Dam Safety Emergency Action Plan: A Current Practice for Hydropower Dam in Malaysia

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Abstract. There are currently 104 dams constructed in Malaysia. The dams were built for various purposes; 16 of them were built for hydropower. The dam's reservoir often presents significant risks to downstream areas if a massive downfall release occurs. The enormous downfall could be due to a dam break event, overtopping, and emergency operational release. An incident may occur due to massive flows over a spillway with high-speed discharge or unexpected peak discharge. The obvious impact of the incident is direct to the community in the downstream area. Although there is no dam failure recorded case in Malaysia since the 1900s, the possibility of dam failure occurring is still there. Therefore, the dams must have an emergency action plan (EAP) to prepare the likelihood of the emergency occurrences. This paper aims to explore the EAP practices for dam incident over the region and review the EAP practices of a hydropower dam in Malaysia. Implementing EAP in the emergency response system would minimise the public and environment's impact due to dam failures. The benefit of establishing an EAP is to create better communication and effective responses system among agencies during dam emergency occurrences. This paper revolves around the EAP practices by dam owners in mitigating the risk of dam failure occurrences.

1. Introduction
Dams were built not only for water supply, irrigation, hydropower, navigation, and recreation benefits but also for flood mitigation to minimise risk to the local population downstream and environment. The high volume of water stored in the reservoir behind the dam will undoubtedly pose harmful impacts to the surrounding community if massive downfall release suddenly occurs [1]. The impact is disastrous when the failure is over the large dam. The concept of large dams has varied, whereby the International Commission on Large Dams (ICOLD) describes a large dam as one over 15 metres high, measured from the bottom of the foundations to the peak of a dam, and store more than 3 Mm$^3$ of water [2]. Whereby the Texas Administrative Code (TAC) defines a large dam as a dam with a height of 100 feet or more, or a maximum capacity of 50 000 acre-ft (approximately 60 Mm$^3$) or more [3]. For all of those, the large dam has been classified depending on dam owners, authorities, and organisations in the particular region. [4] stated that, the large dams are built to sustain various loads of static, earthquake resistance and withstand extreme hydrological event. During the dam design stage, construction, and operation, the factors that cause dam failures can be identified, and the impacts are evaluated. Though the causes of dam failures differ to each dam, collected data reveals that the dam's failures are due to overtopping, toe erosion, loss of storage contents, failure of the appurtenant structure, earthquake, foundation failure, and movement or cracking in dam structure [5].
In Malaysia, at present, there are 104 dams with a total storage of approximately 84,000 million m$^3$ of water. 81 are categorised as large dams, while the remaining 23 are small dams [6]. There are 16 dams built for hydropower (Table 1). The Bakun Dam is the largest dam by Kenyir dam and Temenggor dam as the second and third largest dam [6]. Tenaga Nasional Berhad (TNB) owned the largest amount of hydropower dam and followed by Sarawak energy.

**Table 1. Hydropower Dam Development in Malaysia (Adopted from [7]).**

| Years     | Location                      | Nos |
|-----------|-------------------------------|-----|
| 1900s – 1950s | Chenderoh Dam, Perak         | 1   |
| 1960s     | Sultan Abu Bakar (SAB) Dam, Pahang |     |
|           | Jor Dam, Perak                |     |
|           | Mahang Dam, Perak             |     |
| 1970s     | Temenggor Dam, Perak          | 1   |
|           | Kenyir Dam, Terengganu        |     |
|           | Batang Ai Dam, Sarawak        |     |
| 1980s     | Bersia Dam, Perak             |     |
|           | Kenering Dam, Perak           |     |
|           | Tenom Pangi Dam, Sabah        | 5   |
| 1990s     | Pergau Dam, Kelantan         | 1   |
| 2000 - 2013 | Bakun Dam, Sarawak         | 2   |
|           | Murum Dam, Sarawak           |     |
| 2013 - 2020 | Ulu Jelai Dam, Pahang     |     |
|           | Puah Dam, Terengganu          |     |
|           | Tembat Dam, Terengganu        | 3   |
| Total     |                               | 16  |

This exercise aims to explore the emergency action plan (EAP) practices for dam incident over the region and review TNB-EAP’s hydropower dam development in Malaysia. This exercise would revolve the EAP practices and help dam owners in emergency plans mitigate the risk.

2. Dam Failures incidences

Among the notable dam failures in history was the collapse of the Malpasset dam in France, 1959, the Teton dam-break in the United States, 1976, and the Big Bay dam's failure in Mississippi, 2004, [9][11]. [8] mentioned that unexpected and unforeseen failure of the Malpasset Dam has resulted in a vital loss of life; it was reported that an abutment movement contributed to the cracking at the centre of the dam and has led to the failure of Malpasset Dam. The Teton Dam's failure is due to an internal erosion or piping that has resulted in 14 deaths and caused damage to property downstream worth hundreds of millions of dollars [9]. [10] reported that after 12 years of construction, Big Bay Dam failed in 2004 due to embankment failure; the flood reached up to 23 km of the valley and with depth up to 10 m height. Massive structures have been identified as being damaged and demolished; however, there is no loss of life in this event.

The failure of the St. Francis dam in 1928 has contributed to substantial improvement in the expertise and techniques of rock engineering and rock mechanics, and dam construction and revision methods. They relate primarily to the location, structure, stability, shear strength, and infilling of discontinuities in the foundation and abutment rock masses [4].

A study by [5] estimated that overtopping had caused about 34 per cent of dam failures, the foundation defects was 30 per cent, and piping was 28 per cent. From the past incident, the Tsatichhu dam's failure in 2004 in Bhutan was due to dam-face saturation and progressive seepage [11]. [1], [12]
has stated that many existing dams continue to present an increasing challenge to downstream areas due to structural degradation, insufficient design, poor operation and maintenance and faulty construction. The authors mentioned that developing EAP for dam failure incidents is vital for planning beyond standard operating procedures. This was supported by [13], highlighting the importance of strengthening disaster risk governance, investing in disaster risk reduction, and improving emergency preparedness plans. Thus, EAP preparations are important to mitigate the threat to the people at risk, reduce the actual impact on properties and the environment due to dam failures occurrences.

3. Emergency Action Plan (EAP)

The Emergency Action Plan (EAP) or Emergency Response Plan (ERP) is a "systematic action" to organise the people and resources during emergencies [19]. EAP addressed emergencies action that people may reasonably expect in their place [14].

EAP is defined as the comprehensive contingency program that includes actions that have to be taken in order to control and minimise the impact of an emergency [15]. An EAP is a written document explaining possible emergencies that may arise to the dam and outlining pre-planned measures to mitigate possible dam failure or reduce impacts, including loss of life, property damage, and environmental impacts [16], [17]. This thought supported by [18], [19], indicated that EAP is important for dam owners to respond quickly to possible emergency incidents as soon as they are detected and take appropriate action to prevent the situation from getting worst.

According to [15], large dams require an emergency action plan (EAP) to guide further action to face dam incident. This was supported by [20], which mentioned that EAP helps fast response and control losses of disaster occurrences. The key point of EAP is to save lives, be prepared, charge of control, determining the appropriate level of alarm, making notifications and performing emergency actions [14]. A study by [3] reported that EAP is not a replacement for proper maintenance or corrective of construction. EAP provides instructions to execute an emergency action and provides a standard outline procedure for dam owners to deliver information, facilitate resources, to plan on an emergency plan to mitigate the risk [21].

4. EAP Practices

A study by [14] has identified several dams owned by one owner in the same region has produced one EAP to cover all the dams but separate the description, inundation map and notification flowcharts for each dam. In fact, [22] suggest that dam owners who own a few dams in the same region and involved in the same management should provide one EAP to combine all the dams. Furthermore, [22] added for each dam should provide a specific explanation and operation of each dam.

Several studies stress that every dam area is different; the extent and duration of each dam's possible impacts differ, nor should the emergency plans be the same [18], [24], [26]. Since each dam has different characteristics, it would require a different O&M manual to efficiently operate and manage its civil and hydro-mechanical components [24]. Then, the site-specific features of the dam and its location should have their own EAP [25], [18] summarised that any changes of EAP should be immediately updated for keeping a secure structure of procedures for timely detection, assessment, and classification as well as possible or potential emergencies.

According to [21], [26], [27], in cascading dam system, the failure of upstream dams might consequently affect the downstream dams. In the case of upstream and downstream dams with different owners, the respective owners need to notify the other dam owners at the upstream and downstream areas in case of emergency. The action plans that they should have are emergency notification among the dam’s owners [21]. The dam owners determine the emergency level, contact checklist, actions, and event progression [16], [19].
The EAP has been designed to be as simple and easy to use as possible with discrete sections, which can be read independently. However, there are two basic warning dissemination stages in EAP: notification time and evacuation time [28]. Most EAPs developed to use the international guidelines for dam safety and emergency guideline (Table 2).

| Year | Standard Guideline |
|------|--------------------|
| 2004 | Federal Guidelines for Dam Safety, Emergency Action Planning for Dam Owners (FEMA, 2004) |
| 2009 | Defra Guidance on Reservoir Emergencies of on-Site Plan for UK Reservoir Dam Incidents (DEFRA, 2009). |
| 2012 | Guidelines for Developing Emergency Action Plans for Dams in Texas (Program, D. S., & Division, C. I., 2012) |
| 2018 | Guidelines for Preparing Operation and Maintenance Manual for Dams in New Delhi (Commission, C. W., Development, R., & Rejuvenation, G., 2018). |

5. EAP’s Assessment and Review

An assessment and review of EAP required to determine the effectiveness of the plan developed. This EAP assessment criteria include training for people involved and exercising, such as orientation meeting, annual simulation test, tabletop exercise, functional exercise, and full-scale exercise [23]. [19] [17] stated that these activities would increase preparedness toward emergency response. The drills and simulation exercises train people involved in the EAP to ensure that they are familiar with their responsibilities and duties [24][18].

A drill can be described as a plan and control practice typically used to test specific processes or features, such as testing sirens and alert systems, calling suppliers, inspecting materials on hand, and performing a call-down exercise of those specified in the notification flowchart [18]. Field drills conducted regularly at the dam site would help dam personnel know their roles and responsibilities and improve the emergency response system. It is necessary to have good coordination between dam owners and local agencies to ensure smooth action during field training, where emergencies are being developed [1]. According to [17], the dam owner shall define procedures and list conditions, cause incidents, and steps for the timely and effective identification and classification of an actual or possible emergency. The EAP evaluation depends on the dam location, approval from authority, testing on system, and dam personnel training [14].

Testing equipment and drill exercises should be done regularly to increase the effectiveness of EAP [16], [19], [21], [26], [27]. Additional information such as the lap time for the dam to fail and the failure warning and the rescue operation procedure should be predetermined in the EAP [18], [24], [25]. Simulation tests on dam failures are a good training platform to assess dam personnel readiness and EAP developed [3]. [17], [19], [25] stated that the dam owner should perform a tabletop exercise with local emergency management at least once every five years; it would help enhance the cooperation needed during actual emergencies effectively. The tabletop exercise begins with a summary of a simulated event and continues with discussions among participants to review the EAP, response procedures, address coordination and responsibilities issue [19][25]. Any changes in dam personnel, local officials and downstream residents should be immediately updated accordingly to suit with EAP developed [3]. Case studies from various countries show the importance of EAP to ensure the dam owners and authorities are always prepared and aware of emergency response (Table 3).
| Guideline                                                                 | Aim                                                                 | Finding                                                                 | Action Plan                                                                 | Review                                                                 |
|-------------------------------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------|
| **Development of Rescue Actions Based on Dam-Break Flood Analysis, Finland** [23] | To prepare a plan for dam failure emergency action                    | Not all dams are the same, nor should the emergency plans be the same: a dam with a higher risk will have a more detailed or streamlined design. Thus, each dam has its own EAP | Unexpected actions planned by the dam owner should be consolidated into the final EAP | The time between the dam failure and the failure warning, and the rescue operation launch |
| **Dam Emergency Action Plan (EAP) Template, Rhode Island, USA** [16]    | Provides protocols for detecting rare and unexpected circumstances that could threaten the dam in Rhode Island. | The upstream and downstream area has a different owner. Then, should have the EAP for each dam. | Dam owner determines emergency level, contact checklist, and actions and event progression. | Annual review checklist, record of changes, exercise the Emergency Action Plan (EAP). For example: - seminar, workshop, tabletop exercise |
| **Guidelines for Preparing Operation and Maintenance Manual for Dams, Hirakud dam, Rengali dam (India)** [24] | According to these guidelines, to make it easier for all dam owners to frame or update their relevant operation and maintenance manual. | Since each dam is special, it would require a different O&M Manual to efficiently operate and manage its civil and hydro-mechanical components and safety and public health. | Managing the reservoir according to unique project specifications, maintaining records and success evaluation. Proper operating procedures are essential for keeping a secure structure. | Dam’s service, repair, and inspection procedures are important for an EAP success evaluation. Modifications or changes to the plan and any potential threats to dam construction also included. |
| **Emergency Action Plan for Votehole Dam, India** [19]                 | To guide Votehole dam for emergency response.                         | There are different dams’ owner for each dam. This study contains upstream and downstream dams with separate inundation maps. It only applies to one dam in one EAP. | Dam owners should explain the details of the dam, sample public notification, proof of affliction and supplies, as well as resources. | Annual EAP evaluation checklist, plan review and update, and training record. |
| **Guidelines for Developing Emergency Action Plans for Dams in Texas, USA** [17] | Help dam owner in creating their EAP for dam                         | Several dams owned by one owner in the same region may create one EAP to cover all the dams but separate the description, inundation map and notification flowcharts for each dam. | Dam owner shall define procedures and list conditions, cause incidents, and steps for the timely and effective identification, assessment, and classification of an actual or possible emergency. | Evaluation of this EAP depends on dam location, approval from authority, testing on dam and training for people involved. |
| **Engineering Guide to Emergency Planning for UK Reservoirs, UK** [22]   | Provide information to assist dam owner in planning an emergency plan for their reservoirs as one of the resources used to mitigate the risk. | Dam owner who owns few dams in the same region and involved in the same management should provide one EAP to combine all the dams. Nevertheless, each dam should provide a specific explanation and operation of dam. | As duty holder in charge of the reservoir, the dam owner must make and monitor plans to handle flood circumstances and minimise their effects as part of ensuring that the reservoir danger is handled and maintained at a safe level. | Evaluation of EAP for this guideline includes maintaining the impact assessment and maintenance of the On-site plan, such as training staff, testing equipment, and reviewing and updating the plan. |
Guideline | Aim | Finding | Action Plan | Review |
--- | --- | --- | --- | --- |
**Federal guidelines for Dam safety, USA [18]** | Providing instructions to execute an EAP to promote detailed and coherent measures of the dam safety. | Every dam area is different. Therefore, the extent and duration of each dam's possible impacts differ. This guideline only applies to one dam in one EAP. | Any changes in management and activities should be immediately revised to EAP. | Training and exercise activities results are vital components of an EAP's success evaluation. Those organisations with obligations defined in the EAP will design and implement training and exercise plans. |

**Emergency Action Plan for Class C - High Hazard Dams Instructions and Template, New York [25]** | To mitigate the downstream life, properties, and environmental hazard that could occur during the uncontrolled release of dam-impounded water. | The site-specific features of the dam and its location are defined in this section of the EAP. This guideline implies one dam for each EAP. | Discussion of procedures for timely detection, assessment, and classification and possible or potential emergencies. | EAP assessment criteria include training for people involved and exercising, such as orientation meeting, annual procedures test, tabletop exercise, functional exercise, and full-scale exercise. |

**Defra Guidance on Reservoir Emergencies, UK [21]** | To respond to incidents of emergency concerning their reservoirs. | A cascade dam with failure one of the upstream dams, the owner needs to notify the other dam owners at the upstream and downstream area that they are at risk of dam failure. | Cascading emergency notification among the dam's owner. | Training staff, testing equipment and exercise activities results are vital components of an EAP's success evaluation. |

6. Development of Dam Safety ERP (DSERP) in Malaysia: TNB Hydro Dam

TNB is the owner of the largest dam and also the major owner of hydropower dams in Malaysia was withstanding with inclusive preparedness program for their EAP. According to [1], TNB has performed dam break studies for their hydropower dam to meet corporate duty since 2005. Under the study, an emergency response plan (ERP) was developed and known as Dam Safety ERP (DSERP). The DSERP is an internal TNB's document designed to guide TNB’s dam personnel to detect, observe, respond during dam emergencies. The DSERP developed has been extended to accommodate local authorities' standard operating procedure (SOP) through collaborative training and engagement program between TNB and government agencies at various level (local, state and federal). TNB has decided to standardise the format termed the Emergency Response Plan (ERP), which also cover warning dissemination to the public and evacuation of populations at risk by responder's agencies [1], [12].

TNB actively involves the community and authorities in reinforcing an agenda to protect the people's best interest [29]. TNB’s ERP is connected with the local emergency standard operating procedure (SOP) in managing dam emergency incident. TNB’s ERP is linkage with early warning and evacuation plans established by Disaster Management and Relief Committee (DMRC). A proper connection between TNB’s ERP and local’s SOP is to ensure that the emergency notification and evacuation process at the affected location downstream is efficiently managed. The roles and responsibility of the DMRC are outlined in Directive No. 20, National Security Council (NSC) [30]. Among the guidance of TNB’s DSERP development in Malaysia is shown in Table 4.
Table 4. ERP source of references

| Year       | Standard Guideline                                                                 |
|------------|------------------------------------------------------------------------------------|
| 1997, (revised version 2012) | National Security Council Directive No.20 (NSC 20)                                     |
| 2003       | Australian National Committee on Large Dams (ANCOLD) -Guidelines on Dam Safety Management |
| 2017       | Malaysia Dam Safety Management Guidelines 2017 (MyDAMS)                                |
| 2019       | International Commission on Large Dams (ICOLD)                                       |

DSERP outlined "who does what, when, where and how" during dam emergency incidents. The ERP developed is a guide for TNB's dam personnel to identify emergency conditions that could endanger the dam's integrity and require immediate action. Prescribe procedures should be followed to respond to and mitigate emergency conditions at the dam. It also provides a timely warning to dam personnel and suits the local agencies' mechanism response plan for downstream communities. Additionally, ERP also provides dam break information such as flood arrival time, time to max flood depth, max flood flow velocity, max flood inundation depth, and flood extent [31]. This information would help dam owner and emergency responders to respond adequately during an emergency event. DSERP does not include emergency response guidelines for those responsible for coordinating the emergency response outside the dam site; a warning to public and evacuation exercises is the roles of DMRC as stipulated in NSC 20 [32][33].

The ERP establishes a chain of responsibility, setting up effective communication channels and getting the right people to the right place at the right time [34]. ERP applies to possible, suspected and actual dam safety emergencies involving TNB's Hydro Dam. During an emergency, the dam owner is responsible for prompting the notification to the authorities, who are on duty to warn and evacuate the affected population. The ERP includes notification of warning and liaison with those responsible for coordinating the emergency response outside the dam site. Certain conditions may develop that will require warning and evacuation of the population at risk located downstream of the dam.

6.1. DSERP Management Team
It is the responsibility of all dam personnel not to endanger their own lives while on duty. Each person in charge can delegate some or all of their responsibilities to the next most senior person if they are fit. Furthermore, if the person being represented cannot be contacted, the next senior person should be contacted automatically to assume the role. The following organisational chart of the emergency management team determines the authority and responsibilities in the ERP. Not all staff on the Emergency Management Team chart will be involved in the DSERP. During Emergency, Incident Commander (IC) will activate the ECC (emergency control centre) at a secure and accessible location with the most available communication channels: mobile phone, radio-amateur, satellite phone, fax, e-mail, radio. Having a satellite phone or trunk radio is useful during unpredictable conditions, in which power failure and telecommunications signal go down. Figure 1 shows an example organisation chart for the emergency management team (EMT) for DSERP.

7. Conclusions
The impact caused by dam failure often leads to loss of life, damage to property and environmental value of the affected downstream area. Dam owner must take greater responsibility to ensure the possible risks are being mitigated effectively through communicating with all stakeholders. During emergencies, the dam owner is responsible for prompting the emergencies notification to the authorities. The responsible personnel from authorities warn and evacuate the affected population. The main purpose of preparing EAP is to provide a proper procedure in assisting dam personnel in executing dam emergency
operation. The EAP manual should be maintained and updated regularly to remain up-to-date and practical at all time. Pre-notification and early warning play an important role in the success of dam emergency operations, and therefore it should be prioritised in the plan. A good EAP would help prevent and reduce the impact on life and property in the event of dam failure. No doubt, it is challenging to do rescue operations and evacuation during the dam failure event; thus, early warning and a quick response would save people's life. Practicable EAP potentially minimise the impact on the society and environment due to dam failure.

It is important to conduct drill and simulation exercises to prepare dam personnel and authorities to always ready to face dam incident. Both exercises assess dam owners and local authorities' preparedness to deal with emergencies related to the dam. The benefit of establishing a dam safety emergency action plan is to create better communication and effective responses among dam owners and agencies to save lives during dam emergency occurrences.

Acknowledgement (s)
I would like to thank my superiors and colleagues who helped me gather information from time to time in doing this paper. Despite their busy schedules, they gave me different ideas in making this paper unique. Thanks to my organisation for financial support in producing this paper.

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