27ème CONGRÈS // 90ème RÉUNION ANNUELLE
27 MAI - 3 JUIN, MARSEILLE FRANCE

Development of Piano Key Weirs in Vietnam from 2004 to 2021

M. Ho Ta Khanh (VNCOLD)

1. History of the PKW studies and designs

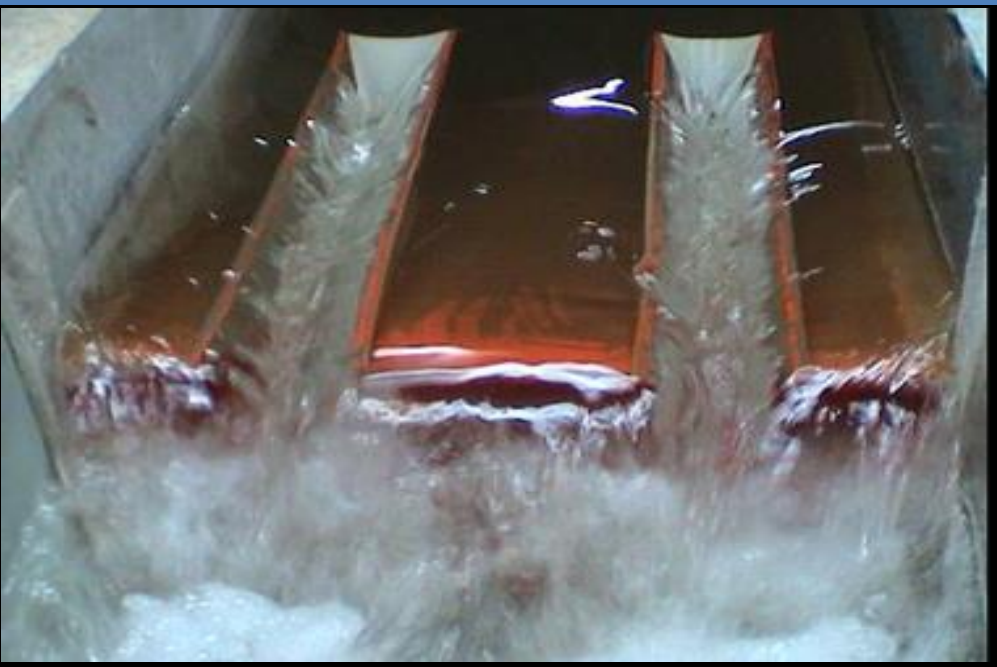
MAIN STAGES

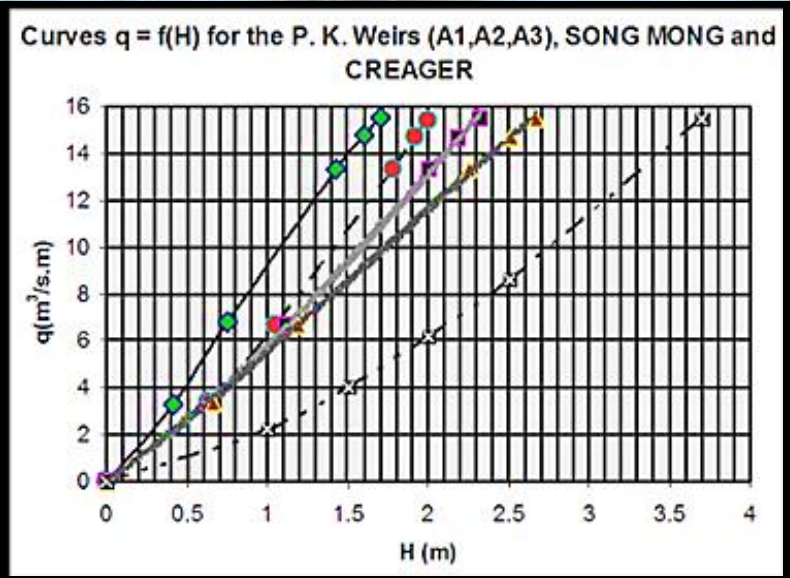
- From 2004 to 2005
  - Characterization of the standard types of PKW
  - Rating curves for standard types of PKW in free flow condition
  - Rating curves for standard types of PKW in submerged flow condition
  - Sensitivity of the minor parameters on the discharge capacities

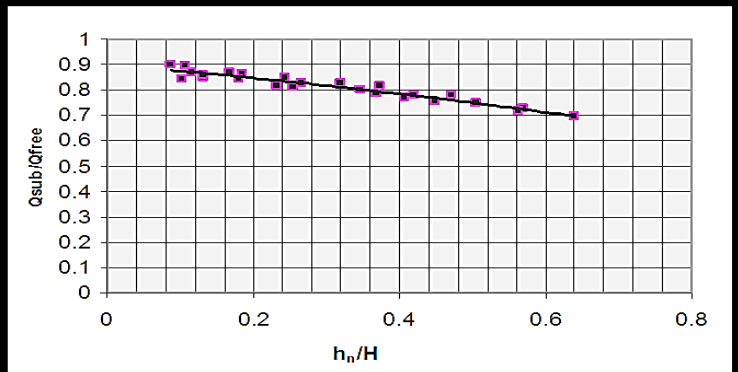
- From 2006 to 2008
  - Aeration and dissipation of the overflow energy on the downstream face of the dam (smooth, steps, with baffle blocks) and downstream the spillway
  - Comparison of the flows for different types of PKW with numerical models
  - Study of the first projects with model tests

- From 2009 to 2022
  - Hydraulic model tests for the different designs
  - Structural analysis of the PKW under design and construction
  - Further research concerning the methods and materials of construction

1.1 Examples of tests for the determination of the rating curves (free and submerged flows)

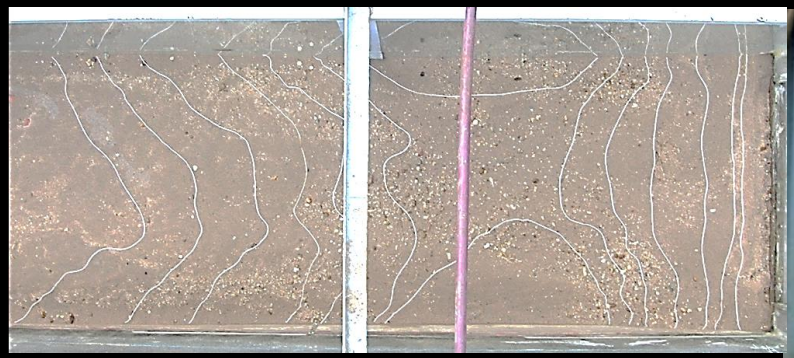


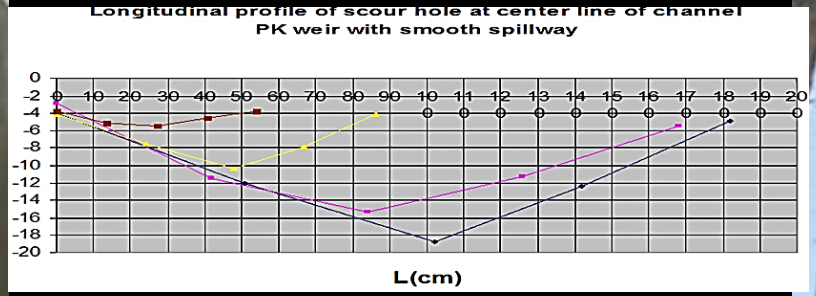




1.2 Tests for dissipation of the energy at the toe of high dams

The tests were performed with Creager weirs and P.K weirs, smooth and stepped spillways, with measurements of the scours at the toe of the dams.



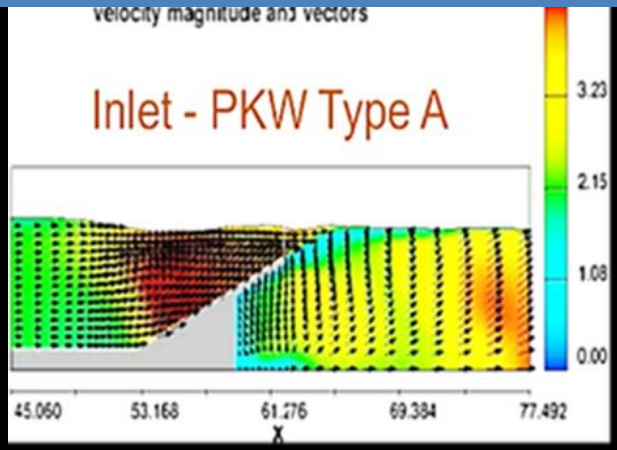


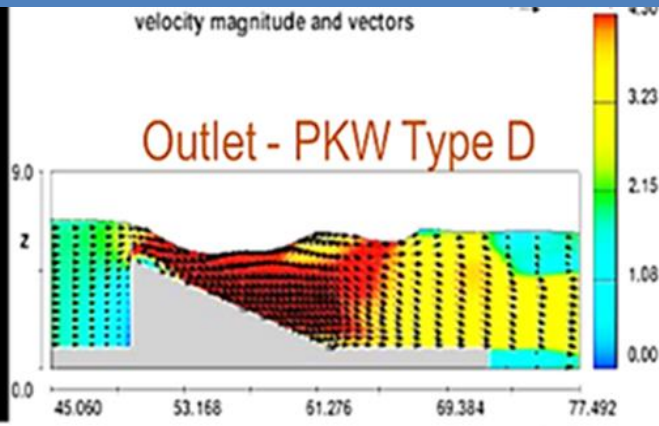
1.3 Example of tests for the protection of the river bed with utilization of a stilling basin

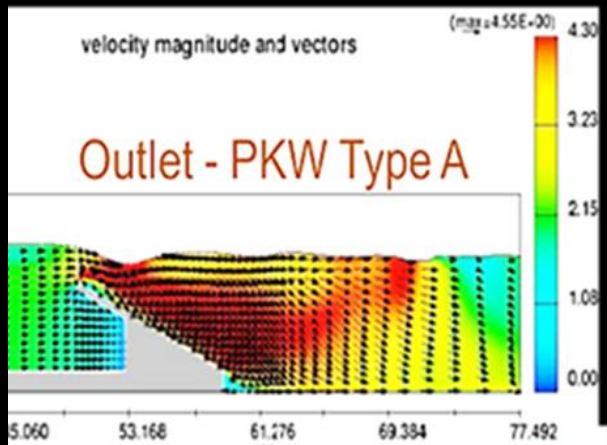
1.4 Comparison of different types of PKW with Flow-3D ®

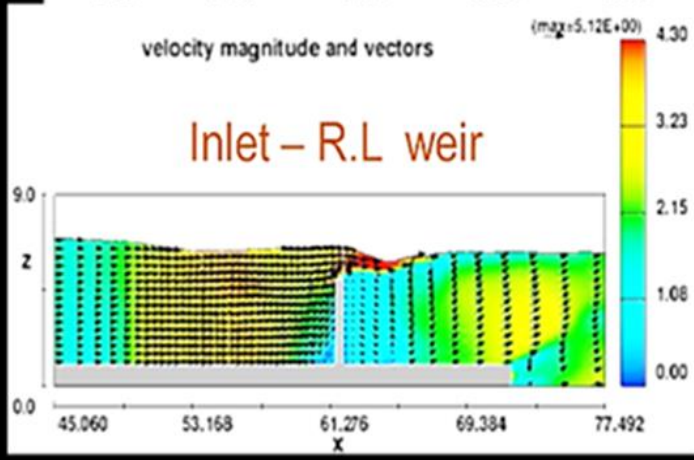
Comparison of the velocity magnitude and vectors of the flows in the inlet and outlet keys for a PKW type A, a PKW type D and a Rectangular weir.

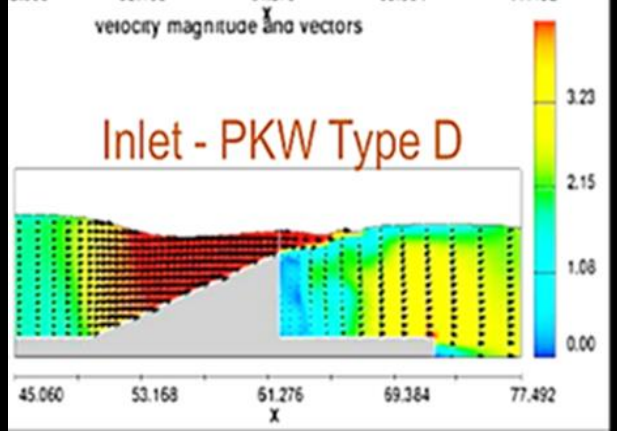
(Study with the cooperation of EDF-CIH)

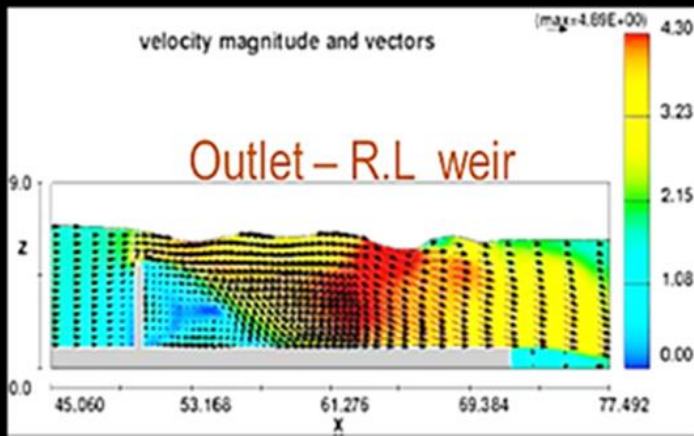




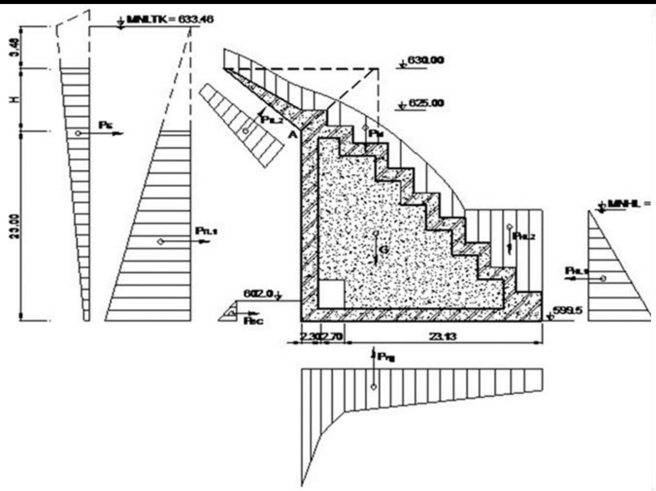


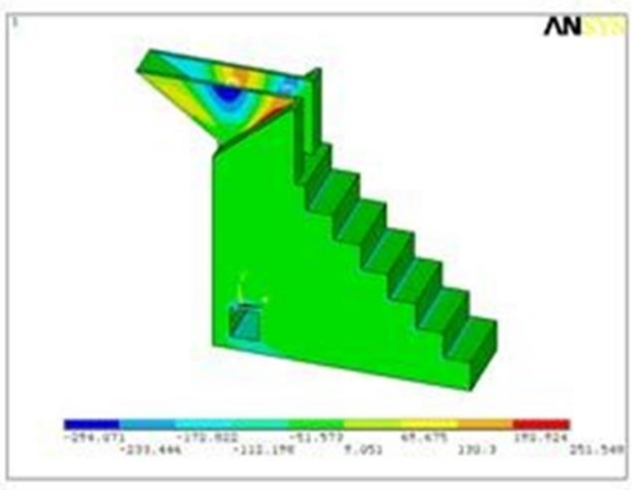


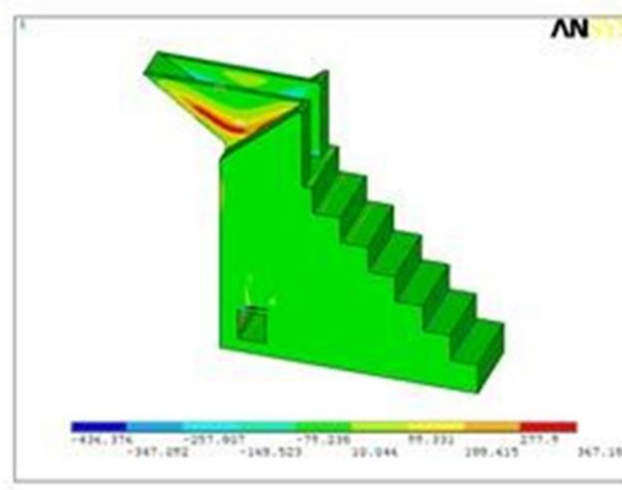


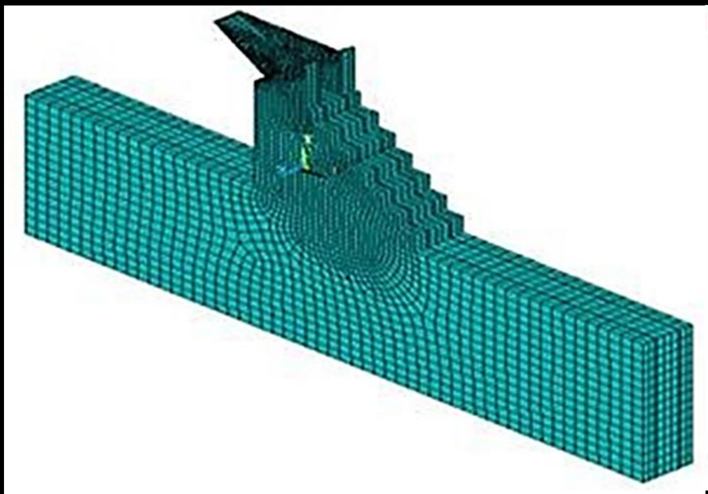
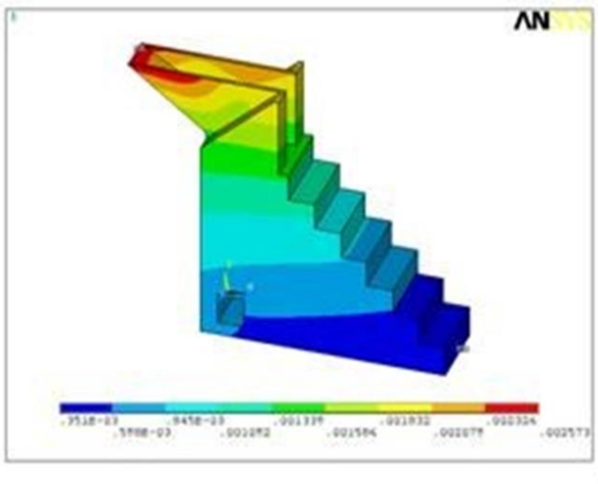


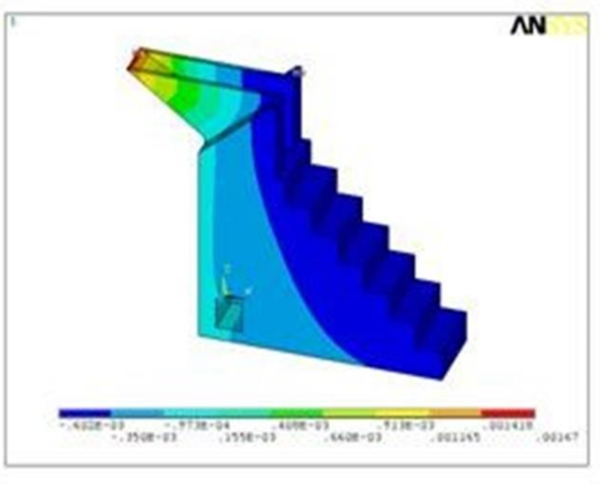
1.5 Structural analysis of gravity dam with PKW



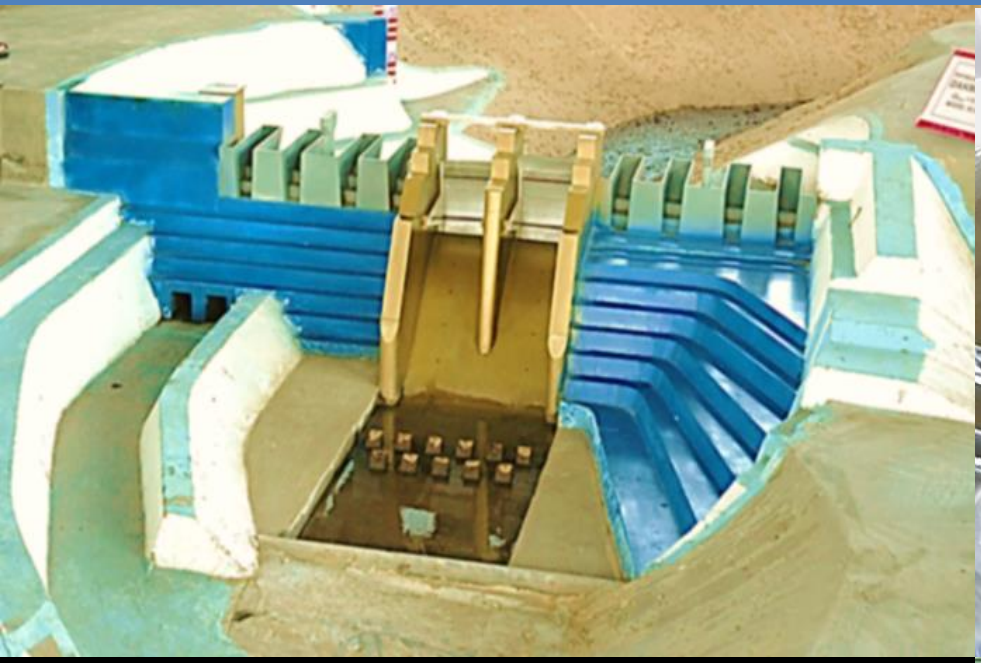


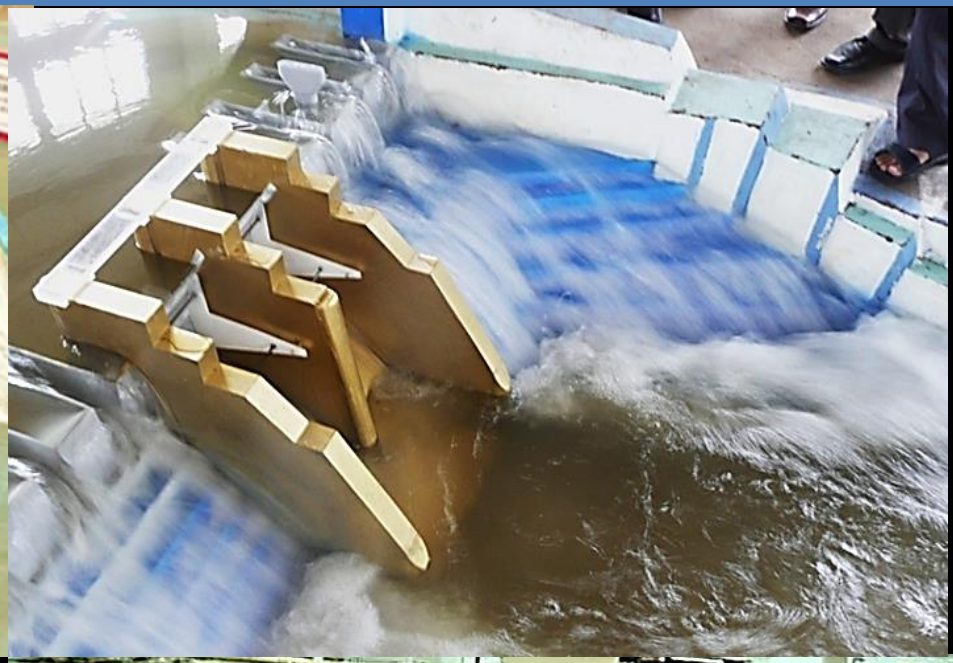


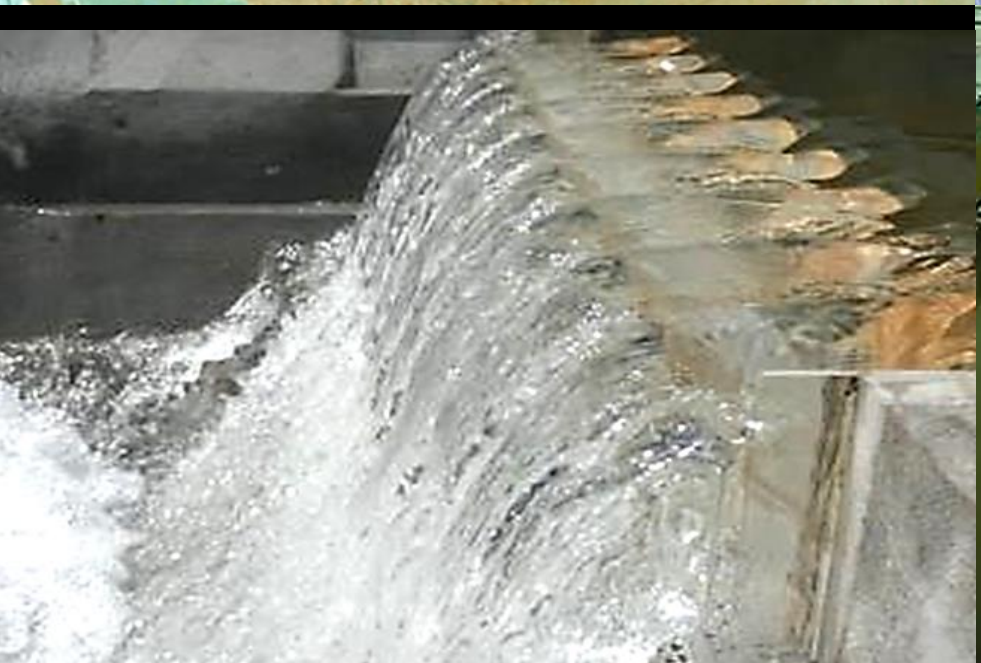





1.6 Models for some PKW projects in the Vietnamese laboratories





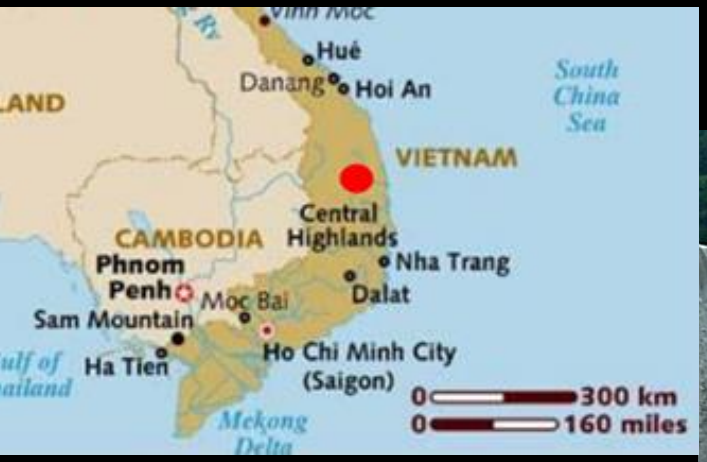


2. Some existing PKWs in Vietnam

The PKWs installed on new hydropower dams with only free flow spillways allow maximizing the head of the HPP and minimizing the MWL

2.1 The Dakrong 3 dam

The Dakrong 3 dam on the Dak Rong River is the first gravity dam with a PKW type A replacing the traditional surface radial gates.



2.2 The Dakmi 4C dam

The Dakmi 4C dam belongs to the power plants in cascade on the Dak Mi River in Central Vietnam.

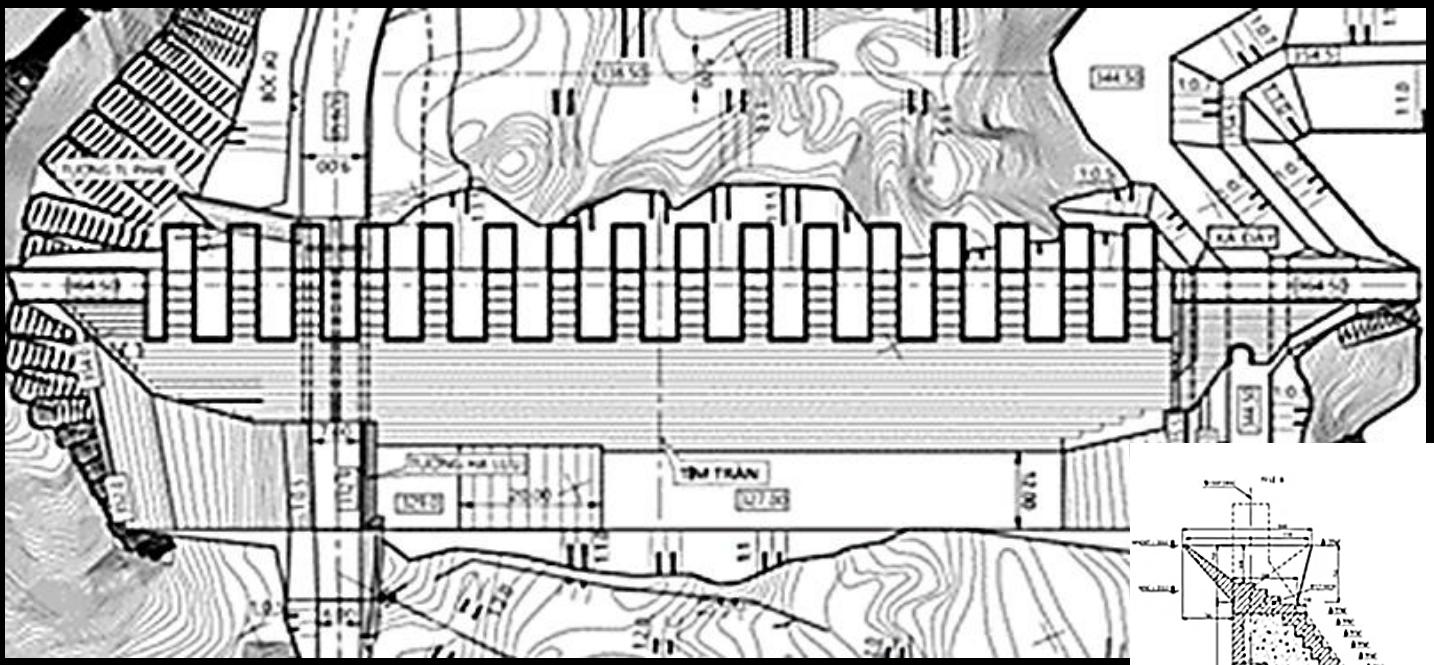
The Dakmi 4C dam is an example of a combination of 2 radial gates and a PKW type B (upstream overhang only) acting as an emergency spillway in case of a gate jamming.

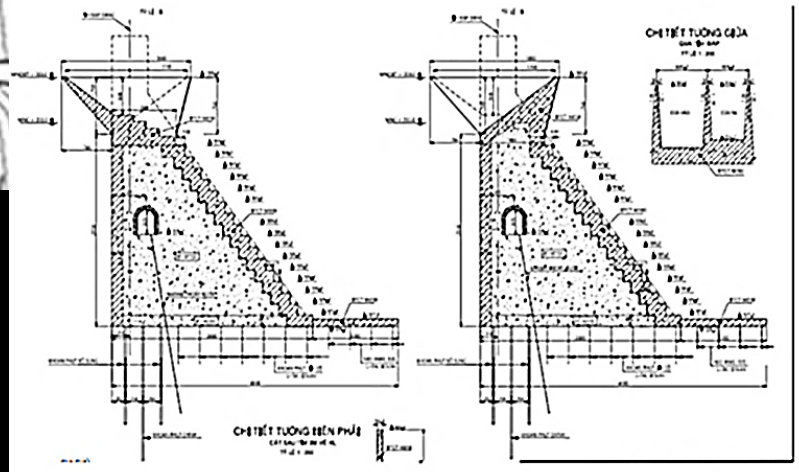
2.3 The Dakmi 4B dam

The Dakmi 4B dam is a combination of a labyrinth weir and a PKW. Compared with the initial design with the Creager weir, the final design - with the PKW, the labyrinth weir and a 0.70 m lowering of the Full Supply Level (FSL) - allows reducing 2 m high the previous MWL, as demanded by the population around the reservoir.

2.4 The Dakmi 3 dam

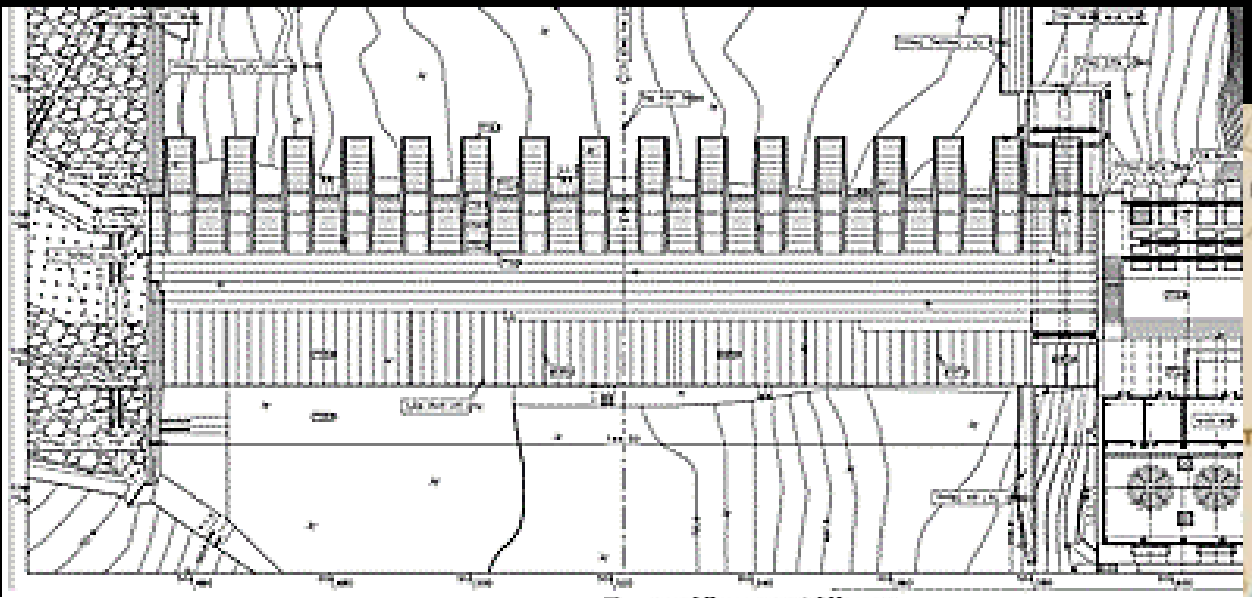
The Dakmi 3 dam belongs to the power plants in cascade on the Dak Mi River. It is a traditional gravity dam 40 m high, 197 m long with a stepped downstream face and with 16 PKW units type B on the crest 144 m long. The 1000-year design flood is 6700 m^3/s.

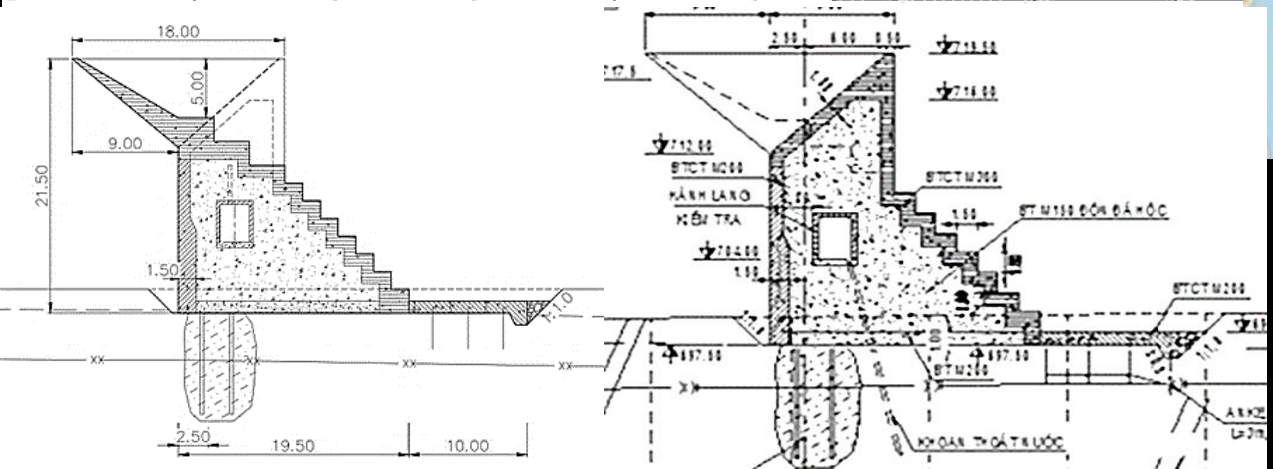




2.5a The Dadang 3 dam

The Dadang 3 dam is on the Da Dang River in the South of Vietnam. It is a traditional gravity dam 22 m high with a stepped downstream face and a PKW type B on the crest. The PKW is 144 m long with 16 units. The check flood is 7300 m^3/s, with q = 52 $m^3/s.m$ and H_u = 6 m.





2.5b The Dadang 3 dam

2.6a The Van Phong Dam
General description

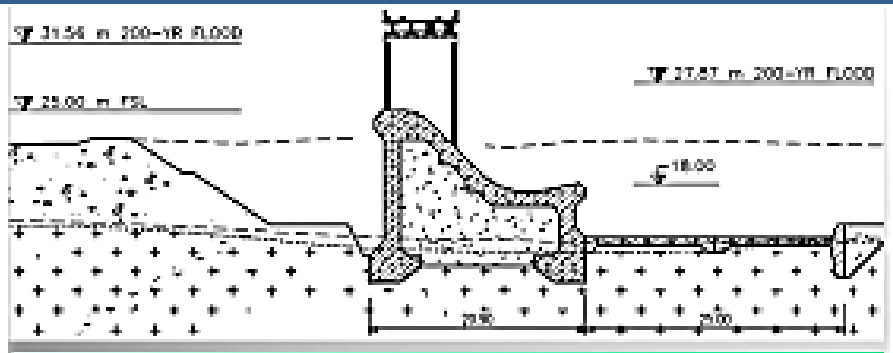
The Van Phong dam is about 70 km from Qui Nhon. The dam derives the water through a main canal for irrigation by gravity of 10 815 ha in the plain near the ocean. The reservoir FSL is determined by the highest possible entrance canal level and the MWL must avoid large inundated zones upstream with probable huge resettlement issues.

Among the 3 alternatives contemplated in order to maximize the FSL and to make this scheme possible:

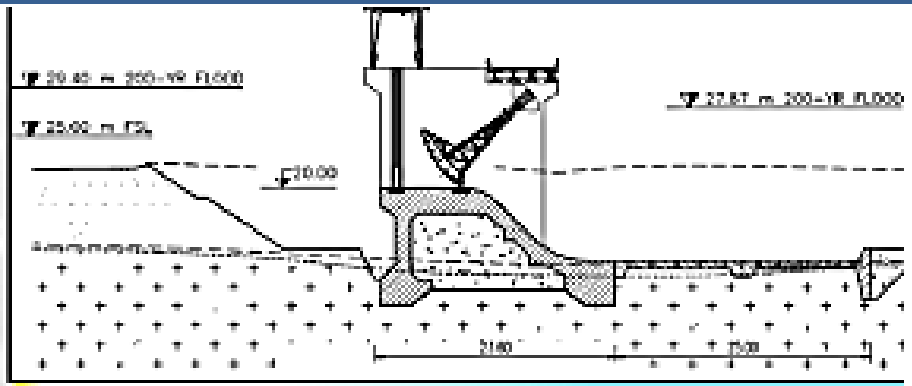
- Alternative 1: a barrage with **28 slide gates**,
- Alternative 2: a barrage with **28 radial gates**,
- Alternative 3: a combination of **60 P.K weir units** on the LB and RB, and **10 radial gates** (H= 3.5m, L= 15m) in the central part, the alternative 3 was found as the most appropriated.

2.6b The Van Phong Dam alternatives

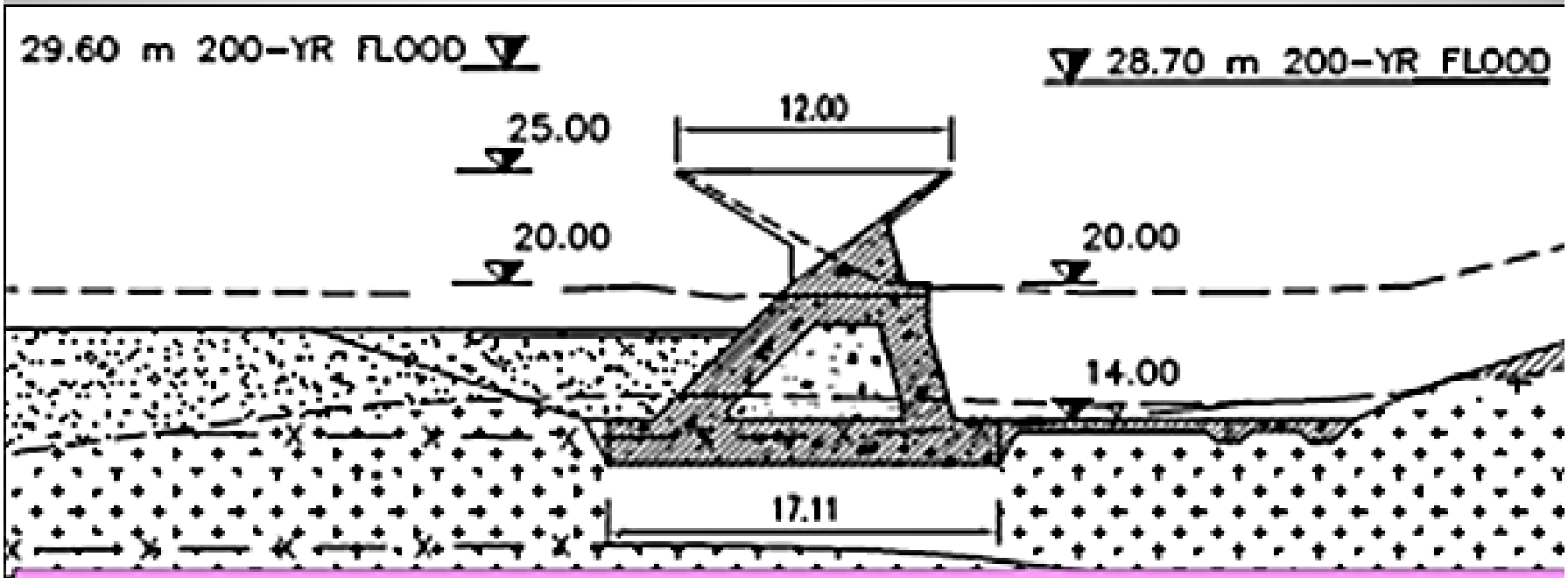
Comparison of 3 alternatives at the feasibility stage



Alt. 1: Free flow Creager Weir



Alt. 2: Gated Weir



Alt. 3: Combination of PKW and Gated Weir

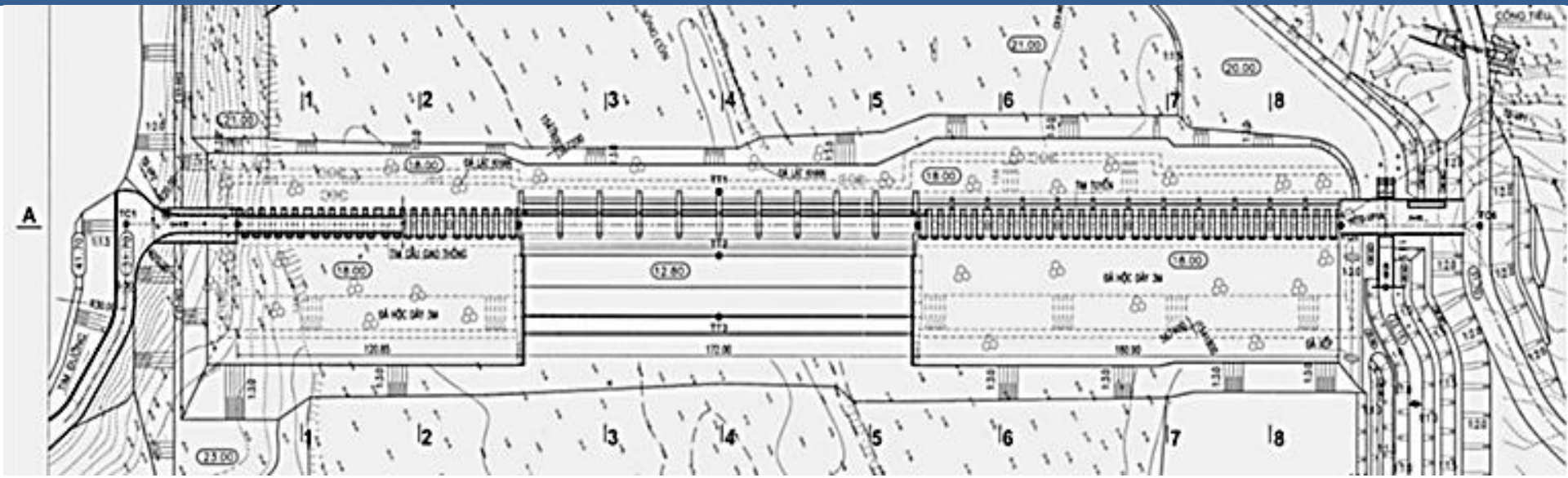
2.6c The Van Phong Dam cost estimates

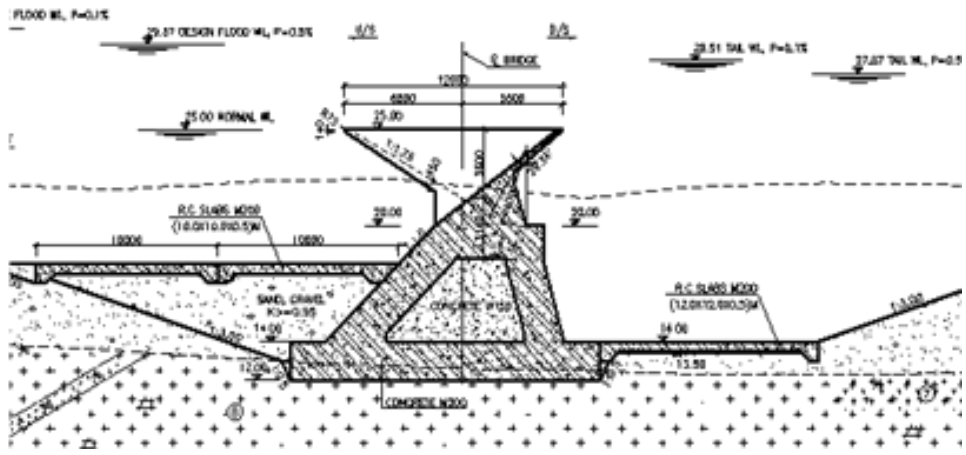
Cost estimate of the 3 alternatives (O.& M. costs not included)

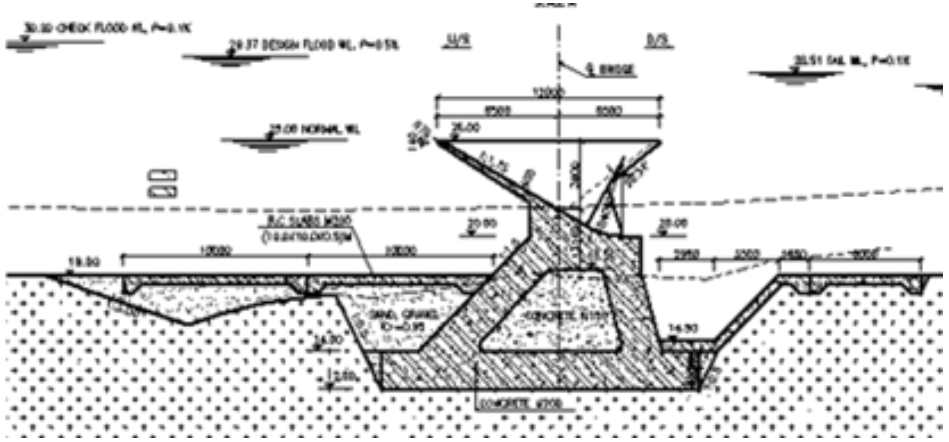
No.	Items	Cost Estimate in USD		
		Alternative 1: 28 slide gates	**Alternative 2: 28 radial gates**	**Alternative 3: 10 radial gates + PKW**
1	Civil Works	23 788 546	24 095 061	19 744 068
2	Mechanic & Electronic Equipment (gates, hoists, stop logs, transformers, etc.)	10 169 289	8 460 492	3 084 613
3	Project Management	365 899	350 790	257 913
4	Consultancy Service	764 123	732 568	641 620
5	Others	492 493	472 156	560 654
6	Contingencies	3 558 035	3 411 107	2 393 571
7	**Total**	**39 138 380**	**37 522 179**	**26 682458**

2.6d The Van Phong Dam

Plan view and cross-sections of the PKW inlet and outlet keys







2.6e The Van Phong dam

Main characteristics

- Total length of the dam : 474 m, with L_{PKW} = (181+121) m and L_G= 172 m.
- Max height of the dam on foundation: 12 to 16 m with 7 m on the river bed.
- Total discharge of the PKW = **8700** m^3/s for the 1000-year Design Flood = 14 440 m^3/s. PKW max nappe depth H_u = 5.20 m

2.6f The Van Phong Dam

View from downstream and the R.B

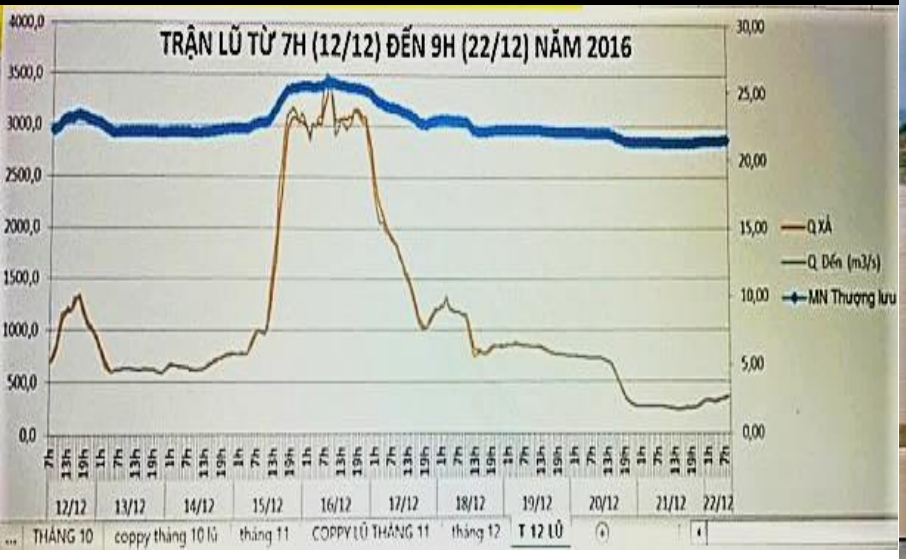
2.6g The Van Phong dam

Peak Flood on the16th Dec 2016

During the peak flood (3500 m^3/s) on the 16th December 2016 the max PKW discharge was 2630 m^3/s, the U/S level was **0.38 m** above the D/S level and 0.55 m above the FSL (El. 25.00), very near the values measured on the hydraulic model, conform to the design.

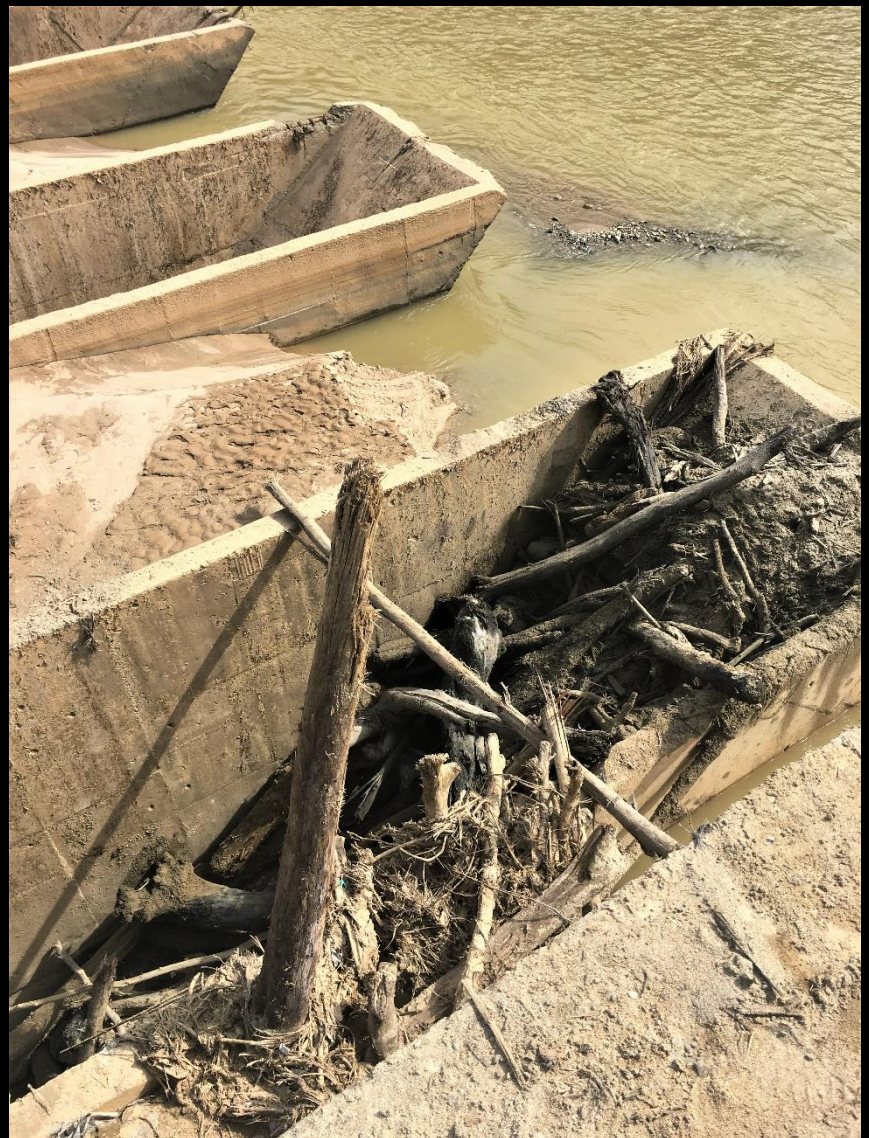
The Van Phong PKW - replacing 18 out of 28 radial gates - has the following two main advantages:

- Safety,
- Cost savings in investment and maintenance.

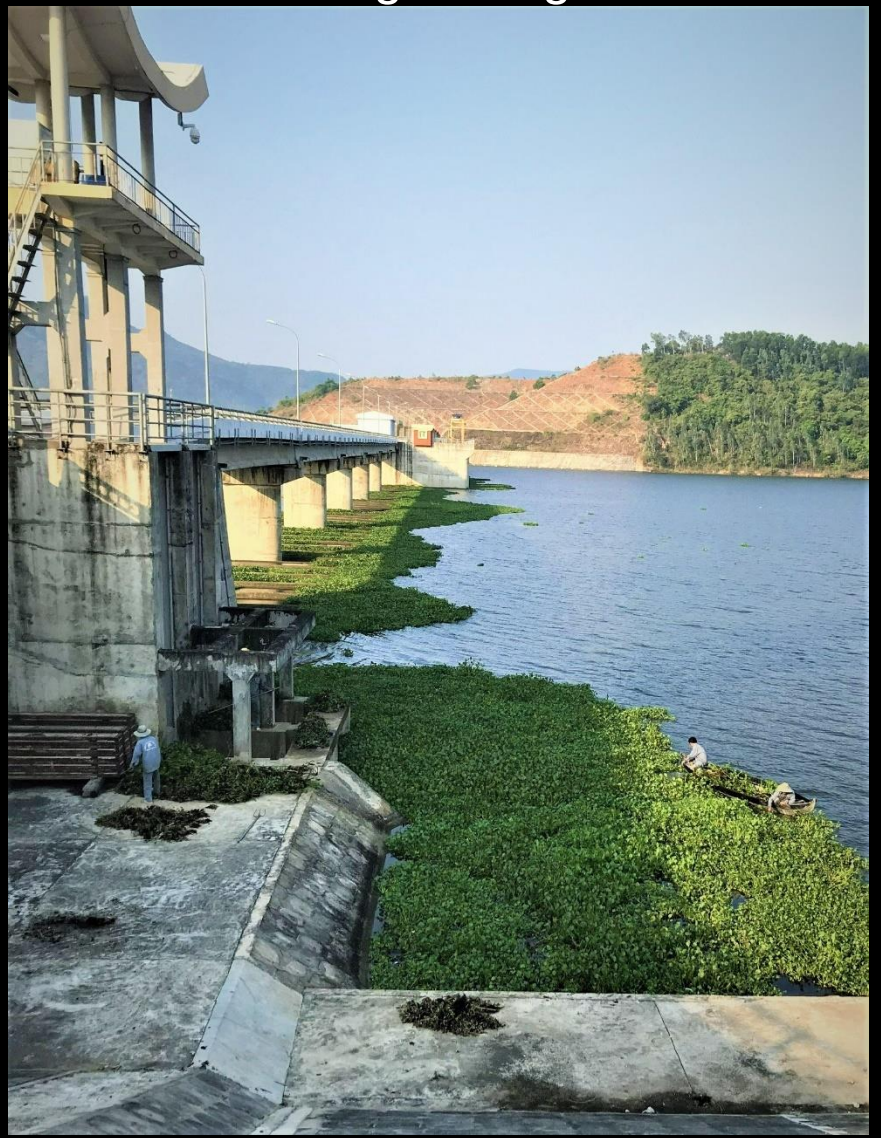


Debris and vegetation on the reservoirs

Branch deposits in a narrow inlet



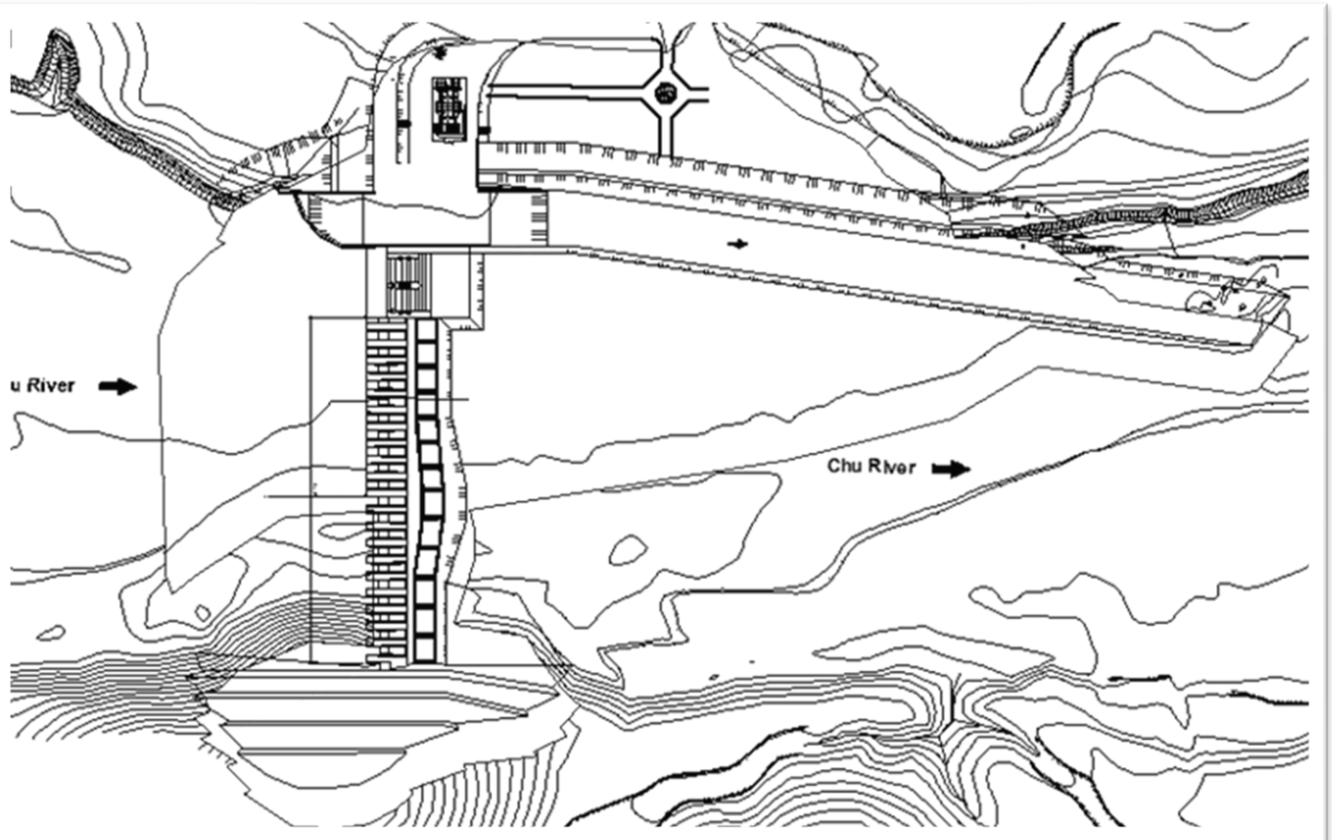
Water hyacinth upstream the Van Phong barrage

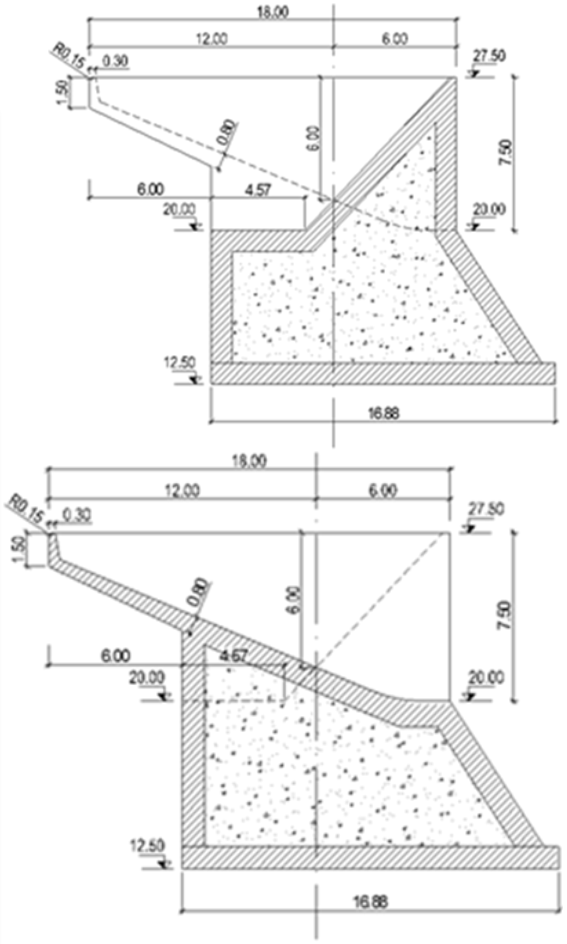


2.7a The Xuân Minh Dam

The initial dam design is with **10 slide gates** (H=10.5m, L=10m) installed on the dam crest. Taking into account the investment and maintenance costs and also considering the risk and the complication during the operation of 10 gates, this alternative presents several disadvantages.

The final design is a **P.K weir** on the R.B **and 2 slide gates** (H=10.5m, L=10m) on the L.B. **It's safer and 2.6 millions USD less expensive.**





2.7b The Xuân Minh Dam

Main characteristics

-Total length of the dam (PKW) : 145m.

- Max height on foundation: 15.5m.
- PKW: 20 units type B and 2 slide gates (H=10.5m, B=10m).
- Design Flood Q_{1000} = 8300m^3/s, with PKW max nappe depth H_u= 5.90m

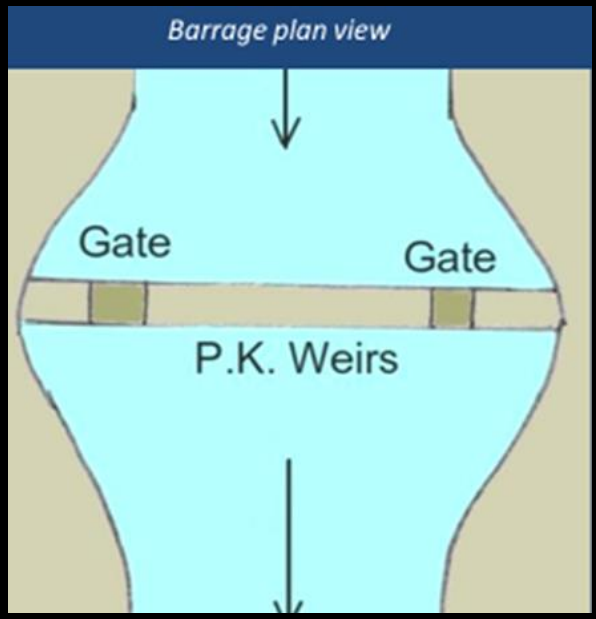
2.7c The Xuân Minh Dam during high floods

The highest flood (3110 m^3/s) since the dam commissioning in 2019.

Q = 2110 m^3/s through the PKW and Q = 1000 m^3/s through the 2 gates.

3. Advantages of a combination of PKW and gates for barrages

For barrages on wide rivers initially planned with large radial gates, an interesting alternative - for construction and maintenance costs and for shorter delay of construction - could be an adapted combination of gates and P.K weirs.



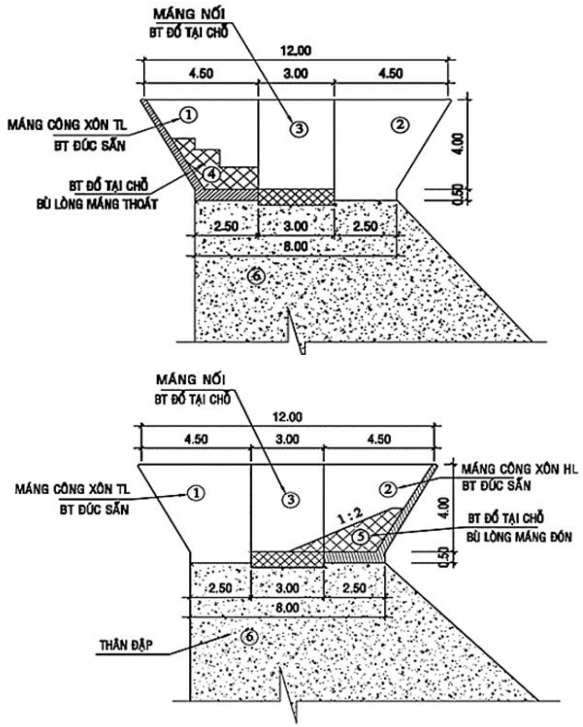
4. Ongoing Research and Development of PKW in Vietnam

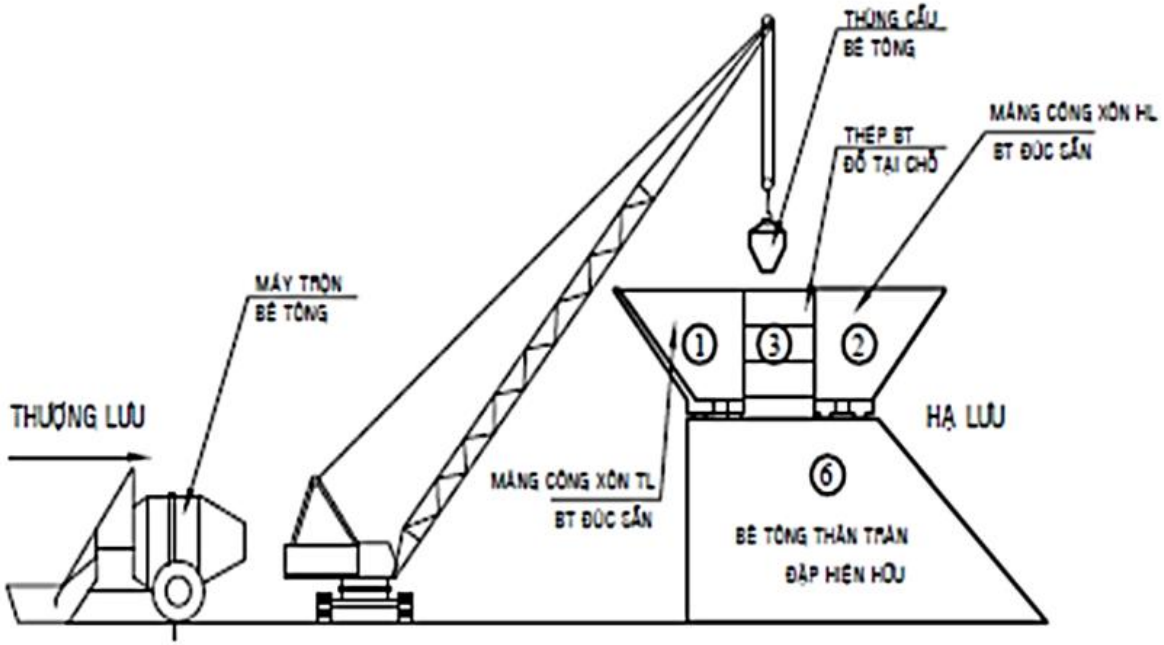
- Establishment of formulas adapted to the future new PKW projects in order to simplify the preliminary studies.

- Establishment and improvement of Vietnamese Guidelines for the design and construction of PKW.

- Research concerning the use of new materials for construction of PKW.

- Research concerning new methods of construction of PKW.





Thank you for your attention and cooperation

3rd International Workshop on Labyrinth and Piano Key Weirs – PKW 2017

Qui Nhon, Vietnam – 21 to 24 February 2017