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Influence of Dams on River Ecosystem and Its Countermeasures

Qicai Lin
Key Lab of Northwest Water Resources, Environment and Ecology, Ministry of Education
Xi'an University of Technology, Xi'an, China
E-mail: *stoneofsky@163.com*
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Abstract

Dam construction is an important engineering measure in dealing with the relationship between water and human being. However, with dam construction, some disadvantages to the river basin may be caused, including flow flux of downstream changed, flooded area reduced, river species and other organisms changed and substance sedimentation. Furthermore, it brings some diseases to human being and human residential areas reduced too. Based on the basic principles of ecohydralic engineering, some countermeasures to minimize the negative effects on rivers were put forward. They are reservoir ecological regulation, ecohydraulic engineering construction and comprehensive water pollution treatment.

Keywords: Dam, River Ecosystem, Ecohydraulic Engineering, Environmental Impact, Countermeasure

1. Introduction

Dam construction is an important engineering measure in dealing with the relationship between water and human being. In the traditional hydraulic engineering, a great deal of dams and dikes were built for the purpose of "harm exception and benefit enrichment" [1-2]. Meanwhile, large-scale river repair have also been done [3-5]. Dams have huge economic benefits and social benefits, such as preventing flood and reducing the disaster, adjusting the water quantity, irrigating and generating electricity [6-7]. However, in dam construction, some disadvantages may be caused to the river basin. With the development of the society, more and more scholars began to consider the effects of dam construction to the river ecosystem [8-10].

2. The Effects of Dam Construction to the River Ecosystem

Dam is an important engineering measure in dealing with the relationship between water and human being. Meanwhile, it is also a significant approach to maintain the balance of ecosystem. The damming of a river creates a reservoir upstream from the dam. The reservoir waters spill out into the surrounding environment, flooding the natural habitats that existed before the dam's construction. Up to the present, over 400 000 km^2 of the earth have been flooded due to damming [11]. This argument remains to be proven scientifically by empirical data.

Dam construction affects the river ecosystem. The impacts of dams to the downstream can be generally categorized into physical changes and their biological consequences [12]. Physical changes involve river and floodplain hydrology, sediment movement and channel structure [13]. Biological consequences include virtually all aquatic and floodplain biota, either through direct physical influence or because of indirect effects on biological interactions and food-web processes [14]. Analyzing the biological and abiological factors, the effects of dam construction to the river ecosystem are as follows.

2.1. Flow Influences as Dam Constructions

Dam acts as a barrier between the upstream and downstream habitat of migratory river animals, such as Chinook salmon and steelhead trout in the USA [15], and Atlantic salmon in Europe [16]. Dams block their migration upstream to spawning areas, threatening to decrease reproduction numbers and reduce the species population. In light of this consequence, efforts have been made to allow the fish a passage upstream, and newer dams often use artificial "fishways" or "fish ladders" [17-19].

Some communities have also begun the practice of transporting migratory fish upstream to spawn via a barge. Fish sometimes have difficulty migrating downstream through a dam, meaning that downstream populations are often reduced unless the fish are able to swim safely through the dams' spillways [18]. Permanent inundation caused by reservoir flooding also alters the wetlands, forests and other habitats surrounding the river. Further ecosystem disruption occurs along the banks of the river and downstream [20]. The areas surrounding riverbanks are of a particularly rich bio-diversity, supported by the natural flooding of a dam-free river. Dammed rivers reduce flood rates, and this has negative consequences on the floodplains downstream that depend on seasonal waters for survival. The invariable ecosystem created by a reservoir-river supports a far-reduced range of wildlife. Dams hold back sediments that would replenish down stream ecosystems naturally. Endemic species may or may not survive the environmental change, and new species are likely to adopt the altered habitat as a home. However, since dams change a key ecosystem to which all surrounding ecosystems have adapted. Dam construction nearly always reduces wildlife diversity, for better or for worse.

Dams are built to modify the timing and distribution of water. Operational rules are usually based on narrow economic criteria. Dam operators are interested in environmental conservation, but are unaware of the hydrologic needs of floodplain ecosystems. Flow variation should be guaranteed by flow regulation. According to arguments of hydropower opponents, reservoirs contribute to greenhouse gas emissions as well.

The flush flux will be changed by the need of power station to adjust the apex. The change ratio of the flush flux has an important effect on the downriver watercourse, and then affecting the habitat of riverside species [19]. The running river may become still pond, and change to the lake condition. Whether minimizing or increasing the current of flush flux, a diversion type power station may affect the conformation of river corridor, the botanic community and biologic habitat.

2.2. Flooded Area Reduced as Dam Construction

Flood is the natural attribute of the river and flooded areas. It has an important effect on the continuous using of regional water resource and holding of flooded area scope and its function. The measures to prevent the flood and reduce the disaster include different and extensive strategies. Some of them may be out of line with the object of river corridor restoration. Floodwall makes the velocity of flow increased and water level heightened as water current was limited. When floodwall back off, we can put apart the river corridor as flooded area or temporarily flooded area.

Usually, the flooded areas are marshes, and it has important effects on purity of water quality and protecting of the biodiversity [21]. Compared with reservoir's submerged areas, the flooded areas are useable soil because it is only little periodical time overpass water on the flooded areas. What is more, floods bring nutrition and species as a supplement repeatedly. Nevertheless, dam construction changed the flood character of river.

In many developing countries the savanna and forest ecology of the floodplains depend on seasonal flooding from rivers. In addition, flood recession cropping is practiced extensively whereby the land is cultivated taking advantage of the residual soil moisture after floods recede. Dams attenuate floods, which may affect the ecology and agriculture seriously [22]. The disadvantages to the flooded areas are mainly as following: The marsh landscape of flooded areas reduced, biodiversity derogated, and ecological function degenerated and so on.

1) Marsh landscape reduced

Due to the hydraulic engineering including bank built and dam constructed control measures, the modes hydrological state and water cycle of flooded areas have been changed. It leads to the ecological environmental function degeneration of flooded area.

In the plus effects of obstructed the contact of rivers and lakes. From 1950's, 82% of the flooded marshes of the middle and lower reaches of Yangtze River was lost [23]. Large-scale loss of flooded marsh landscapes has brought considerable negative effects. The effect of lake mirages of Yangtze River basin to the stream flow was greatly reduced [24].

2) Marsh biodiversity derogated

Dams hold back not only sediment, but also debris. The life of organisms (including fish) downstream depends on the constant feeding of the river with debris. This debris includes leaves, twigs, branches, and whole trees, as well as the organic remains of dead animals. Debris not only provides food, but also provides hiding places for all sizes of animals and surfaces for phytoplankton and microorganisms to grow. Without flooding and a healthy riparian zone, this debris will be scarce. In addition, although debris might come from the river above the dam, it is trapped in the reservoir instead, and never appears in downstream. The bottom level of the food web is removed. Overall, the loss of sediment and debris means the loss of both nutrients and habitat for most animals.

The environment changes of flooded area's habitat and the interdiction of river accesses brought about changes of birds and mammals amount. Gone with the loss of flooded marsh landscapes, more and more biological

species were in danger or extinct as its survival and living spaces lost. It also lead to the propagate ability descended and the quantity and quality of species decreased or degenerated.

3) Marshes and its regions ecological function degenerated

The maintenance and reinforcement of the structure and function of flooded marsh ecosystem mainly enslaved to relative variability of flooded areas and instability of hydraulic and dynamic conditions [13]. The dam altered the hydraulic and dynamic conditions, which made the destroyed of flooded marsh environmental ecosystem. It further lead to the degenerated of regional ecosystem.

2.3. Species Changes as Dam Construction

Dam construction offered preferable conditions of aquiculture development. It also changed many dams to the aquatic serve base. However, dam still submerged lots of ground and blocked the relationship of river being network. It affected the inhere survival and propagate eco-environment of wildlife.

The first effect of a dam is to alter the pattern of disturbances that the plants and animals of a river have evolved. Many aquatic animals coordinate their reproductive cycles with annual flood seasons [25]. Every flood is valuable in that it takes nutrients from the land and deposits them in the river, providing food for the stream's residents. Floods also provide shallow backwater areas on vegetated and shaded riversides; the young of many animals depend on these backwaters to protect them from large predators.

For example, a fish on a certain river may only reproduce during April of every year so that its offspring will have abundant food and places to hide. If the flood never comes because a dam holds the river back, the offspring may be produced during a time when they cannot possibly survive. If the fish can wait until the next flood, which may be in July or October, its young will be born during the wrong time, and will have to contend with the absence of their normal food supply and temperatures for which they are not prepared.

Vegetation, too, depends upon these regular cycles of flood. Quite often, people will decide that they can spare no water and no flooding will occur. On the other hand, they may have built the dams specifically to stop flooding, so they can build houses in the floodplains. When this happens, riparian vegetation, the vegetation bordering the river changes forever. An example of this may be found in Southwest United States [15], where enormous floodplains of cottonwood and marsh have been replaced by dry, barren areas of tamarisk and grass.

The changes of habitat conditions affected the living rule, food chain, species movement, diffuse ranges and spawn of hydrophilic. Parts of species decreased or disappeared as environment maladjustments. After dam constructed, intrinsic river systems completed with allusions, beaches and watercourses became a relative erect single watercourse. This reduced species of intrinsic animals and plants, will depress the biodiversity.

1) The changes of inhabit and propagated environment

River level changes may cause some kickbacks to the water eco-environment followed by the modes of hydropower need changes, such as river level rapidly changed caused the erosion of lower reaches of watercourses. Alternately, exposure and submerged shallow may destroyed the rest locations of shoal and disturbed shoal spawn and so on. Besides, river temperature changes also altered the survival environment and lifecycle of the aquicolous species. Rivers tend to be homogenous in temperature. Reservoirs, on the other hand, are layered. They are warm on the top and cold at the bottom. If water is released downstream, it is usually released from the bottom of the dam, which means water in the river is now colder than it should be. Many macroinvertebrates depend on a regular cycle of temperatures throughout the year. When we change that, we compromise their survival. For instance, a certain stonefly may feel the cold temperatures and delay its metamorphosis. This may mean that at a certain life stage it will be living in deep winter rather than in autumn. Dams destroyed the habitat of parts of triphibian plants and made their biological resource changed. Dams also affected the exchange of species and altered the habitat of lower river aquicolous animals and plants [26].

2) Biological quantity and species changes

Dams weakened the flood peak, adjusted the water temperature and reduced the diluted function of lower reaches of a river. It caused the increase of plankton quantity and distributing character and amount changes of invertebrate. Dams reduced the flood submerge and grass roots erosion. It increases sediment of nutritional silver sand, which led large-scale water plant can be row and propagate. Owing to the head off much cobbles and graves, the invertebrates such as insect, mollusks and testacean lost their living environment.

3) The effect to the fish species

Dams shut off the migrate channels of some migratory fishes. As the released water has a low temperature by dam deep hole, the growth and propagation of fishes may be affected. Released rinsing also influenced the fish feed, which affected its output. When high dams overall and flood discharges, high speed current caused excessively saturation of the water. Moreover, it caused fish bleb disease. For instance, the Gezhou Dam on the

Yangtze Rive, it has a flush flux of 41300-77500 m^3/s, and the oxygen saturation: 112-127, nitrification saturation: 125-135%, lethal ratio of par: 32.24% [27].

The fish passage is concerned with dams. Many fishes must move upstream and downstream to complete their lifecycles. Dams are often built without fish ladders. When fish ladders are provided, they seldom work as needed. If enough adult fishes do manage to climb above a dam, there remains the issue of their young: how will they get back downstream? Predators kill many while wandering in the reservoir above the dam. Many are killed in their falling downward through the dam to the river below. They are not killed by the fall itself, but by the high levels of nitrogen gas at the base of the dam [28]. In other words, like divers who go too deep, they get the "bends".

Many fishes cannot climb dam ladders or leap over low dams. Some of these fishes swim upstream every year to breed, then let the water carry them back downstream. The eggs of pelagic spanners float downstream, in addition, which is why the adults must swim far upriver to breed. Otherwise, the baby fish would soon end up out to sea.

4) The effects to coastal species

The changes of grade, temperature, humidity, loftiness and groundwater would lead to the evolvement of organism community and parts of species were reduced or disappeared. As for the effects of triphibian plants and animals, it can be divided into two parts: one is permanent or direct effect, such as the reservoir region and the permanent engineering buildings causing a direct effect; the other is indirect effect including local climate, soil swamp and basification causing animal and plant species, structures and living environment to be changed.

2.4. Transference of Inner River Organism

As all dams result in reduced sediment load downstream, a dammed river is said to be "hungry" for sediment. Because the rate of deposition of sediment is greatly reduced since there is less to deposit but the rate of erosion remains nearly constant, and the water flow eats away at the river shores and riverbed, threatening shoreline ecosystems, deepening the riverbed, and narrowing the river over time. This leads to a compromised water table, reduced water levels, homogenized of the river flow and thus reduced ecosystem variability, reduced support for wildlife, and reduced amount of sediment reaching coastal plains and deltas. This prompts coastal erosion, as beaches are unable to replenish what waves erode without the sediment deposition of supporting river systems. Channel erosion of rivers has its own set of consequences. The eroded channel could create a lower water table level in the affected area, affecting bottomland crops such as alfalfa or corn, and resulting in a smaller supply.

It is natural that the river, which is accustomed to carry sediment and now has none, will pick up the sediment from the streambed below the dam. It is almost as though the river has been "starved" of its sediment. As in everything else in nature, balance will be achieved one way or the other, frequently at the expense of one or more species.

What happens to the sediment in a dammed river? It reaches the slow-moving reservoir above the dam and drops out, settled behind the dam. If this seems worrisome to you, it should. Dams are engineered to withstand the force of a certain number of tons of water - however large the reservoir will be. They are not engineered to withstand the additional force of tons of wet sediment pressing on their backsides. The muddier the river, the faster this heap of sediment will build up. What happens when it builds up too high? Either the dam bursts, killing people and destroying settlements downstream, or the reservoir's water pours over the top of the dam. In effect, a huge man-made waterfall has been constructed, and will remain there for thousands of years. We can not remove the sediment from dams behind, which appears to be unsafe and economic way to do it.

The interruption of the river blocked or slowed the transference of aquicolous organism, which affected the function of river corridor. If there is no high-speed current, then there will be mush and sand on the screens of the riverbed. In addition, the screens are the spawn space of aquicolous organism. Ascending fishes cannot travel through the little baffle because of the small buildings. Downriver fishes may swim slowly or stop as dam constructing or reservoir running. When river enters into a reservoir, the enormous fingerling may amazed direction or became the quarry as water's chemical substance had changed.

2.5. The Substance Interruption Caused by Dams

Rivers carry four different types of sediment down their riverbeds, allowing for the formation of riverbanks, river deltas, alluvial fans, braided rivers, oxbow lakes, levees and coastal shores. The construction of a dam blocks the flow of sediment downstream, leading to downstream erosion of these sedimentary depositional environment, depositional environments, and increased sediment build-up in the reservoir. While the rate of sedimentation varies from each dam and each river, eventually all reservoirs develop a reduced water-storage capacity due to the exchange of storage space for sediment [29]. Diminished storage capacity results in decreased ability to produce

hydroelectric power, reduced availability of water for irrigation, and if left unaddressed, may eventually result in the expiration of the dam and river [30].

The initial filling of a reservoir floods the existing plant material, leading to the death and decomposition of the carbon-rich plants and trees. The rotting organic matter releases large amounts of carbon into the atmosphere. The decaying plant matter itself settles to the non-oxygenated bottom of the stagnant reservoir, and the decomposition produces and eventually releases dissolved methane.

When river velocity of flow reduced, the suspension load of the river also did. Mud and sand aggravated in the reservoir, and other organic substance aggravated in the reservoir too. Moreover, this organic substance has an important effect on the lower river food chain. Losing these organic substance means losing the lower river ecology. Because of reduction of the suspension load, there will be a new balance between lower riverbed and riverbank. Erosion reduced riverbed and affected riverbank and riparian bank, which is the habitat of many organisms. If there is no new supplement of sand and mud, allusion and its relative living habitat also disappeared. Besides these, river down cutting can cause the changes of underground water level. Some disadvantages change may cause the river corridor's vegetation community, too.

2.6. Dam Effects on Humans

While dams are helpful to humans, they can also be harmful as well. One negative effect of dams is the fact that the artificial lakes created by dams become breeding grounds of disease. This holds true especially in tropical areas where mosquitoes, which are vectors for malaria, and snails, which are vectors for schistosomiasis, can take advantage of this slow flowing water [31].

Dams, as argued by hydropower opponents, contribute to changes of the earth's climate. Accordingly, it is because dams generate methane, a greenhouse gas. Methane is emitted from reservoirs that are stratified, in which the bottom layers are anoxic (*i.e.* they lack oxygen), leading to degradation of biomass through anaerobic processes. In some cases, where flooded basins are wide and plants grow well (as in Brazil), the amount of biomass converted to methane results in power generation that pollutes 3.5 times more than an oil-fired power plant would for the same generation capacity.

For humans, another disadvantage of the construction of dams is that if it is build close enough to residential areas, the relocation of residents will be necessary. This is true in the Three Gorges Dam in China [32]. The Three Gorges Dam will submerge a large area of land, forcing over a million people to relocate. "Dam related relocation affects society in three ways: an economic disaster, human trauma, and social catastrophe", states Dr. Michael Cernea of the World Bank and Dr. Thayer Scudder.

3. Formulate Dam Running Scheme That Benefits Eco-Environment

Dam construction had over century's history. Dams constructed throughout the world caused far-reaching effect to the river basin [33]. It has important function in melding the regional water resource, reducing watering disaster and obtaining cleanly energy sources. It also controls the rivers, in adjusting the seasonal flux change, changing water temperature and chemical components, blocking the sediments, disarranging the river erosion and the process of geological aggradations, blocks the contact of water life networks, altering the landform of river system and so on.

With traditional hydroelectric engineering causing a series of problems, plenty of experts and scholars developed a new subject called "eco-hydraulic engineering", which combined ecology, environmental hydraulics and hydraulic engineering together. This subject is based on traditional hydraulic engineering, absorbing and fusing ecological theories, then becoming a new engineering subject. Based on the principles of ecohydraulic engineering, we can take relevant countermeasures and some other measures to alleviate the disadvantages caused by dam construction. There for, this thesis brings forward some measures.

3.1. Drawing Flood Regulation Scheme That Benefits the Eco-Environment and Managing Flooded Areas Comprehensively

Flood regulation means releasing water operated from the reservoir, and summered certain range of flooded areas or lower river delta. The first principle is releasing water designedly, thus achieving the need of preventing flood, alleviating the negative effects caused by dam construction and satisfying the people's product and living need in upstream and downstream [34]. The second principle is using the traditional and modern river basin synthesis development concept to exploit water resources, which can obtain the max benefits of water resource exploitation (including currency benefits and non- currency benefits).

Some advanced ecosystem functions to human being depends on the periodical inundation. Flood regulation can be the measure of restoration or maintenance to the

lower river ecosystem. When drawing the flood regulation scheme, we should bracket different frequent flood's flooded space range based on basin flood's frequency and historical flood's character. Strict management on the sub-areas for the different frequent flooded area should be practiced. We still need to ascertain the relationship between flooded area's product, function, attribute, and inundation, which can quantify the inundation amount to maintain ecosystem. For instance, some parts of United States to preserve the eco-environment character of flooded areas, the acts forbidden to exploit 10 years meet flooded area.

3.2. Building Hydraulic Engineering That Benefits Ecological Protection

Dam construction lead to the current velocity of flow accreted, which binged about fishes trace to propagate. To protect fish resources, we need to repair some fishway helping fishes through dam to arrive ascending spawn area. In fishway's design, the fish living behavior, posture character and hydraulic buildings should be considered. Besides, we can set sound fitting on the fishway, which can lead the migrated fishes flitting upstream or lower reaches.

Different spawning migration fishes have different living environment. Taking sturgeon for example, the majority parts of them lived on north latitude 45 degree, which are Hokkaido of Japan, Ussuri River, Heilongjiang River and Songhua River of China. Furthermore, not each river has spawning migration fishes. There are mainly two measures in dealing with the spawning migration fishes problems. First, use engineering measures as building fish ladder and fishway and so on. Second, manual propagate to the spawning migration fishes. In the construction of Gezhouba Dam of Yangtze River, to deal with the problems of sturgeon, the government chooses the manual propagation, and it has been proved successful [27]. To ostensive is that constructing dams in different region or rivers with different effects to fishes and other species. We should analyze the specific river.

3.3. Enhancing the Water Pollution Treatment of the Upriver Comprehensively

Dam construction intercepted upriver water resource and made contamination trapped in reservoir. Treatment to the upriver environment pollution has a far-reaching significance to protect whole river system's water resource. Therefore, we should reduce the contamination caused by industry, agriculture, life, pasture husbandry and fishery. We still need to cut off the contamination concentration in the river to avert accumulating, depositing and concentrating, and then alleviate the destroyed degree of water quality caused by dam construction.

4. Conclusions

Dam construction, like a coin, has its two sides. How to exploit favorable conditions and avoid unfavorable ones is the business of dam architects, dam constructors and dam managers. Only taking the ultimate aim of improving the ecosystem and sustainable development [35], and using environmental appraise deeply, setting down dam running mode to take advantage of ecosystem, can our dam construction be better. We should study the disadvantages caused by dam engineering, and demonstrate the feasibility of dam construction project. Through the factors such as humanism, society, ecology, natural resource, climate changes and river sediment, we need a synthesized analysis. We should distinguish the advantages and disadvantages of dam constructions. Moreover, we should promote the beneficial aspects and alleviate the negative effects caused by dam construction. Then we can make new engineering projects to be facilitated in society's sustainable development and accelerate the harmonious coexist between nature and human being.

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