International Workshop on Embankment and Concrete Dams Overflowing Erosion

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Dams in Vietnam

Overflowing Erosion

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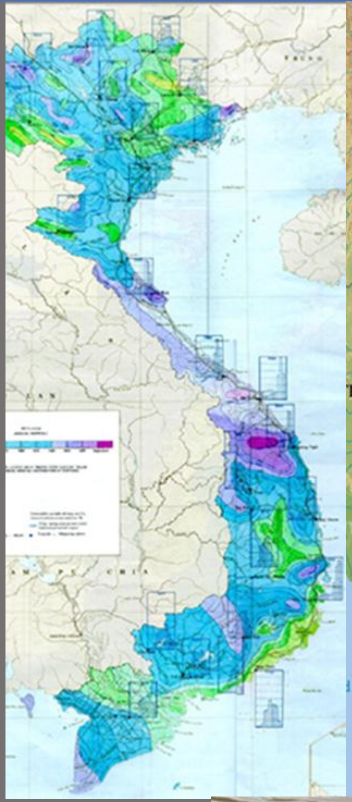
1. General features of Vietnam

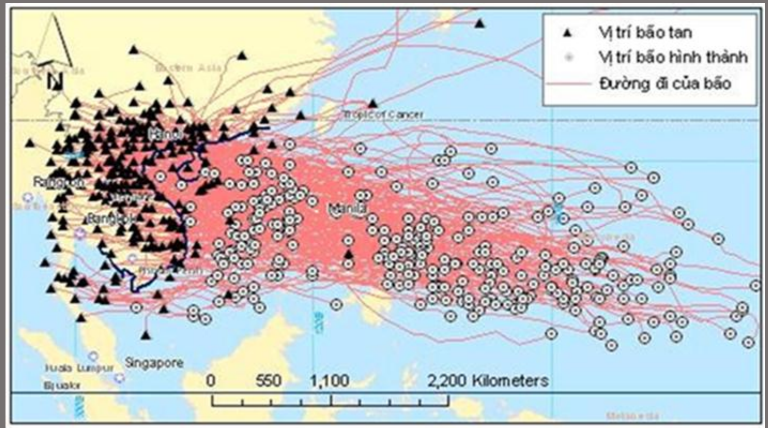
Vietnam has a territory of 331 000 km^2 with about 95 million inhabitants. The vast majority of people live in the lowland plains. The highlands and mountain plateaus in the N and N-W are inhabited mainly by tribal minority groups.

The country's mountainous topography (75% are mountains and hills) and subtropical humid monsoon climate profoundly affect the quantity and distribution, both temporally and spatially, of water. **The mean annual rainfall is 2000 mm, varying from 1200 to 3000 mm** (75% during 3 months of the rainy season). <u>Peak rainfall measured (2nd world record): 1630 mm in 24 hours</u> on the 2-3 November 1999 near Huê. **Rainfall concentrates in a few months yearly during the rainy season therefore, there is an urgent need to be regulated by reservoirs**.

Rainfall distribution map ⟶



All parts of Vietnam, but especially the Central Vietnam, suffer **several typhoons every year (5 in average) with many fatalities (13 000 in 20 years).**



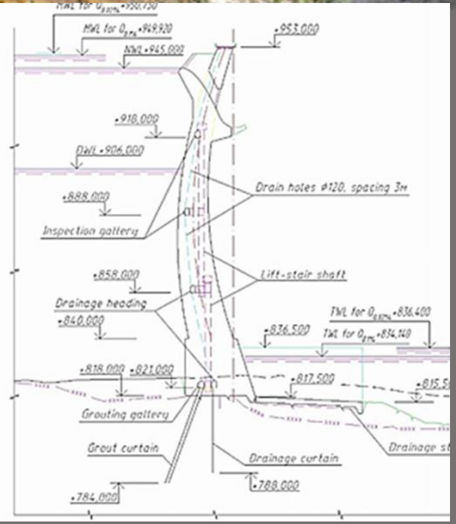
2. Large dams in Vietnam

- Vietnam has 7867 dams in operation **with 657 Large Dams (LD),** according to the ICOLD definition**, of which 606 are embankment dams and 51 are concrete dams.**
- 95% of large dams are multipurpose for combination of flood mitigation, water supply, irrigation and power generation.
- The highest dams of different types are: Hoa Binh (1994) E/R dam: 128 m, Son La (2012) RCC gravity dams: 138 m, Huoi Quang (2016) CVC gravity dam: 104 m, Nam Chien (2012) arch dam: 136 m, Cua Dat (2009) CFRD: 119 m.
- Large concrete dams (H>30 m) are recent in Vietnam, as the oldest (Long Song 48 m high) was built in 2006 and therefore the REX concerning the scour and degradation of spillway is not very important.
- RCC gravity dams were succesfully built, with 15 RCC dams higher than 70 m put in operation between 2012 and 2017.

Some Large Conventional Concrete Dams

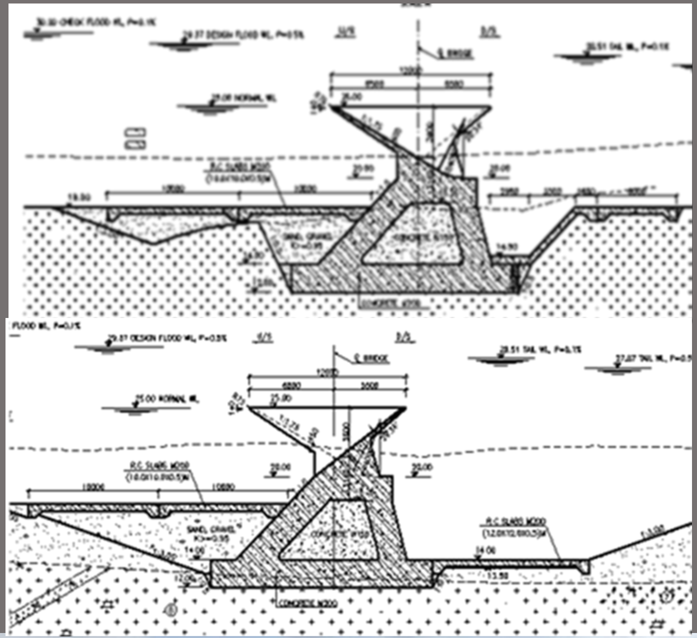
Nam Chien D/C arch dam (2012)

H = *136 m* ↓



Van Phong barrage

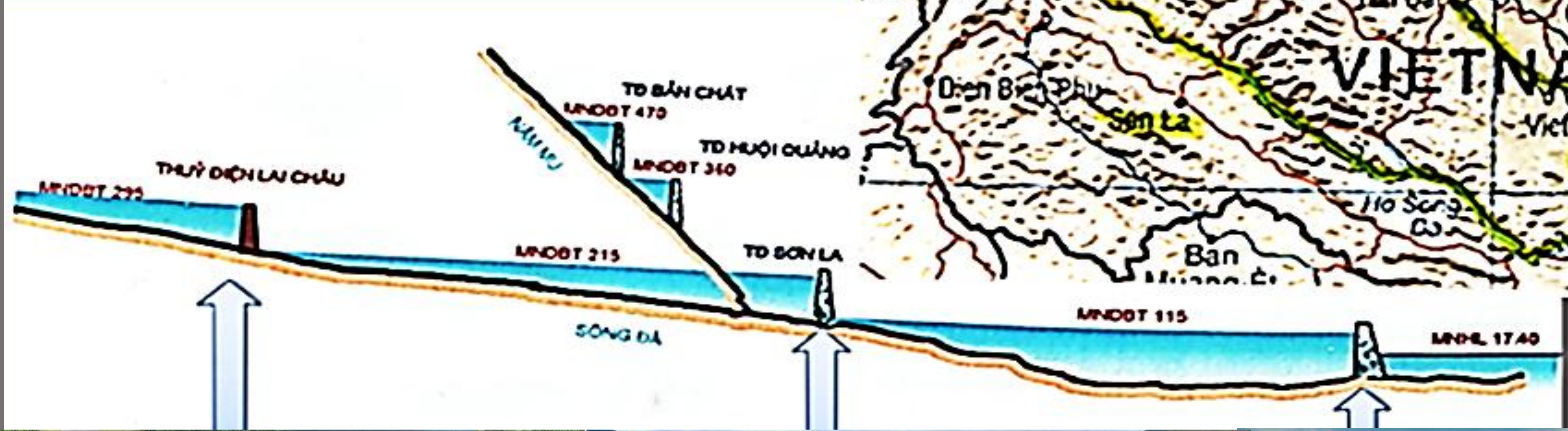
with PKW (2015) ↓

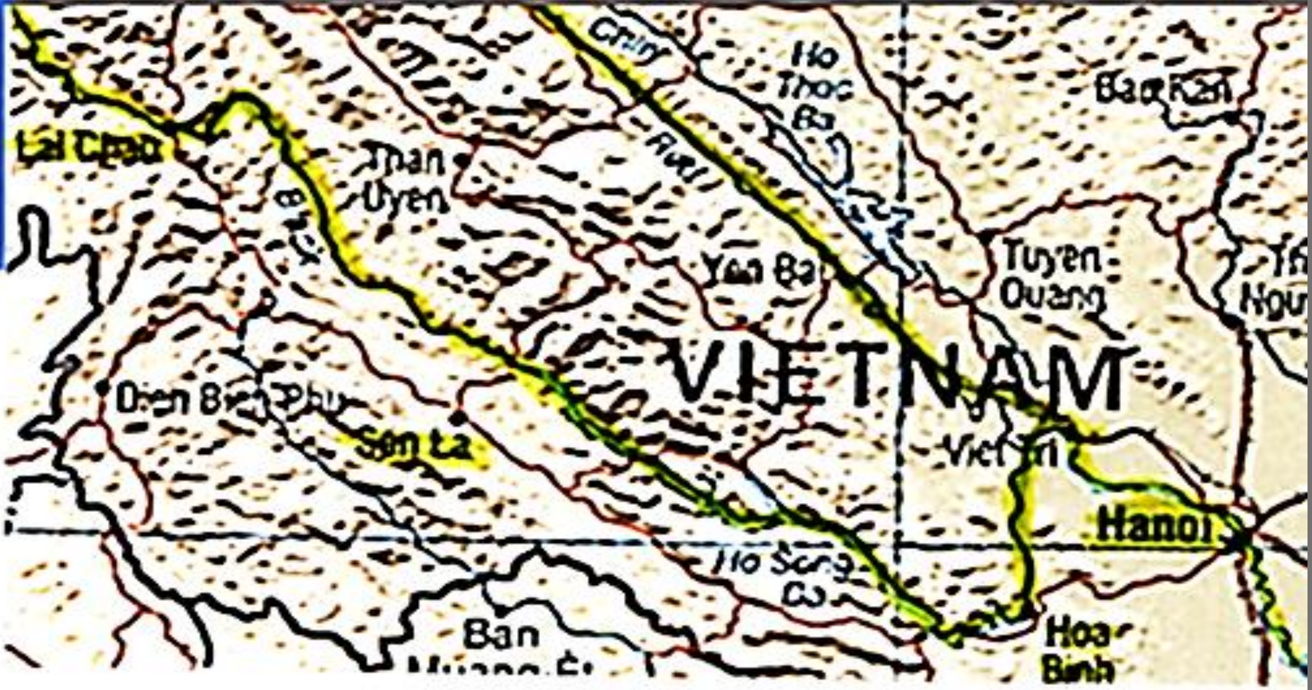


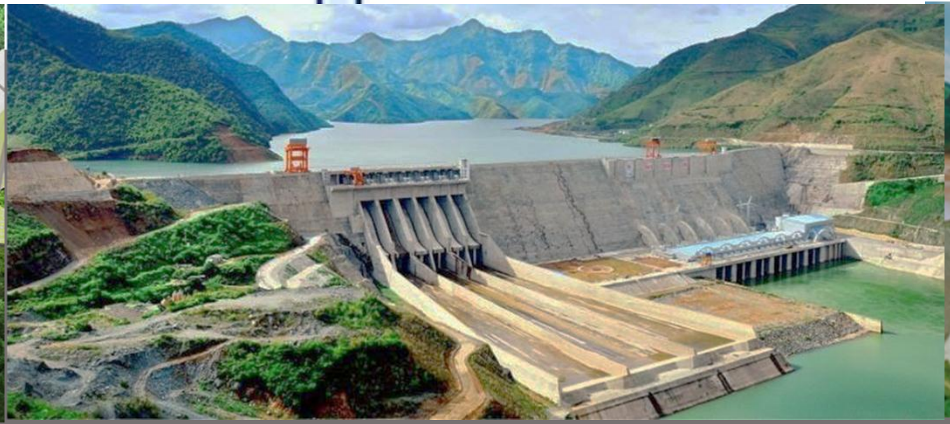
Huoi Quang gravity dam (2016)

H=104 m ↓

The most important HPPs are on the Song Da and Nam Mu rivers (ΣP > 6000 MW)







The hydropower capacity of Vietnam increases from 300 MW to about 17 500 MW during these last 30 years (in average +14.5% each year).

The Hoa Binh E/R dam (1994)

The 1st dam higher than 60 m in Vietnam

Earth/rockfill dam: H = 128 m,

L= 734 m.

Gated spillway capacity = 30 000 m^3/s (Design Flood).

Initial check flood = 32 000 m^3/s

New check flood = 38 000 m^3/s (PMF)

Volume of reservoir: V = 9000 hm^3, S = 20 800 ha.

Underground Power Station:
Installed capacity = 1920 MW.
Annual generation = 8160 GWh

Heightening of the core.

Erosion of the plunge pool.

The Son La RCC gravity dam (2012)

The dam is a **RCC gravity dam 138 metres high** and 90 metres wide at the base. Its length is over 1000 metres. **The volume of RCC is 3.1 hm^3** .

The spillway capacity is 35 000 m^3/s.

The volume of the reservoir: V = 9260 hm^3.

The power plant has a total capacity of 2400 MW with an annual generation of 10 250 GWh.

The Lai Chau RCC gravity dam (2015)

With the last upstream Lai Chau HPP, the Song Da River is totally equipped from the Chinese border to Hanoi.

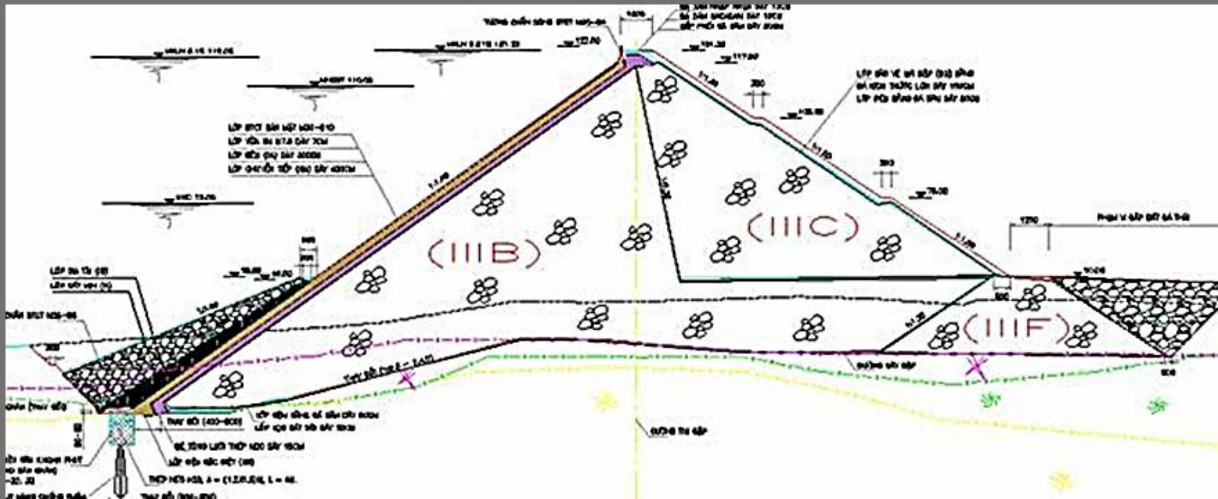
- RCC dam, H= 137 m , L= 611 m, Volume of RCC = 1.9 hm^3
- Volume of the reservoir = 1215 hm^3
- Power plant, P = 1200 MW with 3 units, W = 4700 GWh.

3. Overflowing of the Cua Dat CFRD under construction (2007)

Cua Dat is the highest CFRD in Vietnam with H=119 m, L = 1 023 m and V=10 hm^3.

To minimize the cost of the diversion structures, it was admitted to divert the flow during the most critical stage of the construction (wet season of 2007) by only one tunnel (L=820 m, D=9 m) with a possible overtopping of the main dam 25 m higher than the river bed.
The downstream face of the dam was protected by several ranges of gabions, placed in steps of 1.5 m high and slightly anchored in the rockfill.

In October 2007, a typhoon centred above the site, with an exceptional flood, has submerged and destroyed the partial dam, however its repair in 2008 was finally less expensive and time consuming than the initial design with a traditional diversion by a high cofferdam and 2 large tunnels. The dam was finally commissioned in 2009 with a delay of 3 months.



A portion of the dam collapsed during the typhoon Lekima, with a peak discharge of 7300 m^3/s. The flood lasted 48 hours.

The erosion begun when the discharge was over 2200 m^3/s, with a overflow depth of 1.5 m, the destruction lasted 24 hours, with the opening of a breach from d/s to u/s on one third of the dam portion in the channel and with about 350 000 m^3 of displaced rockfill. The diversion tunnel was partially clogged during the flood.

This failure would be probably avoided if the protection lining was provided by a thick RCC layer in place of the gabions.

4. Overflowing erosion of small homogeneous embankment dams

(There are several cases of overflowing erosion during floods)

4.1 During construction : **La Krel 2 dam**

Two failures in 06/2013 and in 08/2014, due to internal erosion and overtopping during the flood.

(This IPP is presently cancelled by the Authorities due to the concessionaire's lack of competence).

4.2 In operation

- **Ha Dong dam incident (October 2014)**

Overflowing on the main dam and the 2 saddle dams during the flood.

The highest water head over the dam crest was 1.15 m and over the parapet crest 0.35 to 0.40 m. Two dam abutments were severely eroded. Entire downstream slope was eroded 0.20 to 0.40 m.

- **Khe Mo dam accident (16/10/2010)**

Dam failure by submersion following a high flood.

Reservoir capacity: 1 hm^3

1000 houses inundated, 5000 families to be evacuated.

5. Overflowing of the Hoho RCC dam

The Hoho RCC gravity dam incident (2008)

During the extreme rain events (October 2010) several days ago, the all three spillway gates could not be opened for hours because the power station was buried by a land slide and the grid power failed.

Lot of floating logs were trapped on the crest and in front of hand rails.

Overflowing of the Hoho dam and abutments

Flood flow spilled over the dam crest by 2 m.

Mobile generators were brought to the site with much difficulty by flooded road in heavy rain after more than 20 hours and the gates were finally opened.

According to M. Dinh Sy Quat of VNCOLD :
“This accident of gates at Hoho HP provided serious experience of risk of gates in operation. We have just been requested to consider another alternative of the Ngan Truoi spillway consisting of a combination of gates and P.K weirs”.

Erosion of the abutments downstream the Hoho dam

6. Erosion downstream concrete dams

6.1 The Bai Thuong dam

The Bai Thuong dam (H ~ 14 m) is a masonry gravity dam built in 1930, with a fixed crest weir without special protection of the dam toe.

In 1992, a subwater inspection of the dam’s toe detected a scour that can endanger the stability of the dam and favour the seepage trough the foundation.

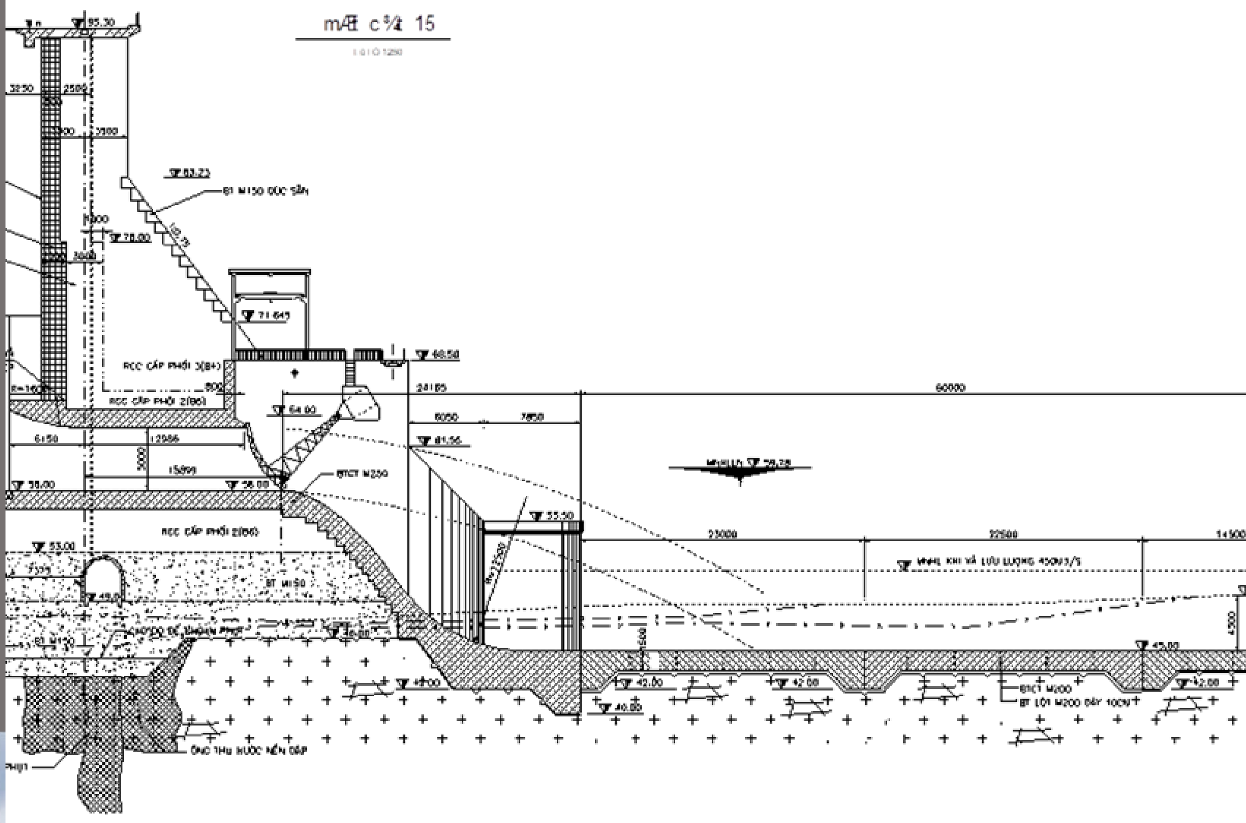
In 1998, the dam was repaired with a grouting curtain upstream and the unloading of large size rockfill downstream.

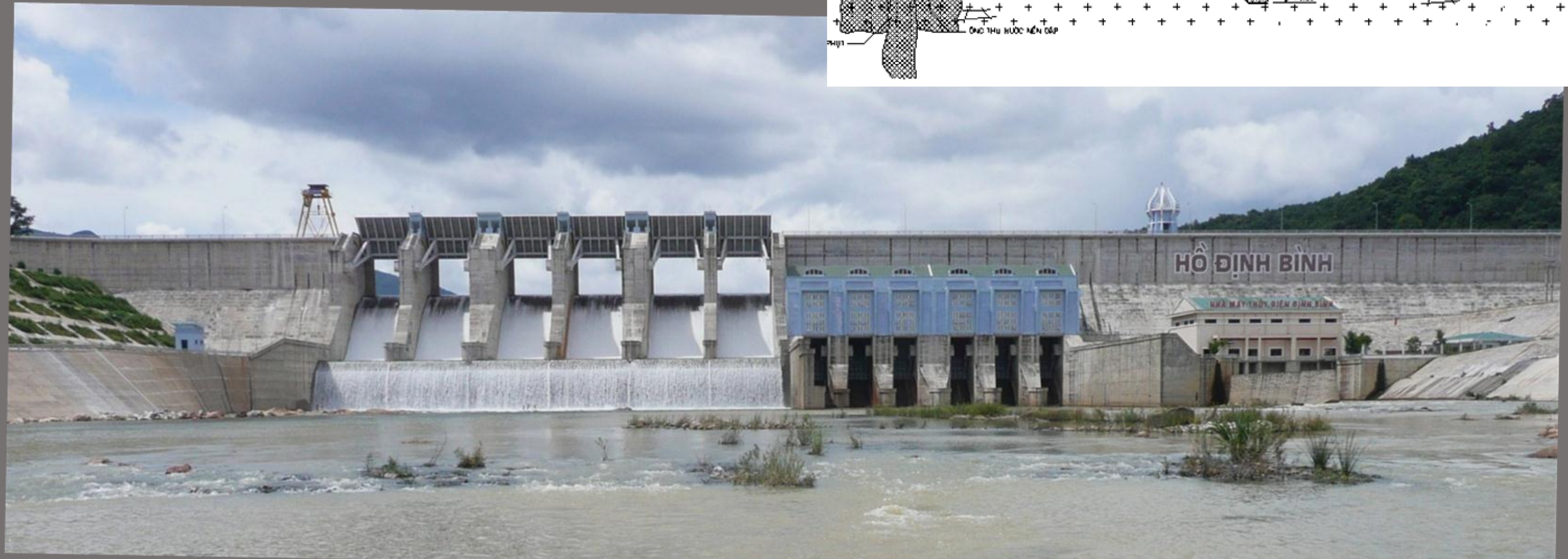
In 2012, a small power plant (6 MW) was added on the left bank.

6.2 The Dinh Binh RCC gravity dam

The Dinh Binh RCC gravity dam (2002-2007) (The 1st RCC dam in Vietnam). H= 55 m.

Degradation of the apron of the stilling pool downstream the bottom outlets 7 years after the commissioning of the dam.





7. Physical model tests for scours downstream spillways
(mobile bed models)

7.1 Comparison of scours at the toe of a gravity dam, with a Creager weir and a PKW weir installed on the crest.

With the PKW, it was observed a better aeration of the flows on the stepped spillway, compared with the Creager weir, but surprisingly the scours were not always significantly reduced by this better aeration, for different values of the flow discharges.

These results should be checked by other tests with different types of impact jets, air entrainment concentration, nature of the foundation and representativity of the models.

7.2 Protection of the river bed downstream a P.K weir with utilization of a baffle basin

The tests were performed with a baffle basin type USBR at the toe of a small gravity dam with a P.K weir on the crest.

The scours were observed downstream the baffle basin, on a mobile bed model with a protected rockfill layer .

Results show that the stilling basin is very efficient for reducing the scour if the end sill is enough high and the rockfill size sufficiently large.

But this solution is generally too expensive compared with other methods.

8. Conclusion

1. Overflowing erosion of embankment dams

- During construction: the solution to foresee in the design an overtopping of the partially constructed dam (namely a CFRD), protected by an adequate lining, is sometimes less expensive and time consumming than the traditional method with a high upstream cofferdam associated with large and long diversion tunnels.
- In operation: the overtopping are generally due to an underestimation of the floods and/or an inadequate spillway or its malfunctionning. The solution - if it is economically justified - is to avoid a totally gated spillway and to add a low cost auxilliary or emergency spillway. For low dams, a short submersion during an exceptionnal flood is acceptable if the downstream face and the dam toe are protected against important erosion by the use of different types of lining. It is a possible solution to reduce the freeboard of small embankment dams in order to maximize the volume of the reservoir and the economy of the project.

2. Overflowing of concrete dams

- The overtopping of concrete dams are generally due to an insufficient capacity of the spillway or a malfunctionning of the existing gates. A limited overtopping is generally not catastrophic for a high dam if the abutments are well protected against erosion.
- A main gated spillway for the frequent floods combined with a fixed crest spillway such as: Labyrinths, P.K weirs, fusible blocks, etc, for the exceptional floods may be the best solution.
- It would be necessary to carry out further research concerning the impact jet downstream spillway, in particular the influence of the parameter β (air/water ratio) on the characteristics of the scour, as pointed out by D.A Ervine (1976) and P.J Mason (1989).

Thank you for your attention

The collapse of one Ha Dong saddle dam by submersion.