Introduction to MIKE FLOOD

HYDROEUROPE, Sophia-Antipolis, February 2011

Julie Landrein, DHI Denmark
Introduction to MIKE FLOOD

- Introduction to MIKE FLOOD
- 1D Modelling: MIKE 11, MIKE URBAN
- 2D Modelling: MIKE 21
- 1D/2D Modelling with MIKE FLOOD
- MIKE FLOOD Links
- MIKE FLOOD Results
Introduction to MIKE FLOOD

Flooding in urban areas...

Prague (Czech Republic)  Dhaka City (Bangladesh)
Introduction to MIKE FLOOD

... in large river basins...

Introduction to MIKE FLOOD

... or in coastal areas.

- Storm surge over the highway during Hurricane Katrina (New Orleans, 2005)
- Storm surge during Hurricane Ivan (Florida, 2004)

Need for Numerical Modelling!
Floods caused by overflowing rivers and lack of drainage capacity causes damages in cities and loss of productive lands.

Integrated modelling of rivers & drainage systems AND flood plains assist in mitigating flood risks by better understanding of the integrated system.

Why detailed flood modelling?
What is MIKE FLOOD?

An Integrated 1D-2D Tool for...

Floodplain modelling

Storm surge studies

Urban drainage assessments

Dambreak simulations

Hydraulic design of structures

Coastal and estuarine applications

Impact assessment of climate change

...
- Short presentation of DHI
- Introduction to MIKE FLOOD
- **1D Modelling: MIKE 11, MIKE URBAN**
- 2D Modelling: MIKE 21
- 1D/2D Modelling with MIKE FLOOD
- MIKE FLOOD Links
- MIKE FLOOD Results
MIKE 11


Areas of application:

- Rivers
- Estuaries
- Urban networks
- Irrigation
- Regulation structures
- Dam break analysis
- Flood management
- Water quality modelling
- Sediment transport
- Real time flood forecasting
MIKE 11 Modular Structure

Modules and Databases that Interact Dynamically

- Rainfall-Runoff
- Hydrodynamics
- Flood Forecasting
- Advection-Dispersion
- Sediment Transport
- Water Quality

Databases
- Topographical Data
- Time Series Data
MIKE 11

HYDRODYNAMICS

Solves vertically integrated Saint Venant Equations

General Assumptions:

- Incompressible and homogeneous fluid
- Flow is one-dimensional (uniform velocity and water level in cross-section)
- Bottom slope is small
- Small longitudinal variation in geometry
- Hydrostatic pressure distribution

Conservation of Mass (Continuity Equation)

\[
\frac{\partial Q}{\partial x} - b \frac{\partial h}{\partial t} = 0
\]

Conservation of Momentum (Momentum Equation)

\[
\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} \left( \alpha \frac{Q^2}{A} \right) + gA \frac{\partial h}{\partial x} + \frac{gn^2Q}{AR^{4/3}} \frac{\partial |Q|}{\partial x} = 0
\]

Kinematic Wave

Diffusive Wave

Fully Dynamic Wave
MIKE 11 Solution Scheme

6 Point Abbott-Ionescu FD Scheme

MIKE11 is fully implicit; the finite difference scheme features:

- $h$-points at every cross-section and junction
- $q$-points between $h$-points and at structures
- Solve the continuity equation between $q$-points
- Solve the momentum equation between $h$-points
- At structures, momentum equation replaced by the energy equation
MIKE 11 Basic Input Data

- **RIVER NETWORK**
- **WEIRS AND FLOW REGULATORS**
- **DIGITAL ELEVATION MODEL (DEM)**
- **HYDROLOGICAL DATA**
- **OTHER GIS DATA**

**Fully unsteady flow model modules for**

- Rainfall Runoff Processes
- Advection - Dispersion
- Water Quality
- Sediment Transport
MIKE 11 Boundary Conditions

Discharge, $Q$:
- Upstream of River
- Lateral Inflow
- Closed End ($Q=0$)
- Discharge Control
- Pump

Water Level, $h$:
- Downstream River boundary
- Outlet in Sea (tide, wind)
- Water level control

$Q/h$ Boundary:
- Downstream Boundary (Never upstream)
- Critical Outflow from Model

In general, Boundaries should be located where key investigation area is not directly affected by boundary condition!
Calibration/Validation

- Goal: ensure that the model fits the reality for scenario testing, flood forecasting, etc...
- Primary parameter: Roughness
- Also Head losses
- Sensitivity testing if no calibration data

Uncertainty

- Hydrology
- Topography and geometry of the network
- Measurements

- Calibration
- Poor model development

Reliable Data Required: ‘GARBAGE IN = GARBAGE OUT’
A 1D Modelling System for Water Distribution and Urban Drainage Networks

**Hydrodynamics**

MOUSE/MIKE URBAN solves the St Venant equations based on an implicit finite difference scheme.

Pipes flow computations can simulate free surface flow and pressurized flow conditions (vertical slot).
The courant number describes the relation between the speed of physical disturbances in the system and the speed at which disturbances travel in the numerical model.

**Courant Number:**

\[ Cr = \frac{\sqrt{g \cdot D + v}}{\frac{\Delta x}{\Delta t}} \leq 1.0 \]

- *Physical propagation speed*
- *Max Numerical propagation speed*
Introduction to MIKE FLOOD

- Short presentation of DHI
- Introduction to MIKE FLOOD
- 1D Modelling: MIKE 11, MIKE URBAN
- **2D Modelling: MIKE 21**
- 1D/2D Modelling with MIKE FLOOD
- MIKE FLOOD Links
- MIKE FLOOD Results
MIKE 21 is a 2D Modelling System for rivers, floodplains, lakes, estuaries, bays, coastal areas and seas.

MIKE 21 can simulate:

- hydrodynamics
- waves
- sediments and
- ecology

Originally for marine applications

**MIKE 21 Engines**

- **Single Grid** - classic rectilinear model
- **Multiple Grids** – dynamically nested rectilinear model
- **Flexible Mesh**
FLOODPLAIN MODELLING REQUIREMENT

- Robust and realistic flooding and drying algorithms simulation correct flood wave propagation
- Modelling of steep gradients and locally supercritical flows
- Hydraulic structures
- Precipitation/Evaporation, Sources and Sinks
- Integration with 1D Models (MIKE 11 - MIKE URBAN)
Mathematical background

- Numerical solution depends on the selected grid:
  - Flexible Mesh
  - Rectilinear Grid (and nested)
  - Curvilinear (river applications)
MIKE21 simulates water levels and flows (fluxes) in response to a variety of forcing functions.

- Solves the equations of continuity and conservation of momentum using implicit finite difference methods.
- Water levels and fluxes resolved on a rectangular grid covering the area of interest.
HYDRODYNAMICS – Flexible Mesh

Finite Volume Method

- Cell-centered finite volume method
- Unstructured mesh
- Triangular and quadrilateral elements
- Spherical and Cartesian coordinates

Cell centres at which primitive variables, u,v and $\zeta$ are mapped.

Volume fluxes - calculated perpendicular to element faces.

- Explicit upwinding scheme limits time step to satisfy a Courant-Friedrich-Lewy number of 1

$$CFL = \left(\sqrt{gh} + |u|\right) \frac{\Delta t}{\Delta x} + \left(\sqrt{gh} + |v|\right) \frac{\Delta t}{\Delta y}$$
**Inputs:**
- Bathymetry
- Boundary Conditions
- Wind
- Atmospheric Pressure
- Bed Resistance
- Eddy Viscosity
- Radiation Stresses
- Source data
- Hydraulic structure data

**Outputs:**
- Time-varying maps of water depths and horizontal fluxes
- Short presentation of DHI
- Introduction to MIKE FLOOD
- 1D Modelling: MIKE 11, MIKE URBAN
- 2D Modelling: MIKE 21
- **1D/2D Modelling with MIKE FLOOD**
- MIKE FLOOD Links
- MIKE FLOOD Results
The MIKE FLOOD Concept

1-D Model of one-dimensional flow (MIKE 11 and/or MIKE URBAN)
2-D Model of two-dimensional flow (MIKE 21 or MIKE 21 FM)

Connection points or “couples”

Bay of Bengal, Bangladesh
MIKE FLOOD Simulation Features

A combination of 1D and 2D engines available

1D Models:

- 1D river network with MIKE 11
- 1D sewer network with MIKE URBAN/MOUSE

2D Engines (MIKE 21/MIKE 21 FM):

- Single Grid
- Multicell Overland Flow Solver
- Flexible Mesh (FM)
1D, 2D or Both?

Some questions to consider before choosing a model:

- What are the phenomena to study?
- What are the required results/outputs?
- Study area (extent, slopes, morphology, etc...)
- Available data (quality, quantity, input, calibration)
- Budget
- Time schedule
1D, 2D or Both?

Simple MIKE 11 Model
1D, 2D or Both?

Quasi 2D MIKE 11 Model

FLOODPLAIN MODEL (QUASI 2-D)

FLOODED AREAS

PARALLEL RIVERS

River

Floodplain

Link channel
2D Overland Flow Model MIKE 21
1D, 2D or Both?

Integrated MIKE FLOOD Model

Integrated 1D-2D Flood Model

2D FLOOD AREA

1D RIVER NETWORK

CONNECTION 1D-2D BY LATERAL LINKS

MIKE 11 MIKE 21

Lateral Link
Advantages of 1D model (MIKE 11):

- Accurate hydraulic description in rivers/channels which are one-dimensional flow;
- FAST, Less computational points relative to 2D model, i.e. less CPU time;
- Easy to analyse and extract results (MIKE View).
- Dam Break analysis, Operational structures

Disadvantages of 1D model (MIKE 11):

- Flow paths must be known beforehand;
- Substantially more effort required for model schematisation relative to 2D models;
- Depth and width averaged flow; no detailed flow descriptions in floodplains.

MIKE 11 suitable for projects:

- Where detailed flow patterns and depths are not important;
- With many complex structures;
- Where short simulation time is important (i.e. river basin models, flood warning).
Advantages of 1D model (MIKE URBAN):

- Accurate hydraulic description of all water networks in the city: storm water drainage systems and sewer collection in separate and combined systems;
- Less computational points relative to 2D model, i.e. less CPU time;
- Easy to analyse and extract results.

Disadvantages of 1D model (MIKE URBAN):

- Substantially more effort required for model schematisation relative to 2D models;
- No overland flow description;
- No dynamic exchanges between the pipe network and the floodplain.

MIKE URBAN suitable for projects:

- Where detailed flow patterns and depths in the floodplain are not important;
- Where modelling of pipe sewer/stormwater systems is required;
- Where short simulation time is important (i.e. flood warning).
Advantages of 2D model (MIKE 21):

• 2-D flow simulated dynamically without prescribing flow patterns;
• Flexibility for tailoring grid resolution within the model (FM);
• Adaptive time step to the dynamics (FM);
• Detailed information on velocity, depths etc. on floodplains;
• FASTER: Multicell Overland Flow Solver for M21 Classic, parallel processing

Disadvantages of 2D model (MIKE 21):

• Requires fine grid in rivers/channels in order to define conveyance accurately.
• Requires more computational effort than 1D engine

MIKE 21 suitable for projects:

• Where detailed velocity and depth patterns are important;
• Where the flow paths are not well defined;
• Where channel flows can be resolved within the model grid.
Advantages of MIKE FLOOD:

• Contains the benefits from both 1D (MIKE 11/MOUSE) and 2D Engines (MIKE21/MIKE21 FM);
• Integration of flood plains, streets, rivers, coasts and sewer/storm water systems
• Visual presentation of flood results;
• Allows sub-grid scale features (hydraulic structures) to be accurately represented;
• Multi Cell Overland Flow Solver and parallel processing with the FM module for faster resolution.

Disadvantages of MIKE FLOOD:

• Two (or 3) models must be maintained instead of one;
• Computational effort

MIKE FLOOD suitable for projects:

• Where an accurate and efficient simulation of combined pipe and overland flows is needed.
• Where a 2D description is needed for the floodplain;
• Where the 1D features (e.g. Advanced Structures, Dambreak, 1D Channel representation, Sewer Network) are required elsewhere in the system.
Why Combined 1D-2D Flood Modelling?

- To reproduce all the situations involving canal/sewer system, and to study at the same time what happens on the flood plain or streets.
- To obtain flood maps taking into account all the details of the topography that we can reproduce.
- **But** it implies more time to set up, more computation time and more disk space, as for every 2D study.

1. More intuitively to set up
2. Precise and realistic results

1. Computational time high
2. Disk space needed
Performance

Performance Improvements – MIKE 21 Classic and FM

- Parallelization using OpenMP (0-50% speedup)
- New approach for dynamic memory allocation implemented (chcmem removed)
- Special single precision option removed

“Probably the Worlds fastest Flood Model”


<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
<th>Test 6A</th>
<th>Test 6B</th>
<th>Test 7</th>
<th>Test 8A</th>
<th>Test 8B</th>
<th>All tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MIKE FLOOD</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.13</td>
<td>1</td>
<td>1</td>
<td>1.14</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>TUFLOW</strong></td>
<td>5.53</td>
<td>4.80</td>
<td>1.80</td>
<td>4.02</td>
<td>1</td>
<td>2.02</td>
<td>6.00</td>
<td>1</td>
<td>5.36</td>
<td>4.42</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>InfoWorks-2D</strong></td>
<td>5.33</td>
<td>1.83</td>
<td>10.00</td>
<td>5.12</td>
<td>1.17</td>
<td>1.01</td>
<td>1.79</td>
<td>8.79</td>
<td>4.25</td>
<td>2.88</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>SOBEK</strong></td>
<td>5.67</td>
<td>4.18</td>
<td>20.00</td>
<td>13.31</td>
<td>4.67</td>
<td>5.04</td>
<td>11.66</td>
<td>19.69</td>
<td>3.90</td>
<td>9.09</td>
<td>9.5</td>
</tr>
<tr>
<td><strong>ISIS-2D</strong></td>
<td>16.00</td>
<td>3.95</td>
<td>23.00</td>
<td>22.60</td>
<td>78.33</td>
<td>280.62</td>
<td>818.14</td>
<td>5.15</td>
<td>12.34</td>
<td>353.03</td>
<td>157</td>
</tr>
</tbody>
</table>

Relative Run-times.
Lower values = faster simulations. Green = fastest package in test.
- Short presentation of DHI
- Introduction to MIKE FLOOD
- 1D Modelling: MIKE 11, MIKE URBAN
- 2D Modelling: MIKE 21
- 1D/2D Modelling with MIKE FLOOD
- MIKE FLOOD Links
- MIKE FLOOD Results
1- MIKE URBAN/MIKE 21

MIKE FLOOD

1D Model

MIKE URBAN

2D Model

MIKE 21
- Single grid
- Multicell
Overland Solver
- FM
2- MIKE 11/MIKE 21

MIKE FLOOD

1D Model

MIKE 11

2D Model

MIKE 21
- Single
- Multicell Overland Flow Solver
- FM
Multiple Coupling Possibilities

3- MIKE URBAN/MIKE 21
MIKE 11/MIKE 21

MIKE FLOOD

1D Model
MIKE 11

2D Model
MIKE 21
- Single grid
- Multicell
Overland Solver
- FM

MIKE URBAN
Multiple Coupling Possibilities

4- MIKE URBAN/MIKE 21
   MIKE 11/MIKE 21
   MIKE URBAN/MIKE 11

3 WAY COUPLING

1D Model

MIKE FLOOD

MIKE URBAN

MIKE 11

2D Model

MIKE 21
- Single grid
- Multicell
- Overland Solver
- FM
### MIKE FLOOD links

#### COUPLING POSSIBILITIES

#### Various Link Types

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Link</td>
<td>M21 to Inlet</td>
<td>MIKE 11 Water level Boundary</td>
</tr>
<tr>
<td>Structure Link</td>
<td>M21 to Outlet</td>
<td>MIKE URBAN Outlet to MIKE 11</td>
</tr>
<tr>
<td>Lateral Link</td>
<td>Weir to M21</td>
<td>MIKE URBAN Weir to MIKE 11</td>
</tr>
<tr>
<td>Zero Flow Link</td>
<td>Pump to M21</td>
<td>MIKE URBAN Pump to MIKE 11</td>
</tr>
<tr>
<td>Side Structure Link</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lateral Links (MIKE 11/MIKE 21 – MIKE 21 FM)

MIKE 11 branch laterally linked to a string of MIKE 21 cells. Good to simulate overflow from a river into the floodplain.
Standard Links (MIKE 11/MIKE 21 – MIKE 21 FM)

Links the end of a MIKE 11 branch to 1 or more MIKE 21 cells.
Structure Links (MIKE 11 / MIKE 21 - Not available with FM)

Good to simulate structures within MIKE 21.

Flow from MIKE 11 HQH branch is inserted into momentum equation in MIKE 21.
Interaction between a MIKE 11 side structure and overland flow.

Explicit link

Works in the same way as standard link

Good for:
- Dam break, embankment failure
- Pumping or local spilling
- etc
Zero Flow Links (X=0, Y=0) (MIKE11/MIKE 21 - Not available with FM)

Zero Flow Link: Grid cells in a zero flow link have either the top face (Y) or right face (X) blocked. A blocking line in the grid can be defined using a pair of zero flow links (X and Y).

Can be used in combination with lateral links to prevent flow circulation.
Urban Links (MIKE URBAN/MIKE 21 – MIKE 21 FM): 4 Types

- M21 to inlet
- M21 to outlet
- Weir to M21
- Pump to M21
River-Urban Links

River – Urban Link (MIKE 11/MIKE URBAN)

4 types of link to describe the interaction between river and sewer system:

- MIKE 11 Water level Boundary
- MIKE URBAN Outlet to MIKE 11
- MIKE URBAN Pump to MIKE 11
- MIKE URBAN Weir to MIKE 11
Recommended Steps

1- Define **model layout** (time, extent, projection, resolution...)
2- Setup and run **MIKE 11/MIKE URBAN** (calibrate and validate model)
3- Prepare the **model**
   - bathymetry
4- Setup and run **MIKE 21**
5- Setup and run **MIKE FLOOD**
   (define links between the 2 or 3 models)
6- Present flood results
*COUPLE FILE EXTENSION*

**How?** MIKE Zero -> File -> New -> File -> MIKE FLOOD -> MIKE FLOOD (.couple)
Introduction to MIKE FLOOD

- Short presentation of DHI
- Introduction to MIKE FLOOD
- 1D Modelling: MIKE 11, MIKE URBAN
- 2D Modelling: MIKE 21
- 1D/2D Modelling with MIKE FLOOD
- MIKE FLOOD Links
- MIKE FLOOD Results
MIKE FLOOD Results

1D-2D RESULT VIEWING

- What kind of outputs do you get from a MIKE FLOOD simulation?

- Which tools are available to view the results?
Overview of MIKE FLOOD Results

MIKE FLOOD SIMULATION

- MOUSE-MIKE URBAN (.prf)
  - MIKE VIEW
    - Grid Editor
    - Result Viewer
    - Google Earth
  - MIKE URBAN
- MIKE11 (.res11; .dfs2)
  - MIKE VIEW
  - Grid Editor
  - Toolboxes
  - Plot Composer
  - Result Viewer
  - Google Earth
  - MIKE URBAN
- MIKE21 (.dfs2)
  - Grid Editor
  - Toolboxes
  - Plot Composer
  - Result Viewer
  - Google Earth
  - MIKE URBAN
- MIKE21 FM (.dfsu)
  - Data Viewer
  - Data Manager
  - Plot Composer
  - MIKE Animator
MIKE FLOOD Results

MIKE 11 and MOUSE/MIKE URBAN results in MIKE View

Water levels
Flows
Velocity
Volumes
Cross-sections
Lateral Inflow MIKE 21
Inflow MOUSE to MIKE 21
MIKE FLOOD Results

1D-2D SEAMLESS DFS2 RESULT FILE

Possibility to generate a result file that combines both MIKE 11 and MIKE 21 2D results

**HOW?** Generate map in HD11 file. Item type (h,p,q)

<table>
<thead>
<tr>
<th>K Cells</th>
<th>Filename</th>
<th>Br</th>
<th>Type</th>
<th>Item</th>
<th>Compo</th>
<th>Storing</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CAUen/Pert</td>
<td></td>
<td>Dynamic</td>
<td>(h,p,q)</td>
<td>1</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

Map showing water depth with color scale from blue to orange.
MIKE FLOOD Results

2D outputs (*.dfs2) can be viewed in GIS with the dfs2pluggin.
MIKE FLOOD Results

View MIKE 11 network files and 2D dfs2 result files in GOOGLE EARTH
MIKE FLOOD Animations

MIKE URBAN/MIKE 21 example
MIKE FLOOD Animations

MIKE 11/MIKE 21 – Canberra, Australia
MIKE 11/MIKE 21, Rain on Dry land – Wendover, USA
Getting Help

- Help Menu: Access the Help from any editors by pressing the **F1 Key**.

- **Manuals:**
  - MIKE FLOOD User Guide (Chapter 7: Tips and Troubleshooting)
  - MIKE 11 User Manuals, Reference Manual, etc...
  - MIKE 21 User Guide, Scientific Documentation, etc...
  - MIKE Zero Manuals
  - MIKE URBAN Manuals

For an easy access to all manuals available, open the **Documentation Index**.

**How?** Start > Programs > MIKE by DHI 2011 > MIKE Zero > Documentation > MIKE FLOOD Documentation Index
MIKE FLOOD Products

The following documentation are available for the MIKE FLOOD Products:

- MIKE FLOOD User Manual
- MIKE FLOOD Step-by-step guide for River Flood Modelling
- MIKE FLOOD Step-by-step guide for Urban Flood Modelling
- MIKE FLOOD Toolbox, User Guide

More information

- Release Note
- Documentation index for the MIKE Zero products
- Documentation index for the MIKE 11 products
- Documentation index for the MIKE 21 products
- Documentation index for the MIKE URBAN products

Please also refer to www.mikebydhi.com for any additional information on the MIKE FLOOD products.

Support

DHI’s Software Support Center can be reached by mail, e-mail, phone or fax:

DHI’s Software Support Center
DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark

E-mail: mikebydhi@dhigroup.com
Phone: +45 45 16 93 33 (Open 7.30-16.00 GMT)
Fax: +45 45 16 92 92
More ways to find help

- Install and check the **examples** that come with each program

- **FAQ** Page on DHI’s website
  
  http://faq.dhigroup.com/

- **Tips and Tricks** Page on DHI’s website
  
  http://tips.dhigroup.com/
HydroEurope, Feb 2011