

Research on Ecological Effects of Reservoir Dam Project

Yaxi Cai^{1*}, Xiaodong Yang²

¹Shaanxi Provincial Land Engineering Construction Group Weinan Branch, Weinan 714000, Shaanxi Province, China

²Xi'an Water Supply Corporation Limited, Xi'an 710082, Shaanxi Province, China

**Corresponding author:* Yaxi Cai, zsjcyxczl@163.com

Abstract: Ecological effects of dam and reservoir development is a new concept proposed in recent years. It refers to the ecological impact and ecological consequences in the dam construction and operation process, which not only including the positive ecological effects, but also the negative. Ecological effect analysis is a kind of analysis which pointed at the influence of the water conservancy projects built on the living environment, the impact of the wild animals and plants, the effect of natural law, the impact of the economic growth. Based on the analysis of previous research results, this paper summarizes the connotation and characteristics of the ecological effects of the reservoir and dam project, and analyzes the ecological effects of the reservoir and dam project from the aspects of Hydrology, water environment, biology, climate, etc., this paper summarizes the connotation and characteristics of the ecological effect of the reservoir dam project, and provides the scientific basis for whether the hydraulic engineering should be retained or whether the function should be improved.

Keywords: Reservoir Dam Project; Ecological effect

Publication date: October 2021; **Online publication:** October 29, 2021

1. Introduction

The ecological effect of water conservancy project is a new concept put forward in recent years. The concept of effect refers to a specific scientific phenomenon produced by a certain power or reason, which is generally used in the field of physics. Ecological effect refers to the impact of human activities and changes in natural environment on the structure and function of natural ecosystem ^[1]. Ecological effects generally include two aspects: ecological positive effects and ecological negative effects. Ecological positive effects are conducive to the survival and development of organisms in the ecosystem; Ecological negative effect means that it is not conducive to the survival and development of organisms in the ecosystem ^[2].

Zongfeng Sun and Zengchuan Dong ^[3] pointed out that the ecological effect of water conservancy projects refers to the comprehensive result of ecological damage and ecological restoration of nature after the completion of water conservancy projects. Ecological damage refers to the environmental problems caused by the decline of ecosystem production capacity and the change of structural level caused by the direct action of water conservancy projects on the water ecosystem, resulting in the disorder of water flow. Ecological restoration refers to the use of water conservancy projects to change the existing water flow operation law, restore river water quality, and form new wetlands. Zhanpo Mao ^[4] and others pointed out that the ecological effect of the dam on the river ecosystem is a composite function in different processes

such as planning, design, construction and dam discharge. During the planning, design, construction and operation of the dam, according to the characteristics of the river ecosystem, measures such as land use, ecological restoration and water resources management should be fully considered, Reduce the impact of the dam on the river ecosystem and realize the sustainable development of water resources in the basin, so as to achieve the goal of harmonious development between man and nature.

2. Characteristic of ecological effect of reservoir dam project

The construction and operation of reservoir dam project will have ecological effects on the ecosystem in the basin, and it is a complex process involving various ecosystem elements in the basin. There will be differences in size and length on time and space scales, differences in direct and indirect effects on the characteristics of effects, and differences in cumulative and joint effects on the results of effects, so that the ecological effects of water conservancy projects show multi-level characteristics.

2.1. Compounding of ecological effects

The construction and operation of water conservancy projects will turn the natural ecosystem of the basin into a composite system composed of natural elements, engineering elements, social elements and ecological elements. In this complex ecosystem, if the project is properly planned and implemented, it can be coordinated and integrated with nature; On the contrary, the composite system will be extremely unstable and will eventually cause disaster.

2.2. Lag of ecological effects

Water conservancy projects provide people with direct and obvious benefits such as water supply, power generation and irrigation. However, because water conservancy projects change the diversity of rivers, the negative impact on rivers with damaged ecological structure is often a slow development process. At the same time, it is also the result of many factors. Coupled with many uncertainties, it often shows slow and latent characteristics. It is difficult to be found before major ecological effects occur, that is, the lag of ecological effects.

2.3. Association of ecological effects

Ecological effects also have the characteristics of association. From the analysis of the impact relationship of the project, it can be seen that the direct impact caused by project construction and operation, such as reservoir inundation and hydrological and sediment situation change, is the source impact; The source impact can change the water temperature, water quality, local climate and the living environment of zooplankton and plants, and may also induce geological disasters such as bank collapse, landslide and earthquake. These are all function influence. Then, the effects, such as vegetation destruction, population health and socio-economic changes caused by migration, are result effects. Therefore, ecological effects can form the characteristics of association. The characteristics of association make the analysis and evaluation of ecological effects need the analysis of direct effects and indirect effects.

2.4. Accumulation of ecological effects

In order to fully develop and make full use of water resources, cascade hydropower stations are often established on rivers where conditions permit. For example, cascade hydropower stations of 8 and 13 levels have been planned on Lancang River and Nujiang River in Southwest China. The impact of cascade hydropower stations lies in cascade development. Cascade development will have a significant impact on the economic resource structure of the basin, the conflict and balance of the ecosystem, and the disintegration and reconstruction of the social structure. Compared with the single project, this impact

usually has significant characteristics such as being collective, being systematic, accumulation and potential, and is more complex and far-reaching than the single project.

3. Analysis of ecological effect of reservoir dam project

The ecological effect of the reservoir dam project is mainly reflected in the impact of the project construction on the local ecological environment. This kind of influence involving physical process, chemical process, biological process and social process is extremely complex and extensive. Some of them are beneficial to the ecological environment and some are not conducive to the ecological environment. It also includes the interaction and influence between many environmental factors. Therefore, the basis and premise of scientific evaluation of the ecological effect of reservoir dam project is to correctly analyze the impact of these factors.

3.1. Hydrological effect

The impounding of river runoff by reservoir dam project will have a very significant impact on the hydrological situation of natural rivers. The multi-year regulation reservoir has the greatest impact and the daily regulation reservoir has relatively little impact. The change of reservoir water level is very different from that under natural conditions, and there will be no obvious seasonal change. Compared with the natural river channel, the velocity change of the reservoir is also obvious. The closer it is to the dam, the smaller the velocity is. As the flow velocity slows down and sediment settles, the sediment content of reservoir water decreases and the transparency increases.

Yongqiang Cao ^[5] and others believe that the construction of the reservoir has changed the flow process of the downstream river, thus affecting the surrounding environment. The reservoir not only stores the flood in the flood season, but also intercepts the river base flow in the non-flood season, which will often cause the water level of the downstream river to drop significantly or even cut off, and cause the decline of the surrounding groundwater level. The downstream natural lakes will also dry up due to the lack of water supplement; The decrease of river flow at the estuary of the river leads to the siltation of the estuary, the backflow of seawater, the increase of groundwater and soil salinity, and the survival of local plants; Because the river flow decreases, the self-purification capacity of the river decreases, which is easy to cause water pollution; Reservoirs that mainly generate electricity should act as peak loads in the power system. The daily variation range of reservoir discharge is large, resulting in large changes in the water level of downstream rivers in a short time, which has a great impact on shipping, irrigation and aquaculture; When the water level of the river downstream of the reservoir drops to a large extent and even stops flowing, it is bound to lead to the deterioration of river water quality, such as water bloom, red tide, etc.

Sediment problem is one of the important environmental problems faced by water conservancy projects. The construction of a dam on the river blocks the natural river channel, changes the flow pattern of the river, changes the sediment content and movement law of the river, then changes the hydrological characteristics of the whole river and estuary, and seriously affects the living environment of organisms in the basin, which is one of the major ecological problems brought by the construction of a dam.

3.2. Water environment effect

Water environment effect will have positive and negative effects on water quality. Among them, the beneficial effects are as follows:

- (1) The turbidity and chromaticity of water body are reduced

This is because the large volume of water in the reservoir has slow velocity and long residence time in the reservoir, which makes a large number of suspended particles settle, so as to reduce the turbidity and chromaticity of the water body.

(2) Water hardness reduction

This is because the flow velocity in the reservoir is slow, resulting in frequent algae activities. The CO₂ produced by algae respiration reacts with calcium and magnesium ions in the water and combines with each other to produce CaCO₃ and MgCO₃. These two insoluble sediments make a large amount of Ca²⁺ and Mg²⁺ settle in the water, thus reducing the hardness of the water body.

In addition, the adverse effects of water environmental effects on water quality are:

- (1) The flow velocity in the reservoir is slow, which reduces the material exchange rate of water and gas in the reservoir, reduces the migration and diffusion capacity of pollutants, weakens the reoxygenation capacity and the dissolved oxygen content in the water, resulting in the weak self-purification capacity of the reservoir compared with the river.
- (2) The flow velocity in the reservoir is slow, the transparency of the water body is increased, and the photosynthesis of algae is enhanced, which makes the water stored in front of the dam for months or even years eutrophication occurs due to the massive growth of algae.
- (3) The submerged vegetation and rotten organic matter consume a lot of oxygen in the water and release biogas and carbon dioxide, resulting in the greenhouse effect of the water.
- (4) Suspended solids in the water are deposited at the bottom of the reservoir and are not easy to migrate after long-term accumulation. If these suspended solids contain toxic substances or refractory heavy metals, they will form secondary pollution sources.

The effects on water temperature are: water temperature change refers to the phenomenon of temperature difference between inflow and outflow due to the special water temperature structure of the reservoir. Water temperature change caused by reservoir engineering is an inevitable phenomenon in reservoir construction [6].

3.3. Biological effects

Biology is the most important part of the ecosystem. It maintains the balance of the natural ecosystem and is the essential basis for human survival and sustainable development. The impact of reservoir dam project on organisms can generally be divided into two aspects: terrestrial organisms and aquatic organisms.

(1) Impact on terrestrial organisms

Generally speaking, the impact on terrestrial organisms has two aspects. One is the direct impact. The inundation of the reservoir area and permanent hydraulic engineering buildings will cause direct damage to terrestrial organisms; The other is indirect impact, which is caused by local climate change, water and soil loss and soil salinization caused by the reservoir dam project on the species, structure and living environment of terrestrial organisms.

The completion of the reservoir will flood a large area of land and seriously threaten the growth habitat of terrestrial organisms. Therefore, the impact of reservoir dam on terrestrial organisms is unfavorable in most cases. However, the land inundated by the reservoir dam project is mainly some farmland, plains and slopes along the river basin or coast, which has little impact on the areas with high terrain. In these low altitude areas, crops are mainly used and there are few animals. Therefore, the construction of inundated land of the reservoir has a great impact on agriculture and little impact on animals [7]. Taking Talinxi hydropower station as an example [8], due to the water storage of the reservoir, the inundated land area is 8664hm², including 7170hm² of forest land. About 120 kinds of plants are damaged by inundation, and the impact of this inundation loss is irreversible. However, because the inundated vegetation types are common in Daxinganling and widely distributed in the world, the inundation of the reservoir has little impact on the flora and vegetation types and will not cause the disappearance and extinction of local plant types. The impoundment of the reservoir makes some coniferous forest animals, swamp meadow animals and broad-

leaved miscellaneous forest animals lose their original habitat. However, from the perspective of the whole evaluation area, the forest vegetation around the reservoir is rich, the habitats are diverse, there are many potential niches, and the above animals are common types in Daxinganling area. Therefore, although the impounding inundation has a great adverse impact on the wildlife in the assessment area, it will never lead to the extinction of these animals.

(2) Impact on aquatic organisms

As the reservoir dam project mainly acts on water, aquatic organisms are more directly and obviously affected by the project than terrestrial organisms.

Phytoplankton and zooplankton are similarly affected by the construction of the reservoir, which are related to the geographical location of the reservoir, the landform around the reservoir, the type and operation mode of the reservoir, the development degree of the environment around the reservoir and other factors. In addition, the change trend of phytoplankton population after the construction of the reservoir is mainly affected by the population of phytoplankton in the water around the reservoir and river tributaries, which are also the basis for the formation of phytoplankton population in the reservoir.

The construction of reservoirs also has a significant impact on the living environment of benthos. Generally, plain lake reservoirs are more suitable for benthos than mountain canyon reservoirs; In the growing season of benthos, the species and quantity of benthos are more in the reservoir with relatively stable reservoir water level, while the species and quantity of benthos are less in the reservoir with frequent changes of reservoir water level; The reservoir with large drawdown area is not suitable for its growth compared with the reservoir with small drawdown area; There are many kinds and quantities in eutrophic reservoirs, but few in oligotrophic reservoirs; There are more kinds and quantities in reservoirs with muddy sediment, and less in reservoirs with rocky and sandy sediment. In addition, other environmental factors affecting the species and quantity of benthos include water quality, water temperature, etc. The original population in the reservoir area and the benthos in the water around the reservoir also have a great impact on the benthos in the new reservoir.

(3) Impact on fish

The impact of the construction of the reservoir dam project on aquatic organisms is mainly reflected in the impact on fish. For the division of fish in nature, in addition to the biological division of fish flora, there are also many common division methods in environmental impact: First, fish are often divided into migratory, semi migratory and sedentary; Second, according to the rarity of fish, fish are divided into rare fish, economic fish and national protected fish; Third, according to the habits of fish, they can also be divided into quick-flow-loving, slow-flow-loving or static-flow-loving, river fish and lake fish; In addition, fish can be divided according to their spawning types, etc. There are many kinds of fish living in different natural water bodies. The construction of reservoirs by human beings will change the natural conditions of rivers, and thus change the composition and structure of fish in water.

3.4. Impact on local climate and atmosphere

Climatic conditions are the most important factor affecting ecosystem stability. In general, the regional climate is mainly controlled by the atmospheric circulation. However, due to the construction of large and medium-sized reservoirs, the original land has been submerged into a water body, which has an impact on the local microclimate, mainly on precipitation, temperature, wind and fog.

(1) Impact on precipitation

Due to the construction of reservoir dam project, the original natural river channel has become a vast lake water area. The increase of water area leads to the increase of evaporation, so the precipitation has

increased. However, due to the influence of atmospheric circulation and prevailing wind, the influence range of humid air is not large, and the influence on precipitation is not significant.

(2) Impact on temperature

The main factors affecting the temperature change are the change of net radiation in the study area, the change of air heat exchange caused by the change of underlying surface and the change of water land ratio. Because the reflectivity of water surface and land surface is very different, the average value of land surface reflectivity is generally 0.2, while the average value of water surface reflectivity is 0.07. Therefore, it can be found that the net radiation of water surface is significantly greater than that of land surface. After the construction of the water conservancy project, the reservoir stores water and inundates the land, which increases the water area and changes the proportion of water and land. Because the heat capacity of water and land is very different, the change of water and land area also changes the absorption of total radiation. From the annual average, the total net radiation in the reservoir area has increased. In addition, after the reservoir is built and stored, the water level rises and the sheltered area decreases, which also increases the solar radiation acceptable to the water surface.

(3) Impact on wind speed

The shape and properties of the underlying surface are the main factors affecting the change of wind speed, which mainly act through the friction between air flow and the underlying surface. After the completion of the reservoir, the land is submerged into water, which changes the shape and properties of the underlying surface of the reservoir area. The roughness of the water surface is less than that of the road surface, increasing the wind speed. After the impoundment of the reservoir, the rise of the upstream river level increases the width of the valley. When the wind direction and the trend of the valley are close to equilibrium, the wind speed tends to slow down. In addition, the increase of wind zone length tends to increase the wind speed on the leeward bank. The factors of wind speed change are diverse, mainly affected by topographic changes. Therefore, during the construction of reservoir dam project, field monitoring and investigation must be carried out when evaluating the impact of the project on wind speed.

(4) Effect on fog condition

Fog is mainly related to air relative humidity, water vapor, condensation nodule, wind radiation and other factors. When the reservoir is built to store water, the water surface widens, the water level rises, the evaporation increases, the water vapor content in the air increases obviously, and the relative humidity increases, which is conducive to the formation of fog days. The wind also has a certain impact on the formation of fog. When the wind speed is high, it is not conducive to the formation of fog days. However, on the whole, the impact of water conservancy projects on fog is not significant, especially for small and medium-sized projects.

3.5. Impact on landscape resources

Water conservancy projects are generally built in the canyon area, which usually has a beautiful natural environment. If the dam is built at historical and cultural sites, many cultural relics will be affected. In general, the natural landscapes involved in the construction of water conservancy projects include rivers, valleys, forests, grasslands and other natural landscapes; cultural relics and historic sites include ancient tombs, ancient buildings, etc. Water conservancy projects can create a new environment, such as the formation of lakes, and can also be combined with other natural and cultural landscapes to form a new landscape area. Water conservancy projects are integrated with the surrounding environment to form an area that can make people physically and mentally happy. However, water conservancy projects will also

bring some adverse effects to the environment, such as inundation and destruction of some scenic spots and historic sites; changed the original natural landscape; blocking the original traffic route, etc.

More and more attention has been paid to the impact of water conservancy projects on natural landscape and cultural relics. Many countries in the world take the coordination and aesthetics of engineering and environment as an important content in the environmental impact assessment of water conservancy projects. Egypt's Aswan High Dam Reservoir has flooded some historic sites, but precious historic sites and temples have been preserved and rebuilt. Gezhouba Water Control Project and the Three Gorges Water Control Project located in famous scenic spots have made special plans for the protection of natural landscape and cultural relics and historic sites in the project area.

3.6. Impact on human beings

Water conservancy project is the product of human beings to improve the quality of their living environment and promote social and economic development. It is of great significance in the process of human civilization and progress. However, while water conservancy projects benefit mankind, they usually produce a series of negative effects to varying degrees, such as: The impact of water conservancy projects on the health of the surrounding population (there are precedents in the world that cause the widespread prevalence of *Diphyllobothrium Latums* and *Opisthorchisfelineus*; After the construction of Danjiangkou Reservoir in China, malaria is also widely prevalent in the reservoir area. These impacts on people's health are closely related to the construction of water conservancy projects). Because human beings do not realize the negative impact of water conservancy projects, many water conservancy projects do not predict the impact and do not take necessary prevention and control measures.

With the development of society and human progress, these problems are gradually recognized by people. A series of prevention and control measures have been taken for some completed water conservancy projects in China to reduce the adverse impact on people's health. Such as drainage, pit filling, land leveling and other measures to change the adverse ecological environment, so as to reduce the breeding ground of diseases; Through biological control methods, the breeding of *Anopheles* mosquitoes and *Oncomelania Hupensis* Gredler is controlled by stocking grass laying eggs by *Oncomelania hupensis* Gredler, and fish feeding on *Anopheles* mosquitos' larvae and adult *Oncomelania hupensis* Gredlers; Or use chemical reagents to kill vector organisms, etc.

The construction of water conservancy projects often submerges the land, which will inevitably lead to the problem of resettlement. Resettlement involves many fields. It is a huge and complex systematic project, which is related to the adjustment of people's right to survival and residence. It is a worldwide problem today.

4. Characteristics of ecological effect evaluation of reservoir dam project

A healthy modern watershed ecosystem is the performance state of the balanced exertion of river natural function and socio-economic function. Only by reasonably and moderately developing the natural service function of river ecosystem and maintaining the health of river ecosystem, can its socio-economic function service price be best reflected and realize the common evolution of watershed natural ecosystem and human ecosystem. Therefore, it is necessary to evaluate the ecological effect of the development of reservoir dam project in order to draw lessons and scientifically manage the watershed ecosystem.

4.1. The ecological effect assessment of reservoir dam project is the space-time continuation of environmental impact assessment

The environmental assessment of water conservancy and hydropower projects predicts the impact of water conservancy and hydropower projects on the natural and social environment through the identification of

the welcome impact of construction projects, so as to reduce or improve the adverse impact, and provide a scientific basis for project scheme demonstration and departmental decision-making.

Ecological effect is the ecological consequence of the long-term impact on the watershed ecosystem after the construction and operation of water conservancy projects, which has reflected the superposition or cumulative impact of multiple projects on the watershed ecosystem. In other words, the ecological effect has sufficient process curves on the time scale and can expand to the watershed on the spatial scale. Therefore, ecological effect assessment is the continuation of environmental impact assessment in time and space, and can better reflect the real situation of the impact and change of water conservancy projects on the structure and function of watershed ecosystem. Thus, the evaluation results can provide practical technical support for the restoration and improvement of watershed ecosystem structure and function under the long-term stress of water conservancy projects, and reservoir operation and management based on ecological protection objectives.

4.2. Ecological effect evaluation builds an evaluation system from the ecological bottom-line level

Ecological effect is the result of the reservoir dam project affecting the watershed ecosystem for a long time. Through the study of ecological effect, we can fully understand the ultimate ecological problems caused by the development of watershed reservoir dam project. These ecological problems often have broken through the bottom line of watershed ecosystem protection. Therefore, the study of ecological effect is helpful to build the evaluation index system of reservoir dam project from the level of protecting the ecological bottom line, so as to truly block the destructive damage of reservoir dam project to the watershed ecosystem, and provide more specific and operable evaluation indexes for the environmental impact assessment management of future development activities.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Fang ZY, 2005, EChina Water Conservancy Encyclopedia - Environmental Water Conservancy Volume. Beijing: China Water&Power Press.
- [2] Jin L, 1992, Environmental Ecology. Beijing: Higher Education Press.
- [3] Dong ZR, 2003, River Morphological Diversity and Biocommunity Diversity. Journal of Hydraulic Engineering, (1L): 1-6.
- [4] Sun ZF, Dong ZC, 2004, Analysis of Ecological Effects of Hydraulic Engineering. Water Resources and Hydropower Engineering, 35(4): 5-8.
- [5] Cao YQ, Ni GH, Hu HP, 2005, Analysis on the Impact of Water Conservancy and Hydropower Project Construction on Ecological Environment. Yellow River, 17(1): 56-58.
- [6] Lei XQ, 2005, Analysis of Water Environmental Safety problems in Water Engineering. Yangtze River, (4): 58-59.
- [7] Fang CS, 2002, wang J, Li WF, et al. Study on Ecological Value Evaluation Index System of Hydraulic Engineering. Environmental Science Trends, 1: 5-10.
- [8] Zhang YD, Li YG, Peng J, 2002, Study on the Influence of Tarlixi Hydropower Station on Ecological Environment. Journal of Changchun Institute of Technology(Natural Science Edition), 3(1): 28-29