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# ESTABLISHMENT AND IMPLEMENTATION OF THE EMERGENCY ACTION PLAN ON THE NAM NGIEP 1 HYDROPOWER PROJECT IN LAOS

**T. TABUCHI**
*Nam Ngiep 1 Power Company Limited, Bolikhamxay, Lao PDR*

**Y. AOSAKA, I. SAKAI, Y. YAMAMOTO AND S. TSUTSUI**
*Kansai Electric Power Company, Osaka,*

## ABSTRACT

*A 167 m high roller-compacted concrete (RCC) dam and a 270 MW main power station are being built in the Lao People's Democratic Republic (Lao PDR) under the Nam Ngiep 1 Hydropower Project (NNP1). The large reservoir of 70 km in length, 67 km2 in area and 2 billion m3 in volume has such risks as floodwater releases, extraordinary dam behavior and so on, that may impact human lives and properties along the downstream river basin. An Emergency Action Plan (EAP) consisting of dam emergency events, hazard map, notification, preparedness, and its procedure, is being established to mitigate issues caused by the above risks. So far, actions related to issues of extraordinary dam behavior have been taken twice during initial impounding. The reservoir water level was lowered to secure dam stability when the uplift pressure increased rapidly. A notification drill for emergency cases is being prepared by NNP1 and the Lao Government before starting commercial operation. This paper presents the process of establishing the EAP and its actions.*

## 1. INTRODUCTION

NNP1 is an Independent Power Producer (IPP) Project developed by Kansai Electric Power Company (KANSAI) in Japan, Electricity Generation Authority of Thailand (EGAT) in Thailand and Lao Holding State Enterprise (LHSE) in Lao PDR. It is located along the Nam Ngiep River, which is a tributary of the Mekong River, 130 km north-east from the Vientiane capital and consists of two sets of dam and powerhouse, namely the main dam of 167 m high and the main powerhouse with 273 MW installed capacity; and the re-regulation dam of 20.6 m high and the re-regulation powerhouse with 17 MW installed capacity. Through constructing of a dam, a reservoir of 70 km in length, 67 km2 in area and 2 billion m3 in storage capacity is created. Any large man-made reservoir possesses inherent risks. And any risk event, however unlikely it might be, including miss operation or dam breach, may severely impact human lives, properties, and livelihoods along the downstream river course. In order to mitigate the extent and severity of the possible impact of such risk events, and to pre-empt or mitigate further consequential events, the EAP incorporates amongst other things the identification and definition of imaginable emergency events, hazard maps, notification to and relation with persons and agencies concerned, preparedness, and response procedures; all in accordance with the Concession Agreement (CA) with Lao PDR and the advice of a third party, the Dam Safety Review Panel (DSRP) hired by the Lao Government. This paper presents the process of the establishment of the EAP and its actions.

## 2. OUTLINE OF EAP

### 2.1 Concept of EAP

According to Federal Emergency Management Agency in USA (Federal Emergency Management Agency. 2013), the EAP is a formal document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize loss of life and property damage. The EAP includes:

- Actions the dam owner will take to moderate or alleviate a problem at the dam
- Actions the dam owner will take, and in coordination with emergency management authorities, to respond to incidents or emergencies related to the dam
- Procedures dam owners will follow to issue early warning and notification messages to responsible downstream emergency management authorities

- Inundation maps to help dam owners and emergency management authorities identify critical infrastructure and population-at-risk sites that may require protective measures, warning, and evacuation planning
- Delineation of the responsibilities of all those involved in managing an incident or emergency and how the responsibilities should be coordinated

In the above guideline, some cases having damages on assets along the downstream river course are introduced and it is recommended that the EAP is uniform with other EAP's that are managed by national level agencies; hence cooperation with the agencies concerned to achieve such uniform implementation is advisable. The contents described in the EAP are the items shown in Figure 1 (Cal OES. 2019).

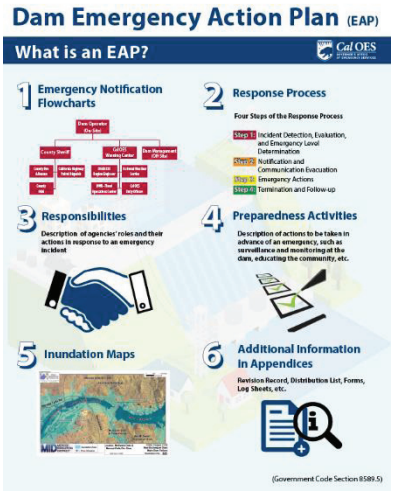



**Figure 1** : Concept of EAP

## 2.2 Implementation of EAP in Lao PDR

The information on the EAP in Lao PDR was kindly provided by a member of the DSRP, Mr. Chris Grant. An EAP is being implemented by a big hydropower project preceding the NNP1 and he gave us recommendations based on plans, procedures, and practices of the EAPs in Lao PDR. The activities of the EAP in NNP1 are also introduced to mini-hydropower projects in Lao PDR, which are mostly invested in by Lao local companies, as a good example of the EAP. The safety and sustainability of hydroelectric projects are of utmost importance to the Government of the Lao PDR and it is continuously pushing and propagating important and positive developments in this respect. Despite this, in recent years several cases have emerged where practices and also procedures were not implemented properly, or were inadequate and even deliberately misguiding; in some cases severe consequences. Below are just three examples:

- Project X under construction had not disclosed the inundation map since residents are likely to panic. When an emergency event did occur, many residents did not get notified because contact persons had not been given essential information.
- At Project Y which has a large reservoir of 450 km2, some of the saddle dams were overflown by the hydraulic gradient in the large reservoir during a flood event. Although it took time for the flood to propagate from the upper-reach to the downstream of the reservoir and the event could have been prevented by controlled spilling, the event happened because project staff had not foreseen the scale of the influx. Now Project Y is upgrading the flood prediction simulation tool to control the reservoir water level during floods. In addition, Project Y is disseminating methods of evacuation to residents in cooperation with the Lao Government. It is the most important for the residents to evacuate to muster points quickly and stay there, leaving behind their livestock and assets.
- Whilst still under construction, one of the saddle dams in Project Z breached gradually over a roughly 24 hour period. It caused substantial damage because, while residents were notified of the event, they did not know how to evacuate effectively.

NNP1 has established contact with key staff of Lao local agencies and representatives of residents, and also focused on effective methods of timely notifying farmers working at cultivation lands. NNP1 has implemented its EAP since the initial impounding starting from May 2018 and has notified the dam operation events to the designated contact persons transparently and effectively. NNP1 also regularly holds information sessions for residents as well as outsiders explaining the project and safety aspects, and responds to concerns that are voiced during the sessions.

Striving to make the notification of events yet more effective and faster, NNP1 is now expanding its IT infrastructure to supplement the established and more traditional methods; this includes the use of Short Message Service (SMS) notifications and of social media such as Facebook, Whatsapp, Line, Twitter, and KLM airlines as well as the development

of a smartphone app. It is key that special attention is given to the elderly, as well as to the less mobile and to mentally impeded persons, so no one is left out. It must be ensured that they too will have an appropriate understanding of the EAP and that, where necessary, special arrangements are made for their evacuation.

Ideally, relevant agencies such as the military join the physical evacuation drills since neither the NNP1, nor villages have sufficient resources (personnel, equipment, and machinery) to handle actual large-scale emergency and evacuation situations on their own.

## 3. IMPLEMENTATION OF EAP BY NNP1

### 3.1 Background of EAP

#### 3.1.1 *Assets of residents*

There exist nine (9) villages along the Nam Ngiep River as shown in Figure 2 (Nam Ngiep 1 Power Company Limited. 2014), total of 1,600 households and 8,500 people residing. They rely on wells for drinking water due to deterioration of the quality of river water, and it is rare to use the river water as irrigation because their main cultivation style is rain-fed agriculture. Fishing is not popular because of decreasing yields. Where in the past people relied mostly on boats for transportation amongst villages, especially during the rainy season, since the construction of the NNP1 project access roads most transport is now by road; and boats are now mainly just used to access farmland across the river. To facilitate this a minimum water depth, allowing boats traversing the river, is maintained in accordance with the CA.

Throughout Lao PDR, traces of damage are found caused by Typhoon Haima in June 2011. Along the Nam Ngiep River, three downstream villages were inundated by the flood of which peak was around 2,500 m3/s, which is equivalent to a 30 year return period flood. However, most houses have escaped the inundation above the floorboards because of the high floor type house shown in (a) of Figure 3 and residents at one village evacuated to the temple located on the hilltop where a certain quantity of drink and food was stockpiled. Nowadays, modern types of houses made of brick are being constructed with raised floors at levels above the trace of the flood by the typhoon Haima as shown in (b) of Figure 3.

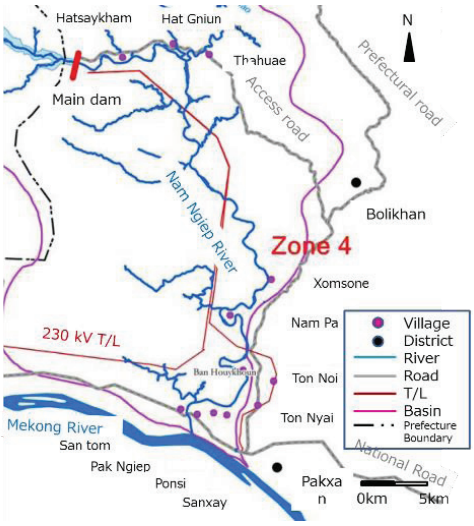



**Figure 2** : Area to be cared for EAP

**(a) High-floor type** **(b) Modern type made of brick**

**Figure 3** : Photo of houses along Nam Ngiep River

#### 3.1.2 *Responsibilities of NNP1 according to CA*

According to CA, the NNP1 is obliged to mitigate impacts on the downstream river course related to the dam operation. The NNP1 is a hydropower exclusive project and flood control is not required for the NNP1. However, except for the period of floods, the river water depth is controlled to keep fluctuations within 0.3 m per 30 minutes, 1.7 m per day and 1.7 m per consecutive 7 days. In addition, a flow of 27 $m^3/s$, which is equal to the minimum monthly mean inflow in the past, must be maintained. The mean inflow of the NNP1 is around 150 $m^3/s$ and the inflow increases in the rainy season from June to September.

As for the dam stability, the dams were designed and constructed based on international standards and its appropriateness was reviewed and endorsed by the DSRP. The dams were designed to accommodate the assumed maximum events such as Credible Maximum Earthquake (CME) and Probable Maximum Flood (PMF).

### 3.2 Outline of EAP

#### 3.2.1 *Position of EAP in the NNP1 management plan*

An outline of the management plan containing EAP is shown in Figure 4.

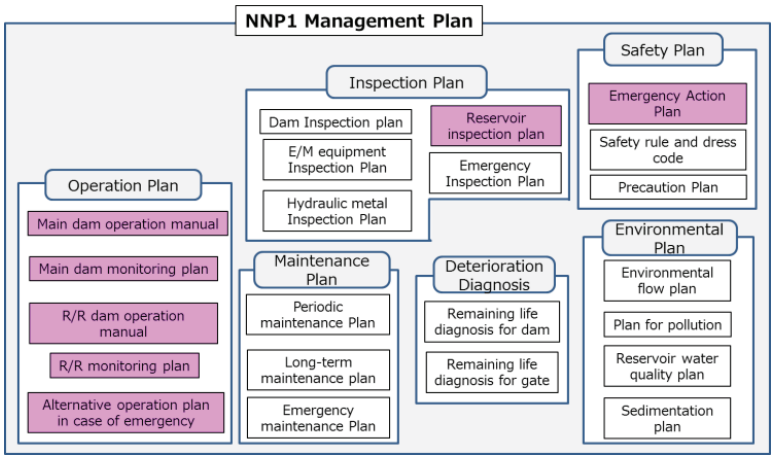



**Figure 4** : Position of EAP in NNP1 management plan

### 3.2.2 *Definition of emergency events*

In order to identify conceivable emergency events, various scenarios are considered, such as; displacement, opening of joints, crack, leakage and uplift pressure of foundation and dam drainages, piping, the trouble of gates, miss operation of gates and so on. For each of these scenarios, risk levels are defined and relevant actions are allocated; The criteria described in Table 1 is temporary set based on practices in other projects, however, they will be adjusted according to the actual behaviours of the dam as suggested by NNP1 and subsequent review by the DSRP.

**Table 1** : Definition of Emergency Event

| **Monitoring Level related to displacement of dam** | | |
|---|---|---|
| I | II | III |
| Dam has no risk to fail | Dam is having a risk to fail | Dam has a risk to fail |
| Displacement converges<br>No rapid change of leakage from foundation and dam body.<br>No rapid change of uplift pressure. | Displacement doesn't con-verge.<br>No rapid change of leakage from foundation and dam body.<br>No rapid change of uplift pressure. | Displacement doesn't con-verge.<br>Rapid change of leakage from foundation and dam body.<br>Rapid change of uplift pres-sure. |

During the initial impounding, the plumb line installed in the dam body and foundation in the right bank side showed unusual behaviour in July 2018, which was larger than expected and deviated from the data of the other plumb lines. The part of the dam in question sits on a weak layer, which seemed to have been formed due to folding activity. The dam behaviour was replicated through non-linear elastic-plastic analysis with a 2-dimensional Finite Element Analysis (FEA) and was conducted by re-checking the material properties of the weak layer. The input criteria were adjusted based on the observed and analyzed data as shown in Figure 5. The criteria were re-set by using the double deviation (2 x sigma) of the observed data which is more accurate than analyzed data. Currently, the dam behaves elastically to changes in reservoir water levels close to the full tank level of EL.320 m. The initial impounding was suspended twice in accordance with the guidelines set out in the EAP and each time investigations were undertaken and appropriate measures were taken. It is judged that the plastic movement of the dam foundation closely corresponds with repeatedly raising and lowering the reservoir water level.

The items to be monitored and their frequency are determined along with the period of convergence of dam behaviours, and dam behaviours are monitored and evaluated by the NNP1 staff daily. The engineers concerned upload the monitoring results to NNP1's secure special purpose web site, which is then compiled into the weekly and monthly reports.

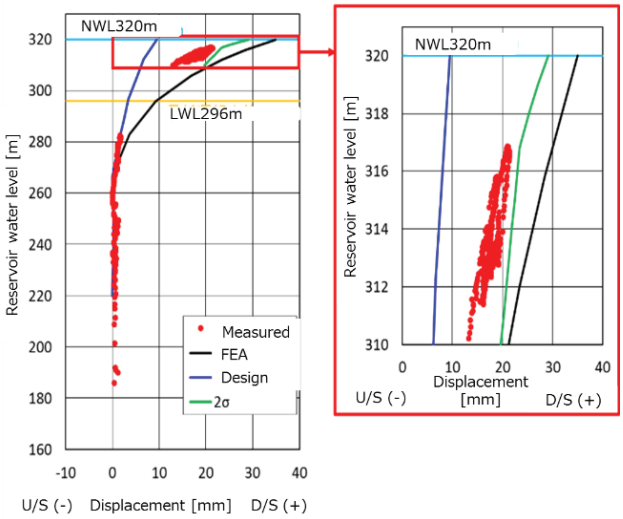



**Figure 5** : Observed data and criteria of plumb line on the right side of dam

### 3.2.3 *Precaution of damage along downstream river course*

Up to some amount during flood NNP1 should control the gate operation not to release the water sharply, but over this value NNP1 gets free from this limitation. Based on flood records, the condition of inundation was simulated by using a 2-dimensional non-uniform flow analysis. In the case of 2 year return period flood of 1,000 m3/s, Hat Gniun and Thahua villages start to be inundated at the edge of each village at EL.170 m and EL.168 m respectively as shown in Figure 6. However the inflow at the high rainy season from June to September was in excess of 200 m3/s and the lands along the river sides and transportation by boats were affected by floods during this period. It is not practical to operate gates frequently to control the river water fluctuation in this period. Up to the flood comes NNP1 should control the gate operation not to release the water sharply, but NNP1 gets free from this limitation when the flood comes.

Table 2 shows the precautions taken along the downstream river course to prevent damage resulting from dam operation. NNP1 has installed a fence around the re-regulation dam reservoir, installed warning signboards at each village and distributed handbills. Whenever the gates are to be operated, advance warning is given from the fixed point at the re-regulation dam, a NNP1 car drives along Nam Ngiep River, and notification flyers are distributed to the contact persons.

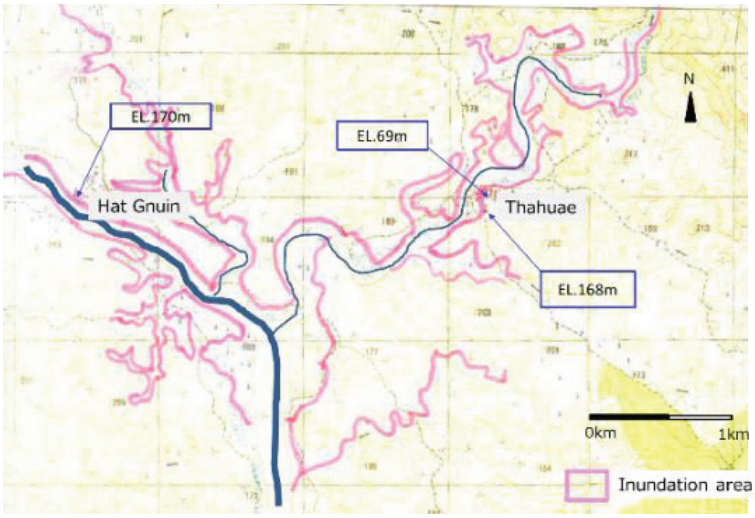



**Figure 6** : Inundation area by flood of 1,000 m3/s

**Table 2** : Precautions taken along the downstream river course to prevent damage during dam operation at various projects in Lao PDR

| Project Name | A | B | C | NNP1 |
|---|---|---|---|---|
| Standards | N/A | N/A | Discharge control | Under study |
| Discharge test | N/A | N/A | A to determine discharge which has no impact on D/S river | To be implemented during flood |
| Warning method | Alarm devise at 10 km D/S<br>Notification to D/S villages | Alarm device at dam<br>Warning by car | Alarm devices at main and R/R dams<br>Warning by car | Alarm device at R/R dam<br>Warning by car up to 10 km D/S<br>Notification to D/S villages |
| Prevention from entering | Fencing up to 800 m D/S from dam<br>Floating in front of intake and outlet | N/A | Fencing around R/R dam reservoir<br>Floating in front of intake and outlet | Fencing around R/R dam reservoir<br>Floating in front of intake |
| Others | - | - | 24 hour patrol | Warning sign board at each village<br>Delivery of flier |

### 3.2.4 *Dam operation*

The NNP1 has made a rule curve to regulate the reservoir water annually for maximizing electricity generation since there is a significant difference in inflow between the dry and rainy season. The followings are paid attention for dam operation especially during the rainy season:

- Not to allow the reservoir water level to exceed the dam crest elevation of EL.322 m for dam safety;
- Not to cause artificial floods by dam operation, by following the gate operation rules;
- Not to allow the reservoir water level to exceed NWL.320 m for minimizing the backwater effect to the upper-reach of the reservoir;
- To keep the reservoir water level high so as to maximise electricity generation.

Table 3 shows the practice of upholding gate operation and controlled reservoir water level in Lao PDR. The former is conducted to control the river water depth fluctuation against the large flood by storing the flood discharge in the reservoir and increasing the discharge from gates gradually. Figure 7 (Nam Theun 2 Hydropower Company Ltd. 2015) shows the location of Project A and C. The Project C has a huge reservoir of 450 km2 along the C River and releases the water used for electricity generation to the Y River through the C Powerhouse located at the southeast of the reservoir. The re-regulation reservoir was made to control the river water depth fluctuation along the downstream river channel up to the confluence to the Y River with regulation of discharge amount fluctuation within 50 $m^3$ per hour. On the other hand, the environmental flow of 16 m3/s is released to the C River at the C Dam located in the northwest of the reservoir. While the flood is discharged through this dam by gate operation, phasedly controlled reservoir water levels are set by allowing surcharge reservoir water level, in order to minimize the impacts on the downstream C River course-including the A project and not to exceed the reservoir water level at the saddle dams around the reservoir.

The NNP1 determined not to apply the controlled reservoir water level since the flood control is not required for the NNP1 and the controlled reservoir water level much deteriorates the project economy. When the damage due to the backwater effect is found, compensation will be conducted case by case. NNP1 has continued dam operation and notification of contact persons and villagers by following the EAP since the start of the initial impounding in May 2018, and the emergency discharge was carried out twice along due to unusual events. So far no accidents occurred and NNP1 received only minor claims for damages on cultivation lands along the river sides by residents.

**Table 3** : Holding up gate operation and controlled reservoir water level in Lao PDR

| Project Name | A | B | C | NNP1 |
|---|---|---|---|---|
| Delayed gate operation | N/A | N/A | A | N/A |
| Controlled reservoir water level | N/A | N/A | A | N/A |
| Operation over NWL | A | N/A | A | Partially A |

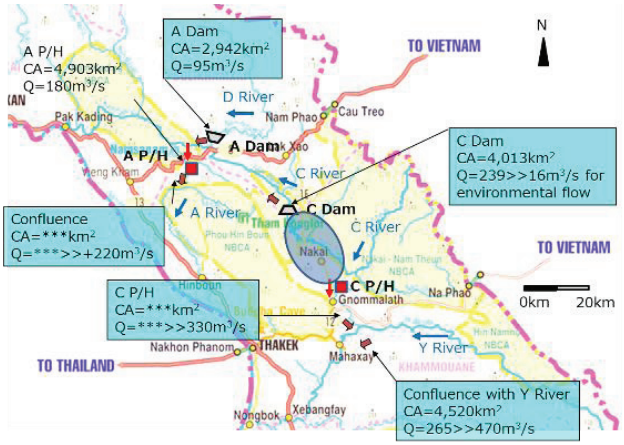



**Figure 7** : Location of Project A and C

### 3.2.5 *Flood inundation simulation*

The Nam Ngiep River has a gorge at the upstream reach from the dam site, while its downstream river course of 55 km long is meandering at the flat fan extending from the mouth of the gorge as shown in Figure 2. Figure 8 (Kansai Electric Power Co., Ltd. 2011) shows the Nam Ngiep River profile. The state of flood inundation is divided into three types along the upstream, middle and downstream river courses from the topographic terms; namely flow, storage, and expansion types as shown in Figure 9 (Ministry of Land, Infrastructure, Transport and Tourism, 2006 in Japanese). If there were to be a dam breach, it may cause a complex flow depending on topography and, due to the large flow, create a storage even if it is categorized as flow type. In view of the above reason, a combined model was applied for simulation by 2-dimensional non-uniform flow analysis for the ground and 1-dimensional non-uniform flow analysis for the river course. The simulated area is 55 km long east to west and 50 km south to north including from the dam site to the confluence with the Mekong River. The data of elevation is entered in a 250 m x 250 m mesh as an overlay on a scale 1 to 25,000 topographic map. Two (2) cases of the Mekong River water level are set; 1) Mean water level in August and September (EL.153.08 m) and 2) 50-year return period flood water level (156.925 m).

Figure 10 shows the mean inflow of 300 $m^3/s$ during the rainy season and the hydrograph in the case of a design flood of 5,210 m3/s equal to 1,000 year return period flood. Figure 11 shows the hydrograph in a case of a dam breach. The case conservatively assumed that a 130 m long right side section of the dam, out of the 530 m long section where the folded zone exists, under the dam body has been fully destroyed.

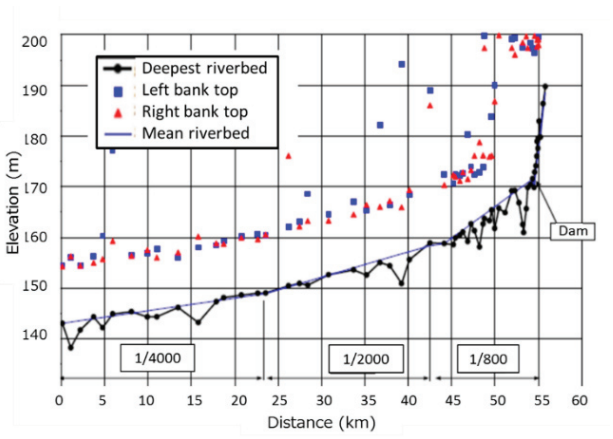



**Figure 8** : Nam Ngiep River profile

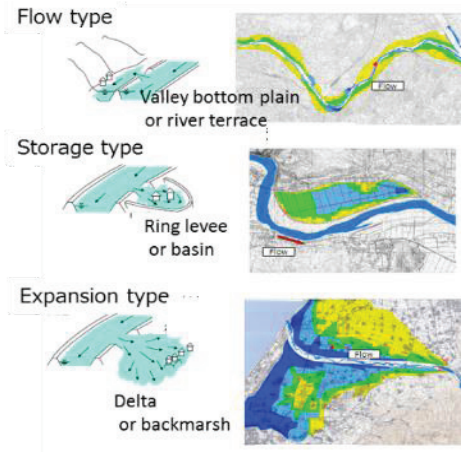



**Figure 9** : State of inundation

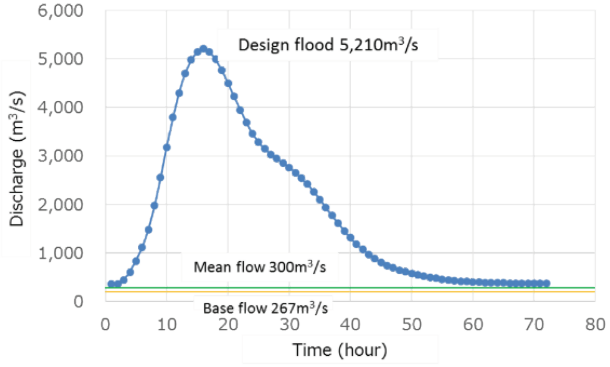



**Figure 10** : Hydrograph in case of design flood

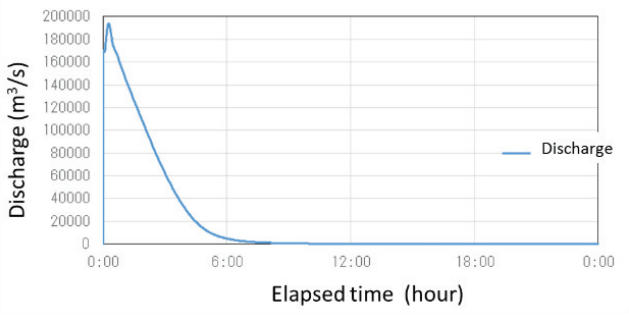
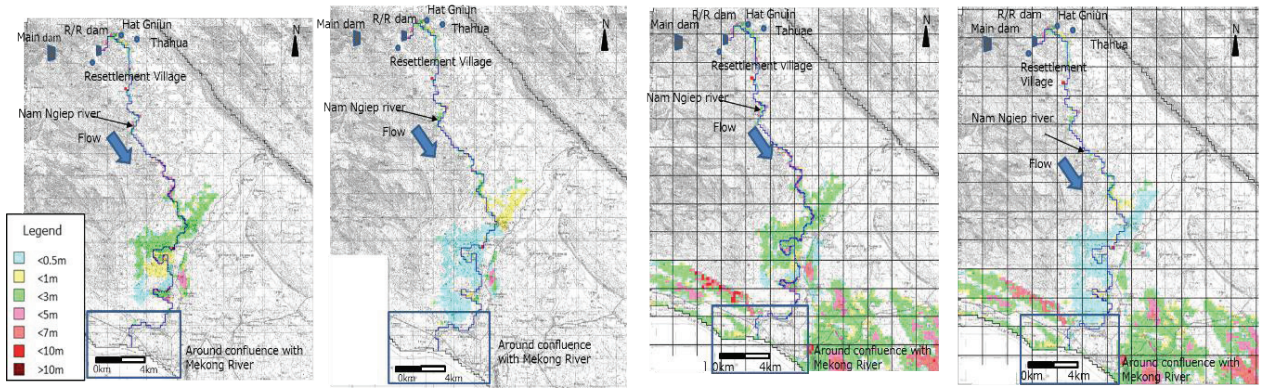



**Figure 11** : Hydrograph in case of dam breach

Figure 12 is the inundation map in case of the design flood. Ten hours from the start of the flood, flood discharge amounting to 3,000 m3/s occurs, resulting in inundation at the middle river course which reaches the maximum inundation after 28 hours as shown in (a) . After 48 hours the inundation turns to convergent and is reduced to below 0.5 m at the middle river course as shown in (b) of Figure 12. From the middle to downstream, the river course will be widely inundated with 1 to 2 m depth and partially with 5 m depth, however, around the confluence with the Mekong River no inundation occurs. In case of 50-year return period flood, inundated area develops same as the above case as shown in (c), however, the inundation prolongs as shown in (d)




(a) Design flood with mean Mekong River water level 28 hours later

(b) Design flood with mean Mekong River water level 28 hours later

(c) Design flood with 50 year return period Mekong River flood 24 hours later

(d) Design flood with 50 year return period Mekong River flood 72 hours later

**Figure 12** : Inundation map in case of design flood with mean Mekong river water level and design flood with 50-year return period Mekong River flood

Figure 13 is the inundation map in the case of the dam breach with 50-year return period flood of the Mekong River. The flood reaches the downstream river course one hour later from the dam breach and has the peak of the inundation 10 hours later. The inundation expands widely from upstream to downstream with the maximum depth of 20 m in the upstream area. It is found that the inundation map in the case of the re-regulation dam breach, of which storage capacity is 770 million m3, shows a tendency similar to that in the case of the design flood.

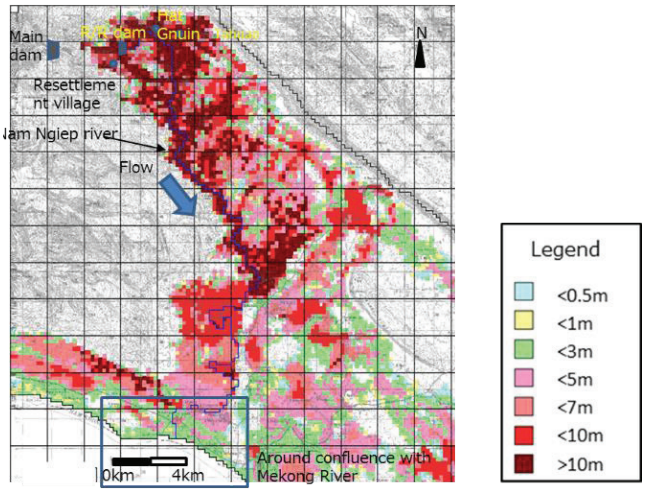



**Figure 13** : Inundation map in case of dam breach

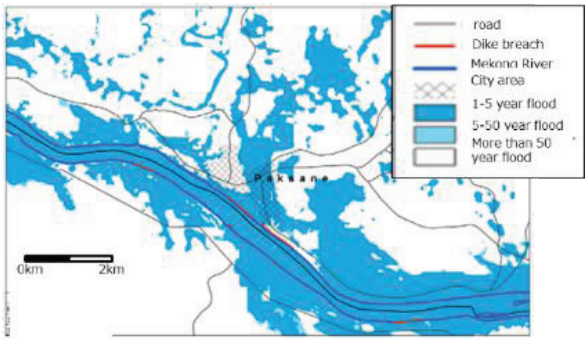



**Figure 14** : Inundation map in case of 50-year with 50-year return period Mekong River flood period Mekong River flood

The inundation map of Figure 14, which illustrates the case of the Mekong River flood is provided by the Mekong River Commission (Mekong River Commission. 2018). Since it has no inundation area around the confluence with the Mekong River at Pakxan town in case of the design flood as shown in Figure 11, it appears that the Mekong River flood would have a larger impact at this area than the flood by the Nam Ngiep River, though Figure 14 does not show the boundaries of the inundation area for this case.

### 3.2.6 *Notification to residents and evacuation drill*

As recommended by the Lao Government discussions have taken place with related agencies about the implantation of training for information notification and evacuation drills. Especially the latter is strongly recommended by the Lao Government due to the severe incidents such as the saddle dam breach at Project X. The Emergency Evacuation Plan (EEP), which at the time of issue of this paper is substantially complete but still being refined, specifies the timing of evacuation, muster points, and methods of evacuation etc., as detailed in Chapter 2. Striving to make the notification of events yet more effective and faster, NNP1 is now expanding its IT infrastructure to supplement the established and more traditional methods; this includes the use of SMS notifications and of social media such as Facebook, Whatsapp, Line, Twitter, as well as the development of a smartphone app. It is key that special attention is given to the elderly, as well as to the less mobile and to mentally impeded persons, so they too will have an understanding of the EAP and that, where necessary, special arrangements are made to ensure they too are evacuated. Ideally, relevant agencies such as the military join the physical evacuation drills since neither the NNP1, nor villages have sufficient resources (personnel, equipment, and machinery) to handle actual large-scale emergency and evacuation situations on their own. Figure 15 is the notification flowchart. According to the agreement with the Lao Government, the NNP1 does not have responsibility for notification and evacuation of residents, however, the NNP1 is making efforts to work cooperatively with the Lao Government.

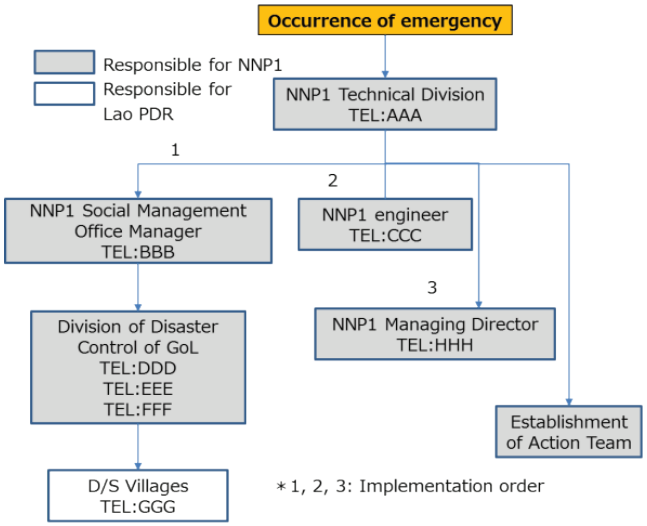



**Figure 15** : Notification flowchart

## 4. CONCLUSIONS

Firstly we have to identify dam behaviours related to dam safety and set phased criteria for making actions. In order to identify conceivable emergency events, various scenarios are considered; and for each of these scenarios, risk levels are defined and relevant actions are allocated. The initial impounding of the dam was suspended twice and rectified in accordance with the EAP through investigation, analysis, and undertaking appropriate measures. The NNP1 has established the methods to notify the dam operation with timely and appropriate manner. So far the NNP1 has had no significant damages along the downstream river course and received only minor claims related to dam operation and anxiety about dam safety from residents.

It is important to know the short and long-term behaviour of the dam. When unusual movement is found, the quick responses such as investigation, evaluation, and measures are also required. The monitoring items and frequency should be modified according to the actual dam behaviour. In order to secure appropriate dam operation, it is essential to upgrade the accuracy of inflow and flood prediction. And it is required to upgrade the skill of the dam operation staff. The flood inundation map should be upgraded by using more accurate topographic map. The river cross section should be surveyed frequently especially after the rainy season (Gippel, Christopher J. 2019). It is found the Mekong River flood has much impact around the confluence with the Mekong River (Gippel, Christopher J. 2019), so that it is necessary to share information and discuss with related agencies on how to mitigate this area. As requested by the Lao Government, it is desirable to disseminate the flood inundation map and implement evacuation drills soon. The NNP1 achieved the commercial operation date in early September 2019 and will continue to mitigate the impacts on the downstream river course as much as possible by following the EAP.

## REFERENCE

Cal OES, GOVENER's OFFICE OF EMERGENCY SERVICE. 2017.

https://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/dam-safety-planning-division.

Federal Emergency Management Agency. 2013. Federal guidelines for dams safety, Emergency action plan-ning for dams: 64.

Gippel, Christopher J. 2019. Estimation of flood risk for villages on Nam Ngiep River downstream of NNP1 to Mekong River: 22

Mekong River Commission. 2018. Flood Sector Key Findings Report - Flood protection Structures and Flood Infrastructure, unedited version 3.1, The Study on the Sustainable Management and Development of the Me-kong

River Basin, including Impacts of Mainstream Hydropower Projects: 79.

Ministry of Land, Infrastructure, Transport and Tourism in Japan. 2006. Guideline on mapping of inundation area along the small and middle size rivers: 14 (in Japanese).

Nam Ngiep 1 Power Company Limited. 2014. Environmental Impact Assessment Main Report: 703.

Nam Theun 2 Hydropower Company Ltd. 2015. Emergency Contingency Plan for Nakai dam, Saddle dams and Nakai Reservoir: 59pp.

Kansai Electric Power Co., Ltd. 2011. Flood Survey Report by tropical typhoon Haima on Nam Ngiep 1 Hydropower Project: 12.