Disaster response and river infrastructure management during the 2015 Myanmar floods: A case in the Bago River Basin

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ABSTRACT

In July-August 2015, massive floods caused extensive and severe damage throughout Myanmar. We investigated the disaster response of the Myanmar government, prevailing weather conditions, and river infrastructure function in the Bago River Basin. We found that disaster risk reduction was managed through the Emergency Operation Centre, provided for in the National Natural Disaster Management Law, enacted in 2013. For the first time the disaster response system in Myanmar functioned also at a local level, with local agencies sharing relevant data and providing information to the public. It was evident that authorities in the Bago River Basin had learnt from the floods of 2011 and had implemented structural and non-structural measures for flood risk reduction.

1. Introduction

1.1. Background

On 16 July 2015, torrential rain started in the northern part of Myanmar. The rain caused extensive and severe floods throughout Myanmar. The floods produced a large number of evacuees, especially in the Sagaing Region (399,567 people evacuated); Magway Region (308,046 people evacuated); and Ayeyarwady Region (505,761 people evacuated), located north to south along the Ayeyarwady River\textsuperscript{[14]}. Although the Myanmar government, international organizations and NGOs took countermeasures against the disaster and provided humanitarian aid, a lack of information restricted their responses. In most areas of Myanmar, and the rural areas in particular, traffic and information networks are not yet developed.

In August 2015, our investigation team collected information from the Bago Region in the Bago River Basin, an area that was comparatively easy to access. This article is based on information collected at this time and information gathered at the same site in June and July 2015. We analyze the response of the Myanmar government to the 2015 floods and the effectiveness of its flood disaster risk reduction systems.

1.2. Previous studies and purpose of this article

The damage caused by Cyclone Nargis (2008) prompted many studies and reports on disaster risk reduction in Myanmar and the response of international organizations and NGOs to emergencies [1,3,4,10,15,16,17,19]. Otherwise, academic papers on flood disasters in Myanmar are few. This is due to the limits placed on academic organizations during the long period of military rule in the country [11,20,6,7].

Tahira et al.\textsuperscript{[17]} studied documents and conducted interviews to provide a complete picture of disaster management in Myanmar. Since Cyclone Nargis in 2008, through transition to civilian rule and the Bago River flood in 2011, and Cyclone Mahasen in 2013, the disaster management system of the Myanmar government has changed and improved drastically. However, the system is still being developed.

This article begins with a review of weather conditions at the time of the Myanmar floods in 2015. Then it examines how the Myanmar central government and local governments responded to the floods; the state of river management facilities; and the flood prevention function of canals. Investigation results are reviewed, and the article ends by considering future challenges and the ongoing development of a disaster risk reduction system in Myanmar.
2. Overview of weather conditions during the 2015 Myanmar floods

The Situational Report \[13\] concluded that the floods were the result of torrential rain in the northern part of Myanmar around 15 July, and the rain brought by Tropical Cyclone (TC) Komen from 26 July to 2 August. We defined six rainfall areas along the path of the cyclone (Fig. 1), including the Bago River Basin. Fig. 2 shows the 1-day moving average time-series of the Global Precipitation Measurement (GPM) satellite product \[5\], which has been area-averaged over defined areas (see Fig. 1) from 10 July to 5 August. Figs. 2a and 2b show two distinct rainfall peaks, centered on 16 July and the occurrence of TC Komen. Fig. 2a shows the 1-Day Moving Average Rainfall (time-series) in the five main rainfall areas, while Fig. 2b shows the 1-Day Moving Average Rainfall (time-series) in the flood areas of the central plain and deltaic region.

As shown in Fig. 2a, from 15 to 17 July there was rain across Myanmar. The northern region of Myanmar received the most, the deltaic area almost half as much. The amount of rain in the west was similar to that in the north, although it came later. In the central and eastern areas of Myanmar, the amount of rain was similar to that in the deltaic area.

The time-series in Fig. 2a show that the western Myanmar area, covering the Chin and Rakhaing States, received the highest rainfall. The rainfall over northern and eastern Myanmar arrived one day and two days earlier, respectively. Rainfall over the central and delta areas
came several hours later, after the time peak in the western Myanmar area.

Fig. 2b shows that Bago River Basin experienced two rainfall peaks during TC Komen. This amount of rainfall was enough to cause severe flooding in the basin: rain on 14 and 18 July had saturated the soil. Conditions in the outflow area of the Bago River Basin were another cause of the flooding. If water levels in the outflow area are high, as they were, the peak discharge from the basin cannot flow directly to the sea.

The Bago River Basin is connected to the Ayerawaddy River through the Yangon River (Supplementary Fig. 1). Inundation of the lower deltaic area of the Ayerawaddy River can affect outflow from the Bago River Basin. As shown in Fig. 2b, rainfall on 15 July in the northern region potentially caused a peak discharge, with water flowing from the central plain to the delta area and flooding it. High water level conditions in the Bago and Yangon rivers worsened the flooding conditions.

3. Disaster response of the central government

3.1. Outline of disaster response in Myanmar

Myanmar had 32 ministries as of August 2015, 24 of which are concerned with disaster response [17]. Since Cyclone Nargis in 2008, disaster management functions in Myanmar have been strengthened by international collaboration. At that time, Myanmar was under military rule and internationally isolated because of economic sanctions applied mainly by Western countries. The need for aid after Cyclone Nargis forced Myanmar to accept and participate in international efforts, a response that was recognized domestically and internationally as advanced given the political situation.

Fig. 3 shows the water disaster response system for the 2015 Myanmar floods. It illustrates the relationship between the National Natural Disaster Management Committee (NNDMC), the Emergency Operation Centre (EOC), and related committees [14]. Special authorities support emergency responses during disasters, and coordinate long-term recovery planning at the central government level. The EOC assists the NNDMC through the National Disaster Management Work Committee. This committee is operated by the manager of the Relief and Resettlement Department (RRD) of the Ministry of Social Welfare, Relief and Resettlement (MSWRR). The Recovery Coordination Work Committee was established on 10 August "YEAR*" with the Minister of Construction as chairman. The main concern of this committee is supporting long-term recovery planning and coordination, including reconstruction and rehabilitation.

The disaster response system and activities of the Myanmar government are summarized in a timeline at Table 1, while in the following passage we describe the efforts of the Natural National Disaster Preparedness Central Committee (NDPCC), the NNDMC and the EOC in responding to disasters. This discussion considers two specific periods: after Cyclone Nargis in 2008, and the floods of 2015. Here it is important to note that the NDPCC and the NNDMC are essentially the same organization. The NNDMC label is common in news and reports written in the language of Myanmar, while NDPCC tends to be the English language label.

3.2. Support from International community after Cyclone Nargis

3.2.1. National Natural Disaster Management Committee (NDPCC/ NNDMC)

The Myanmar central government attempt to establish the disaster management system began with the adoption of the 'Hyogo Framework for Action 2005–2015 (HFA)', and the signing of the 'ASEAN Agreement on Disaster Management and Emergency Response (AADMER)', formulated in 2005 as an ASEAN disaster management framework influenced by the HFA (Table 1). The NNDMC did not function before the arrival of Cyclone Nargis in 2008. Its first official role was in recovery efforts after Cyclone Nargis.

Cyclone Nargis hit the Ayeyarwady Delta on 2–3 May 2008, killing more than 130,000 people. The first meeting of the NDPCC was held in Nay Pyi Taw on 3 May with Thein Sein, then Prime Minister and former President, as chairman. Its actions were outlined in 'News Release No. 1', released overseas on 17 May. The release mentioned that some international media had reported misinformation, such as the 'Myanmar government is rejecting international support'.

The disaster response required cooperation between ministries in the Myanmar central government, as well as cooperation between states and within regions. On 19 May 2008, ASEAN Foreign Ministers, meeting with United Nations officials in Singapore, decided to form the Tripartite Core Group (TCG). The NDPCC represented Myanmar on this body. From 31 May, meetings of the TCG were held at least once a week, with close cooperation from the NDPCC. On the same day, the TCG agreed to conduct Post Nargis Joint Assistance (PONJA), a disaster assessment organized by the World Bank. The report of the PONJA investigation, conducted from 10 to 19 July, became a model in the field of disaster recovery.

The national disaster management plan was formalized through the development of the 'Myanmar Action Plan on Disaster Risk Reduction (MAPDRR)' in 2009, and by the 'Standing Order on Natural Disaster Management' which specified the roles of the ministries. MAPDRR consists of 64 components to be tackled in order to prevent disasters and/or reduce the risks they pose. The DRR Working Group, which was established under the leadership of UN agencies, is responsible for implementing these components. It consists of 53 agencies, among them the UN, international NGOs, local NGOs and professional organizations working for the DRR.

After Cyclone Nargis, more natural disasters struck Myanmar. In August 2010 Cyclone Gir left 45 people dead or missing in Rakhaing State. Torrential rain in the Magway Region in October 2011 left 106 dead and missing, while in 2012 the 6.8 magnitude Shwebo earthquake left 11 dead and 52 injured in the Sagaing Region. The NDPCC was not called to respond to these events as the central government did not consider them disasters.

The first NDPCC meeting since Cyclone Nargis was held in 2013 in response to Cyclone Mahasen. This cyclone, which formed over the Bay of Bengal in the middle of May, initially was forecast to hit the central part of Myanmar, but gradually it changed track to the north and made for Bangladesh. Responding to the initial prediction of the cyclone’s movement, President Thein Sein published a presidential decree to call the NDPCC, and individual working groups started operations. Though the ‘National Natural Disaster Management Law’ had not yet been approved by the Assembly, the coordination work was conducted with that law in mind.

3.2.2. Emergency Operation Centre (EOC)

The NDPCC is the coordination system of the union government. It provides for disaster response and recovery planning and is the responsibility of the Vice President. The EOC, which forms part of the MSWRR, disseminates information about disasters and, thus, supports the activities of the NDPCC.

EOC was established in 2012, with the support of the Japan-ASEAN Integration Fund (JAIF). It allows Myanmar to share information with
Table 1  
Time line of Disaster response system and activity by Myanmar government.

| Year  | International event and large-scale disaster in Myanmar | Disaster response system and activity by Myanmar government |
|-------|---------------------------------------------------------|----------------------------------------------------------|
| 2005  | – Hyogo Framework for Action 2005–2015 (HFA)            | – National Natural Disaster Management Committee (NNDMC) was established |
|       | – ASEAN Agreement on Disaster Management and Emergency Response (AADMER) | | |
| 2008  | – Cyclone Nargis                                      | – Natural National Disaster Preparedness Central Committee (NDPCC) was established and had a meeting (3 May) |
|       | – Tripartite Core Group (TCG) and Post Nargis Joint Assistance (PONJA) | | |
| 2009  |                                                        | – Myanmar Action Plan on Disaster Risk Reduction (MAPDRR) |
| 2010  | – Cyclone Giri                                        | – Emergency Operation Centre (EOC) was established |
| 2011  | – Torrential rain in Magway Region                   | – NDPCC meeting (May) |
| 2012  | – Bago River Flood                                    | – National Natural Disaster Management Law |
| 2013  | – Cyclone Mahasen                                      | – NDPCC meeting (30 April) |
| 2014  | – Sendai Framework for DRR 2015–2030                    | – NDPCC meeting (16 May, 30 July) + C13 + C11 |
| 2015  | – Myanmar Floods                                      | – NNDMC was assembled and had a meeting (31 August) |
|       |                                                        | – Special Disaster Zones were designated |

the ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management (AHA Centre) located in Jakarta, where AADMER is based.

The EOC supports decision-making and enables the prompt response of national organizations during disasters [17]. Its focal task is the coordination of national and international partners in emergencies and in sending disaster information to the AHA Centre. The main activities of the EOC are to gather and summarize information related to disaster risk reduction and report to the heads of agencies and ministers. The EOC also supports NNDMC in planning and developing national level policies, and providing authority and funds for prompt emergency support.

The specific role of the EOC is not stipulated in the English-translated version of the National Natural Disaster Management Law [12], according to which NNDMC is to establish a ‘Natural Disaster Management Centre’ and ‘Emergency Management Centre’ for natural disaster responses. Neither of these matches the definition of the EOC. However, it can be said that the EOC has an important position in national disaster management. Staff members were dispatched to EOC of RRD from AHA. While Cyclone Mahasen did not cause large-scale damage, the response was preparation for the future flood disaster in 2015.

3.3. Response for 2015 Myanmar floods

3.3.1. NDPCC/NNDMC

After the ‘National Natural Disaster Management Law’ was passed by the assembly in 2013, there have been continuous efforts to implement NDPCC operations. NDPCC meetings were held on 30 April 2014 and 16 May 2015, before the arrival of the rainy season. On 30 July 2015, in response to the floods, President Thein Sein assembled the NNDMC. The next day, Chin and Rakhine states, and the Sagaing and Magway regions, which had suffered tremendous damage, were designated special disaster zones. Under the National Natural Disaster Management Law, the President has a responsibility to declare a ‘disaster zone’ to ensure support for the affected area is provided by the central government. The criteria for declaring special disaster zones is defined under law, though the exact rules and regulations are still being prepared.

3.3.2. EOC

The EOC of MSWRR plays an important role in the decision making of NNDMC. During the 2015 Myanmar floods, the EOC collected and summarized situation information to support the designation of special disaster zones by the NNDMC. On 10 August 2015, a ‘Situation Report’ was issued by the NNDMC. The report outlined the central government’s analysis of the disaster and its response [13]. Such reports were issued in English every week until 2 September, which meant information about the activities of the Myanmar government was shared around the world.

The EOC consists of an eleven member working group, led by the United States Agency for International Development (USAID). Member organizations include the AHA Centre, the UN Office for the Coordination of Humanitarian Affairs (UNOCHA), the World Food Programme (WFP), the MIMU (Myanmar Information Management Unit), the United Nations Development Program (UNDP), and the Japan International Cooperation Agency (JICA). Staff from private companies are also involved [14].

The EOC led the disaster response of the central government. This was the result of efforts by MSWRR, the most important ministry of the Myanmar government in terms of disaster management.

4. Local government responses to disasters and the status of river basin management

This part examines the status of river management facilities, including canals for flood prevention, in the Bago River Basin. It then sums up the response of the local government to the disasters centered in the basin. There are many river management facilities located in the delta region in the middle and downstream areas of Bago River. However, there are no clear written documents in the Myanmar language regarding procedures for basin management and flood control.

4.1. Outline of the Bago River Basin

The Bago River Basin is located north-east from Yangon, the largest city in Myanmar, and occupies 5400 km², extending 335 km (Supplementary Fig. 1). The basin has a tropical monsoon climate with annual precipitation of about 3300 mm. The source of the Bago River is situated in the southern part of the Bago Mountains, more than 800 m above sea level. In 2012 the Bago Region had a population of about 4.9 million, and it has the second largest grain belt in Myanmar. As agriculture is the principal industry of Myanmar, and social stability is sought through agricultural production, it is crucial that the Myanmar government reduce the risk of water-related disasters in the Bago River Basin. Myanmar has been experiencing tremendous socio-economic development, and there are increasing expectations about the Bago River Basin supporting primary industries of agriculture and timber trading, and secondary and tertiary industries.
4.2. The current status of river management facilities

The Bago Region consists of four districts, and the Bago District of eight townships. Four of these townships – Bago, Waw, Thanatpin, Kawa – are flood-prone. The Irrigation Department (ID) of the Ministry of Agriculture and Irrigation has been overseeing the flood-prone areas and preparing facilities for the purpose of flood disaster mitigation. It is responsible for the construction, maintenance, management and operation of such facilities as banks, dams, and sluices. In the following sections we describe the current status of flood disaster mitigation infrastructure, with a focus on Bago District.

4.2.1. Dams and weirs

A total of four dams were constructed. Zaung Tu Dam, completed in 1994 and about 65 km upstream from Bago City, is the uppermost dam on the Bago River. There are three more dams downstream (Fig. 4) – Kodukwe, Shwelaung and Salu – located on tributaries connected to the left bank of the Bago River. These dams were completed in 2012.

Zaung Tu Dam has the largest storage capacity and is used for power generation by the Department of Hydropower Generation Enterprise (HPGE), and the Department of Hydropower Implementation (DHPI). The Ministry of Electric Power (MoEP) manages the amounts released from the dam. All the dam’s management staff, including those involved in power generation, work under the HPGE.

The other three dams, constructed for irrigation and flood mitigation, were completed in 2012. The total storage capacity of the dams is about 404 million m³, which is almost equal to that of the Zaung Tu Dam (Table 2). The dams release water for irrigation during the dry season, allowing dam reservoirs to empty before the rainy season.

According to staff at the ID Bago office, before 2011 the Zaung Tu Dam was operated solely by the HPGE and DHPI. In times of flood, no consideration was given to conditions prevailing in the Bago River downstream. Since the 2011 flood, the ID and the HPGE/DHPI have coordinated their responses to floods. Coordination is through ID, which operates and manages dams in the river basin and implements flood management measures.

When the water level of the Bago River, measured at Bago Bridge by the Department of Hydrology and Meteorology (DMH) of the Ministry of Transport, reaches 860 cm, the ID stops discharge from its dams [8].

**Table 2**
River infrastructures in the Basin.

| Name           | Facility overview                                         |
|----------------|----------------------------------------------------------|
| Dam            | Storage 407MCM, Dam height 44.8 m                        |
|                | Electric generating capacity 20 MW                        |
| Kodukwe Dam    | Storage 183MCM, Dam height 27.4 m                        |
| Shwelaung Dam  | Storage 117MCM, Dam height 24.3 m                        |
| Salu Dam       | Storage 104MCM, Dam height 26.8 m                        |
| Weir Zaung Tu Weir | Weir height 8.5 m, Weir length 122 m, Benefit area 11,472 ha |
| Canal Bago-Sittaung Canal | Length 60 km                                           |
| Zaung Tu Irrigation Canal | ZaungTu-Kyaik Hla Irrigation Canal, Zaung Tu-Moe Yin Gyi Irrigation Canal |

(MCM: Million Cubic Meters).
4.2.2. Bago-Sittaung Canal

The Bago-Sittaung Canal, which links the Bago and Sittaung rivers, was completed in 1876. About 60 km long, it was built for moving lumber from the Sittaung River to the Bago River.

Nowadays, the Canal is used as a reservoir to collect and control flooded water. There are five sluice gates along the Canal, through which discharge can be managed in both the rainy and dry seasons. During the dry season, the gates deliver irrigation water.

The left bank of the Canal (from the Sittaung River to the Bago River) was built higher than the right (Fig. 5). Thus, floodwater coming from north to south is stopped at the left bank (if the height of the water is less than the height of the bank). Sluice gates are used to control the floodwater, once it has been directed from the left bank to the south.

Lock gates for ship navigation are located at the Canal's junctions with the Bago and Sittaung rivers, and the gates are also used to drain water into the rivers.

At each sluice gate there are 30–70 small flash-board type gates equipped with manual winding machines. Tawa Sluice gate, for example, has 33 small gates. It takes ten workers about one week to open and close these fully.

4.2.3. Extension of Zaung Tu Irrigation Canal

Zaung Tu Irrigation Canal was built originally for irrigation. Later, it was extended to Bago-Sittaung Canal and became two canals: Zaung Tu-Son Pi and Zaung Tu-Kyaik Hla. Zaung Tu-Moe Yin Gyi Irrigation Canal was extended to the Moe Yin Gyi Retarding Basin. As shown in Fig. 4, these connections link Zaung Tu Weir with Moe Yin Gyi Lake and Bago-Sittaung Canal.

During rainy season, water can be taken from the Bago River at the Zaung Tu Weir and conveyed through these irrigation canals to Bago-Sittaung Canal and to Moe Yin Gyi Regarding Basin. Thus, the flow volume of Bago River can be kept at lower levels, which helps to reduce the risk of floods in Bago City [8].

4.2.4. Moe Yin Gyi Retarding Basin (Moe Yin Gyi Marsh)

Moe Yin Gyi Marsh and surrounds were covered with embankments to form a retarding basin to collect flood waters from neighboring areas during rainy seasons. The basin receives water discharged from the canal extended from Zaung Tu Irrigation Canal, and functions as a retarding basin to mitigate flood damage in and around Bago City. During dry season it serves as an irrigation source as stored water can be released to Bago-Sittaung Canal.

4.3. Improvement of river management facilities since the 2011 large-scale flood

The Bago River Basin was worst affected by the 2011 floods [20] (Fig. 6). The head of the regional government made a direct request to the President of Myanmar to improve flood mitigation measures. As a result, drainage measures were implemented in Bago township, excavation work was done on the Bago-Sittaung Canal, and the three dams (mentioned above) were completed (Fig. 4). Staff of the Bago ID office have mentioned that the following measures have been effective in preventing and containing floods.

4.3.1. Dredging of Bago-Sittaung Canal

Dredging and embankment work was finished in May 2014 after a four month construction period. Total project cost reached 25 billion Kyat (about 2.5 million USD), with dredged sediment amounting to 2,000,000 m³.

To secure the proper design heights for the bed and cross sections of the canal, sediment deposition sections were dredged, and eroded sections rehabilitated using dredged gravel and sand. As a result, Bago-Sittaung Canal has increased water storage capacity and smoother water flow.

An increase in the stored water volume resulted in the Canal having an increased regulating capacity. The difference between inflow amount to the canal and the amount of water drained from the sluice gates produced this result. This dredging work also resulted in smoother water flow, particularly in sections where there are sluice gates. According to ID staff managing the Bago-Sittaung Canal, flood disasters decreased by almost half after the dredging work.

4.3.2. Dredging of Bago River and related river improvement

The Bago River runs through the urban area of Bago City from north to south (Fig. 7). The east bank of the river is raised higher than the west to protect the old city from floods. The western side of the river is, thus, prone to inundation damage.

Bago River follows a meandering course and within its bends are many places where sediment has accumulated and formed bars, obstructing smooth water flow. Dredging work to remove the bars was carried out at eleven spots between Bago City and Tawa Village, where Bago River connects to Bago-Sittaung Canal. The total volume of sediment removed was 771,000 m³.

Dredging and river improvement work was done on other small rivers that flow into Bago River through Bago City. Mazin River, a Bago River tributary, flows along the side of a small settlement where our survey was done. Improvement work, including straightening, widening and deepening the river, took place from October 2014 to April 2015, with the flow area increased by about five times.

4.4. Reinforcement of meteorological and hydrological observation facilities

The current status of the observation system at the Bago Regional office of DMH was examined. The observation system in Myanmar consists of 39 meteorological/hydrological observation stations, 30 hydrological observation stations, 17 agricultural meteorological observation stations, and one aviation observation station. Most meteorological observation work is done on a manual basis. Precipitation observation is done five times a day (every three hours from 6:00 a.m.). The reading at 9:00 a.m. is taken as the precipitation reading for the day. Water levels are observed at two locations on the Bago River – Bago Bridge and the Zaung Tu Weir upstream. Water levels are measured three times a day (6:30, 12:30, 18:30). If the reading at Bago Bridge exceeds 860 cm, more frequent measurements are taken – every three hours for water levels in excess of 860 cm, and every hour for water levels greater than 910 cm.

The Bago DMH office represents the entire Bago Region. It summarizes the data from the four meteorological stations in the Region...
and reports to DMH headquarters in Nay Pyi Taw. DMH headquarters then releases the latest data, including forecasts and warnings. Telephone lines are used in this station. For some stations with poor communications, a wireless telecommunication called Single Side Band (SSB) is used. Work is being done on transitioning from manual observation and collection to an automatic data collection network, which would transmit information about water levels, precipitation, wind direction and wind speed directly to computer systems at regional offices and headquarters.

4.5. Local governments’ responses to disasters

As described in the previous chapter, the central government supports local governments in terms of disaster impact assessment. This is done through the EOC and involves allocating emergency relief supplies donated by domestic and international organizations. Local governments are responsible for collecting information about disasters, including the effect on people, property, and infrastructure in the local area, and reporting this to the central government. Local governments are also responsible for warning people in the local community of impending disasters, establishing and operating official evacuation sites, and distributing emergency relief supplies.

4.5.1. Management of river facilities by sharing data among different departments/bureaus

Three main organizations are involved in managing river facilities in the Bago River Basin: the ID, DMH and HPHE/DHIP. Before the 2011 flood, there was little data sharing about flood conditions in Bago city and the operation of river facilities. The flood made organizations understand the importance of data sharing to mitigate flood damage.

As a result of this realization, the organizations keep a careful watch on the four dams, the Zaung Tu Weir, the Bago-Sittaung Canal, the Moe Yin Gyi Retarding Basin, and various linking canals (Fig. 4). Some information about water discharge from the spillways of dams is distributed to residents of the Bago region. This is a new development. HGPE and DHPI manage the Zaung Tu Dam, while ID manages the other dams and facilities. The total capacity of those dams is about 20% of the total annual flow volume of the Bago River. According to the ID, this total volume is not large enough to control flood regulation (Table 2).

Because its ministries are divided, the Myanmar government is not well placed to implement disaster risk reduction activities [17].
Meteorological and hydrological data are the jurisdiction of the DMH, and the release of meteorological data to other departments or agencies must be paid for. ID, which administers most dams in Myanmar, bears this cost. Data from the DMH is combined with data from dams and other facilities and gathered into the ID’s Bago office, with operational instructions then issued by the head of the office.

Zaung Tu Dam is used mainly for power generation, while the three downstream dams are used for irrigation. Operate these dams separately has the potential to cause danger in downstream areas. The staff of ID and HPGE/DHPI are trying to improve the situation by exchanging information, based on their close collaboration after the 2011 flood.

From the middle of July 2015, following the floods, the ID started to release information in newspapers on dam release. This is done only when the water level of dams exceeds the natural overflow level, but nonetheless such action is a positive step. The Myanmar government is willing to share river management information with the public.

4.5.2. Damage Information Collection by the General Administration Department (GAD)

In Myanmar, state regional governments ensure the Disaster Preparedness Committee, which plays a central role in disaster prevention administration, has a presence in each district, township, and village [18]. In Bago District, organizations hold meetings to exchange information once a week during the June-October rainy season. These organizations include some voluntary organizations involved in disaster risk reduction, in addition to the regular administrative bodies.

One of the key roles of GAD in disaster response is the delivery of relief supplies. These supplies come mostly from local governments, central government, local donors, and international organizations such as JICA. RRD plays an important role in the central government, but it is a small organization so relief goods received from donors are directed to GAD which then distributes them to evacuation facilities. Unused goods are kept at local temples for future need.

At the time of the 2015 flood, the relationship between water level information and number of evacuees was clarified. Through reference to experiences in the 2014 flood, the delivery of relief supplies was linked to regional inundation levels. This resulted in smooth supply. It was recognized that a more ordered framework to manage and distribute relief supplies was necessary.

4.5.3. Information dissemination to local residents and evacuation

The Bago DMH observatory, located in Bago City, has made it a rule to raise the alarm when water levels reach 860 cm and 910 cm, respectively (Fig. 6). Water levels and river banks are monitored on a 24-h basis when water levels reach 910 cm. A warning message release system was introduced in 2014 and began operation around May 2015. It allows for automatic release of warning messages to certain people, including the head of the executive office for the Bago Region and other administrators involved with disaster risk reduction. DMH also issues warnings to residents through radio (City FM, Voice of Myanmar), television (MRTV, MWD, MRTV-4), and via loudspeakers telephones, facsimile machines and other means. In addition, since July 2015, ID has disseminated information daily, through newspapers, on dam and weir release. This is being done as a result of experiences during the 2011 Bago flood. The national newspaper of Myanmar (Myanmar Alin) reports each day on matters of relief supplies and economic support for flood victims. This information is also available on the Ministry of Information website.

However, forecasts/warnings and evacuation instructions are not reaching enough local residents. In the flood-prone areas of Bago Township, most residents are poverty-stricken and not necessarily able to access information online or through newspapers. The evidence of this is clear. At the time of the 2015 flood, many residents knew, from radio and television, that heavy rainfall was expected in various places, but they had not heard warnings direct from the government or predictions of flooding where they lived. In this regard, the widespread use of cell phones is promoting contact and information exchange between friends and families.

In general, it is recommended that residents evacuate to areas such as schools, playgrounds, and monasteries. Some evacuation areas are run by and for the public, while others are private. In Bago township, certain monasteries volunteer to care for very poor residents affected by floods. Surveys from monasteries show that monks have issued evacuation instructions without waiting for advice from the government. Monks at one monastery, which is in a flood-prone area and surrounded by about 750 families, urged evacuation and reminded people of the possible spread of disease. At another monastery, also located on the Mazin River, monks predetermined that when the water reached a certain level they would issue a warning. 595 people from 146 households were evacuated to the monastery. Poor families often could not afford 200 Kyat (0.2 USD) per person for a one-way boat ticket. A typical family of five earns only 3000–5000 Kyat (3–5 USD) a day.

5. Discussion

5.1. Disaster risk reduction activity cooperation between central government and local residents

With regard to disaster management in the central government, the EOC and the Disaster Management Centre, under the National Natural Disaster Management Law, play an important role in disseminating information. Financial support from United Nations agencies, JICA and other NGOs, have allowed the ministries involved with disaster risk reduction, such as MSWR, the focal ministry in terms of legislation, to strengthen capacity in respect to facilities and human resources development. This is done by providing training and workshops.

At a local level, GAD connects observed data with disaster damage and uses water level information to identify numbers of victims. Monasteries also play an important role at the local level by delivering evacuation advice and relief supplies to residents. Many pious Buddhists take a proactive approach to the safety of local residents. Through investigations conducted at a local level we were able to observe how disaster management activities have improved, from the local level to the national level. There have been particular improvements with regard to sharing data and information.

Information and communication technologies and systems in Myanmar are expected to develop rapidly, which will likely lead to stronger disaster management activities. This means that analysis of river runoff characteristics for the Bago River Basin and appropriate management of river management facilities are becoming increasingly important.

5.2. Managing river management facilities in the Bago River Basin

With regard to river management and canal facilities in the Bago River Basin, the following issues must be tackled.

Streamlined and integrated systems for river management facilities are necessary so that operations can take account of observation data. These operations include discharge in the southern part of the Bago-Sittaung Canal (affected by the tide in the delta area); discharge flowing into the Bago-Sittaung Canal from the north; discharge from the Bago-Sittaung Canal through five main sluice gates and two lock gates; and release from dams located upstream on the Bago River.

The completed extension of the canal enabled a reduction in the volume of water running through the urban areas of Bago City. By keeping water in the existing irrigation canal from Zaung Tu Weir, water bypassed the area. But these current methods for managing facilities may not be sufficient to support planned design functions, so further study of operation methods is necessary.

A coordination framework should be established between DMH, ID, and the Ministry of Electric Power. This framework would utilize DMH
hydrological and meteorological observation data for ID/HGPE/DHPI operation of hydropower and reservoir facilities. For example, simultaneous sharing of telemetry system data with the administrators of upstream dams and the Bago-Sittaung Canal would coordinate facility operations and help mitigate the effects of floods.

Of the dams located upstream on the Bago River, Zaung Tu Dam generates electricity during the dry season using water stored during the rainy season. Water in the other dams is used for irrigation. Thus it is of primary importance to retain as much water as possible before the dry season starts. If this is done, it becomes much easier to decide when to release water before heavy rain is expected, and thus to secure flood control. Since 2007 DMH has held a Monsoon Forum at the beginning and end of each rainy season for the purpose of long-term forecasting. Both medium and long-term forecasts are presented. These forecasts need to be as precise as possible for flood control to be effective.

Although the people of Myanmar are used to floods and have adapted their lives accordingly, they still suffer greatly from the economic impacts. Flood control is important from both structural and non-structural perspectives.

6. Conclusions

This article, based on evidence from floods in the Bago River Basin, reviews the disaster risk reduction system of Myanmar. The article will help to connect flood control and governance in Myanmar.

According to the National Natural Disaster Management Law [12], minimization of losses and emergency and recovery response are aims of the national development program. Our comprehensive investigation studied the implementation and progress of disaster risk reduction activities in Myanmar. The following points were addressed: minimization of losses; construction and improvement of river structures and canals; emergency responses; EOC information gathering; NNDMC coordination supported by EOC; GAD and DMH support of activities in local areas; and recovery, response and relief supply by RRD and monasteries.

Effort and progress were confirmed through this study. Efforts have been made to enhance infrastructure based on ID and to improve the capacity of drainage facilities, share information between organizations since 2011, and communicate information to local residents. The central government’s disaster management system and framework, developed through international collaboration after Cyclone Nargis and utilizing EOC, has started functioning.

The Myanmar disaster risk reduction plan has been further strengthened by local governments sharing information with relevant authorities (a process that supports residents), taking note of the information provided by residents living in flood prone areas, and through the cooperation of monasteries, which voluntarily provide relief.

Residents of flood prone areas in Myanmar tend to live in houses on stilts – they ‘live in good harmony with nature’. However, after major floods often there is little consideration of the financial effects on these people. The disaster management system must take account of this and the many other consequences of floods for local communities, as this study has done. The system also needs to reflect local knowledge [2]. These developments are essential if Myanmar’s disaster management system is to operate effectively and with regard to all citizens.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ijdrr.2017.06.004.

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