Together in the future: possible approach for new/existing multipurpose reservoirs - From identifying the right partners up to sharing the resource water: operational & legal aspects

Ensemble vers l'avenir : des approches potentielles pour des réservoirs (nouveaux ou existants) à multifonctionnalité – De l'identification des bons partenaires au partage de la ressource en eau : des aspects opérationnels et juridiques

Christian Dupraz[1], and *Bettina* Geisseler[2*]

[1] Swiss Federal Office of Energy SFOE, 3000 Bern, Switzerland
[2] GEISSELER LAW (law firm), 79112 Freiburg, Germany

Abstract. Climate change has, in recent years, dramatically shown the importance and impact of the resource water: extreme situations such as floods respectively scarcity become more and more frequent. Multipurpose reservoirs can help to mitigate the negative impacts. Sharing water means in principle sharing the benefits and the risks. But how to balance the complementary, sometimes even conflicting interests of all "share-holders", i.e. the users concerned, - "Shareholders", which usually are independent non-connected legal entities? How to balance efficiency and sustainability? Defining the corresponding rights and obligations of the different users sharing the water stored in a reservoir is challenging from an operational as well as from a legal point of view. The authors will illustrate what could be a possible blueprint for a new/ existing multipurpose reservoir, from the planning up to the operation phase, and what the relationships among the users could look like, by taking into account operational needs and legal aspects. Additionally, the paper will discuss how the relationship of all users to other stakeholders such as the financing institutions, the state (bundled permitting/concession procedure?) or affected communities could be organised.

* Corresponding author: geisseler@geisseler-law.com

Résumé. Le changement climatique a démontré de manière dramatique ces dernières années l'importance et l'impact de la ressource eau : les situations extrêmes telles que les crues ou la sécheresse deviennent de plus en plus fréquentes. Les réservoirs multiusages peuvent contribuer à atténuer les impacts négatifs. Partager l'eau signifie le partage des gains et des risques. Mais comment équilibrer les intérêts complémentaires voire parfois contradictoires de tous les partenaires, soit les usagers concernés, qui sont généralement des entités juridiques indépendantes et sans lien entre elles ? Comment équilibrer l'efficacité et la gestion durable ? Définir les droits et devoirs des différents usagers partageant l'eau stockée dans le réservoir est un défi tant d'un point de vue opérationnel que juridique. Les auteurs illustreront ce que pourrait être le schéma directeur pour un réservoir existant/nouveau multifonctionnel, de la phase de planification à la phase d'exploitation, et ce à quoi pourraient ressembler les relations entre les utilisateurs, en tenant compte des besoins opérationnels et des aspects juridiques. En outre, le document abordera la relation de tous les usagers envers d'autres parties prenantes, comme des institutions financières, l'état (autorisation/procédure de concession) ou les communautés affectées, pourrait être organisée.

1 Introduction

Sharing the resource water collected and stored in water reservoirs is nothing new. Examples are the Jawa Dam and Jawa water system in Jordan or the Sadd El-Kafara dam in Egypt, both erected in the B.C. era and serving as flood protection and a water source for irrigation [1]. It has tradition in both countries, Switzerland and Germany. The advantages of a *multi-purpose* reservoir are obvious: the advantages of a water reservoir, i.e. providing flexibility for various situations (flood control, power generation) and being able to adequately respond to climate change challenges and power generation from renewable, but intermittent sources, are multiplied; one water reservoir can serve multiple uses, whereas the potential negative impacts, which the reservoir might have on the environment, third parties, their property and their activities might be reduced – due to the fact that there is only need for one single reservoir at one site.

But on the other hand, it must be stated that due to natural, technical or economic constraints and requirements the multiple uses of a water reservoir often are not complementary, but highly conflicting. Regarding the multiple use of stored water for *hydropower,* EDF (Electricité de France) and the WWC (World Water Council) have agreed in 2012 to cooperate and launched a program to work on a SHARE concept framework for multi - purpose hydropower reservoirs [2]. The purpose is to maximise the benefits of the multi – purpose use of hydropower reservoirs by considering, among others, the principles of

- Shared resource
- Shared rights and risks
- Shared costs and benefits

in order to achieve more sustainability. It is without any question that those principles have a high value. In addition, the implementation of these principles in general is desirable not only for hydropower multiple–purpose reservoirs, but for any kind of multi-purpose water reservoirs.

This paper investigates the current situation of multi-purpose reservoirs in Switzerland and Germany and shows the tasks and responsibilities of the stakeholders involved. Both countries have a long tradition in using the resource water for generating hydroelectricity in connection with water reservoirs and in operating reservoirs. Whereas in Germany quite a few of the water reservoirs served right from the beginning multi- purposes. The issue of how to solve conflicting uses of water reservoirs became increasingly important in both countries only in recent decades.

The paper describes the process of considering the interests of the different users from the planning over the permitting into the operating phase and focusses on ways how the operators of multi-purpose reservoirs monitor and manage potentially conflicting interests of the different users of the water. This is accomplished by taking into account the several operational needs of the reservoir, the requests from respectively the obligations vis-à-vis the users, and the legal framework.

Finally, the authors will discuss whether some lessons learnt should lead to new approaches for either "to be built" new multi–purpose reservoirs or those already in operation and to what extent the existing legal framework should be modified.

2 Switzerland

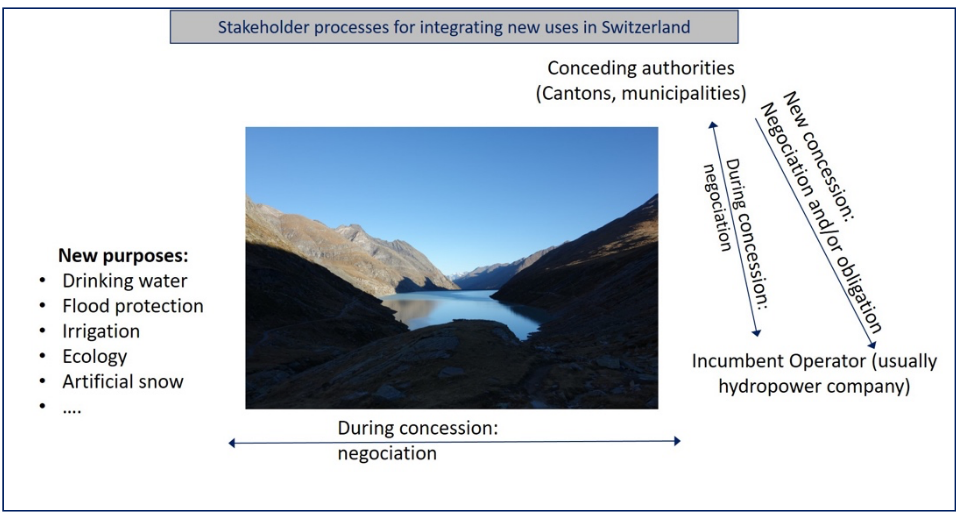


Fig. 1. Stakeholder processes for integrating new uses in Switzerland.

Switzerland has around 200 reservoirs with large retaining structures, which are supervised by the SFOE and over 200 smaller dams, which are supervised by the cantons. Over 60% of the smaller dams are used as flood retention basins and only 27% of the smaller dams serve primarily for irrigation or hydropower generation. This compares to 85% of the large dams that are used, primarily, for hydropower generation and 10% for flood retention. Given that almost all of the flood retention basins have no permanent pond and are only filled during flood events, they are of minor interest for a multipurpose use. The large dams for hydropower generation lie mostly in the Alps and are a major source for Switzerland's electricity supply. They are also important for power balancing in cross border markets, due to the high installed flexible capacity. Hydropower accounts for around 60% of the Swiss electricity production, 56 % of the mean annual hydroelectricity production of 38 TWh is provided by storage schemes [3]. The main operation mode of the large reservoirs is seasonal storage, where the water of the snowmelt is stored during spring and summer and thus provides water for electricity production in winter. The reservoirs usually reach their lowest level at the beginning of spring. This leads to an attenuation of low-flows that are typically occurring in autumn and winter.

An important characteristic of Swiss hydropower is that it's both local and regional. In fact, while there is one federal act on water utilization that sets the law providing guidelines, each canton has its own legislation and is managing the licensing of hydropower plants. In some cantons water rights concessions are controlled by the municipalities. Therefore, it is difficult to assess the use conditions of hydropower on a national level. Another important feature of concessions in Switzerland is their strong protection against later changes. The core content of a concession is considered a vested right. Especially, the usable amount of water can only be changed slightly after the grant of a concession or otherwise a compensation has to be given. The legislation on residual water flows considered this rule, by using a two step process of restoration. Firstly, an augmented residual flow has to be economically feasible for running concessions and a full application of the residual flow only at concession renewal.

When it comes to different users and their interactions, the federal act on water utilization has an interesting disposition in its paragraph 33. Although designed for different hydropower plants, it could also influence the regulation of different uses. It covers those users, benefitting from the works developed by others e.g. a reservoir which has also provides benefits for all downstream users, These other users can be obliged to pay a contribution for the construction and operation of the works. The following examples show that this basic idea can help to find solutions for the integration of different uses in the management of one reservoir.

2.1 Current Situation and Lessons Learned

There is no global analysis of multipurpose reservoirs in Switzerland, but the awareness of climate change and changing water resources is also leading to an intensified interest in multipurpose reservoirs [4 - 6]. For new hydropower projects, it is not uncommon, that the concession authority to require an analysis of potential multifunctional uses. This was the case for the project Trift in the Bernese Alps [7, 8]. The study [7] concluded that it would not be necessary to add further restrictions for flood control, that go beyond the usual operational mode of 10% reserve volume. As for low flow periods, which will be more frequent in the future, the relatively remote Oberhasli cannot contribute to a substantial contribution for the midlands and no contribution is needed for the adjacent valley.

While reference [4] states that multipurpose use is rarely applied in Switzerland in comparison other European countries, an extensive research about multipurpose use in the canton of Grisons [9] demonstrates, that all assessed hydropower plants have, to some extent, a multipurpose uses. This result can be attributed to the wide interpretation of multipurpose use in the study, as it comprises also fishing or touristic use and ecological restoration as multipurpose use. Those uses are not very conflicting for the examined plants, similarly to firefighting water, which is also a frequently encountered use, but the quantities used are usually negligible. Many concession acts in Switzerland mention the use of firefighting water as to be tolerated. The use for touristic purposes and firefighting water may be conflicting in other circumstances, with frequent wild fires or when water levels have to be maintained at a certain level for scenic reasons.

The management of different conflicting uses is more ambitious, but less frequent. While in the drier regions, namely in the cantons Valais and Grisons where irrigation is important, the water rights for irrigation date back to times before hydroelectric use. Therefore, the irrigation water rights were usually considered as given and are respected in the concessions. The same applies to drinking water as long as the demand is not exceeding the quantities, which were used at the time of licensing.

The reservoir of Tseuzier in the Montana region in the canton of Valais is an example, where the construction of a reservoir improved the existing uses for irrigation and drinking water. Before the construction of the reservoir only very limited storage capacities could be used, and especially no seasonal shift was possible. Today the high drinking water demand in winter is met by water stored in the Tseuzier reservoir (51 million (mil,). m^3). The communities are able to buy a part of the drinking water [10, 11], stored in the reservoir. Today 88, 5% of the water is used for hydropower production and the rest for irrigation, drinking water and artificial snow production. Currently the optimization project "Lienne-Raspille" is in elaboration in the Montana region, to profit even more from the reservoir of Tseuzier and to recalculate and revise the water supplies according to their actual needs. Three new hydroelectric powerplants integrated in the plan should augment the overall electricity production.

Another example in Valais shows how changing needs could be met during an ongoing concession. The Mattmark reservoir was built in the 60ies and started operation in 1969 in the Vispa valley, a tributary of the Rhone River. With its 100 mil. m^3 of retained water volume it is one of the largest reservoirs in Switzerland and one of the rare embankment dams of this size in Switzerland. It isdivertingthe waters of the glaciated Mattmark region from 2200 m to the power station in Stalden at 700 m. While in the years after 1948 no larger floods occurred in the canton of Valais, there was a series of floods in the 80ies and 90ies [12]. In 1993 at the end of the usual filling period of the reservoir occurred a strong precipitation event leading to a significant flood which caused high damages in the Vispa Valley. The reservoir was about 92% full before the event. Of the 11.5 mil. m^3 inflow in its catchment area Mattmark managed to contain 7.5 mil. m^3 through normal storage, 1 mil. m^3 through further retention and 1.2 mil. m^3 through diversion for hydropower. This led to a significant decrease of the flood wave. A similar event occurred just one year later, also at the end of the filling period and was fully absorbed by the reservoir. In 1997, during a period, where only 50% of hydropower capacity was available prior to when another flood event was forecasted. As the lake was filling quickly, the canton ordered, based on police law, to hold a free reserve volume of 3.5 mil. m^3. Mattmark had to do forced releases through the turbines, to guarantee this volume. In the end, the flood event did not materialize. In the year before, an expert group had studied the influence of reservoirs on flood protection in Valais and came to the conclusion, that reservoirs always contribute to a certain extent to flood protection [13]. They also concluded, that the powerplant could operate the plant within the framework given by the concession But with the consent of the operator, the canton could ask for flood protection measures, like providing free storage volume. Those measures would have to be compensated for. Consequently, the Mattmark plant asked for compensation for the 1997 order from the canton. The methodology of the calculation of the compensation amount is described in [14]. It is important to note, that the operator went below the level of the exact free volume, to create the same situation in terms of energy optimization for the utilities using the powerplant. It was not sufficient to exactly hold the imposed limit, as this would have led to a reduced flexibility of the plant, operating near to a complete filling. As the reservoir did not return to the maximum level in that year, there were significant opportunity costs due the forced releases through the turbines, as the seasonal shifting of energy into winter was reduced. For the calculation of the compensation, it was necessary to have the water balance, the amount of energy that was lost or produced forcibly and the valuation of those amounts. At that time of monopoly and with no electricity exchange in operation, the valuation was still based on generation costs, which were seasonally adjusted. Today the calculation can be done more transparently and easily with energy market prices. In the Mattmark example, the calculation was done in vain. The canton did not accept a compensation, but instead of appealed to a court. Mattmark then decided to suggest to the canton the creation of a multipurpose reservoir. This could be done by maintaining the original volume for hydropower utilization. The idea was to enlarge the spillway, so that the maximum level could be 2 m higher, reducing the freeboard by 2 m leading to a reserve of 3.6 mil.. m^3. The price for this 3.47% part of the total volume was calculated based on the estimated value of the dam, the investment for the adaption of the spillway and the annualized operation costs. The canton did not pay 3.47 % of the total amount calculated, but further considerations, like the increased electricity production when the normal operation level is exceeded, gave a reduced lump sum for the cantonal participation. The works were executed in 2001 and the Mattmark reservoir is a multipurpose reservoir since then.

The major flood of the year 2000, which affected the whole canton of Valais resulted in the initiation of two major flood protection measures. Firstly, the planning of the gigantic Rhône3-correction was started, and secondly, the flood prevision system Minerve was established over the course of many years. The project Rhône3 consists in the deepening and enlargement of the Rhone riverbed and will cost over 3 bn. CHF.

The project Minerve created a flood forecasting system for the Upper Rhone River basin, based on a hydrologic model [15]. The system is operational since 2013 and provides a basis for managing flood events in the Upper Rhone River basin. An important element for managing floods are the existing hydropower reservoirs in Valais. It is planned to integrate them into the flood management system, so that they can be ordered to create a free volume, when a flood is forecasted. As described above, this needs the acceptance of the reservoir operators and, therefore, conventions have to be signed, which will also regulate the calculation of the compensation.

The examples cited demonstrate, that multipurpose reservoirs are an issue in Switzerland. Some sites initially erected for a single use, have been transformed to multipurpose reservoirs already. For non-conflicting use the management of different uses is much easier and operators are usually open to integrate them. In view of the major investment and high risks related to the construction of a reservoir or hydropower plant, Swiss legislation sets a high degree of protection against later changes of the main dispositions of a concession. Consequently, the integration of new uses into existing reservoirs with ongoing concessions have to be regulated usually on an economic and contractual basis. In accordance with this logic the new restrictions for the incumbent operator have to be compensated, what can be done based on opportunity costs or by obtaining a part of the work itself. This is also applicable when the state side introduces the new use. In the current conditions with low electricity market prices, this can also be a positive opportunity for an operator, as the risk exposure is reduced and the operator can lower the overall costs. As the main use of reservoirs in Switzerland is hydropower production and this is not likely to change in the future, it makes sense that the benchmark for the opportunity cost is the electricity market. By applying this principle other users have to reflect on their willingness to pay. This leads to choices that are more rational and should maximize the benefit of all users. For some uses, especially in touristic areas the opportunity costs are easily met, e.g. in ski areas, where artificial snow has to be produced.

2.2 A Future Set-up

Although in Switzerland new reservoirs are only rarely built, it is possible, that for the adaption to climate change at some locations, new reservoirs may be an option. Areas experiencing glacier retreat have been recently studied for the potential realisation of new reservoirs [16]. Furthermore, the Swiss energy strategy envisages an increase in hydropower production, not only by expansions of existing plants, but also through new plants. In view of the mostly non-controllable renewable energies that will have a massive impact to power production, a flexible power source like storage power plants should have advantages in the future.

As the designer of a hydroelectric plant may not take into account other possible uses and partnerships of different uses might be inadvertently overlooked, it is important that in case of a new reservoir project somebody is considering the possibility of a beneficial multipurpose use. Usually this will be the authority responsible for the preparation of the issuance of the water rights. Those considerations should be done at an early stage, e.g. when integrating the project in the framework of spatial planning. This ensures that the project can be designed properly for multiple uses and that a partnership can be established for the licensing process. Not all partnerships are private and it is possible that the entity issuing the concession may have its own interest in integrating further uses. There are different ways to accomplish this. In Switzerland the concession giving community can impose further restrictions, e.g. for flood protection measures or irrigation. On the other hand, the project executing company might then reconsider its business plan and in some cases, the project will not be realized. The principle of benchmarking the cost of different uses is usually leading to a more efficient allocation of the different uses and should be followed in the interest of the community issuing the water rights, too.

The same questions have to be treated for a concession renewal. One has also to study possible new uses at the time of renewal or anticipate new uses during the course of the new concession. Most of the concessions of the large storage schemes in Switzerland end in the 2030's or 2040's. At this time the disposition of the renewed concession are negotiated. The old limits of the concession are open to be revised. But new restrictions mean also less value for a utility operating the plant. In Switzerland at the end of a concession, the works are to be returned to the concession-issuing community. However, usually the community declines to take over the works against the payment of a significant sum. If we stick to the example to flood preventing measures, e.g. lowering the level when a flood is forecasted. If those measures are integrated into the concession without compensation, the operator will reduce accordingly the sum he is willing to pay for the new concession and add a margin for the uncertainty of his estimate of the frequency of such ordered reservoir releases. For uses, whose extent and frequency is difficult to estimate it might, therefore, be better to follow a model in which single events are compensated. On the other hand uses, like irrigation and drinking water that are more predictable would better fit into a participation model. By direct participation, interests of different stakeholders can better be integrated and the risks are shared more evenly.

In conclusion we can state that there exist different ways to integrate multiple uses in one reservoir in Switzerland. One has to distinguish, whether it is done in the course of an ongoing concession contract or with a new constructed reservoir respectively at the concession renewal. For ongoing concessions contractual solutions have to be found. These solutions should ensure a rational use of the reservoir and may also be a model for new multipurpose reservoirs. In addition to the contractual solutions a major challenge is the identification of potential stakeholders and the clarification if there is really a need for a multipurpose reservoir. A single use reservoir is usually easier to manage for the operator but sharing risks over the long duration of a concession contract has advantages, too.

3 Germany

Germany's water reservoirs are existing since decades. Some of the largest (with respect to the reservoir capacity) multi-purpose reservoirs – among them Sylvenstein Dam and the Forggensee/Rosshaupten Dam in Bavaria, the Möhne Dam in North Rhine Westphalia, the Eder(see) Dam in the federal state of Hesse or the cascade of the Saale river (Bleiloch and Hohenwarte Dams) in Thuringia or the Rappbode Dam (Saxonia-Anhalt), have been built in the first half respectively the 50ies of the last century. The Möhne reservoir dam was at its erection in 1913 Europe's largest dam.

3.1 Historical Development

Many of the around 200 German multi-purpose reservoirs, each with a storage capacity of at least 1 million m^3 served from the beginning as multi-purpose reservoirs and were designed and operated accordingly. In other cases, the original purpose (e.g., power generation or flood protection) has been modified following the (industrial) development or natural disasters, in particular floods, within the nearer or greater surroundings of the dam. Additional purposes have been added and, if necessary, the structure of the dam modified.

3.2 Current Situation and Legal Framework

3.2.1 Multi-purpose projects and stakeholders

The purposes of the existing German multi – purpose dams are

- Flood protection
- Hydropower generation
- Water supply for drinking water
- Supply of process water for the industry
- In some cases, water supply for irrigation
- Raising low water levels (“Niedrigwasseraufhöhung”, “NWA”) in the river (basin) downstream of the dam to e.g., either assure the navigation or the use of the water by smaller downstream power plants and industries requiring process water or to protect to flora of the riverbed by diluting the existing water in the downstream river impacted by the release of wastewater from downstream cities or industrial activities.
- This purpose exists apart from the always requested (ecological) residual water flows.

At last, but increasingly considered are the recreational opportunities and in particular the interests of the neighbouring communities to offer those opportunities to local people and tourists.

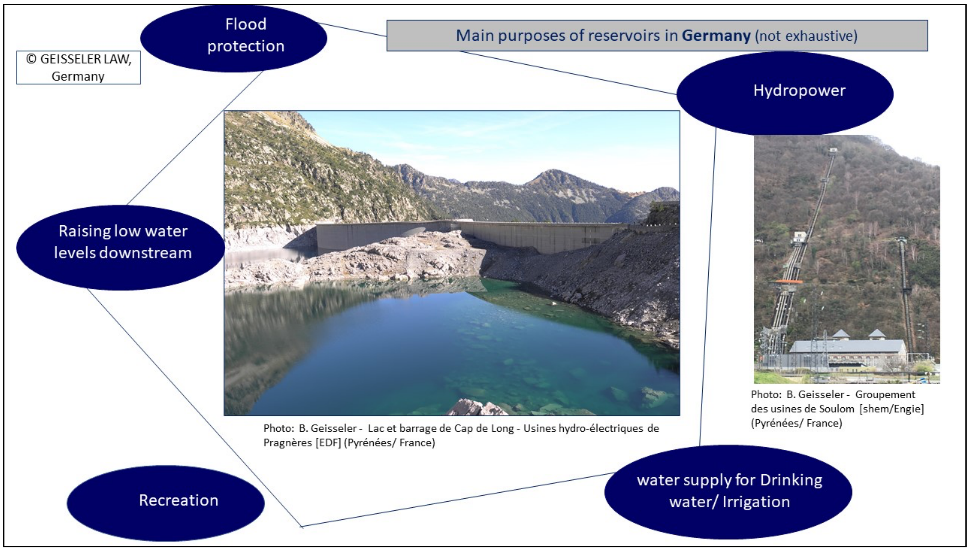


Fig. 2. “The magic pentagon”: multi – purposes of reservoirs in Germany.

Most of the dams with water reservoirs with a storage capacity above 1 million m^3 are owned by one of Germany's federal states, their state agencies or their state-owned companies.

Another type of owners, in particular in North Rhine Westphalia, are special purpose corporations under public law ("öffentlich-rechtliche Körperschaften"), whose purpose is the water management of the reservoir and the water supply to third parties. Those corporations are usually based on special purpose laws incorporating these corporations. Their members are either cities, municipalities, districts and private companies or the industry located downstream, which benefit from the water supply. Examples are the *Aggerverband* operating the Agger reservoir or the *Ruhrverband*, which operates the Möhne Dam and reservoir.
Only a few among the large (as mentioned) reservoirs in Germany are owned by private companies, primarily serving the hydropower generation.

It should be noted that dam owners and owners of hydropower plants using the stored water and being located either directly at the bottom of the dam or further downstream sometimes are legally separate entities. Hydropower plant owners and operators are often private companies whereas the dam is owned and operated by one of the federal states or another public legal entity.

In this respect, a potential negative impact arising from a conflict between different stakeholders of a multi-purpose dam is likely to be shifted from the dam owner to the power plant owner and operator.

When talking of multi-purpose and potential conflicts and discussing how to balance the different interests of the various stakeholders the question is: who are – apart from the environmental aspects to be considered - the potentially affected parties and their legitimate interests and who the beneficiaries of those multi–purpose reservoirs are. The stakeholders can be divided into the following categories, even though the categories cannot always be clearly distinguished:

1. The users of the multi–purpose water *reservoir* in a wider sense. That means those parties benefitting from the flexibility of a reservoir allowing either to store and withhold the water or to release the water in cases of climate situations where without a water release out of the dam those parties could not exercise their activities.

   The first case concerns flood protection, which is the state's original duty. The state uses the storage capacity to fulfil its responsibilities. The second case applies to cases, in which third parties relying on a minimum water flow in a river in which the dam is erected, such as fishers or navigation, benefit from the water release. Compared to the situation without a dam, the dam operation may allow them to exercise their activities which they could not otherwise perform without the water release from the reservoir.

2. The users of the *water*. These are often the cities or companies in need of drinking or process water. Also, these are the hydropower plant owners in case the dams are designed for hydroelectricity.

   As it is sometimes true for the hydropower plant operators, generally speaking the owners of the dam and the users are often separate entities, which then usually requires the conclusion of adequate water supply contracts between the dam owner and the user. In case of the abovementioned special purpose corporations owning and operating a dam the users such as the cities requiring water supply, or the power plant owners are often members of the corporations. There membership fee is calculated by considering the volume of supplied water.

3. Third parties whose interests should be considered when the construction/ erection of a dam as such and later on its operation might have a (negative) impact on their legitimate interests, protected by law. The same applies to all sorts of environmental concerns.

   These parties might be persons owning property which will be affected by the dam or it might be the environmental aspects of an ecological system as protected by law.

4. Further interested parties, who *indirectly* can be benefit from a dam and a reservoir and who's benefit might be affected in case of a changing operation mode. These stakeholders are typically the neighbouring communities wishing to facilitate recreation activities for their inhabitants or tourists.

3.2.2 Current Practice: Operation Mode and Conflicting Interests

- Flood protection vs. hydro power generation

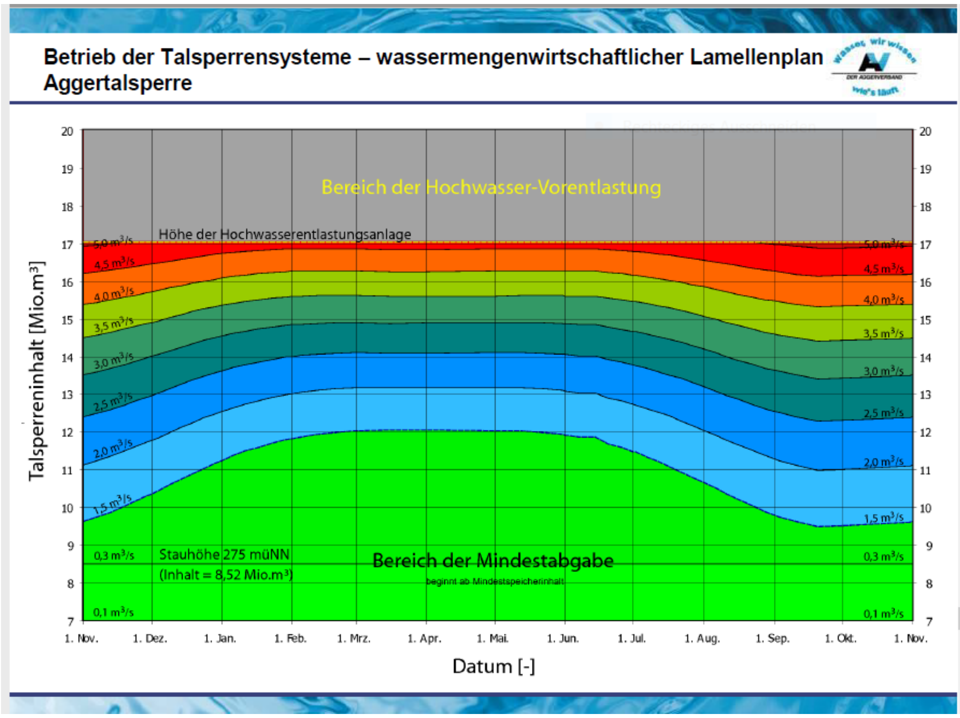
It is obvious that the flood protection water management will often conflict with the hydropower generation. Depending on the region – whether expected floods in winter or in summer are the critical issue - the following applies e.g., in case of winter floods expected: in the normal course of operation, the dam will likely have its lowest operation water level around the 1st of October of a given year in expectation of the floods coming in the winter/ spring following rainfall and snow melting.

In cases of unusual floods only predicted on short term in advance before they reach the reservoir the dam operator will be requested / obliged to urgently lower the water level in the reservoir. This means that the owner has to open the bottom outlet in order to evacuate the water to the extent possible. If this is not sufficient, the water will be evacuated via the spillways nearer the top of the reservoir.

Keeping the water in the reservoir at a rather low level respectively the urgent lowering of the water level to a relatively low level might conflict with the hydropower plant operator wishing to use to the extent possible a high headwater level. Even though the water will in many cases of urgent lowering pass through the turbines of the hydropower plant it might be at the wrong moment for power generation in view of volatile power market prices and even sometimes with negatives prices. In the worst-case scenario the water will be evacuated via the spillways, and is lost for the power production.

The operation of the dam is based on a so-called Water Management Plan ("Wasserwirtschaftlicher Betriebsplan"), which has to be submitted to the competent authority and will be approved by this authority. A good example of a part of such an operation plan is the so – called Lamellenplan (plan regarding different segments), used (among other operators) by the operator of the *Agger Dam* and reservoir, the *Aggerverband*. The Water Management Plan provides either for a so-called rigid water management or a dynamic water management. It might be divided into a summer and a winter plan. This plan provides for various situations such as predicted floods. The plan establishes the actions the dam operator then has to follow.

Table 1. "Lamellenplan" Aggertalsperre.



(© Aggerverband, with the courtesy of the Aggerverband)

The Lamellenplan above shows the operating modus for the normal situation. The graph above [17] defines different segments ("Lamellen") (starting with 1.5 m^3/sec up to 5m^3) and shows which volume has to be evacuated, depending on how the actual situation is (volume of water in the reservoir at a certain date). When on the other hand the expected inflow exceeds the available storage volume, the operator has to change into another operation mode ("Hochwasservorentlastungsplan"/ operation modus regarding the evacuation of water and lowering the water level in expectation of floods). When a particularly defined level is exceeded, the operator must inform the supervising authority which in case of emergency then can request that additional urgent measures to be undertaken.

The same conflict will appear, when the water level at a defined point downstream is above a defined level. To protect the downstream population, houses and industrial sites, the dam operator in those cases is requested to close all gates to reduce or stop any water discharge.

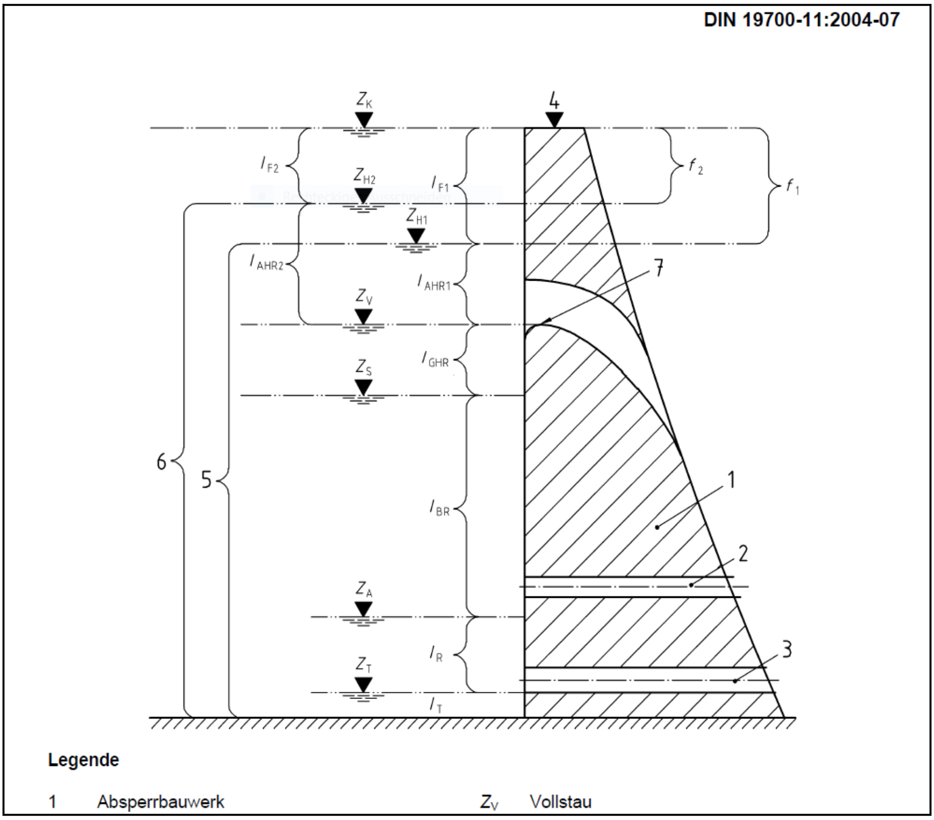
But when at a certain moment the predicted inflow volume at this situation will exceed the volume the reservoir can retain, e.g., in cases of continuing heavy rainfall, the operator might, regardless the already existing high water level downstream, want to change into the mode of urgently lowering the water level in the reservoir in order to avoid uncontrolled water outflow via the spillways and thus not endanger the stability of the dam.

- The definition of clearly attributed m^3 space in the reservoir

The German DIN norms 19700 – 10 and 19700 – 11 [18], which reflect the state of art requirement according to which the dams in Germany have to be constructed , erected and maintained, define the different storage spaces of a reservoir according to its type: (i) the usual operation storage space [I_{BR}], plus (ii) an additional flood storage capacity space, i.e.

the usual flood retention room [I_{GHR}] as well as (iii) a retention potential for unusual events in case of the design flood BHQ_1 [I_{AHR1}] respectively design flood BHQ_2 [I_{AHR2}], [5] and [6] being the total storage capacity in case of the design floods BHQ_1 respectively BHQ_2 .

Table 2. DIN 19700-11, clause 4.4.: storage spaces and water level targets.



These data are specifically defined for each reservoir and are an integrated part of the construction and erection permit. The permit will define the highest and the lowest water level for the normal operation.

- Raising the water level downstream (“NWA”), volume of residual water remaining in the riverbed versus water supply

A similar conflict can occur in the case of a reservoir primarily serving at the raw water supply for drinking water, but at the same time the providing NWA and as well as flood protection, and perhaps hydropower generation. An example is the Eibenstock reservoir in Saxony, mainly serving the raw water supply for drinking water.

If e.g., the water level/ discharge per sec. downstream at a given location falls below the defined level, the operator will have to comply with the Water Management Plan, which in these cases obliges the operator to increase the water release from the dam into the river downstream. If in a period of long-lasting drought, the remaining water level in the reservoir will further drop down provoking the conflict among different users/ needs, the Water Management Plan might provide for the option to lower the otherwise required volume to be released into the downstream water to satisfy the needs of the off-takers for the (raw) drinking water. If the water shortage situation is extremely severe the operator might come to the position where informing the contractual partners and the supervising authority that only 80% of the agreed volume of raw water can be provided for the drinking water supply will be required.

- Recreation vs. flood protection or “NWA” (raising the water level downstream) vs. hydropower generation

An example for the increasing importance of aspects of recreation is the Edersee in the federal state of Hesse. The erection of the dam owned and operated by an agency of the Federal Republic of Germany (not by one of the federal states; rather exceptionally) was completed in 1914. It is the third biggest reservoir in Germany when considering storage capacity. Its primary purpose was to raise the water level downstream in the river Weser and then the Mittellandkanal, so that commercial vessels could navigate from the Ruhr area with its heavy industry up to Berlin. Additionally, it serves the flood protection and the hydropower generation. The power plant at the base of the dam is owned by a privately owned large company. It is agreed that the reservoir & dam operator will inform the hydropower plant operator on a week’s / days’ ahead basis about the volume of water which can be released and allocated for the power plant’s use. Within these limits, in particular for the hours to come, the operator of the power plant is flexible in deciding to which extent to use the water available.

Over the years the tourism has become more and more important with leisure boats circulating on the reservoir and the creation of a national park in the nearer surroundings.

In order to satisfy the various needs of the different stakeholders and in particular to consider the wishes of the tourism, the supervising authority started to define exemptions from the water release requirements, i.e., in case that the downstream level sinks below a defined level. At the same time researchers from the University of Kassel were asked to develop a tool allowing the reservoir owner and the supervising authorities to forecast the weather and thus monitor the water release more precisely. The tool went into operation in 2016 [19]. Last year (2019) the supervising authority invited all interested parties to find a balance between the different interests. The result of this conference was an agreed-upon trial operation of 5 years (2019 – 2024) with an optimized trigger – line. In the winter period the authority agreed to switch to a water saving mode and reduce the required water release into the downstream riverbed from 6 to 4 m3/ sec, in case the water level downstream falls under the originally defined level. If on the other hand in the summer months, when ideally the reservoir should be filled up to the maximum level, the storage water in the reservoir falls below 175 million m3, the water release is triggered by an adjusted water level at Hannoversch Münden (downstream), which is defined as 1.15 m instead of originally 1.20 m [20].

Another example of the potentially conflicting interests, which have to be balanced is the cascade of 7 reservoirs (with the reservoir Bleiloch at the head being Germany’s biggest reservoir in terms of storage capacity) at the river Saale in Thuringia, operated by Vattenfall [21].

3.2.3 The legal framework for the erection and operation of a dam; cases of monetary compensation

Water Acts have a long tradition in all of the federal states of Germany: each federal state has/ had its own Water Act. Only in 2009, when the Federal Republic of Germany’s legislator completely revised and re-issued the Water Resources Act (“Wasserhaushaltsgesetz”/

“WHG”) [22], which came into force in 2010, a unified water law came into force in the Federal Republic of Germany. Until then, this Water Act had only been a framework legislation. The concurrent water laws of the different federal states which existed long-time before the revision of the WHG remain in force but might have to be adapted to the new legislation of the federation. Only as far as the Water Resources Act does not regulate a certain aspect, this aspect can be governed by the water laws of the federal states.

According to § 36(2) of this Act dams are to be designed, planned, built and operated according to the generally accepted technical rules and standards (the “state of the art” requirement), and if already erected dams do not fulfil this specification, they have to be rehabilitated accordingly.

In Germany, DIN 19700 with its different parts (e.g., DIN 19700-10 and 11) is considered to be the generally accepted technical rule and standard. Unlike the former regulations of the federal states’ Water Acts, DIN 19700 applies to any dam regardless its height/ storage volume and/or classification. These norms contain detailed provisions regarding the management of the water reservoir by the above – mentioned Water Management Plans (see Fig.2.)

§ 8 of the WHG (respectively the still existing provisions of the state Water Acts) requires a state permit for the erection of a dam with a reservoir, as this activity is considered to be a use of the resource water. This single permit is granted in a concentrated administrative procedure in which all legitimate aspects and stakeholders’ interests, which, according to the law, have to be considered. These aspects, such as the Environmental Impact Assessment, are taken into account. Dams and reservoirs owners with obligation towards other “stakeholders” using their water based on (partially very) old so- called legacy rights have the possibility to apply for one new permit incorporating all these ancient rights.

It should be noted that apart from specific situations in relation to the EU Water Framework Directive and mainly relating to the water supply for drinking water and the wastewater disposal or regulations in some federal states (e.g., in some cases in Bavaria), the “use of water” by operating a dam or a hydropower plant is not submitted to the obligation to pay a regular fee such as a concession fee known in other states.

The issuing of the permit is within the “due discretion” (§ 12) of the issuing state authority, which means that once the legal prerequisites for granting the permit are fulfilled the authority has, nevertheless, a certain margin of discretion to weight the different legitimate interests which have to be considered by law. A specific volume of water (to be put at the applicant’s disposal) is explicitly not guaranteed (§ 10).

§ 36 WHG is the legal basis for the various conditions to be complied with by the reservoir operator. Example: an integrated part of the state permit is the Water Management Plan according to cl. 9 of DIN 19700 - 11, which provides for different situations (e.g., summer – winter operation). It defines the maximum water level (in normal operation) and thus the space reserved for retaining of floods and defines the water level at the beginning of the winter as well as the overall minimum water level.

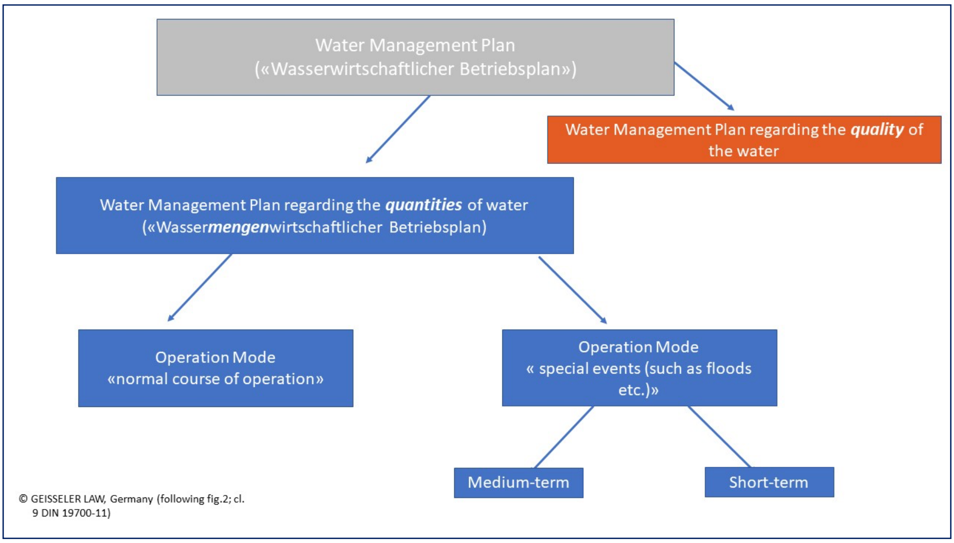


Fig. 3. Water Management Plan scheme according to cl. 9 of DIN 19700 – 11.

The primary purpose of the permit is to guarantee the absence of negative impacts for the overall water regime and to ensure an intact hydrological balance of the river basin is achieved. In cases of multi-purpose reservoirs, it determines exactly the obligations of the reservoir operator in different situations.

As mentioned, it is up to the state authority to consider – and balance – the legitimate interests of all users and stakeholders concerned. One can say that the permit and the integrated Water Management Plans pre - defines, in particular in respect of emergency situations, not only the operation modi, but as well the priority in case of potential conflicts, e.g., 1. flood protection; 2. Niedrigwasseraufhöhung "NWA" (raising the water level downstream); 3. Hydropower generation. Only within those limits the operator has flexibility regarding how to operate the reservoir.

Furthermore, this norm allows the supervising authority in defined cases to even give daily operation instructions to the operator. The operator not complying with those instructions risks receiving a fine. From a purely legal point of view, it should be discussed who has to assume the liability in case those instructions lead to a consequence for which the dam operator would be held liable, if he had taken that decision on his own initiative.

There is no doubt, that flood protection is not only a legitimate interest, but a task, for which the state is responsible. Flood protection is explicitly mentioned in §§ 72 ff WHG. From a monetary point of view, it seems to be standard that in cases where a federal state is – via an agency or a wholly owned company - owner of a reservoir serving at the same time the hydropower generation and the flood protection, the later one being within the state's primary responsibility, the reservoir owner receives a monetary compensation from the state for reserving storage capacity which can be used as flood protection. To the authors' best knowledge, a private owner (company) operating a reservoir for primarily hydropower generation does not receive any monetary compensation from the state, if he has to operate the reservoir in a mode to protect people and property against floods, but with the effect, that he generates less income as a consequence of the specific operating modus leading to a loss of available water for the hydropower generation.

Under German administrative law the permit to erect a dam and operate a reservoir can – as any other permit – unilaterally be modified in cases of legitimate state interests.

This was – apparently - the case after a major flood event in 2005, when the competent authority modified the water permit for the Forggensee reservoir in Bavaria, which is the head reservoir for the river Lech. Originally built for hydropower generation, its important role nowadays is the protection of the area downstream, e.g., the city of Augsburg. The modified water permit allows the state authority to intervene in case of forecasted major flood events and request from the reservoir operator to urgently lower the water level and extent the reserve space for retaining the floods, the “Vorabsenkung” [23]. It is obvious that this could have an impact in the hydropower generation.

On the other hand, the operator of a reservoir might apply for a modification, e.g., the reduction of the retention room for potential floods, in order to be more flexible in respect to future raw water supply for an increasing population relying on the water supply from the reservoir.

Regarding the need of the tourism and consideration of recreation activities while operating the reservoir, this is sometimes already part of the state permit and will then not be compensated. There are few cases in Germany where the owner and operator of a dam has concluded a Letter of Intent as sort of pre- contractual agreement with the neighbouring communities of the reservoir. Theoretically such a contract could provide for a monetary compensation e.g. in cases where the operator and at the same time owner of a hydropower plant would like to keep the reservoir at another water level than requested by tourism associations.

3.3 Lessons Learnt and Outlook for a Future Set-up

The last decades have shown that a special event such as a major flood event often triggered discussions and reflections on how better to balance the interests of the users and other stakeholders of a multi-purpose reservoir. It is common sense that a good communication between the operator of the reservoir and its supervising authority is as important as the dialogue with its contractual partners/ users and further stakeholders. The example of flood protection vs. hydropower generation shows how important tools are, which make the forecast more precise and reliable. Tools for a more precise weather forecast will give the reservoir operator more flexibility. They mitigate at the same time potential negative impacts for the operation of a connected hydropower plant due to a wrong forecast of an expected major flood event forcing the reservoir owner to urgently lower the water level which might have a considerable negative impact on the hydropower generation.

The example of flood protection vs. hydropower generation shows how important tools are, which make the forecast more precise and reliable. Tools for a more precise weather forecast will give the reservoir operator more flexibility. They mitigate at the same time potential negative impacts for the operation of a connected hydropower plant due to a wrong forecast of an expected major flood event forcing the reservoir owner to urgently lower the water level which might have a considerable negative impact on the hydropower generation.

On the other hand, the climate change and the increasingly dry summer seasons are particularly challenging for reservoir operators, in particular in case of reservoirs serving among other purposes the water supply for drinking water.

The main public corporations owning reservoirs in the state of North Rhine Westphalia and the state agency for dams and reservoirs of the federal state of Saxony as well as the state agency for nature, environment and consumer protection of North Rhine Westphalia and some other cooperation partners decided to initiate a research project, receiving funds from the Federal Republic of Germany, called T(alsperren) A(npassungs) S(trategie) K(limawandel) (‘adaptation strategies for reservoirs in view of the climate change’) [24]. The research project is intended to develop strategies for reservoirs enabling the operator to better adapt to changing climate situations and thus to better predict the volume of water to be released / supplied respectively retained. The owners and operators then will be put into the position to evaluate the weather situations and the available (dry weather) or extensive water (expected floods) more precisely. This will enable them to better face potential conflicts of the different users / stakeholders of the reservoir and mitigate those conflicts.

The project plans to identify appropriate (e.g. weather) indices and develop forecasting models allowing to predict the rainfall for a period up to 24 months. This will allow a better evaluation of the coming climate situation and result in operation concepts being more flexible and giving the operator the chance to find a dynamic response to climate changes instead of being obliged to comply with rather rigid Water Management Plans as before. An example: the Aggerverband [25] informed stakeholders at the beginning of 2020 that it intends to modify its Water Management Plans (with the approval of the competent authority) by adding a Plan for low water levels in the reservoir and by taking into account weather predictions according to the TASK principles.

4 Summary and Recommendations

Balancing the interests and needs of the users and stakeholders of multi-purpose reservoirs is a challenging task. Solving potential conflicts in the use of water reservoirs in Germany is well established and functions in a given legal framework complemented by the proven DIN norms and operating plans which are commonly accepted since decades. Ad hoc discussions and negotiations on compensation issues for loss of opportunity to generate income from hydropower generation as consequence of operational decisions to provide “protection against floods” instead of generating power do not take place.

This is different in Switzerland where the main use of the reservoirs is hydropower generation and the integration of new purposes during an ongoing concession is mostly done by negotiation. This approach leads also to a practice of valuation of the reservoir use for different purposes, which helps to find the adequate assignment of risk and compensation.

Though the legal framework for a reservoir’s operation seems to be quite different in Switzerland and Germany, a good communication between the parties concerned and a transparent process to find a balance between conflicting interests is essential. Climate changes will aggravate potential conflicts. In view of scientific models that provide a more precise weather forecast, there is an increasing trend in both countries that operators of multi-purpose reservoirs can react in a more flexible way instead of using rigid operating plans. This might help to mitigate potential conflicts.

Acknowledgements

The author ad 2 would like to thank the following named persons and representatives of ministries, institutions, agencies. Without their willingness and patience to explain and discuss with the author the current dam operation practise in Germany this article could not have been written:

- The former and current members of the Executive Committee of the Deutsches TalsperrenKomitee e.V. (national German Committee on large dams) and its General Secretary: Dr. Sieber, Dr. Müller, Prof. Scheuer, Prof. Godde, Dipl.-Ing. Popp.
- Some representatives of the Landestalsperrenverwaltungen of Sachsen and Sachsen-Anhalt

- Some representatives of the Aggerverband and privately owned companies owning and operating dams
- And namely the following persons: Mrs. Dietze, MM Apel, Ernst, Eichhorn, Rudolf, Kleber-Lerchbaumer, and in particular MM. Klopsch and Zobel.

References

1. S. Amaral, Experimental characterization of the failure by overtopping of embankment dams, IST Press, December 2017 (374 pages.) – PhD Thesis (2017)

   S. Amaral, S. Valente, M.T. Viseu, R.M.L. Ferreira, Historical framework on dams, *General history of ancient dams, largest and historic failures of embankment dams* (2020)
2. E. Branche, EDF – WWC "Multipurpose uses of hydropower reservoirs" (2015)
3. SFOE, Schweizerische Elektrizitätsstatistik 2019, Berne (2020) https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/elektrizitaetsstatistik.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTAxMTI=.html
4. R. Weingartner, Wasser Energie Luft 108 (4), 273-275 (2016)
5. W.K. Thut, R. Weingartner, B. Schädler, Wasser Energie Luft 108 (3), 187-194 (2016)
6. E. Kellner, R. Weingartner, Wasser Energie Luft 110 (2), 101-107 (2018)
7. P. Mani, C. Berger, U. Caduff, E. Schönthal, Multifunktionsspeicher im Oberhasli, Berne (2017) https://www.bve.be.ch/bve/de/index/direktion/organisation/awa/formulare_bewilligungen/wasserkraft.assetref/dam/documents/BVE/AWA/de/WASSER/Wasserkraft/BE01k_map%2C%20MultifunktionsbeckenOberhasli.pdf
8. P. Mani, J. Monney, B. Wehren, B. Schwegler, Wasser Energie Luft 110 (2), 113-118 (2018)
9. P.F. Roth, Mehrzwecknutzung von Grosswasserkraftwerken im Kanton Graubünden heute und in Zukunft, Master Thesis, Zurich (2019) https://www.slf.ch/fileadmin/user_upload/WSL/Ueber_die_WSL/Forschungsprogramme_Initiativen/Energy_Chance_Impact/PhilippeRoth_MA_Final.pdf
10. E. Reynard, M. Bonriposi, Water Use Management in Dry Mountains of Switzerland. The Case of Crans-Montana-Sierre Area, in M. Neményi, B. Heil, The Impact of Urbanization, Industrial, Agricultural and Forest Technologies on the Natural Environment, 281-301, Sopron, Hungary (2012)
11. L. Jossen, A. Björnsen Gurung, Wasser Energie Luft 110 (2), 108-112 (2018)
12. B. Sander, P. Haefliger, Wasser Energie Luft 93 (7/8), 169-174 (2001)
13. R. Biedermann, H. Pougatsch, G. Darbre, P.-B. Raboud, C. Fux, B. Hagin, B. Sander, Wasser Energie Luft 88 (10), 221-266 (1996)
14. B. Sander, P. Haefliger, Wasser Energie Luft 95 (9/10), 303-305 (2003)
15. J. Garcia Hernández, A. Claude, J. Paredes Arquiola, B. Roquier, J.-L. Boillat, Integrated flood forecasting and management system in a complex catchment area in the Alps—implementation of the MINERVE project in the Canton of Valais, in A. Schleiss, J. Speerli, R. PfammatterSwiss Competences in River Engineering and Restoration, 87-97, London (2014)

16. D. Ehrbar, L. Schmocker, D. Vetsch, R.M. Boes, Hydropower Potential in the Periglacial Environment of Switzerland under Climate Change, Sustainability 10 (8), 2794 (2018)
17. Prof. Dr. Lothar Scheuer, Kooperation von Kommunen und Wasserverbänden bei der Maßnahmenumsetzung – Beispiele, in : proceedings of the HWRM-Symposium 2016, organised by the Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz NRW (North Rhine Westfalia) et.alia (2016) https://www.flussgebiete.nrw.de/hwrm-symposium-2016-6980
18. DIN (Deutsche Norm) 19700 (revision 2004), and its parts 10 (DIN 19700-10) : "Dams plants – Part 10: General specifications" respectively part 11 (DIN 19700-11): "Dam plants – Dams", July 2004; https://www.beuth.de/de/norm/din-19700-11/72497593 (2014)
19. Cf as well: A. Rötz, S. Theobald, Model-Based Operation of Multi-Purpose River and Reservoir Systems, in «Water Resources Management", 15/2019 (2019)
20. "Wasserstand Edersee" http://wasserstand.edersee.de/
21. https://group.vattenfall.com/de/siteassets/de/energie/wasser/uebersichtskarte_obere_saale.pdf
22. Gesetz zur Ordnung des Wasserhaushalts (Wasserhaushaltsgesetz - WHG), 31.7 (2009) https://www.gesetze-im-internet.de/whg_2009/
23. https://www.wwa-ke.bayern.de/fluesse_seen/gewaesserportraits/forggensee/hochwasserschutz/index.htm
24. https://task.sydro.de/
25. https://www.aggerverband.de/service/presse/artikel/anpassung-der-betriebsplaene-der-talsperren-an-den-klimawandel