defining different parameters. The parameters are often connected to grid intersection points. The point that was last activated by the mouse is used as default.

The first option is *Give coordinates. This gives a dialog box where the user can give numerical* values for x,y and z for a grid intersection.

The second option is *Set NoMovePoint. This invokes a mode where the user can define certain* points which will not be moved by the interpolation, called *NoMove Points.*

In NoMovePoint mode it is not possible to move the grid points with the mouse. When the user clicks on a grid intersection, a blue star emerges on the intersection as a sign that this is chosen. Up to 200 *NoMove Points can be chosen. To verify that this mode is present, the letters "Point mode, 0" is* shown on the lower part of the edit window when the *Set NoMove Point is chosen.*

The integer shows how many points you have chosen. To return to the normal mode, choose *Define and Set NoMovePoint again. It is verified that the normal mode is set because the text "Point mode" disappears. In the normal mode the user can move all points including the NoMove-Points.*

The third option is *Delete NoMovePoint. This deletes the last point set under the NoMove- Point mode.* The following four options are setting of attraction to certain points or lines in the grid. This is used by the elliptic grid generator. A dialog box emerges when the choice is made, and the user must give two integers which describes the location of the attraction point/line. Then two attraction parameters are given.

The *Prop. att. value is proportional to the attraction. If negative,* the grid lines are moved away instead of attracted. The *Sq. att. value gives an attraction* proportional to the grid line difference raised to a power of *Sq. att. This value is used to determine* how far out in the grid the attraction works. Note that a smaller value will give larger attractions.

Point attraction gives attraction to points, and Line attraction gives attraction to lines. Up to 200 attraction points can be defined. The attraction points can be seen on the grid by coloured rectangles at the grid intersections.

The last option in the Define menu is Delete last attraction. This deletes the last defined attraction.

Generate

The first choice in the pull-down menu is Boundary. This choice interpolates linearly along the four border lines of the grid. Note that the z values are also interpolated. This will create a rectangle unless a NoMovePoint has been defined on the border. Then the interpolation will be between the corners and the NoMovePoints. The second choice is Elliptic. This starts the elliptic grid generator. Note that this will not change the z values. The third choice is Transfinite I.

This is transfinite interpolation in the streamwise direction. The z values will be interpolated. IMPORTANT: In this mode the NoMovePoints will also be moved. The fourth choice is Transfinite J. This is the same as Transfinite I, except it is in the cross-streamwise direction.

The second last choice, Bed levels/Bed interpolations, generates z values for the bed surface of the grid. The z values are interpolated from a set of geometrical data read from the geodata file. If there is no geodata file present, an error message is given. The interpolation routine goes through all the grid points (i,j), and finds the closest points in the geodata file in all four quadrants where the grid intersection (i,j) is the centre of the coordinate system. Then a linear interpolation from these four points is made. If one of the points in the geodata file is closer than 5 cm from the grid point, this z value is chosen and no interpolation is done.

The outcome of the interpolation is logged to the file boogie.bed. If the interpolation routine is unsuccessful in finding the point, the z value is set to zero.

The last choice, 3D Grid/Implementation, is used after having changed the z values on any of the coordinates. The grid editor only moves the grid in the layer bordering the bed. So if any of the grid points have been moved in the vertical direction, the water level and the grid points above the bed needs to be recalculated. The new grid is computed by using the 3D Grid option.

Thank you for your attention