

Integrating a dam on a territory with multiple reservoirs

Intégrer un barrage sur un territoire avec plusieurs réservoirs

Özge Türk^{1*}, and Necdet Türk²

¹PhD candidate at Public International Law Department, University of Geneva, Switzerland

²Emeritus Professor, Geological Engineering Department, Dokuz Eylul University, Izmir, Turkey

Abstract. Water has been a vital resource for the continuity of life. This is why states are trying to ensure water security for their citizens by building water infrastructures on their rivers. It is important to consider the purpose of the dam when planning it, especially when the dam is to be built on a territory where multiple reservoirs exist. Hydropower dams are convenient choices in many conditions as they cause very small water loss in the basin. They can be integrated into multiple basins without causing many problems. They only cause water loss during the infilling of their reservoirs. Once the reservoir is filled with water, the water flow in the basin will be as it was before. However, compensation might be paid for the period of water filling to the downstream states or other dam owners. Before constructing a dam, economic, social, environmental and cultural impacts that the dam will create should also be examined. Also, the responsible should make sure that the dam is not planned on tectonically active zones. Another important issue building a dam in a multiple reservoir terrain causes induce earthquakes. Reservoir induced earthquakes are regarded as natural disasters in most countries.

Résumé. L'eau est une ressource vitale pour la continuité de la vie. C'est pourquoi les États tentent d'assurer la sécurité de l'eau pour leurs citoyens en construisant des infrastructures hydrauliques sur leurs rivières. Il est important de considérer l'objectif du barrage lors de sa planification, en particulier lorsque le barrage sera construit sur un territoire où il y a plusieurs réservoirs. Les barrages hydroélectriques sont des choix pratiques dans de nombreuses situations, car ils entraînent de très faibles pertes d'eau et peuvent être intégrés dans plusieurs bassins sans causer beaucoup de problèmes. En effet, ils ne provoquent des pertes d'eau que lors du remplissage de leurs réservoirs. Une fois ce dernier rempli, l'écoulement de l'eau dans le bassin reste tel qu'il l'a été avant la construction du barrage. Cependant, une compensation pourrait être versée pour la période de

* Corresponding author: ozge.turk93@gmail.com

remplissage d'eau aux États en aval ou à d'autres propriétaires de barrages. Néanmoins lorsque qu'un projet de barrage est envisagé, il est important d'examiner et de prendre en compte les impacts économiques, sociaux, environnementaux et culturels que ce dernier pourrait engendrer. De plus, il faut s'assurer que le barrage n'est pas planifié sur des zones tectoniques actives. En effet, la construction d'un barrage sur un terrain à réservoirs multiples peut aussi provoquer des tremblements de terre, considérés, dans la plupart des pays, comme des catastrophes naturelles sans lien avec les nouvelles structures.

1 Introduction

Technological developments and population growth have increased the water need of states. Besides, climate change threatens water quantity available for use in different parts of the world as it is expected to lead to changes in precipitations. [1] Nonetheless, States require dams more and more to provide water, food, and energy security to their inhabitants. [2] To provide the water needed to their residents, states have different approaches such as desalinizing the seawater or utilizing the groundwater. However, the most common and preferred method is constructing dams on rivers which is less costly and more sustainable in the long run when compared to other methods.

A well-planned dam might be very beneficial as it may respond to several needs at once. However, trying to place a dam on a river that already has multiple reservoirs might be problematic as it may disturb the existing system if not well planned. It might have several positive and negative economic, social, environmental, and cultural impacts on the area, people, and the environment. If the dam to be built will be located on a river that stays in the national borders of one state, it is easier to plan, construct and operate. Nevertheless, a new dam on a transboundary river might change the water share of the states or how they share the benefit obtained from the river which may cause disputes between riparian states.

A dam constructed by an upstream state might disturb the downstream riparian state regarding the downstream water availability and might empower the upstream state as the state will have control of the water flow. Dam construction by the downstream riparian might also have negative impacts on the environment and might limit the future water rights of upstream states. Besides, political reasons might lead states to contest the construction of a new dam on a watercourse with multiple reservoirs. It is important to consider possible impacts of a new dam not only to avoid the conflict in-between the riparian states but also not to devastate the hydrologic system that is created in time by multiple reservoirs.

This article aims at setting forth main points to be considered when constructing a dam on a territory where multiple reservoirs already exist. Although dams are planned considering the dam site and dam type, there are other features as well. This article examines various impacts of the dams on people and on the environment and legal aspects that should be considered before, during and after the dam is constructed on a territory where several dams already exist in addition to the dam and dam site features.

This article suggests that integration of a hydropower dam could be easier on a territory with multiple reservoirs when compared with other dams. The proposal is based on the fact that hydropower dams do not intend for water consumption. As they only utilize water for energy production and give it back to the river, they maintain the river water quantity the same as before they were constructed except for the impoundment period.

2 Different purposes for dam construction

Natural resources, including water, are getting scarcer. Besides, the population growth has increased the consumption of water, food and energy. [2] The data indicates that this increase will continue in the future. [2] States are responsible for providing water, food and energy to their residents as part of their security. Water security is an essential aspect of security as it is a vital source for the continuity of life and as it is related to food and energy security. Thus, states should provide water in good quality and quantity in a sustainable way. To render water available and accessible regularly, states construct dams on their rivers. However, there are different type of dams that should be considered when constructing a dam on a river.

The size, the material used, the dam site, the purpose of the dam should be considered when constructing a dam. Dams are generally categorized as small and large dams according to their size. The dam size depends on why the dam is constructed, needs of the population and expectations from the dam. Besides, when constructing a dam, mostly material that is easily accessible around the construction area is used as it becomes more economic and easier to collect the material. [3] Engineers need to consider the topography of the catchment area, the morphology of the river and the geological features of the dam site.

Finally, the purpose of the dam should be considered when planning a new dam. Dams are usually constructed for irrigation, water supply, hydropower, flood control and inland navigation purposes. [4] Navigation will not be explained in this paper as other purposes step forward. A dam may serve multiple purposes. [5] While multipurpose dams respond to two or more needs, they are more difficult to construct as they need more technical expertise and specialization. The choice of the type of dam depends, therefore, on why the dam is needed.

The map Chen, Shi, Sivakumar & Peart prepared using the GRanD database shows the distribution of large dams higher than 10m in the world and their percentage according to their purpose. [6] According to the map, 39% of the large dams are hydropower dams, followed by the irrigation dams with 29%. [7] These statistics indicate that 68% of 2815 large dams are irrigation and hydropower dams, illustrating that hydropower and irrigation have been the main concerns of states when constructing large dams [7].

Dams have an important role in agricultural production. Together with the growing population, the food demand and agricultural production have increased thus the irrigated area needed to be expended. [2,4] Irrigation consumes the most water, especially in the least developed countries. [8] Besides, climate change is predicted to force people to increase the water quantity used for irrigation and the amount of land to be irrigated as the evaporation is expected to be higher in some parts of the world. [9] Irrigation is vital to provide food security which can be defined as “guaranteeing that consumers are reasonably certain of being able to eat properly”. [10] States do not want to depend on other states for food. Where the dependence is inevitable, states prefer to minimise this dependence as much as possible. Therefore, they are eager to develop dam projects which can help with water management and guarantee their inhabitant’s food security. [2] This increases water needed for agricultural production. Thus, even with the developing technology, water need for agricultural production is expected to increase in parallel with the need for dams.[4]

Energy production is another purpose for dam construction. The main aim of hydropower dams is energy production. They store the water and after having used it in the tribunes to produce energy, give it back to the river. Hydropower dams produce 24% of world’s electricity and 90% of the world’s renewable energy. [4] When different ways of energy production are examined, hydropower steps forward in certain ways. It is a “clean, low-cost, renewable” energy which makes hydropower an attractive energy source for states. [11] Besides, the amount of energy produced can be arranged through the hydropower dams. [12] This prevents energy loss and helps to increase the amount when needed. Hydropower is

highly related to the country's energy security. [13] However, hydropower dams, when compared with irrigation and water supply dams, require more funding and know-how. [14]

Supplying water for household and industrial production is another water-consuming activity. As precipitation fluctuates through seasons and years, dams serve to reserve water for drier times and provide it as much as and when needed. [15] Also, for industrial production, states need to provide water and energy which lead them to build a dam if there is a suitable river near the industrial area. States run national [16] or international water projects [17,18] that include the construction of several dams to increase their industrial production by supplying water and energy thanks to new dams constructed.

Flood control is another purpose to construct dams. Floods are the world's highest damaging natural disasters. [11] Together with high precipitations and melting snow when water increases to an amount that the soil cannot absorb, it starts to destroy all living and non-living creators. [15] Dams help to prevent destruction and possible material losses. Dams made for flood control release water when there is a drought or when the water flow drops under the expected amount. [4] Together with climate change, precipitations are expected to change in different parts of the world as more destructive and frequent floods are predicted in some parts. [19] Thus, dams are expected to gain importance as the water flow will naturally be deregulated in the future [20].

It is very important and vital for states to control, use and manage their water resources especially their transboundary rivers. The use and management of shared waters might easily raise tensions and cause disputes among states as happened in the past. [21] That's why a new dam on a territory with multiple reservoirs must be seriously evaluated.

The basin is a closed system. Hence, water quantity of the system has high importance especially for downstream states as the water flow and quality might decrease from the upstream state water usage. Water consumption from the river by upstream states reduces the available water quantity for downstream states. Irrigation and water supply dams lead to water loss of the system as they are made to provide water for irrigation, household and industrial production purposes. The water that is taken out of the system for usage is not lost, however, as it leaves the system it becomes a loss for the downstream states and the downstream environment. [12] Hydropower dams, on the other hand, store water, use it to produce energy and give it back to the system [22] that maintains water quantity of the watercourse the same for downstream states.

3 Impacts of dams

Dams have several economic, environmental, cultural, and social impacts on the area. It is possible to foresee these impacts through the Environmental Impact Assessment (EIA) report which provides a pre-evaluation of the project on the possible future adverse effects of a dam on the area, people, and environment when the dam is still being planned. So, all riparian states will be aware of the possible damage and take precautions since the planning of the dam. For a new dam that will be built on a river with multiple reservoirs, EIA will help to understand the possible impacts on the watercourse and other dams located on the same river.

3.1 Environmental impacts of the dams:

Environmental impacts of dams are the most controversial ones. Their negative impacts such as the modification of the ecosystem and negative affecting the biodiversity, greenhouse gas emission, sedimentation, increase in evaporation step forward. [23] These impacts vary depending on the dam and environment. OECD mentioned the possibility to plan dams,

particularly multi-purpose water infrastructures, by preserving the biodiversity and helping the surrounding ecosystems to develop [24].

3.1.1 Dams may modify the ecosystem and negatively affect the biodiversity

Dams may modify the ecosystem which might have negative impacts on the habitat. They may render the river ecosystem more vulnerable and open to the invasion of other harmful species. [25] These new invasive species may develop, change the habitat, and lead the ecosystem to become unstable in the long term [25].

Dams damage the habitat and the landscape but might help to create a new one. [26] In time, the environment and the habitat adjust to the change caused by the new dam. This has both positive and negative aspects. Negative changes for some species might favour the development of other ones or new species. In Switzerland, construction of water infrastructures had negative impacts on some of the fish species, as they have made it difficult to migrate and reproduce which had positive impacts on the immigrant birds as these water infrastructures hosted them. [26] The opposite example was detected in New Zealand on the Waitaki River. As the dams built on the river helped to regulate the river flow, a type of salmon developed easily which was destructive for a bird kind in the habitat [27].

Deoxygenation is another negative impact which was seen in the Lake Kariba because of the Kariba dam built on the border between Zambia and Zimbabwe. [28] The lake was invaded by an invasive species causing harm to the other species of the lake ecosystem [28]. Hartebeespoort Dam in South Africa and Roodeplaat Dam near Pretoria have suffered from the blue-green algae, that releases toxins and decrease the oxygen level of the water. [28]

Dams may cause a change in water temperature which has vital importance for the aquatic ecosystems. An unexpected change might modify the ecosystem. [29] Besides, water-related industries such as fishery would be negatively affected in such a case. [29] For instance, the release of water from the base of the dam may lead to a decrease in the water temperature leading to a decline in the fish population as in the case of Colorado river [30].

Salinization of the soil because of irrigation and the high evaporation of the dam surface water is another problem. [31] As the water surface area increases, evaporation increases accordingly. However, water that evaporates goes back to the water cycle and does not disappear but only changes form. Besides, the quantity of water that evaporates is linked with where the dam is located. Even though the evaporation from the Aswan High Dam (AHD) is very high [32], because of the meteorological conditions and its location the evaporation from the Grand Ethiopian Renaissance Dam is expected to be much less when compared with AHD. [33] Besides, the desalinization of the land also has a price and may cost more than the dam itself as in the example of Aswan Dam in Egypt. [32] Also, the yield obtained from the salinized lands is almost half of what it has been before [34].

Any negative environmental impact of a new dam on a territory with multiple dams would affect the other dams and the downstream environment. Thus, it is important during the dam planning to consider the size of the landscape and the habitat that will be affected [28], to prepare an EIA report and to foresee any possible harm the new dam might cause.

3.1.2 Greenhouse gas emission

Dams are associated with increased greenhouse gas emission that stimulates the impacts of climate change. [35] Lakes also release greenhouse gases because of the decomposition of the organic materials [36], but dams are claimed to increase and accelerate that impact. As mostly there is not enough data on the situation before the dam construction, it is difficult to show precisely how much greenhouse gas a specific dam release. The World Commission on Dams (WCD) report mentioned that the amount of greenhouse gas dams release into the

atmosphere changes between 1% to 28%. [37] This interval is huge which shows the lack of research in the area. The amount of the gas released depends on several conditions including the climate of the dam area, the location of the dam and the size of the reservoir [37,38].

Besides, hydropower obtained from dams leads carbon-based energy resources to be used less. When compared with the CO₂ produced from the fuel or coal burning, large dams produce far less CO₂. [39] Thus, even though dams cause pollution by producing greenhouse gas emission, the decrease in fossil fuel burning would make a bigger difference for climate change. International Hydropower Association states that if coal was burned to compensate for energy obtained from the hydropower, more than 4 billion metric tonnes of greenhouse gases would be released into the atmosphere increasing the greenhouse gas released at least 10%. [39] Moreover, if well planned, the amount of greenhouse gas released from dams can be lowered down. [40] There are also projects to capture the methane gas in the dam before it is released into the atmosphere and to use it to produce electricity. [41] So, there are ways to use that gas in a way that would harm less the environment. Thus, the benefit obtained from the hydropower dams might be balanced with the harm they cause.

3.1.3 Sedimentation

Sediment that normally flows through the end of the river accumulates in the reservoir which decreases the reservoir capacity and affects both the dam operation and the downstream environment. [42] When the river is dammed more than once and no solution is sought to overcome the sedimentation problem, the accumulated sediment stays in the upstream dams which the downstream environment needs for the river ecology and morphology.[42] As sedimentation causes fertile land to cumulate in the dam, the agricultural yield might decrease in the downstream part of the river as happened in the Nile river [43].

Sedimentation might also modify the habitat and the vegetation of the river and the dam territory. [44] Sometimes the sedimentation in the dam changed the river ecology favouring one species to develop and other(s) to reduce severely or disappear. [45] It also threatens the sustainability of the river and reservoir. [46] Therefore, how to overcome the sedimentation should be planned as there are different methods to handle this problem depending on the hydrology of the river, location of the dam, geology and the topography of the dam land surface. [47] These methods are used on the rivers where a series of dams are built. [16,48]

Cooperation has high importance to manage the sedimentation of the dams in series especially when the dams are located on a transboundary watercourse and within the borders of different countries. [49] A good example of that is the Verbois Dam in Switzerland and the Genissiat Dam in France that are both on the Rhône River. Both states cooperate to flush the sediment from dams. [50] Data sharing and coordination between states are also important to resolve the sedimentation problem of dams built in series [49].

3.1.4 Sudden or Insufficient water release

The sudden release of water without giving prior notice to other riparian states or release of inadequate quantity of water also cause harm both to the downstream states and environment. The sudden release of water in great quantity without giving notice to downstream riparian states would prevent them to take precautions to protect their habitats and the environment. As this can be done on purpose [51], this might also happen because of an accident. [52] Nevertheless, insufficient water release can cause diplomatic problems between states. If a state's water share changes dramatically after a new dam is built by an upstream state on a territory that already was dammed, it probably will be a reason for dispute between states. Both situations can be avoided or at least be dealt with less damage through strengthening cooperation and dialogue between riparian states.

International water law has foreseen regulations against such intentional acts. The damage caused by not releasing sufficient water or by releasing excessive water on purpose is prohibited by Article 7 of the 1997 Convention on the Law of the Non-navigational Uses of International Watercourses (1997 UN Convention) [53] which aims to prevent a state to cause significant harm to other states. Besides, the damage to the environment is tried to be prevented through Article 20, 27 and 28 [53]. If the harm cannot be prevented, the 1997 UN Convention foresees any harm to another state and the environment to be compensated.

The international community has not yet agreed on a certain amount of water that should be released from dams. However, when states release water from a dam, they need to consider the water need of the downstream state and environment. Hydropower and flood control dams would prevent these problems from arising as they give water back to the basin.

3.2 Economic impacts:

Building a dam is costly. Especially large dams require an important amount of technical and economic resources. [54] States mostly request credit from international financial organizations to build large dams. Another possible option is the private sector contribution. [55] However, dams have positive economic impacts as they create jobs for people directly and indirectly. [56] They may also have positive impacts on the country's economy. Lesotho Highland Water Project is an interesting example where 4% of Lesotho's GDP and 10% of the government revenue is obtained from the water and hydropower sale to South Africa. [57] Bhutan has also increased its GDP thanks to the Chukha I and II hydro projects from the lowest to the second highest in South Asia [58].

Dams also increase agricultural and industrial production, generate hydropower, prevent floods, facilitate navigation, increase fishing, tourism and sport. [59] The additional water supplied by a dam helps to increase agricultural production and to produce crops that require more water just as rice and sugarcane. [60] Dams also help to increase industrial production as they provide water and energy for production leading to more water-consuming industries to develop. [61] This has positive impacts both on the household and state economy as they help to increase GDP and government revenues.

Hydropower is cheaper than the energy obtained from fossil fuels and thus is attractive for states. [62] Canada, Japan, Norway and the USA meet an important amount of their energy need from hydropower. [63] The developing BRICS (Brazil, Russia, India, China and South Africa) countries have been constructing large dams as part of their development to meet their growing energy need, to decrease the amount of energy bought from other states, to provide energy security for their countries and to sell the surplus energy [63].

Besides, dams prevent the destruction caused by a flood. For instance, in Switzerland, it is estimated that dams have prevented destruction equivalent of 120 million Euro per year from 1972 to 1996. [64] In 24 years, the dams in Switzerland helped to prevent damage equivalent to the cost of a large dam. [64] Thus, if well planned, dams are not as costly as they are thought of when their economic benefits are considered.

The economic impacts of the dams indicate overall that even though they are costly infrastructures, they contribute to the state budget and people's incomes in a considerable way. Therefore, states still tend to construct dams considering their economic return. In between different dam types, hydropower dams have more economical benefits. The WCD indicated that to compensate for construction and operation costs, irrigation dams are sometimes modified and equipped with the hydropower generators [59].

3.3 Social impacts:

Dams also have social impacts on society. The construction and operation of dams serve to provide jobs to people, to increase the household income and thus have positive impacts on certain parts of society. Still, when a dam project is planned in a residential area, states displace people residing in that area. Displacement causes important social problems such as loss of jobs, integration problems of displaced people to their new homes and jobs, integration problems of the indigenous people to their new living areas. As indigenous and tribal people have been living in the same area for centuries and they are highly integrated with their environment, in case of forced resettlement they get more affected than other people. Therefore, there are special regulations to reduce the negative impacts of the forced displacement on the indigenous and tribal people [65].

In any case, states should try to compensate for the loss people bear because of the forced displacement upon the national and international regulations. [66] The compensation might be monetary or in form of land. Also, states search for legal ownership of the land for people to have the right to seek compensation. There are examples where people could not obtain compensation as they were not the legal landowners of the place they have been living on just as some people living on Ilisu dam site [67] and some farmers living on the Sardar Sarovar dam area. [68] When people do not have legal ownership of the land or the house, states in most cases do not accept to compensate which puts these people into a difficult situation.

3.4 Cultural impacts:

As water is the most vital human need, the first civilizations have established around water resources. [69] Ruins of the first civilizations located by the Nile or Euphrates-Tigris rivers prove this behavior. [70] Therefore, dams constructed on or near cultural resources may cause damage or loss of cultural heritage in part or total. [71] The AHD sparked debate on measures to be taken when building a dam on a historical site leading an international effort to be made to protect the Nubian Monuments.[72] States were successful in saving cultural heritage which triggered the development of the UNESCO World Heritage Convention [72].

Especially after the Nubian Monuments, states pay more attention and evaluate whether there are cultural resources in the dam site area through impact assessment reports that include evaluations of “cultural and archaeological resources”. [71,73] However, there are still dams built without any pre-evaluation. [73] Cultural heritage should be evaluated during the planning of the dam to find out the possible future damage. After evaluation, some states decide to change the dam site to protect the cultural and archaeological heritage as happened with the Pak Mun dam in Thailand. [74] There are counterexamples as well. During the construction of both the Grand Coulee Dam in the USA and of the Inanda Dam in South Africa, the remains of the Indian graves were found. [73] Even though the Bureau of Reclamation removed some of the remains of the buried bodies [75], the South African constructors buried the remains in a hole all together which disturbed the native community. [71] Recently the impoundment of Ilisu dam caused flooding of cultural heritage. Although some of the cultural resources have been safeguarded, as Hasankeyf is a town carved into rocks, it was not possible to save the ancient city unless the dam site was changed [76]. Hence, when the dam site is chosen, cultural heritage should be considered as it can be protected or less damaged through detailed research and precautions.

4 The construction zone and reservoir induced earthquakes

Dams can be built on the active zones. This can be prevented through a prior study on the dam site. However, dams are generally built-in valleys, which is the uplifted area meaning that there has been a seismic activity on that area. [73] So, seismic activity is possible on dam sites as they are built on earthquake-prone areas.

Besides, construction of a dam may induce earthquakes in the dam site area. This is called “Reservoir Induced Seismicity” (RIS). Dr V. P Jauhari has stated that RIS is “related to the extra water pressure created in the micro-cracks and fissures in the ground under and near a reservoir. When the pressure of the water in the rocks increases, it acts to lubricate faults which are already under tectonic strain but are prevented from slipping by the friction of the rock surfaces.”. [77] The excess weight of the water that causes more stress on the area or the increase in the pressure of the groundwater pore that impacts the strength of the area under the reservoir, might cause seismic movements. [73] ICOLD has published “a list of frequently cited RTS cases” in its bulletin that the length of the list shows that reservoir induced seismicity is not a rare event. [78] Thus, it has to be considered when making calculations.

5 Legal and political aspects

States have sovereignty over their natural resources. This has been acknowledged in international law and emphasized in the Lake Lanoux Arbitration. [79] Damming rivers is also under state sovereignty. However, as the state sovereignty is not without limit, states need to consider some restrictions when they intend to build a dam. [80] They should not block water on a shared watercourse through dams and should consider the needs of the downstream states and the environment. So, states are free to build dams, yet they need to consider their obligations [80].

In international law, states are bound with the agreements they sign. They are also expected to comply with the customary law developing from generally accepted and applied regulations of the international actors. [81] Customary law has high importance for the development of the international water law as it has started to develop through customary principles. [82] Three principles, the “obligation not to cause significant harm” “equitable and reasonable use of a shared watercourse” and the “obligation to cooperate” have been admitted as customary water law obligations that states should respect when utilizing and benefitting from transboundary waters. [83] So, when states benefit from a shared watercourse, they should consider the needs of other riparian states, should not cause harm to the water or through the water and should cooperate if possible. This has also been indicated in the 1997 UN Convention under Article 5, 7 and 8. [53] Besides, the same convention prohibits states to damage the environment under Article 20, 27 and 28 [53].

A new dam on a territory that already has several reservoirs should be constructed considering the water need of the downstream state and environment. The international community agrees that neither any state nor the environment should be damaged because of a new dam built on a territory with multiple reservoirs as codified in the 1997 UN Convention under Article 7. [53] States have the responsibility to foresee the possible harm and prevent it as much as possible when constructing a new dam on a territory.

A dam project planned on a transboundary river might be contested by other riparian states especially when a new dam possibly has negative impacts on other states and the environment. This is directly related to hydro-politics. The relation between the upstream and the downstream riparian states might cause rather conflicts or cooperation between states. [21] When a state located on a transboundary watercourse decides to build a dam, other states might object to it as they might be affected by it. This opposition generally comes from the

downstream state when the upstream riparian state starts planning a new dam on the transboundary river. The new dam, upon its purpose, might decrease the water flow that the downstream riparian state receives. The international community has not agreed on a certain amount of water that should be released from dams yet, but states would not like the amount of water allocated to them to decrease. In most cases, downstream states have constructed dams before the upstream riparian states. However, they oppose dam construction by upstream states as a new dam might decrease water share of the downstream states if the dam is an irrigation or water supply dam or that they might not have the same yield for energy production as foreseen for AHD after the Grand Ethiopian Renaissance Dam starts working at full capacity. [84] Again, environmental harm or political reasons might also cause downstream states to contest a new dam to be built by an upstream state.

Disputes might be settled through communication, cooperation and mutual compromise. Even though cooperation seems to be the best choice, to cooperate states need directly or indirectly to benefit from the project. Besides, it is easier to build a dam through cooperation as the financial and the technical difficulties will be borne by all project making states together. However, this is not always the case as there are several court and arbitral decisions on the use and management of water resources. After all, some bilateral agreements have permitted the construction of hydropower dams. For instance, Article 9(g) of the Rio Grande Agreement has emphasized that water use for hydropower production has been permitted for both states as this does not reduce the water quantity of the river. [85] Likewise, Indus water treaty has a similar regulation in Article II (2-4), III (2) and in Annexes C and D which state that even though waters of Indus and its tributaries have been allocated between states, non-consumptive uses including hydropower production are legit reasons to interfere with the river water flow. [86] As hydropower dams do not make a change in the flow quantity, they mostly do not create disputes and some agreements specifically allow their construction.

6 Conclusion

Damming rivers is complicated as it is necessary. States need and want to dam their rivers as it has several positive returns. Integrating a new dam on a territory with multiple reservoirs causes more problems since different criteria need to be considered all together. The size, the material used, and the dam site should be chosen upon the suggestions of the engineers involved in the project. Besides, economic, environmental, social, and cultural impacts of the new dam need to be analyzed. Also, possible changes in conditions including the impacts of climate change should be considered in the evaluations. An EIA report can be very useful for the dam-building state and other riparian states that will be affected by the construction of a new dam. Upon these analyzes, possible optimum conditions need to be provided.

Likewise, when planning a new dam, the environment and other riparian states should be considered. The new dam on a territory with multiple reservoirs should not change dramatically the water allocated to either state or the environment as this would cause disputes among states and harm the environment. Hydropower dams step forward in-between different dam types as the water quantity of the water flow stays the same apart from the impoundment period. Plus, they help the state economy through the production and sale of hydropower. Besides, irrigation and water supply dams cause water flow quantity to decrease as some of the water is taken out of the hydrologic system. Also, as it prevents the use of carbon-based energy resources, they are good for the environment. Even if the state decides to build a multipurpose dam, the benefits of hydropower dams indicated in this paper show that that dam should have hydropower purpose as one of its purposes.

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