

APPLICATION OF iRIC SOFTWARE FOR FLASH FLOOD DISASTER PREDICTION IN LAOS AND THAILAND

WONGSA SANIT

Department of Civil Technology Education, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, sanit.won@kmutt.ac.th

URUYA WEESAKUL

Department of Civil Engineering, Thammasat University, Bangkok, Thailand, wuruya@engr.tu.ac.th

ABSTRACT

Indochina is one of the most disaster prone regions in the world. Floods are one of the most frequent natural disasters, with devastating impacts on agricultural, infrastructure, industrial and human life who live along river basins. Flood forecasting and early warning is one of the most effective flood risk management strategies to minimize the negative impacts of floods. Flood risk information, to be useful for planning and decision-making for risk reduction. The iRIC software is a free numerical simulation platform supporting a wide variety of applications for water science and engineering. This research is performed by iRIC software for flood disaster study in terms of analyzing dam-break and dike-breach flash flooding in Laos and Thailand. The results shown that the iRIC software can accurately calculate flash flood disaster for gauge and ungauged basins. Therefore, indicating that iRIC software playing important challenge for flood forecasting and early warning tool.

Keywords: Flash flood, flood disaster, Laos, Thailand, iRIC software

1. INTRODUCTION

The Asian summer monsoon system consists of two major and distinct components: the South Asian and the East Asian–western North Pacific summer monsoons. The former is strongly influenced by high rising topography in South Asia because of the anchoring effect of precipitation near the topography and mechanistically induced perturbations. The 2011 monsoon season saw one record flood event in Indochina across several countries and a few separate limited flood events parts of the same nations: Thailand, Cambodia and Myanmar and heavy flooding in Vietnam. By late October 2011, 1.2 million people have been hit by flooding in Cambodia, while the flooding in Thailand has affected close to 2.3 million people. Unrelated to the northern floods, Southern Thailand near Malaysia has been lashed with flooding in early November and again in December also affecting Chumporn Province. In the November event, Southern Thailand near Hat Yai was hit, North-central Vietnam had their own event in October. Myanmar had reported a series of limited but still deadly and destructive events from June to October. Floods in Thailand are regular natural disasters which happen nearly every year during the monsoon season. The monsoon seasons in the country are distinct by region, start from northern to southern and monsoon begins in June and ends in March. The rest of the nation has monsoons and/or frequent heavy intensity rainfall during summer season through October.

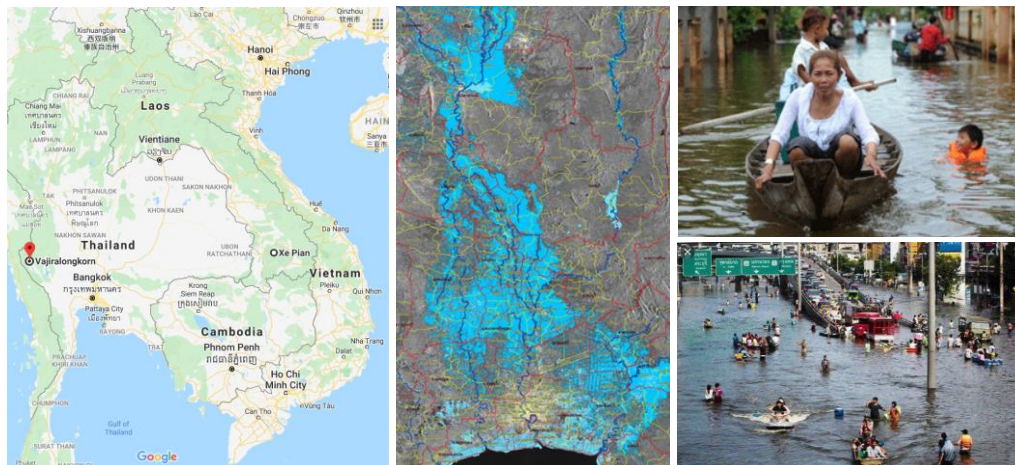


Figure 1. Study area of the Indochina. (<https://www.google.com/maps/>)

Although the high flooding that Indochina experienced due to storm surge from monsoon as due to extreme weather, it has brought more attention to the impacts of the regional climate change.

For urban areas have experienced water logging for the last few years. Even a little rain may cause severe problems for certain city areas, which are inundated for several days. The water depth in some areas may be as much as 0.5-1.0m, which creates large infrastructure problems for the city and huge economical losses in production together with large damages of existing traffic system, infrastructures, properties and goods (Figure 1.)

This study focus on three locations; Xe Pian Dam in Laos, Bang Saphan and Vajiralongkorn Dam in Thailand, which experience flash flood disaster for gauge and ungauged basins. Performance of the numerical simulation were applied to simulate flash flooding to show that iRIC software playing important challenge for flood forecasting and early warning tool. DEM represents land elevation data, which are crucial for estimating flood depth and storage volume of surface flooding. In addition, result presentation in form of flood inundation map are performed based on application of iRIC Software and Google Earth. Hence, the quality of the output depends on the quality of the DEM. Available free DEM from STRM DEM (NASA) and Land Development Department: LDD DEM, resolutions were 90m and 30m, respectively.

2. iRIC SOFTWARE AND MODEL SETUP

2.1 iRIC Software

The iRIC software is public domain interface for calculating flow, sediment transport and morphodynamics in rivers and other geophysical flows. This interface is completely free to any users and includes 13 models ranging from simple one-dimensional models through three-dimensional models. The Nays2DFlood, which is one of the models enclosed in the iRIC system, is a flood flow solver developed by Shimizu et al. (<http://i-ric.org/en>). Tools for creating these systems are supplied in iRIC webpage (Wongsa, 2013; Wongsa 2015; Nelson et al., 2016). This model can be used in a general, non-orthogonal coordinate system with adaptable grid. The architecture of a iRIC software consists of 3 functions: pre-processor, post-processor, and solver. (Figure 2). Pre-processor is for creating calculation lattices and setting calculation conditions, hydrologic conditions, calculation methods. Calculation lattices can be created from survey data such as river survey data and DEM data. Post-processor is for visualization and analysis of calculation results. Visualization of calculation results can be used for purposes such as creation of vector, contour, and other diagrams, as well as creation of graphs. Nays2DFlood is a flood flow analysis solver that relies on unsteady two-dimensional plane flow simulation using boundary-fitted coordinates as the general curvilinear coordinates.

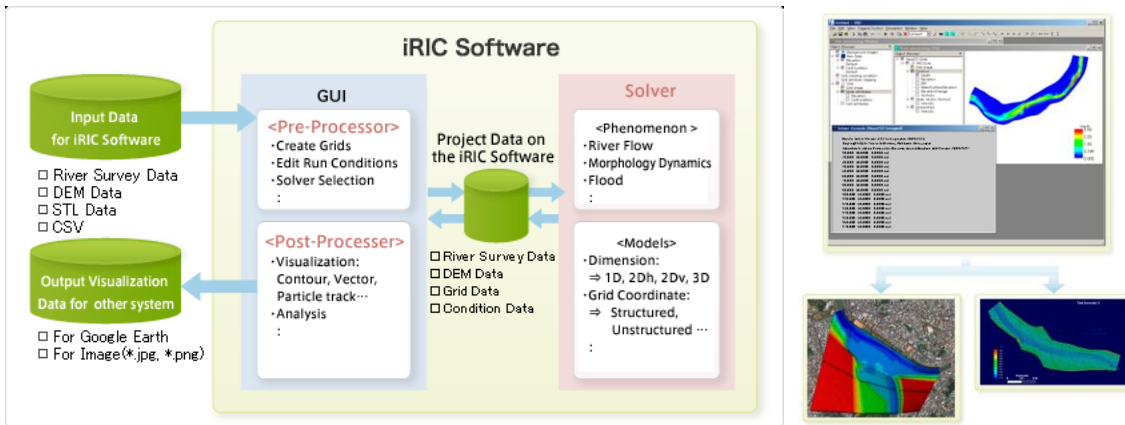


Figure 2. Architecture of the iRIC software (<http://i-ric.org/en/>).

The model employs time stepping with a choice of differencing schemes for advection of momentum, including the upwind scheme and the CIP (Cubic Interpolated Pseudo-Particle) scheme (Yabe et al., 1990). The water surface elevation is calculated using a successive relaxation technique. In order to consider the effects of roads and buildings on flood analysis, the governing equations of previous Nays2DFlood have been modified to express effects of obstructions by building and road against two-dimensional water flow. In numerical model, the governing equations for a two-dimensional plane flow field are written in a general, non-orthogonal coordinate system. However, we can rewrite the continuity and x - y momentum equations here in an orthogonal coordinate system for simplicity, and can be written as following (McMillan, and Brasington, 2007, Miura et al., 2011),

$$\frac{\partial h}{\partial t} + \frac{\partial \gamma_x h u}{\partial x} + \frac{\partial \gamma_y h v}{\partial y} = q_{in/out} \quad (1)$$

$$\gamma_v \frac{\partial u h}{\partial t} + \frac{\partial \gamma_x h u^2}{\partial x} + \frac{\partial \gamma_y h u v}{\partial y} = -\gamma_v h g \frac{\partial H}{\partial x} - \frac{\tau_x}{\rho} - h R_x \quad (2)$$

$$\gamma_v \frac{\partial v h}{\partial t} + \frac{\partial \gamma_x h u v}{\partial x} + \frac{\partial \gamma_y h v^2}{\partial y} = -\gamma_v h g \frac{\partial H}{\partial y} - \frac{\tau_y}{\rho} - h R_y \quad (3)$$

where, h is water depth, u and v are velocities, g is gravitational acceleration, H is water level, $q_{in/out}$ is the rate of water entering or leaving ground surface per unit area, including the excess rainfall, the upstream catchments inflows, the influent and effluent of sewer networks, and the overland flow drained by hydraulic facilities, τ_x and τ_y are bed shear stress, ρ is water density, x , y and t are direction and time, respectively.

A building might occupy a significant, but not full, area within a computational grid, which has similar or slightly higher size than the building scale. Neither the ground elevation nor the roof elevation is appropriate to interpret the condition. γ_x , γ_y and γ_v are the parameters for indicative of the effects of buildings against two-dimensional flow, which can be expressed as following.

$$\frac{\tau_x}{\rho} = c_f u \sqrt{u^2 + v^2} \quad (4)$$

$$\frac{\tau_y}{\rho} = c_f v \sqrt{u^2 + v^2} \quad (5)$$

$$h R_x = \frac{h}{2} C_d' (1 - \gamma_x) u \sqrt{u^2 + v^2} \quad (6)$$

$$h R_y = \frac{h}{2} C_d' (1 - \gamma_y) v \sqrt{u^2 + v^2} \quad (7)$$

$$C_f = \frac{g \gamma_v n_m^2}{h^{1/3}} \quad (8)$$

where, C_f is a drag coefficient of shear stress, n_m is Manning's roughness parameter and C_d' is drag the ratio of a drag coefficient to typical length of building in a calculation grid.

There are consisting of 4 steps for numerical model simulation. First, the calculation grids are created from DEM data are used to create a grid and to determine the attributes of each node or cell by interpolating relevant values. Second, the calculation parameters were set to the model. The conditions of study are based on real parameters. Third, model is simulating in a small time step. Finally, the numerical results are visualized to graphic animation.

2.2 Model setup

For model simulation, grid sizes = 100-200m were adopted, with time step, Manning's roughness coefficient and parameter γ_v are $\Delta t = 0.5-2.0s$, $n_m = 0.03-0.035$, and $\gamma_v = 1.0$, respectively. Geographic data are used to create a grid and to determine the attributes of each node or cell by interpolating from SRTM DEM (resolution 90 m) and Land Development Department: LDD DEM (resolution 30 m) data. For model simulation, assumed inflow discharges which estimated from dam breach portion/overflow, was set as upstream boundary condition.

3. STUDY AREAS

3.1 Xe Pian Dam, Champasak, Laos



Figure 3. Xe Pian Dam, Champasak, Laos flooded in 2018. (<https://baomoi.com/>)

The Xe Pian -Xe Namnoy power project is located on the Bolaven plateau, approximately 550km southeast of the capital Vientiane. The project includes the construction of three dams: Houay Makchan Dam, Xe Pian Dam, and Xe Namnoy Dam along the Mekong River. In addition, the project includes three auxiliary, or saddle dams, such as the Saddle Dam D which collapsed. It includes a large storage reservoir on the Xe Namnoy River, underground tunnels, shaft waterways, and an open-air powerhouse featuring four generator units. The Xe Namnoy reservoir was designed to be 73m-high and 1,600m-long, and have the capacity to store approximately 1,043 MCM of water. Approximately 1,000MCM of water will be collected from Houay

Makchan and Xe Pian catchments and stored at the Xe Namnoy reservoir. The power house, which was located at the base of the valley, would generate power using gravitational force of fall and flowing water from a height of 630m. (Figure 3). The Saddle Dam D, part of a larger hydroelectric dam system under construction in Champasak Province, was collapse. The dam collapse occurred around 8 p.m. on Monday 23 July, 2018 and caused immediate flash flooding through the villages downstream. The dam collapse lead to widespread destruction and homelessness among the local population in neighbouring Attapeu Province. As of 25 September, 40 people were confirmed dead at least 98 more were missing and 6,600 others were displaced.

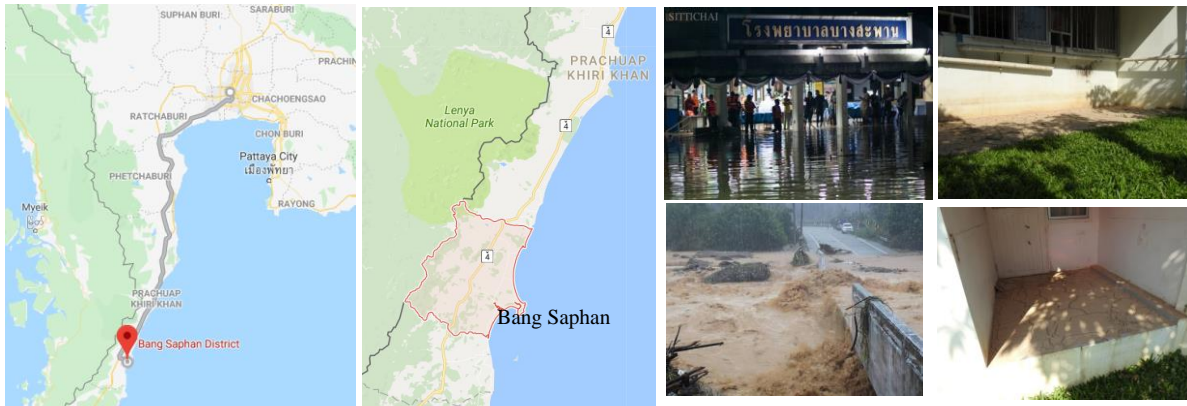


Figure 4. Bang Saphan, Prachuap Khiri Khan, Thailand.



Figure 5. Vajiralongkorn Dam, Kanchanaburi, Thailand.

3.2 Bang Saphan, Prachuap Khiri Khan, Thailand

Bang Saphan District is located in the central of Prachuap Khiri Khan Province, southern of Thailand. It is a long and narrow coast stretching to the south, the climate is classified as tropical. Geographically, Bang Saphan is a moderate plain with elevations varying from sea level to 1,200 m (Myanmar border). The annual rainfall is 1,176 mm. Bang Saphan's neighboring districts are Thap Sakae to the north and Bang Saphan Noi to the south, to the west is Myanmar, and to the east the Gulf of Thailand. As of January, 1017 heavy storm and flash flooded in Southern part of Thailand, 95 people were confirmed dead and affected 1,815,618 people (Figure 4.)

3.3 Vajiralongkorn Dam, Kanchanaburi, Thailand

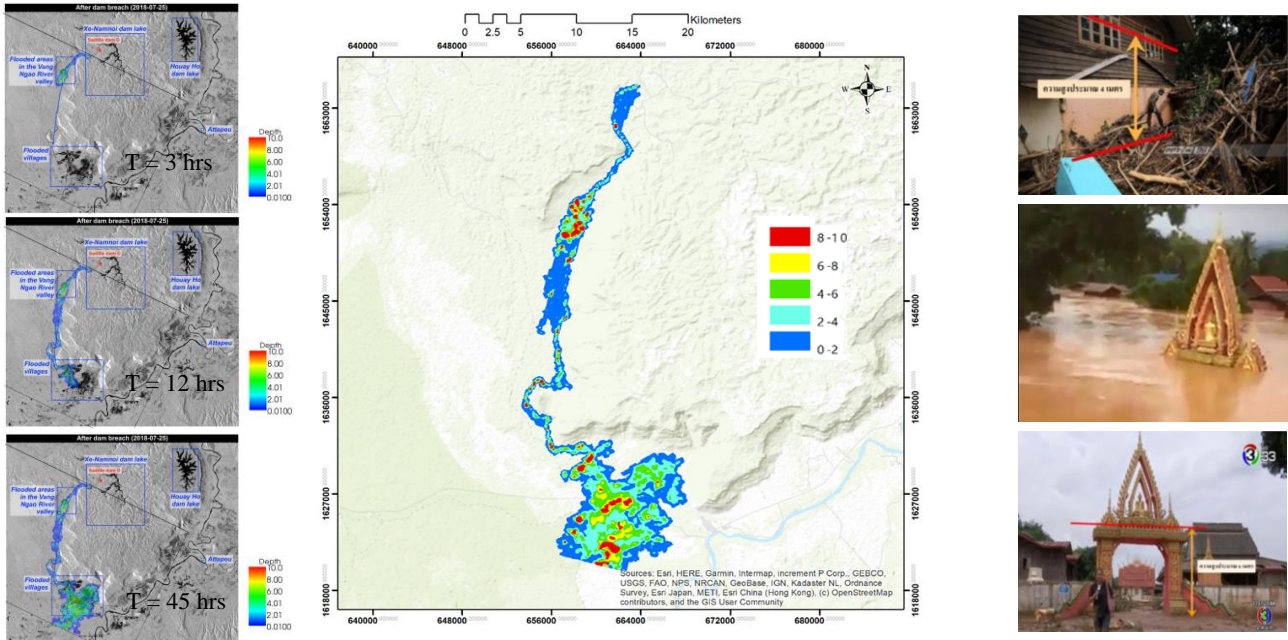
Vajiralongkorn Dam is a concrete-faced rock-fill dam (CFRD) located at Thong Pha Phum District, Kanchanaburi Province, which is in the west, 276 km from Bangkok. Topographically, it is covered with timber and evergreen forests, and cover the source valleys of the river Kwae Noi, which merge Kwae Yai at Kanchanaburi city to form the Mae Klong River. The monsoon season runs from May through October, with heavy rainfall, and annual rainfall is 1,065 mm. The dam lies across the Khwae Noi River and supplies a 300 MW hydroelectric power station. The dam was built and is managed by the Electricity Generating Authority of Thailand: EGAT (Figure 5).

4. RESULTS AND DISCUSSION USING THE TEMPLATE FOR SEVERAL COMPONENTS

4.1 Xe Pian Dam, Laos, collapse flooding in 2018.

The analyses of the Xe Pian Dam collapsed in 2018 have been carried out based on ungagged river basin, without topography and outflow data. The resolution 90*90m from SRTM DEM, assumed outflow from breach portion has been used. The flooded damage areas downstream from Saddle Dam D have shown in Figure 6. For model simulation, grid size 100m x 100m were adopted, with time step and manning's roughness parameter are $\Delta t = 1.0s$ and $n_m = 0.03-0.04$, respectively. It was found that manning's roughness $n_m = 0.03$ has been used in entire simulation domain. The time series flood depths for those selected locations are

also shown in Figure 6(a). Close matching of simulation results from iRIC model and observed satellite data ensures that the model was able to reproduce the actual flooding situation, maximum flood height is about 4 m as shown in Figure 6(c). Flood water propagating downstream and attacked flooded village after 10-12 hours after Saddle Dam D collapse. The simulated maximum flooding levels have been traced for several selected locations along with the available actual flood marks to provide a general idea on how the simulated flood depths deviate from the real data. The figure shows a clear close agreement between the simulated flood depths and the observed flood marks. Good matching of model results and actual data ensures that the model was able to reproduce the actual flooding situation, Saddle Dam D collapse, which is ungagged river basin, Xe Pian Dam, Laos.



(a) Time = 3, 12, 45 hours (b) Simulated maximum flood depth (c) Actual flood marks
Figure 6. Simulation results of Saddle Dam D collapsed, Xe Pian Dam, 2018.

4.2 Bang Saphan, Thailand flooding in 2017

The analyses of the Bang Saphan District flooding problem that caused by heavy rainfall event as Figure 7, flash flood from mountainous to lower area, seaside, Gulf of Thailand. In this area, there are some of the most critical flooding points, including Sukhumvit Road, bridge, Bang Saphan city and the surroundings of Bang Saphan Hospital. The government has advised more than 1,000 households in five villages located in the back of the reservoirs in the province to evacuate to a safe place. For model simulation, grid size 100m x 100m were adopted, with time step and Manning's roughness parameter are $\Delta t = 0.5s$ and $n_m = 0.035$, respectively. The resolution 30*30m from Land Development Department: LDD DEM, assumed released outflow from Khlong Loi Reservoir has been used. The flooded damage areas downstream from Khlong Loi Reservoir have shown in Figure 8. The simulated maximum flooding levels have been traced for several selected locations along with the available actual flood by field survey. Good matching of model results for both depth and duration with field data ensures that the model was able to reproduce the actual flooding situation.

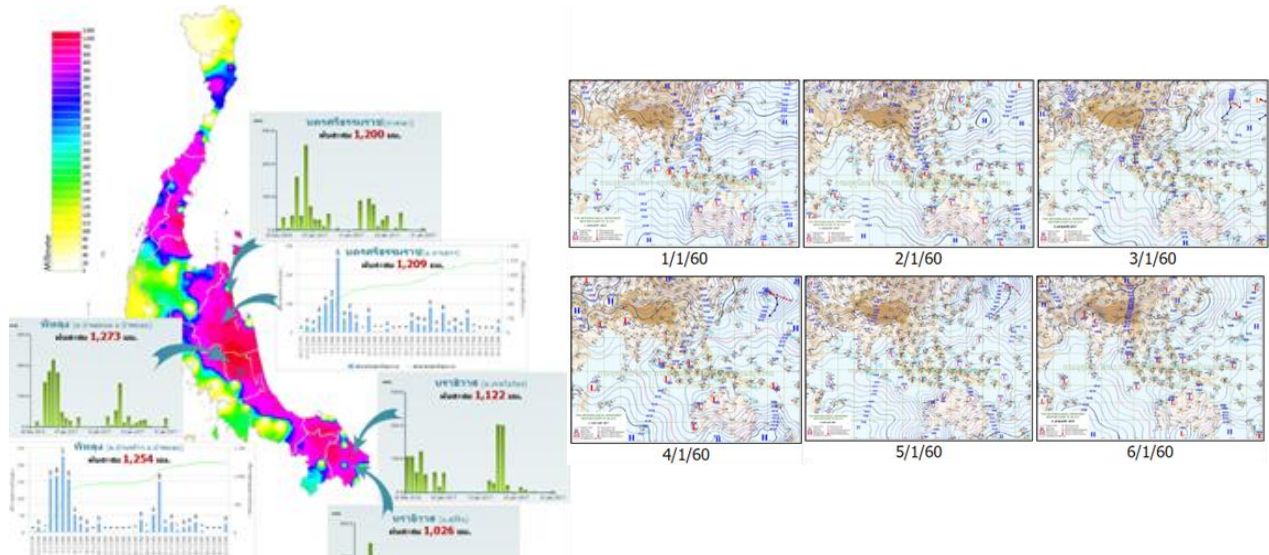
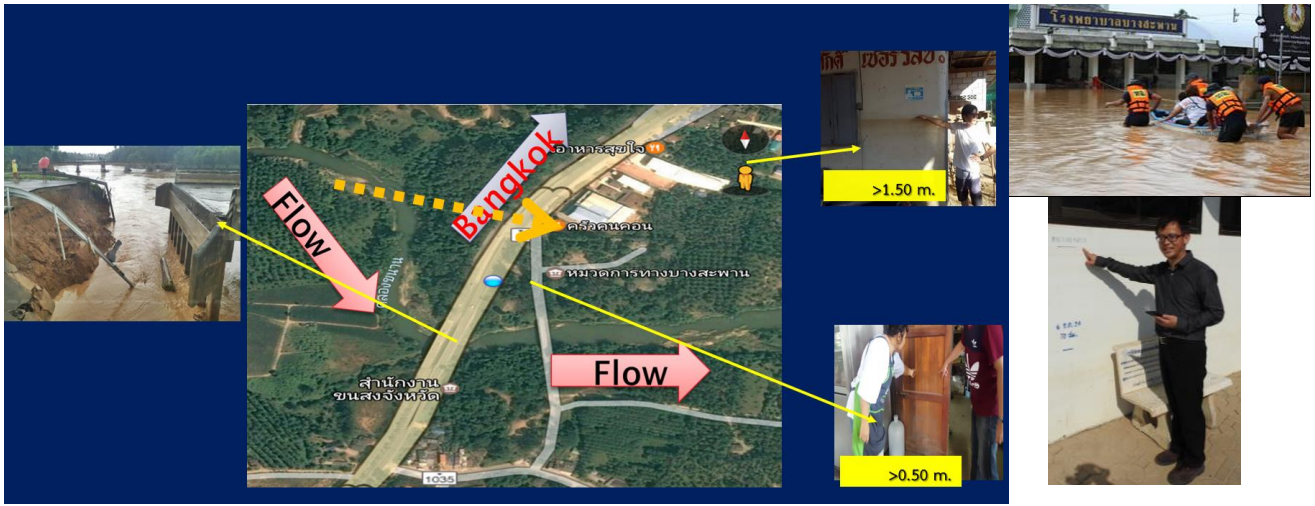
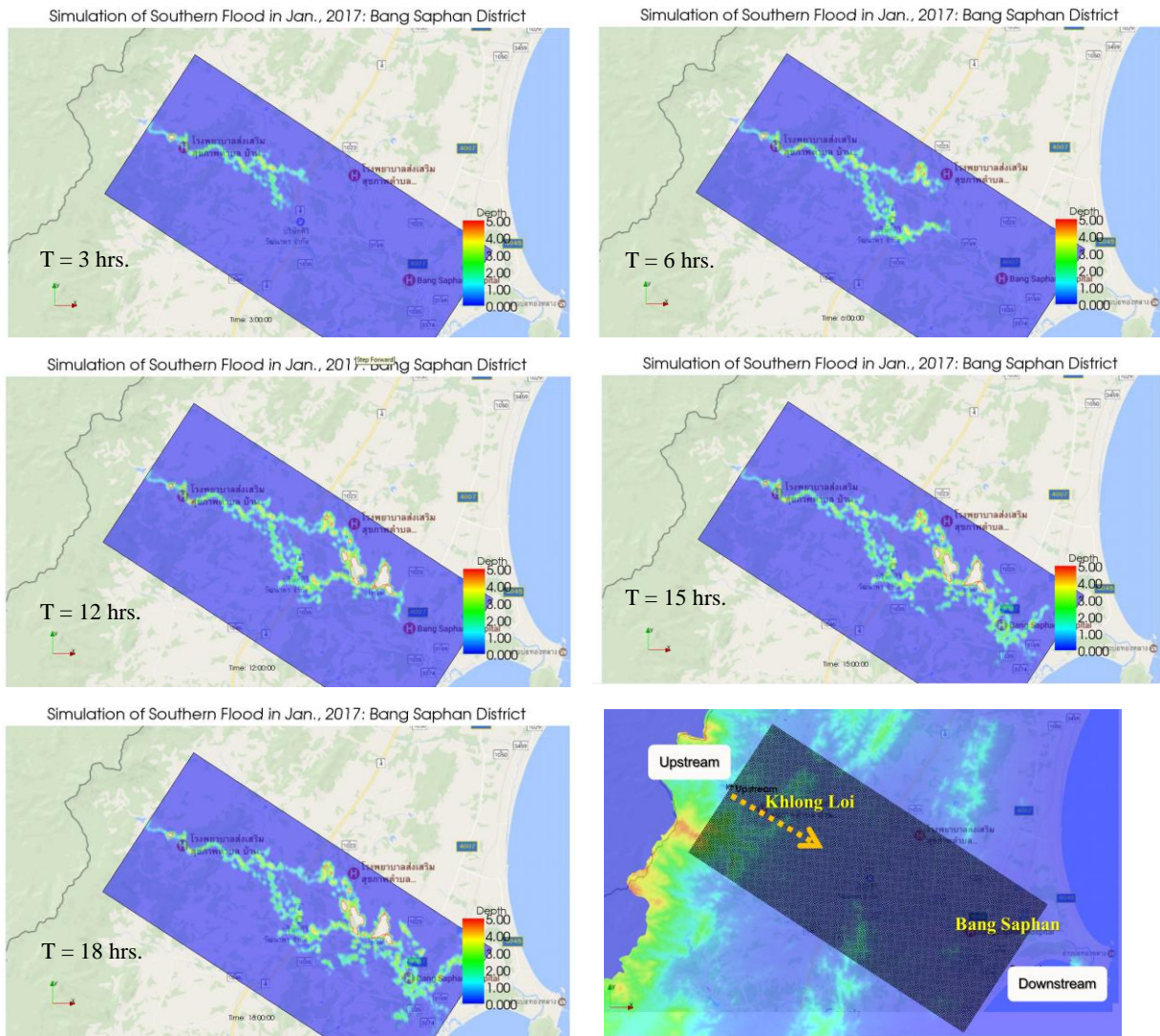


Figure 7. Heavy rainfall event during January, 2017 (Himawari-8).



(a) Flood damage by heavy rainfall in Bang Saphan District.



(b) Time series of simulation results and grid of Bang Saphan flash flooded.
Figure 8. Flood damage and simulation results of Bang Saphan flash flood, 2017.

4.3 Simulation of Vajiralongkorn Dam, Thailand flooding

The analyses of the Vajiralongkorn Dam flooding problem that caused by heavy rainfall event, release flooding from dam spillway to downstream areas in Kanchanaburi Province. The resolution 30*30m, LDD DEM, grid size 200m x 200m were adopted, with time step and manning's roughness parameter are $\Delta t = 2.0s$ and $n_m = 0.03$, respectively. The assumed rainfall with release flow hydrograph and free flow have been used for upstream and downstream boundary condition, respectively. Good performance of model results ensures that the model was able to reproduce the actual flooding situation. The time series of flood depth and

propagation is shown as Figure 9. A series of maps created to demonstrate the change of flooded area during the inundation process.

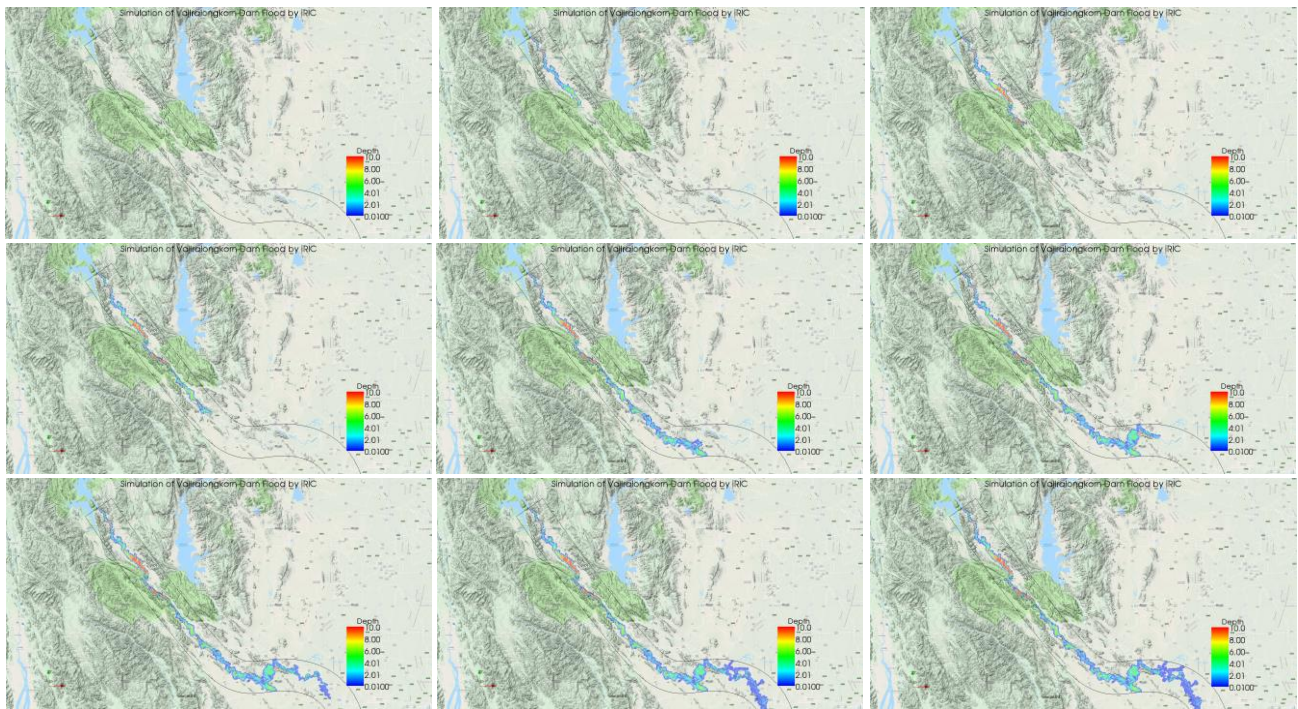


Figure 9. Time series of simulation grid and results of Vajiralongkorn Dam, Thailand flooding.

The above results can be shown as flood risk and warning map in different index and/or at different grid size, so the flood risk warning has a high spatial resolution. Also the result could be used more precisely in real-time flood management. In fact, different area within the city could have different flood risk warning level, not the same level for the whole city. In addition, DEM accuracy and grid size may have impacts on inundation simulation, especially on the catchment boundary. Currently, the finest available DEM grid size are 90m and 30m, which should be enough for remote areas ungauged and gauge river basin, respectively.

5. CONCLUSIONS

This study presented a physically based distributed hydrological for ungauged and gaged river basin flooding by using iRIC software. This study explored the potential simulation for 3 cases; (1) Xe Pian Dam, Laos, collapse flooding in 2018, (2) Bang Saphan, Thailand flooding in 2017 and (3) Vajiralongkorn Dam, Thailand flooding simulation. The results shown that the iRIC software can accurately calculate flash flood disaster for gauge and ungauged basins. Good matching of model results for both depth and duration with field data ensures that the model was able to reproduce the actual flooding situation. Therefore, indicating that iRIC software playing important challenge for flood forecasting and early warning tool.

ACKNOWLEDGMENTS

We are indebted to Royal Irrigation Department (RID), Department of Highway (DOH) for providing some fields data.

REFERENCES

- McMillan, H. K., and Brasington, J. (2007) "Reduced complexity strategies for modelling urban floodplain inundation." *Geomorphology*, 90(3-4), 226-243.
- Miura, S., Kawamura, I., Kimura, I., and Miura, A. (2011) Study on inundation flow analysis method in densely populated urban area on alluvial fan, *Journal of Hydr. Eng. JSCE*. 67(4): 979-984.
- Nelson, J.M., and 16 co-authors. (2016) The international river interface cooperative: Public domain flow and morphodynamics software for education and applications, *Journal of Adv. in Water Res.*, 93: 62-74.
- Wongsa, S. (2013) 2011 Thailand Flood, *Journal of Disaster Research*, 8(3):380-385.
- Wongsa, S. (2015) Experiment and Simulation on Earthen Embankment Breach, *Journal Geoscience and Environment Protection*, 3:59-65. (<http://dx.doi.org/10.4236/gep.2015.310010>).
- Yabe, T., Ishikawa, T., Kadota, Y., and Ikeda, F. (1990) A Multidimensional Cubic-Interpolated Pseudoparticle (CIP) Method without time splitting technique for hyperbolic equations, *Journal of the Physical Society of Japan*, 59(7), 2301-2304.