

## Chapter 29

# Adaptation to Flood Risk in Areas with Cultural Heritage



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**Abstract** The present paper discusses a novel approach for flood risk assessment and mitigation in areas with cultural heritage. The ambition of the present paper is to provide a ‘road map’ of the holistic way of working towards climate change adaptation which was introduced in some earlier publications of authors. It is designed to provide the reader with some basic ideas of the holistic view of flood risk, its practicalities and supporting frameworks for implementation. The work was undertaken in Ayutthaya heritage site in Thailand. The approach combined qualitative and quantitative data and methods. The qualitative part of analysis involved a more active role of stakeholders whereas the quantitative part was based on the use of numerical models and engineering principles. Based on the results obtained, this paper argues that perceptions of flood hazard and flood risk (i.e., qualitative part of analysis) yield a richer understanding of the problems and should be incorporated into the engineering analysis (i.e., quantitative part of analysis) to achieve more effective climate change adaptation and flood risk mitigation. Several benefits can be achieved applying the approach advocated in this paper. First, the combination of qualitative and quantitative data and methods opens up new views for risk analysis and selection of measures. Second, since it is based on a more active stakeholder participation the potential for success of this novel approach should be higher than any of the traditional approaches. Finally, design of measures can generate more favourable alternative as it employs a combination of measures that can deliver multiple benefits to stakeholders.

**Keywords** Adaptation · Holistic flood risk assessment · Qualitative data and methods · Quantitative data and methods

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## 29.1 Introduction

The world is experiencing a growing number of natural hazards-induced disasters where floods are most dominating the records. One way of responding to natural disasters, and particularly to flood related disasters is by collecting spatial and temporal data and developing numerical models (see for example, Mynett and Vojinovic 2009). With reliable data and models it is possible to analyse effects of various scenarios concerning urbanization, population growth and climate change and identify mitigation measures (Alves et al. 2016). However, as invaluable as they may be, a number of issues associated with data and models need to be carefully considered in order to gain full benefits, such as reliability of data, models calibration, computing time, etc., see for example Vojinovic and Tutulic (2009) and Vojinovic et al. (2011).

In 2011, following five consecutive storm events, Thailand experienced one of the worst floods in its history. The World Bank estimated 1,425 billion baht (US\$ 45.7 billion) in economic damages and losses due to this flood event. As reported in Thailand Flood Executive Summary by Hydro and Agro Informatics Institute (HAI), 90 billion square kilometres of land was inundated by floodwaters, which is approximately more than two-thirds of the total country area, and 65 of Thailand's 77 provinces were announced as flood disaster zone. Six provinces were particularly affected, namely, Nakornsawan, Nakorn Sri Thammarat, Pra Nakorn Sri Ayutthaya, Suphan Buri, Pichit, and Phisanulok. Ayutthaya province, which is located about 80 kms north from Bangkok, has been submerged for approximately two months with flood depths ranging from 1 to 3 m. Floodwater entered the Ayutthaya island from the north, inundating the World Heritage Site and major industrial estates and forced evacuations. Figure 29.1 depicts aerial views of the Chao Phraya river basin before and during floods in 2011.

Most of the land area in Ayutthaya province is used for agricultural purposes. The historical park, which is part of UNESCO World Heritage sites, is located in the Ayutthaya Island. In the period 14th to 18th century, this area was a capital of Siam and grew into an important economic center. The 2011 flood event had caused significant damage to the historical sites and buildings (see for example ICOMOS 2014). Besides severe flooding, some areas also suffered from land subsidence. Since the historical sites and buildings contain precious cultural value for local population the damages incurred are immense and practically impossible to express in monetary terms.

Following the 2011 flood event, the government of Thailand collaborated with international and national institutions in the assessment of flood damages and identification of possible mitigation measures at both regional and local levels. However, most of the proposed measures can be regarded as “traditional engineering solutions” which are sometimes also referred to as “hard” engineering or “grey” infrastructure measures. Examples of such measures are various kinds of defences that provide barriers flood waters, construction and/or amplification of pipe networks and channels to increase conveyance and storage characteristics, etc. These measures are well established but lack in integration with surroundings and conservation of the heritage



**Fig. 29.1** Aerial view of Chao Phraya river basin before (left) and during (right) floods in 2011 (Source Nasa Earth observatory\_25102011)

character. To conserve the integrity of monuments and heritage compositions, finding the appropriate flood protection at a World Heritage Site requires more appealing structures that can better fit with the character of the area. In 2013, UNESCO launched the project “Developing a Flood Risk Mitigation Plan for Ayutthaya World Heritage Site” which was funded by the Asian Development Bank (ADB) and aimed at developing a flood risk mitigation plan for Ayutthaya World Heritage Site. The authors of this paper had the privilege to be involved in that work.

## 29.2 Materials and Methods

Figure 29.2 depicts the framework which was used to address the main objective and aim of the ADB-funded project which is the Community Based Disaster Risk Management (CBDRM). There are six main components of this framework: stakeholder identification and mapping, risk communication study, participatory flood risk assessment, participatory disaster risk management plan, participatory monitoring and evaluation. This paper focuses on the two main aspects: stakeholder analysis and the use of numerical modelling for hazard delineation, vulnerability and risk assessment. An important step for the development of the numerical model is the acquisition of the necessary data through experts and stakeholders’ interviews, field inspection and measurements. Data examples include: hydrological and hydraulic data (i.e. rainfall time series, catchment characteristics, drainage system, etc.), geographical data (i.e. DEM, surface features and land use), the knowledge of existing flood

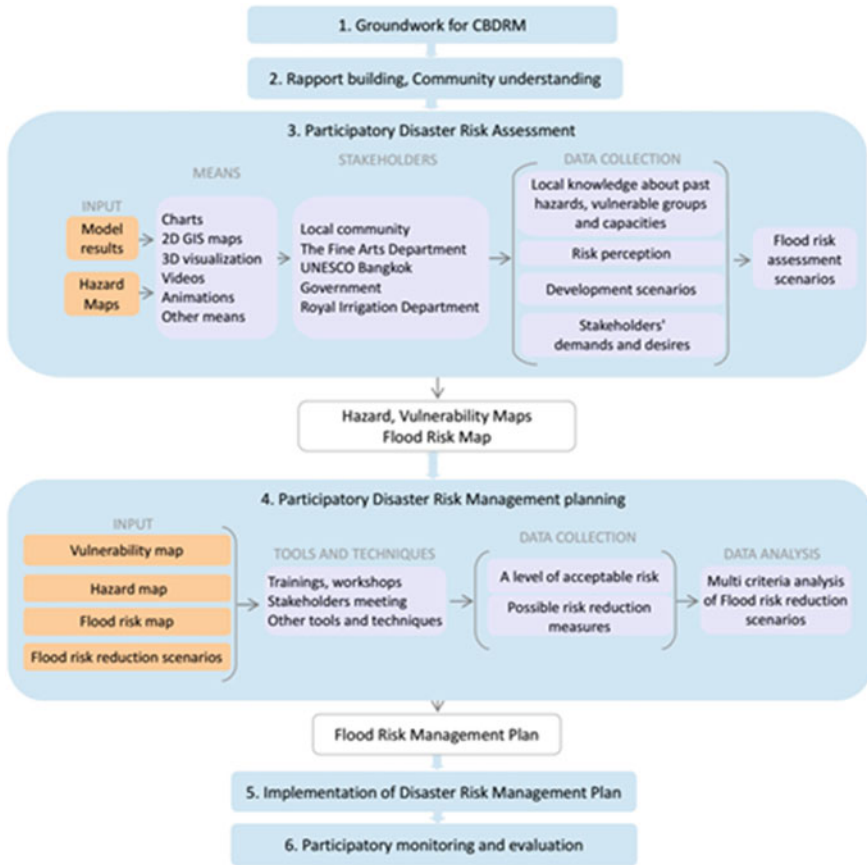


Fig. 29.2 Framework used in the present work

protection measures, and long-term cultural and heritage plans for the case study area. From these data sets, coupled 1D/2D models were instantiated which were subsequently used for the participatory flood risk assessment, Fig. 29.2. The actual risk assessment work combines hazards and vulnerabilities. The models were used to test various scenarios combining climate change, urbanisation and population growth projections. Moreover, the analysis also considered the terrain data for identifying the location of measures and further modification of the 2D model domain to introduce measures such as detention and retention ponds. The model results were presented to stakeholders and their feed-back was obtained. The feedback from stakeholders was necessary in order to come up with solutions that are more acceptable and appealing.

The key stakeholders for the Ayutthaya case study are the Fine Art department, local communities and authority, the government, UNESCO Bangkok, and the Royal irrigation department. The flood mitigation measures are classified into two groups; regional flood mitigation measures and local flood mitigation measures.

**Fig. 29.3** Modelling framework: 1D-2D model where 1D is used for the river network and 2D for the terrain in the Ayutthaya Island



The hydrodynamic models used in the present work are MIKE 11 and MIKE 21 models and the flood event used for simulation is the event from year 2011 (Fig. 29.3).

### 29.3 Results and Discussion

The results from this study focus on two main aspects of the general framework presented previously. First aspect deals with identification of the key stakeholders and their feedback about the preferred measures. Second aspect deals with discussion of results obtained from the numerical model.

#### *Stakeholder Analysis*

Stakeholders’ analysis included stakeholders’ characterisation and production of a stakeholders’ interactions/dependences map depicting their positions and interrelations. Stakeholders’ analysis within the present work aimed at providing the insight of existing administrative system, legal action, and practical action systems with respect to flood risk management.

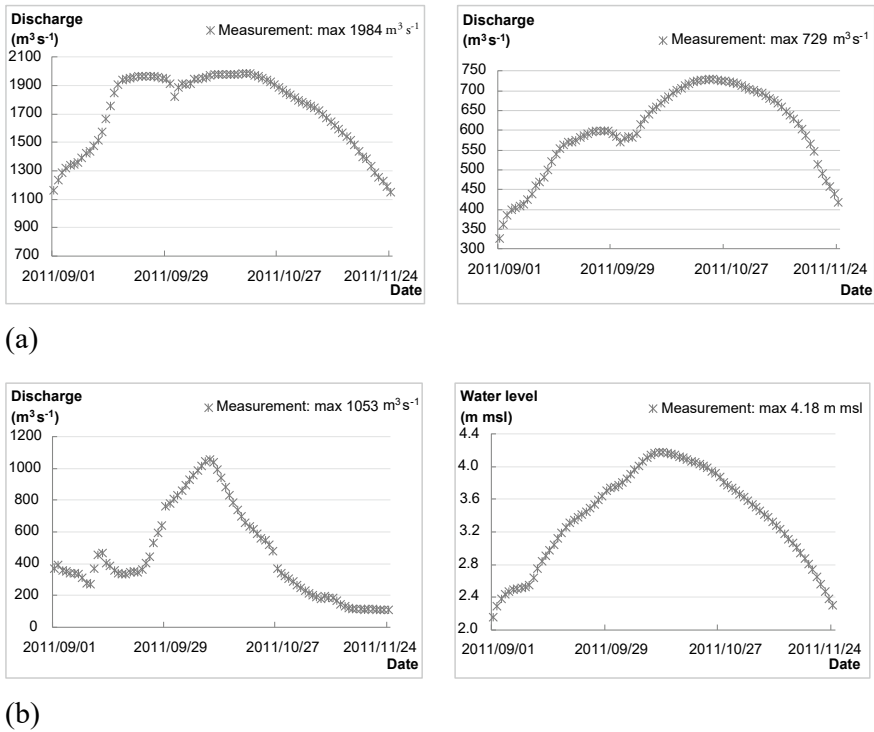
The following categorisation of stakeholders is based on the role and relevance of the stakeholders for flood risk management on Ayutthaya Island. Three groups were differentiated for stakeholders’ categorisation:

- core stakeholders;
- secondary stakeholders;
- tertiary stakeholders;

Through this analysis the most important stakeholders were identified and these are: Fine Art department (Ministry of Culture), local communities and authority, the government, UNESCO Bangkok, and the Royal irrigation department.

*Flood Modelling Work*

As mentioned previously, 1D and 2D models were built in MIKE 11 and MIKE 21. The 1D model was calibrated with discharge and water level data collected at points A1, A2, A3 and A4 (Fig. 29.4). The calibration results are discussed in Meesuk et al. (2017). The 20 × 20 m DEM resolution was used as an input into the 2D model. The time step used for simulation was 5 s and the simulation period was between 1/07/2011—30/11/2011.



**Fig. 29.4** Time series input at boundaries: (a) discharges of Chao Phraya River (location A1) and discharges of Lopburi River (A2), (b) discharges of Pasak River (location A3), and water levels of Chao Phraya River (location A4)

By merging computer vision techniques with advanced photogrammetry, high-resolution topographic maps were created to support this project. The so-called Structure from Motion (SfM) technique was applied and identified structures on the surface which were important for numerical modelling purpose.

Example of model results obtained is given in Fig. 29.5 (see also Vojinovic et al. 2016) (Fig. 29.5). The flood hazards were mapped on the basis of computed water depths and velocities (Fig. 29.6).

The overall simulation results have shown that the combination of measures such as detention pond, improvements of the local drainage and raising the UThong Road (which currently acts as a dyke) would substantially reduce the flood risk in the Ayutthaya area. The following Fig. 29.7 illustrates locations for some of the key drainage and flood protection measures in the Ayutthaya area. Special characteristics of the measures selected, which were of interest for this heritage area, were identified through discussions with local stakeholders. For instance, the relevance of reviving ancient canals, or the interest on retention and detention areas which could be designed to be used as multifunctional spaces.

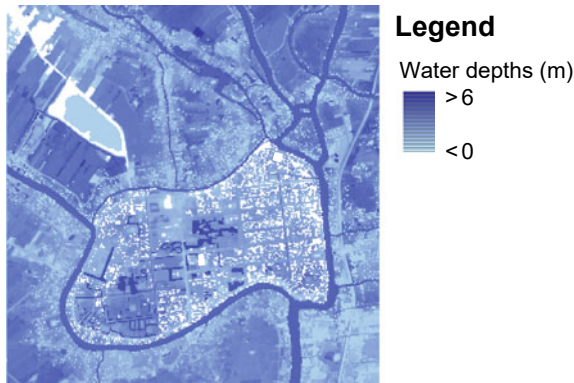


Fig. 29.5 Example of the 1D/2D model result



Fig. 29.6 Example of hazard assessment (existing situation—left, and incorporation of new flood protection measures—right); The hazards were substantially reduced with the proposed measures



**Fig. 29.7** Illustration of the key drainage and flood protection measures in the Ayutthaya heritage area

## 29.4 Conclusions

Destruction of heritage properties through disasters has a considerable effect on national and local communities, not only because of the cultural importance of heritage assets but also because of their socio-economic value. The present work addresses the issue of adaptation to flood risk in areas with cultural heritage. The work was undertaken in Ayutthaya, Thailand. The work performed highlights the importance of stakeholder participation, numerical modelling and innovative design in order to achieve adaptive capacity of flood protection measures while preserving the heritage character of the area.

The work undertaken fills the gap in the current methodologies by advancing the flood risk mitigation practice at heritage sites. It aims to provide engineers, local authorities and utility managers with an example of how to approach flood risk mitigation at such locations.

The framework developed and implemented was effective in the evaluation and selection of flood risk management measures and some of the proposed works are currently being implemented.

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