Investigation of the flood hazard of the Nuclear Power Plant KKG by earthquake induced dam breaks waves at the River Aare

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ABSTRACT

The flood safety of the Nuclear Power plant KKG in terms of dam breaks scenarios at the River Aare was investigated through using a deterministic method. Based on the requirements of the Swiss Federal Nuclear Safety Inspectorate (ENSI), four dam break scenarios were identified for the investigation. The scenarios were based on conservative assumptions of different combinations of weirs' breaks.

The propagation of the flood waves were computed by means a hybrid model as a combination of one (1D) and two-dimensional (2D) models.

Based on the simulations it was possible to estimate the risk of flooding of the KKG area and if needed to suggest some measures to prevent such flooding. Additionally it has been investigated, if important water intakes were at the risk in regard to the allowable maximum and minimum water level.

The sediment transport was studied qualitatively, if there were high erosion risks. According to the calculated bottom shear stresses the river bed erosion is possible only locally and over a very short time period.

KEYWORDS

Dam break; Hybrid model; Flood wave; NPP

INTRODUCTION

After Fukushima, the question arises, how strongly the nuclear power plants (NPP) could be impacted by the natural extreme events in Switzerland. The Swiss Federal Nuclear Safety Inspectorate (ENSI) requires new investigation from all plant operators in Switzerland. Flood waves which are due to dam breaks caused by extreme earthquakes, are categorized under extreme events against which Swiss nuclear plants have to be protected. In order to ensure such protection, the NPP operators are obliged to review the hazard at regular intervals on the basis of experience and the latest developments in science and technology [ENSI 2014]. Based on previous ENSI's requirements, the flood safety of the nuclear power plant Gösgen-Däniken AG (KKG) has been already evaluated and ensured for an extreme flood with an annual probability of occurrence of 10^{-4} (HQ_{10000}). Additionally ENSI requested KKG to

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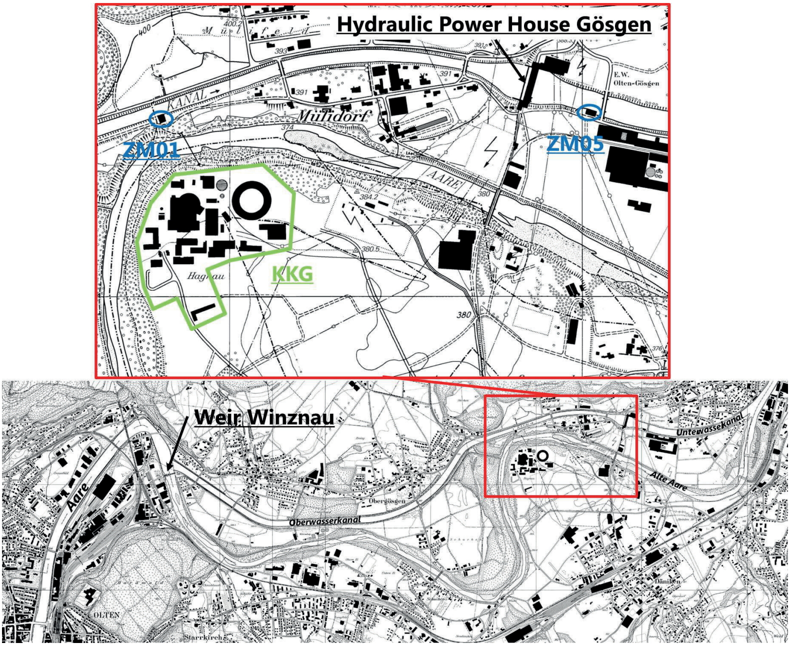

Figure 1: Layout of the KKG area.

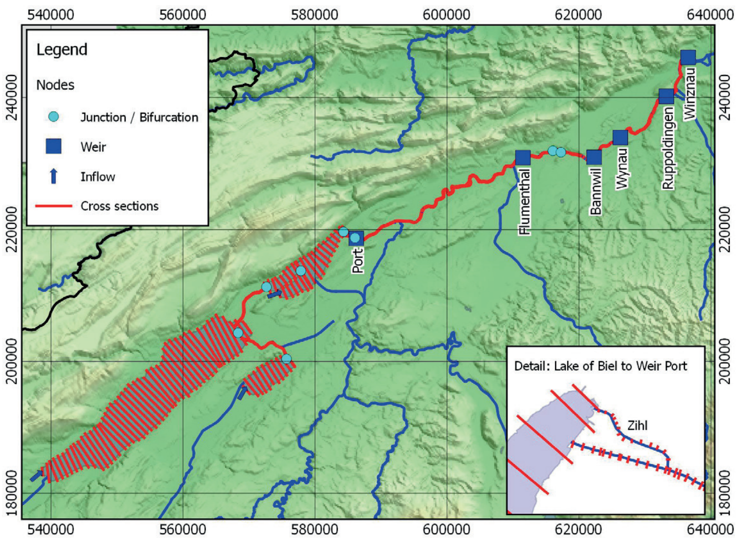

Figure 2: Layout of the investigated reach of the river Aare.

investigate the impacts of the flood waves due to the extreme earthquake-induced dam breaks (annual probability of occurrence of 10^{-4}) on KKG area and especially on important cooling water intakes (Figure 1). The break of all weirs upstream the KKG till the lake Biel has to be considered for the investigation (Figure 2).

BASIC DATA

Hydrology

The important inflow and discharge measurement stations between the lake Biel and KKG are shown in Figure 3. The significant hydrological parameters are represented in Table 1.

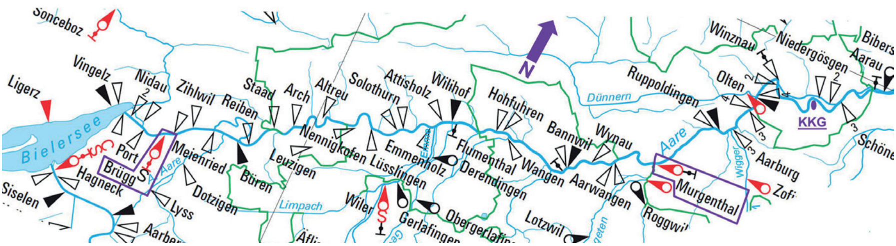

Figure 3: Important inflows and stations of the river Aare between the lake Biel and KKG [BAFU 2014].

Table 1: Important discharge values of the river Aare.

Parameter	Value (m^3/s)
Mean Discharge (Q_m) of Aare at Brügg	244.0
Mean Discharge (Q_m) of Aare at Murgenthal	287.0
Low discharge (Q_{347}) of Aare at Brügg	106.0
Low discharge (Q_{347}) of Aare at Murgenthal	128.0

TOPOGRAPHY

The topography data of the investigated Area consisted of different forms of data. There were more than 850 cross sections measurements of the river Aare for a distance of 170 km and also a detailed DTM of the area close to KKG.

METHODOLOGY

For the modeling and computing of the flood waves due to dam breaks the investigation area has been subdivided into perimeters (Figure 4):

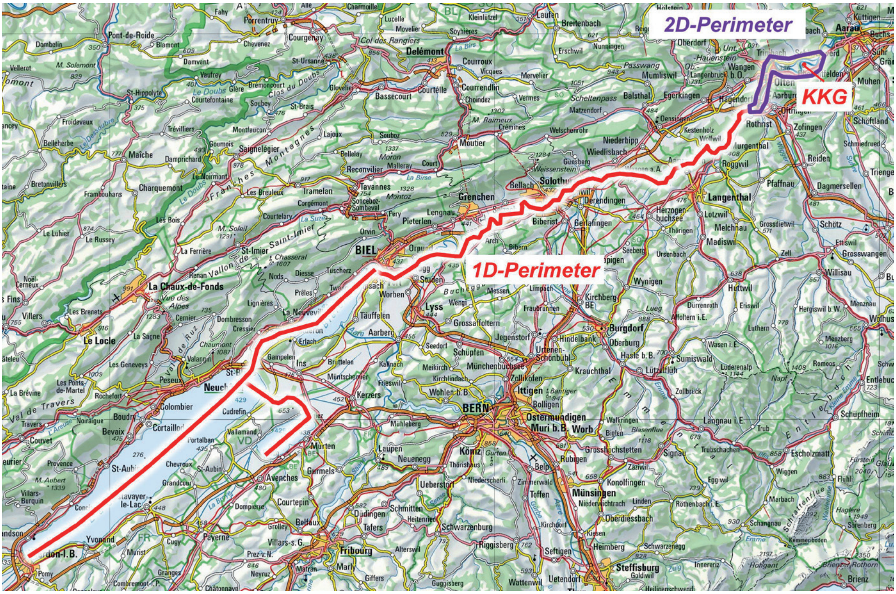

Figure 4: Hybrid model of the investigation perimeter.

A) 1D-Perimeter: the area from the three lakes (lake Neuenburg, Murten and Biel) to weir Ruppoldingen.
B) 2D-Perimeter: the area from weir Ruppoldingen to the connection of hydropower channel and the old Aare.
All dam breaks have been considered as sudden failure of the whole weir, which is based on a conservative assumption and is a well-established method in Switzerland [BFE 2014]. In case the hydropower house and weir are in the same place, the sudden break has been considered for the whole structure. For regulation of weirs the condition (n-1) has been adopted, in which the capable weir segment has been considered to be closed. The programs Flux/Floris, HYDRO_AS-2D and BASEMENT have been used for the simulation.

SCENARIOS

On the basis of ENSI's requirements four different worst-cases have been defined as modeling scenarios (Table 2).

The two mean and low discharges (Q_{347}, Q_m) have been considered as basic discharges in the river Aare, because the peak discharge in case of any dam break depends on the water surface

Table 2: Scenarios for the assessment of the flood hazard of KKG due to the dam breaks.

Scenario	Event	Discharge in River Aare [m^3/s]
1	Sequential dam breaks at the River Aare (Weir Port to Weir Winznau)	Q_{347}
2	Sequential dam breaks at the River Aare (Weir Port to Weir Winznau)	Q_m
3	Sequential dam breaks at the River Aare (Weir Port to Weir Ruppoldingen) and WKW Gösgen	Q_m
4	Simultaneous dam breaks at the River Aare (Weir Port to Weir Ruppoldingen) und Sequential break of the Weir Winznau	Q_m

difference between upstream and downstream of a weir. A combination of extreme flood event and earthquake-induced dam break was beyond the investigation criteria and has not been considered.

The following assumptions have been considered in all scenarios:

- The Weir Port breaks first due to the closeness to the epicenter of the earthquake
- The downstream weirs are heavily damaged by the earthquake and can't be regulated anymore.
- All turbines are out of service after the earthquake (No discharge through Hydropower house).
- The downstream weirs break in arrival time of maximum wave (Sequential breaks).

INITIAL CONDITIONS

The initial conditions in the river Aare has been calculated as steady state for the both discharges Q_{347} and Q_m, with an assumption that all turbines of the power houses are in service. The water elevation upstream of the weirs has been set to the regulated storage level. Table 3 shows the regulated storage level for both discharges.

Table 3: Regulated water elevation upstream head of the weirs (Initial condition).

Weir	Q_{347}	Q_m
Port	429.00 (lake level)	429.50 (lake level)
Flumenthal	426.00	426.00
Bannwil	417.30	417.30
Wynau	408.08	408.08
Ruppoldingen	397.20	398.20
Winznau	388.14	388.14

RESULTS

The modeling of dam breaks has been run in two phases. In the first phase the break of weirs from Weir Port to Ruppoldingen has been simulated through the 1D-Model (see Methodology). In the second phase the outflow of the 1D-Model has been defined as a boundary condition for the 2D-Model and the break of the Weir Winznau und WKW Gösgen has been simulated. The time point 0.00 corresponds to the break of the Weir Port in all results.
1The results show that sequential dam breaks induce very large peak flow at Weir Ruppoldingen and in the case of the scenario 2 the peak flows are larger (Figure 5 & 6). The peak flow discharge at Ruppoldingen is almost 4 times larger than the peak flood discharge with an annual probability of occurrence of 10^{-2} (HQ_{100}). Contrary the peak discharge reduces at the time of the dam break of the Weir Winznau due to the overflow of the arriving flood waves, which reduces the water elevation difference between upstream and downstream of the weir (Figure 7 & 8).

In Figure 9 and 11 the time history of the water surface elevation at the intake ZM05 is illustrated. As it is shown the critical elevation of the intake will never be touched by the flood waves.

CONCLUSIONS

The flood hazard of the KKG area has been investigated through different dam break scenarios of the weirs between the lake Biel and KKG. This investigation has been carried out

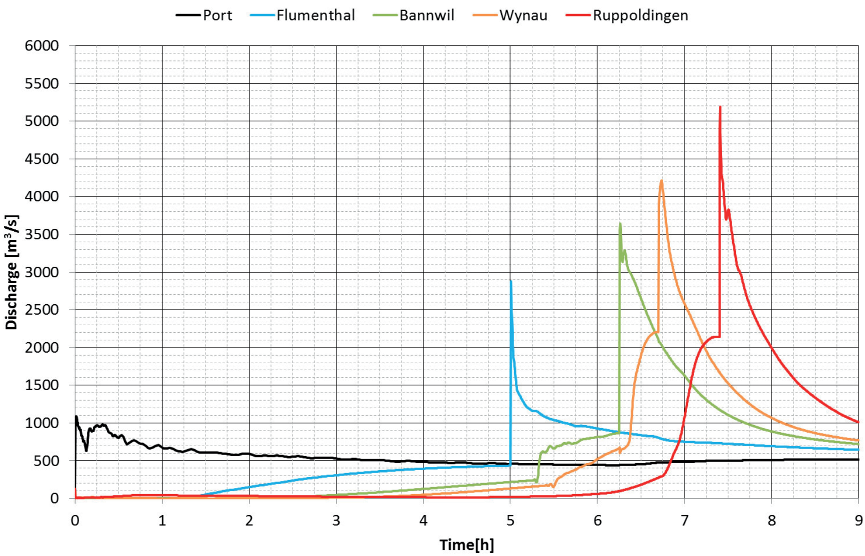

Figure 5: Time history of the discharge at weirs for the scenario 1.

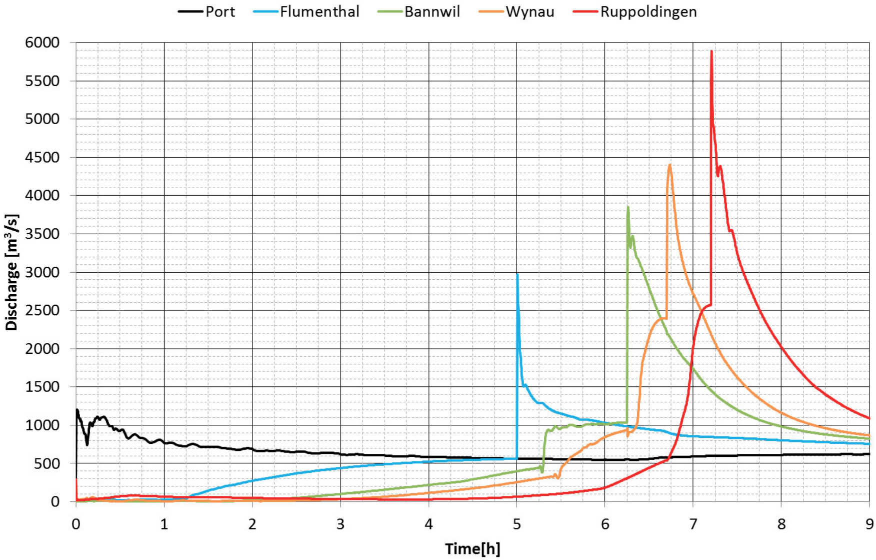

Figure 6: Time history of the discharge at weirs for the scenario 2.

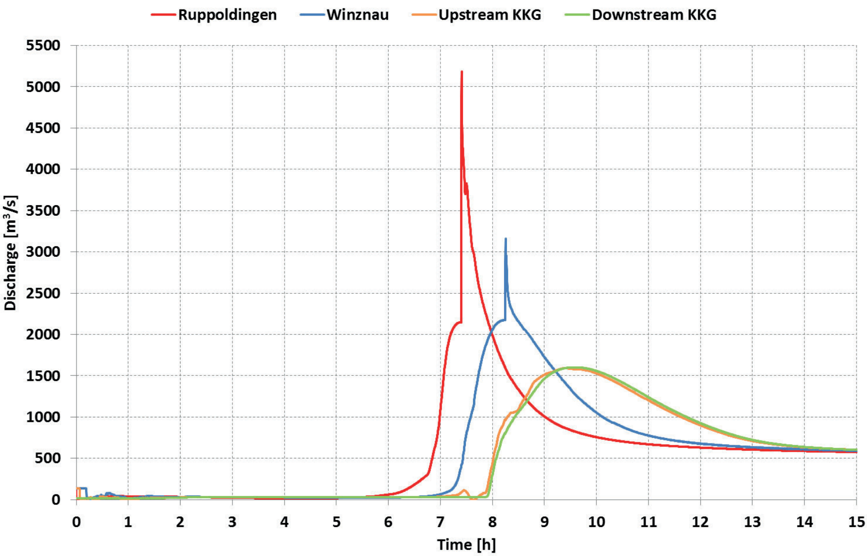

Figure 7: Time history of the discharge at the Weir Winznau and at KKG for the scenario 1.

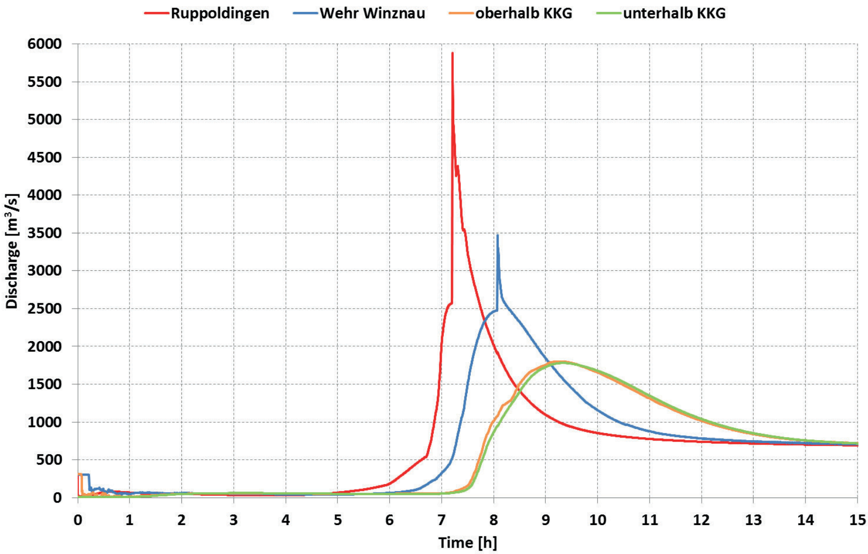

Figure 8: Time history of the discharge at the Weir Winznau and at KKG for the scenario 2.

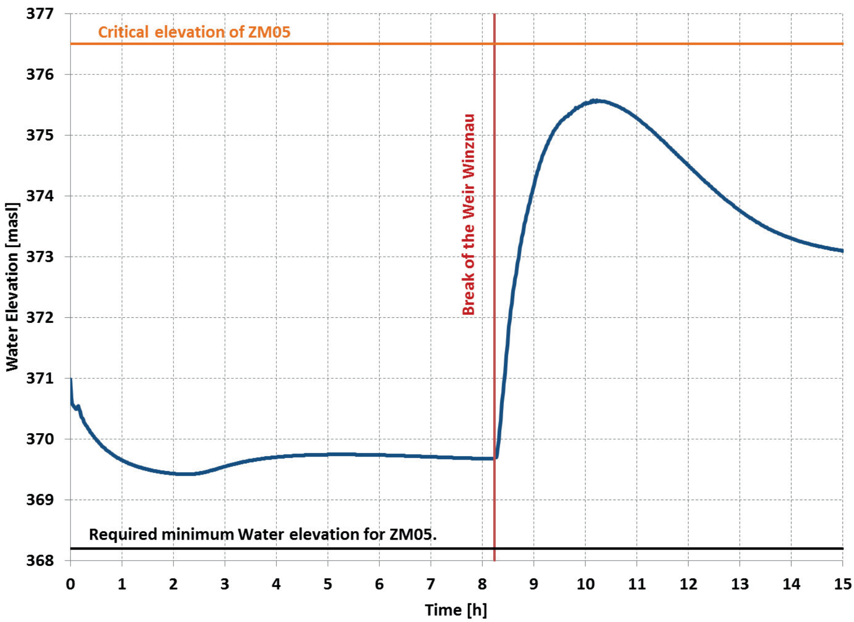

Figure 9: Time history of the water elevation at the intake ZM05 for the scenario 1.

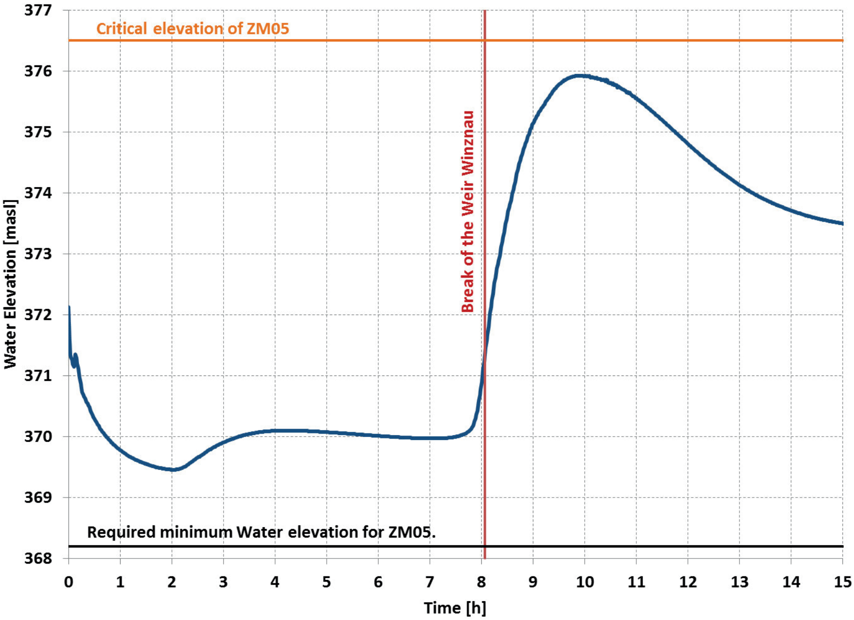

Figure 10: Time history of the water elevation at the intake ZM05 for the scenario 2.

based on a hybrid simulation model, which consists of 1D and 2D-model. With the simulations it can be shown, to what extent the KKG area and also the cool water intakes are imperiled through the flood waves of dam breaks. The scenarios are based on conservative assumptions such as sudden break of weirs and can be considered as worst cases. The simulations show that the scenario 2 induces large flood waves and has the worst impact on the area close to the KKG.

REFERENCES

- BAFU (2014). Homepage des Bundesamtes für Umwelt (BAFU), Bern, www.hydrodaten.admin.ch
- ENSI (2014). The Safety of Swiss Nuclear Plants in case of External Flooding, www.ensi.ch.
- BFE (2014). Richtlinie über die Sicherheit der Stauanlagen, Teil B: Besonderes Gefährdungspotenzial als Unterstellungskriterium.