FORECASTING THE RISK OF FLOODING WHEN THE PAC CAP HYDROPOWER DAM BREAKS ON NA RI RIVER IN BAC KAN PROVINCE

Pham Thi To Oanh
Vietnam Cooperative Alliance

ABSTRACT

Pac Cap hydropower was approved investment policy in Decision No.96/QĐ-UBND dated 18/01/2018 on Na Ri River, Na Ri district, Bac Kan province with the capacity of 6MW. During the construction and operation of 02 units, dam breakdown can occur when the crests of dams, horizontal cracking and cracking along the dam, sliding roof upstream and downstream of the dam, etc. This study focused on simulation of breakage occurrence using the Mike Flood model. The results show that the largest flood depth would be over 10 meters with the flooded area of about 15 hectares, which is mainly land for annual crops, rice land and production forests; depth from 4 to 10 meters would occupy about 10 hectares; depth of 1 to 4 meters in addition to the forest land and inundated agricultural land would engulf about 30 houses in Luong Thanh and Lam Son communes of Na Ri district and some other infrastructure projects. The results of the study are the basis for introducing preventive measures to minimize the damage to the downstream area, as well as to determine the responsibility of the plant in the compensation process if the incident occurs.

Keywords: *hydropower; risk; dam break; model; inundation*

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DỰ BÁO KHẢ NĂNG NGẬP LỤT KHI VỠ ĐẬP THỦY ĐIỆN PẮC CÁP TRÊN SÔNG NÀ RÌ TỈNH BẮC KẠN

Phạm Thị Tố Oanh
Liên minh Hợp tác xã Việt Nam

TÓM TẮT

Thủy điện Pác Cáp được phê duyệt chủ trương đầu tư tại Quyết định số 96/QĐ-UBND ngày 18/01/2018 trên sông Na Rì, huyện Na Rì tỉnh Bắc Kạn với công suất 6 MW. Trong quá trình thi công, vận hành 02 tổ máy, vỡ đập có thể xảy ra khi lũ tràn đỉnh đập, nứt ngang nứt dọc đập, trượt mái thượng và hạ lưu đập,… Nghiên cứu này tập trung mô phỏng sự cố vỡ đập thông qua việc sử dụng mô hình Mike Flood. Kết quả chỉ ra rằng: chiều sâu ngập lớn nhất >10 m với diện tích ngập lụt khoảng 15 ha trong đó chủ yếu là đất trồng cây hàng năm, đất lúa và rừng sản xuất; chiều sâu ngập từ 4-10 m chiếm khoảng 10 ha; chiều sâu từ 1-4 m ngoài các loại đất rừng và đất nông nghiệp bị ngập còn nhấn chìm khoảng 30 ngôi nhà của xã Lương Thành và Lam Sơn thuộc huyện Na Rì và một số công trình hạ tầng khác. Kết quả nghiên cứu là cơ sở đưa ra các biện pháp phòng tránh nhằm giảm thiểu tác hại đến vùng hạ lưu công trình, đồng thời cũng là căn cứ để xác định trách nhiệm của Nhà máy trong quá trình bồi thường nếu để sự cố xảy ra.

Từ khóa: *Thủy điện; rủi ro; vỡ đập; mô hình; ngập lụt*

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Email: oanhphamto@gmail.com

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1. Introduction

On 23/7/2018, a hydropower plant dam in Laos broke down, killing at least 26 people, leaving 6,000 people homeless and around 25,000 people were forced to evacuate. In Vietnam, safety hazards in many hydropower plants show the importance of building preventative measures as soon as a hydropower plant is being built. Pac Cap hydropower plant was approved by Decision No 96/QDD-UBND dated 18/01/2018 on Na Ri River, Na Ri district, Bac Kan province with the capacity of 6MW. During the construction and operating 2 units, dam breakdown can happen when floods pass the top of the dam, vertical and horizontal cracking, roof sliding at upstream and downstream. According to the dam safety handbook and recent research toward dam breakdown, dam breakdown simulation, the severity and the area of flood downstream can be evaluated [1]-[4]. This is the basis to not only carry out preventative measures in order to reduce the damage dealt to downstream areas, but also to identify the responsibility of the plant during the indemnification process if an incident occurs.

2. Research methods

This paper used multiple methods, both traditional and modern within the field of nature and environment to collect and process data, statistically analyze, investigate and field survey in combination with math models (the primary method in this paper).

River hydraulic simulation and flooding process has been mentioned by scientists for a long time and specific programs have been built such as: Mike Flood (Denmark), Hec Ras (USA), WENDY (Holland), some programs from Vietnam such as: VRSAP by Nguyen Nhu Khue, KOD-01 by Nguyen An Nien, FWQ86M by Nguyen Tat Dac, HGKOD by Nguyen The Hung, HYDROGIS from The Institute of Meteorology and Hydrology... These models can all be applied to calculate the risk of dam breakdown based on the research on cracking lines, experiments on physical models and retrieved data from recent years [5], [6].

Even though each model has its good and bad points, they all try to simulate an exact map of flood level when the dam breaks. Tingsanchali [7] realised that using Hec Ras or WENDY to calculate the biggest amount of water show about twice bigger than the amount observable; MIKE model show the total amount of water is as approximately 0.2 times as the measured value. At the same time, MIKE also provides a more complete look into the dam breakdown, simulates flooded areas, combines with graphical maps to help display the spread of the flood [7].

Utilizing MIKE FLOOD to simulate floods has many advantages. For instance, it’s dynamic in calculation and changing scenarios; the simulated areas are quite large and it costs less than using physical models. However, one of its disadvantages is that it has too much data input..

3. General information about Pac Cap hydropower plant and the cause of dam breakdown

In 2010, Bac Kan People’s Committee approved Decision No 2461/QĐ-UBND about Planning of medium and small hydropower plants. Pac Cap hydropower plant was in the list of plants with good economic parameters: 3.2 MW capacity, total power output E_o= 13.18 million kWh, mND = 323m on Na Ri river, Luong Thanh commune, Na Ri district (Figure 1). However, in 2018, the area was surveyed, recalculated and updated with new technologies with the new capacity of 6MW and Bac Kan People’s Comittee approved the investment plan at Decision No 96/QĐ-UBND on 18/01/2018. The main parameters are as follow: MND = 246.5m, MNC = 245.5m, annually average output E_o= 21.26 mil kWh. Coordinate: $22^0 12'38''$ N, $106^0 07'48''$ E, F_{lv} = 540 km^2.

Figure 1. *Pac Cap Hydropower plant position*

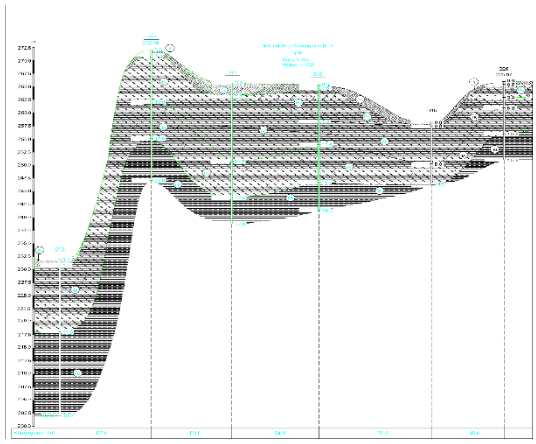

Figure 2. *Dam typical geological section*

Focal area and dam topography: The dam is located on the section of a river that has a cross section in V shape. Surface topography on both side of the river bank is steep, with the height ranging from +235m to +305m. Topography is influenced by reformation activities, a process in which rocks are raised, speed up the erosion to form eroding topography. The surface area consists of mainly weathered ruins and not many of accumulated terrain, mainly a thin layer of pebble in the soil.

Geological condition: The project is within Na Ri river stratum, acidic erupted rocks with Rionit ingredients, petrology ingredients are powder sand, rock, shale and pebbles. These rocks usually appear on mountain slopes, Na Ri river banks and small streams. The majority below the surface is layers of Ruins (elQ), alluvial (alQ) and slope (elQ). The thickness of each layer is around 1-4m. The main ingredients are sand or clay with a lot of dirt, in small sizes in blue white or grey yellow. The section of the dam is presented at Figure 2.

Earthquake: On the map of Vietnam earthquake with a cycle T = 500 years on a scale of 1:2000000, Pac Cap hydropower plant is in the area with earthquake level VII. Overall, the area is in the Na Kep – Pac Cap Fx Fissures. These are fissures within the tectonic plate differences between zones, but their existences also create changes in the area geological structure. The fissures develop following North East – South West, travelling upstream 800m from the dam and following the right bank of the river.

The structure of spillways and raising dam:

- *Rising dam*: Gravity concrete structure, core dam using M150 concrete, upstream dam using M200 concrete 1m thick, the dam section is covered with concrete layer M200 1m thick to increase adhesion to the dam foundation. The dam's highest elevation is 250,8m, the total length of the rising dam is 64,9m, the highest part of the dam is 22.8m, the whole bottom of the rising dam beneath MNDBT is above IB or IIA rock layer.

- Spillways with door valves: A trapezoid shape with the water spill area is 3x10m, the total length of the entire spillways including pillar is 40m, upstream maximum water output Q = 2561 m^3/s. The spillway elevation is 237m, curve radius is 7m, the hightfrom the bottom to the top is 9m. Door valves are curved, repair valve is straight. Spillway surface is M300 concrete, the core is M150 concrete. To ensure the hydrodynamic conditions about power and stability, the rocks and pebbles at the back of the dam are removed and reinforced with concrete 15m long, 2m thick.

With the structure and design of the dam combined with local topography evaluation, the reasons for dam breaking are predicted as follow:

- The first cause might be flaws in design, construction. Local geological features were not paid attention, so some details were not appropriate and operations failed to follow safety procedures. Some structure details and equipment which were not handled appropriately also affect the safety of the dam. In time, some parts of the dam or equipment did not receive enough maintenance causing a threat to the safety of the whole dam. In addition, there was a lack of emergency energy supply for spillways.

- The dam is on unstable ground; therefore, its safety can be affected by sliding, erosion on its foundation. Large and stimulate earthquakes also make the dam unsafe.

- The amount of input water might exceed the dam capacity, causing huge, unplanned floods. The amount of water in the lake exceeding its capacity can also cause landslide at the shore on a large scale.

When operating the power plant, all of the above possibility can happen and cause massive damage to downstream area.

4. Result and discussion

This paper is written based on three steps: (1) Calculate the amount of floods coming to the lake, match with emergency flood scenario; (2) Simulate dam breaking, (3) Evaluate the scale, the level of flooding and the effect toward downstream area.

4.1. Calculate the amount of water

Na Ri river is a first level tributary to Bac Giang river and also a confluence for smaller streams such as Ban Buoc stream (Liem Thuy commune), Ban Chao stream (Dong Xa commune)... Because the research area is small, there is no hydrology station in the area, therefore it's necessary to refer to the data of Thac Gieng hydropower plant data and some nearby hydrology stations such as Van Mich, Pac Luong as the basis to calculate.

Pac Cap hydropower station is a level III construction project, according to Viet Nam building regulations (QCVN 04-05:2012/BNNPTNT: National technical standards, Hydrology construction standard in design) the design frequency with the main building is 1,5%, control flood frequency is 0,5%. According to Hydrology design calculation norm QPTL.C-6-77 to area with more than 100km^2 in size can use shortened or Sokolovsky equation to determine amount of designed floods. The calculation is done by Sokolovsky equation [8]:

$$Q_{maxP} = 0{,}278\frac{\alpha(H_{Tp} - H_0)}{T_l}Ff$$

In which, $\alpha = 0{,}77$; $H_0 = 22$; $f = 0{,}7$; The time floods rise equal to the time to concentrate water in the river $T_l = \tau_s$, with τ_s determined by the following:

$$\tau_s = \frac{L}{3{,}6\overline{V_\tau}}$$

With: $\overline{V_\tau}$ the speed in which water is concentrated is determined by the following formula $\overline{V_\tau} = (0{,}6\text{-}0{,}7)\overline{V_{max}}$ .In which, $\overline{V}_{max}$ is the maximum average speed at the exit of the spillways downstream $\overline{V}_{max} = 2{,}8$ (m/s). Result is shown at Figure 3.

The relation between the lake and downstream of the plant: Documents used to build Q = f(H) line for the plant include horizontal and vertical cut of the dam and the plant (from field trip and from 1/2000, 1/500 máp). The relationship of Q = f(H) is calculated following Sedi-Manhing equation:

$$Q = \frac{1}{n}.\omega.R^{2/3}.J^{1/2}$$

With Q: The amount of water that flow through the cut section (m^3/s); n: roughness index; ω: total area of cut section (m^2); R: Hydraulic radius; J: hydraulic slope.

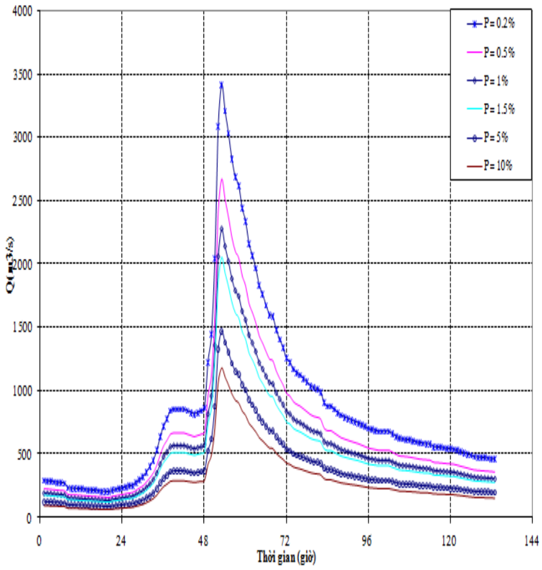

Figure 3. *Designed flood at the dam by time*

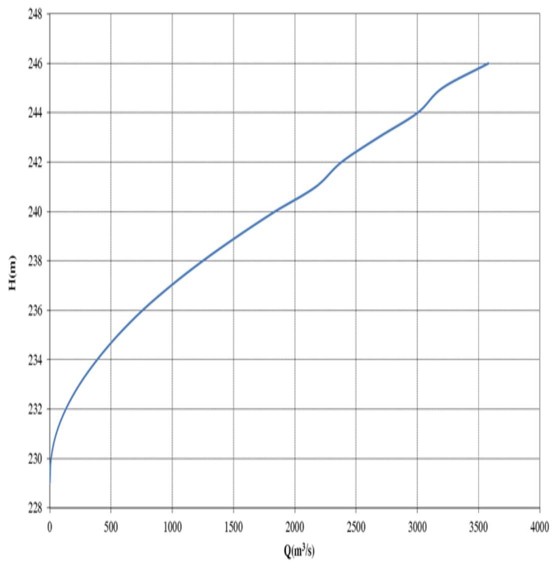

Figure 4. *The relation between Q =f(H) at downstream Pac Cap hydropower plant*

Results are shown in table 1 and Figure 2.

Table 1. *Q =f(H) at downstream Pac Cap Hydropower plant*

Q (m^3/s)	0.2	9.7	51.2	129.9	241.9	385.4	556	755.8	988.2
Z(m)	229	230	231	232	233	234	235	236	237
Q (m^3/s)	1247	1532	1837	2170	2380	2681	3002	3204	3580
Z(m)	238	239	240	241	242	243	244	245	246

4.2. Simulate dam breaking because of the flood

This research focus on the danger when Pac Cap dam broke. The area downstream is mainly half mountain terrain with no big river, water will first overflow and after that concentrate on smaller streams, springs, creeks in the area and finally will come down the Delta area. Input data for the simulation:

- Map of the area on a scale of 1/2000.

- Na Ri river horizontal cut section.

- Data on daily, monthly, yearly amount of rainfall at the dam area (Figure 5,6).

- Relation between H~Q at Thac Gieng hydro station (Figure 2).

- Data on the frequency line of yearly water flow (Figure 6), design and control floods at Pac Cap dam (Figure 3).

- Indexes such as: MNDBT, MNLKT, MNLTK... taken after design specification of Pac Cap hydropower plant.

- Hydrology data taken from weather and hydrology station (Bac Kan and Thac Gieng) from 1960-1979 and some nearby hydropower plant such as Van Mich, Pac Luong with data from 190 to the present day. Na Ri river hydrological conditions from 1960 to present day is as follow::

+ The amount of water flow daily through the river.

+ The amount of floods and floods process

Calculation result from MIKE Flood model simulating the flooded areas of Na Ri river is shown below.

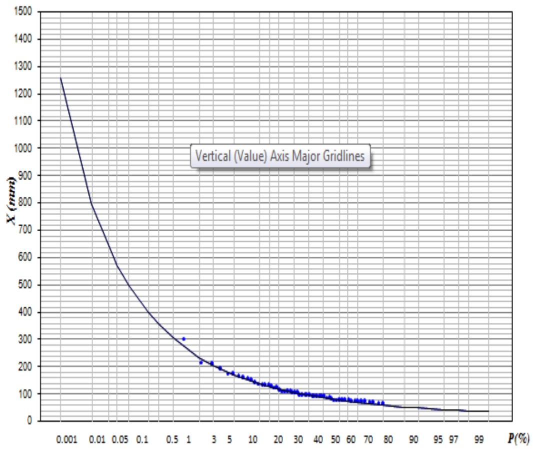

Figure 5. *Frequency line of the heaviest 1 day rain at Bac Kan station*

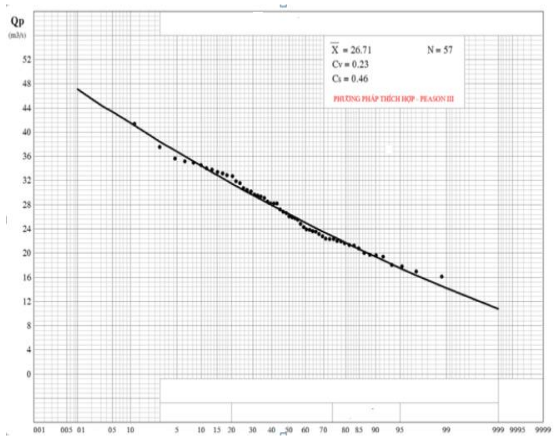

Figure 6. *Frequency line of yearly water flow at Pac Cap hydropower plant*

Figure 7. *Simulated flooded areas in case Pac Cap hydropower plant dam break*

4.3 Damage evaluation

Simulated results show that, in the case of dam failure, part of the communes of Van Minh, Luong Thanh, Lam Son may be affected with the lowest flood depth of about 1m and the highest of over 10m.

Maximum inundation depth is> 10m, affected objects are the villages of Na Du, Pac Lieng, Pac Ban, Na Ngoa, Na Deng, Na Muc, Khuoi Tuc, Na So, Na Piet, Van Minh commune and a part of the lower side. The total flooded area would be around 15ha including 5-7 ha of annual crops, 4-5 ha of production forest, 2-3 ha of rice paddies. In the area flooded deeper than 10m, there are no house or people living inside it and there aren't any sensitive structure.

The area under 4-10m deep is around 10ha, all within administration boundary of Luong Thanh commune, including 2-3ha of rice paddies, 3-4ha of annual crops, 2.5ha of production woods and 0.5-1ha of old trees. In this area, there are 10-20 house scattered near the river banks, mainly 4-level houses and semi durable houses would be flooded.

Luong Thanh and Lam Son commune, Na Ri district would be flooded under 1-4 m deep. The total flooded area would be around 18ha, including 6 ha of annual crops, 4 ha of old trees, and 1-2 ha of various usage. In addition, around 50-100 houses with local road, electricity and other infrastructure in the area would also be flooded. Even though the water may not be very deep, it would still cause major damage in man and properties.

In general, the chance for a dam to break can happen at any hydropower plant and it'll cause many negative effects to local society and economy, including endangering the lives of people downstream and workers of the power plant; damage to the economy, destroying local infrastructures (traffics, schools, water, electricity...); polluting the environment..

Proposals to lessen the chance of dam break down can be given as follows:

- Before operation, the plant should form detailed plans for each situation that can happen. In case the dam loses its safety, workers and people living downstream have to begin evacuation to reduce damage to life. It is necessary to support the local population to move their belonging from the flooded areas identified as above.

- It is important to identify the evacuation limit, where landslides happen and how to strengthen the shore at downstream and exam the area to discharge water when there is flood after the dam breaks.

- It is also necessary to set up alarms, notice and work with local government to ensure the safety for people and their properties, boats and other water travel vehicles downstream to get to safety. Work with BCH-PCLB and local authorities to set up rescue attempt when needed.

5. Conclusion

Results from calculating the research area, determining areas affected by the incident are the basis to create methods to prevent and reduce the damage to the people such as: evacuation to higher ground based on the flood activity and priority to heavily flooded area first and area that lie on the way water flow. These are also the basis to govern and find out who's responsible for the plant when the indemnification process happens.

Limit: (1) The article has not done the calibration and model testing. If it is possible to continue the research direction, after the plant goes into operation, we will make a modification of the model. (2) The article has not determined the time of flooding due to its large dependence on the Plant's incident prevention and response plans.

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