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ASSESSMENT OF THE DISCHARGE CAPACITIES AND SAFETY OF MAIN STRUCTURES IN LARGE DAMS OF DRINI RIVER CASCADE

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ALBANIA

1- INTRODUCTION

Climate change will lead to increased flood and drought risks in the Mediterranean region, particularly in the Western Balkans. The adaptation to climate change is presently inadequate, especially in terms of flood and drought risks and risk management.

This report provides a description on the Assessment of the discharge capacities and safety of main structures in large dams of Drini river cascade in Albania including the current monitoring and management of the dams and reservoirs, efforts to improve operations, and measures planned for the future to increase energy potential and dams safety.

The height and types of dams, conditions of operation, the water volumes of reservoirs created by dams, the multiply purpose of their operation, the installed power capacities and the dynamic of exploitation of Hydro power plants make the Drini river cascade to be unique cascade in Europe.

The design of this cascade has started 60 years ago. Till now, In Drini river basin are constructed 7 large dams in Albania (Dam of HPP Fierza is the biggest dams in Albania) and 6 HPPs with current total power capacity of 1450 MW and average energy production of 5 000 GWH per year. KESH operates three hydropower plants in the Drin River cascade which produces approximately 70% of the electricity of the country.

From the beginning of the study on the exploitation of the hydro power potential of the Drin River, the idea was accepted that the Drin River should be exploited by creating large reservoir. For the creation of these reservoirs it was required to design and build very high dams with the heights of 60-170 m. In 1964 in the Europe were built only 10 dams with a height of over 160 m.

Relying on the achievements of science and technology in the world for the construction of large dams as well as the professionalism, determination and belief in the technical-scientific values of Albanian designers and engineers it became possible to successfully solve all the problems that arose during the design and construction of these dams and the creation of the largest cascade in our country. During the study of the exploitation scheme of the Drin River, the solution of various problems related to the geological conditions of the area, the type of dam, construction materials, the time of their construction were taken into account.

2- GENERAL INFORMATION ON DAMS OF DRINI RIVER CASCADE

Currently, on the Drin River are built 7 large dams (4 dams of HPP Vau i Dejes with height of 12-60 m, Dam of HPP Fierza with a height of 166.5 m, Dam of HPP Koman with a height of 115.5 m and Dam of HPP Okshtuni with height 65 m) and is in the design phase dam and HEPP Skavica.

Also, In the downstream part of this river is constructed the hydro-technical complex of HPP Ashta and Spathara.They use the water of HPP Vau I Dejes.

The Exploitation scheme of Drini river in Albania is given in the fig.No.1 below

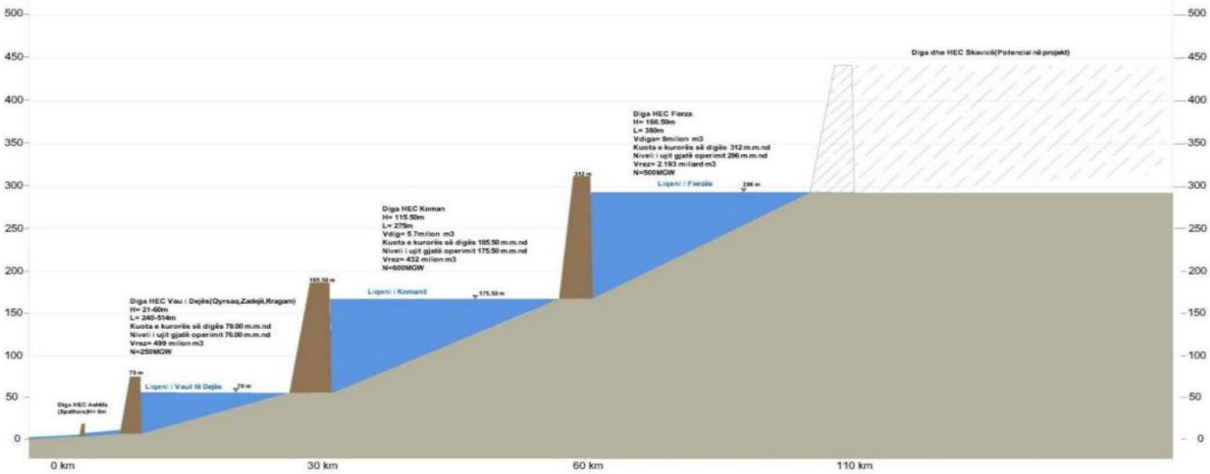

Fig. No.1 - Hydro- power Exploitation Scheme of Drini River in Albania

Dam of HPP Fierza that is the first dam in upper part of this cascade, it is the highest dam in Albania. It is a rock-fill dam with a clay core (RFDC), measuring 166.5 m in height and 380 m in length at the crest. The reservoir created by this dam is the biggest reservoir in Albania with water designed maximum volume of 2.7 billion m3 and current maximum volume of 2.3 billion m3. Two main branches of Drini river discharge their inflow in this reservoir. On the left side of the dam are all the facilities for the hydro power plant, while on the right side are the water spillway systems with a total capacity of 2670 m³/s.

Fig. No.2 - Dam of HPP Fierza

Dam of HPP Koman that is the second dam in middle part of this cascade, it is a concreted faced rock-fill dam (CFRD), measuring 115.5 m in height and 275 m in length at the crest. The reservoir created by this dam is designed with water maximum volume of 500 million m3. Actual maximum volume of this reservoir is 432 million m3. 12 rivers and streams of Drini basin discharge their flow from Albanian Alps to this reservoir. On the left side of the dam are all the works of the Hydro-power plant as well as a spillway tunnel of the water discharge system and on its right side there is a water spillway tunnel. The total maximum capacity of them is 3 600 m3/sec

Fig. No.3 - Dam of HPP Koman

The main dams of the **hydro-technical complex of HPP Vau i Dejes** consists of:

- **Qyrsaq Dam** with a height of 54 m and a length of the dam crest of 514 m. This dam consists of 2 parts where the first part is a rock-fill dam with clay core and the second part is a concrete dam with gravity. In the concrete dam are also the intake system and the spillway system with a total capacity of 3900 m3/s.

- **Zadeja Dam** with a height of 60 m, length of the dam crest of 387 m. This dam is of the type of rock-fill dam with clay cores. On the left side of this dam is built the discharge system consisting of 2 spillway gates and discharge tunnel with a length of 322 ml and height of 11 m. The current discharge capacity of this tunnel is about 2000 m3/s.

- **Rragam dam** with a height of 21 m and a length of the dam crest of 240 m.

- **Gjocaj Dam** with a height of 11.2 m and a length of of dam crest of 295 m. In this dam there is an intake system with a capacity of about 8 m3/s for the irrigation purpose

Fig. No.4 - Qyrsaqi Dam of HPP Vau I Dejes

3- HYDROLOGYCAL ANAYLSE AND MODEL OF DRINI RIVER.

Drini river cascade is part of Drini - Buna Basin. The Drin – Buna basin is a large river basin located in the Western Balkans with international importance as it is shared by the countries Albania, Montenegro, Macedonia and Kosovo. Its catchment covers approximately 20,380 km²1 based on most actual calculations by the consultant. Headquarters of the main river system Drin are the Black Drin which drains the western part of Macedonia (catchment 3,320 km²1) and the White Drin (Drini i Bardhë) which rises in Kosovo (catchment 4,650 km²1).

After crossing the borders to Albania, the two streams merge near the city Kukës at the eastern part of Albania and form the Drin. Further westwards the Drin flows in direction to the Adriatic Sea where it joins the outflow of the Shkodra lake (377 km² - 530 km²) and becomes the Buna river. The water balance of the Shkodra lake, shared by Albania and Montenegro, is highly influenced by the Morača and Zeta rivers which drain the northern mountain range of the sub-basin Montenegro. Upstream of the confluence with the lake outlet, the Drin passes the dam cascade of the three reservoirs: Fierza (73 km²), Koman (12 km²) and Vau Dejës (25 km²) operated by the Albanian power corporation (KESH sh.a). Several tributaries flow directly into the reservoirs.

Among them, the Valbona river draining the central eastern Albanian Alps is the largest one. The outflow of the Vau Dejës reservoir is influenced by a weir at Spathar further downstream.

Because of thecomplex hydrodynamic interaction between the lake, the rivers Buna/Bojana and Drin and the releases of the Vau Dejës dam, the lower part of the river basin is susceptible to flood events and regional inundations. With regard to the potential of extreme flood flows in the past and flood damage, this area requires special attention for data monitoring and hydrological modeling, in future presumably in combination with hydrodynamic modeling of the surface water levels.

An extensive analysis was performed for rainfall events of different durations. This analyse is done by a Team of LWI in a study funded by GIZ/Germany. Considering PMPs of different durations, temperature and snow cover analysis, PMFs of 1-day to 7-day events were generated by means of the PANTA Rhei rainfall-runoff model.

PANTA Rhei is a hydrological modeling system for the simulation of the rainfall-runoff-process and the water budget at any location within a catchment resp. river basin. The model allows simulations with high spatial and temporal resolutions. The preparation of catchment data is supported by GIS techniques. The model has been developed and is continuously maintained at the Leichtweiss Institute for Hydraulic Engineering and Water Resources (LWI), University of Braunschweig, in collaboration with the Institute for Water Management IfW GmbH, Braunschweig. The model is used for flow forecast, for planning purposes, and – in a more sophisticated version – for research of climate changeimpact on water resources. Computation time steps can be defined according to the available data and project aims. Often, a time step of 1 hour for flood flow analysis (event-based simulation) and 1 day for the analysis of the water balance (simulation for long-term periods) is selected.

PANTA Rhei is dominated by three model components which reflect the relevant hydrological processes for the transformation of rainfall into runoff. The transformation is divided into (i) the formation of runoff, (ii) the concentration of runoff, and (iii) the routing of flow through the river system.

The Panta Rhei structural model now comprises:

- A total catchment size of AEo= 20,380 km²
- 2,562 sub-catchments
- 25,200 hydrotops
- 50 gauges or locations to view or generate runoff time series (107 potential locations)
- 13 lakes and reservoirs
- 2 bifurcations to simulate the flow of lake Prespa and lake Ohrid

The quality and reliability of hydrological modeling results depend on a consistent and continuous operating data acquisition network in every country. Regional data exchange and cooperation between the related stakeholders was therefore a key condition to establish an integrated flood early warning system for the whole Drin– Buna basin.

A first analysis and inspection of data quantity and quality with focus on topographic, meteorological and hydrometric data has been accomplished. during this study. The final outcome of the data collection and the resulting needs for further investigation are summarized in the study. A detailed digital terrain model exists as the base for hydrological modeling. It covers completely the sub-basins located in Albania, Macedonia and Kosovo and includes parts of the Montenegrin sub-basin.

The meteorological data investigation shows a high density of stations although partly location and condition of stations are unclear. Several stations have been renamed and relocated during the time period 1961 – 2013. A number of historical time series data exist for the parameters precipitation and air temperature (daily minimum, daily maximum, daily average) which contain randomly distributed data gaps. Time series data for additional meteorological parameters was rare.

The Drini river cascade is an important influencing factor and offers a high potential to improve the existing flood risk management. Dams Operator (KESH sh.a) provided hydrometric data for this study which included hydrographs for daily reservoir inflow, side inflow and spillway outflow from 1991 till 2010. Additional data such as turbine outflow and/or total outflow from each reservoir and storage elevation curves for the three reservoirs was required for calibration purposes and will help to optimize a combined and multi-objective reservoir operation with the help of modeling. In general precipitation data are evaluated as sufficient

A proper hydrological modeling of a catchment requests a credible simulation of the following components of a long-term simulation:

- event based rainfall-runoff events and response time of soil storages
- peak runoff during floods
- travel time of flood waves
- seasonal high flow and low flow
- snow accumulation and melting
- evapotranspiration

The hydrologic modeling system PANTA Rhei was applied. It has proved to gain – in total - reasonable results and a good overall model fitting with respect to the available spatial input data and available time series.

4- FLOOD ROUTING AND RESERVOIR OPERATION

Drini River Cascade is a reservoir operation and flood routing model, which has been specifically tailored for the performance of flood routing and reservoir operation studies in this cascade. Based on the hydrological modeling of the Drin River Basin and applying the existing KESH operation rules (they are approved at 1988) for the three main HPPs, flood routing and reservoir operation studies were carried out. The existing rainfall data base was extended for the operation period from 1980 till 2015. An extensive analysis was performed for rainfall events of different durations. Considering PMPs of different durations, temperature and snow cover analysis, PMFs of 1-day to 7-day events were generated by means of the PANTA RHEI rainfall-runoff model.

Accordingly, the following additional discharge capacities need to be installed.

	HPP of Fierza	HPP of Komani	HPP of Vau I Dejes
Max. Outflow after routing	5 250 m³/s at 306.5 masl	7 100 m³/s at 175.5 masl	7740 m³/s at 77.0 masl
Available discharge capacities	2 670 m³/s + 500 m3/s (from turbines)	3 600 m³/s + 500 m3/s (from turbines)	7740 m³/s (incl. turbines)
Additional discharge capacities required	2 080 m³/s	3000 m³/s	no additional capacities required

Different options for reducing the required additional spillway capacities at Fierza and Komani were analyzed, including:

- providing additional storage capacity in future upstream Skavica Hydropower Project
- removal of sediment deposits from the reservoirs
- diversion of floods into adjacent catchments
- construction of additional spillway.
- increase of maximum water level
- lowering of operation water level during flood season;

The studies has showed that a combination of the different measures can reduce the required additional capacity at Fierza and at Komani. Though, taking into account that most of the measures described above are technically, economically and environmentally not feasible additional spillway capacities are required. Therefore, additional spillways with discharge capacities of 2080 m³/s and 3000 m³/s were engineered for Fierza and Komani.

5- CONCLUSIONS

The results show that, in order to render the Drin River Cascade safe for the event of a PMF:

- Dam of HPP Fierza requires additional spillway capacities of some 2,080 m³/s;
- Dam of HPP Koman requires additional spillway capacities of some 3,000 m³/s;
- Dams of Vau I Dejes are safe
- KESH must update the existing Operation Rules for the integrated management of Drini river cascade.

Given that the Drin River Cascade is safe for PMF by adding additional spillway capacity, the simulations show that the cascade would be safe for a flood event of 1,000 years return period, even in case that the gate of the highest capacity would fail.

Other measures, such as:

- reduction of reservoir operation level during the flood season
- restoration of original reservoir storage capacity by means of sediment dredging
- increase of dam height and flood water level
- watershed diversion
- provision of flood retention dams upstream of Fierza

have been assessed as above, but found not to be feasible for technical, economical and ecological reasons.

A financial and economic analysis was performed to assess the viability of additional spillway capacity to safely discharge a PMF at the Drin river cascade from the perspective of the economy and from an Investor. In terms of economic viability, it was shown that in case such an event happens, the benefits of the investment significantly outweigh their costs.

Given that safety measures try to prevent exactly such a scenario, an investment decision with respect to safety measures should be based on such considerations. In addition to a static analysis, a cash flow model has been set up to take the probability of the occurrence of the event into account. The results were not favorable towards the investment; however, it must be considered that the value of human life was not taken into account and if the event were to happen, thousands of people would be at risk.

6- REFERENCES

1) Mott MacDonald: A post-disaster comprehensive flood risk assessment & Management study. Final Report – The flood risk management plan for the lower Drini & Buna river basin, July 2012.
2) Sanxhaku, M. and Ko, P.: Design Flood Studies for the Drini Hydropower Cascade. Report for KESH, December 2012.
3) World Meteorological Organisation (WMO, 2009): Manual on Estimation of Probable Maximum Precipitation (PMP). WMO-No. 1045, 2009
4) Meon, G; Pätsch, M: Assessment Study for Gaps and Needs in Establishing a Drin Early Warning System. Final Report for GIZ. Braunschweig, May, 2013.
5) GIZ: Flood risk management plan in Shkoder region and Emergency Preparedness Plan, Tirana, 2015
6) GIZ: Potential of multi-purpose-use of the hydropower reservoirs of the Drini cascade in Albania, Tirana, 2016
7) Fichtner GmBH, “Study for providing safe flood management of the Drini river cascade, WB project, 2017
8) ICOLD Bulletin No.156. “Integrated Flood risk management”. 2010
9) ICOLD Bulletin No. 170 “Flood Evaluation and Dam Safety”, 2015
10) ICOLD Bulletin No. 186, “Integrated Optimal Operation of Cascade”, 2019
11) Albanian Power Corporation (KESH sh.a), “Annual Report for Actual Conditions of dams and reservoir in Drini river cascade and their Monitoring and Dam Safety, Tirana, 2018, 2020, 2022
12) ALBCOLD, “Annual Report for Dam Monitoring and Safety in Albania, Tirana, 2018, 2020, 2022.
13) ALBCOLD Website, www.albcold.gov.al, english version, Tirana, Albania, 2022