Numerical application of SCHISM about flood inundation modeling due to levee breach in idealized channel and field case

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  - Dam break
  - Uniform flow
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Introduction

- Background
  - Increase of danger to collapse for hydraulic structure due to abnormal climate and increase in the frequency of extreme flood
  - The levees breach accounted for 70 percents of entire damage of hydraulic structure in Korea
  - The proportion of the damage caused by overflow was 40 percents.
  - Many inundation areas occurred due to levee breach resulting in loss of life and property loss.
  - Prediction of damage due to inundation is increasingly a major task for river engineers and managers.

- Understanding the characteristics of flood wave flow and propagation patterns is important.
- Predicting the damage by performing Inundation simulation on real terrain is necessary.
Introduction-SCHISM

- Model description
  - **SCHISM**: Semi-implicit Cross-scale Hydrosience Integrated System Model
  - A derivative product of SELFE v3.1, developed by Dr. Zhang in Virginia Institute of Marine Science
  - Distributed with open-source Apache v2 license, Operationally tested and proven (DWR, NOAA etc.)
  - Finite-element and finite-volume approach: unstructured grids (Mixed grids: tri-quads)
  - Semi-implicit time stepping: large time step and no splitting errors
  - Eulerian-Lagrangian method (ELM) for momentum advection: more efficiency & robustness
  - MPI (Message Passing Interface) is available.

SCHISM modeling system

- Ecology / Biology module
- Water quality module
- Hydraulics & Hydrostatic
- Inundation module
- Sediment module
Introduction-SCHISM

- Previous Research with SCHISM
  - SCHISM which has a wet / dry function is suitable to simulate inundation modeling.
  - Through inundation simulation, information on inundation area, flood wave velocity and inundation direction can be checked.
  - Forunato et. Al (2013) simulated the coastal flooding due to storm surges using SCHISM model.
  - Chen et. Al (2013) simulated the coastal inundation in Massachusetts to examine the impact of current-wave interaction on storm-induced inundation and confirmed the inundated areas.

- Most inundation studies using SCHISM were focused on the coastal region but inundation on the river was insufficient.
- In this study, we performed inundation simulation in ideal open channels without or with uniform flow and field cases, Saemangeum Basin in Korea for several flood conditions.
Detailed in SCHISM

Model description

- Using module
  - Hydraulics module & Inundation module

- Governing Equation
  - The SCHISM model follows the Navier-Stokes equation for incompressible fluids under the Boussinesq assumption.
  - Continuity Equation: \( \nabla \cdot u + \frac{\partial w}{\partial z} = 0 \) \( \text{---- (1)} \), \( \frac{\partial \eta}{\partial t} + \nabla \cdot \int_{-h}^{\eta} u \, dz = 0 \) \( \text{---- (2)} \)
    (where, \( u \): horizontal velocity, \( w \): vertical velocity, \( h \): bathymetric depth, \( \eta \): free-surface elevation)
  - Momentum Equation: \( \frac{Du}{Dt} = \frac{\partial}{\partial z} \left( v \frac{\partial u}{\partial z} \right) - g \nabla \eta + f \) \( \text{---- (3)} \)
    (where, \( v \): eddy viscosity, \( g \): gravity acceleration, \( f \): component of horizontal viscosity, air pressure etc.)

- Wet / Dry Condition
  - Set up the threshold depth
  - If one of the nodes is dry, the elements should be set as dry
Inundation module in SCHISM model

- Inundation module
  - In order to use the Inundation module in the SCHISM model, the terrain depth value should be changed with time in conjunction with the Hydrodynamic module.

- Deformation process of Terrain Depth

  In the SCHISM model, the terrain can be transformed over time using the `bdef.gr3` file and the `ibdef` variable.
  - The `bdef.gr3` is a file that gives the node a transformation value, in which negative values are descending and positive Integers are rising.
  - The `ibdef` parameter is the number of time step required to change the terrain, and the time step value can be used to specify the rate of decay of the bank.
Numerical Implementation for Ideal Cases

1. Dam break case
2. Uniform flow case
3. Confluence case
Numerical Simulation Implementation # 1

☐ Purpose
  ○ Ensure whether the wet / dry conditions in the SCHISM model are applied well or not.

☐ Classification
  ○ Still water case & uniform flow case with mesh dependence.

☐ Topography
  ○ Inundation simulation was implemented in ideal channel.
  ○ Dam break Case : Ideal channel was constructed with a width of 500 m and a length of 2000 m and levee slope is 1:2
  ○ Uniform flow Case : Ideal channel was constructed with a width of 15 m and a length of 50 m and levee slope is 1:2
  ○ Levee collapse width & shape : 100 m & rectangular
Numerical Simulation Implementation #1

☐ Still water Case
  ○ Flow Chart

  \[ T_1 \text{ : Initial Condition} \quad T_2 \text{ : Inundation in progress} \quad T_3 \text{ : Final Inundation} \]

☐ Configuration
  ○ Check the propagation range, flood wave velocity after levee breach in stationary state
  ○ Compare the results according to mesh type effect (Rectangular vs. Triangular)
Numerical Simulation Implementation #1

- Dam break Case
  - Inundation Process (animation)
Numerical Simulation Implementation #1

□ Model setup
  ○ Grid & Time step
    → Total 216000 elements, 216941 nodes (quads grids) & Total 500068 elements, 250975 nodes (triangular grids)
    → Grid spacing is 5 m & Time step is 5 seconds (CFL number = 1.5)
    → CFL (Courant-Friedrichs-Lewy condition) number
      
      $\text{CFL number} = \frac{u \Delta t}{\Delta x}$ (where, $u =$ flow velocity, $\Delta x =$ grid spacing, $\Delta t =$ time step)

  ○ Boundary Condition & Initial Condition

<table>
<thead>
<tr>
<th></th>
<th>Boundary Condition</th>
<th>Initial Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Container</td>
<td>Discharge (No output)</td>
<td>Wet condition (Constant Elevation value)</td>
</tr>
<tr>
<td>Interior floodplain</td>
<td>Elevation</td>
<td>Dry condition</td>
</tr>
</tbody>
</table>
Numerical Simulation Implementation #1 (모의수행 진행 중)

□ Model setup
  ○ Levee Information
    → Collapse Shape is Rectangular (Collapse Width: 100 m, Collapse Time: 80 min)
  ○ Numerical Simulation Case
    → Total 2 Case according to mesh type

<table>
<thead>
<tr>
<th>Case</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesh Type</td>
<td>Rectangular</td>
<td>L-Triangular</td>
<td>R-Triangular</td>
<td>Triangular</td>
</tr>
</tbody>
</table>

Mesh Type 1
Mesh Type 2
Mesh Type 3
Mesh Type 4
Numerical Simulation Implementation #1

- Results
  - Inundation Process (Rectangular mesh)
    - Surface elevation results (Time history)

- $T_1$: Start Inundation
- $T_2 = T_1 + 500$ sec
- $T_3 = T_2 + 500$ sec
- $T_4 = T_3 + 500$ sec
Numerical Simulation Implementation #1

□ Results
○ Inundation Process (Triangular mesh)
→ Surface elevation results (Time history)

\[ T_1 : \text{Start Inundation} \]
\[ T_2 = T_1 + 500 \text{ sec} \]
\[ T_3 = T_2 + 500 \text{ sec} \]
\[ T_4 = T_3 + 500 \text{ sec} \]
Numerical Simulation Implementation #1

- Results
  - Inundation Process (Rectangular & Triangular mesh)
    - Depth averaged velocity & velocity vector (at $T = T_4$)

Mesh Type 1 (Rectangular)  
Mesh Type 2 & 3 (L- and R-triangular)  
Mesh Type 4 (Triangular)
Numerical Simulation Implementation #1

Results Analysis from Dam break case

- The wet / dry condition is well applied in the SCHISM model.
- However, after the levee breach, the propagation patterns of the flood waves were different according to mesh type.
- The maximum flow velocity appears at the same point, but the magnitude of flow velocity is different according to mesh type.

The results of SCHISM model such as propagation patterns, flow velocity are strongly influenced by the mesh type.

Therefore, the results of the SCHISM simulation according to the mesh type and mesh orientation should be examined.
Numerical Simulation Implementation #2

- **Uniform flow Case**
  - Flow Chart

  ![Initial Condition](image1)
  ![Inundation in progress](image2)
  ![Final Inundation](image3)

- **Configuration**
  - Check the propagation range, flood wave velocity after levee breach in flow state
  - Compare the results according to mesh orientation (4 case)
Numerical Simulation Implementation #2

☐ Uniform flow Case
  ○ Inundation Process (animation)
Numerical Simulation Implementation #2

☐ Model setup
  ○ Grid & Time step
    → Total 1280 elements, 693 nodes (triangular grids),
    → Grid spacing is 2.5 m & Time step is 5 seconds (CFL number = 1.5)
    → CFL (Courant-Friedrichs-Lewy condition) number
      
      \[
      \text{CFL number} = \frac{u \Delta t}{\Delta x} \text{ (where, } u = \text{ flow velocity, } \Delta x = \text{ grid spacing, } \Delta t = \text{ time step)}
      \]
  ○ Boundary Condition & Initial Condition

<table>
<thead>
<tr>
<th>Location</th>
<th>Boundary Condition</th>
<th>Initial Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream</td>
<td>Discharge</td>
<td>Wet condition (Constant Elevation value)</td>
</tr>
<tr>
<td>Downstream</td>
<td>Elevation</td>
<td>Wet condition (Constant Elevation value)</td>
</tr>
<tr>
<td>Interior floodplain</td>
<td>Elevation</td>
<td>Dry condition</td>
</tr>
</tbody>
</table>
Numerical Simulation Implementation #2

□ Model setup
  ○ Levee Information
    → Collapse Shape is Rectangular (Collapse Width: 2.5 m, Collapse Time: 20 min)
  ○ Numerical Simulation
    → Total 4 Cases according to mesh orientation
    → Mesh configurations are as below:

Type 1                                          Type 2                                           Type 3                                         Type 4
Numerical Simulation Implementation #2

Results

- Inundation Process (type mesh)
- Surface elevation results (Time history)

\[ T_1 : \text{Start Inundation} \]
\[ T_2 = T_1 + 10 \text{ sec} \]
\[ T_3 = T_2 + 10 \text{ sec} \]
\[ T_4 = T_3 + 10 \text{ sec} \]
Numerical Simulation Implementation #2

Results

- Inundation Process (type mesh)
  - Surface elevation results (Time history)

\( T_1 \): Start Inundation
\( T_2 = T_1 + 10 \text{ sec} \)
\( T_3 = T_2 + 10 \text{ sec} \)
\( T_4 = T_3 + 10 \text{ sec} \)
Numerical Simulation Implementation #2

- Results
  - Inundation Process
    - Surface elevation results (Time history)

- Time stamps:
  - $T_1$: Start Inundation
  - $T_2 = T_1 + 10$ sec
  - $T_3 = T_2 + 10$ sec
  - $T_4 = T_3 + 10$ sec
Numerical Simulation Implementation #2

- Results
  - Inundation Process (type mesh)
  - Surface elevation results (Time history)

\[ T_1 : \text{Start Inundation} \quad T_2 = T_1 + 10 \text{ sec} \quad T_3 = T_2 + 10 \text{ sec} \quad T_4 = T_3 + 10 \text{ sec} \]
Numerical Simulation Implementation #2

- Results
  - Inundation Process (Rectangular & Triangular mesh)
    → Depth averaged velocity & velocity vector (at $T = T_4$)
Numerical Simulation Implementation #2

- Results Analysis from uniform flow case
  - Through sensitivity analysis, the SCHISM model is affected by the mesh orientation.
  - After the levee breach, the propagation patterns of the flood waves were different according to mesh orientation.
  - In case of mesh type 3, the flow velocity is faster than the other grid type and Maximum velocity also occurred elsewhere in other mesh types.

- The results of SCHISM model such as propagation patterns, flow velocity are strongly influenced by the mesh orientation.
- Therefore, Understanding the flood wave characteristics and physical meaning is important to set the mesh directionality.
Numerical Simulation Implementation # 3

- **Purpose**
  - Configuration of the inundation area according to variation of tributary flow rate
  - Configuration of the direction of velocity vector and analysis of flood wave velocity according to variation of tributary flow rate

- **Classification**
  - River with tributary in terms of ration of discharge

- **Topography**
  - Inundation simulation was implemented in ideal channel.
  - Ideal channel consists of main channel which width is 500 m and length is 4,750 m, tributary channel which width is 200 m and length is 2,000 m
  - Levee height is 25 m, levee width is 50 m, levee slope is 1:2
Numerical Simulation Implementation # 3

- **Tributary flow Case**
  - Flow Chart

- **Configuration**
  - Check the propagation range, flood wave velocity after levee breach in flow state
  - Compare the results according to variation of tributary flow rate (5 case)
Numerical Simulation Implementation #3

- Confluence flow Case
  - Inundation Process (animation)
Numerical Simulation Implementation # 3

□ Model setup
  ○ Grid & Time step
    → Total 11800 elements, 12171 nodes (quad grids)
    → Grid spacing is 25 m & Time step is 5 seconds (CFL number = 1.5)
    → CFL (Courant-Friedrichs-Lewy condition) number
      
      \[
      \text{CFL number} = \frac{u \Delta t}{\Delta x}
      \]
      (where, \(u\) = flow velocity, \(\Delta x\) = grid spacing, \(\Delta t\) = time step)

○ Boundary Condition & Initial Condition

<table>
<thead>
<tr>
<th></th>
<th>Boundary Condition</th>
<th>Initial Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream</td>
<td>Discharge</td>
<td>Wet condition (Constant Elevation value)</td>
</tr>
<tr>
<td>Downstream</td>
<td>Elevation</td>
<td>Wet condition (Constant Elevation value)</td>
</tr>
<tr>
<td>Interior floodplain</td>
<td>Elevation</td>
<td>Dry condition</td>
</tr>
</tbody>
</table>
Numerical Simulation Implementation # 3


- Model setup
  - Observing Points
    - Configuration of Mass Conservation → Discharge (Section 1 ~ 4)
    - Configuration of velocity vector → Propagation direction
    - Configuration of flood wave velocity (maximum velocity)
  - Numerical Simulation Cases
    - $Q_m$ is main channel discharge, $Q_t$ is tributary channel discharge

<table>
<thead>
<tr>
<th>Case</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Channel</td>
<td>400 m³/s</td>
<td>400 m³/s</td>
<td>400 m³/s</td>
<td>400 m³/s</td>
<td>400 m³/s</td>
</tr>
<tr>
<td>Discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tributary Channel</td>
<td>200 m³/s</td>
<td>320 m³/s</td>
<td>400 m³/s</td>
<td>480 m³/s</td>
<td>600 m³/s</td>
</tr>
<tr>
<td>Discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tributary flow rate (Qt/Qm)</td>
<td>0.5</td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Numerical Simulation Implementation # 3

- Results
  - Froude numbers are between 0.2 and 0.27 in main channel
  - When Inundation starts, the velocity in levee breach point is maximum value
  - The collapse flow is formed perpendicular to the main channel flow
Numerical Simulation Implementation # 3

- Results
  - As the tributary flow rate ratio increases, the velocity ratio of the levee breach point to the main channel decreases
  - $V_{b\text{ max}}$: maximum velocity in flood plain (at nose of levee breach point in most cases), $V_{m\text{ max}}$: maximum velocity of main channel (center point in most cases)
Numerical Simulation Implementation # 3

- Results
  - Compare the water surface elevation at the center of the main channel with at flood plain during progress.
  - Water surface elevation at the center of the main channel decreases as soon as the levee breach starts
  - As the tributary inflow rate increases, water surface elevation of the flood plain slightly increases.

<table>
<thead>
<tr>
<th>Change of WSE (dived by $V_m B/Q_t$)</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main channel</td>
<td>- 1.1</td>
<td>- 1.2</td>
<td>- 1.3</td>
<td>- 1.4</td>
<td>- 1.5</td>
</tr>
<tr>
<td>Floodplain (overflow area)</td>
<td>4.4</td>
<td>4.6</td>
<td>4.7</td>
<td>4.8</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Drop: 6.6%  Drop: 4.2%  Drop: 4.6%  Drop: 4.9%  Drop: 5.1%
Numerical Verification
Numerical Verification

- Reference
  - Kakinuma et al. (2014) “Large-Scale Experiment and Numerical Modeling of a Riverine Levee Breach”, ASCE

- Experimental flume, Specification of the flume & Numerical Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Boundary Condition</th>
<th>roughness</th>
<th>Grid spacing</th>
<th>Time step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream</td>
<td>Discharge (70 m³/s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downstream</td>
<td>Elevation</td>
<td>0.023</td>
<td>1.0 m</td>
<td>1 sec</td>
</tr>
<tr>
<td>Interior floodplain</td>
<td>Elevation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Numerical Verification

- Comparison of experiment results (Kakinuma et al., 2014) & SCHISM results.
  - Check Point: Temporal Change of water level and discharge and velocity vector field near levee breach.
Numerical Verification

□ Reference

□ Compared Previous Research
- Difference of SCHISM levee breach process and Yoon’s study
  → SCHISM levee breach direction : Vertical
  → Yoon’s study levee breach direction : Horizontal

![Diagram showing levee breach and water gate comparison]

SCHISM : Vertical direction  
Yoon’s study : Horizontal direction
Numerical Verification

☐ Comparison of Results (Yoon, 2006)
  ○ Compare the results with the previous study using the results of the SCHISM simulation (Still water case)
  ○ Point of Measurement is perpendicular to the flow direction
  ○ Previous Research have shown the relationship between dimensionless propagation distance and dimensionless maximum depth

  → Dimensionless propagation distance : propagation distance \(Y\) / collapse width \(B\)  Dimensionless maximum depth : maximum depth \(h_{\text{max}}\) / Initial Water Elevation \(H_0\)
Case Study: Jeonju stream in Saemangeum Basin
Case Study

- **Study Area**
  - The study area is Jeonju stream in the Mangyeong River Basin in Samangeum, Rep. of Korea
  - The flooded areas in Jeonju stream are as follows.
Case Study

☐ Topography
  ○ Depth Contour
    → Using survey data about Saemangeum Basin (2011, Ministry of Land, Infrastructure, and Transport)
    → Using shape file format data about Inland (2014, National Geographic Information Institute)
    → Building Information (2017, National Geographic Information Institute)

☐ Model setup
  ○ Grid & Time step
    → Total 338,048 elements, 253,365 nodes (quad grids & Triangular grids)
    → Grid spacing is 20 m & Time step is 5 seconds (CFL number = 1.5)
  ○ Manning Coefficient
    → Upstream & Downstream : 0.025 ~ 0.030
    → Flood Area : 0.100
Case Study

Model setup

1) Geometry mesh workflow
   - Export xyz Data
     - Because survey data about Saemangeum basin is 20 m interval, interpolation work is required between data.
   - Interpolation Data
     - To perform terrain interpolation, Surfer 8.0 program was used in this study and interpolation was performed by the Krigging method.
   - Mesh creation.
     - To generate mesh file, SMS program was used in this study and the grid spacing and mesh type can be set through the SMS program.
     - Building information and Contour of Jeonju were reproduced using Arc GIS program
Case Study

Model setup

Boundary Condition & Initial Condition

<table>
<thead>
<tr>
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<tr>
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<td>Downstream</td>
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</tr>
<tr>
<td>Interior floodplain</td>
<td>Elevation</td>
<td>Dry condition</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Frequency</th>
<th>Mangyung River</th>
<th>Dongjin River</th>
<th>Soyang Stream</th>
<th>Jeonju Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 year flood</td>
<td>1,585</td>
<td>871</td>
<td>848</td>
<td>1,143</td>
</tr>
<tr>
<td>200 year flood</td>
<td>3,802</td>
<td>980</td>
<td>1,200</td>
<td>2,281</td>
</tr>
<tr>
<td>500 year flood</td>
<td>4,345</td>
<td>1,180</td>
<td>1,359</td>
<td>2,594</td>
</tr>
</tbody>
</table>

(unit : m³/s)
Case Study

☐ Model setup
  ○ Assumption of Levee breach configuration
    → Collapse Shape : Rectangular
    → Collapse Width : 200 m
    → Collapse Time : 30 min
    → Collapse Position : Palbok-dong

  ○ Configuration
    → Comparison of flood depth and flood wave propagation range according to frequency
    → Identification of flood wave velocity and flow velocity vectors according to frequency
Case Study

- Results (Frequency: 100 year flood, Q=1,143 m³/s)
  - Flood depth and flood wave propagation range according to frequency
  - Check the results for the flood depth at 2-hour intervals.

- Map images showing inundation start times at 2-hour intervals:
  - $T_0$: Inundation start
  - $T_1$: 2 hour
  - $T_2$: 4 hour
  - $T_3$: 6 hour
  - $T_4$: 8 hour
  - $T_5$: 10 hour
  - $T_6$: 12 hour
  - $T_7$: 14 hour
  - $T_8$: 16 hour
  - $T_9$: 18 hour
  - $T_{10}$: 20 hour
  - $T_{11}$: 22 hour
Case Study

- Results (Frequency: 200 year flood, $Q=2,218 \text{ m}^3/\text{s}$)
  - Flood depth and flood wave propagation range according to frequency
  - Check the results for the flood depth at 2-hour intervals.

![Map 1](image1)
20 hour
- $T_0 = $ Inundation start
- $T_1 = 2$ hour
- $T_2 = 4$ hour
- $T_3 = 6$ hour
- $T_4 = 8$ hour
- $T_5 = 10$ hour

![Map 2](image2)
22 hour
- $T_6 = 12$ hour
- $T_7 = 14$ hour
- $T_8 = 16$ hour
- $T_9 = 18$ hour
- $T_{10} = 20$ hour
- $T_{11} = 22$ hour
Case Study

- Results (Frequency : 500 year flood, \( Q=2,594 \text{ m}^3/\text{s} \))
  - Flood depth and flood wave propagation range according to frequency
  - Check the results for the flood depth at 2-hour intervals.

\( T_0 \) = Inundation start

\( T_1 = 2 \text{ hour} \)

\( T_2 = 4 \text{ hour} \)

\( T_3 = 6 \text{ hour} \)

\( T_4 = 8 \text{ hour} \)

\( T_5 = 10 \text{ hour} \)

\( T_6 = 12 \text{ hour} \)

\( T_7 = 14 \text{ hour} \)

\( T_8 = 16 \text{ hour} \)

\( T_9 = 18 \text{ hour} \)

\( T_{10} = 20 \text{ hour} \)

\( T_{11} = 22 \text{ hour} \)
Case Study

□ Results

○ Identification of flood wave velocity and flow velocity vectors according to frequency flood
○ Compare each velocity field at $t = 12$ hour after levee breach

Magnitude of velocity & Velocity vector (100 year flood)

Magnitude of velocity & Velocity vector (200 year flood)

Magnitude of velocity & Velocity vector (500 year flood)
Concluding Remarks & Future works
Concluding Remark

- The SCHISM model is well suited for inundation simulations because it reflects well wet / dry conditions for several cases.
- Compared with the experimental results in the literature, the SCHISM model can accurately simulate the inundation simulation.
- The propagation patterns and propagation velocity from the SCHISM are dependent on the mesh configuration (e.g., In case of triangular mesh (△), more accurate simulation is possible).
- From the sensitivity analysis, the SCHISM model is highly affected by the mesh orientation. Therefore, the attention is needed to construct the mesh based on understanding the physical meaning of the flood wave.
- When the inundation simulation was performed on the Jeonju stream in Korea, the propagation range and the maximum flood depth were affected by the flood discharges and the propagation patterns were different due to the geometry in flood plain and urban area.
Things should be followed:

- In-depth calibration & verification
  - Effect of sectional shape of levee breach
  - Effect of Froude number in main channel on flooded area
- Application into more field cases with monitoring data
- Economic analysis due to flood damage
  - Based on inundation map, economic loss can be calculated for flood insurance (e.g. FEMA Flood map service center)
  - Impact damage from flood wave on buildings, infra-structures and so on

Islam et al. (2015)
**Reference**


Thank you for your attention

Q & A