

Study on Water Resources Allocation in the Lancangjiang River Basin of China

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Abstract : Based on water resources availability and development condition of the Lancang River, as well as considering the international river water resources characters, the paper put forwarded an integrated allocation way of the water resources of Lancang River Basin. According to the basic rules of equitable and suitable utilization of water resources of international rivers, water resources demand for domestic, industrial, irrigation and ecosystem system, and principles of society stabilities and the food safety etc, an index system of Lancang River water resources allocation was set up.

Two levels scheme of Lancang River water allocation are proposed. First level is for an international water, which primarily to analysis the water quantity at the national boundary. Second level is for provincial water allocation among Qinghai, Yunnan provinces and Tibetan Autonomous Region.

In the allocation schemes, the water resources development of Lancang River Basin at different scenarios and the related water allocation in different years and seasons were analyzed. A discharge to some cross sections of the river and a total amount water quantity for each district has been given as well.

Key Words: the Lancang River Basin; water resources integrated allocation; International River

Rational allocation, utilization and management of water resources in an international river basin are always the focal issues concerned and key targets of coordination between countries. The Lancang - Mekong River is the biggest international river in South-East Asia. To establish the water resources integrated allocation schemes of the Lancang River Basin will provide basic references for international water resources allocation among China, neighboring and downstream countries in the aspects of cooperative development and coordinated management, protection living creature diversification and contamination control.

1. Water Resources Situation in the Lancang River Basin

1.1 Water Resources Distribution

The Lancang River has a total length of 2,160 km (including 31 km river reach at the boundary between China and Myanmar) with an average gradient of 2.12‰ and catchment's area of 16.44 km². The south-west monsoon climate dominates the whole Basin with dry season from November to next April and wet season from May to October. About 85% precipitation is in wet season. Runoff in the Basin is mainly contributed by precipitation and supplemented by groundwater and thawing snow.

The mean annual rainfall in the Basin is 996mm with a general distribution tendency of decreasing from south to north. Rainfall within a year is very uneven with obvious pluvial period and less rainy period, i.e. about 72-85% annual precipitation in wet season and 15-28% annual precipitation in dry season.

The Lancang River Basin covers the south part of Qinghai Province, east part of the Tibet Autonomous Region and south-west part of Yunnan Province with mean annual runoff of 74 billion m³ (Tab.1). The distribution of runoff depth is basically in accordance with precipitation. Runoff distribution within a year is also very uneven with 3 quarters of runoff in wet season and one quarter of runoff in dry season. There are abundant mountainous groundwater resources of 28.27 billion m³ and thawing water of 620 million m³ from iceberg with an area of 268.8 km², occupying 38.1% and 0.8% river runoff respectively in the Basin. Regional distribution of water resources in the Basin is uneven as well, which basically corresponds to regional distribution of precipitation with a general decreasing tendency from south to north.

Tab.1 Catchment's Areas and Water Resources Amount in the Lancang River Basin

Area	Catchment's area		Runoff Ratio in the Whole Basin %
	(10,000 km ²)	Proportion %	
Qinghai Province	3.7	22.5	15
Tibet Autonomous Region	3.89	23.7	16
Yunnan Province	8.85	53.8	69
Lancang River Basin	16.44	100.0	100.0

1.2 Water Resources Utilization

There are abundant water resources in the Lancang River Basin. However, the degree of water resources utilization is low due to topographic relief and complexity. In regard of water supply, water diversion dominates. In regard of composition of water consumption, water is mainly used for agricultural irrigation. According to statistics data in year of 2000, the actual annual water supply amount in the Basin is 2.3 billion m³, water for agriculture, industry, urban and rural life are 1.9 billion m³, 130 million m³, 80 million m³ and 170 million m³ with a proportion of 84%, 5.5%, 3.5% and 7.3% respectively.

Surface water provides main source for water supply in the Basin, 2.29 billion m³ surface water supplied in the year of 2000, it's about 99% of total water supply in the Basin. Surface water supply system is composed of water diversion, storage, lifting and other engineering. Total tapping amount of groundwater in the whole Basin is only 19.7 million m³, it's about 0.85% total water supply. In the year of 2000, water consumption per capita and per hectare in the Basin are 366 m³ and 1830 m³ respectively. Comparison of water consumption between the Basin and whole country in the year of 2000 is shown in Tab. 2.

Tab. 2 Comparison of Water Consumption between the Basin and Whole Country in 2000

Index	Per capita (m ³)	Comprehensive Index in City (l/person•day)	Index for Farmers' Life (l/person•day)	Index for Big Livestock (l/head•day)	Index for Small Livestock (l/head•day)	Index for Industry (m ³ /10000yuan)	Comprehensive Index for Irrigation (m ³ /hectare)
China	453	215	67	43	20	61	7125
Basin	366	185	47	38	17	122	8925

It can be seen from Tab.1 that water resources in the Basin is abundant and the utilization ratio of water resources is low relatively. At present, water consumption amount in the whole Basin is only 3% total water resources in the Basin. It can be seen from Tab.2 that quotas of water consumption per capita, comprehensive water consumption in urban area, water consumption of farmers' life and livestock are lower than average ones in China, while quotas for industry and irrigation are higher than average ones in China.

Currently water for agriculture occupies the main proportion of water consumption. As society and economy develop, proportion of water consumption of life and industry will be increased.

2. Water Resources Integrated Allocation in the Lancang River Basin

2.1 Taking Ecological Protection Zones and National Boundary as Index for First-Graded Allocation

The key of rational water resources allocation is to master water resources amount to be utilized at different river reaches. According to various factors such as water demand of sensitive ecological zones in the upstream and midstream of the Lancang River, present regional utilization of water resources, runoff contribution ratios in different areas, the min. and max runoff for maintaining ecological and present essential water demand is controlled at different reaches and in different seasons in order to draft the limits and time arrangement of inlet flow to and outlet flow from various areas in the Basin.

In view of essential demand of water resources utilization and good eco-system, index of water resources allocation among countries shall be determined in accordance with relevant provisions of international river conventions. Following factors shall be taken into account: social stability, food security, priority order of using right of water resources, regional priority, current situation of existing engineering, water resources saving and rational utilization, fairness and economic benefits etc.. Besides the consideration of eco-system water demand, demand of national economic development on water resources shall be taken into account.

2.2 Water Allocation Among Countries, Taking Outflow at National boundary and Ecological Critical Water Demand as Controlling Points

Water amount through the controlled section of upper river reach can be estimated which start from downstream to upstream by comparison between outflow at the national boundary and ecological critical water demand, as well as consider the total water consumption in upstream areas. In this way, total water allocation amount in

various areas can be determined. Meanwhile, water demand of economic development planning and population increase in areas will be analyzed. Under the precondition of guarantee of current essential water demand, it will be considered that water demand increase as the economic developing.

2.3 Based on Water Consumption Priority in Provinces

Under the prerequisite of controlling outflow at the national boundary, water resources will be reallocated for provinces in the Basin after water consumption priority is ordered. For the provinces in the Basin, it is necessary to arrange the priority order of water utilization which provides bases for water resources allocation among provinces, so as to realize the first-graded index and fulfill the targets of local hydro-power generation and irrigation.

3. Main Principles and Bases of Water Allocation in the Lancang River Basin

3.1 Main Principles of Water Resources Allocation in the Basin

Water resources allocation principles provide bases for the design of water allocation indexes and detailed allocation schemes. Thus water resources allocation in the Basin shall abide by the following principles.

(1) Principle of equitable and suitable utilization

Principle of equitable and suitable utilization is the most important principle of water resources allocation. In water allocation, the fairness embody is mainly in unify of water use quotas, consistency with level of per capita water use and regional water consumption

Therefore, following factors shall be considered in order to reflect the equitable and rational utilization of water resources:

- Geographical, fluvial, hydrological, climatic, ecological and other natural factors in the Basin;
- Social, economic and ecological water demands in different areas in the Basin;
- Population in different areas in the Basin;
- Present situation of water resources development and utilization in the Basin;
- Each regional water resources development and utilization planning in the Basin;
- Influence between regional water resources utilization in the Basin.

(2) Principle of loss compensation

Upstream and downstream relation is relative. For example, Qinghai Province is upstream to the Tibet Autonomous Region, while Tibet is upstream to Yunnan Province. Since the activity of water utilization in upstream areas usually affects downstream areas, so principle of loss compensation embodies responsibilities undertaken by upstream areas. Together with limits of inlet and outflow amount at regional borders, this principle can control inflow quality and quantity from upstream.

(3) Principle of benefit compensation

In view of runoff regulation in time and quantity in downstream areas, this principle needs cooperation with upstream areas. These requirements can not be imposed only by cooperative obligations, but be encouraged by benefit compensation principle, which is the concrete reflection of fairness, rationality and benefit sharing.

(4) Principle of information exchanges

Water resources features in the Basin are important bases for the water resources allocation within the Basin. Corresponding basic data are needed for agreement among the areas to control min. and max. inflow and outflow at boundary and it's time distribution.

(5) Principle of ecological priority

There is a need for various areas to maintain river ecology in order to protect aquatic biological diversity of this world-class River, which provides a stable and fundamental prerequisite for sustainable development of the Basin. In general, water resources in the Basin are abundant but with low degree of exploration. Compared with many other river basins, water quality in the Basin is better. Hence, this principle is practicable.

3.2 Determination Bases of Water Resources Allocation Schemes

According to principles of water resources allocation in the Basin, quantitative indexes of water resources allocation will be determined according to the following bases.

Basis 1: Contribution of various areas to river water amount

Water yield and contribution of different areas in the Basin shall be weighted in water right allocation, which will result in a significant influence on coordinating contradiction between water resources utilization and protection in different areas in the Basin.

Basis 2: Utilization priority of water resources

Utilization priority of water resources is determined by various water use targets and water resources conditions in the Basin. According to these water use target's affects to social stability and promoting economic sustainable development. To evaluate these aspect's function on maintenance of regional prosperity, equality development and poverty elimination ,then determine the weight ratio of priority of water. Usually, the life uses the water is given the first priority of water consumption. Due to difference of water resources quantity in different frequency years, so the water resources allocation also varied.

Priority orders of water resources utilization of the three areas in the Basin are: water for eco-environment comes first and water for other usage comes next for Qinghai Province; water for agriculture and animal husbandry comes first and water for eco-environment comes next for the Tibet Autonomous Region and Yunnan Province.

Basis 3: Determination of water quantity and quality for eco-environment of river interior and exterior according to ecological priority principle

Under the general tendency of realizing sustainable utilization of water resources, it is required to utilize water resources in an optimal manner in order to maintain better aquatic ecosystem. Water resources to be utilized in a river means the rest water amount after deduction of water for better circulation of aquatic ecosystem.

Future target in the source area of three rivers in Qinghai Province is to develop ecological protection zones without human beings. Taken ecology as a main target for water resources protection in this area, water for eco-environment is guaranteed in water amount allocation.

Basis 4: Maintenance of present rational utilization of water resources in the Basin

To select the index sign of water allocation is consideration the present case of water utilization in principle, and avoids future uncertainty and at the same time encourages rational utilization of water resources in areas .

Basis 5: Consideration of water demand for economic and social development

In water resources allocation, it will be taken into account fully that water resources utilization quantity and water use form. Essential irrigation water is determined which based on present population and cultivated land, and meet the needs of survival as well.

Basis 6: Consideration of water allocation indexes in different frequency years and periods

Because of uncertainty of climate and runoff changes, water allocation indexes shall be determined according to different frequency years and periods in order to fulfill basic water demand in the whole basin. It is better to adopt relative water amount to determine water allocation indexes in various areas of normal years, min. runoff in dry years, min. water allocation amounts in the areas, and water allocation amounts in wet and dry seasons.

Basis 7: Consideration of water demand composition in the areas

Water use in the Basin can be decomposed into following three parts: ecosystem environment water demand, current water demand and potential water demand for economic development. Ecosystem environment water demand can be divided into the interior and exterior ecosystem environment water demand of the river. So water resources allocation will be estimated on the basis of the above-mentioned parts.

4. Index System of Water Resources Allocation in the Lancang River Basin

4.1 Integrated Index System of Water Resources Allocation in the Basin

Integrated index system of water resources allocation in the Basin is mainly classified into three kinds:

The first kind indexes are controlling indexes of total water resources amount, which can be further divided into cross-section controlling indexes of certain reaches and regional controlling indexes of total water amount. The

former one means the indexes of total outlet water amount at the national boundary, inlet and outlet flow at regional boundary, max. water amount in wet season and min. water amount in dry season, while the latter one means controlling indexes of total water amounts of two provinces and one region in different frequency years.

The second kind indexes are water demand indexes for eco-environment, including ecological flow indexes of various reaches to maintain the healthy life of a river, min. water demand indexes for ecological protection zones, etc.

The third kind indexes are water consumption controlling indexes, i.e. micro-controlling indexes in the areas, which are used to control water allocation within the areas, such as quotas of various water consumption in two provinces and one region in the Basin.

These indexes reflect water resources allocation principles in the Basin with involvement of many aspects, such as catchment's areas and their proportions of two provinces and one region in the Basin, runoff contributions of the areas, precipitation, river runoff, runoff changes between dry and wet seasons, present situation of development and utilization of water resources, construction status of hydraulic engineering, water demand for life, production, ecology and social and economic development, social economy and population development in the Basin.

4.2 Water Resources Allocation Data Platform for the Basin

Establishment of real, precise and authoritative data platform provides a basis for water resources allocation in the Basin. Hence, two-level (national and regional) water resources allocation mechanism is executed based on international water laws and Chinese water laws. Starting from overall benefit of the Basin, two-levels water allocation principle are drafted and macro- and micro- water allocation index systems are established to allocate total water resources amount in the Basin and to control at different stretches.

Water resources allocation data platform formed is composed of following data: catchment areas and total water resources amounts of different countries in the Lancang – Mekong River Basin, catchment's areas and total water resources amounts of two provinces and one region in the Lancang River Basin, water resources amounts of two provinces and one region in different frequency years, runoff at various controlling cross-sections of the Lancang River in wet and dry seasons, average annual water demand for eco-environment of river interior and exterior, current water consumption of life, industry and agriculture in the Basin.

5. Integrated Water Resources Allocation Scheme in the Lancang River Basin

Water resources allocation in the Basin is based on the above allocation principles and in accordance with actual natural and economic development conditions in the Basin. In view of current situations, low development degree and vulnerable eco-environment of the River, water for eco-environment shall be guaranteed with consideration of water demand increase of future regional economic development at the same time.

The multi-graded water resources allocation scheme in the Basin can be divided into three levels. The first one is national level mainly determining the controlling outflow at the national boundary of the River. The second one is provincial or regional level mainly determining the controlling flow of two provinces and one region in the

Basin. The third one is to determine water allocation within two provinces and one region. Only first level water allocation is statistically analyzed and the second level water allocation is studied in this paper.

1. Statistical Analyses of the First-Level Water Amount

Statistical analyses mainly list outflow indexes of the River at the national boundary under the circumstances of average year, medium drought year of $p=75\%$ and extreme drought year of $p=95\%$. At present, it is not ready for water resources integrated management in the Lancang – Mekong River. In respect of water demand of history, reality and future development, only water resources status at the national boundary is statistically analyzed based on data of mean annual discharge and in different frequency years in the study.

Statistical analyses of the first-level water amount are as following.

- Under the circumstance of average year, mean annual outflow of the River at the national boundary is about 64 billion m^3 with controlling outflow in dry season of 48% mean annual runoff;
- Under the circumstance of medium dry year of $p=75\%$, mean annual runoff of the River at the national boundary is about 57 billion m^3 with controlling outflow in dry season of 46% mean annual runoff;
- Under the circumstance of extreme dry year of $p=95\%$, mean annual runoff of the River at the national boundary is about 51 billion m^3 with controlling outflow in dry season of 47% of mean annual runoff.

2. Allocation Scheme of the Second-level Water Amount

The scheme is mainly for water resources allocation among two provinces and one region in the Basin.

According to data provided by water resources allocation data platform for the Basin and principles for water resources allocation, the scheme includes flow controlling schemes of cross-sections of various reaches and regional water resources allocation schemes under circumstances of average annual, medium dry year of $p=75\%$, and extreme dry year of $p=95\%$.

Water resources allocation schemes in the two provinces and one region in different frequency years are as follows.

(1) Controlling flows at cross-sections of various reaches in the Basin are:

- At the cross-section of the Xiangda Station in Qinghai Province: mean annual flow is 139 m^3/s ; annual average flow is 112 m^3/s in medium dry years of $p=75\%$; annual average flow is 102 m^3/s in extreme dry years of $p=95\%$;
- At the cross-section of the Ludu Station in the Tibet Autonomous Region: mean annual flow is 454 m^3/s ; annual average flow is 393 m^3/s in medium dry years of $p=75\%$; annual average flow is 300 m^3/s in extreme dry years of $p=95\%$.

(2) Water resources allocation proportions in the areas are: 14.5% in Qinghai Province, 15.5% in the Tibet Autonomous Region, and 69% in Yunnan Province.

6. Conclusions

The multi-levels water resources allocation scheme in the Basin is drawn up on the basis of current exploration and utilization situation and analyses of measured runoff data of long series with combination of features and future economic development tendency in the Basin. The scheme requires not only to control flow at cross-sections of various reaches, but also to control total water resources amount in the areas. The scheme consideration of water sharing of an international river, current and future water demand and changes of water resources amount in different frequency years and seasons. So the scheme fundamentally reflects the practical situation in the Basin. However, there is no precondition for water resources integrated management in the Lancang -Mekong River at present. As water resources allocation scheme among countries, only real statistical data is preliminarily analyzed. Practical and rational water resources allocation scheme needs consultation with downstream countries under the prerequisite of international laws and conventions. Therefore, water resources allocation scheme in the Basin mainly focuses on the study of domestic water rights, taking the Lancang River as a pilot, which provides references for future water resources study on the Lancang -Mekong River.

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