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The sustainable use and extension of hydropower
reservoirs is vital to ensure the energy transition

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Extended Abstract

Part I: Reservoir sedimentation endangers sustainable use of hydropower reservoirs

Sedimentation is known as the process of filling up natural lakes and manmade reservoirs by sediment transforming finally into floodplains. Its main reason is the sediment yield transported by rivers as suspended or bed load into the reservoirs. Reservoir sedimentation is already today one of the most serious problem endangering sustainable use of the worldwide reservoir volume. Climate change will further increase in many regions this problem [7, 8, 18]. The today's worldwide yearly loss of storage capacity due to sedimentation is already higher than the increase of capacity by the construction of new reservoirs for irrigation, drinking water and hydropower. Thus, the sustainable use of the reservoirs is not guaranteed in long term.

In the case of deep and long reservoirs the sedimentation rate is often much below the world mean value. Nevertheless, the sedimentation also threatens these reservoirs, since turbidity currents are sporadically transporting large volumes of sediments down to the dam. There the concentrated deposits are hindering the safe operation of the outlet structures as intakes and bottom outlets. The amount of suspended fine sediments load entering a reservoir is often much larger than the bed load and may represent typically 80-90% of the total sediment yield [8]. The bed load and larger components of the suspended load settle and contribute to the delta development. The particles remain suspended and may leave the reservoir with the outflow. Nevertheless, the sediment-laden inflow has a larger density than the reservoir water. Thus, a density current can occur transporting along the reservoir bottom sediments towards the dam. Especially in narrow and long reservoirs, turbidity currents are the main transportation process of fine sediments within the reservoir. The problem is that at each turbidity current event a high amount of sediment is deposited just upstream of the dam, affecting only after some decades the operation of bottom outlets and power intakes. For example, only after only 30 to 40 years of operation, sedimentation has become a serious problem in many reservoirs located even in catchment areas with moderate surface erosion as in the Alps in Europe.

To control the transport of fine sediments within the reservoir, the effects of obstacles, screens, water jets and bubble curtains on the turbidity current were investigated with physical experiments and numerical simulations [1, 13, 14, 15, 16, 17]. The investigations showed that turbidity currents can be influenced effectively by properly designed constructive measures [8, 13, 16]. Another possibility is venting of turbidity current which is already successfully done in many reservoirs worldwide. The effect of the outlet discharge or the capacity of the low-level outlets on the efficiency of turbidity current venting has been studied systematically recently both with flume experiments and numerical simulations. The influence of the venting degree, defined as the ratio between outflow and turbidity current discharges, on the efficiency of venting, was highlighted and recommendations could be given for achieving high venting efficiencies [2, 3, 4, 5]. Furthermore, a method was developed which can keep sediment in suspension by a jet induced artificial turbulence and releasing it through the water intake of hydropower plants [9, 10, 11, 12]. In the case of reservoirs in a cascade, eventually combined with pumped-storage operation, the locations of inlets and outlets in a reservoir can have a strong influence on the turbulence pattern in the latter and consequently on the routing of fine sediments through the reservoir [6, 7].

The geometry of shallow reservoirs has a strong effect on the flow pattern and sedimentation process of suspended sediments [19, 20]. The trap efficiency and the sedimentation index can be expressed with empirical relations as a

function of a geometrical shape factor defined by Kantoush [21]. Furthermore, the flushing efficiency for free flow and drawdown flushing can be also linked with geometrical shape factors [22, 23, 24]. Thus, if there is freedom to select an optimum geometry of shallow reservoirs in the design procedure, as it is often the case for compensation basins, then the sedimentation process can be reduced significantly by using appropriate shapes.

Many possible measures for sedimentation management are known from practice, but they are strongly depending on the local conditions [8]. For alpine reservoirs technical measures, which can govern turbidity currents are of special interest. The problematic of sedimentation and sediment management should be considered in the early stage of the design of the reservoir in order to obtain sustainable solutions. Although methods for erosion volume estimation and empirical relationships for trap efficiency estimation are available, unfortunately this is still not the case for many reservoirs built recently all over the world.

A replenishment of adequate gravel material downstream of large dams combined with an artificial flood release during flushing or venting sequences for mobilizing sediment can restore the morphology of rivers downstream of dams to some extent. Battissacco et al. [25] performed systematic physical flume experiments to study which arrangements of sediment deposits downstream of a dam are suitable for recreating morphological variability. Recommendations were given regarding the placement of the artificial gravel deposits and the required discharge to mobilize them, with the purpose that deposits recreate morphological bed forms when transported in the river reach downstream. The concept was tested at Rossens Dam in Switzerland [26, 27].

After the discussion of reasons and problems of reservoir sedimentation, the keynote lecture will discuss possible measures for sediment management in reservoirs. Then examples of some recent research projects, which focused on mitigation measures against turbidity currents in particular and deposition of fine suspended sediments in general are given together with design recommendations.

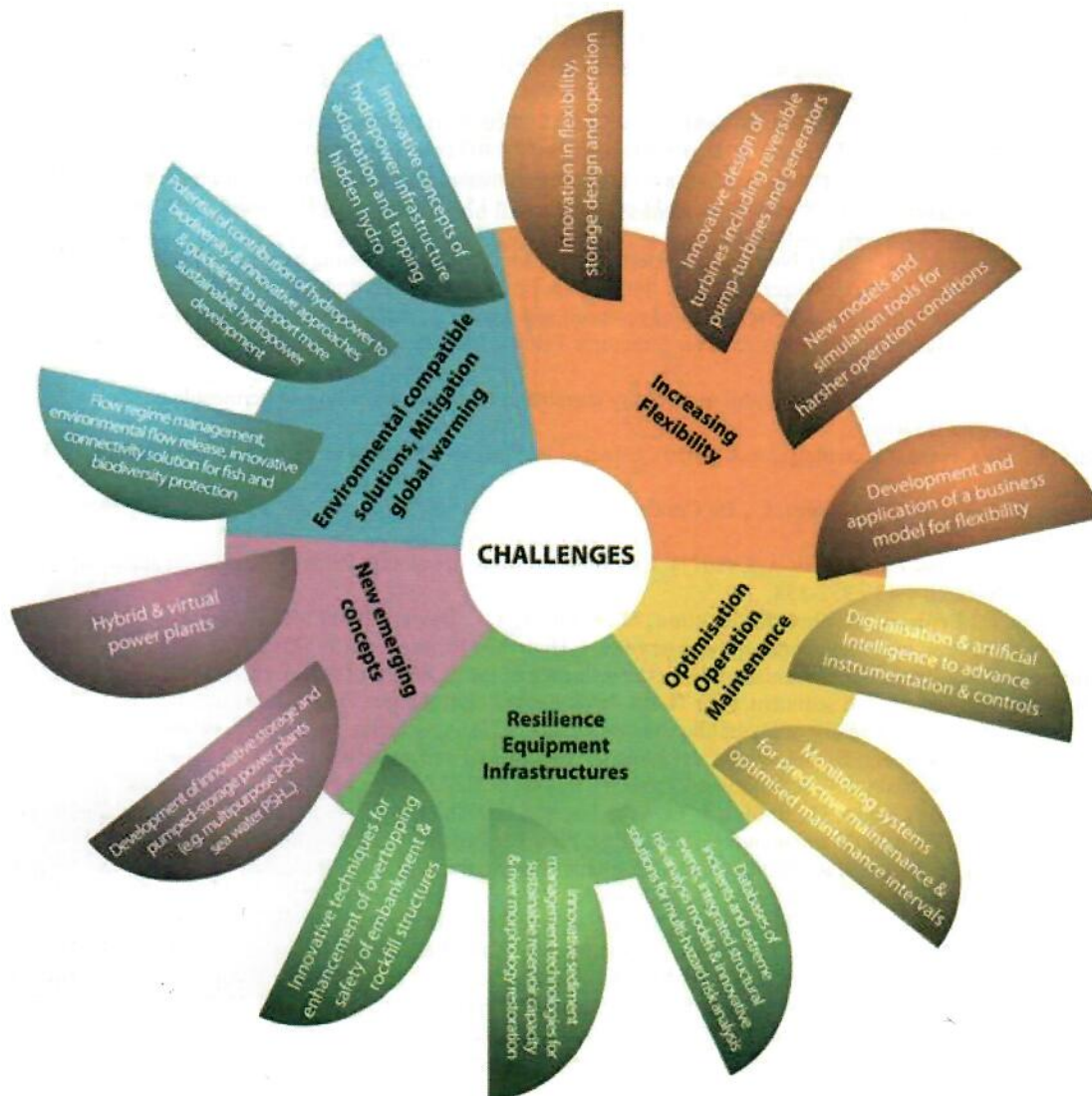


Sediment depositions in Sufers Reservoir, Switzerland, during drawdown (Courtesy Kraftwerke Hinterrhein)

Part II: Importance of hydropower reservoirs and dams in Europe to mitigate the energy crisis and to serve as a catalyst and enabler for the Green Deal

Hydropower has a long tradition in Europe and contributed significantly during the last century to industrial development and welfare in most of the countries in Europe. The ambitious plan for an energy transition in Europe now seeks to achieve a low-carbon climate-resilient future in a safe and cost-effective way, serving as an example worldwide. The key role of electricity will be strongly reinforced in this energy transition. In many European countries, the phase out of nuclear and coal generation has started with a transition to new renewable sources comprising mainly of solar and wind for electricity generation. However, solar and wind are variable energy sources and difficult to align with demand. The International Energy Association IEA (2021) concludes that hydropower provides “unmatched” flexibility and storage services required for ensuring energy security and

delivering more solar and wind power onto the grid. In the future, these services will be in much greater demand to achieve the energy transition in Europe, and worldwide. Hydropower has all the characteristics to serve as an excellent catalyst and enabler for a successful energy transition. The HYDROPOWER EU-ROPE Forum brought together some 650 relevant stakeholders representing all sectors (including design, construction, production, sectoral associations, environmental and social issues), who participated actively for 40 months (2018-2022) through an extensive pro-gram of review and consultation addressing needs of the whole hydropower sector targeting an energy system with high flexibility and renewable energy share. The follow-up ETIP HYDROPOWER project (2022-2025) consolidates the strong network of the HYDRO-POWER EUROPE Forum into a sustainable association and helps to unify the voices of hydropower in Europe. ETIP HYDROPOWER will facilitate, enhance and disseminate the Research and Innovation Agenda (RIA) and the Strategic Industry Roadmap (SIR) (drafted under the HYDROPOWER EUROPE project) taking into consideration the future needs of the sector and the R&I targets and the emerging policy priorities. This will help to ensure that hydropower can play the vital role of an enabler in the transition to a clean and safe energy system and the achievement of climate neutrality by mid-century. Furthermore, be-sides unifying the voices of hydropower, ETIP HYDROPOWER will further align and co-ordinate the industry RIA and SIR strategies to provide consensus-based strategic advice to the SET Plan (European Strategic Energy Technology Plan) covering analysis of market opportunities and research and development funding needs, biodiversity protection and ecological continuity. Another goal is, in one with Europe and the latest EU climate and energy related policies, deepening the understanding of innovation barriers and the exploitation of research results. The ongoing activities regarding hydropower will be addressed in the keynote lecture.



Suggested research themes by HYDROPOWER EUROPE with high to very high priority grouped according to the challenges which hydropower must address.

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The Keynote speaker

Prof. Dr. Anton J. Schleiss graduated in Civil Engineering from the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland, in 1978. After joining the Laboratory of Hydraulic, Hydrology and Glaciology at ETH as a research associate and senior assistant, he obtained a Doctorate of Technical Sciences on the topic of pressure tunnel design in 1986. After that he worked for 11 years for Electrowatt Engineering Ltd. (now AFRY) in Zurich and was involved in the design of many hydropower projects around the world as an expert on hydraulic engineering and underground waterways. Until 1996 he was Head of the Hydraulic Structures Section in the Hydropower Department at Electrowatt. In 1997, he was nominated full professor and became Director of the Laboratory of Hydraulic Constructions (LCH) in the Civil Engineering Department of the Swiss Federal Institute of Technology Lausanne (EPFL). The LCH activities comprise education, research and services in the field of both fundamental and applied hydraulics and design of hydraulic structures and schemes. The research focuses on the interaction between water, sediment-rock, air and hydraulic structures as well as associated environmental issues and involves both numerical and physical modelling of water infrastructures. In May 2018, he became Honorary Professor at EPFL. Until today more than 50 PhD and Postdoc research projects have been carried out under his guidance. From 2006 to 2012 he was the Head of the Civil Engineering program of EPFL and chairman of the Swiss Committee on Dams (SwissCOLD). In 2006, he obtained the ASCE Karl Emil Hilgard Hydraulic Price as well as the J. C. Stevens Award. He was listed in 2011 among the 20 international personalities that “have made the biggest difference to the sector Water Power & Dam Construction over the last 10 years”. Between 2014 and 2017 he was Council member of International Association for Hydro-Environment Engineering and Research (IAHR) and he was chair of the Europe Regional Division of IAHR until 2016. For his outstanding contributions to advance the art and science of hydraulic structures engineering he obtained in 2015 the ASCE-EWRI Hydraulic Structures Medal. The French Hydro Society (SHF) awarded him with the Grand Prix SHF 2018 and IAHR as honorary member in 2021. After having served as vice-president between 2012 and 2015 he was president of the International Commission on Large Dams (ICOLD) from 2015 to 2018. With more than 40 years of experience he is regularly involved as a consultant and expert in large water infrastructures projects including hydropower and dams all over the world. On behalf of ICOLD is coordinating the ETIP Hydropower projects funded by the EU Horizon 2020 research and innovation program.

More details including publications see: <http://people.epfl.ch/anton.schleiss?lang=en>

