Lancang-Mekong Cooperation Special Fund Projects

Water Quality Improvement Capacity Building for Lancang-Mekong Countries

生态环境部对外合作与交流中心
Foreign Environmental Cooperation Center

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Lancang-Mekong Environmental Cooperation Center

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Foreword

0.1 Geographic and Ecological Environment of the Lancang-Mekong Basin

0.1.1 Overview of Geography

The Lancang-Mekong River originated from Zaqu at the Gangguori Peak of Tanggula Mountains in Qinghai Province, China. The section between Changdu and Yunnan in China is called Lancang, while the section beyond the border through Nanla River Mouth is known as Mekong. From north to south, the Lancang-Mekong River runs through China's Qinghai, Tibet and Yunnan provinces and five other countries, i.e. Myanmar, Laos, Thailand, Cambodia, and Vietnam, and empties into the South China Sea in the Mekong Delta near Ho Chi Minh City, Vietnam. This important international river in Asia has a total length of about 4,900 km, ranking sixth in the world. It drains an area of810,000 km^2, as shown in Figure 0-1.

Figure 0-1 Lancang-Mekong River Basin

The Lancang-Mekong River flows in the north-south direction in China. Due to special geology and complex topography, there are various landforms in the basin, including snow-capped mountains and glaciers, plateau meadows, deep canyons, shallow hills, alluvial plains, and estuary deltas, which gives rise to rich and unique biodiversity. The basin stretches from the Qinghai-Tibet Plateau to the South China Sea, involving the cold zone, temperate zone, and tropical zone. Among Asian rivers, only the Yangtze River and the Ganges River have larger runoff than the Lancang-Mekong River.

According to the topography, the Lancang-Mekong River can be divided into two major parts. The upper river flows through a long narrow valley comprising about 1/4 of the total basin area, cutting through the Hengduan Mountains and the Yunnan-Guizhou Plateau. The lower river passes through the Khorat Plateau in Thailand, the western slope of Annan Mountains in Laos and Vietnam, and Thailand, Cambodia and Vietnam, before reaching the South China Sea through the distributary channels of the Mekong Delta in Vietnam.

According to the terrain, they can be further divided into five regions: Northern Plateau, Annan Mountains (Changshan Mountains), Southern Uplands, Khorat Plateau, and Mekong Plain. The Northern Plateau covers northern Laos and Lei and Chiang Rai provinces of Thailand, and has an elevation of 1500–2800m due to high mountains and deep valleys. The Annan Mountains extend 800 km from northwest to southeast, with steep slopes in the north and middle and hilly areas in the south. The southern and western slopes are prone to heavy rainfall because of southwest monsoon, while the central valleys are arid. The Southern Uplands include the Cardamom Mountains in Cambodia, with rolling hills in the east and hilly areas in the southwest. The Khorat Plateau occupies northeastern Thailand and some parts of Laos. It is a butterfly-shaped basin (about 500 km * 500 km), which receives the main tributary Mun River. The Mekong Plain is a large area of lowlands, including the Mekong Delta. Below Phnom Penh, the Lancang-Mekong River splits into two tributaries: the Mekong proper and the PaSak River. Below this point, the Mekong Delta spreads out to the coast and forms an area of about 64,750 km^2.

0.1.2 Main river systems

The mainstream length of the Lancang-Mekong River is 2,161 km in China, 1,987 km in Laos, 976 km in Thailand, 501 km in Cambodia, 265 km in Myanmar, and 229km in Vietnam. Many of the river boundaries are shared by countries. The Lancang-Mekong River Basin is rich in water resources, with an average annual runoff of 476.5 billion m^3 (as shown in Tables 0–1 and 0–2).

Table 0–1 Basic fact table of Lancang-Mekong River

Section	Length/km (% of the river)	Basin area /10^4 km^2 (% of the basin)	Annual runoff/100 million m^3 (% of the basin)	Water resources m3/s (% of the basin)
Lancang River	2161（44.3%）	16.44（20.2%）	761（16%）	2140（16%）
Mekong River	2719（55.7%）	64.66（79.8%）	4004（84%）	12650（84%）
Lancang-Mekong Basin	4880（100%）	81.10（100%）	4765（100%）	15060（100%）

Table 0–2 Water resources occupied by Lancang-Mekong countries

Country	Runoff mileage /km	Water resources m^3/s (% of the basin)	Basin area /104 km^2	Percentage in the basin area (%)	Percentage in the territorial area (%)
Myanmar	265	300（2%）	2.40	3.80	3.60
Laos	1987	5270（35%）	20.20	31.24	85.34
Thailand	976	2560（18%）	18.40	28.45	35.87
Cambodia	501	2860（18%）	16.17	25.00	89.34
Vietnam	229	1660（21%）	6.50	10.05	19.70

In China, there are many tributaries of the Lancang-Mekong River, of which the larger ones are the Bijiang River, Yangbi River, Weiyuan River, and Buyuan River. In the upper and middle reaches, the river flows through a deep, steep-walled, V-shaped canyon amid the Hengduan Mountains after rising the Qinghai-Tibet Plateau. In the lower reaches, it runs through a largely flat valley with many rapids and shoals.

The Lancang-Mekong River mainstream is wide and bendy. It flows to the lowlands through the Khone Falls in Laos, meets the Tonle Sap River in Phnom Penh, Cambodia, and enters the Vietnam Delta. The Lancang-Mekong River divides into two tributaries below Phnom Penh, i.e. the Mekong proper and the PaSak River, and further into three tributaries near the estuary to the sea. The Mum River located in Thailand is the largest tributary of the Lancang-Mekong River. Rising in Nakhon Ratchasima Province, the 550 km long river runs northeast, receives the Chi River, its main tributary after turning east, and finally enters the Mekong River. It has a drainage area of 154,000 km^2 and an average annual flow of 720 m^3/s. The Tonle Sap River is another large tributary of the Lancang-Mekong River. It rises in the Cambodia-Thailand border and runs southeast before draining the Mekong River in Phnom Penh. Two tributaries branching off near Phnom Penh and six other tributaries in the Mekong Delta, forming an area with nine estuaries known as "Nine Dragons". When the Lancang-Mekong River rises, water flows into the Tonle Sap Lake, expanding the lake area from 2,590 km^2 to 7,700 km^2. When the Lancang-Mekong River subsides in winter, water flows out of the Tonle Sap River. Tonle Sap Lake and Tonle Sap River are navigable.

Figure 0–2 Lancang-Mekong river systems

0.2 Establishment of the Lancang-Mekong Cooperation (LMC) Mechanism

The Lancang-Mekong River serves as a natural link that closely connects the six countries. In terms of historical origin, China and the Mekong countries are culturally similar good neighbors connected by rivers. In terms of practical conditions, China has forged comprehensive strategic partnership and political mutual trust with all the Mekong countries. The borders, river systems, and water, land, and air transportation routes closely link, like blood, the major economic zones and development resources of the six countries, creating prominent advantages for cooperation. It is based on a wide range of mixed interests that forward-looking visions and plans are required to strive to make the subregion a true community of shared future. Hence, the LMC mechanism has emerged as needed. At the 17th China-ASEAN Leaders' Meeting in November 2014, Chinese Premier Li Keqiang first proposed to establish the Lancang-Mekong dialogue and cooperation mechanism under the China-ASEAN (10+1) framework. In November 2015, the First LMC Foreign Ministers' Meeting was held in Jinghong, Yunnan, China to discuss the LMC framework and scope, which reached a consensus on cooperation. On this basis, the First LMC Leaders' Meeting took place in Sanya, Hainan, China on March 23, 2016, marking the formal establishment of the LMC mechanism.

0.3 Problems of water resource utilization and water environment protection in the Lancang-Mekong Basin

In the management and cooperative development of the Lancang-Mekong River, countries adopt different water resource development objectives and water environment protection measures due to disparities in geographic locations and socio-economic levels. Upstream countries (e.g. China and Laos) with steep terrain have great potential for hydropower development, while downstream countries (e.g. Cambodia and Vietnam) with flat terrain focus on irrigation and fishery. As a result of the asymmetric relations created by international rivers, downstream countries are often in a weak position relative to upstream countries. They are concerned that upstream water pollution, water transfer and storage, hydropower development, and channel clearing will damage the river's natural ecosystem and impair downstream water quality, and may reduce the production of fishery and agriculture, which is an important part of the national economy.

At present, there are four main contradictions in the development of Lancang-Mekong River Basin: i) China's upstream cascade hydropower development plan has caused anxiety in downstream countries; ii) Thailand has planned to transfer water from the Mekong mainstream to the Chi River and Mun River, two tributaries near Ubon Ratchathani Province, through a 200 km long canal, to solve the problem of irrigation in the dry season of its northeast land. The large-scale water transfer project has triggered unease of the downstream countries Vietnam and Cambodia; iii) Laos has begun to implement the Mekong mainstream development plan in recent years. The Xayaburi Hydropower Station and Dong Sahong Hydropower Station under construction have been confronted with strong opposition from Vietnam and Cambodia; and iv) Vietnam and Cambodia have built cascade hydropower stations on the shared tributaries Se San, Sre Pok and Se Kong, provoking disputes about the cross-border impact of hydropower development.

In addition, the Mekong River Commission (MRC) and China are divided in the governance system for the Lancang-Mekong River. With multiple parties involved, the river has not been well protected because of many factors. The agreements concluded by the MRC cannot be truly put into practice, hindering the overall planning. Due to the lack of awareness of basin-wide holistic environmental protection, each country acts in their own way and overprotects their own interests. Non-governmental organizations (NGOs) are not authoritative and forceful enough to solve the fundamental problems of environmental protection.

Despite the general trend of water resource cooperation, establishing an effective cooperation mechanism poses challenge to the Lancang-Mekong countries. "Water resources in the Mekong River Basin are moderately vulnerable... The contrasting scenario of abundant water availability and lack of water service provision in the Mekong River Basin calls for a balance between resource exploitation and maintenance of ecological health. There is an urgent need to reach consensus on equitable water utilization and management among co-riparian countries by consolidating ongoing cooperation," said the report entitled "Freshwater under Threat South East Asia—Vulnerability Assessment of Freshwater Resources to Environmental Change (Mekong River Basin)" jointly released by the United Nations Environment Programme (UNEP) and the Asian Institute of Technology (AIT) in 2009.

0.4 Cooperation and development in the Lancang-Mekong Basin

China has always taken a positive attitude towards reciprocal and win-win LMC. Leaders of the six countries announced the Sanya Declaration following the First LMC Leaders' Meeting. They agreed to carry out pragmatic cooperation in political security, economic and sustainable development, and social and cultural exchange, and to start with five priority areas, i.e. connectivity, production capacity, cross-border economic cooperation, water resources, agriculture, and poverty reduction.

In January 2018, the Second LMC Leaders' Meeting proposed to launch the Green Lancang-Mekong Initiative to advance Lancang-Mekong environmental cooperation. In March 2018, the Roundtable Dialogue on Lancang-Mekong Water Environment Governance was held in Yunnan to implement the initiative proposed by Chinese President Jinping for setting up a mechanism for water pollution investigation and monitoring and data sharing for the Belt and Road countries. In May 2018, the Shanghai Cooperation Organization (SCO) Environmental Information Sharing Platform, a sub-platform of the Big Data Platform, was officially launched, which strengthens the monitoring and data collection capabilities of countries along the route. Based on shared data, the Comprehensive Belt and Road Environmental Database was formed, serving the green Belt and Road Initiative by providing consulting services and decision support for international environmental cooperation among the Belt and Road countries. The China-ASEAN Environmental Information Sharing Platform was released in September 2018 and went online on the Big Data Platform website in December. The Big Data Platform can not only promote cooperation, but also benefit related scientific research in the Lancang-Mekong Basin.

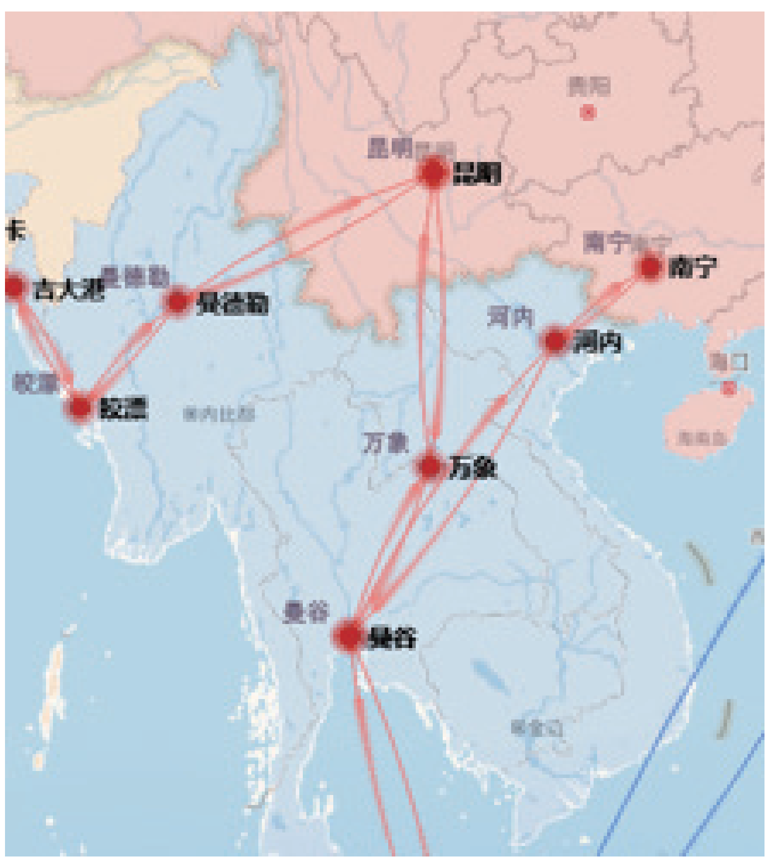


Figure 0-3 The Belt and Road routes through the Lancang-Mekong Basin

In November 2018, the First Lancang-Mekong Water Resources Cooperation Forum was opened in Kunming, Yunnan, which is an important event to implement the results of the Second LMC Leaders' Meeting. Under the theme of "Water Partnership and Sustainable Development", the forum aims to create a platform for policy dialogue, technical exchange and experience sharing on water resources. At the meeting, representatives of the five Mekong countries all spoke and reached consensus on supporting and advancing win-win water resource cooperation and exchange. In March 2019, the Lancang-Mekong Week Activity for Water: Youth Forum on Lancang-Mekong Water Resources Cooperation was successfully held in Nanjing. During the event, the Ministry of Water Resources (MWR) of China vigorously moved to strengthen high-level communication and coordination and actively carried out a series of technical exchanges, talent training and pragmatic cooperation projects in the field of water resources. The six Lancang-Mekong countries jointly formulated the Five-Year Plan of Action on for Lancang-Mekong Cooperation on Water Resources, drawing a blueprint for water resources cooperation and development. The LMC mechanism is a new subregional cooperation mechanism established spontaneously by the riparian countries based on their actual conditions and common needs, through which they discuss, build, share, and win together.

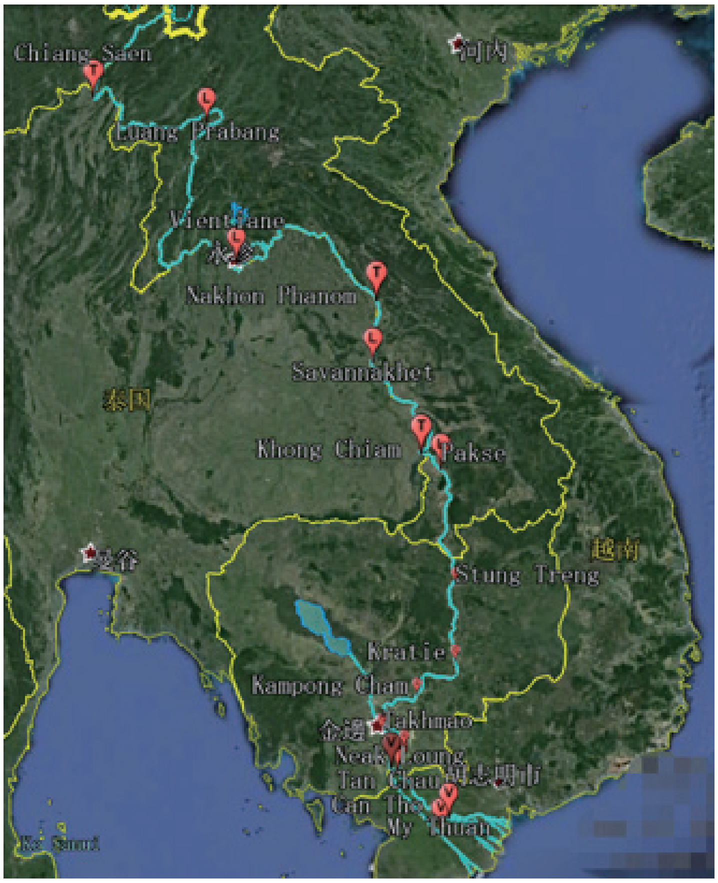
Chapter 1 Water Quality Status Analysis of Lancang-Mekong Countries

1.1 Sources of water quality monitoring data

In order to grasp the water quality status of the Lancang-Mekong River, the MRC established 22 conventional water quality monitoring stations in the basin, as shown in Table 1–1 and Figure 1–1. These basic monitoring stations can provide detailed water quality monitoring data. Myanmar's data largely come from literature research because the local monitoring stations are temporarily not open to the public. China's data are mainly sourced from the annual environmental status bulletins of Qinghai and Yunnan provincial departments of ecology and environment.

Table 1–1 Locations of 22 water quality monitoring stations in the Lancang-Mekong River Basin

No.	Station	River	Country	Latitude	Longitude
1	Houa Khong	Mekong	Laos	21.5471	101.1598
2	ChiangSaen	Mekong	Thailand	20.2674	100.0908
3	LuangPrabang	Mekong	Laos	19.9000	102.0000
4	Vientiane	Mekong	Laos	17.9281	102.6200
5	NakhonPhanom	Mekong	Thailand	17.4250	104.7744
6	Savannakhet	Mekong	Laos	16.5583	104.7522
7	KhongChiam	Mekong	Thailand	15.3255	105.4937
8	Pakse	Mekong	Laos	15.1206	105.7837
9	StungTreng	Mekong	Cambodia	13.5450	106.0164
10	Kratie	Mekong	Cambodia	12.4777	106.0150
11	KampongCham	Mekong	Cambodia	11.9942	105.4667
12	ChrouyChangvar	Mekong	Cambodia	11.5861	104.9407
13	NeakLoung	Mekong	Cambodia	11.2580	105.2793
14	KaormSamnor	Mekong	Cambodia	11.0679	105.2086
15	TanChau	Mekong	Vietnam	10.9079	105.1835
16	MyThuan	Mekong	Vietnam	10.2725	105.9100
17	MyTho	Mekong	Vietnam	10.3430	106.3505
18	Takhmao	Mekong	Cambodia	11.4785	104.9530
19	KohKhel	Mekong	Cambodia	11.2676	105.0292
20	KohThom	Mekong	Cambodia	11.1054	105.0678
21	ChauDoc	Mekong	Vietnam	10.9552	105.0867
22	CanTho	Mekong	Vietnam	10.0580	105.7977



With reference to China's surface water quality standards, water quality at the monitoring stations in the Lancang-Mekong River Basin is analyzed. Where the water quality indicators are not specified in China's standards, the MRC standards will be applied.

Table 1–2 China's surface water quality standards for eight indicators monitored by the MRC

Indicators	Unit	China's surface water quality standards				
		I	II	III	IV	V
Permanganate index (COD_{Mn})	mg/L	15	15	20	30	40
Dissolved oxygen (DO)	mg/L	7.5	6	5	3	2
Electrical conductivity (EC)	mS/m	——				
Ammonia nitrogen (NH_3-N)	mg/L	0.15	0.5	1	1.5	2
Nitrate (NO_3-)	mg/L	<10				
pH	/	6−9				
Total phosphorus (TP)	mg/L	0.02	0.1	0.2	0.3	0.4
Total suspended solids (TSS)	mg/L	——				

1.2 Water quality at the Lancang-Mekong monitoring stations

Through data analysis, it is found that between 2011 and 2017, the permanganate index (COD_{Mn}) at the 22 monitoring stations all met China's Class III standard for surface water, with relatively small intra-annual fluctuations. In specific, the indicator showed an upward trend at Vientiane in Laos; Chiang Saen in Myanmar; Vientiane, Nakhon Phanom, Savannakhet, and Khong Chiam at the junction of Thailand and Laos; Tan Chau, My Thuan, and My Tho in the Mekong proper basin and Chau Doc and Can Tho in the PaSak River basin in Vietnam. It tended to decline at other monitoring stations.

During the same period, dissolved oxygen (DO) reached China's Class III standard for surface water at all monitoring stations, except for Chau Doc in the Tonle Sap Lake Basin in Cambodia in 2017. The indicator exhibited a downward trend at Stung Treng in Laos; Khong Chiam in Thailand; Stung Treng, Kratie, Chrouy Changvar, Neak Loung, Tan Chau, Koh Khel, and Chau Doc in Cambodia; Tan Chau, My Thuan, and My Tho in the Mekong proper basin and Chau Doc and Can Tho in the PaSak River basin in Vietnam. It tended to rise at other monitoring stations.

Ammonia nitrogen (NH_3-N) at the 22 monitoring stations was stable between 2011 and 2016 before increasing in 2017, but overall, it met China's surface water quality standards in these past years.

Both electrical conductivity (EC) and nitrate nitrogen at the 22 monitoring stations between 2011 and 2017 maintained relatively stable and below China's Class III limit for surface water.

The total suspended solids (TSS) at the 22 monitoring stations were all below 50 mg/L between 2011 and 2016, but increased slightly in 2017. Generally, it conformed to China's sanitary standards for drinking water (<1000 mg/L).

The following conclusions can be drawn based on the analysis: At present, water in the Lancang-Mekong River Basin is basically in good condition as most of them can meet the Class III standards for surface water. The water quality at certain stations tended to deteriorate, so monitoring needs to be strengthened. For example, the dissolved oxygen at Chau Doc in the Tonle Sap Lake Basin in Cambodia exceeded the limit in 2017.

Chapter 2 Research on Water Quality Needs of Lancang-Mekong Countries

2.1 Water demand analysis

Abundant in water resources, Lancang-Mekong countries are fully able to meet respective annual freshwater demand. Among them, Myanmar boasts the greatest availability of water resources, but the water demand is very small, equal to 3.31% of the total freshwater resources.

In China, Qinghai, Tibet, and Yunnan provinces have the largest demand for surface water resources from the Lancang River because of the high population density and strong economic development demand in the lower reaches. Thailand also uses a high ratio of the surface water resources in the Mekong River Basin. While the relatively large amount of surface water resources in the large basin satisfies the demand in the country, economic development has brought more pollution loads to the Mekong River. The amount of water resources and the ratio of water demand in Lancang-Mekong countries are as shown in Figure 2–1.

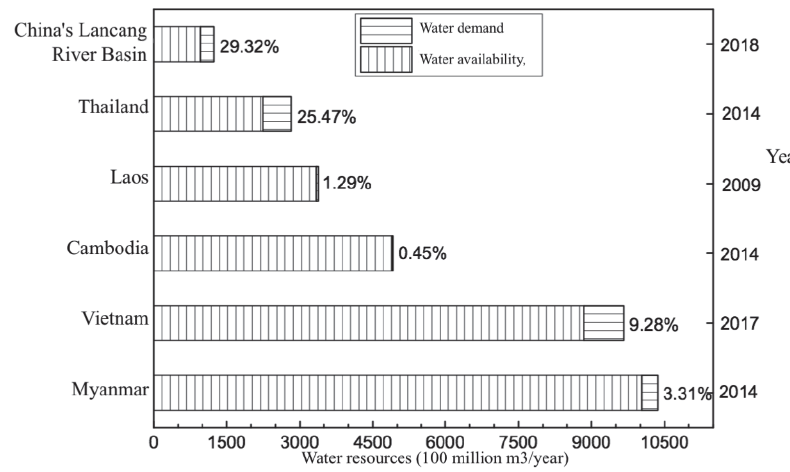


Figure 2–1 Amount of water resources and ratio of water demand in Lancang-Mekong countries (Source: WEPA 2018)

In terms of freshwater use structure, agriculture accounts for a very high proportion of water use in various countries, with an average of 90.5%. Among them, Vietnam presents the highest proportion and China, the lowest proportion, as shown in Table 2–1 and Figure 2–2.

Table 2–1 Agricultural water use in Lancang-Mekong countries

	Water use (100 million m^3/year)	Proportion of agricultural water use (%)	Agricultural water use (100 million m^3/year)
Vietnam	820	94.8	777.36
Thailand	573	90	515.7
Myanmar	332	89	295.48
Lancang River Basin, China	280	82	229.6
Laos	43	93	39.99
Cambodia	22	94	20.68

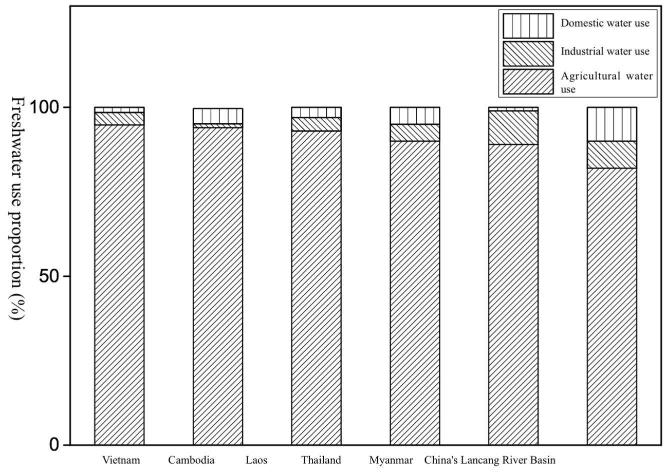


Figure 2–2 Freshwater use comparison of Lancang-Mekong countries

The high proportion of agricultural water use reflects the economic development status of Lancang-Mekong countries (or southwestern provinces in China). Compared with industry, agriculture does much smaller harm to rivers, and it is unlikely to cause malignant water pollution incidents. Nevertheless, agricultural pollution is a non-point source pollution, with harmful substances left by pesticides more difficult to manage. It can only be solved gradually by developing eco-agriculture, such as making best use of biological agents to kill insects; controlling the application of pesticides and fertilizers; and improving the cost efficiency of pesticides.

The proportion of industrial water use averages 5.3% in Lancang-Mekong countries. Vietnam and Thailand have a lower proportion of industrial water use than China's Lancang River Basin and Laos, but Myanmar, Vietnam, and Thailand take the top three positions in terms of the amount of industrial water use.

Table 2–2 Industrial water use in Lancang-Mekong countries			
	Water use (100 million m^3/year)	Proportion of industrial water use (%)	Industrial water use (100 million m^3/year)
Vietnam	332	10	33.2
Thailand	820	3.7	30.34
Myanmar	573	5	28.65
Lancang River Basin, China	280	8	22.4
Laos	43	4	1.72
Cambodia	22	1.15	0.253

The proportion of domestic water use averages 4.2% in Lancang-Mekong countries. China's Lancang River Basin far exceeds several other countries, with Myanmar at the bottom. Thailand is second to China's Lancang River Basin, although with the second largest population, it uses the most water in the domestic sector. Vietnam tops in both water use quantity and population base, but domestic water use represents a very low proportion of only 1.5% in water use, ranking only third.

Table 2–3 Domestic water use in Lancang-Mekong countries			
	Water use (100 million m^3/year)	Proportion of domestic water use (%)	Domestic water use (100 million m^3/year)
Vietnam	573	5	28.65
Thailand	280	10	28
Myanmar	820	1.5	12.3
Lancang River Basin, China	332	1	3.32
Laos	43	3	1.29
Cambodia	22	4.48	0.9856

2.2 Water environment management legislation comparison and recommendation

The water environment management regulations of Lancang-Mekong countries are as shown in Table 2–4.

Table 2–4 Relevant laws on water environment protection in Lancang-Mekong countries

Country	Main laws
China	Law of the People's Republic of China on Water Pollution Prevention and Control, Environmental Protection Law of the People's Republic of China, Water Law of the People's Republic of China, Law of the People's Republic of China on Soil and Water Conservation, Flood Control Law of the People's Republic of China, and Environmental Impact Assessment Law of the People's Republic of China
Cambodia	Law on Environmental Protection and Natural Resource Management, Law on Water Pollution Control, Drinking Water Standard, and Law on Water Resource Management
Laos	Law on Water and Water Resources, Policy on Water and Water Resources, Environmental Protection Law, and Agreement on National Environmental Standards
Myanmar	Pesticides Law, and the Conservation of Water Resources and Rivers Law
Thailand	Groundwater Law, and the Enhancement and Conservation of National Environmental Quality Law
Vietnam	Law on Water Resources, National Water Resources Strategy, and Environmental Protection Law

The comparative analysis reveals that:

Myanmar has not yet established a legal system for water environment governance, so it still lags far behind other Lancang-Mekong countries. Currently, there is only the Conservation of Water Resources and Rivers Law in place. The Environmental Protection Law was adopted in 2012, marking a major leap forward in Myanmar's environmental protection cause.

Cambodia's main water legislation is the Law on Environmental Protection and Natural Resource Management passed in 1996. The law stipulates the implementation of a system that combines the development and protection of natural resources in the country, but it does not yet form a legal system.

Vietnam's environmental legal system is composed of some core laws covering major areas of environmental protection. It includes the Environmental Protection Law promulgated in 1993, and the Law on Water Resources promulgated in 1998.

Laos has fostered a preliminary legal system of environmental protection, and achieved certain results in environmental protection under this system, but the law enforcement and supervision system are still not perfect.

Thailand does not have a special environmental impact assessment law, but reflects this in the Environmental Quality Law.

All countries in the Lancang-Mekong River Basin have formulated relevant laws on water environment governance. However, the standards differ in content and degree of perfection. It is more necessary for Lancang-Mekong countries to strengthen cooperation and learn from each other, so as to gradually build a perfect, united legal system for water environment governance.

2.3 Analysis of water pollution treatment facilities and the recommendations

Countries in the middle and lower reaches are relatively economically backward, and to a large extent, financially constrained in the work on water pollution control. Through investigation and research, the water treatment technologies of Lancang-Mekong countries are analyzed as shown in Table 2–5.

Table 2–5 Sewage treatment technologies of Lancang-Mekong countries

Country	Sewage treatment facilities	Sewage treatment process
Laos	No corresponding sewage collection and treatment system	1.1 Direct sewage discharge
Myanmar	No complete set of laws and regulations on water pollution prevention and control; No corresponding sewage collection and treatment system	1.1 Direct sewage discharge
Thailand	Sewage treatment plants built	1.1 Stabilization tank, aeration oxidation tank, activated sludge system
Cambodia	Ditches built to collect and process sewage	1.1 Centralized sewage treatment
Vietnam	Centrally operated sewage treatment plants constructed, but lack of sewage collection facilities	1.1 Centralized sewage treatment system
China	Improving urban sewage treatment technologies, but relatively conservative treatment methods; Lack of scale effect and standard for rural sewage treatment; Missing rural sewage discharge standards, and imperfect evaluation index system	1.1 Traditional activated sludge method; 1.2 Reaction tank process of continuous circulation aeration system (CCAS); 1.3 Biological treatment technology, ecological treatment technology, and combined treatment technology; 1.4 An/O and its refined technology, oxidation ditch technology, and SBR technology

Obviously, Laos and Myanmar basically do not have sewage treatment facilities. In particular, Myanmar, which has been in a state of war for a long time, is in extreme shortage of infrastructure. Compared with Cambodia and Vietnam, Thailand has basic sewage treatment facilities and uses the most basic sewage treatment processes. Compared with countries in the middle and lower reaches, China has formed relatively mature sewage treatment technologies, as shown in Table 2–6. Sewage treatment facilities in various countries cannot achieve full coverage, especially for rural sewage collection and treatment.

Table 2–6 China's urban sewage treatment processes

Process classification	Number of sewage treatment plants/%	Total design processing capacity/10,000 m^3/d	Average design processing capacity/10,000 m^3/d	Maximum processing capacity/10,000 m^3/d	Minimum processing capacity/10,000 m^3/d	Process type
Activated sludge process	10/0.7	299.5	29.95	170	0.5	* Traditional activated sludge method, etc.
An/O and its refined processes	541/39.5	4587.76	8.48	280	0.25	* A/O, A2/O, inverted A2/O, A2/O+MBR, UCT and MUCT, Barton, multi-stage multi-stage A/O, OCO process, etc.
Oxidation ditch	390/28.4	1467.23	3.76	30	0.3	* Carrousel (2000), DE, Orbal and the modified oxidation ditch, integrated oxidation ditch
SBR process	242/17.7	995.22	4.11	50	0.13	* Traditional SBR, CASS and its improvement, CAST, IC TANK and its improvement, DAT-IAT, AICS, CTECH, ZT UNITANK, etc.
Biolac process	37/3.0	107.7	2.91	10.6	1	* Biolac and modified Biolac, suspension chain aeration, etc.
Artificial wetland process	22/2.7	56.05	2.55	25	0.1	*(Enhanced) constructed wetlands, ecological treatment system (ETS), high-efficiency compound pond + constructed wetlands, artificial rapid infiltration, etc.
Biofilm process	52/3.8	218.53	4.2	40	0.025	* Biological aerated filter, moving bed biofilm reactor, biological contact oxidation, biological fluidized bed, floating biological bed, etc.
MBR and its modification	12/0.9	94.15	7.42	16	0.3	* AB method, silica gel soil, oxygen-enriched aeration, some compound processes, different technologies used in the first and second phases, etc.
Other processing technology	64/4.7	507.3	7.93	35	0.5	* AB method, silica gel soil, oxygen-enriched aeration, some compound processes, different technologies used in the first and second phases, etc.

In China's urban sewage treatment system, the average operating load rate is 77.3%, and the average power consumption per unit of sewage is 0.33 kWh/m3. Among them, oxidation ditch registers the highest load rate of 83.5% and unit power consumption lower than the average. Biolac process presents the lowest load rate of 70.5% and the unit power consumption higher than the average. In general, compared with several other countries in the Lancang-Mekong River Basin, China possesses the highest level of wastewater treatment technologies. Especially in most parts of Yunnan as tourist cities, the local government attaches great importance to water pollution prevention and control.

The selection of sewage treatment plants and processes needs to take into account various factors, including the treatment efficiency and economic benefits of sewage treatment plants and the financial support for government agencies. Sewage treatment is subject to discharge standards. In the light of this, we need to adopt appropriate sewage treatment processes, establish sewage treatment plants, or improve the existing sewage treatment system, according to the local needs of discharging or re-using reclaimed wastewater. On this basis, bearing in mind financial support and benefit maximization, we should ensure that the local economic development is not constrained by environmental protection while protecting the water environment, with a view to harmonious development of man and environment. In addition, it is not necessarily better to apply stricter discharge standards to sewage treatment plants. For the purpose of harmony between man and nature, we must look into the negative impact of discharge standards on the local economy along with environmental protection. The actual situation of various countries should be considered when formulating discharge standards. For some economically underdeveloped areas with low level of sewage treatment technology, stringent discharge standards will greatly limit their overall sewage treatment capacity. For areas with different environmental capacity and environmental carrying capacity, the adoption of completely unified discharge standards without considering the above-mentioned factors would not effectively help to govern the water environment. Therefore, the formulation of national discharge standards should take full account of regional applicability and scientificity. All areas should suit standards to local conditions, and comprehensively consider the impact of local environmental carrying capacity, treatment technology, and economic development on the sewage treatment industry.

It can be learnt from the above analysis that Chinese environmental engineering companies can go out and help countries in the lower Mekong basin to improve water treatment infrastructure. Such companies will be able to develop their capacities to the fullest to contribute to the sustainable development of the Lancang-Mekong River Basin.

Chapter 3 Research on Water Quality Management Technology in the Lancang-Mekong River Basin

3.1 Water pollution load management

The monitoring data on water environment indicators at 22 monitoring stations in the Mekong River Basin are made public by the MRC. Most of these monitoring stations are built in densely populated areas and are away from each other, except for some concentrated sites. In Cambodia, the Mekong River is mainly divided into the Mekong proper and the Tonle Sap Lake. On the two sides of the river, water quality monitoring stations are relatively closely set up, considering agriculture and dense population. The monitoring station near Tonle Sap Lake can monitor the quality of urban sewage discharged from Phnom Penh.

Based on the data of these monitoring stations, the pollution load of each section of the Lancang-Mekong River can be estimated. Among them, the pollution load of chemical oxygen demand (COD) in 2017 is as shown in Figure 3–1.

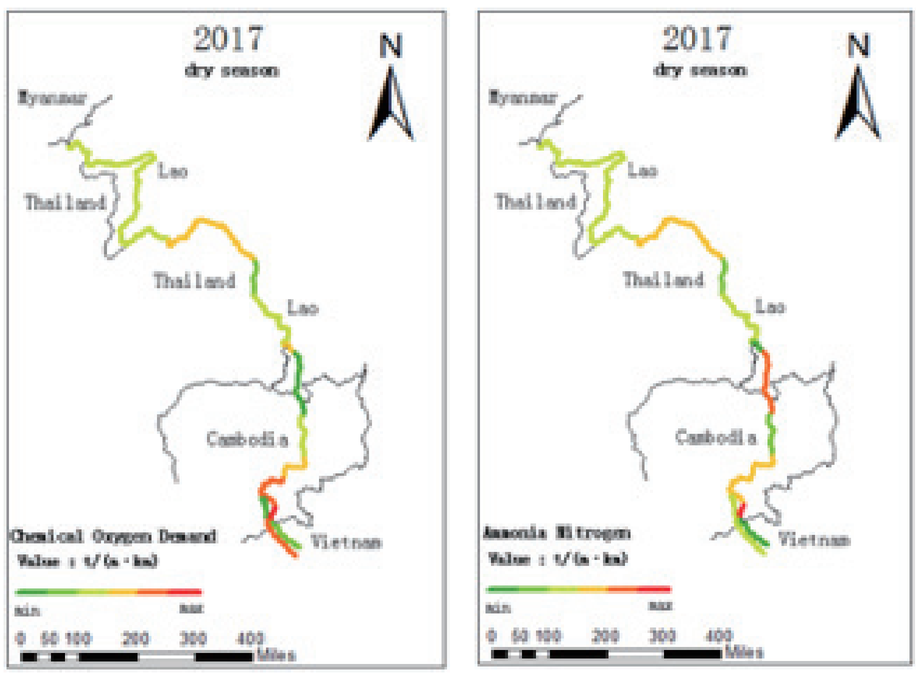


Figure 3–1 COD and NH_3-N pollution load in the Lancang-Mekong River Basin, the dry season of 2017

According to the calculation results, the overall pollution load of the Lancang-Mekong River is relatively small, largely because industrial production capacity has not yet been fully developed in the basin. In specific, the largest COD pollution load occurs in the middle section in Laos and Thailand and the section at the border between Cambodia and Vietnam. The NH_3-N pollution load is heaviest at the junction of Laos and Cambodia. With the rapid economic development in the basin, the water pollution load of the Lancang-Mekong River will increase. Therefore, it is necessary for the government departments of all countries to perform appropriate water environment governance and formulate basin-wide water environment plan in advance.

3.2 Water environment capacity analysis

To further analyze the pollution load that can be accommodated in each section of the Lancang-Mekong River in the future, water environmental capacity is estimated based on China's Class III water quality standards for surface water, as shown in Figure 3–2.

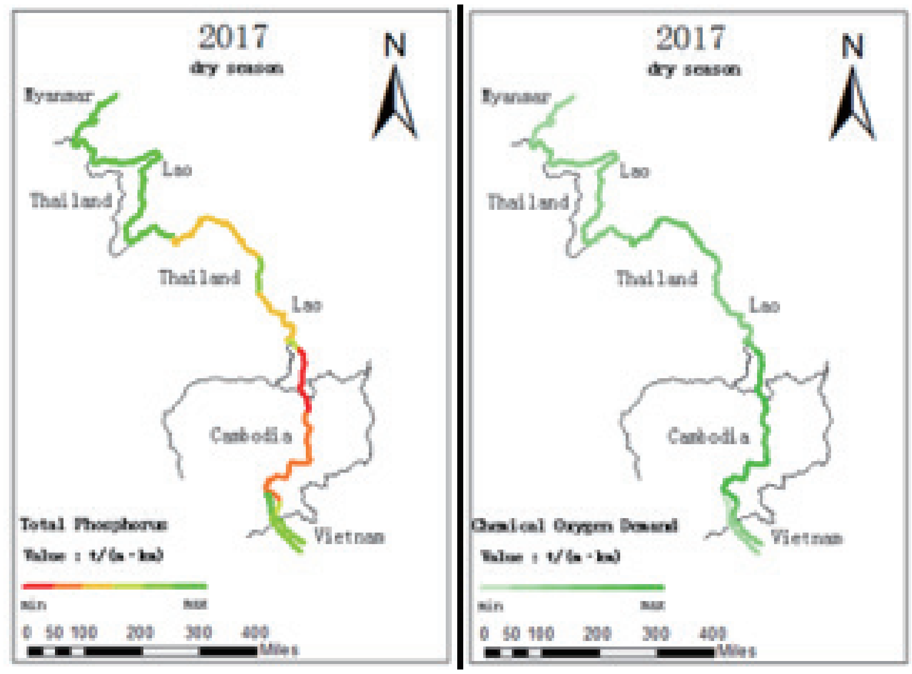


Figure 3–2 Environmental capacity of TP and COD in the Lancang-Mekong River Basin, the dry season of 2017

It is found that the Lancang-Mekong River has relatively large environmental capacity of COD overall. As to TP, the environmental capacity is relatively low in the sections of Laos entering Thailand and Cambodia, but significantly higher than the limit in Cambodia and Vietnam. Due to dense population and advanced agriculture, Cambodia and Vietnam fail to meet the TP standard, though performing well in other indicators. The local governments should adopt policies specific to production practices to reduce the pollution load in low environmental capacity sections.

Chapter 4 Research on Water Quality Improvement Pathways for the Lancang-Mekong River Basin

4.1 Information system construction for water environment governance

4.1.1 Unified water quality monitoring standards

Unified water quality standards are the basis for water quality management of international rivers. In accordance with the principle of strict water environment protection of the Lancang-Mekong River Basin, it is recommended to establish the Water Environment Indicator System and Standard Value System based on the surface water quality standards of various countries, as detailed in Table 4–1.

Table 4–1 Water environment indicator system and standard value system for the Lancang-Mekong River Basin Unit: mg/L

No.	Indicator	I	II	III	IV	V	Method	Indicator source
1	Water temperature (°C)	Human-induced changes in environmental water temperature should be limited to: Weekly average maximum temperature rise ≤1 Weekly average maximum temperature drop≤2					On-site measurement	China
2	pH	6~9					On-site measurement	Thailand
3	DO≥	7.5	6	5	3	2	On-site measurement	China
4	COD_{Mn}≤	2	4	6	10	15	GB11892-89	China
5	COD≤	5	10	30	40	50	GB11914-89	Vietnam
6	BOD_5≤	1.5	2	4	6	10	HJ505-2009	Thailand
7	NH_3-N≤	0.15	0.5	1.0	1.5	2.0	HJ535-2009	China
8	NO_3--N	1	2	5	10	15	Liquid ion chromatography	Vietnam
9	NO_2--N	0.05	0.1	0.2	0.4	0.5	Liquid ion chromatography	Vietnam
10	TP≤	0.02	0.1	0.2	0.3	0.4	GB11893-89	China
11	TN≤	0.2	0.5	1.0	105	2.0	HJ636-2012	China
12	Copper ≤	0.01	0.1	0.2	0.4	0.5	HJ700-2014	Vietnam
13	Zinc ≤	0.05	1.0	1.0	2.0	2.0	HJ700-2014	China
14	Arsenic ≤	0.05	0.05	0.05	0.1	0.1	HJ700-2014	China
15	Mercury ≤	0.00005	0.00005	0.0001	0.001	0.001	HJ694-2014	China
16	Cadmium ≤	0.001	0.005	0.005	0.005	0.01	HJ700-2014	China
17	Chromium (+6) ≤	0.01	0.05	0.05	0.05	0.1		China
18	Lead ≤	0.01	0.01	0.05	0.05	0.1	HJ700-2014	China
19	Cyanide ≤	0.005	0.05	0.2	0.2	0.2	HJ484-2009	Vietnam
20	Fecal E. coli (Pcs/L) ≤	200	2000	10000	20000	40000	HJ/T347-2007	China
21	DDT	0.001	0.005	0.01	0.015	0.02	Gas chromatography after	Vietnam
22	Dieldrin	0.01	0.05	0.10	0.13	0.15	liquid-liquid extraction	Vietnam

According to the principle of strictness, China's surface water quality standards are adopted for such indicators as DO, COD_{Mn}, NH_3-N, TP, TN, zinc, arsenic, mercury, cadmium, chromium (+6), lead, and fecal E. coli. Vietnam's standards are applied to the indicators of COD, NO_3-N, NO_2-N, copper, cyanide, DDT, and Dildrin, and Thailand's standards to BOD_5.

Few of the six Lancang-Mekong countries have established the Pollutant Discharge Standards. In view of serious experience inadequacy, the MRC standards and China's national standards for wastewater discharge can be considered, and the final standards need to be further improved through negotiations.

4.1.2 Water quality monitoring stations and real-time information transmission network

The comprehensive development of water resources and management of water environment in the Lancang-Mekong River Basin involve multiple countries and fields with different objective and requirements, which calls for multi-objective coordination. To this end, it is necessary to build water quality monitoring stations and real-time information transmission network to facilitate information sharing. The data shared will provide decision support for comprehensive water environment governance of riparian countries.

According to the requirements of basin water environment governance, it is recommended to set up about 50 standard monitoring stations, approximately every 100 km away from each other along the river, of which some can be retrofitted on the basis of existing stations. These standard monitoring stations adopt advanced means to conduct automatic real-time monitoring and manual emergency monitoring, and share monitoring data in a timely manner through the network.

Based on the information sharing system, integrated information database, and decision-making system, the objectives and standards for water resources and water environment management of different countries are analyzed by taking the Lancang-Mekong River Basin as a whole ecosystem. Through information analysis and water quality prediction model, the gap between the current water quality status and the water environment management objectives is measured. The impact of actual chemical, physical and biological changes on the ecological environment of the water body is also assessed. On this basis, appropriate measures can be taken to mitigate the damage to the water environment and maximum the protection of interests of various countries.

For the purpose of information openness and transparency, it is necessary not only to establish information sharing platforms in different countries, but also to strengthen information sharing among different administrative regions. This will reduce international and regional disputes while promoting cross-border river cooperation and the Lancang-Mekong integration.

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4.1.3 TMDL-based water environment management mechanism

A water environment management mechanism should be built based on total maximum daily loads (TMDL) for the Lancang-Mekong River Basin to implement refined and accurate management. First, based on ARC GIS, a water environment management system should be established to collect real-time data from water quality monitoring stations and form a database that includes water governance objectives, spatial information, monitored water level, water quantity, and multiple water quality indicators for each section. Then, section-specific water pollution load and water environment capacity are carefully estimated. Measures for dynamic allocation of pollution load will be adopted to achieve section-specific water quality objectives. The mechanism is as shown in Figure 4–1.

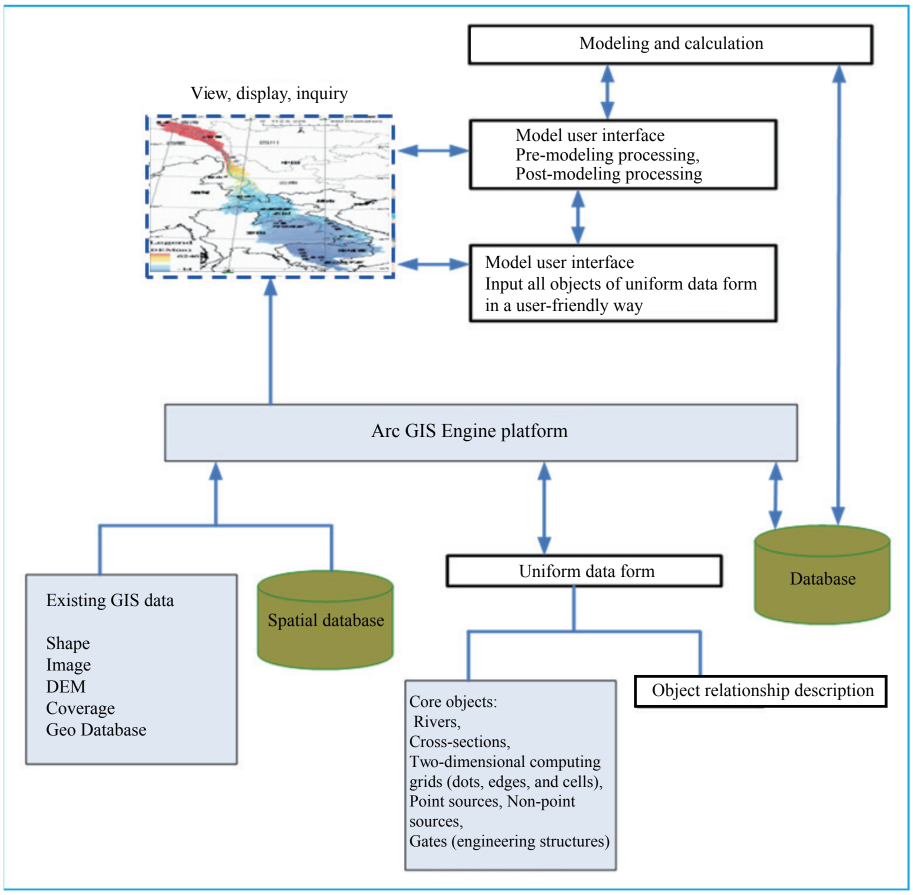

Figure 4–1 ARC GIS water environment management information platform

The overall water quality of the Lancang-Mekong River Basin should at least meet China's Class III standards for surface water. First, the main sources of major pollutants are analyzed on the basis of the division of water area functions. Then, a cap control system that covers sources, outlets and water quality will be established, and appropriate discharge standards developed for relevant major pollutants. The two are combined to serve water environment management objectives. At the same time, biodiversity changes in the basin are also included in the scope of water environment management. Riparian countries should put into practice water pollution prevention and control of each section and coordinate economic development with the overall environmental protection objectives.

4.2 MRC-based establishment of Lancang-Mekong River Commission (LMRC)

4.2.1 "4+2" cooperation model

Drawing on the advanced management experience of international rivers such as the Rhine and Danube, it is recommended that the six Lancang-Mekong countries establish the Lancang-Mekong River Committee based on the MRC to form a "4+2" cooperation model. The LMRC's mission is to promote equitable and sustainable water resource management. It will actively engage member countries in to provide a platform for the sustainable use and integrated management of water resources. The LMRC, also called International Commission on Water Environmental Protection of the Lancang-Mekong River, will make efforts in ensuring water quantity and quality, controlling pollution sources, improving the ecological environment for many species, and protecting the basin from pollution. In addition, it will adopt a multi-participatory approach to ensure comprehensive decision-making on the management of water resources in the Lancang-Mekong River Basin, including cooperation with national organizations, international organizations, NGOs, and scientific research groups.

According to the actual needs of the Lancang-Mekong River Basin, the following six departments can be set up under the proposed committee:

(1) The Lancang-Mekong Coordination Office is mainly responsible for reviewing and voting on the water environment planning and convention drafting of the subordinate departments, and coordinating the unified actions of the six riparian countries based on the resolutions and plans adopted by the vote; (2) The Department of Water Resource Management has the responsibility of formulating and implementing water resource planning to meet the water demand of the six riparian countries for sustainable development; (3) The Department of Water Environment Management mainly takes charge of water environment issues, such as the formulation of surface water quality standards and sewage standards; water quality monitoring and reporting; supervision and law enforcement for water environmental protection; control of point and non-point source pollutant discharge; and in particular, ecological compensation accounting; (4) The Department of Water Shipping Management is mainly responsible for shipping licensing and related shipping rules, as well as waterway construction; (5) The Department of Disaster Emergency Management has the following responsibilities: forecasting floods and droughts; reducing economic losses caused by disasters; developing sustainable flood and drought prevention planning; formulating incident reduction strategies and planning; implementing the incident early warning system; and developing the emergency plan; (6) The Department of Sustainable Development takes charge of economic cooperation in the sustainable development of the six riparian countries to protect the aquatic environment from pollution caused associated with economic development.

The LMRC's organizational structure and functions are as shown in Figure 4–2.

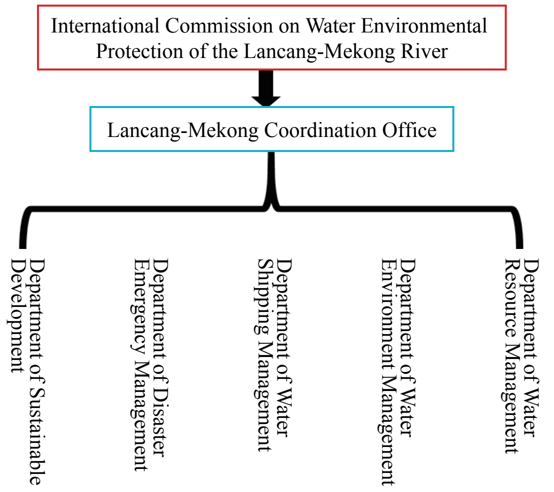

Figure 4–2 LMRC's organizational structure

The LMRC has the right to manage the river basin in a unified way and to plan unified water environment governance. An international river basin convention can be concluded by the six riparian countries to stipulate the LMRC's status, composition, and rights, and empower the LMRC to manage the Lancang-Mekong River across borders and across sectors beyond nations.

4.2.2 Legal system

Legal system is the basis for establishing an efficient governance system. Due to disparities in hydrogeography, natural environment, and socio-economic development of riparian countries, it is necessary to formulate basin governance laws adapted to the national conditions of countries in the Lancang-Mekong River Basin, in order to facilitate more practical resource regulation and management. Currently, the six riparian countries lag behind in terms of basin legislation as there is a lack of laws on specific issues and comprehensive planning of international rivers, as well as water pollution prevention plans.

The Lancang-Mekong River involves the vital interests of nearly 500 million people in six countries. It is necessary to formulate a legal system at the international basin level as the problems of the river cannot be addressed only by individual countries alone or cooperation of some countries. For example, comprehensive basin management legislation has been established for the protection and management of the Rhine, encompassing the Convention on the Protection of the Rhine as the foundation, relevant laws and regulations on water pollution control, and basin environment planning. The Danube River Protection Convention and related environmental action plans have been adopted to support water pollution prevention and comprehensive management of the basin. Therefore, the legal system for the governance of the Lancang-Mekong River should be improved by developing laws on comprehensive environmental management and regulations for water pollution prevention and control. It will provide an important guarantee for the prevention and control of water pollution in the basin.

The laws and regulations for environmental management of the Lancang-Mekong River should reflect the principle of comprehensive management based on the natural attributes of the river. They should clearly stipulate the authority and organization of comprehensive management agency, set forth the comprehensive water environment management planning and resource development and utilization system, and contain provisions on the resolution of water resource disputes and water pollution incidents. Environmental quality and pollutant discharge standards for the Lancang-Mekong River should be formulated based on the water pollution control and environmental standards of riparian countries. The principles and objectives of water pollution prevention and control should be clarified, taking into account the diverse water functions of the basin. A water quality centered basin monitoring system should be established. In addition to specific requirements for production and construction planning, a water pollution compensation liability system should be set up.

4.2.3 Responsibilities and objectives

Drawing on the experience of the International Rhine Commission, the LRMC can be divided into three basic commissions for the governance of the Lancang-Mekong River: International Commission for the Protection of the Lancang-Mekong River, Central Commission for the Navigation of the Lancang-Mekong River, and International Commission for the Hydrology of the Lancang-Mekong River. The International Commission for the Protection of the Lancang-Mekong River is responsible for investigating pollution sources, pollutant transportation and sedimentation, providing advice to the governments of riparian countries, drafting and implementing agreements for the protection of the Lancang-Mekong River, and formulating flood control action plans. The Central Commission for the Navigation of the Lancang-Mekong River is responsible for shipping cooperation of riparian countries, waterway maintenance, and the development of standardized technical and policy guidelines. The International Commission for the Hydrology of the Lancang-Mekong River is responsible for promoting cooperation between hydrological institutions, carrying out data and information exchanges and collection and literature research, conducting and facilitating scientific research, and establishing a hydrogeographic information system for the Lancang-Mekong River Basin.

On this basis, with reference to the International Commission for the Protection of the Danube River, expert groups or task groups with clearly defined responsibilities can be set up under the the LRMC: flood prevention, ecology, discharge, incident prevention & control, water quality, and river basin management.

In line with the concept of TMDL-based refined management, the water environment protection data of various river basins in various countries will be collected. On the basis of the existing MRC facilities, an incident warning system covering the entire Lancang-Mekong River will be built, including monitoring stations on the mainstream and on tributaries with relatively dense per capita distribution. The system should disclose flood warning information and water pollution warning information. Its database will contain not only the hydraulic characteristic values of each tributary, but also source-specific pollutant discharges, water quality standards for pollutant discharges, dynamic water quality monitoring data, potential affected range and spread speed of water pollution, and pre-cautionary measures taken by these tributaries. Monitoring stations that have reached the standards, monitoring stations that fail to meet the water quality standards, and the progress of required rectification are clearly reflected in the entire system. This system will bring considerable ecological and social benefits to the riparian countries. Of course, the premise of achieving goals is to take into account the interests of all riparian countries and the sustainable development of the Lancang-Mekong River Basin.

Chapter 5 Conclusions

(1) The water quality of the Lancang-Mekong River basically meets China's Class III standards for surface water, with some indicators of individual sections exceeding the limits.

(2) Among the riparian countries, China has relatively mature sewage treatment technology, while other countries lag behind in water treatment facilities, especially Myanmar and Laos. Chinese environmental protection companies can help other countries to build water treatment facilities to achieve sustainable development of the basin.

(3) Pollution load is relatively small in most sections of the Lancang-Mekong River, with the largest in the sections within Laos, southern Thailand, and Cambodia. Environmental capacity is relatively small in the upper sections from Laos into Thailand and the lower sections from Laos to Cambodia, but far exceeds the limits in sections of Cambodia and Vietnam.

(4) It is recommended to form the LMRC by adding Myanmar and China into the MRC, to foster a “4+2” cooperation mode. The dynamic water quality monitoring system and information sharing platform, and the legal system for basin water environment management should be established to support refined TMDL management in all sections and promote the sustainable development of the Lancang-Mekong River Basin.

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About LMEC: Lancang-Mekong Environmental Cooperation(LMEC), established in 2017 in Beijing, China, aims to boost the capacity of environmental governance of each country and achieve regional sustainable development through the promotion of environmental cooperation among the Lancang-Mekong Countries.