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Environmental Monitoring Network and Practice

Science Press
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Foreword

The Three Gorges Project (TGP) is such a large project that it has aroused extensive concerns both at home and abroad. Its ecological and environmental issues, in particular, have become the focus of attention, so much so that there were worries on the feasibility study stage that whether or not the ecological and environmental issues would affect the start of the project. I was then working at the Chinese Academy of Sciences (CAS), participated in demonstration of the project, and wrote a report on its ecological and environmental impact and other researches. I was then appointed to lead the CAS leading group for the TGP Ecological and Environmental Studies. On recalling my experiences, I am filled with deep feelings that it is not an easy job.

It is often the case with a mega project that there are both advantages and disadvantages. Since the state decided to build the project based upon a trade-off, the mission of our scientists was to do whatever possible to avoid disadvantages and display advantages—reducing its adverse impacts on the ecology and environment and trying to maximize the benefits. The TGP eco-environmental impacts are very complicated and some are of long-term in nature. The scope they cover is so extensive, the influencing factors so many and the concerns so intensive that they have never been seen in the history of hydropower engineering at home and abroad. With pressures mounting, we had to save time and start our planning of TGP Ecological and Environmental Monitoring System (TGPEEMS) immediately and sum up our experiences for perfection, just as Dr. Zhou Guangzhao, Vice-Chairman of the Standing Committee of the National People's Congress (NPCSC) and academician and president of CAS, and Mr. Guo Shuyan, Vice-Chairman of the State Council Three Gorges Project Construction Committee (SCTGPCC) said at a interview discussing the problems in September 1993 that the pressing task was to establish as soon as possible TGP's own ecological and environmental monitoring system, obtain the baseline data and, on that basis, get command of the changing trend and the logic governing these changes, identify problems that might be caused by the dam and adopt timely measures to ease them.

Starting from 1994, coordinated by the Executive Office of the SCTGPCC, some related CAS research institutes began to take an active part in planning and building the TGPEEMS. A dozen state departments and many scientists poured their energy and sweat into the effort from implementary plan and review to the official start of the project. Thanks to their 10 years of hard work, the project has proceeded smoothly. After June 2003, a number of objectives have been realized one after another, including reservoir impoundment, power generation, and the permanent shiplocks open to traffic. The TGP ecological and environmental monitoring system also accumulated a wealth of background materials before the impoundment. The reservoir began to take shape. The impact of the project on the ecology and environment also began to reveal itself. After the dam is completed, resettlement and eco-environmental protection would become a long-term task.

The TGP ecological and environmental monitoring is a massive work in terms of content, scale, and scope. Many thorny problems have to be resolved such as how to make scientific and rational arrangement and how to timely master and control changes caused by the dam. This book, "Three Gorges Dam: Monitoring Network and Practice", written by Dr. Zhenli

Huang and others, who have participated in the planning and building-up of the system, is the first exhaustive account of the experiences and shortcomings in building the system based upon completing the baseline material monitoring, with theories well integrated with practice. This is very important and of great significance. It is believed that the book may well serve as a guide to further upgrading the monitoring system and is of great reference value in undertaking similar work.

It is, therefore, my pleasure to write this preface.

April 2017

Chen Yiyu
Former Chairman of the National Natural Sciences Foundation Committee, Academician of the Chinese Academy of Sciences, Beijing, China

Preface

The Three Gorges Project (TGP) is a mega-water control project that has attracted worldwide attention. It is a key project in harnessing the Yangtze River, bringing about benefits in flood prevention and control, power generation and navigation. However, the project will partially change the hydrological regime of the Yangtze that will induce changes in and exert impacts of different degrees on ecology and environment and even on the whole social and economic development in the middle and lower reaches of the river. Prior to the start of the project, China had organized national research institutions to carry out a demonstration work and compile the "TGP Environmental Impact Statement (EIS)" from different perspectives, including natural environment, social environment, public concerns and the impacts on ecology and environment, on the basis of a huge amount of investigations, studies, and scientific experiments.

In accordance with EIS requirements and official directions, the Executive Office of SCTGPCC organized in 1996 the preparation of an Action Program to establish a TGP ecological and environmental monitoring system, covering such areas as water power, environmental protection, agriculture, forestry, meteorology, health, geology and mineral resources, earthquake, and communications, with a joint effort by a number of departments and units, including CAS, the China Three Gorges Corporation (CTGC), and related departments of Hubei Province and Chongqing Municipality. The system is designed to track down and monitor the ecological and environmental impacts that might be caused by the construction and operation of the dam, and to issue timely warnings so as to provide scientific basis for the management and for the central leadership to take policy decisions and to accumulate a complete data for a retrospective assessment of the TGP environmental impacts.

The monitoring system covers mainly the Three Gorges reservoirs area, with its extension reaching the middle and lower reaches of the river, the estuary, and other related areas. It mainly undertakes to monitor the changes and development trends of all ecological and environmental factors to be affected by TGP, explores laws governing the changes before and after the dam is erected and maintains a good dynamics of the ecosystem in the project affected areas. Apart from the monitoring objectives, the system will also provide countermeasures to mitigate adverse effects and carry out experiments and demonstrations to drive for a harmonious development of economy and environment. In regard to issues which have no thorough understanding, more active efforts will be exerted in experiments and applicable researches for a systematic solution to construct the ecology and specific countermeasures to optimize the solution.

A fair TGPEEMS has taken a complete shape through 10 years of hard work, including several major adjustments and supplements in view of making it standardized, scientifically and systematically. The system has 12 sub-systems, including 15 key monitoring stations, 4 for experiments and some dedicated to special purposes, covering disciplines such as hydrology, water quality, atmosphere, terrestrial animals and plants, aquatic life, agricultural ecology, eco-agricultural experiments, social and economic development, pollution sources, and public health. Thanks to the Executive Office of the SCTGPCC, who played a key role in mobilization and coordination, specialized monitoring networks have been set up, such as the one in the dam-site area, and those for possible induced-earthquake and geological disasters in the reservoir area as well as the sediment stations in the reservoir and downstream one after another on the stem of the river. Together, they have formed the TGPEEMS. By June 2003, when the reservoir began to store water, the system had already accumulated a lot of baseline data and materials about the ecological and environment.

The TGPEEMS has gone through a process of planning–adjustment—recompilation, which is also a cycling of theory-practice-improvement. This system is China's only trans-regional, trans-sector comprehensive monitoring and research-oriented network involving multiple disciplines. It is an essential part of the ecological and environmental protection program of TGP. It is also an engineering network essentially different from those operated by relevant governmental agencies. For the sake of saving costs, the system relies mainly on the existing monitoring contingents of different departments and units and places it in the service of the TGP.

The TGPEEMS had nothing to go by in its making-up, only with the approved TGP EIS as its basement, while there were new situations and new problems cropping up in the course of construction. Financial constraints and the segmentation control of Yangtze River by different departments imposed great challenges to us both in the building and operating of the program, so that it experienced coordination technically and administratively.

The book is a tentative account of the planning and operation of the TGPEEMS, over which I presided, not only as a participant. I hope that it would be of some reference and guidance in the ecology and environment monitoring particularly after the reservoir is impounded. I came to work with the Technology and International Cooperation Department, Executive Office of the SCTGPCC in September 1993. As a leading member responsible for technology, I was fortunate enough to personally experience the compilation, building, and improvement of the monitoring system, which is a crystallization of hard work and sweat of scientists, technicians and people of central government departments. Without the wise leadership and the support of the older generation of scientists, it would have been impossible to complete this monitoring system, make it work efficiently and fulfill all the anticipated monitoring tasks.

The book has nine chapters. Chapter 1 is an introduction to TGP, including the dam project, people resettlement, and power transmission, together with an overview of the pre-TGP ecological and environmental situation of the reservoir area and the Yangtze River basin as a whole. Chapter 2 is devoted to the environmental impact assessment (EIA) of the TGP, which contains basic and background information about the TGP ecological and environmental monitoring system, including its arrangement and targets. Chapter 3 is a briefing of the environmental protection and monitoring practice of big dams at home and abroad, such as the Aswan High Dam, the Itaipu Dam of Brazil, the Glen Canyon Dam of the United States, and the Ertan Dam of China, with a hope to draw on alien experiences. Chapter 4 gives a general picture of the TGP monitoring system, depicting the course of events, general structure, and the characteristics. Despite the difficulties and complicatedness, we have tried to present a framework of the general structure and an indicator system from the perspectives of theory, management, and operation. Chapter 5 is devoted to a detailed description of each major monitoring station in the sequence of sub-systems, chosen according to the conclusions reached in the EIA and the characteristics of the environmental impact of the hydropower project. Chapter 6 is about the plan for building the system, which is essential for its management. There have been two scenarios for building the information system: one is decentralized management (management by different key stations) and centralized management (management by the information management center). We have chosen the centralized management scenario for fear of data being lost and for the purpose of leaving comprehensive and complete monitoring data to future generations. Chapter 7 is devoted to the achievements at different key stations, which are only the tentative summation of the technical reports of various key stations, without an integrated analysis of the monitoring system as a whole. Chapter 8 gets deeper into problems about key stations and targets of monitoring as dictated by the new situations and new problems after water is stored. Chapter 9 introduces a series of measures and progress with regard to environmental protection since the start of the TGP.

Presented in the book are also a large amount of color photos taken and carefully chosen by the authors for the purpose of presenting additional visual information.

Our gratitude should go to Mr. Zhang Dazhi for his careful review of English.

The TGP ecological and environmental problems are very complicated, involving many disciplines of study, which all have their own terms, standards, styles, and habits of writing. Due to limitations of knowledge on the part of the authors, some terms and way of expression may not be professional or accurate. What we can do is to base our analysis and judgment on solid grounds and evidence. Errors may exist and it behooves us to invite in real earnest bona fide criticisms and comments from the readers.

Beijing, China
April 2017

Zhenli Huang

Contents

Photos

Resolution on the construction of the Three Gorges Project was adopted at the 5th session of the 7th National People's Congress on April 3, 1992

Panoramic view of the TGP in construction

About the Authors

Dr. Zhenli Huang, Professor, born in 1966 in Pingba County, Guizhou Province, China, has been engaging in technology and management for the Three Gorges Project (TGP) since 1993. He graduated from the hydraulic engineering department of Tsinghua University in 1993, with a Ph.D. Eng., serving 20 years as the Deputy Director-General of the Reservoir Management Department, Executive Office of SCTGPCC (a high ranking decision-making agency); he is long-time responsible for the research, monitoring and management of the work concerning TGP environmental protection, participating in the reviewing of the major technical designs of TGP and coordinating the TGP's navigation and sediment studies. He is now serving as Director/Professor of National Research Center for Sustainable Hydropower Development, IWHR (China Institute of Water Resources and Hydropower). He has published more than 60 papers and more than 10 works and technical reports in academic publications and conferences at home and abroad. He is the winner of the third class award for scientific and technical progress from the State Education Commission in 1996, the second class award for scientific and technical progress in 1998 from the State Education Commission, and the national second class award for scientific and technical progress in 2005.

Dr. Bingfang Wu, Professor, born in 1962 in Yushan County, Jiangxi Province, China, graduated from the environmental engineering department of Tsinghua University in 1989, with a Ph.D. Eng. He is now serving as a Director Assistant of the Institute of Remote Sensing and Digital Earth of Chinese Academy of Sciences (CAS), and Director of the Information Center of Ecological and Environmental Monitoring Network for the Three Gorges Project (Information Center), responsible for the construction of the TGP Eco-Environment Monitoring Information System, carrying out remote sensing dynamic and real-time monitoring and revising the Action Program for the implementation of the TGP Eco-Environment Monitoring System. He has published more than 100 papers in academic publications and conferences at home and abroad. He is winner of the national second class award for scientific and technical progress, second class award for scientific and technical progress from the Ministry of Water Resources, advanced individual in the State "863" Program.

Abstract

The Three Gorges Project Ecological and Environmental Monitoring System (TGPEEMS) is a trans-regional, trans-sectoral, multidisciplinary, integrated and research-oriented project, targeted at the ecological and environmental problems that might be caused by the Three Gorges Project (TGP). The system tracks and monitors possible ecological and environmental problems during TGP construction and future operation, provides timely forecast and warnings and lays scientific basis for the management of the ecology and environment in the process of TGP construction and for the management agencies to take policy decisions in addition to providing complete data for the retrospective assessment of the TGP's environmental impacts.

This book is the first academic monograph on the TGPEEMS, initiating a primary study and an overview at an angle of planning level. It looks at the achievements in the assessment of the TGP environmental impacts, sums up experiences of large dam projects at home and abroad in this respect, forms a general framework of the TGPEEMS, plus its sub-systems and the information system; discusses the key and difficult technologies involved in building the TGPEEMS, and gives a brief account of the achievements in the baseline data monitoring. In the end, this book studies modifications of the TGPEEMS to adapt it to the changing situation after the impoundment of the reservoir and produces a general picture of countermeasures and progresses already made in this respect.

The Chinese version of this book was published in September 2006 by China Science Press and English version will be published in 2017 jointly by China Science Press and Springer Press. The book is a valuable reference for researchers and professionals of universities and research institutes in environmental protection and monitoring work, specialists of different organizations in this field, relevant government officials, and readers who are interested in the TGP ecological and environmental monitoring.

1 An Overview of Project and Its Environmental Issues

1.1 Features of the Three Gorges Project (TGP)

The Yangtze River (also called Changjiang in Chinese), the largest in China and the third in the world, is originated in the southern side of the Gela Dandong snow-capped mountain on the Qinghai–Tibet Plateau. Measuring 6300 km in length of the mainstream, it drains about 1.8 million km^2, about one-fifth of the total land territory of China. Its total volume of water flowing into the sea averages annually 960 billion m^3. Its total water power potentials come to about 268,000 MW, about 40% of the nation's total and the exploitable reserves are about 197,000 MW. The Three Gorges section of the Yangtze is one of the places holding the biggest water power reserves in the world.

The idea of developing the hydropower of the Three Gorges and improving navigation conditions of the Yangtze was initiated by Dr. Sun Yat-sen, the pioneer of the Democratic Revolution of China. He first mentioned it in the article "Industry Planning" in 1919; and again in 1924 in his article "Principles of People's Livelihood", he further expounded the importance of developing the hydropower of the Three Gorges. The initial research started at the beginning of the 1930s, when the Construction Commission of the Kuomintang Government in Nanjing organized, in October 1932, a survey group to investigate the hydropower potentials in the upper Yangtze. The survey team compiled a "Survey Report on Hydropower in the Upper Reach of the Yangtze," which recommended a low-dam plan at Gezhouba or Huangling Temple upstream of Yichang, Hubei Province, after deliberating the technical conditions and the scope of power supply. The low dam proposed would be 12.8 meters high, with a shiplock, and the installed power-generating capacity would be 300 MW. In April 1933, the Yangtze Waterway Control Committee put forward a "Hydropower Plan of the Upper Reach of the Yangtze". But the proposal was pigeonholed in 1936, when Austrian Engineer Mr. Brandt (Brown), advisor to the Yangtze Water Resources Committee, advanced the idea that it was too difficult to launch the mammoth project under the then poor social and economic conditions and even it were a success, the huge amount of electricity could not be marketed, had he studied how to improve the navigation conditions of the Three Gorges and develop the hydropower resources.

The earliest to offer a specific development plan was an American Economist Mr. Passhal, who, in 1944, proposed a power plant at the Three Gorges with a total installed capacity of 10,500 MW so that the cheap hydropower would be used to power a fertilizer plant invested and equipped by the United States to pay off the American debt in 15 years. In May of the same year, the Resources Committee of the Kuomintang government invited Dr. J.L. Savage to China, who was the chief design engineer of the U.S. Bureau of Reclamation and the world famous dam expert. With an on-the-spot on-foot

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survey, he wrote a “Preliminary Report on the Yangtze Three Gorges Project Plan”, suggesting a 200-m high dam somewhere between Nanjinguan and Shipai 5–15 km upstream Yichang, with an installed capacity of 1056 MW, also to benefit flood control, irrigation, and shipping.

Then, the Resources Committee of the Kuomintang government organized a series of surveys. In 1945, it organized a Three Gorges Hydropower Planning and Technical Committee to discuss the plan, covering issues such as shipping, irrigation, flooding of the reservoir area, resettlement of the displaced people, fertilizer manufacturing, and the measurement of the reservoir. In August of the same year, a Three Gorges survey team was formed. At the beginning of 1946, the Changjiang Water Resources Commission (CWRC) carried out surveys and came out with a number of reports, including the “Survey Report of the Yangtze Three Gorges Reservoir”, the “Investigation Report on the Economy of the Three Gorges Reservoir Area” and the “Yichang Report on Three Gorges Geology”. In the same year, more than 50 Chinese engineers and technicians were sent to the United States to participate in the designing of the Three Gorges project, which was stopped due to the tumultuous political situation of civil war in China.

The People’s Republic of China was founded in 1949, when everything was awaiting for development. The Three Gorges project caught the attention of the Chinese government. But it took 38 years from the verification to its approval in 1992, with several generations of Chinese scientists and engineers endeavoring heart and soul to the project. Also, many experts from the former Soviet Union, the United States, and Canada participated in the project planning, designing, and consultation. As result of meticulous studies, full discussions, and repeated reviews, a “Feasibility Study Report of Three Gorges Water Control Project” was completed in May 1989, with the main conclusions as that the project is necessary for China’s modernization program; it is feasible technically and reasonable economically; it is better to be built than never and it is favorable to be built earlier than late. In the following, the State Council set up a temporary Three Gorges Project Examination Committee (TGPEC) inviting 163 experts of all disciplines to scrutinize the feasibility study report and got it sail through an executive meeting of the State Council. On April 3, 1992, the fifth session of the 7th National People’s Congress adopted a resolution, giving green light to the construction of the Three Gorges Project.

The TGP is a superlarge hydropower project with huge comprehensive benefits in flood prevention and control, power generation, shipping, and water supply. It is so large that it has attracted worldwide attention. In a narrow sense, TGP refers to the Three Gorges Water Control Project, that is, the Three Gorges Dam. But in a wide sense, it consists of the Dam, people resettlement, and the power transmission. Construction preparations started in 1993, with the State council Three Gorges Project Construction Committee (SCTGPCC) being set up, for which the Premier was the head, and empowered it with taking major policy decisions. Under the committee, there established an Executive Office (responsible for organization and coordination), a Supervision Bureau, a Resettlement and Development Bureau (responsible for the organization and coordination of resettlement affairs)[1], and the China Three Gorges Corporation (CTGC) (owner of the water control project). Construction, operation, and management of the power transmission were entrusted to the former State Grid Corporation of China (SGCC) affiliated to State Power Corporation of China (SPCC). The people resettlement project was put under a mechanism of unified leadership by the central government, separate responsibilities to Chongqing Municipality and Hubei Province and the counties as the basic units. On December 14, 1994, TGP construction was set to motion officially. On November 8, 1997 the river was closed successfully. After June 1, 2003, the water pool level of the project reached 135 m; the permanent shiplocks started operation; the first group of turbine-generator units went on operation. Benefits of the project began to reveal.

[1]In December 2001, the Executive Office of SCTGPCC, the Supervision Bureau and the Resettlement and Development Bureau of SCTGPCC merged to become the new Executive Office of the SCTGPCC, responsible for organization, service, coordination, and supervision.

Three Gorges Dam holding water. The barrage structure on the left bank is completed and those on the right bank are still under construction. (Photo by Xinhua Reporter, May 2005)

1.1.1 The Dam Project

As defined in the "Brief Report (revised in 1990) on the Comprehensive Utilization of the Yangtze River Basin" officially approved by the State Council in 1990, the Three Gorges Dam is the key project for controlling and developing the Yangtze River. Its main tasks are to prevent and mitigate disastrous floodings in the middle and lower reaches of the river, especially in the Jingjiang section of the main stem, provide electricity to central China, east China, and eastern Sichuan Province, and improve the navigation conditions of the Yangtze River section from Chongqing to Yichang and to the middle reach of the river as well.

To carry out the Three Gorges Project, a principle has been set as "one-cascade development with the dam to be compiled at one go, while reservoir impoundments in stages and people resettlement in a continuous sequence." It means to build one dam in the section from Chongqing to the Three Gorges dam site and complete it to the final scale one time, while to impound the reservoir stage by stage to ease the difficulty in people resettlement and to obtain actual observation data about siltation of the reservoir at the beginning of the operation and verify the experimental research. The continuous resettlement means to resettle the people of the reservoir area under a unified plan without any suspension once it starts.

The Three Gorges Dam is located at Sandouping town, the middle section of the Xiling Gorge, one of the three gorges, about 40 km from the Gezhouba Dam. The dam commands a basin area of about one million km^2, with an average yearly runoff of 451 billion m^3. The normal water level of the Three Gorges reservoir is at El.175 m (Wusong's sea level hereafter is a reference point for the altitude in this book), and the flood storage is up to El.145 m and the lowest drawdown in the dry season is at El.155 m, corresponding to a total storage, a flood control capacity and an active storage, respectively as 39.3 billion m^3, 22.15 billion m^3, and 16.5 billion m^3. Figure 1.1 shows the general layout of the Three Gorges Project, including the water barrage structures, the hydropower plants, and the navigation facilities.

The dam is of a concrete gravity type dam, with its crest at El.185 m, an axial length of 2335 m, and a maximum height of 175 m. The spillway section of the dam is situated

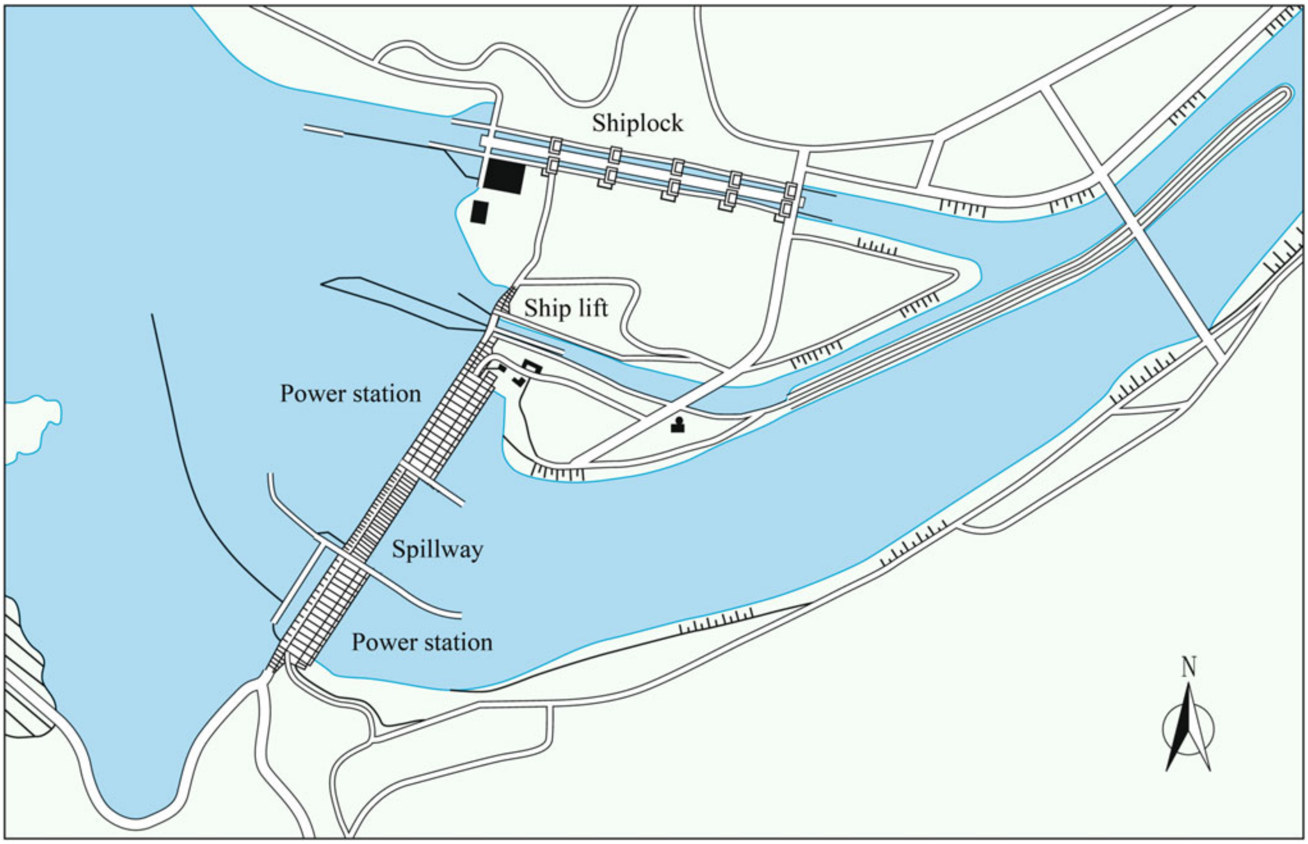

Fig. 1.1 Layout of the Three Gorges Dam

centrally, flanked by the power plant sections plus the non-overflows.

The power houses are of the behind-dam type, the left equipped with 14 units and the right with 12 units, 700 MW each, totally 18,200 MW, for an annual electric power generation of 84.7 TWh.

The navigation facilities are all arranged on the left bank, composing of the double-line five-step shiplocks and a single-line one-stage vertical ship lift, for a combined one-way throughput capacity about 50 Mt/year.

The main working volumes of the project include 10,283 million m^3 of earth and rock excavation, about 31.98 million m^3 of backfill, about 27.94 million m^3 of concrete, 260,000 tons of metal work and 460,000 tons of steel bars. Calculated by the price at the end of May 1993, the total static cost is estimated at ¥50.09 billion.

The project has been undertaken in three phases: The first was to build a longitudinal cofferdam on the small Zhongbao Island on the right bank for making a construction pit of the open channel; and to build a temporary shiplock on the left bank. The second was to build the spillway section, the dam section of power house, and the power plant on the left bank, plus other the permanent facilities. During that phase, water and ships would pass through the open channel, but during flood season ships would also be handled by the temporary shiplock. The second phase was to see water blocked, electric power generated, and the permanent shiplocks open to traffic. The third phase turned to the open channel again, which was to build the dam section of power house and the power plant while constructions on the left bank were going on for completion.

The first phase including preparatory work covers 5 years, from 1993 to 1997, symbolized by damming the river. The second is 6 years, marked by the operation of the first group of generating units in 2003. The third is 6 years, up to the year 2009. Therefore, it had taken 11 years from the preparation to the first power generation covering the permanent shiplocks ready for traffic. The whole project has been completed in 17 years, everything going as scheduled.

1.1.2 The Resettlement Project

The number of people displaced and the physical substances to be resettled of submergence are rare in the history not only of China but also of the world. At the normal water level, El.175 m, it affected 6301 natural communities of 1680 administrative villages belonging to 277 townships of

20 counties in Hubei Province and Chongqing Municipality. Two cities and 11 county seats and 116 towns and townships have been relocated and rebuilt partially or entirely. The water surface of the reservoir against a 5-year-frequency flood (a flood that has one-fifth chance of occurring in any given year) is 1045 km^2, inundating 600 km^2 of land areas, but that against a 20-year-frequency flood is 1084 km^2, with 632 km^2 (1.11% of the whole reservoir area) of land submerged.

There are eight county seats submerged wholly or partially: Guizhou Town of Zigui County, Gaoyang Town of Xingshan County, Xinling Town of Badong County, Wuxia Town of Wushan County, Yong'an Town of Fengjie County; Shahe Town of the former Wanxian County, Hanfeng Town of Kaixian County, and Mingshan Town of Fengdu County. The Yunyang County Seat, Yunyang Town, has been under water for most part of it. The city districts and county seats submerged partially include Wanzhou District, Fuling District, Zhongzhou Town of Zhongxian County, and Chengguan Town of Changshou District. According to the 1991–1992 survey, there were 26,000 km^2 of cultivated and vegetable land to be inundated and 847,500 people to be resettled, (288,200 rural and 559,300 urban people including those of factories and mines). In consideration of the natural growth and other reasonable factors, the people to be resettled by 2009 would come to about 1.13 million. The static investment in resettlement would come to ¥40 billion (at the price level at the end of May 1993).

The Three Gorges Reservoir is of a typical river-type, 600 km long and only 1.1 km wide on average, about twice as wide as the natural river, affecting 277 townships of 20 counties, without a submerge of a whole county. Inundation is only a small territory portion of those affected counties, 1–4% of the total cultivated areas of a county, with Zigui County, being suffered most heavily, losing 5.9% of the total cultivated land.

Guihua new village for displaced people in Wushan County (Photo by Huang Zhenli)

Street view of the new county seat of Xingshan (Photo by Huang Zhenli)

1.1.3 The Power Transmission Project

The power transmission project is an important TGP part, equipped with a total installed capacity of 18,200 MW, supplying electricity to central China, including Henan, Hubei, Hunan, and Jiangxi, with a designed transmission capacity of 9000 MW through 500 kV AC facilities. To east China, covering Shanghai, Jiangsu, Zhejiang, and Anhui, it has a capacity of 7200 MW through 500 kV DC lines. It supplies also electricity to Guangdong through a 500 kV DC line with a transmission capacity of 3000 MW. With all the above completed, a TGP power grid is formed linking central China, east China, and south China, which can also connect to the neighboring power grids for a purpose of establishing a whole nation power grid. The total cost of the TGP power transmission is estimated at ¥27.532 billion as calculated at the price of late May 1993.

1.1.4 The Reservoir Characteristics

At the normal pool level, El.175 m, the reservoir water extends 660 km upstream from the dam site to Jiangjin, with an area of 1084 km^2, flowing through low hilly land and low mountain valley areas of east Sichuan and Hubei, typically of a river alike, for a width from 700 m to1700 m on the main stem, mostly not more than 1000 m in width, but the section of 150 km from Wanzhou to Fengdu, which is more than 1300 m wide. The tributaries are generally 300–600 m in width and there are 171 tributaries with a backwater above 1 km in length, totalling about 1840 km. There includes 16 tributaries with a backwater over 20 km each, totaling 1083 km, 59% of the total tributary length of the reservoir.

The reservoir is operated to satisfy different requirements such as for flood control, power generation, navigation and sediment flushing. The operation process is shown in Fig. 1.2. Every year from late May to early June will see a water level drawdown behind the dam to the flood storage level, El.145 m, which is normally kept during the flood season from June to September, to discharge a flow almost the same as that of the natural condition. If a big flood occurs, the pool level will be raised to hold flood water, but when the flood peak is over, it is reduced again to El.145 m.

At the end of the flood season in October, the reservoir begins to store water to raise the water level gradually to El.175 m, and it will be kept at high levels as many as possible, to make the power plants operating according to peak load requirements. By the end of April the pool level should not be lower than 155 m in order to ensure a necessary power head and an adequate water depth for navigation upstream. Then, the next May will start another pool level drawdown, indicating that the dry season downstream discharge of a normal-water-year and a rich-water-year will, therefore, increase significantly as compared with the natural conditions.

According to the reservoir operation scheme, the reservoir water of dry season can extend back to Jiangjin of Chongqing, but in the other seasons, due to the regulated water levels lower than those of the natural conditions at

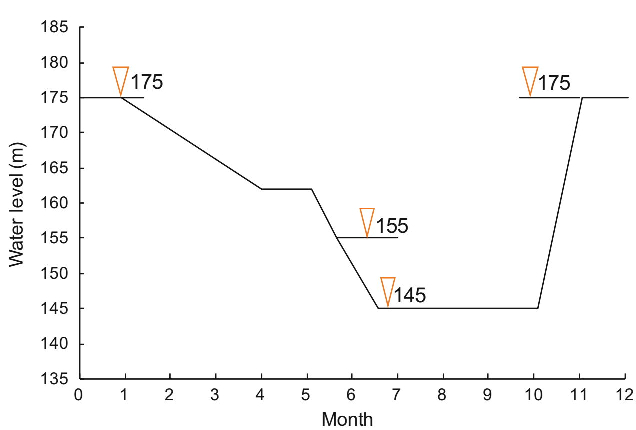

Fig. 1.2 Operation mode of the Three Gorges Reservoir

Cuntan hydrological station, the river section at Chongqing, known traditionally as "Chongqing section of the Yangtze", appears in a natural condition. However, the hydrological regime undergoes a great change at Fuling and Wanzhou, where the river channel has become a part of the reservoir, the middle section of the reservoir.

1.1.5 Main Benefits of the TGP

Flood Control

The TGP is deemed to be an irreplaceable key project in controlling serious floods in the middle and lower reaches of the Yangtze, for the upper Yangtze generates flood peaks much larger than the carrying capacity of the middle and lower reaches, especially at Jingjiang where the ground outside the banks is lower than the flood water level, like a "suspended" river. Once an extraordinary flood occurs, it would overtop the dykes, directly threatening the 15 million people, 1.53 million ha of farmland and a number of big and medium-sized cities and enterprises and vital communication facilities in the Jianghan plain and the Dongting Lake areas. That had always been a potential danger to China. With the completion of the TGP, forming a large reservoir of 39.3 billion m^3 in storage, 22.15 billion m^3 of which is set for regulating flood peaks and storing flood water, it thus raises the flood control capability of Jingjiang up to a standard against a 100-year-frequency, and if combined with other measures, it can prevent the occurrence of devastating floods. So, the building of the TGP is an important move to ensure the safety of the people and economic development in the middle and lower reaches of the Yangtze.

Power Generation

The TGP is an important component of China's energy program and power production, and one of the important measures in balancing the proportions of energy sources, realizing electricity to be transmitted from west to east and unifying the arrangements of electricity supply of the whole country.

The total installed capacity of the TGP is 18,200 MW (26 × 700 MW/unit), with an annual output of 84.7 TWh, and if plus the six generating units of the underground plant and the two plant power supply units, the total installed capacity is up to 22,500 MW, accounting for one-tenth of the national total in 1996. At the same time, Yichang of Hubei Province, where the Three Gorges Hydropower Station is located, is about 1000 km from the main power load areas in the east and south of the country, all in a scope of economic power transmission. Therefore, the TGP power station is the leading station in the national power grid in the future, obviously, occupying a significant position in the country's energy development program and power production.

Navigation

The Yangtze River is regarded as China's "golden waterway", with a navigable length of more than 70,000 km, or 70% of the national total for an annual shipping volume about 80% of the national inland waterway transportation, and in particular, it has always been a shipping artery for the east, mid, and west China. But the navigation channel, especially the 660 km-section from Yichang to Chongqing, runs through steep canyon, where the water head is as high as 120 m, the current is rapid and dangerous reefs are numerous; the depth and width of navigation routes are not enough; and the shipping cost is high.

The TGP will improve fundamentally the navigation conditions of the section from Chongqing to Yichang, with dangerous reefs submerged, navigable depth increased, water current gentle and navigable water surface widened, allowing a 10,000-ton towboat to Chongqing from Shanghai. The one-way annual handling capacity will be raised from the current 10 million tons to 50 million tons while the shipping cost will be lowered by one-third. When the golden waterway comes true, low shipping cost and great handling capacity will be realized, demonstrating a far-reaching significance in mitigating load pressure to rail transportation and accelerating cargo flowing between east and west and changing the industrial arrangement.

Other Benefits

Hydropower is a kind of clean energy. The Three Gorges Hydropower Station can replace seven 2600 MW thermal power plants, thus saving 50 million tons of coal annually and reducing emission about 100 million tons of CO_2, 2 million tons of SO_2, 10,000 tons of CO, 370,000 tons of NOx compound, and other industrial wastes. It thus plays a major role in reducing acid rain, fly ash and other pollutants for China, so as to mitigate the global warming effect caused by CO_2 discharge. Besides, the TGP will help slow down siltation and shrinkage of the Dongting Lake and improve water quality of dry season for the middle and lower reaches of the Yangtze, as the reservoir is an important water source of China.

1.1.6 TGP Construction

Dam

The project officially started in 1993 and has been proceeding well on schedule, under an effective organization and coordination by the China Three Gorges Project Corporation (CTGPC) and the support of the governments at all levels and the people of the whole country and by efforts of nearly 20,000 stuffs from designing, engineering, and supervision units.

The river was closed successfully in November 1997, with the second-phase cofferdam completed before the flood season, which stood tests of eight major flood peaks in 1998, ensuring the safety of the construction pit. In 1999, the dam construction turned from excavation to concrete pouring on a large scale, with a world record of annual 4.58 million m^3 of concrete placement created, averaging 554,000 m^3 a month. But the record was renewed in the following year, when 5.43 million m^3 of concrete were placed.

In June 2003, the TGP reservoir storage reached El.135 m, and in 2004, the dam successfully blocked about 500 million m^3 of flood water, demonstrating initially its anti-flood function. By November the same year the storage level came to El.139 m, making it possible for the dam to display its functions in flood control, power generation, and navigation. Up to the end of 2004, the TGP had used a total investment of ¥66.043 billion (or ¥40.369 billion in static terms, accounting for 80.59% of the total estimates), covering a total earth-rock excavation 139 million m^3 and the earth-rock backfill 52 million m^3, 26 million m^3 concrete placement, machinery, and electrical equipment installation 97,100 tons, and metal works 177,100 tons, when the dam portion on the right bank reached a maximum height, El.138 m and the power house thereof reached El.105 m as the maximum.

From August 2003, when 11 generating units on the left bank (totaling 7700 MW) were put on line, to the end of December 2004, the power plant had produced 47.642 TWh of electricity, 15.521 TWh of which was transmitted to central China, 23.105 TWh was to East China, 0.776 TWh to Chongqing and 8.240 TWh to Guangdong, to ease effectively power shortage in those areas.

The TGP has a stringent quality control system over all the procedure from raw material procurement, equipment manufacture, workmanship to construction sites, replete with testing, experiment and supervision, according to very strict project quality and management standards, some of which are even severer than those issued by the state. The supervision departments exercise independent supervisory powers and set up on-the-spot supervisory stations at concealed work and during concrete pouring, plus a complete set of onsite tests. World-known foreign companies were invited to provide consulting service and/or supervise manufacturing of some key work and equipment. In order to tighten quality control, the SCTGPCC has set up an expert group of quality inspection made up of a number of academicians of the Chinese Academy of Sciences and the Chinese Academy of Engineering to carry out regular checkups and quality evaluation.

People Resettlement

The Chinese government has paid a great deal on people resettlement, pointing out by Central leaders that the success or failure of the TGP lies in people resettlement. A proper resettlement is related to the whole national situation of peace and stability. It is, therefore, essential to make it possible for the displaced people to move out and settle down stably and gradually get rich. Only by doing so, is it possible to ensure the smooth-going of the TGP.

People resettlement work officially started in 1993, when the TGP officially got moving after eight years of pilot work since 1985. Up to the end of 2004, ￥45.582 billion of investments had been put in place for 980,900 people to be displaced and resettled, accounting for 87% of the total, including 534,000 urban people, 124,300 people living towns and 322,200 people of the rural areas, with 13 new cities and county seats (wholly or partially inundated by the reservoir) rebuilt, according to the rehabilitation principle of original standards, sizes, and functions, much better in terms of land space, transportation, telecommunications, power, and water supply. Houses and buildings completed amount to 39 million m^2, 31 million m^2 of which is of rehabilitation, or 89% of the total. Of the total factories and mines, 1428 or 88% were displaced; roads built came to 1105 km, 135% of the total planned length; power transmission lines erected came to 2955 km, 90% of the total planned.

In order to improve the ecology and environment of the reservoir area and raise the living standards of the local people, the State Council has modified the resettlement policy, to increase the number of rural people moving out of their own counties and enhance the structural adjustment of enterprises in the reservoir area. The major policy amendments have a far-reaching and profound impact on the sustainable social and economic development of the reservoir area.

Power Transmission

The power transmission project is another important part of TGP. The Three Gorges power installed capacity is 18,200 MW, to transmit power by 15,500 kV lines, with two reserved for expansion. Among them, the 500 kV AC line transmits electricity to central China, with a designed capacity of 12,000 MW; the 500 kV DC transmission line carries electricity to east China, with a designed capacity of 7200 MW. The 500 kV DC line transmits electricity to Guangdong, with a capacity of 3000 MW. Another 500 kV AC line transmits electricity from Ertan Hydropower Plant to central China via the Three Gorges and, after a change-over, transmits it to Guangdong, with a designed capacity of 2000 MW. The completion of the Three Gorges Power Station and its corresponding transmission projects will give rise to a complete Three Gorges power grid covering central China, east China, and Sichuan and Chongqing. It will then connect up to the neighboring power grids to form a national power grid.

Since 1999, the Three Gorges power transmission projects have been adjusted according to the requirements by the State council to market electricity to Guangdong, while the power transmission capacity to east China will be 4200 MW after 2003 when the power station is completed and the exchange capacity between central China and Sichuan–Chongqing power grids will reach 1000 MW, with two lines from the Three Gorges to east China capable of transmitting electricity of more than 2000 MW.

From 1997 when construction of the power transmission project started to the end of December 2004, a total of ￥22.981 billion of dynamic investment or ￥21.047 billion static investment was used, calculated at the 1993 price, equal to 65.2% of the total static investment. Completed and put into operation during that period were 38 AC individual works, totaling 4875 km in length, or 74.8% of the total; 18 AC transformer stations, with a total capacity of 12,250 MW; two DC projects, including two DC lines, totaling 1865 km, 62.95 of the designed total and four DC converter stations, with a combined capacity of 12,000 MW, 66.7% of the total. The Three Gorges-Guangzhou DC power transformation project was accepted by the SCTGPCC on December 19, 2004; the Three Gorges-Shanghai DC power transformation project started officially on December 28, 2004; the northwest to central China back-to-back DC project was completed basically in civil construction and installation. All the AC power transmission projects were going on well with superior quality.

1.2 Pre-Dam Environment

1.2.1 Overview of the Environment of the River Basin

The Yangtze River is divided into three sections: the upper, the middle, and the lower reaches, with the main stream running 6300 km through Qinghai, Tibet, Sichuan, Yunnan, Chongqing, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, and Shanghai, plus its tributaries involving 19 provinces, autonomous regions, and municipalities. The section upstream from Yichang is the upper reach, the mainstream extending 4300 km for a drainage area of one million km^2, accounting for 56% of the whole river basin. The section downstream from Yichang to Hukou in Jiangxi Province is the middle section, which extends 950 km in length. The section downstream from Hukou to the estuary is the lower reach, 930 km long.

Most of the Yangtze drainage areas are in the subtropical zone of the middle latitude, with an annual mean temperature ranging 6–20 °C and the mean temperature in January ranging 4–10 °C. Part of the area belongs to high altitude and high cold climate, with modern glacier and frozen earth development.

The Yangtze River basin is situated in the southeast subtropical monsoon belt, where the southwesterly and southeasterly monsoons are the most active and big rains or rainstorms often occur with the monsoon meeting the cold current from the north. That makes, therefore, the main source of water in the basin. The annual mean precipitation in the area is over 1000 mm. May–October is the flood season. The annual runoff into the sea is about 1000 billion m^3, 35% of the total runoff in the country. The Yangtze River has the richest water resources in China. Its annual discharge of sediment into the sea is 486 million tons, mainly coming from the sections upstream from Yichang. The annual mean runoff at Yichang is 451 billion m^3, with the sediment washed downstream averaging 530 million tons. Of that, 46% come from the Jinsha River and about 27% from the Jialing River.

The Yangtze is also a treasure house of aquatic life. The output of freshwater aquatic products makes up 50% of the nation's total. There are more than 350 fish species, one-third of which is endemic. Black carp (*Mylopharyngodon piceus*), Grass carp (*Ctenopharyngodon idellus*), Silver carp (*Hypophthalmichthyys molitrix*), and Bighead carp (*Aristichthys nobilis*) are the major native species, famous commercial fishes in China.

The terrestrial animals and plants are also available in abundance. There is China's second largest forest zone in the upper Yangtze, which is noted for such rare species as Dawn redwood (*Metasequoia glyptostroboides*), Dove tree (*Davidia involucrata*), and Cathay silver fir (*Cathaya argyrophylla*). Many have been listed in the category for a prior protection by the state. They include animals such as Snub-nosed monkey (*Rhinopithecus roxellanae*), Giant panda (*Ailuropoda melanoleuca*), and cloud leopard (*Neofclis ncbubosa*), Baiji dolphin (*Lipotes vexillifer*), and Thorold's deer (*Cervus albirostris*), birds such as Siberian crane (*Grus leucogeranus*), Scaly sided merganser (*Mergus squamatus*), Red-breasted goose (*Branta ruficollis*), Red-crowned, crane red-crested crane (*Grus japonensis*), reptiles such as Chinese alligator (*Alligator sinensis*), and fish such as Chinese paddlefish (*Psephuyrus gladius*), Chinese sturgeon (*Acipenser sinensis*), Dabrys sturgeon (*Acipenser dabryanus*), and Chinese sucker (*Myxocyprinus asiaticus*).

The Yangtze River basin abounds in beautiful natural landscapes and historical relics. Of the 44 national key scenic areas in China, more than half are in the Yangtze River basin. Huangshan, Jiuzhaigou, Zhangjiajie, and Dazu Stone Carving have been listed by the UNESCO as natural and cultural heritage of the world. The Three Gorges is one of the most famous canyons in the world and one of the best scenic areas in China. The Ermei Mountain and the Jiuhua Mountain are two of the four most famous sacred places of Buddhism in China. Hengshan Mountain is one of the five best known mountains in China. Lushan Mountain is the most famous summer resort.

The Yangtze River is the cradle of the Chinese nation and also one of the economically developed areas in China. It has a population of 400 million and the land under cultivation accounts for one-third of the country. Its total industrial and agricultural production value accounts for 40% of the nation's total, while the grain output accounts for one-third of the country's total.

Three Gorges are the most famous scenic spots (Photo by Huang Zhenli)

Little Three Gorges at Daning River, Wushan County (Photo by Huang Zhenli)

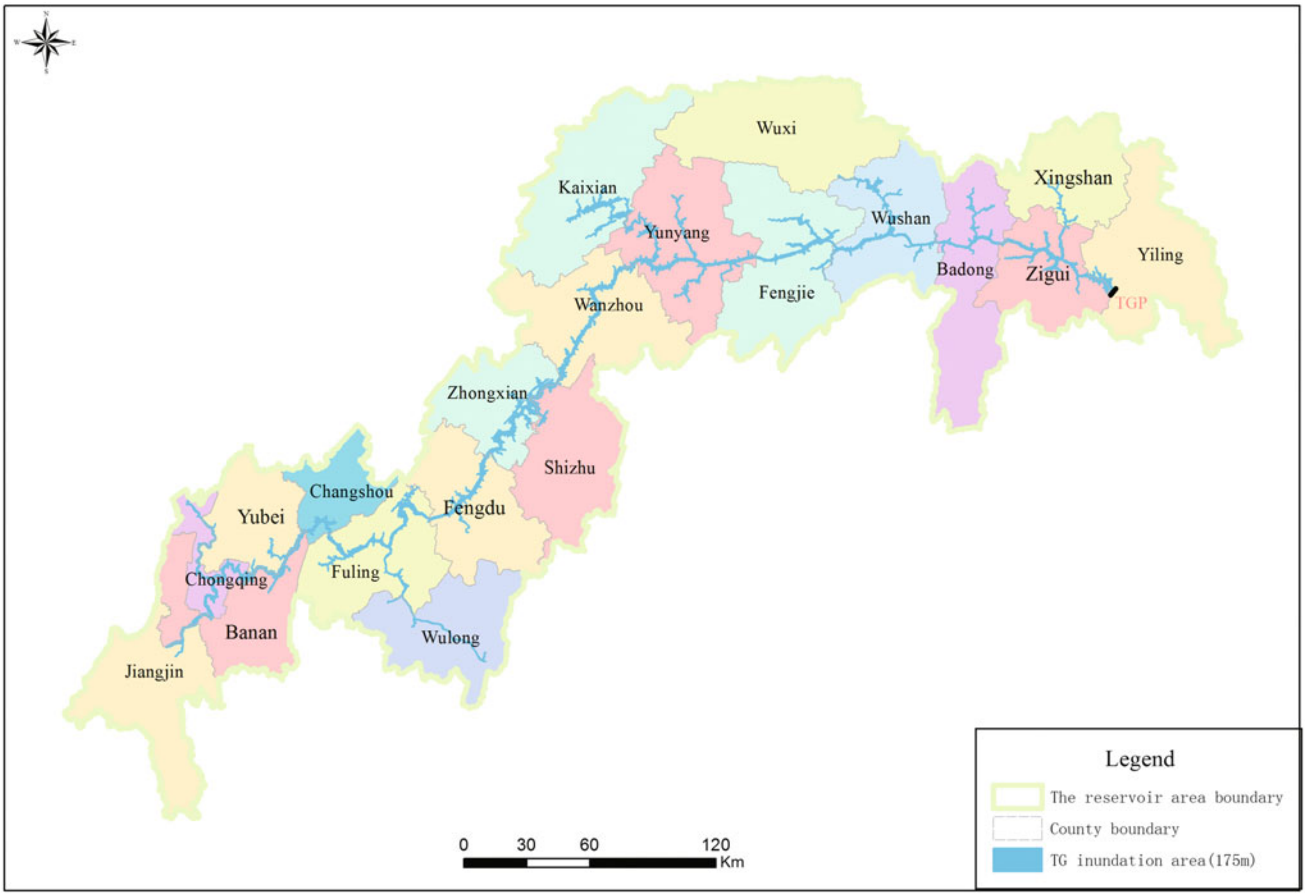

Fig. 1.3 Administrative division map of the Three Gorges Reservoir Area

1.2.2 Environment of the Reservoir Area

The reservoir area of the TGP is situated at a point 106º00′–111º50′east longitude, 29º16′–31º25′north latitude in the lower part of the upper reach of the Yangtze, stretching from Yichang of Hubei Province back to Jiangjin City of Chongqing Municipality, covering the inundated area and the places involving people resettlement, i.e., affecting 20 counties or cities, as shown in Fig. 1.3. They include Yiling, Zigui, Xingshan, Badong of Hubei Province and Wushan, Wuxi, Fengjie, Yunyang, Kaixian, Wanzhou, Zhongxian, Shizhu, Fengdu, Fuling, Wulong, Changshou, and Jiangbei districts of Chongqing as well as the seven main city districts and the Banan District of Chongqing and Jiangjin City.[2] The reservoir area covers 57,900 km^2. 2001 statistical data show that the total population in the reservoir area was 19,621,200, including 14,389,300 agricultural population and 5,231,900 nonagricultural population. The land area is 57,939 km^2, including 9777 km^2 of cultivated land, accounting for 16.9% of the total, averaging 0.76 *mu* per capita (one mu ≈ 1/15 of a hectare).

[2]The reservoir area referred to is the general term of administrative units related to the inundated land and resettlement of people based on the County and District, rather than the term of watershed. According to a survey by the Changjiang Water Resources Commission (CWRC) from the end of 1991 to the beginning of 1992 on the inundated amounts, the reservoir would inundate 19 counties (districts) and part of Chongqing city, which is called reservoir area. They included Yichang County, Zigui County, Xingshan County, Badong County in Hubei Province, Wushan County, Wuxi County, Fengjie County, Yunyang County, Kaixian County, Wanxian City, Zhongxian County, Shizhu County, Fengdu County, Fuling City, Wulong County, Changshou County, Jiangbei County and Baxian County of Sichuan Province, and parts of the poulder areas of Chongqing city. In 1997, Chongqing city was made a municipality under the direct administration of the central government, enjoying the status as a province. The reservoir areas belong to Sichuan was returned to Chongqing Municipality. The names of counties/districts in the area have been changed on several occasions. These names in this book were adopted after 1997 when Chongqing was made a centrally administered municipality. By June 2003, the Three Gorges reservoir area covered Yiling District, Zigui County, Xingshan County and Badong County of Hubei Province, Wushan County, Wuxi County, Fengjie County, Yunyang County, Kaixian County, Wanzhou District, Zhongxian County, Shizhu County, Fengdu County, Fuling District, Wulong County, Changshou District, Jiangbei District, Seven-main-districts, Banan District and Jiangjin City of Chongqing Municipality, totaling 20 counties or districts.

The TGP reservoir stretches in valleys of the medium high or low mountains or hilly land areas in the boundary of Chongqing and Hubei Province, flanking the Daba Mountain to the north and the Yunnan–Guizhou Plateau to the south, topographically higher in the west and lower in the east. In geomorphology, the west part, divided at Fengjie, is quite different from the east part, the former of mainly low hilly areas with wide valleys made up of clastic rocks of the Jurassic Period and the mountain range ranging from an elevation of nearly 1000 m at Fengjie gradually to 300–500 m at Changshou County; while the latter of the Sichuan–Hubei mountainous area made up of carbonatite of the Sinian System to the Triassic System, usually at elevations from 800 to 1800 m. In the reservoir, 74% is of mountainous areas, 21.7% of hilly land, and 4.3% flatland.

The reservoir area has a humid subtropical monsoon climate, warm in winter, hot and dry in summer, rainy, humid, foggy, cloudy, and breezy in autumn. The annual mean temperature is 17–19 °C, with 300–340 frost-free days, and the annual mean precipitation ranges 1140–1200 mm, evenly distributed in general from place to place, but over 80% of the year concentrated in April–October and rainstorms are frequent in May–September, often resulting in floods. So summer droughts often occur in July–August. There are 16 subtypes of soil in seven major categories, including yellow soil, mountainous yellowish brown soil, mountainous brown soil, purple soil, lime soil, moisture soil, and rice soil. The purple soil occupies 47.8% of the total land area, rich in phosphorous and potassium, soft and easy to till, suitable for different crops, particularly, it is important for citrus production in the reservoir area. Lime soil occupies 34.1%, mostly distributed in low hilly areas, while yellow soil and yellowish brown soil make up 16.3%, which is the basic soil type in the reservoir area, distributed in the river valley and hilly land below El.600 m, where the soil is fertile. The cultivated land is distributed mainly on slopes on banks of the mainstream and tributaries of the Yangtze River.

The main vegetations are evergreen coniferous forests, deciduous coniferous forests, mountain bushes, and economic forests (timber forests). Due to agricultural development and human activities, the hilly vegetation and natural vegetation is gradually replaced by agricultural crops. The forest cover is low in the reservoir area, only 16–17% of Chongqing and 25–38% of west Hubei.

There are 363 land vertebrate animals in the area, including 26 species listed in the catalog for priority protection by the state. The area boasts a rich variety of native produces, with the cash products having their unique advantages, such as tung oil, lacquer, goat skin and silk. The reservoir area is also a natural medicinal herb-producing area, with a variety of famous and precious herbs reaching more than 1900 species. The Shizhu County is renowned as the "home of China goldthread (*Coptis chinensis*)."

Shibao Zhai (Photo by Huang Zhenli)

Mineral resources in the area are also rich, verified up to a dozen types, including gold, silver, iron, uranium, coal, phosphorous, natural gas, and rock salt.

Agriculture, especially plant culture, is the main occupation in the reservoir area, where its industrial foundation is weak and outdated in equipment, plus backward land communications, showing an underdeveloped commodity economy. It is one of the poor areas in China, with the per capita GDP and income all lower than the average of Chongqing and Hubei and as well the average of the nation.

The level of science, culture, and education is also low, because of a serious lack of scientific and technical personnel, whereof, there are more than 25% illiterates and semi-illiterates among adults. The Three Gorges is the general term for the Qutang Gorge, Wu Gorge, and Xiling Gorge, which starts westerly at Baidicheng, Fengjie in Chongqing and ends easterly at Nanjingguan, Yichang in Hubei Province, totaling 192 km, flanking with beautiful landscapes on both banks and in tributaries, the Three Gorges magnificent and picturesque and the lesser three gorges gentle and elegant, dotted with many historical relics, such as the Baiheliang stone carving in Fuling, Ghost City in Fengdu, Shibao Zhai in Zhongxian, Temple of Zhang Fei in Yunyang, Baidicheng in Fengjie, Temple of Qu Yuan in Zigui, Sanyou Cave and Temple of Huangling in Yichang, all having a great value in tourism.

1.2.3 Main Environmental Problems of the Yangtze River Basin and the Reservoir Area

The Yangtze River basin is vast in territory and superior in natural conditions. Most places were developed long, long time ago, with human activities leaving a strong impact on the natural ecological system, especially in the recent decades, when the population increased sharply and resulted in springing up a large number of cities, townships, and industrial enterprises and mines. The land reclamation index has been rising steadily. All those have stimulated the local economic development but at the same time brought increasing pressures on the environment, harming the local ecology, and hampering further development in the river basin.

There were mainly the following environmental problems of the pre-dam period [1–4].

Water Loss and Soil Erosion in the Upper Reaches

The upper Yangtze is rich in forest resources, and it is, in fact, the second largest forest zone in China, next only to Northeast China. It is also an important guarantee for the protection of the water sources of the Yangtze. Owing to long time destruction of forests and land reclamation, most of the natural forests in the upper reaches of the river have been destroyed and its water containing abilities have dropped significantly and so did the ability of preserving the soil and blocking the sand. Those areas and intensity of soil erosion have been expanding. The natural ecosystem has been destroyed. The forest cover in Sichuan Province dropped from 20% in the 1950s to 13% by the 1980s. It is now only 4% in the Sichuan basin. The annual amount of soil erosion has reached 1.027 Gt. The total areas suffering from soil erosion have reached 355,000 km^2, accounting for 62.6% of the total soil erosion areas in the Yangtze River basin, with the annual amount of soil erosion reaching 1.57Gt.

The land degradation in the upper reaches of the river has been expanding. Such natural disasters as debris flow and landslide have become more and more serious, causing death and injuries every year.

Ecological Degradation in the Reservoir Area

The Three Gorges reservoir area is predominated by mountains. But still, the population density is high and the land reclamation index is big. Even before the TGP started, the ecological and environmental problems had already become outstanding due to intensified human activities. Before the TGP started, great changes had already taken places in the vegetation and outlook of the current reservoir area. Apart from high mountains in the fringe areas, little primitive vegetation had survived. Distributed were large expenses of Pine (*Pinus massoniana*), Cypress Tree (*Platycladus orientalis*), and shrubs and grass. Agricultural vegetation occupies a large proportion. The forest cover was low. Few forests could be seen in areas at an elevation below 800 m. Instead, there were mostly terraced fields and cultivated slope land. Only terrestrial animals with shrubs and grass as habitats had survived. Rare terrestrial animals have hidden up in mountains at a high elevation, where vegetation was good.

- Forest cover was low and water loss and soil erosion was serious. Before the start of the TGP, the forest cover in all the counties of the reservoir area ranged 7.5%–13.6%, except the three counties in western Hubei. The forest cover along the river was only about 5%. There were not many species of trees surviving. The shelter belt occupied a small proportion. The standing timber structure was simple, being mostly pure forests, with pine occupying 70%, mostly young trees. The cultivated land with a gradient of bigger than 25º made up 17.6% of the total slope land and 25% of the arid land. The areas subject to water loss and soil erosion occupied 58.2% of the total land area. The vegetation assumed a state of reverse succession, say degrading from forest → shrubs → thick growth of grass → grass slope → barren slope.
- Natural disasters were serious and ecological system became weak against adversities. The reservoir area was the most famous summer dry area, with frequency of drought during summer reaching 80–90%. The area was also a rainstorm-prone area, subjecting to floods and mountain torrents, with such mountain disasters as debris flow and landslide taking place frequently, often causing serious injuries and deaths or causing shipping to stop.
- Some species is on the verge of extinction. The vertebrate animals used to be dominated by forest communities. But now it is dominated by grass and shrub communities, with the number of musk deer, leopards and ferocious animals that used to live in forests dropping significantly. Tiger and leopards were on the verge of extinction. But the species adapting to the farmland life, such as Striped field mouse (*Apodemus agrarius*), which has the maximum catch of 19.1/per clamp/day in the reservoir area, seriously threatening agricultural production and spreading leptospirosis, epidemic hemorrhagic fever, and other diseases.
- Environmental pollution was serious. Chongqing and Fuling suffered the worst acid rains in China. Before the start of the TGP, there were no sewage and garbage treatment plants in Chongqing, Fuling, Wanzhou, and

Yichang cities. More than one billion tons of sewage and industrial wastes were discharged directly into the Yangtze, creating serious pollution belts at cities. Besides, the high mercury background of the Wujiang River basin had a serious impact on the water body and sedimentation. The solid wastes along the Yangtze also constituted pollution and caused environmental problems.

Floods and Waterlogging on the Plains in the Middle and Lower Reaches

The lake area covers 126,000 km^2; cultivated land covers 60,000 km^2; and there is a population of 75 million on the plain of the middle and lower reaches of the Yangtze, which is the major commodity grain, cotton, and edible oil producing area in China. The area is also economically developed. As the ground is usually several meters or a dozen meters lower than the flood water level, it has to rely on the 3600 km of mainstream dykes and the 30,000 km tributary dykes for protection. It is all times threatened by floods. Whenever there is a big flood, it would fall victim. It is an area where the flood and waterlogging are the most serious and the most frequent in the Yangtze River Basin.

According to historical records, in the about 2000 years from the Han Dynasty to the end of the Qing Dynasty, there were more than 200 floods, averaging one in every 10 years. In the twentieth century, there were floods in 1931, 1935, 1949, and 1954. The floods did not only cause huge losses in life and property but also seriously damaged the ecology and environment. Concomitant with the floods there come epidemics such as snail fever, causing a large number of death and mental injuries. The dykes are usually of a standard withstanding a (10–20)-year-frequency flood. If there is a flood more serious than that, flood diversion measures have to be taken, but the flood diversion areas are reclaimed areas, with a dense population and flood diversion would cause great losses. The plain on the two banks of Jingjiang totaled about 40,000 km^2 and has a cultivated land of 15,300 km^2 and a population of 15 million. The anti-flood standard is able to withstand 10-year-frequency floods. During the flood season, the water level of the Yangtze is usually more than ten meters higher than the ground level on the northern bank of Jingjiang. If a 100-year-frequency flood occurs, especially extraordinary flood like that in 1870, it is likely to breach the dykes on both banks, thus bringing about devastating calamities to the people, the eco-environment and social-economic development. A flood would bring about serious consequences and it would take years to restore the ecosystem and natural environment.

Eco-Environmental Problems in the Lower Reaches and Estuary Area

Water quality of the lower reaches and the estuary area of the Yangtze was generally good before the start of the TGP, with water only nearing the city's banks polluted. The pollution of some tributaries was very serious; all the cities along the river were facing serious challenges of water pollution. In Suzhou, Wuxi, and Changzhou cities, 80% of the water bodies were polluted. In Shanghai, about 5 mt of industrial wastewater and sewage water were discharged into the river, making the Huangpu River smell badly for 5 months a year. Shanghai had to seek clean water sources and make great efforts to control pollution.

The dykes in the estuary area and the delta area were eroded. Of the 449.7 km coastlines in Shanghai, 48.44% were eroded, with the silted up sections reaching 37.94%. At present, there are 63 km sections having hidden dangers. There were also about 100 km on the northern bank suffering from erosion.

The Yangtze estuary and the offshore areas are the important fishing ground of China. But excessive catches and offshore pollution have reduced the fishing resources. The amount of large yellow croaker (*Larimichthys crocea*), little yellow croaker (*Larimichthys polyactis*), hairtail (*Trichiurus haumela*), and silver pomfret (*Pampus argenteus*), the major traditional targets of catching, has been diminishing sharply and the weight of single fish caught was low.

The invasion of salt water in the estuary area was serious, especially in the dry season (November–April), with the situation more serious in the northern tributaries than in the southern tributaries. A survey shows that the instant cholorides density at Wusong reached 1850 mg/L and that at Baoshan Steel Corporation, 2256 mg/L, far exceeding the drinkable standard. From the winter of 1978 to the spring of 1979, the salt water invasion during the extraordinary dry season caused more than ¥14 million direct economic losses to 44 factories in Shanghai. The indirect losses were inestimable. The saline land in the estuary area and the coastal sections totaled 2330 km^2.

Snail Fever

No snail distribution was found in the reservoir area before the start of the TGP. But Sichuan and Yunnan in the upper reaches of the Yangtze used to be Snail fever infested areas. Through more than 40 years of prevention and control since the 1950s, the areas infested with Snails (*Oncomelania hupensis*) in Sichuan Province dropped from $2.5 \times 10^8 m^2$ to

$4.2 \times 10^7 m^2$ and the number of patients was reduced from 1.1 million to 880,000. Hubei used to be one of the areas with the most serious snail fever infestation. The more than 40 years of control efforts are very fruitful, but the areas infested with snails have remained large. The transformation of sandbars and shoals holds the key to eliminating snails and snail fever. Up to 1989, the snail-infested areas in Hubei, Hunan, Jiangxi, Anhui, and Jiangsu provinces 3.4×10^9 m^2 in 1989 and the number of Snail fever patients was nearly 900,000. Acute breakout happens sometimes. It remains an arduous task to control and prevent snail fever.

Other Environmental Problems

Although the Yangtze River basin is better than other China's river basins such as the Yellow River, Huaihe River in terms of water quality, water pollution of the Yangtze is still very serious. The pollution of water near city's banks of the mainstream is already threatening the water safety of cities. Most of the tributaries have been polluted. The eutrophication of major lakes is worsening. The increased use of chemical fertilizers and farm chemicals in the Yangtze River basin, plus serious water loss and soil erosion, has enabled a large amount of chemicals to flow into the Yangtze. It is estimated that the sediment transportation at the Yichang hydrological station in the upper Yangtze is 530 million tons, containing about 5 million tons of nitrogen, phosphorous, and potassium, occupying a significant proportion in the pollutants. In Taihu Lake and Dianchi Lake, farm fertilizers contribute to over 50% of the eutrophication of the lake water bodies.

Biodiversity has been diminishing. Land reclaimed from lakes in the middle and lower reaches of the Yangtze has reached 13,000 km^2. The excessive utilization of biological resources has led to attenuation of major economic species. The fish catch in the Yangtze has dropped from more than 400,000 tons in the 1950s to about 100,000 tons in the 1980s. The shrinking living space has thrown more and more rare species into the verge of extinction. Some rare water species, such as Baiji dolphins is already on the verge of extinction.

The water shortage in local areas has already become outstanding. Despite the rich water sources of the Yangtze River basin, the flow is unevenly distributed. Plus the lagging in water conservancy projects, water shortages have occurred to the central Yunnan plain, the fringes of the Sichuan basin, the Hengyang hilly areas and southern Hunan, Jitai basin of Jiangxi and Beigang of western Hubei. In part of the areas, urban and rural people have difficulty to find clean drinking water.

Water shortages caused by water quality problem need urgent solution. Due to lack of the treatment of industrial and sewage water, part of the areas, although rich in water sources, have begun to suffer from clean water shortages. In the densely populated towns on the plain area in the middle and lower reaches, it often happened that the water extraction places have to be moved due to pollution of water near banks, thus causing great investment in water extraction facilities.

Since the 1990s, the state has organized and implemented a series of major water-related projects, such as the ecological protection and building-up program in the Three Gorges reservoir area, the natural forest and headwater protection scheme in the upper reaches of the Yangtze, the returning reclaimed land back to lakes in the middle reaches of the Yangtze, the water pollution control projects in the Three Gorges reservoir area and in the upper reaches of the Yangtze and the urban sewage water and garbage treatment projects in major cities along the Yangtze. The completion of those projects will have a big role to play in rational utilization of the River water sources and water environmental protection. Favorable conditions have been created and a solid foundation has been laid toward this direction.

2 TGP Environmental Impact Evalution

2.1 Related Studies

2.1.1 Research and Scrutinization

China started its environmental protection in the 1970s. But it did not start the study of the impact of engineering projects on ecology and environment until 1986, when the State Planning Commission (National Development and Reform Commission) and the State Environmental Protection Administration (SEPA) issued a joint document “Management Rules on Environmental Protection Concerning Construction Projects”, demanding that every construction project must have an environmental impact report at the feasibility study phase. However, the study of the possible ecological and environmental impact of the proposed TGP can be traced back to the 1950s, when the Yangtze Valley Planning Office carried out investigations and study on environmental factors such as backwater, human activities on runoff, stability of reservoir banks, induced earthquake, sedimentation, biology, flooding of reservoir and resettlement of displaced people, natural epidemic foci diseases and endemic diseases, those resulted in documents, “Highlights Report on Yangtze River Basin Planning” and “Highlights Report on the Preliminary Design of the Three Gorges Water Control Project”. Those studies were brought onto a new stage of development in 1976 when the Yangtze Water Resources Protection Bureau (CWRPB) and the Changjiang Water Resources Protection Institute (CWRPI) were established.

After 1979, CWRPI cooperated with more than 40 universities and research institutions in carrying out research and assessment of the environmental impact of TGP and produced in the following year a report on the environmental impact of TGP under an operation alternative with the normal water storage level at El. 200 m. Then it went on with the assessment of the environmental impact for the feasibility study of an operation alternative of a water storage level at El. 150 m. In 1983, it completed the study “Environmental Impact of the Three Gorges Dam”. On this basis, CWRPI completed a number of studies, including “TGP Impact Study on Water Quality”, “TGP Impact Study on Soil Environment”, “TGP Impact Study on Forests and Vegetation, Rare Plants and Cash Trees”, “TGP Impact Study on Public Health” and “TGP Impact Study on the Spread of Snail fever”. In July 1985, CWRPI completed the “TGP Environmental Impact Statement (EIS)” (operation alternative of normal storage level of 150 m).

The TGP environmental impact research is so fruitful that it is rare in the history of hydropower projects in China (Photo by Huang Zhenli)

In review and verification of the preliminary study of a 175-m operational alternative, CWRPI focused on the study of the environmental carrying capacity of the reservoir area in respect of people resettlement, the waterlogging of the middle reaches of the Yangtze River, habitat of the Poyang Lake for migrating Siberian crane (*Grus leucogeranus*) and

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the environmental impact on the estuary area, which are the foci of concern in China and abroad.

In November 1984, the State Commission for Science and Technology (SCST) entrusted the "TGP Impact Study on Eco-environment and Counter-Measures" to the Chinese Academy of Sciences (CAS) as a major research project for the preliminary design stage of the TGP. In December 1984, CAS gathered a contingent of more than 700 researchers of all disciplines and specializations from 38 research institutes and universities to undertake in-depth comprehensive studies and review of 12 categories and 65 topics. The project was completed in 1987, yielding such results as the "Review Report on TGP Impact on Ecology and Environment", "Selected Papers on the TPG Ecological and Environmental Impact and Counter-Measures", "Selected Papers on the Eco-Environmental Impact of TGP and Counter-Measures" and the "Atlas of TGP Ecology and Environment". In the same year, the "Study of TGP Ecological and Environmental Impact and Counter-Measures" was listed into the national major research projects for the 7th Five-Year Plan period. Sponsored by CAS, the project was completed in 1991. Its achievements included "TGP Impact Study on Yangtze Riparian Terrestrial Ecosystem and Counter-measures", "TGP Impact Study on Aquatic Life and Rare Species of the Yangtze River and Counter-Measures", "Study of TGP Impact on Lakes and Flood-Prone Areas in the Mid and Lower Waterlogging Yangtze River Reaches and Counter-measures", "TGP Impact Study on Estuary Ecosystem and Counter-measures", "TGP Impact Study on Environmental Pollution and Public Health in the Reservoir Area", "Impact Study of Soil Erosion Status and Development Trend of the Reservoir Area on Eco-Environment and Counter-measures", "Study on Resettlement Carrying Capacity of the Three Gorges Reservoir Area" and "Integrated Assessment Study on TGP Impact on Eco-Environment".

In 1986–1988, in cooperation with CWRPI, the Canadian Yangtze Joint Venture (CYJV), according to common international practice and requirements, completed the "Feasibility Study Report of Three Gorges Water Control Project", which devotes wholly Volume VIII to environmental issues.

TGP is so massive in scale that its impact on ecosystem and environment has become a worldwide concern. Researches in this area have experienced a step-by-step, progressive and systematic process, thoroughly through the feasibility study, preliminary design and construction design of this water control project. They were quite fruitful, especially in the recent two decades, laying a reliable, objective and scientific basis for the project planning, review, and policy decision-making.

The researches had the following characteristics:

- They have a long history, participated with a great deal of research organizations, varying in depth and perspectives, some resulting in significant and extensive disputes.
- The preliminary TGP study focuses from the pure construction perspective to consideration in the screening of project plans, taking environmental indicators, construction indicators, and economic indicators.
- The research are systematic covering a wide range of subjects, involving multiple environmental factors, applying systematic engineering, mathematical models, ecological mechanism analysis, remote sensing technology and theories about environmental biology, environmental geology and environmental hydrology, hence laying a solid foundation for ecological EIA and the review and at the same time promoting the development of related disciplines.
- The researches have made fairly systematic and comprehensive study of basin ecology and environment and the reviews are rare for large construction projects in China in both scope and depth.

2.1.2 Environmental Impact Statement (EIS)

In June 1986, 55 experts in disciplines of ecology, environment, and water resources formed a group to review and validate the past achievements from the studies of the TGP impact on ecology and environment according to a "Notification on matters concerning the review of the TGP" issued by the State Council. The group also organized CWRPI and CAS to hold discussions on specific topics and carry out supplementary studies. A "Verification Report on TGP Eco-environment Impact and Counter-measures" was completed in January 1988, which was then incorporated into the "Yangtze Three Gorges Water Control Project Feasibility Study Report" completed by the Changjiang Water Resources Commission (CWRC) in May 1989. Then in March 1991, the Ecological and Environmental Pre-Examination Expert Panel of the State Council Three Gorges Project Examination Committee (STTGPEC) produced the result of the pre-examination. In July of the same year, STTGPEC finalized the assessment for the feasibility study phase.

The biodiversity research station of Chinese Academy of Sciences (CAS) at the Longmenhe Forest Farm of Xingshan County, Hubei Province (Photo by Huang Zhenli)

In compliance with related laws and the requirements of TGPEC, the Environment Impact Assessment Department (EIAD), CAS, and CWRPI compiled a "Work Outlines of TGP EIS". In October 1991, the SEPA examined the document and agreed in principle with the views of the expert panel and made it the basis for compiling environmental impact statement after necessary modification and additions were made. Then EIAD/CAS and CWRPI organized experts to complete "The TGP Environmental Impact Statement (EIS)" in December 1991 and submitted it for approval. The SEPA officially examined and approved the EIS in February 1992, with the comments: "With the whole river basin in view, a systematic analysis at different levels and a comprehensive assessment method, the report has analyzed both favorable and unfavorable impacts of TGP on the ecosystem and environment, put forward countermeasures to ward off unfavorable impacts and therefore provided an important basis for policy decisions about the project. So long as effective measures are adopted in policy, engineering, supervision, and management and in research and investment to mitigate the unfavorable impacts, the ecological and environmental problems should not affect the feasibility of TGP.

In accordance to those comments and the rules on environmental protection design for construction projects, CWRPI completed in 1992 the environmental protection design for TGP, covering water quality, terrestrial animals and plants, aquatic life, environmental protection of the dam site area and the ecological and environmental monitoring system. The design was then included in Chap. 11 (Environmental Protection) of the "Preliminary Design Report on the Yangtze Three Gorges Water Control Project" [1–3].

2.1.3 Scope, Hierarchical System, and Methodology of EIA

Scope

The scope of assessment, as dictated by the functions, characteristics, the hydrological changes, and environmental variance likely to be caused by the project, covers:

- Reservoir area: reservoir submerged areas and the related counties or districts for resettlement due to the impact of backwater from Sandouping of Yichang City, Hubei Province, to Jiangjin District of Chongqing Municipality;
- River sections of the middle and lower reaches and nearby areas: from the dam site at Sandouping to Jiangyin of Jiangsu Province, including Dongting and Poyang lakes and the four-lakes area of Hubei Province;
- Estuary area: area from Jiangyin City of Jiangsu Province to the estuary and the seaside, a place where fresh water and salt water meets.

The assessment area covers the upper part of the reservoir and that near the shores in view of the impact on soil erosion upstream and the impact on changes of fresh-and-salt water balance in the estuary area of the offshore areas.

Hierarchical system

According to the characteristics of the TGP environmental impact and the requirements for predictions and assessment, the assessment system is a hierarchy with four levels: the overall environment system, environment sub-system, environment component, and environmental factor (see Fig. 2.1).

Methodology

The following methods are used in assessing the TGP environmental impact:

- Environmental setting survey, including monitoring, field survey, the use of remote sensing technology, and collection of historical data.
- Qualitative and quantitative prediction methods according to the characteristics and changes of different

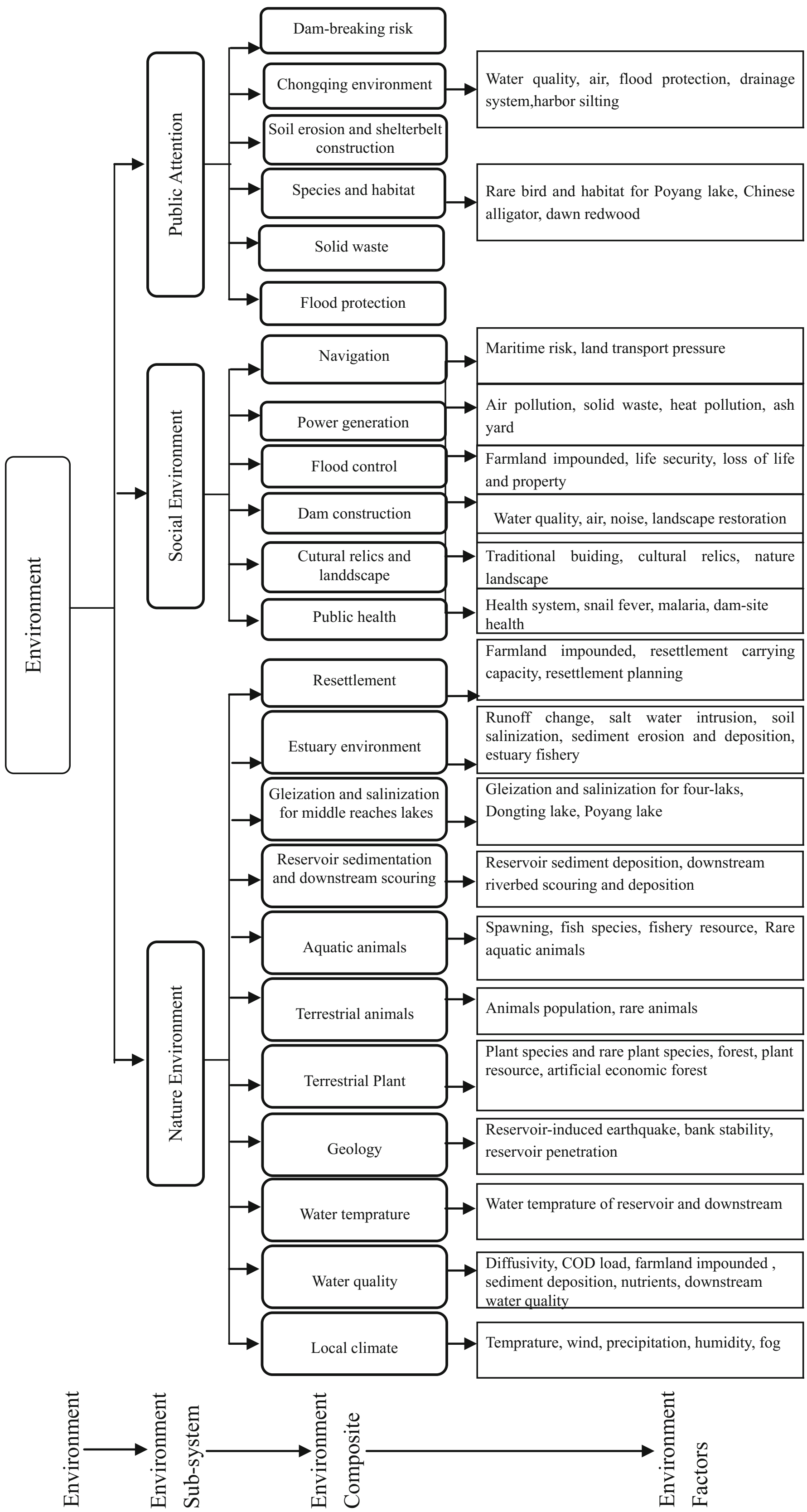


Fig. 2.1 Hierarchic System of EIA for the TGP

environmental factors and the impact of the project. Mathematical models have been employed for quantifiable factors, such as the impact on the hydrological regime of the Yangtze, precipitation, temperature, wind and fog, the impact of turbulent diffusibility and re-oxygenation on water quality, water temperature of the reservoir and downstream, the impact on sediment of reservoir and scouring of the river course downstream and the impact on the salt water's intrusion in the estuary area. All these will be predicted quantitatively based on observation data, identifications of models and parameters. For some environmental factors that are hard to be quantified, qualitative prediction will be made by adopting analogy or mechanism analysis, such as possibility analysis of snails spread, the impact on fish and terrestrial vertebrates, for which ecological mechanism analysis will be adopted. About impact on natural landscape, the qualitative description and computer simulation will be adopted.
- According to the predicted results and comparison with the standards or threshold values, assessment is done of the nature, magnitude, and importance of the impact
- General assessment is done to put forward recommendations on measures to mitigate adverse impacts.

2.2 Major TGP Impact on Environment and Comments

This chapter has collected all the major achievements and conclusions of the EIA of TGP carried out by related research units according to EIS before the TGP. And those are the main basis for ecological and environmental monitoring and protection work with the TGP breaking earth. It is, therefore, very important to review and integrate achievements in research of the TGP environmental impact, so as to establish and improve the TGP ecological and environmental monitoring system and adopt corresponding countermeasures. It must be pointed out that, first, predictions out of the EIS and the research findings are obtained by analysis and calculation of the models under different hypothetic conditions but not the impact that has really happened. Practice shows that from the start of the TGP to the present, thanks to a series of measures adopted, many of the adverse impacts predicted have been generally brought under control; second, the possible TGP ecological and environmental impacts have aroused extensive concern in and out of China. The general public, specialists, and different groups have different views and the divide might be very big; third, great progresses have been made in assessing and predicting the TGP environmental impact over the past few years and many new views and conclusions have been arrived at as compared with the assessment in the previous period of the 1990s. This chapter reviews the EIA achievements conducted before 1992 when the TGP started so as to present a complete picture of the understandings of related research institutions and specialists on the TGP environmental impact in the pre-dam period [1–4]. At the same time, this chapter comments on conclusions of the environmental assessment by using new monitoring data and the state-of-the-art research achievements made after the project started.

2.2.1 Hydrology, Water Quality, and Underground Water

Impact on hydrological regime

Damming the river, with reservoir impoundment and operation has changed the hydrological regime of the river at the reservoir, and its downstream sections. Before the reservoir was built, the water level was the highest in summer and the lowest in winter. With the reservoir, the water level is kept low for flood water in summer and is the highest in winter. In natural condition, water level in the flood season can be raised by more than 100 m at the dam site, or about 40 m at Wanzhou, 10 m at Fuling, about 3 m at Changshou. After the reservoir is built, the change of the water level is no more than 30 m, less than the natural amplitude and the change is gradual. Before the reservoir is built, when the river flowed through hilly and high mountainous valleys, the flow speed was generally 2–3 m/s with rapids much greater. After the reservoir is built, the cross-section of the channel has increased, with rapids eliminated and, under the condition of the same flow, the velocity is sure to slow down, varying with different parts of the reservoir and during different seasons. Generally, in the perennial backwater areas of reservoir, the velocity gradually slows from the tail of the reservoir to the dam site. When operating at a high water level during the dry season (January–April), the velocity in perennial backwater area will not exceed 0.1–0.5 m/s. When operating at a low water level during the flood season, the velocity in the reservoir will vary with flow volumes, with that in the forebay of the dam being mostly below 0.5 m/s.

When water is stored, the natural stream of the reservoir section will become part of the reservoir, with water level rising, water surface increasing and velocity slowing, and the sediment will deposit in local areas. In the middle and upper reaches of the Yangtze, due to reservoir regulation, the discharge of the reservoir will increase slightly during the

Table 2.1 Yearly changes in the flow at Yichang without and with the TGP

Month	Without		With	
	Monthly average flow discharge (m^3/s)	% of monthly runoff in annual runoff	Monthly average flow discharge (m^3/s)	% of monthly runoff in annual runoff
1	4220	2.5	5390	3.2
2	3780	2.0	5540	3.0
3	4240	2.5	5720	3.4
4	6540	3.8	6179	3.6
5	12,340	7.3	16,100	9.6
6	18,200	10.4	18,670	10.8
7	30,980	18.4	30,460	18.2
8	28,670	17.0	26,500	17.0
9	26,630	15.3	26,360	15.3
10	18,980	11.3	11,090	6.6
11	10,480	6.0	9780	5.7
12	5970	3.5	6080	3.6

Table 2.2 Yearly changes in the flow at Datong Station without and with TGP

Month	Without		With	
	Monthly average flow discharge (m^3/s)	% of monthly runoff in annual runoff	Monthly average flow discharge (m^3/s)	% of monthly runoff in annual runoff
1	10,630	3.1	11,200	3.3
2	10,710	2.8	11,860	3.2
3	14,420	4.2	15,080	4.4
4	22,260	6.3	21,890	6.3
5	34,690	10.2	38,450	11.3
6	41,060	11.7	41,530	11.9
7	49,730	14.6	49,210	14.5
8	45,480	13.4	45,310	13.4
9	41,210	11.7	40,940	11.7
10	36,010	10.6	30,490	9.0
11	24,880	7.1	24,180	6.9
12	14,710	4.3	13,990	4.1

dry season from January to April and decrease toward the end of the flood season in October. The water level of the stream and alluvial conditions will change to a varying degree, indicating that the change of the hydrological regime will have an impact on the environmental factors in the reservoir areas and the middle and lower reaches of the Yangtze.

Tables 2.1 and 2.2 show the flow changes within a year at the Yichang and Datong hydrological stations with and without the reservoir. Comparison shows that without flood storage in operation during the flood season, there would be no big impact on the runoffs at the Yichang and Datong stations. The impact of the reservoir during the non-flood season is bigger at Yichang than at Datong, because there are many big tributaries flowing in between Yichang and Datong, such as Hanjiang, Xiangjiang, Zijiang, Yuanjiang, and Fengjiang rivers, thus alleviating the impacts on the runoff.

Estimate of pollutant load in the reservoir area

During the environmental assessment period, three aspects of pollution sources in the reservoir area were mainly taken into consideration: Industrial wastewater and sewage water of cities and towns in the reservoir areas that are directly or indirectly discharged into the Yangtze, the farm chemicals and solid wastes brought into the river through the farmland and surface runoff, and oil and other pollutants discharged into the river by ships and boats and other floating carriers operating in the reservoir area.

(1) Industrial and urban pollution sources

According incomplete statistics in 1991, there were 40 major industrial pollution sources in the more than 600 km section from Sandouping of Yichang in Hubei Province to Jiangjin of Chongqing Municipality in the reservoir area. The wastewater discharged annually by Chongqing, Fuling, Wanzhou, and Yichang was estimated at 760 million tons, including 510 million tons of industrial wastewater and 250 million tons of sewage water, posing a serious threat to the water quality of the reservoir.

The solid wastes piled up on the banks were also one of the important factors affecting water quality of the reservoir. According to the 1992 preliminary survey, the annual discharge of solid waste in the reservoir area was about 4.62 million tons, including 3.14 million tons of coal slags, 555,000 tons of gangue, 284,000 tons of chemical slag, 162,000 tons of metallurgical slag, 255,000 tons of other industrial slag, and 220,000 tons of garbage. The total amount of solid waste in the reservoir area was about 21.7 million tons. The toxic matters in the solid wastes could be washed into the reservoir by rain, posing a direct threat to the safety of drinking water of the people on the banks.

(2) Ship pollution sources

Ships may cause water pollution in many ways: pollution, caused by accidents and misacts, could be huge in amount and vast in polluted area and the pollutants enter the water body directly. Erroneous operation may cause diesel overflow or leaking or dripping, and illegal discharge of oily water of the engine cabin and sewage water and dumping of garbage into the river contaminate seriously the water body. According to the annual statistics of the port supervision bureau about pollution events along the Yangtze, of the pollutants discharged into the river, the oil amounts more than 2800 tons and garbage discharged into the water is about 8000 tons.

Impact on water quality

(1) Turbulent diffusivity and pollution belt

In the EIA stage, researches on the impact on turbulent diffusivities of pollutants and pollution belts was mainly based on the two-dimensional advection–diffusion equations, which assumed water flow to be uniform, the depth of the cross-section as well as flow velocity to vary slightly, continuous sewage water discharged to be located at bankside and fully mixed along the water depth. The study was conducted by the Sichuan Research Institute of Environmental Sciences (SRIES) and the CWRPI. But the two

Before 1992, urban sewage and industrial wastewater were directly discharged into the Yangtze without treatment. People worried that the water quality would be worsened after the TGP. Experts were divided in opinion as to whether the sewage water untreated would pollute the water of the Three Gorges Reservoir or the TGP would affect the water quality of the river. Picture on the left shows the urban sewage discharge at Chuqimen in Chongqing. Picture on the right shows the wastewater from a illegade mine in the Xiayang River, a tributary of the Xiangxi River in Hubei Province (Photo by Li Congming) research units arrived at different conclusions as they viewed it from different perspectives. The SRIES held that after the reservoir was impounded, the water velocity would slow down, pollution belt near the banks would be wider and pollutant concentration would increase correspondingly, hence there would be lower exploitable water environment carrying capacity. If the concentration of pollutants was maintained as same as that of pre-TGP at the control point, it needs to be cut by 20% in order to compensate for the water environment carrying capacity. The CWRPI held that so long as the pollutants were discharged in consistency with the state standards, the water quality at the control point would not change beyond the standards even if the diffusion ability dropped. This meant that the impact on water quality came from pollution sources rather than from the TGP.

Pollution belt is caused by the Chongqing Wanyuan paper mill (It is closed now). Photo by Huang Zhenli on August 6, 1997

The common problems existing and being neglected with the researches are:

- The math model is too simple, ignoring the impact of the water depth and nonuniformity of flow velocity of cross-sections.
- Diffusivity is not only reflected in velocity, but also in the diffusion coefficient, which should be determined by experiments.
- The impact of the increase in water depth on diffusivity should be taken into consideration after river is dammed. The increase in water depth is favorable for diluting the dispersion.
- After the dam is built, the average velocity of the mainstream will be reduced and the ratio of pollutant discharge speed to the mainstream average velocity may increase, thus to make the pollution belts move toward the center of the river. That has been neglected by the SRIES and the CWRPI.

Different scholars have offered different definitions of pollution belt. Mr. Shida et al. (1991) gave the following definition: the water area was where the concentration of pollutants was higher than that of the environmental function category standard at pollutant outlets and their downstream. He also proposed the pollution belt assessment indicator $P_i = C_{ni}/C_{si}$ Where C_{ni} is i pollutant concentration at the control point (1000 m downstream of the pollutants outlet and 10 m from the bank where the pollutants are discharged); C_{si} is the water quality standard with i pollutants in the water body environmental function category. The water body pollution at the pollutant outlet is divided into four grades according to the size of P_i, that is, $P_i < 1$, allowed; $P_i = 1–3$, pollution; $P_i = 3–5$, heavy pollution; $P_i > 5$, serious pollution.

At the preliminary design stage, the CWRPI cross-checked the issue of the impact of the TGP on water quality, especially the riparian pollution belt (using the riparian water concentration 1000 m downstream of the sewage discharge outlet as the control point) and arrived at the same conclusion as is stated above. On the basis of the two-dimensional advection–diffusion equation, they adopted the dimensionless cumulative discharge coordinate and the finite-difference method in order to reflect the changes in water depth and velocity at various cross-sections of the natural stream. This brought the study at that stage into depth. However, the related model parameters, especially the diffusion coefficients were estimated by the rule of thumb instead of calibration and verification through experiments and field observations.

(2) BOD

With the dam built, water velocity in the reservoir will drop and the re-oxygenation capacity will be weakened, thus reducing the BOD_5 carrying capacity. The analysis based on Streeter–Phelps model for a stream (Streeter and Phelps, 1925) holds that when calculated by DO no less than 6 mg/L according to the GB3838-1988 III grade surface water standards, the BOD_5 carrying capacity will drop by 59%. But, due to the big volume of runoff, the carrying capacity will remain at 1.56 million t/a, much bigger than the pollutants discharge volume. So, the water quality of the reservoir will not be worsened. Besides, due to water storage, the retention time for pollutants in the reservoir would increase. Under the natural conditions, it is 5d. It will be 33d when calculated under the 175 m operation alternative. Longer retention time would increase BOD degradation.

(3) Impact of inundation on water quality

When the reservoir stores water, the toxic, harmful and nutrients in the soil inundated would be leached out and cause the water quality to deteriorate. But analogical analysis shows that as the ratio of inundated land area to the annual runoff flow is small, there is little possibility for inundation to exacerbate water pollution. But such ratio is big in the tributaries and bunds of the reservoir, the inundation would cause bigger water quality problem.

(4) Impact of riparian solid wastes on water quality

In the Three Gorges Reservoir area, the solid wastes randomly piled up on the banks of the river have already caused serious pollution of the river. If not removed in time, they are bound to affect the water quality.

(5) Impact of sedimentation on water quality

The EIA study was mainly concentrated on the impact of sediment by using unitary box model to calculate the total concentration and soluble concentration of heavy metals in the steady state (subject to influence of distributing coefficient). The calculation result shows that the sediment under the 175 m operation alternative will reduce the total concentration of heavy metal elements by 63–70%, with the soluble concentration not changing much. The water environment with absorption conditions will not lead to secondary pollution due to desorption.

(6) Impact on nutrients

The nutrients such as nitrogen, phosphorous in the reservoir have the function of accumulation. Research shows that it is not likely for the reservoir water to be eutrophicated because of the big volume of runoff. But it is possible that eutrophication may appear in local areas of the tributaries where flow velocity is slow. 70–80% of the nutrients at the Yangtze Estuary come from the river sections downstream of the dam. The reservoir has negligible impact on the change of nutrients in waters downstream of the dam.

(7) Impact on water quality downstream of the dam

With the operation of the reservoir, the turbidity and concentration of solid elements in the Yichang section will drop significantly. As the operation of the reservoir increases the flow during the dry season, the flow downstream would tend to be stabilized, making it easy to control and manage pollutants discharge and raise the stability of water quality downstream of the dam and to improve the riparian pollution. But in October, when water is stored, the riparian pollution in the city sections of the river may increase slightly as compared with that before the dam is built.

The deposition of sediment will enable the reservoir to discharge less sand downstream. In certain sections downstream of the dam, the river absorption and self-purification capacity will be lowered, thus affecting the water environmental capacity.

In a word, the impact on the water quality downstream of the dam is favorable during the dry season and riparian pollution may increase in October when water is stored. So, there are both advantages and disadvantages with regard to the impact on the water quality downstream of the dam.

Impact on water temperature

The stratification of the reservoir temperature will have a big impact on the reproduction of fish and agricultural irrigation, especially in the rivers like the Yangtze, where fish resources are very rich and agricultural production in the surrounding areas is well developed. It is, therefore, very important to predict water temperature.

(1) Stratification of reservoir

Two simple methods have been tried to predict the stratification of the reservoir in the EIA stage. One is the reservoir water exchange indices (α and β methods) and the other is the densimetric Froude number (F_d) method.

Prediction by α value: When the normal water storage level is 175 m, the total holding capacity of the reservoir is about 39.3 billion m^3; the average perennial runoff at the dam site is about 451 billion m^3, $\alpha = 11$, slightly bigger than 10. This shows that a stable stratification of reservoir water is unlikely, but it does not rule out the possibility of feeble stratification.

Prediction by the F_d method: the criterion of densmetric Froude number was suggested to judge the stratification of reservoir or lake by the US Water Resources Engineering Inc in 1969. The reservoir is characterized by a densimetric Froude number that compares the inertial force with the gravitational force tending to maintain densimetric stability.

There are two scenarios for the Three Gorges Reservoir: One is to take the reservoir as an entity and calculate by water level at 175 m, total holding capacity at 39.3 billion m^3, and minimum flow of 3700 m^3/s, then, $F_d = 0.46$, indicating that the reservoir has the tendency of feeble stratification (similar to the case of the Lake Roosevelt behind Grand Coulee Dam in US), but the usually higher-than-air water temperature during the dry season of winter restricts the process of stratification. The second is to calculate by dividing the reservoir section by section: the total length of the reservoir is 600 km; there is a big difference in the water depth at the tail end of the reservoir and at the forebay of the dam. Divide the reservoir into 185 units to calculate F_d. The result shows that segments with $F_d < 0.1$ are bigger during the dry season and turbulent fluctuation is small and has the hydraulic conditions for stratification of the water body. But due to the fact that the water temperature is higher than atmospheric temperature at this time, there is no tendency of stratification. Only in April, when the flow of the reservoir is less than 6000 m^3/s, $F_d < 0.1$ in the reservoir front section about 10 km near the dam. And there is temperature stratification for a short period of time. After May, when $F_d > 0.1$, apparent stratification is unlikely. The calculation of F_d value of the ten major tributaries shows that there might be stable stratification in three tributaries: Modaoxi, Meixi River, and Longchuan River, which will happen mainly in the tributary mouths.

The one-dimensional thermodynamic model was used to analyze the stratification at the section near the dam. The results of the prediction based on the typical 1965 (normal-flow year) and 1966 (low-flow year) water years show that the temperature stratification in the reservoir would start in early April and disappear in late May, with the temperature difference in the upper and lower strata being 1.7–9.3 °C.

(2) Reservoir outflow temperature

As is stated above, there might be reservoir stratification for a short time in April–May. So it needs to further analyze the temperature difference between the water released and the natural flow so as to predict the “cold hazard”. According to the prediction in the EIA stage, although the outflow temperature in April–May is lower than that of the natural river flow, it is still higher than 18 °C required for the spawning of four major endemic fishes.

Impact on the underground water

After the dam is built, changes in the water level of the Yangtze will have an impact on the underground water level of the four-lake area and on the gleyed and swamped soil.

The four-lake area borders on the Yangtze in the south, Dongjinghe River in the north. It is so named because it has the Changhu, Sanhu, Bailuhu, and Honghu lakes. It covers a total area of 11,000 km^2, including 4530 km^2 of cultivated land and it has a population of 4.5 million. The Neijiang River in the heart of the area flows into the Yangtze through the Xintan sluice gate, a main draining channel in the four-lake area. The lateral feed to the underground water by the Yangtze is one of the main sources of underground water in the area.

There are mainly two factors affecting the Yangtze water level in the four-lakes area after the completion of TGP. One is the increasing effluent released from the dam during the dry season will raise the water-level downstream. The water level outside the Xintankou sluice gate is estimated to rise by 0.20–1.23 m from January to May according to the data for the high-flow, low-flow, and normal-flow years. The other is that the general scour of the river bed downstream of the dam will cause the water level to drop. Under the action by the two factors, the rise and fall of the Yangtze water level vary during different periods of time and at different sections of the river, thus affecting the underground water level.

Comments

- The dam’s eco-environmental impact will mainly be caused by such factors as the change in hydrological regime, inundation, resettlement, and construction sites of the dam. Among them, one of the main inducing factors is the flow regulated by the dam, which brings about changes in the hydrological regime in the reservoir areas and downstream of the dam, such as smoothing the flood peak, increasing the flow volume in the dry season. So, the analysis of the impact on hydrological regime is the prerequisite for assessing and analyzing the dam’s environmental impact. At the EIA stage of the TGP, the analysis of the impact on hydrological regime was carried out in depth and is, therefore, reliable.
- The survey and analysis of pollution sources in the assessment period were mainly concentrated on industrial pollution, pollution from people’s living and ships. It is, therefore, not systematic and complete, making it hard to accurately estimate the pollution sources of the reservoir area and the total amount of pollutants or the total pollution load discharged directly into the reservoir. The investigation shows that the Three Gorges Reservoir mainly has seven pollution sources: the background load from the upper reaches of the mainstream and tributaries, urban sewage water, industrial wastewater, ships, urban and agricultural non-point sources, the released load of the pollutants of the soil submerged, and the load of urban garbage entering into the reservoir after being drenched and melted by rain. During the EIA period, there was a lack of long-term-monitored data or systematic study of the pollutant load of the pollution sources in the reservoir.
- The impact on water quality is one of the issues that cause common public concern. In studying the impact on water quality during the EIA period, the preliminary

assessment was made analytically by using simple water quality models. The models and their computation methods were too simple to reflect the complexity of the impact of the TGP on the water quality, and furthermore the parameters were not determined by field experiments. The latest research achievements by Huang et al. (2006) based on the advanced math models and field investigations have shown [5]: the cross-section average concentration of water quality indicators as a whole will drop after the TGP is completed but the total environmental carrying capacity will increase; the riparian pollution belts will generally increase and riparian environmental carrying capacity will drop. This conclusion has been evidenced by the water quality monitoring data after the water is stored in 2003 and 2004. On the other hand, as the reservoir is of the river- type, like something between a river and a lake, the assessment of the water quality should neither adopt the river standards nor simply the lake standards. This has caused difficulty and perplexity with regard to assessment standards and assessment results. With water storing and research work going into depth, some problems have cropped, such as the eutrophication of tributaries, which, due to the small flow exchange frequency, is closer to the static water environment of lakes. If the nitrogen and phosphorous contents of the water catchment areas are not to be controlled effectively, it is possible for the water to be eutrophicated at a unpredictable time, as evidenced by the blossom of algae, the hint of eutrophication, at Xiangxi River, Daning River and part of the reservoir bayou areas after damming the river.

- As the solid wastes on the banks of reservoir had been completely moved out and treated carefully before water impoundment according to the requirements of relevant Laws and Regulations, the solid wastes will not have any obvious impact on the water quality.
- With regard to the impact of sediments on water quality, the assessment in the past was focused on heavy metals. In reality, sediments also have a strong capability of absorbing organic pollutants. The monitoring result soon after the water is stored shows that sediments have deposited and water has become clearer and the water quality has become better. As the total amount of water and sediments is big in the upper reaches of the Yangtze, the contents of pollutants in the sediments are far from being saturated. It is, therefore, hard to judge whether the deposited sediments would cause secondary pollution.
- The assessment of the impact on underground water was mainly concentrated on the changes of the downstream water volume and level brought about by the reservoir regulation and its impact on the underground water level, gleization and swamping of soil in the four-lake area. Due to the special geographical conditions, the soil in the four-lake area has already been gleyed and swamped to a certain degree. The hydrological calculation at the EIA stage shows that the changes in the water level in the lower reaches of the Yangtze caused by the reservoir regulation fell within the scope of natural changes. But experts are still divided as to how to quantify the impact on soil gleysation and swamp by the water level of the Yangtze. Some experts hold that the water level of the Yangtze will change within the scope of natural changes and will not have much impact on the four-lake area; but others think vice versa. Solution to the problem requires, on one hand, intensification of monitoring and, on the other hand, further studies of the impact of the Yangtze water level changes on the gleization and swamping of soil in the four-lake area.
- Preliminary monitoring with water storage in June 2003 shows that the study is not adequate enough in the assessment period with regard to the oversaturation of oxygen and nitrogen of the water body downstream of the dam brought about by ski-jump and aeration, as water is released through bottom and surface holes. This merits attention.

2.2.2 Fish and Aquatic Life

Impact on native species of fish in the upper reaches

Due to the unique and long history of evolution in the fish zones and families, there existed a large amount of species native to the Yangtze in the upper reaches, which have adapted to the local hydrological, food-base, and habitat conditions. Once the environmental conditions change, the native species will be unable to adapt themselves and the biodiversity would be destroyed to a certain extent. The EIA predicts that the TGP will bring about adverse impact on about 40 species of fish, of which two-fifth are species native to the upper reaches of the river.

Impact on rare and endangered species

(1) Baiji dolphin and Yangtze finless porpoise

Baiji dolphin (*Lipotes vexillifer*), also called Chinese river dolphin, belongs to Whales (*Cetacea*), Toothed whales (*Odontoceti*), and River dolphin (*Platanistoidea*). It is one of the five freshwater dolphins in the world, only inhabiting in the middle and lower reaches of the Yangtze. Finless porpoise (*Neophocaena phocaenoides*) belongs to Porpoises (*Phocaenidae*) of Toothed whales, a widely distributed small Toothed whales. The Yangtze finless porpoise is an independent freshwater sub-species. The population of Baiji


Baiji dolphin


Finless porpoise


Chinese sturgeon


Chinese paddlefish


Dabrys sturgeon


Chinese Sucker


Longsnout catfish


Rock carp


Megalobrama pellegrini


Ancherythroculter nigrocauda


Elongate loach


Largemouth bronze gudgeon


Spinibarbus sinensis


Onychostoma sima


Rhinogobio ventralis

Rare and endemic fish and aquatic animals dolphin in the Yangtze was estimated at 300 in 1986 but had been reduced to less than 200 by 1990. The population of porpoise was estimated at 2700 in 1993.

The direct impact of the TGP on the Baiji dolphin and Yangtze finless porpoise is to make the scope of distribution smaller. The EIA predicts that the two species in the upstream of Xinchang of Shishou City will disappear due to serious scouring of the river bed, making it hard to survive for the about 10 Baiji dolphins in the river section between Zhicheng and Xinchang. The area of the distribution of Baiji dolphin in the Yangtze will be cut by 155 km.

With the Three Gorges Reservoir is completed, the navigation conditions will improve so as to increase the number of passing ships and exacerbate noise pollution. So, there is an increasing probability of accidental death of Baiji dolphin and Yangtze finless porpoise. Besides, the reduction of fishery resources in the river section downstream of Yichang after the dam is built will have an adverse impact on the food-base for Baiji dolphin and Yangtze finless porpoise.

(2) Chinese sturgeon, Chinese paddlefish, and Dabry's sturgeon

There are 27 species and 5 sub-species of sturgeons in the world, of which there are 25 species and five sub-species in the *Acipenseridae* and two species in the *Po1ydontidae*. There are two species of fish in the *Acipenseridae*: Chinese sturgeon (*Acipenser sinensis*) and Dabrys sturgeon (*Acipenser dabryanus*). There is one species in the *Po1ydontidae*: Chinese paddlefish (*Psephuyrus gladius*). Chinese Sturgeon has a habit of breeding migration, dwelling along the coasts of China's eastern areas and migrating to the Jinsha River in the upper reaches of the Yangtze for reproduction before the Gezhouba dam is built. It mainly lives in the sea. The Dabry's sturgeon is a pure freshwater fish. Its migration habit remains unclear. The damming of the Yangtze by Gezhouba directly affects its migration route of the Chinese sturgeon.

Chinese sturgeon has special requirements for water temperature, water flow, sand content, and river bed in spawning and reproduction. Due to the segmentation of the river by the Gezhouba dam, rather than the Three Gorges dam, Chinese sturgeon had to find a natural spawning ground below the Gezhouba Dam. But the reservoir regulation of the Three Gorges will change the annual distribution of the river runoff. When it begins storing water in October every year, the water released downstream will be reduced, thus reducing the scope of the spawning ground. It will also change the water flow, water temperature, and river bed conditions, which will bring about unfavorable effect on the spawning and reproduction of Chinese sturgeon.

The spawning ground of Dabry's sturgeon is dispersed, mainly in the section from Hejiang in the upper reaches to Maoshui in the lower reaches of the Jinsha River. There are also spawning grounds in the Three Gorges reservoir. But Dabry's sturgeon is not so strict in the spawning and reproduction conditions as the Chinese sturgeon. Changshou Lake of Chongqing succeeded in breeding Dabry's sturgeon at a bay of a reservoir. The TGP will not affect these spawning grounds. But when the reservoir stores water, the hydrological conditions of the reservoir will change and so will the original habitats of Dabry's sturgeon.

Before the 1980s, Chinese sturgeon, Chinese paddlefish and Dabry's sturgeon used to be the main cash-yielding fish species in the upper reaches of the Yangtze. An estimate shows that since the 1990s, the population of Chinese sturgeon has assumed a downward trend. The 1999 estimates it at 1500 adult individuals. There has been no estimation of the population of Chinese paddlefish and Dabry's sturgeon. Since the 1980s, the mis-catch record of fishermen shows that such mis-catch has been reduced year by year, indirectly indicating that its population has been reduced sharply. A survey shows that there was a record of 3 mis-catches of Chinese paddlefish and one mis-catch of Dabry's sturgeon in the upper reaches of the Yangtze in 1997 and there was only one mis-catch in the Hejiang section of Yangtze in 1999.[1] There was a record of 32 mis-catches of Chinese paddlefish downstream of Gezhouba Dam in 1984. There was no mis-catch record after 1995.

(3) Chinese sucker

Chinese sucker (*Myxocyprinus asiaticus*) belongs to the family of Cypriniforms (*Cypriniformes*) in the suborder *Catostomidae*. It is a noted ornamental fish, with long body and bright colors. Native to China and other parts of Asia, it is widely distributed in the Minjiang River and the Yangtze, especially the upper reaches, where it used to be an important source of catch for local fishermen. According to the 1958 statistics by Yibin City, Sichuan Province, the catch of Chinese sucker in the Minjiang River (a major tributary of upper reach of Yangtze) made up more than 13% of the total. In the 1960s, the Chinese sucker at Bianchuangzi in Yibin made up 13%, but it dropped to 2% by the 1970s. At present, there have been few mis-catch records, 3 in Yibin, 2 in Luzhou and 4 in Chongqing, and 7 downstream of the Gezhouba Dam from 1997–1998. The population of Chinese sucker has declined sharply, mainly due to over-catch and

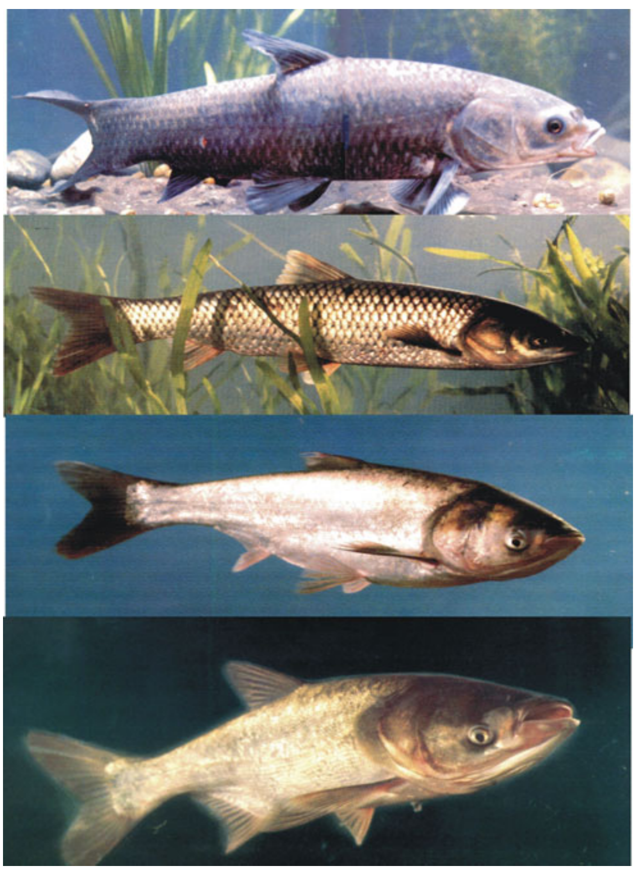
[1] Institute of Hydrobiology of CAS. Annual Reports (1997, 1998, 1999 and 2000) of the Aquatic Life Floating Monitoring Station.

environmental pollution. Artificial reproduction experiments proved to be a success in 1987. Some Chinese research units have bred F_2 generation. There is not much problem for such fish to survive.

The EIA predicts that the Chinese sucker population would be kept stable for a number of years to come in the upper reaches of the Yangtze. But recruitment in the middle and lower reaches from larval fish from the upper reaches is lacking and it would be difficult to maintain the stable population by relying on the reproduction at these sections of the river.

Impact on the Yangtze fishery resources and their survival environment

(1) Impact on the fishery resources of the Three Gorges reservoir area and middle and lower reach of Yangtze.



Four major endemic species of economic fish of the Yangtze. *Upper to lower* black carp, grass carp, silver carp and bighead carp. As the Yangze is a gene bank of the four major fish, the impact of the TGP has aroused great attention

TGP affects other types of fish in the following two aspects. One is that inundation will change the hydrological regime and affect the fish that likes fast moving water environment. These types of fish are mostly native to the upper reaches of the Yangtze, which are of great value in the protection of biodiversity. Such fish like flowing water as Catfish (*Silurus meriaionalis*), Longsnout catfish (*Leiocassis Longirostris*), Largemouth bronze gudgeon (*Coreius guichenoti*), Bronze gudgeon (*Coreius heterodon*), Common carp (*Cyprinus carpio*) and *Rhinogobio typus*, and with the dam, the population of these kinds of fish is likely to be reduced. But fish of the *Xenocyprinae* and *Cultrinae* will increase greatly. Study shows that TGP will affect more than 40 native species of fish in the reservoir area. The other is the impact of TGP on the four major endemic fish, namely Black carp (*Mylopharyngodon piceus*), Grass carp (*Ctenopharyngodon idellus*), Silver carp (*Hypophthalmichthys molitrix*), and Bighead carp (*Aristichthys nobilis*). The Yangtze is the habitat and reproduction ground and natural seed fry gene bank of these fish. They are of great value. The four native species have similar spawning habit and river/lake migration pattern, often spawning in the same place. The spawning grounds are distributed in the mainstream of Yangtze and its tributaries. After spawning, the fry grow in lakes. Study also shows that the spawning conditions of the fishes are closely related with the process of the rise of water level and water temperature. According to the 1986 survey, there were 11 spawning grounds between Chongqing and Yichang, with the biggest at Zhongxian County. There were another 11 spawning grounds between Yichang (Hubei Province) and Chenglingji (Hunan Province), with the largest situated in Yichang and Huyatan near the Gezhouba Dam. There were eight spawning grounds between Chenglinji and Wuxue (Hubei Province), with the largest at Huangshi and Huangjiazhen (both in Hubei Province). Impact on the four major endemic species in the reservoir area: As the river section near the end of the reservoir has the conditions for their reproduction and plankton in the reservoir will increase, the four major species will increase, too. Impact on the fish in the middle reaches: the spawning grounds will change in size and location. In the river section from Yichang downstream of Gezhouba Dam and Chenglingji will seriously affect the reproduction of the fish if the rise of water level and water temperature are ignored in reservoir regulation. The fry of the four major species in the middle and lower reaches will be reduced by 50–60%. This will reduce the amount and capture of the four native fish in the Dongting Lake. The reservoir storage regulation will make the Dongting Lake to enter the dry season one month ahead of time and advance its fishing season. The fish catch and quality will drop slightly.

Years of monitoring show that the amount of fry of the four major endemic species in the Jianli section in Hubei Province assumes a downward trend, estimated at 7.19, 3.587, 2.747, and 2.154 billion in 1986, 1997, 1998 and 1999, respectively, indicating that the number of reproductive fish has been reduced and the resources have been on the decline. This has increased the difficulty and variations in review of the assessment of the impact of TGP on the fishing industry.

(2) Impact of riparian pollution belt on the fish resources

The pollution belts formed by sewage and industrial wastes discharged directly by many cities and towns along the Yangtze have a great impact on the fish resources.

- These belts poison to death migrant fish and fry passing. A survey of the pollution belts in nine sections in the lower reaches of the river shows that more than 30 million fry and young fish die every year, especially the most valued fish species.
- They obstruct and change the fish migration routes, making it impossible for migrating fish and anadromous fish to reproduce and grow in their given environments, thus leading to changes in the fauna and amount of these kinds of fish.
- They directly spoil the spawning grounds, including spawning grounds of the four major endemic species and resident species. A survey shows that over a dozen spawning grounds have been ruined in the lower reaches, including Siheshan of Wuhu City, Baguozhou of Nanjing City, Jiangtan of Yangzhong City, and Jiangyin City.

(3) Impact of toxic remnants in fish body on fishing resources

Toxic matter monitoring of such economic species as Tapertail anchovy (*Coilia mystus*), estuarine tapertail anchovy (*Coilia ectenes*), Chinese mitten crab (*Eriocheir sinensis*), young Crab (*Decapoda*), Japanese Eel (*Anguilla japonica*), and Chinese sturgeon in the lower reaches of the Yangtze has found in their bodies 4–12 mg/kg of hydrocarbon, 0.3–3 times the 3 mg/kg standard. The contents of mercury and lead in 18 species are 0.005–0.116 mg/kg and 0.001–0.091 mg/kg, respectively, averaging 0.049 mg/kg and 0.046 mg/kg. The mercury content in Common carp (*Cyprinus carpio*) in the mainstream of Yangtze, Fujiang, Qujiang, and Qingjiang Rivers is higher than the background value of the Yangtze basin. The cadmium content of fish body was 0.08–0.7 mg/kg, with the maximum being 2.5 times the standard value of 0.2 mg/mg. The phenol remaining in the fish body is 0.08–4.0 mg/kg, with the maximum topping the standard value by 7 times and that remaining in Chinese sturgeon topping the standard by 25 times.

The above data show that in the pre-dam period, the remnants of toxic matters in fish bodies had already exceeded the reference or normal standard value and had a direct impact on the insemination, survival rate and sex gland maturity of stock fish, the embryo development and the germplasm and generic mutation of fish. It is a leading cause for the decline of fishing resources in the Yangtze in recent decade years.

Comments

- The impact of the dam on fish and other aquatic life is an important environmental issue in the building of the dam. Fish and aquatic life have had their unique species and their habitats through long-time evolution and development in given local water areas. For instance, the four major endemic species and many endemic species produce drifting eggs and the inseminated eggs drift with the current and fry enters the Dongting Lake and Poyang Lake to grow. The change in the hydrological regime has a direct impact on the living and reproductive habits of fish. The impact of segmentation by the dam and the runoff regulation on fish is studied mainly by taking into account of the following factors: (1) whether or not fish can adapt to the changed hydrological regime, especially in their habit of spawning and reproduction; (2) whether or not they will affect the food sources and habits of fish; (3) whether or not they will affect the growth of fish, such as size, sexual ratio, and genetics. All these issues are very complicated and there are many influencing factors. The impact would last long. Some impacts may be evaluated quantitatively, but most of them can only be evaluated qualitatively, which easily lead to differences in cognition and even big disputes.
- The Yangtze is a river with the richest resources of freshwater fish, the richest seed fry resources, famous and superior quality fish, the richest germ plasm resources and unique population of aquatic life. Inhabiting in the river are 350 fish species, including 142 native (endemic) ones (112 species in the upper reaches, 21 in the lower reaches, and 9 extensively distributed in the river). Aquatic life on the national list for top-class protection includes Baiji dolphin, Chinese sturgeon, and Chinese paddlefish; those on the list for second-class protection include Yangtze finless porpoise, Dabry's sturgeon, and Chinese sucker. The EIA was focused on rare and endangered species, paying little attention to endemic species due to their multiple species, many in small number and living in very special environment.
- Impact on Baiji dolphin and finless porpoise. Studies on the TGP impact on the two species of aquatic animals started in the 1980s, when their number was dropping fast. Baiji dolphin was estimated at about 300 in 1986, less than 200 in 1990 and less than 100 in 1998. The Baiji dolphin was declared "functional extinct" after a 6-week survey of Yangtze River by 30 researchers in 2006. The number of finless porpoise was 2700 in 1993, and the population also declined steadily. There are many

reasons accounting for the decline of the population of Baiji dolphin and finless porpoise. Among them are the decline of their food-base, destructive fishing gear, shipping, and pollution. The population of the two species dropped sharply and even to the verge of extirpation long before the dam was built. Traditionally, the reservoir area was not the habitat of Baiji dolphin and finless porpoise. The Three Gorges dam changed the habitat due to release of clear water and scouring of the river bed downstream. The impact of the dam on finless porpoise should be the focus of attention in the future.

- Impact on Chinese paddlefish, Dabry's sturgeon, and Chinese sucker. No estimation of population has ever been made. We can only assume that its population has been declining fast on ground that it has become very difficult for fishermen to catch. The reasons for the population decline are similar to those of Baiji dolphin.
- Monitoring after the reservoir impoundment shows, as the result of EIA, the composition of fish species has changed. The dropped is the capture of Largemouth bronze gudgeon, Bronze gudgeon, *Rhinogobio ventralis*, and Longsnout catfish and it is difficult for the use of traditional fishing method of bottom net fishing to catch them. When the water level reached El.135 meters from May 20 to June 10, 2003 fishermen in Wushan, Fengjie, and Wanzhou said that the fish was quite easy to catch as fish gathered in shoals. In the spring of 2004, fish in the Little Three Gores at Daninghe River in Wushan moved upstream to Dachang to spawn, indicating that fish was seeking new spawning grounds. This indicates that fish is very sensitive to changes in the hydrological regime.
- Impact of TGP on Yangtze fishing resources. The impact on the spawning and reproduction of the four major endemic species has received the greatest attention. The river section from Yichang to Chenglingji is the major spawning ground and the four major species usually spawn in April–May every year, when it is time for the reservoir to regulate its flow. The flow regulation without taking into account the fish reproductive habits will have a profound impact on the fish. But it is a difficult subject needed to be further studied as to how to regulate the flow of the reservoir so as to create "artificial flood peak" to stimulate spawning and reproduction of the four major fish and turn unfavorable factors into favorable factors.

2.2.3 Terrestrial Animals and Plants

Terrestrial plants

Historical records and literary works show that the Three Gorges area used to be covered with dense forests more than 1200 years ago and it was a habitat of concolor gibbon (*Hylobates concolor*). In 1986, a skeleton and a teeth fossil of concolor gibbon were discovered near the Taiping Village of Wushan. Carbon dating shows that the soil embedding the lower jaw bone is about 290 years old, in the reign of Emperor Kang Xi of the Qing Dynasty. Records also show that there were Giant panda (*Ailuropoda melanoleuca*) in the reservoir area in the eighteenth and nineteenth centuries.

But human activities have seriously damaged the natural ecology, making the ecosystem fragile, cultivated area less per capita and the land carrying capacity much heavier. The vegetation of the reservoir area has undergone great changes. Apart from tall mountains around, there is little primitive vegetation left, in stead, there grows Pine (*Pinus massoniana*) open forest, China weeping cypress (*Cupressus funebris*) open forest and shrubs or grasses as well as a significant proportion of agricultural vegetation. The forest cover is 22% in the Chongqing Reservoir Area, 32% in the reservoir area of Hubei. There is virtually no existence of forests below El 800 m on the river banks, but terraced fields and cultivated slopes. Terrestrial animals in the reservoir area have changed along with the change of forests to shrubs or grasses. Rare terrestrial animals can be found only in areas of high elevations or areas with good forest and vegetation covers.

The land inundation, people resettlement, and engineering projects have a certain impact on the plant species, especially rare and endangered species, which used to live in the reservoir area.

According to statistics at the EIA period, the reservoir could affect 550 species in 358 genuses and 120 families. In terms of absolute amount, those most seriously affected would be plants of Grass family (*Gramineae*), Sunflower family (*Compositae*), Spurge family (*Euphorbiaceae*), and Rose family (*Rosaceae*). All the two families of plants of Litchi family (*Sapindaceae*) have virtually been submerged. The Distylium Chinense (*Distylium chinense*) of the *Hamamelidaceae* (Witch hazel family) and Chinese Box of the *Buxaceae* (Box family), Harland's Box (*Buxus harlandii*), Rose of sharon (*Hibiscus syriacus*) of *Malvaceae* (Cotton family), and Thinleaf adina (*Adina rubella*), Coffice Family (*Rubiaceae*), Lindley's butterflybush (*Buddleja lindleyana*) of Strychnine family (*Loganiaceae*), Faber bauhinia (*Bauhinia brachycarpa*) of Pea family (*Leguminosae*), *Neyraudia reynaudiana* (*kunth*.) Keng, and Reedlike sugarcane (*Saccharum arundinaceum*) *of* Grass family would also be affected by inundation.

Impact on plant species

TGP might threaten the existence of the following three species [6]:

- Chinese kidney maidenhair (*Adiantum reniforme* var. *sinense*) is an endangered fern on the national list for second-class protection of China. Endemic to the reservoir area, it is of medical and ornamental value. It has some linkage with Kidney maidenhair (*Adiantum reniforme*) on the Azores Islands on the Atlantic. Chinese kidney maidenhair is mainly growing by the Yangtze at Wanzhou and Shizhu counties at an elevation of (170 ± 30) m. Part of them is affected by inundation. The EIA holds that the reservoir would inundate most of them.
- Looseflowered falsetamarisk (*Myricaria laxiflora*) is a rare species endemic to the Three Gorges area. EIA holds that the species are distributed in Zigui, Badong and Wushan at an elevation of 80–130 m. There are about 200 individuals by the Yangtze at Zigui, prone to be affected by people resettlement. The species has been listed by the State for second-class protection.
- Chuanminshen (*Chuanminshen violaceum*) is a unique species in China. There is only one species in the family, native to Sichuan and Hubei. It is of great medicinal value, mainly growing in Wenjiang and Daxian area in Sichuan Province. A topotypus of *Chuanminshen* was taken from the weathered shale rock seam at an elevation of 140 m near Liantuo of Yichang. The EIA holds that the wild species is extremely rare. Liantuo is situated between Gezhouba Dam and Sandouping. Although the area is not to be inundated or in the dam site area, it needs careful protection as construction of roads and other facilities from the dam site to Yichang are might damage them.[2]

Impact of reservoir area on big-and-ancient trees

Big-and-ancient trees are the important natural resources and precious historical heritage and should receive special protection. Although inundation would not cause extirpation, losses would be irretrievable. They are easily destroyed by human activities including the building of houses and roads, reclamation of land and the building of water works. The big-and-ancient trees are the witnesses to ancient climate and geography and are, therefore, of great significance in scientific study.

Impact on primordial vegetation

As the building of new houses for resettlement, the building of factories, township enterprises, and irrigation projects all need a large amount of timber; it would be inevitable that part of the primordial forests would be destroyed. Besides, local farmers are used to cut broad-leafed tree as firewood. Some of the primordial vegetation, especially the ever-green broad-leafed forests, native plants, rare plants, and big ancient trees would disappear due to massive felling.

The wild species on the El.175 m inundating line in Wanzhou is skiophyt. Chinese kidney maidenhair is under the second-class protection by the state. Endemic to the reservoir area, it is of medical and ornamental value. It is mainly growing by the Yangtze at Wanzhou and Shizhu counties at an elevation of (170 ± 30) m. Part of them is affected by inundation

Looseflowered falsetamarisk is distributed in the gravelly, sandy and rocky flood bed at an elevation at 80–130 m on the banks of the Three Gorges. Most of them were submerged by the TGP and a few was found in small islands below the Gezhouba Dam

[2]This was a mistake for the EIA, which carefully confirmed by the original papers in 2011 [35, 36]. The topotypus of *Chuanminshen violaceum* was founded in Jintang County near Chengdu City of Sichuan Province. The reason of *Chuanminshen violaceum* conservation was the ruin of topotypus for the TGP was invalid. During the construction period of the TGP, many mitigations of *Chuanminshen violaceum* have been finished, such as the ex situ conservation.

Chuanminshen is not endemic to the reservoir area. It is mostly planted artificially in Sichuan, Chongqing and Hubei. It is dispersed in Zigui, Yichang, and Wanzhou usually at an elevation of 80–380 m. It is partially inundated. Photos by Huang Zhenli

Fig tree (*Ficus virens*), an ancient big tree to be affected by the inundation at the Wuling Town, Wanzhou District. Photo by Huang Zhenli

The impact of TGP on terrestrial plant species has aroused great attention at home and abroad. Many scholars misconceived the reservoir area in the administrative sense as the affected area, In the EIA stage, listing *Adiantum reniforme* var. *sinense*, Looseflowered falsetamarisk and *Chuanminshen* for protection. The species affected by inundation and for protection established by the 2001 integrated survey are: *Adiantum reniforme* var. *sinense*, Looseflowered falsetamarisk, *wushan Neyraudia reynaudiana* (*kunth*.) *Keng* and *Wuxi ardisia* (the latter two have not been published). A comprehensive background survey of terrestrial animals and plants in the reservoir area found new distributions of *Adiantum reniforme* var. *sinense*, and *Chuanminshen* at places above the 175 m, Looseflowered falsetamarisk at a small island below the Gezhouba Dam.

Fig tree (*Ficus virens*) is both an big tree and part of the cultural relics at ancient Dachang town located in the middle reach of Little Three Gorges, Wushan county. Photo by Huang Zhenli

Terrestrial animals

(1) Current conditions of terrestrial animals in the reservoir area

EIA survey shows that there are 369 known species of vertebrate animals in the reservoir area. They include 85 species of mammals, 237 species of birds, 27 species of reptiles, and 20 species of amphibious animals. Among them, the most widely distributed species make up 14.9%, oriental region species make up 51.5%, Palaearctic Region species, 33.6%. The Three Gorges reservoir area belongs to the western highland sub-region of the Central China area of the Oriental region in terms of animal geographic zoning.

Wild animal species in the reservoir area on the national list for priority protection are 26, including 4 for the first-class protection: Snub-nosed monkey (*Rhinopithecus roxellanae*), cloud leopard (*Neofclis ncbubosa*), Leopard (*panthera pardus*), and South China Tiger (*Panthera tigris amoyensis*); 22 species for the second-class protection: rhesus macaque (*Macaca multta*), Chinese pangolin (*Manis pentadactyla*), Asiatic black bear (*Selenarctos thibetanus*), Common otter (*Lutra lutra*), Large Indian civet (*Viverra zibetha*), Little civet (*Viverricula indica*), Asiatic golden cat (*Felis temmincki*), Chinese forest musk deer (*Moschus berezovskii*), Serow (*Capricornis sumatraensis*), Chinese goral (*Nacmorhedus goral*), Northern goshawk (*Accipiter gentilis*), Eurasian sparrowhawk (*Accipiter nisus*), Temminck's tragopan (*Tragopan temminckii*), White-crowned long-tailed pheasant (*Syrmaticus reevesii*), Chinese copper pheasant (*Chrysolophus amherstiae*), Mandarin duck (*Aix galericulata*), Chinese giant salamander (*Andrias davidianus*), Black kite (*Milvus migrans*), Kestrel (*Falco tinnunculus*), and Koklas pheasant (*Pucrasia macrocopha*).

There are 30 species (27 animals and 3 birds) of vertebrates. Some species, such as harmful species of Striped field mouse (*Apodemus agrarius*), Brown rat (*Rattus norvegicus*), and Mole shrew (*Anourosorex squamipes*), are distributed widely and in large numbers harmful to people.

Water fowls have increased significantly after the reservoir stored water. The picture shows the water fowls on the bank of the tributary of Shennuxi in the reservoir area. Photo by Huang Zhenli, on June 6, 2004

(2) TGP impact on terrestrial animals

The Three Gorges reservoir will inundate a large expanse of land and the water surface will be expanded. That will reduce some non-migrating species and increase the number of water-related species (water fowls) and will have a direct impact on terrestrial vertebrates. Resettlement and land reclamation will easily destroy their habitats.

The development of vertebrates cannot be separated from a given biotope. The wild animals in the reservoir area have by and large formed five ecodemes corresponding to their biotopes. The Three Gorges Dam will have the following impacts:

- Water bodies and river valleys (below the elevation of El.175 m and nearby areas). With completion of the Three Gorges Dam, the biotope of the inundated water bodies will be expanded and the hydrothermal conditions will be improved, and the water level change will form fluctuating zone (water scour). The wildlife in these areas, such as Black-spotted pond frog (*Rana nigromaculata*), Hubei gold-striped pond frog (*Rana plancyi*), Guenther's frog (*Rana guentheri*) and Terrestrial frog (*Rana limnocharis*) will increase in number while their habitats improved and food-base increasing. Such reptiles as Reeves' turtle (*Chinemys reevesii*) and Chinese soft-shelled turtle (*Trionyx sinensis*) will also increase; the number of such water fowls as Mallard (*Anas platyrhynchos*), Spot-billed duck (*Anas poecilorhyncha*) and Little egret (*Egretta*) will increase, too, possibly giving rise to new species. The number of such animals as Chinese ferret-badger (*Melogale moschata*), Striped field mouse and Siberian weasel (*Mustela sibirica*) will increase greatly. The rare animals in the areas, such as Chinese giant salamander and Mandarin duck will not be affected by inundation and their number will increase in a limited manner. The fluctuating flow of the reservoir will somehow threaten hideouts of otters.

- Agricultural areas and cultivated plant belts (above the inundation line and up to an elevation of about 400 m). The dam will inundate some of the cultivated land, thus shortening the original biotope and the resettlement and land development will form new environments. The amphibious animals and reptiles in these areas will suffer losses partially, but their habitats will be restored soon and develop. With a period of time after the impoundment of the reservoir, the density of large animals will increase in the agricultural areas. The change in biotope will not have any adverse effect on such rare animals and birds as Eurasian sparrowhawk, Kestrel, Chinese pangolin, small Indian civet (*Vierra indica*) and Leopard cat (*Felis bengalensis*).
- Low hill grass growth and open forest belts (at an elevation of 400–800 m). The biotope in this belt is distributed mostly above the inundation line and the reservoir will not have much effect on it. But they will be affected by human activities. Rare animals in these belts include sparrow hawk, common kestrel, white-crowned long-tailed pheasant, golden pheasant, rhesus macaque, Chinese pangolin, large Indian civet, Leopard cat and Chinese forest musk deer. The depletion of the vegetation will cause these animals to lose their food-base, habits and activity zones. This, plus the killing by people, will be a disastrous threat to them and they are likely to assume a downward trend in species and number.
- Middle high mountain needle and broad leaf forest belts (at an elevation of 800–2000 m). The inundation and hydrothermal conditions will not have any effect on these areas. Only human activities might destroy forests and vegetation.
- Sub-alpine grass growth and needle leaf forest belt (at an elevation of above 2000 m). There are few animals in such alpine areas and if any, their habitats are far from the inundated areas. The dam will not directly cause the ecology to change and therefore will not affect the animals in those areas.

Comments

- The impact of TGP on terrestrial plant species easily arouses attention. But the opposite views are misleading and easy to touch off media frenzy, such as misconceptions of "reservoir area" and "affected area", and the erroneous idea that all the species in the reservoir area would be affected. The impact of TGP on terrestrial plants is directly caused by inundation and resettlement and the main areas affected are the areas inundated (only about 1.1% of the total reservoir area) and resettlement area, which also takes up only a small part of the total reservoir area. In assessing the TGP impact on terrestrial plants, many scholars often misconceived the reservoir area in the administrative sense as the affected area. This is entirely wrong.
- The 2001 integrated survey and cross-checking study suggested that major efforts should be focused on the protection of rare and endemic species, which include *Mayricaria laxiflora, Adiantum reniforme var. sinense* [6]. *Mayricaria laxiflora* is distributed in the gravel, sandy and cobble riverbank bed in the water fluctuating zone from Zigui in Hubei to Banan District of Chongqing, which is covered by the reservoir area, totaling 90,000

in 31 groups [33]. According to the present survey, it is the only rare and endemic species that will have to be submerged totally.[3,4] Ironically, new unexpected distributions of *Mayricaria laxiflora* were found at three small islands below the Gezhouba Dam in 2007 and 2008 and then corrected the previous view. *Adiantum reniforme var. sinense* is a plant on the national list for second-class protection. It is an endemic species in the reservoir area, mainly growing on the shoreline at an elevation of 170 ± 30 m at Wanzhou and Shizhu counties. It will be partly inundated. The *Chuanminshen* is a plant not native to the reservoir area. It is mostly artificially planted and distributed widely in Sichuan, Chongqing and Hubei. It is sparsely distributed at an elevation of 80–380 m in Zigui, Yichang and Wanzhou, with only part to be inundated. From 1996, the Executive Office of SCTGPCC organized a comprehensive survey of terrestrial animals and plants in the reservoir area and found new distributions of *Adiantum reniforme var. sinense, Chuanminshen vilaceum* and their coenosis at places above the inundating line of EL.175 m and the distribution of a number rare tree species at an elevation above El.1000 m, a discovery that is of great significance for the survival of wild coenosis and security of species. Wang et al. (2004) upgrade *Rosa multiflora var. cathayensis* from a variation to an independent new species. The herbal plant is distributed at Fengweiba of Mingshan Town in Fengdu County, Chongqing Municipality, with an elevation of 145 m and the Tangtuba of Wuyang Town in Zhongxian County, with an elevation of 140 m. The reservoir will inundate the primordial biotope of the species. The plant has been removed to the Wuhan Botanic Garden of the CAS for protection [34].

- According to the 1993–1995 survey [24], there are 3418 species, 1940 genuses, 242 families and 19 orders in the insecta, including 16 new genuses, 289 new species, 16 newly recorded genuses and 94 newly recorded species. Besides, there are 67 species in 44 genuses, 23 families and two orders in the *Arachnoidea*, including two newly recorded species. Studies show that TGP does not have any direct effect on areas with a high insect diversity index.

On May 15, 2001, a meeting was held to prove the project of domestication and naturalization of *Adiantum reniforme var. sinense*, *Myricana Laxiflora* and *Chuanminshen*. In order to protect the rare and endemic species, the Executive Office of SCTGPCC organized scientists to solve the technical problems of proliferation of the three species before the water impounding. The project turned out to be a success at the Sixi Base in Zigui County of Hubei. On this basis, 2.4 million yuan was invested from September 2002 to September 2007 to continue the work of rescuing and protecting species and to ensure their security

New distributions of *Mayricaria laxiflora* were found at three small islands (Yanziba near Yichang City, Guanzhou and other anonymous island near Zhijiang City) below the Gezhouba Dam in 2007 and 2008

[3]Wuhan Botanical Garden of CAS (2001) Studies of Domestication and Returning to Nature of Rare Plants of *Adiantum reniforme* var. *sinense*, *Mayricaria laxiflora* and *Chuanminshen violaceum* in the Three Gorges Reservoir Area.

[4]Xiong (1997). Study of the Ecology and Propagation of *Mayricaria laxiflora*, Master degree paper of Institute of Botany of CAS.

2.2.4 Local Climate

The EIA predicts that TGP would have some impacts on the climate of the reservoir area and nearby regions, but not very great. The impacts on temperature, humidity, wind and fog would be limited to an area of not more than 10 km, especially the areas near the reservoir. There would be changes with all the climatic factors in the post-dam period, but not very big. There were some changes in all the climatic factors before the reservoir was built, but the changes were not big.

Impact on air temperature

With operation of the reservoir, the rolling hills in the inundated areas have been replaced by water, thus changing the modes and intensity of energy exchange between the underlying surface and air. As the thermal capacity of the water body is bigger than the soil, the air temperature in the same area would inevitably change. The differences in temperature between the water body and land would cause horizontal exchange, thus leading to changes in the temperature on land around the reservoir.

Study shows that the reservoir has some impact on air temperature to certain extent, but not big, with the affected areas covering place below the elevation of 400 m vertically and usually 1–2 km horizontally. The stability of atmospheric structure tends to be neutral and days with temperature inversion would be reduced. The annual mean temperature in the reservoir area would rise slightly, by somewhat between 0 and 2 °C, with the monthly mean temperature in winter and spring rising 0.3–1.0 °C, that in summer dropping 0.9–1.2 °C, extreme high temperature dropping 4 °C and extreme low temperature rising about 3 °C.

In the eastern section of the reservoir area is mostly canyon, with narrow river surface. Even after the reservoir stores water, the expansion of water surface will be limited. So the impact on temperature in this section is smaller than in the western section in terms of intensity and scope.

Zhang et al. (2005) [37] indicated that annual average air temperature at the dam site area has an obviously increasing tendency since 1990s and the Three Gorges reservoir has the obviously effect of decreasing air temperature on the vicinity of the dam site after the reservoir storing water.

Impact on wind

With the dam is built, the water surface will be expanded and wind velocity would increase. The water level of the reservoir will rise in winter and the surface area would increase and that will increase the changes in wind velocity. When the water level drops in summer, the water surface would become smaller and there would be little change in wind velocity.

Impact on precipitation

In the EIA stage, the reservoir would have little effect on the total precipitation in the affected areas, with the annual mean precipitation to increase by only 3 mm. Precipitation in the sections over the reservoir and in the lee side of the riparian current would be reduced and that on the windward side will increase.

The independent satellite data sets and numerical simulation by Wu et al. (2006) [38] indicate that the land use change associated with the Three Gorge Dam (TGD) construction has increased the precipitation in the region between Daba and Qinling mountains and reduced the precipitation in the vicinity of the TGD after the TGD water level abruptly rose from 66 to 135 m in June 2003. This study suggested that the climatic effect of the TGD is on the regional scale ($\sim$100 km) rather than on the local scale ($\sim$10 km) as predicted in the EIA stage.

Impact on humidity

As the water body will increase after the reservoir is built, the total evaporation would increase, thus leading to the increase in average vapor pressure. Study shows that such pressure will increase to varying degrees in all months of the year, with that in winter to increase 20–30 Pa, that in summer, 130–180 Pa, and that in spring and autumn, staying at something in between winter and summer. The absolute humidity is subject to the control by temperature. Although there are some differences between winter and summer, the increase in all seasons is not very big, generally by less than 0.4 g/kg. The relative humidity will increase about 6% in summer, 1–3% in spring and autumn and decrease by 2% in winter.

Impact on fog

Radiation fog prevails in the reservoir area, often occurring in the morning of winter. The EIA holds that there would be not much change in the mean foggy days, probably increasing by 1–2 days, after the reservoir is impounded.

视 点 新 闻

人民日报

不久前发生在四川、重庆的洪灾损失巨大，引起国内外的广泛关注。有人认为，是三峡水库的大量蓄水，造成了川渝地区连降暴雨。针对这种传言，本报记者独家专访了国家防汛抗旱总指挥部办公室、水利部和中国气象局的几位专家，他们认为——

川渝大洪水与三峡蓄水无关

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川渝特大洪灾是怎样形成的？

简单地说，这次川渝特大洪灾是由西南低涡切变天气系统造成的，这是西南地区比较常见的天气系统，也是造成西南地区降雨的主要原因。虽然造成这次洪水的天气系统是常见的，但是它带来的降雨是大是小，落在西南地区什么地方有一定的偶然性。自然现象有一定的周期性，但也有不可重复性，它不会在同一时间同一地点简单重复。

由于西南暖湿气流携带大量水汽，在四川、重庆局部地区上空与北方南下的冷空气相遇，形成对流性强降水。当时恰好有一个低压槽系统稳定在该地区上空，因此造成了持续的降水。

这次川渝洪水有什么不同于以往的地方？

长江上游也即川江的洪水一般发生在7、8月份，但今年拖到了9月份。不过历来就有“华西秋雨”的说法。汉江、川江、黄河中游和松花江流域都常发秋汛。我国幅员辽阔，每年4月珠江入汛，6、7、8三个月为全国的主汛期，到10月份霜降之后，黄河流域的汛期才告结束。去年也是在这个时候，渭河和汉江发生了较大洪水。

川渝这场洪水之所以造成巨大的损失，是因为短历时的强降雨，导致洪峰流量大、水位高、涨势快。而且暴雨集中在嘉陵江支流渠江和长江支流小江4万平方公里的较小范围内，水势陡涨陡落，让人猝不及防。渠江一天多时间猛涨20多米，造成不少堤段漫顶淹没，灾情严重。

洪水经过三峡水库削峰调度后，宜昌水文站的洪峰流量仍达6.08万立方米每秒，为1998年以来最大洪峰。

这次洪水的发生与三峡工程蓄水有无关系？

专家认为，这次川渝特大暴雨与三峡蓄水造成水汽蒸发量加大没有直接关系。虽然蓄水增加、水面增大，但是水汽蒸发量仍很有限，不可能引起这么大的降雨。

四川、重庆降水多集中在5月—9月，而且秋季降水较多，部分地区受天气形势影响有可能出现暴雨。有资料显示，此区域局部地区降水量较大的年份也曾出现过，如：巴中1973年9月4日—7日出现399毫米的大暴雨过程，9月10日—20日出现313毫米的大暴雨过程。

根据水文观测站建站50多年的历史资料分析，尽管在这个季节，这个地区发生这么大量级的洪水是比较少见的，但是今年嘉陵江支流渠江来水2万多个流量，而1975年10月，渠江来水曾达到2.4万个流量，超过今年发生的洪水；今年渠江上游的洪水量级为历史实测第四，下游的洪水量级为历史实测第二，历史实测最高记录均出现在修建三峡工程之前。

三峡蓄水对周围气候变化影响大不大？

按照设计，三峡工程建成后最高蓄水位可达175米，将增加水面1084平方公里，这对周围的小气候可能会有一些影响，比如降水次数有所增加，降水更加均匀，但是这种影响对一个大的天气系统来说，是非常微弱的。

气象专家经过对三峡库区近50年气候监测数据分析和气候数值模式模拟结果分析，认为目前发生的气候变化仍属自然变化，三峡周围的气候变化与整个西南地区的气候变化趋势是一致的。三峡蓄水仅对局部地区气候产生很小影响，影响范围在20公里以内。具体而言，接近湖面地区降水可能减少，远离湖面在15公里左右的地区年降水量可能增加10毫米左右；受水库蓄水影响，库区夏季的气温可能会降低0.5—1.0摄氏度，而冬季的气温可能会升高0.3—1.0摄氏度，变化幅度不大，库区湿度可能会更加均衡；由于水面扩大，可能会出现雾气增加、风力加大，但在不同季节情况也不尽相同。

中国气象局已在三峡地区增设了自动气象站，并在国务院三峡建设委员会的支持和帮助下开展立体气象观测，以积累更多更可靠的观测数据。气象专家也会利用今后的监测数据进行三峡工程对周围气候环境影响的深入研究，验证数值模式模拟结论。

In July 2004, a rare flood struck Kaixian of Chongqing and other areas in Sichuan, causing much concern in China and abroad. Some people asserted that the flood was caused by the storing water in the reservoir. Expert of the State Meteorological Center gave the lie to the rumor. The picture shows the expert interviewed by a correspondent representing the People's Daily and the CCTV

Comments

The EIA has a comprehensive assessment of the impact of TGP on local climate, demonstrating that it has both advantages and disadvantages. But the quantitative prediction has to be tested by long-term monitoring and studies to see whether it conforms to reality.

- After the reservoir is built, temperature in summer would drop and wind velocity would increase, thus to cool down the scorching living environments in the Wanzhou area. But humidity and foggy days will increase, especially in winter, and would affect the living environment, affecting waterway navigation, land and air transportations. The increase in wind velocity will drive acid rains in cities to outskirts. When vapor and fog increase, acid rain will somehow increase.
- Although the reservoir has a limited impact on the local climate, the climatic factors increase will not be very big. But the climatic change will have a profound impact on agricultural production and the livelihood of the people. It is, therefore, necessary to strengthen monitoring and forecast so as to display advantages and avoid disadvantages.

2.2.5 Agricultural Ecology and Environment

Impact on the reservoir area

The Three Gorges reservoir area is a traditional agricultural area, dominated by mountains. For a long time, due to rapid population growth, steep slopes have been reclaimed into terraced fields for growing cereal crops to relieve the pressure on food grain supply. This had a serious consequence in soil erosion, making the local ecological conditions deteriorating and inadequate supply of reserved land.

The changes in air temperature, humidity and soil structure after the reservoir is built will cause some changes in the agricultural ecology and environment, thus to bring about adverse effect on plant structure, populations, types and composition of animals and plants. The local climatic change has both advantages and disadvantages, i.e., that the wintry temperature will rise; precipitation will increase slightly; the frost time will come late and its end will be earlier, making it favorable for such thermophilous plants as Orange (*Citrus reticulata*), Oiltung (*Vernicia fordii*), Longan (*Dimocarpus longgana*) and Litchi (*Litchi chinensis*). While the temperature drops and wind velocity increases in summer will reduce the harm done by high temperatures in the low elevation valleys and the summer drought will be lightened.

Impact on the four-lake area in the middle reaches

The four-lake area in the middle reaches of the Yangtze is noted for abundant rainfall, even terrain, fertile soil, a web of waterways and rich agricultural resources, for agriculture, industry and commerce. The operation of the dam is likely to change the ground water level, which will, in turn, have some impacts on the agricultural ecology and environment.

Comments

- What affects the agricultural ecology and environment in the Three Gorges reservoir area is, apart from natural factors, the resettlement of people and the adjustment of the agricultural structure. Agriculture occupies an important and traditional position in the reservoir area. The significance of agricultural ecology and environment to agriculture, rural areas and farmers should merit attention.
- The latest studies [5] show that in 1998, the non-point agricultural pollution sources occupied 77.85% (ratio of the equivalent pollution load) of the total pollutants generated in the reservoir area, which has become an important factor affecting the water quality of the reservoir and making parts of tributaries eutrophicated. The non-point pollution source of agriculture is the major "culprits".

2.2.6 Impact on the Ecology and Environment of the Estuary Area

Impact on the estuary runoff

The reservoir will not change the total amount of water emptying into the sea. It can only regulate such volumes during different water seasons. Comparing the flow volumes for the low-flow, normal-flow and high-flow years with the natural flows, the flow discharge in October at the Datong Station will be reduced by 32.4% in the low-flow year, 20.3% in the normal-water year and 16.9% in the high-flow year. In January–May, the water released from the reservoir would increase by 1000–2000 m^3/s. The flows for the three typical years increase by 24.5, 19.9 and 5.1% respectively as compared with that of natural flows.

Impact on salt water invasion

When water release increases during the dry season, the peak value of chlorides in the water body at the estuary will be reduced and the days in which no standard water can be obtained successively will be reduced. But when the water release decreases in October and November during the low-flow year, the time of salt water invasion would be great and the duration will be lengthened, thus increasing total number of days of salt water invasion.

Impact on the soil salination

Salinized soil is widely distributed in the delta area at the estuary. It has reached up north along the banks of the Yangtze to the salt water invasion line. The general trend of the evolution of the saline soil is developing toward desalination. The reservoir will change the hydrological regime of the Yangtze, thus exerting a certain impact on the water-salt balance of the soil in the estuary area.

Impact on sediment silting and erosion process

In the first 50 years of the dam operation, the average transport of suspended load at the Datong Station will be reduced by 23.4% or 114 million tons as compared with the pre-dam period. After that, more sands will come. The decrease in sand and the seasonal adjustment of water volume will cause the shoreline of the estuary delta to change in erosion and deposition. An unfavorable impact is that speed of depositing in some shorelines would slow down and scoring would become stronger in some shorelines. The favorable effect is to increase the stability of the river channel in the estuary area.

Impact on nutrients and fishery resources

20–30% of such nutrients as nitrogen, phosphorus and others come from the water bodies upstream from the dam site. The main source of nutrients in the estuary area comes from the tributaries and lakes in the middle and lower reaches. It is estimated that the reservoir will retain 10% of the nutrients after the reservoir is built, the estuary and offshore areas will still maintain a fairly high level of nutrients.

The Yangtze estuary and the offshore waters are important fishing grounds of China. The Three Gorges dam will affect the fishery resources as it will change the allocation of estuary runoff. As different species of fish have different habits, advantages for some kinds of fish may be disadvantages to the others. The spawning ground of Chinese mitten crab will move and young crabs will be reduced. But the situation will be favorable for Tapertail anchovy (*Coilia mystus*), Icefish (*Salanx cuvieri*) and Reeves shad (*Tenualosa reevesii*). But it is unfavorable for Japanese grenadier anchovy (*Coilia ectens*) and Bighead croaker (*Collichthys lucidus*). During the water storage season in October, the fishing ground will move inward and change the migration routes, favorable for catching, but unfavorable for the replenishment and protection of fishery resources. The dam will have potential impact on the ecosystem structure and functions at the estuary and offshore areas.

Comments

- The Three Gorges reservoir is a seasonally regulated reservoir and the runoff at the dam site makes up only about half of the flow volume emptying into the sea. Its impact on the estuary is mainly reflected in the change of runoff during the water storing period from September to October every year and the water release period in March–May. The EIA estimated that the changes in monthly flow downstream from the dam would be all within the fluctuation range of natural (pre-dam) flow and the annual runoff into the sea will not change. This is quite different from the Aswan high dam, which is a perennial-regulated reservoir, with the annual runoff at the dam site being 84 billion m^3 and the average volume flowing into the sea in the 1980s being 6 billion m^3.
- The Yangtze estuary is a complicated and sensitive area. There are many influential factors, but with the runoff being only one of the important factors affecting the ecology and environment. In horizontal distribution of the primary productivity of the Yangtze estuary an upward trend is assumed, lower from the estuary and offshore area to the higher off the coast, with the highest of the waters in the northeastern part. The whole estuary area is rich in biotic resources. There are 51 frequently seen Phytoplanktons, 47 kinds of Planktonic animals, 40 kinds of Bristle (*Polychaete*), 19 kinds of mullusca, 7 kinds of *Crustacean*, 4 kinds of Echinoderm (*Echinodermata*), 3 kinds of fish and one kind of Cnidarians (*Coelenterata*). Besides, there are 69 kinds of aquatic life that is of resource value. They include 40 fish species, 13 Shrimp (*Decapoda*) species, 6 Crab species, five *Cephalopoda* species and *Gemmula deshayesii*, Arminid (*Armina* (*Linguella*) *babai*), Ark shell (*Scapharca subcrenata*), Green sea urchin (*Hemicentrotus pulcherrimus*) and Mantis shrimp (*Oratosquilla oratoria*). Resources captured are mostly small and miscellaneous fish.
- The Yangtze estuary and the offshore areas are the main fishing grounds of China. Different species of fish have different habits and the changes in runoff may be favorable to some but unfavorable to others. The influential mechanism is still not clear by now, making it hard to make a clear assessment or estimation and still less the quantitative analysis.

2.2.7 Public Health

Impact on Snail fever (*schistosomiasis*)

The reservoir sets between two major Snail fever epidemic areas in the upper and middle reaches of the Yangtze. Till today, there are no Snails (*Oncomelania hupensis*) found in the reservoir areas. Neither is there outbreak of Snail fever. After more than 40 years of control efforts since 1950s, the areas infested with snails in the upper basin of Sichuan has been reduced. The distance to the tail of the reservoir has increased from the original 299 km to more than 400 km, far farther than the distance for the survival of snail floating down with planktons. So it will not spread in the reservoir areas. There is no snail distribution, either in the areas within 100 km downstream from the dam. It is impossible for snails to move upstream to the reservoir area. That is why the EIA holds that it was not possible for Snail fever to spread in the reservoir area.

Impact on malaria

It has preliminarily been verified that there are more than 50 species of Mosquitoes in the reservoir area. Among them, *Anopheles sinensis*, the female one, is the main vector of malaria. Historically, it was a serious epidemic area in all counties of the reservoir area. Thanks to the massive control campaign, the incidence of malaria has been assuming a downward trend, but there are still pockets of such epidemic.

The key factor possibly leading to the spread of malaria is the overgrowth of weeds in shallow waters. After the reservoir is built, gorges where the mainstream goes through are still precipitous rock faces and sheer cliffs. This, plus the strong wind and interference of ships, makes water in a constant state of fluctuation, making it difficult to form a shallow area for weeds to grow. The fish in the reservoir will feed on larva of Mosquitoes and weeds, making it difficult for Mosquitoes to multiply and spread malaria. Influenced by backwater, the water of tributaries in the flatland areas may become shallow at local areas, making it favorable for Mosquitoes to proliferate and spread malaria.

Impact on other diseases

(1) Natural epidemics

Leptospinosis. The epidemic foci and hosts of *leptospinosis* are Rodents, especially striped field mouse, which has the highest bacteria-carrying rate. When the reservoir water level rises, it will force Rodents to move up highland areas and the density of such Rodents would inflate, thus leading to the increase of epidemic foci. But the inundation of land may reduce the paddy epidemic areas.

Paragonimiasis and Clonorchiasis. The carrier hosts of the two kinds of diseases are Cats, Rodents, Goats and Wild bora (*Sus scrofa*). Rodents and Cats are the major hosts of *paragonimiasis*. The Three Gorges was once a high incidence area for *paragonimiasis*. But years of efforts have reduced the incidence. The inundation of the land will make it unfavorable to the intermediate hosts to survive. After the destruction of the biotope of such vectors as snails and Crabs, new proliferation areas for intermediate vectors may appear in places above the normal water level. The disease may spread if people eat raw River crabs. If efforts are made to make publicity about not eating raw Crabs, the way for spreading the disease would be cut off.

Epidemic encephalitis B. This is an acute central nerves infectious disease spread by Culex (*Culex tritaeriorhynchus*) and *Aedes albopictus*. After the dam is built, the reservoir will inundate part of the land and the water level will rise. The original mosquito breeding area will disappear and the shallow waters in local areas are likely to become new areas for Mosquitoes to proliferate.

***Epidemic hemorrhagic fever*, EHF**. Rodents carrying EHF virus are striped field mouse, Himalayan field rat (*Rattus nitidus*) and Edwards's long-tailed great rat (*Niviventer edwardsi*). At the beginning of impoundment, the habitats of these Rodents would be inundated and Rodents on the shoreline would move upwards, thus increasing the density of the Rodent population, possibly leading to the increase in such diseases.

Rickettsiosis. The EIA has proved that the Sandouping area near the dam site is the epidemic focus of *Rickettsiosis* and related diseases (spotted fever, Q fever). The change in ecology and environment by the dam, the migration of Rodents and birds and the movement of susceptible persons might lead to local outbreak of such diseases.

Filariasis. The disease has been eliminated in the reservoir area and the water storage of the reservoir will not cause the disease to recur.

(2) Endemic diseases

The EIA found that the dam would not have direct impact on endemic diseases.

Comments

Although predictions are optimistic about the impact of TGP on public health, it is a matter of people's health of those resettled and local residents and worth of full attention. It is necessary to strengthen monitoring and work out emergency plans.

2.2.8 Social Environment

Impact of inundation and resettlement on environment

TGP has an impact on local social environment in many facets, mainly concerning the people resettlement and other environment issues associated with the resettlement.

The reservoir inundates 6301 groups in 1680 villages of 277 townships and towns in 20 counties/districts in Hubei Province and of Chongqing Municipality. Two cities, 11 county towns and 116 townships have to be rebuilt completely or partially. The inundated area covers 26,000 hm^2 and a population of 847,500. Factories and mines to be inundated have to undertake losses due to temporary stop of production, and that will also affect their partners in normal production though they are not involved in inundation. But the relocation will help to increase economic efficiency through improvement of production environment, equipment replacement, and technical upgrading.

The TGP reservoir inundation is characterized as there is a great number of people living sparsely below the inundation line; the absolute Fig. is large and the relative is not so big of the cultivated land, which is distributed unevenly; and a huge number of cities and towns are to be affected so as to impede seriously the development of riparian industries and communications.

It is estimated that 120 million–200 million kilograms of grain will be reduced due to inundation if calculated by 300–500 kg per mu (4500 kg–7500 kg per hectare). This, plus the growth of population and the newly reclaimed land that has to go through a process of ripening, will create a big shortage of grain and exert great pressure on the land. It is estimated that the grain shortage would be 140 million kg, 850 million kg and 1.56 billion kg if calculated by the average amount of 300 kg, 350 kg and 400 kg per person. The population is estimated to grow to 16.09 million after the TGP reservoir is impounded and the cultivated land would be 866,000 hm^2. If calculated by the per capita possession of grain of 300, 350 and 400 kg, the grain shortage would be even greater by 2000.

After the dam is built, the land reclaimed on slopes with a gradient bigger than 25° will be returned to forests totally up to 202,000 hm^2, thus further reducing the cultivated land. So the grain shortage will be even worse by 2010. If without strong supports, there would be no way to solve the contradiction between people and farm land, to say nothing of development of other industries.

Reclamation of land will destroy vegetation and induce soil erosion. The building of new township and village enterprises will cause new environmental pollution. But rehabilitation of cities and towns will help improve urban environment and stimulate economic prosperity.

Impact on natural landscape and cultural resources

(1) Impact on scenic spots

The Three Gorges is 192 km in total length, with the dam sited in the middle section of the Xiling Gorge, 34 km from Nanjinguan the mouth of the gorge. The 158 km river section from the dam–site to Baidicheng will be of the reservoir covering the whole Qutang Gorge, the Wuxia Gorge and the western section of the Xiling Gorge. Downstream from the dam 34 km to Nanjinguan in will be affected by the water release from the dam.

After the reservoir is built, in the flood season, the water level at the forebay of the dam will rise by about 80 m while that at Fengjie of the gorge mouth will rise about 30–40 m. In the dry season, The forebay water level will rise up to more than 100 m and that at Fengjie will rise about 60–70 m. It is the dry season that sees the biggest change in water level, water surface width and velocity. The natural landscape of the Three Gorges will change correspondingly; especially the magnificent view at famous Kuimen will become not so spectacular. Rapids and gorgeous scene of the tributaries will change due to rise in water level. The Little Three Gorges on the Daning River will be partially affected.

With the reservoir operation, water discharge from the reservoir will be similar to the natural flow in most time of the year, decreasing in the flood regulation period and the water storage period at the end of the flood season and increasing during the dry season. The change because of the water release will not have significant impacts on the natural landscape.

But the huge man-made structures, such as the high dam, the shiplocks and the shiplift will be become new magnificent scenic spots on the tourist route.

(2) Impact on cultural resources

There are many cultural relics and historical sites in the Three Gorges and surrounding areas. But as there has been no detailed survey, the EIA did not put much of the cultural relics under protection. Found in the list for protection are one state class cultural relics (Baiheliang stone carving in Fuling), 5 provincial level cultural relics (Zhangfei Temple in Yunyang County, Shibao Zhai in Zhongxian County, Baidicheng in Fengjie County, Qiufeng Pavilion in Badong County, and Quyuan Temple in Zigui County).

Comments

- The resettlement of over million people displaced due to the Three Gorges Dam project is rare in the world. The resettlement has a great bear on the success or failure of the TGP, just as State Council leaders put it. The general goal for people relocation put forward by the State is: "sure to move out, stable in new place, and become rich gradually". It needs sustainable efforts to realize the goal. As seen from the eco-environmental perspective, the contradiction between the large population density and people to be resettled and limited land is the fundamental reason for the ecology and environment to become fragile.

- The large expanses of fertile land to be inundated will exacerbate the contradiction between people and land. In the EIA period, some experts held that there were enough barren slopes for resettling the people and the environmental carrying capacity could well meet needs of the people moving back from the reservoir. But practice shows such view is one-sided, because the dislocated people are unwilling to till the land of infertile soil on barren mountains and slopes lack of irrigation facilities and difficult to reach. And it would require huge investment to ameliorate the soil so to enable the resettled people to regain similar level of income as before. Furthermore, it requires the change and optimization of the traditional plant culture and breeding structure.
- In 1999, the State Council issued directives, 'two adjustments' to the resettlement policy, to accelerate resettlement of people and structural adjustment of factories. By June 2004, 166,000 people had moved out of the reservoir area and settled down in 11 developed provinces and cities along the Yangtze, and 1222 factories had completed structural adjustments. These have effectively eased the contradiction between people and land and industrial pollution in the reservoir area. The policy will have a prolonged and profound significance in maintaining a sustainable social-economic development of the reservoir area.

2.2.9 Construction Sites

Impact on water quality

(1) Drainage of the construction pit. Water in the construction pit comes mainly from leakage, rainfall, concrete curing water, mortar water, water for washing engineering machinery, and water discharged by affiliated enterprises. The TGP construction is undertaken with cofferdams in three phases. The drainage is the biggest in daily water discharge, being 3.2 m^3/s. According to data of other hydropower projects, the pH value of the pit water is often 11–12 and the turbidity is high. Besides, the chemical grouting causes pollution.

(2) Water for washing sand and stone aggregates

The water discharged from the natural gravel and sand screening system is 11,000 m^3/d at the maximum, containing more than 60,000 mg/L of sand. The maximum water discharge from the Gushuling artificial coarse aggregate processing system is 34,600 m^3/d; the maximum from the Xia'anxi artificial sand production system, which adopts the dry process in sand making and wet method in screening, is 17,100 m^3/d. The wastewater discharged into the Yangtze will cause pollution.

(3) Water for washing concrete benching plant and concrete drums

The revolving drums of concrete mixers have to be washed once every 6 h and the aggregate tanks have to be washed once per shift. The pH value of the water used is about 12. Part of the water will flow into the base pit and part will be discharged directly.

(4) Sewage water

There would be 25,000 people working in the construction sites during the peak period and a year's average labor is 15,100, and the sewage water discharged is estimated at 5000 tons a day.

(5) Oil-containing wastewater

There are more than 3000 pieces of engineering machinery on the work sites, all using diesel as fuel. The oil spill-over and leakage during operation and repairs will pollute the water. The oil-containing wastewater discharged by ships and boats will also pollute the water.

(6) Maopingxi stream

Maopingxi stream is situated just upstream from the dam. It flows into the Yangtze through the Maopingxi town. In order to prevent the town and the cultivated land of the Maoping basin from being inundated, an auxiliary dam is built, changing the mouth of the Maopingxi stream to a place about 1.2 km from the right bank downstream from the dam. Before 1998, the Maopingxi stream had been seriously polluted. It discharged about 46,000 tons of wastewater containing sodium cyanide (NaCN) from gold mine, 1.64 million tons of wastewater from paper mills plus sewage. If no measures were adopted, it would have caused serious water pollution in this section of the Yangtze.

Impact on the air quality

(1) Particles and dust pollution

The particles and dust in the construction sites mainly come from explosion of stone and loading and unloading of cement and coal powder, mining and crushing of aggregates and artificial sand and the dust stirred up by running vehicles, especially the excavation of the construction pit, tunnels and open channels by using explosives. According to the references of Gezhouba Dam, the peak daily dust fall reached 1.0 ton/km^2. The earth and stone work of the Three Gorges project is 14 times that of the Gezhouba Dam. If no measures are taken, the particle and dust pollution would be more serious than Gezhouba. The dust stirred up by vehicles will also affect areas along the roads.

(2) Soot

The TGP will use liquefied petroleum gas and pipeline coal gas in the construction period instead of coal used in the past. If all the enterprises, factories, government offices and residents will have to use stoves and furnaces, the total amount of coal used is estimated at 170,000 tons during the construction period, averaging 16,000 tons a year, with the maximum reaching about 20,000 tons. But the climatic and geographic influences in the dam site surrounding area make it difficult for the harmful gas to disperse, and as the environmental capacity is too small, the air would be prone to serious pollution.

(3) Emissions by large- and medium-sized oil-burning machines

There are about 3000 pieces of large and medium-sized machinery in operation at the worksites. They include excavators, bulldozers, transport vehicles, ships, and other machinery. They will consume an estimated 53,000 tons of fuel oil, averaging 11,800 tons of gasoline and 41,200 tons of diesel oil a year. The peak consumption would reach 133,200 tons, including 29,600 tons of gasoline and 103,600 tons of diesels. The earth and stone work machinery makes up 70%, mostly operating in the center of the construction pit, which will be excavated to a depth of 122–140 m. The emissions from the machineries will cause the air quality in the base area to drop.

Noise pollution

There are three main sources of noise pollution: excavation and drilling, gravel and stone processing and large tonnage transport vehicles. The noise is usually above 90 dB, with the highest at about 120 dB.

Drilling and explosion will mainly affect the people working in the center of the base. Large tonnage vehicles will mainly affect areas on the two sides of roads and nearby living area and office areas.

In a word, construction of the dam will totally change the original natural ecology and environment and will affect the water body, air, and environment.

Comments

TGP pays great attention to environmental protection of the dam site. It has worked out an implementation plan and adopted a series of measures to protect the environment. They include hardening the road to reduce dust, treat the wastewater and sewage before being discharged, adopting modern engineering technology, strengthening greening and restoration of destroyed vegetation, reducing noise and air pollution, adopting stringent anti-epidemic measures to protect the health of the workers; strengthening the monitoring, supervision and management of the environment. The environmental quality of the construction area (15.28 km^2) has been kept at a very good standard.

In 1998, the pollution of the Maopingxi stream was thoroughly resolved by shutting down, stopping the operation and merging polluting enterprises, and adopting other measures. The water of the stream has become clear.

2.2.10 Reservoir Sedimentation and Scouring of Riverbed Downstream

Sediment characteristics of the reservoir and applied plans for regulation

There are, on both upper and lower stream of the dam, hydrological and sediment control stations, which have accumulated a rich pool of data for the past 40 years. They serve as reliable basic materials for studying the sediment of TGP. Field survey statistics show that the average annual transportation of suspended load and bedload at the Cuntan and Yichang hydrological stations has reached 460 and 5530 million tons, averaging 1.32 and 1.2 kg/m^3. The sand mainly comes from the upper reaches of the Jialing River and its tributaries of Xihanshui River and Bailong River,

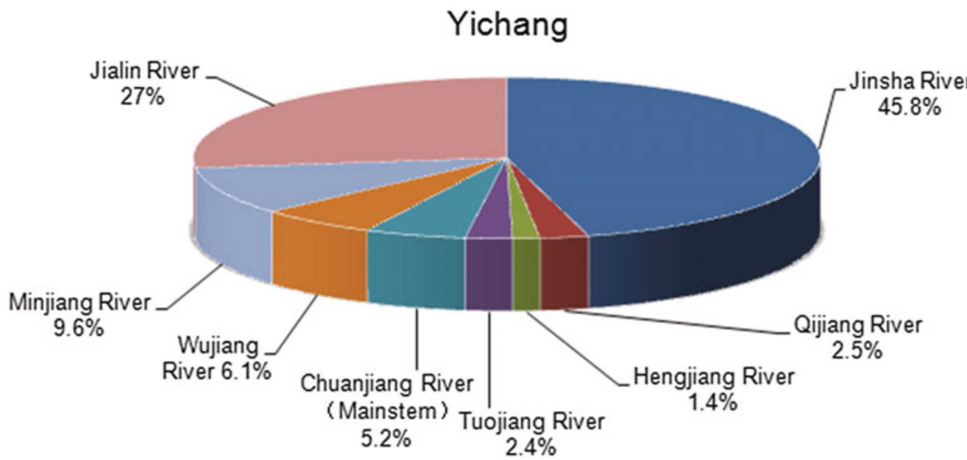


Fig. 2.2 Contributions of sand sources from the upper reaches of the reservoir

lower reaches of the Jinsha River and the middle reaches of the Dadu River, as shown in Fig. 2.2. All those areas have been listed for priority control. Work has started. This, plus the building of upper reaches reservoirs, the sand entering the Three Gorges reservoir will assume a downward trend.

The reservoir will discharge sand by lowering the water level during the flood season and store up water in the dry season (see Fig. 2.3). Mathematical model calculation shows that this way of operation will keep active most part of its effective storage capacity for a long time to come.

Sediment siltation in the reservoir area and its effect

As shown in Fig. 2.3, sand enters the reservoir mainly in the flood season. The reservoir operation of the 145 m flood control level is favorable for discharging sand. The calculation results show that the dam operates for 100 years according to the 175 m alternative, the reservoir will reach a sediment balance between the inflow and outflow, with the flood control storage capacity to be retained by 86% and the regulatory storage capacity to be retained by 92%.

(1) Sedimentation impact on flood water level at the reservoir tail

The backwater level of the 175 m alternative reaches below Chongqing. According to calculations, after the reservoir operates for 100 years, the silt deposition upstream from Changshou will make up about 3.6% of the total. When a 100-year frequency flood occurs, the flood water level close to Chongqing will be 199.09 m, 4.79 m higher than the natural water level, with 1–3 m variations in the calculation. When sediment trapping and flood regulating functions of reservoirs upstream are considered, the water level at Chongqing may be lower.

(2) Problems of navigation and port in the fluctuating backwater area and countermeasures

According to the 175 m alternative, the fluctuating backwater is about 130 km long. Siltation will mainly occur in the river section downtown of Chongqing. After the reservoir operates for dozens of years, the main problem that will occur in this section of the river will be the siltation in the harbor area, hence affecting navigation and port operation thereof. Study shows that those problems may be resolved by reservoir regulation, riverbed control, rebuilding of harbor and dredging. In view of the fact that the effect will occur 20 years from now, and serious impact will not come until the reservoir operates for scores of years, there is enough time to work out proper solutions.

(3) Impact of siltation on navigation route and power plant behind the dam

Physical model experiments show that after 30 years operation, the annual sand deposition in the upstream approaching channel will be 0–100,000 m^3 and that downstream will be 20,000–180,000 m^3, that may be resolved by dredging. When the reservoir operates for 81–90 years, the annual siltation of the approaching channels upstream and downstream would be 0.36–1.01 and 0.79–1.39 million m^3 respectively, those may be removed by scouring plus measures of silting prevention, reduction and clearing. At EL.45 m in front of the power plant, if the siltation is higher than the water inlet, the sediment flushing outlets can be used to solve the problem.

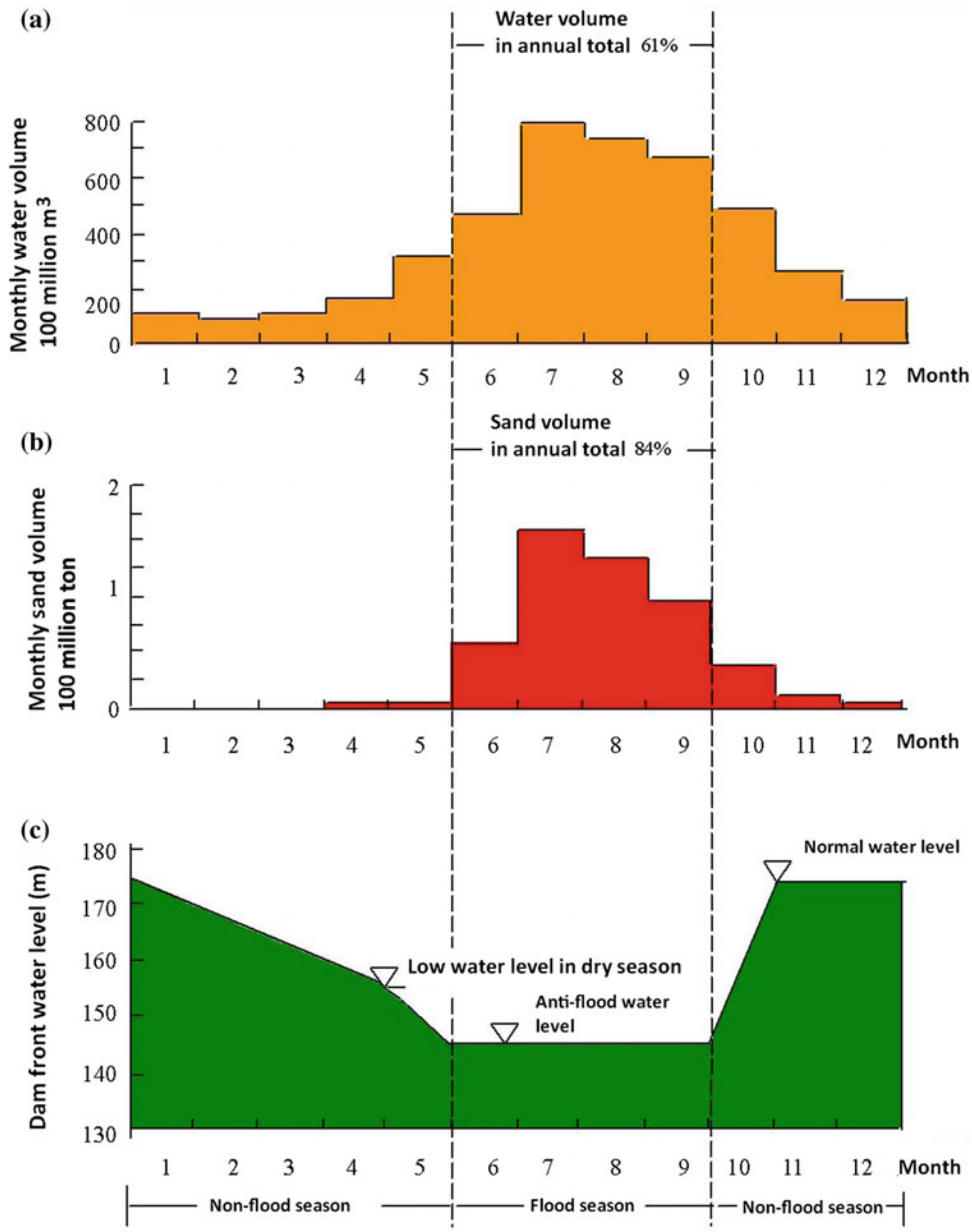


Fig. 2.3 Sand entering the reservoir and operational method **a** Water volume from Cuntan; **b** Sand volume from Cuntan; **c** Operational mode

Impact of scour downstream from the dam

The Yangtze River downstream from the dam flows mainly in flat area, with many bends, and the banks are not stable. After the reservoir is put in operation, the sand content of the water released will be reduced, thus causing scouring of the river bed and lower the water level with the same flow discharge. The river regime will change, thus having some effects in bank collapse, shoal, and river-and-lake relations.

Mathmatical model calculation shows that the most serious scour may occur somewhere near Jiujiang City, with a maximum cumulative amount to take place in 40–50 years in the section from Yichang to Chenglingji, 60–70 years from Chenglingji to Wuhan and even longer from Wuhan downward. The water level with the same flow discharge in the dry season will drop 1.5–2.0 m in Yichang, 1.0–2.5 m in Songzikou, 1.5–5.0 m in Taipingkou, 1.0–6.0 m in Shashi, 4.0–8.0 in Ouchikou, 1.0–3.5 m in Luoshan, 0.5–2.0 m in Longkou and 0.5–1.5 m in Hankou.

The riverbed degradation will have the following impacts on the environment:

(1) When the water level in the dry season in Yichang drops and the water released cannot reach 5000 m^3/s, it will affect the operation of the shiplock on the third navigation channel at the Gezhouba dam. This may be resolved by reservoir operations and engineering control measures.
(2) Riverbed scour will lower the water level, thus increasing the flood carrying capacity of the river channel, but weakening the bank stability, possibly leading to bank collapse. This calls for efforts to strengthen monitoring and protection.
(3) With the reservoir, the flow volume will increase and stabilize during the dry season, thus making it favorable to improve the navigation condition. But the scouring all along the river bed downstream from dam will change the river regime to varying degrees, possibly leading to a shallow water that obstructs navigation. This must be resolved by control measures or by dredging.
(4) After the water level drops, the flow and sediment diversions at Songzikou, Taipingkou and Ouchikou of the Dongting Lake will be reduced, making it favorable for reducing floods in the Dongting Lake area, cutting the silting of the lake, and retarding the shrinkage of the lake.

Comments

- Sediment is an important technical issue that merits full attention in building reservoirs on the Yangtze, the Yellow River and other sand-laden rivers. Chinese scientists have taken a good care of the problem and made much progress in their studies. The problem with the TGP is one of the key technologies that would affect the normal operation and efficiency of the project. A large amount of studies and researches for the TGP sediment issue have been done on the basis of the studies for Gezhouba and other major hydropower projects. The general conclusion is that the problem can be resolved, but more research needs to be done for an optimal solution.
- The previous studies may not be so accurate due to the complex nature and uncertainty of the issue and the current level of study. That is why the TGP set up an expert group to study the issue in both the upper and lower reaches of the reservoir. The sediment observation is a special sub-system of the environmental monitoring network.
- The TGP adopts the operational method of "storing clear water and discharging muddy water." When the water level of the reservoir reaches 145 m, the backwater will reach the mouth of Wujiang at Fuling. When the reservoir operates at 175 m, the backwater will reach the mouth of the Jialing River. Both are the two major tributaries of the reservoir area. Besides, the downtown river section at Chongqing is usually silted during the flood season and when the flood season is over in September and October, the silts will be washed away. However, the reservoir has to store water starting from late September; it may affect the silt washing. With the cascade of hydropower development, the sediment trapping function of reservoirs upstream and the implementation of ecological projects such as the water and soil conservation project at Qujiang River, Jialing River and Jinsha River, all will greatly reduce the sediment flowing in the Three Gorges reservoir. That has been evidenced by the prominent reduction in the sand transportation of the Jialing River in recent year.
- Three regional issues merit attention. One is the sediment issue of the dam site, which will affect the approaching channel of the shiplock, but is relative easy to resolve. The second is the siltation in the fluctuating backwater area at the reservoir tail, so as to affect the navigable channel, the harbor and the Wujiang and Jialing Rivers. It is a difficult and uncertain issue. The third is the scouring of riverbed downstream, which involves a series of complicated and long-term issues such as bank collapse, making up of shoals, adjustment of river regime, and the river-and-lake relations.

Model tests have been done to tackle the sediment problem, one of the main technical problems with the TGP. Testing (*upper left*); Sediment model of the dam site area (*lower left*); Collecting and processing data (*upper right*)

2.2.11 Environmental Geology

Reservoir-induced earthquake

There are usually two types of reservoir-induced earthquakes, that is, tectonic type and non-tectonic type. The first occurs when rocks in the earth's crust break due to geological forces created by movement of tectonic plates. The strain energy of tectonic earthquake gathers in the active fault. The second refers to collapse earthquake and explosion earthquake. Both types may occur after the dam is bulit. The most disastrous is the tectonic earthquake. Analysis shows that the Xiannushan fault, the Jiuwanxi fault, and the Jianshi fault (northern section) and the cross-section of small faults in the western fringe of the Zigui basin in the second reservoir section may induce earthquake.

The Xiannushan fault and the Jiuwanxi fault which are situated in the western fringe of the Huangli land block are deemed as the major active tectonic structure in the Three Gorges area, where there are weak tremor activities along the faults, as the karst stratum is cut up by fault seams and the water may penetrate into it and accumulate. That section has the most geological conditions for reservoir-induced earthquake.

The Jianshi fault and the joint of some small faults in the western fringe of the Zigui Basin are like the cross-section between the weak seismic belt from Qianjing (Chongqing) to Xingshan (Hubei) and the reservoir. Surface survey has found a large-scaled border fault belt, a series of inter-disconnected regional vertical faults developing parallel along northern axis. There have been four earthquakes of above the magnitude 5 on the Richter scale since 1855, with that occurring at Daluba of Ganfeng in 1856 with a magnitude of 6.25 on the Richter scale being the biggest ever recorded. The fault belt extends to the banks of the Yangtze, with folds narrowing and accompanying faults smaller. The conditions for reservoir water to penetrate and accumulate are poorer than in the fault from Jiuwangxi to Xiannushan. It is estimated that earthquake is possible at the joint of the Pingyangba fault and Longchuanhe fault, the joint between Panshi fault and Lengshuixi fault and the east-west Nanmuyuan fault on the southern bank of the reservoir.

Reservoir bank stability

The banks of the Three Gorges Reservoir are made up of hard and semi-hard rocks. The slope of the banks is generally very good. The deformation of bank is mainly caused by the re-activity under the new imbalanced conditions of ancient avalanche and landslides, and the debris flow of the slope surface and the loose accumulative landslide occur only in local areas.

The stability analysis of 140 large and medium-sized avalanche or cave-ins, landslide bodies, and dangerous rock bodies show that 118 of them are stable and 14 are poor in stability and 8 are in the process of deformation. The stable and fairly stable avalanche and landslide bodies will generally not be destabilized in integrity. But the avalanche (including dangerous rock bodies) that is poor in stability and in the process of deformation and landslides may be destabilized in their integrity or in part under the actions of a number of factors such as rainstorm, earthquake, flood, and human activities.

The avalanche and landslide bodies weak in stability along the mainstem of the reservoir include: Xintan landslide body, Daping landslide body, Zuiyilun avalanche, Xiangjiawan landslide body, Taping landslide body, Huangguashu landslide body, Micaolun landslide body, Sandengzi landslide body, Kuping landslide body, Lishuping landslide body, Biaogangshang landslide body, Baota landslide, Jipazi landslide body, and Yunyang Xichang landslide body, totaling 14.

Avalanche (including dangerous rock bodies) and landslide bodies in the process of deformation include: Lianziyan dangerous rock body (Section I), Xiangxizhen landslide body, Huanglashi landslide body, Yaqianwan avalanche body, Yutang landslide body, Qianxigou landslide body, Dongzi landslide body, and Wangyemiao landslide body, totaling 8.

The instability of avalanche and landslide bodies will be a threat to shipping. Some cities and villages in the reservoir area are situated close to the danger zone, to be threatened by the activities of avalanche and landslide bodies. After the impoundment of the reservoir, the collapse of loose accumulative landslide on the banks and local bank slide are also potential threats to part of the living centers. Monitoring and timely forecast may mitigate the risk of landslide and avalanche.

Comments

- Reservoir-induced earthquake is a major technical issue we have to face in building large dams. It is all the more important for the gigantic dam at the Three Gorges. This has been listed as a special program of study. Starting from 1997, the State Seismological Bureau began to set up a monitoring system to study reservoir-induced earthquake. The major target of monitoring is the area near the dam east of Wushan. In recent years, some departments proposed to strengthen monitoring of the reservoir area west of the Three Gorges, as there are such major cities as Wanzhou, Fuling, and Chongqing downtown, where geological disasters are frequent. If reservoir-induced earthquake and geological disasters take place at the same time, it would bring about more serious consequences. Up to the present, forecasting the location and intensity of a reservoir-induced earthquake depends mainly on the survey of active faults. But the intensity has to take into account the length of the active faults and the activity level of regional tectonic earthquake. In fact, active faults in the Three Gorges area need an urgent deep study. Particularly, not enough work has been done and more efforts should be put into about the sectionalization and quantification of the active faults.
- The reservoir area, subject to a frequent geological hazard, has especially a hidden danger if an improper selection of sites is chosen for a city or town rehabilitation, which involves a large amount of infrastructure constructions including houses and roads. The central government, aroused to take care of the issue, has invested a lot since 2001 to prevent and control geological problems thereof following a fruitful work in dealing with the Lianziyan and the Huanglashi landslides. Work includes re-verifyng the number of different

avalanche and landslide bodies and setting up a people-participated monitoring system as a great program led by national land departments. The geological hazard may affect the dam safety and the reservoir storage capacity, plus the impact on navigation, cities and towns. After water impoundment of the reservoir, changes in water levels might induce more avalanches and landslides, to result in a so-called “reservoir disease”. It is, therefore, a long-term task in the future reservoir management to prevent and control geological disasters.

- The monitoring of reservoir-induced seisms and geological disasters is an important component of the Three Gorges eco-environmental monitoring system. There are special reports and monographs on the subject. This book only gives a very brief account of the systems. For details, see related reports or monographs.

2.3 Major Countermeasures Adopted Since the Start of TGP

The following countermeasures have been adopted since the start of the TGP to mitigate the unfavorable effects on the ecology and environment:

(1) In 1996, the Yangtze Water Resources Protection Bureau, with great support and assistance from related departments, compiled the “Action Program on the Eco-environmental Monitoring Network of the TGP” in line with the EIS. The TGP Eco-environmental Monitoring System, jointly set up by related departments and units, has started officially running and the SEPA issues an environmental monitoring gazette on June 5 (World Environmental Day) every year.

(2) To prevent and control pollution sources, the State Council approved the “Upper Yangtze Water Pollution Control Planning” in January 1999, and the “TGP Reservoir and its Upstream Water Pollution Control Planning (2001–2010)” in November 2001. The program and plan set the State to invest heavily in a series of sewage treatment plants (including supporting pipelines) and garbage treatment plants, which are scheduled for operation in June 2003 when the reservoir impoundment starts.

(3) To resolve the problem of geological disasters, in January 2001, the State Council approved a “General Plan for Anti-Geological Hazard of the Three Gorges Reservoir Area” and decided to invest four billion yuan to deal with the geological problems and set up a geological disaster monitoring system.

(4) The resettlement work undertook two policy adjustments to stress resettlement-associated environmental protection

Starting from 1999, the State Council decided to adjust the resettlement policy. One is to direct and encourage more rural displaced people to move out of the reservoir area to lighten the burden on the environmental carrying capacity of the reservoir area and strive for a sustainable development; the other is to strengthen structural adjustment of factories and mines, ordering enterprises that are small in scale, poor in efficiency, wasteful in resources and polluting the environment and noncompetitive on the market to shut down, stop production, merge with others, or shift to other production.

Besides, work started to restore ecology, monitor the environment, protect and monitor the public health as required by the plan for resettlement-associated environmental protection, along with promoting high efficiency eco-agriculture in the reservoir area, improving the living and production conditions and building greens and parks in new resettlement towns.

(5) Strengthening the control of soil erosion in the upper basin of the Yangtze and the reservoir area. The shelter belt project and water-and-soil conservation project in the middle and upper basins of the Yangtze continued, biasing toward the reservoir area in policy and funds. In 1998 and 1999 alone, the central government invested 720 million yuan in the reservoir area for planting 49.77 million mu (3,318,000 ha) of forests. In 1998, work started on the eco-agriculture demonstrative projects. After 1998, the State set going the project of protecting natural forests and returning land to forests, mainly in the reservoir area and the upper basin of the Yangtze.

(6) Organizing the execution of the “Action Program on Environmental Protection for TGP Dam-site Area”. In the construction sites, wastewater treatment facilities have been built and the trace fields left from work have been timely planted with grass or trees. Garbage has been treated in a centralized manner. The water quality is strictly controlled in the dam area. The environmental monitoring bulletin is issued on a quarterly basis.

(7) Strengthening studies of biodiversity and setting up nature reserves. After the start of the project, a number of natural preserves have been demarcated for protecting terrestrial and aquatic life. Corresponding projects of research have been launched, which have yielded significant results in the study of the proliferation, migration and habits of rare and endemic species affected.

(8) Based on the in-depth survey in the mid-1990s, the SCTGPCC has listed 1087 cultural relics protections, including 723 unearthed programs and 364 surface protection items. All those have been finished.

(9) Formulating technical standards for reservoir bottom clearing in preparation for the impoundment. Related government departments have organized the formulation of technical standards for clearing (solid wastes, structures, woods and hygiene) the reservoir bottom. Governments at all levels in the reservoir area worked flat out and completed the clearing tasks by the end of 2002 to create the conditions for the impoundment scheduled for June 2003 and prevent the impounded water from being polluted.

2.4 Summary

It is too early to make a posterior environmental impact assessment for the TGP. It can be done only after the whole TGP is completed in 2009 when enough materials are accumulated. It is, in fact, a long-term task. However, the understanding of the TGP environmental impacts has been deepened step-by-step with the deepening of the research and the obtaining of baseline data during the decade from the construction preparation of the project in 1993 to the beginning of impoundment in June 2003.

In general, the EIA of the review period is systematic, comprehensive and complete, without any major items missing. Compared with other hydropower projects, the EIA of TGP is deeper and more detailed. Although there have been different conclusions and disputes, the independent assessments by different departments are all of valuable reference in undertaking such a massive project.

On the other hand, as required in legal procedure, the EIA made many predictions based on suppositions in front of the issue complexity and limited time. But the ELA work and studies could not have too high expectations and too much in depth, nor take them as "having really happened". They have to be proved through systematic monitoring, study and post review in construction and operation of the project, so as to provide useful experiences for building other hydropower projects, in terms of ecological and environmental protection to help to know what the EIA has not yet unfolded fully, what are still improper in the technical route and what have not been analyzed fully. In a word, the posterior environmental impact assessment is of one of the major targets of systematically study of the TGP Environmental impacts in the future.

3 Eco-Environmental Protection and Monitoring of the Famous Dams in the World

This chapter introduces the eco-environmental protection and monitoring of large dam projects in China and other countries for the purposes of borrowing useful experience in undertaking the TGP and in realizing sustainable development of the Yangtze River basin and other large rivers. In discussing the TGP environmental impact, people often mention the Aswan High Dam of Egypt; when talking about the size and efficiency of the TGP, people often compare it with the 12600 MW Itaipu hydropower project in Brazil. The environmental impact assessment of the American Glen Canyon Dam was made 20 years after the dam was built, in the hope of seeking the optimum alternatives for the operation of the power plant. All those are of great significance in the operation and management of China's TGP. In the end, we have added the Ertan Dam in China, which was built with the World Bank loan. Dr. Huang Zhenli, one of the authors of the book made field study tours of the Itaipu project in October 1995 and the Aswan High Dam of Egypt in November 1999. This chapter is written based on the field reports he compiled and related materials [7–19].

3.1 Environmental Protection and Monitoring of the Aswan High Dam in Egypt

3.1.1 Aswan High Dam

The Nile is the second longest river in the world, with the mainstem extending about 6825 km. If along with the tributaries, the total length is 37,205 km, draining 2.90 million km^2, including 81,550 km^2 of lakes and 69,720 km^2 of marshland. The Nile originates in the Equator Highland and the Ethiopian Highland and flows northward through Africa's Burundi, Uganda, Zaire, Kenya, Tanzania, Ethiopia, Rwanda, the Sudan, and Egypt before emptying into the Mediterranean Sea (see Fig. 3.1). The annual average runoff of 84 billion m^3 of Aswan comes mainly (about 84%) from turbid flood water from Ethiopian highlands, principally during August–September. The rest 10% of clear water come from the Equatorial Lakes Plateau.

The annual runoff of the Nile varies greatly, with that in 1913–1914 being the smallest, 45.6 billion m^3 and that of 1978–1979 being the biggest, 150.3 billion m^3. From 1922's 275 m^3/s to 1978's 9500 m^3/s, the flow of the river changed so greatly that it often causes floods in the flood season and drought in the dry season, making it hardly possible to maintain normal agricultural and industrial production. There are many lakes in the Nile catchment areas. Egypt and the Sudan planned and built a series of water projects that put the whole of the Nile under control and full utilization.

The Nile is the birthplace of the ancient Egyptian civilization. All the historical sites in Egypt are distributed along the river, which is dubbed by Egyptians as the "Mother River". The Nile is the only fresh water source of Egypt. After it enters Egypt from the Sudan, it does not have any tributaries until it reaches Cairo, where it breaks into two parts to form the Nile Delta, which feeds 95% of the 70 million people in the country. Egypt has a territory of 1.02 million km^2, of which 96% are deserts and the rest 4% are arable land mainly in the Nile Delta. So Nile is the lifeline of Egypt. The Egyptians began to tame the Nile ever from the Pharaohs period.

Inside the territory of Egypt, there are 10 barrages projects (two dams and eight flood gates) as shown in Fig. 3.2. The two dams are the old Aswan Dam and the Aswan High Dam 7 km upstream. The old dam has become a regulatory reservoir of the Aswan High Dam. The relations between the two dams are just like those between the Three Gorges Dam and the Gezhouba Dam in China. The former is for power generation and water regulation and the latter is for power generation, shipping, and water regulation.

The old Aswan dam is a gravity dam. Work started in 1898 and was completed in 1902. It used to have a water holding capacity of one billion m^3. It was expanded to 2.5 billion m^3 in 1908–1912 and up to 5 billion m^3 in 1929–1933.

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2_3

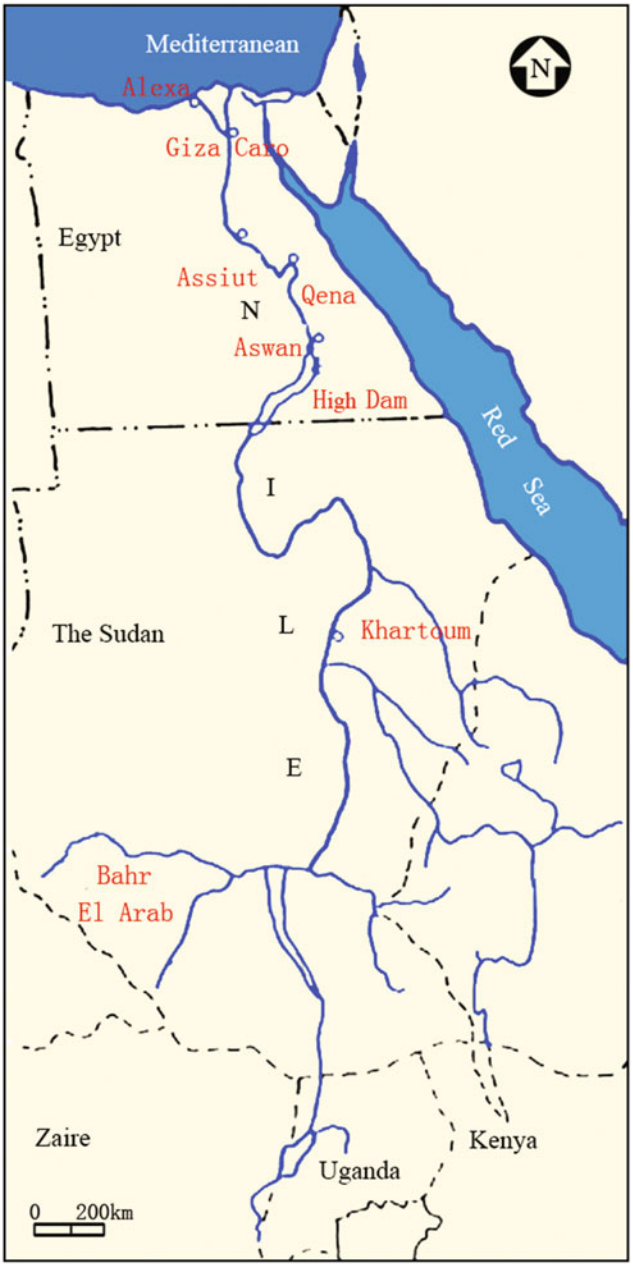


Fig. 3.1 Map of the Nile Basin

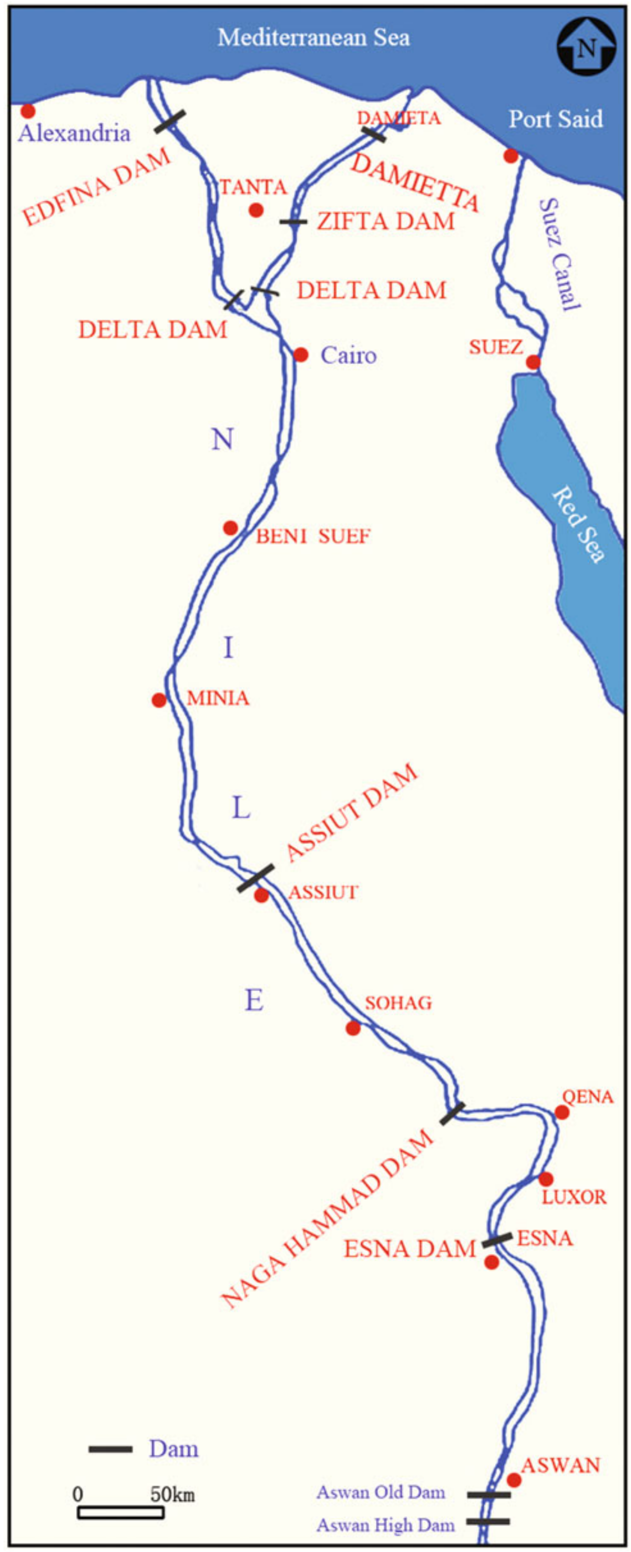
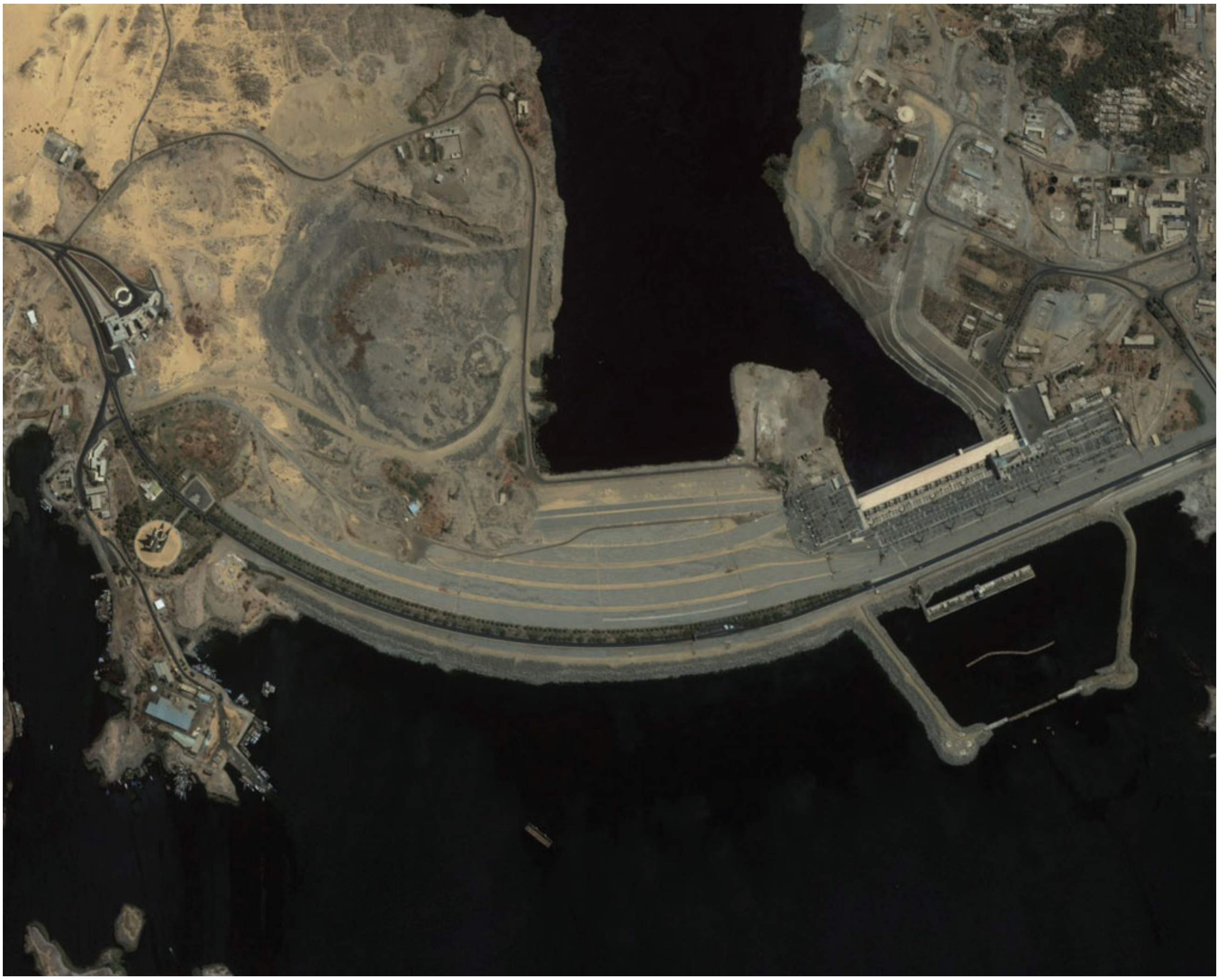


Fig. 3.2 Dams on the Nile in Egypt

The construction of a big dam was proposed by a Greek agricultural engineer residing in Egypt, Andre Damino. The design of the dam was completed by German Company (Hochtief and Dortmund Union) in 1954. But due to a string of international conflicts, construction work did not start until 1964 with the assistance of the former Soviet Union. The dam was completed in 1971. It is a rock-fill dam with grout curtain and clay core. Its maximum height is 111 m (the dam foundation is at an elevation of 85 m and top at El. 196 m) and its total length is 3830 m. Its designed maximum flow is 11,000 m^3/s. The installed capacity of the hydropower station is twelve 175 MW generating units, with a total installed capacity of 2100 MW. The maximum electricity output is 10 billion kWh. The reservoir, which is a



Remote sensing image of the Aswan High Dam

perennial regulating reservoir, extends for 500 km along the Nile River and covers an area of 6000 km^2, of which northern two-thirds known as Lake Nassar (named after the late Egyptian President Nasser) is in Egypt and one-third called Lake Nubia in Sudan, with a storage capacity of 168 billion m^3 (when the water level is the highest of 183 m) and the dead storage capacity of 31 billion m^3. The annual runoff at the dam site is 84 billion m^3. The high dam costs 450 million Egyptian pounds, including costs of the dam, hydropower plant, power transformation and transmission and resettlement. The main functions of the dam are irrigation, power generation, and shipping. The operation of the reservoir is very complicated, with multiple objectives. Normally, irrigation is the main objective while giving full consideration to flood control, power generation, shipping, the scouring of river beds downstream, and water quality.

Egypt is a semi-arid country. Apart from the shore areas of the Mediterranean Sea, most areas have little rainfall. The main water source is the Nile. That is why Lake Nasser is dubbed as Egypt's water bank. The perennial mean water inlet of Lake Nasser is 84 billion m^3. Deducting the annual evaporation of 10 billion m^3, there is about 74 billion m^3 left. According to a water agreement between Egypt and the Sudan, Egypt uses 55.5 billion m^3 and the Sudan, 18.5 billion m^3 (the 1929 water agreement provided that the share of Egypt was 48 billion m^3 and that of the Sudan was 4 billion m^3). Of its share of more than 50 billion m^3, 64% are used for agriculture, 5% for urban consumption, 5% for industrial use, and 5% for shipping. Evaporation makes up 4% and water drained into the sea is 22%. The Aswan project has enabled Egypt to expand its irrigation areas from the pre-dam 2.52 million hm^2 to 3.36 million hm^2, making it possible to grow two crops or even three crops a year instead of the former one crop only and to change from flood season irrigation to irrigation all year round. The abundant water has enabled water consuming crops such as rice to become possible. Water supply to cities and shipping has also been secured.

Lake Nasser (Photo by Huang Zhenli)

Downstream of Aswan High Dam (Photo by Huang Zhenli)

3.1.2 Impact of the Project

In the era when the high dam was built, the eco-environmental issues caused by dams did not arouse extensive attention internationally. When people came to realize it, the Aswan High Dam has become the focus of international debate. The Egyptian government and scientists did a lot of work to mitigate the unfavorable impact of the project [9]. In 1988, 21 years after the Aswan High Dam was completed, Gilbert F. White gave a comprehensive review of the environmental impact of the Aswan High Dam, as he said that some people acclaimed it as a national treasure and some criticized it as an ecological catastrophe [11]. When China was building the Three Gorges Dam, environmental critics often quoted Aswan High Dam. That is why China has paid great attention to the Aswan High Dam, hoping to draw lessons from it.

There have been extensive studies and predictions about the major unfavorable impacts of the Aswan High Dam. The completion of the project was followed by timely monitoring and post-assessment to test the views of both optimism and pessimism. Those major unfavorable predictions of the Aswan High Dam include widely sedimentation, river bed scouring, shoreline erosion, reservoir-induced earthquake, fishing resources, ecological issues in the river mouth, spread of snail fever, people resettlement, and the protection of cultural resources. The studies and monitoring after the completion of the dam have given clear answers to these problems. For details, see refs. [7, 9] and [11].

A huge amount of study and monitoring materials show that the Aswan High Dam has brought about huge benefits. Its unfavorable impacts that some critics said have been exaggerated and some have been proved groundless. Of course, there are some problems that have gone far beyond what the studies and predictions show, such as the impact of nutrition laden sedimentation on water quality, flood release problems, and the reduction of materials for making traditional bricks [11]. Regarding a large dam project, there should be neither blind optimism nor willful overstate. Careful summing up and making a comparative study are necessary and important on how to make a scientific assessment of the unfavorable impacts of hydropower projects on the ecology and environment.

3.1.3 Protection and Monitoring

Silting and Scouring

Lake Nasser is the largest artificial lake in the world. But, as the sediment problem has not been resolved, the designed 31 billion m^3 dead storage capacity will be entirely silted up in about 500 years. Sonar testing in 1992 showed the silting mainly happened at the tail of the reservoir 380–400 km from the dam and was moving toward the dam site. Since 1973, 850 million m^3 have been deposited in the river section 370–470 km from the dam site.

The Aswan High Dam and the agricultural and industrial development around have greatly changed the chemical composition of the sediments of the Nile. The White Nile contains a huge amount of soluble elements flowing from the Lake Victoria to the arid area of the Blue Nile. The water is further evaporated when it passes through Lake Nasser, further increasing the density of ion. The solubles increase by nearly 33% in the water near the Aswan High Dam. So does the transportation of Al, Fe, and other stable elements that attach to the planktons. Now, the Nile has become a big river with the highest salt content in Africa. A special monitoring and study [12] has been devoted to the Sohag area 500 km downstream of the Aswan Dam. The area is densely populated and developed industrially. The choice of this area is conducive to controlling the impact of artificial factors on the transportation of sediment. Targets of monitoring include surface water (27 components), underground water (8 components), suspended matters (12 components), and sediment (12 components). The timing of sampling is chosen during the flood season. Take the flood season in August 1998 for an example. Ten surface water sampling points were chosen, of which seven were in the west bank and 3 in the east bank. The sampling points were chosen in order to reflect fully the impact of cities and factories in the river valley. In order to give full consideration of the impacts of the Aswan High Dam, additional monitoring points were chosen in the forebay and at the back of the dam. 13 underground water sampling points were chosen, of which 11 were in the cultivated area and two in the silting area.

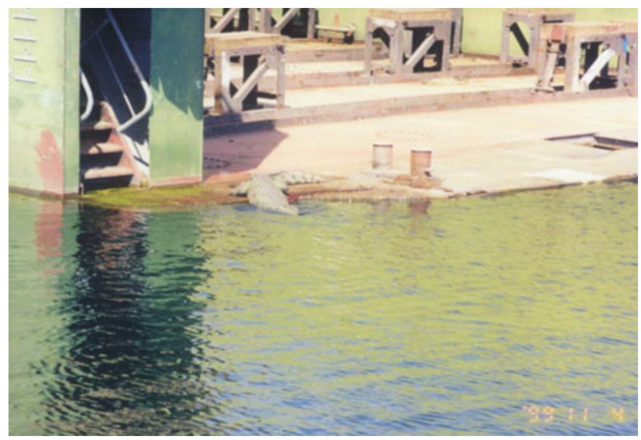
After the completion of the Aswan High Dam, the Kaoling clay in the sediments downstream has increased significantly. So the study of the content of Kaoling may be used to monitor the impact of the high dam on the silt carrying capacity, the changes in the Nile Delta and in the eastern coasts of the Mediterranean. The monitoring of Kaoling at Cairo and the South Nile Delta is designed to last for 50 years and that of the coast of the Mediterranean will be even longer. Kaoling is the main mineral in the sediment of the river basin. It enters into the lake due to the desert wind erosion and the washing of Lake Nasser and discharges into downstream through the high dam. Besides, the Kaoling in the flood siltation stratum below the dam is also transported downstream. Starting from 1992, 59 sampling points were set up in the river course, banks, and dried valleys between Cairo and the coasts of the Mediterranean Sea (19 in the river course, 20 on the banks and 20 on the dried valleys) to monitor the changes in the Kaoling content and analyze the distribution of sediments downstream of the Nile. The sediment with a high content of Kaoling (>30%) has been extended 350 km northward after the dam was built, averaging an annual speed of 10 km/a. If this speed continues, the sediments with a high content of Kaoling will reach gradually Cairo in 50 years.

Water Quality

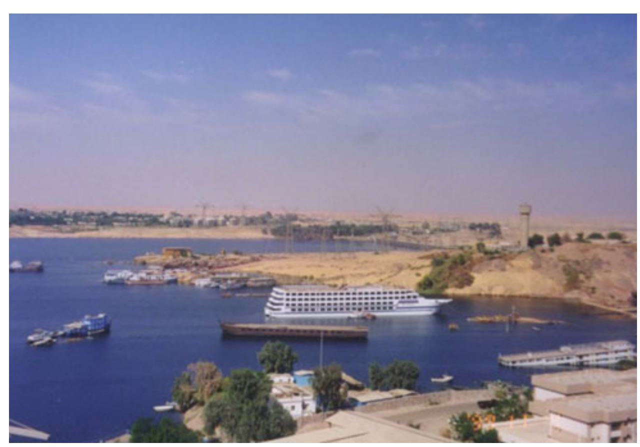
The Institute of Nile Research (former Aswan High Dam Side-Effect Research Institute) started assessment of the water quality of Nile in 1976. Samples were collected in every 10 km and monitoring was done within 200 m of the pollution sources. It set up 34 fixed monitoring points from Aswan to the estuary to carry out monitoring in cooperation with other departments at irregular intervals.

From November 1991 to April–May 1992, the Institute of Nile Research carried out a comprehensive monitoring of water quality of Lake Nasser before and after the flood season, at 29 cross-sections (including those in the territory of the Sudan) along the reservoir as is shown in Fig. 3.3, covering scores of physical and chemical indicators, such as temperature, clarity, electric conductivity, N, P, and SS. The monitoring results show that the water quality of the reservoir is quite good, with no eutrophication, and temperature stratification is spotted only at few still waters. This is, probably, because the area around the reservoir is a desert, sparsely populated. As the upstream area in the Sudan is lagging economically, with an underdeveloped industry, the water body of the reservoir is free from pollution.

From July 1991 to April 1992, Institute of Nile Research organized a comprehensive monitoring at 34 cross-sections of the Nile downstream from the dam as shown in Fig. 3.4. The results show that although the Nile takes in wastewater



Crocodiles in Lake Nasser (Photo by Huang Zhenli)



Crusers downstream of the Aswan High Dam (Photo by Huang Zhenli)

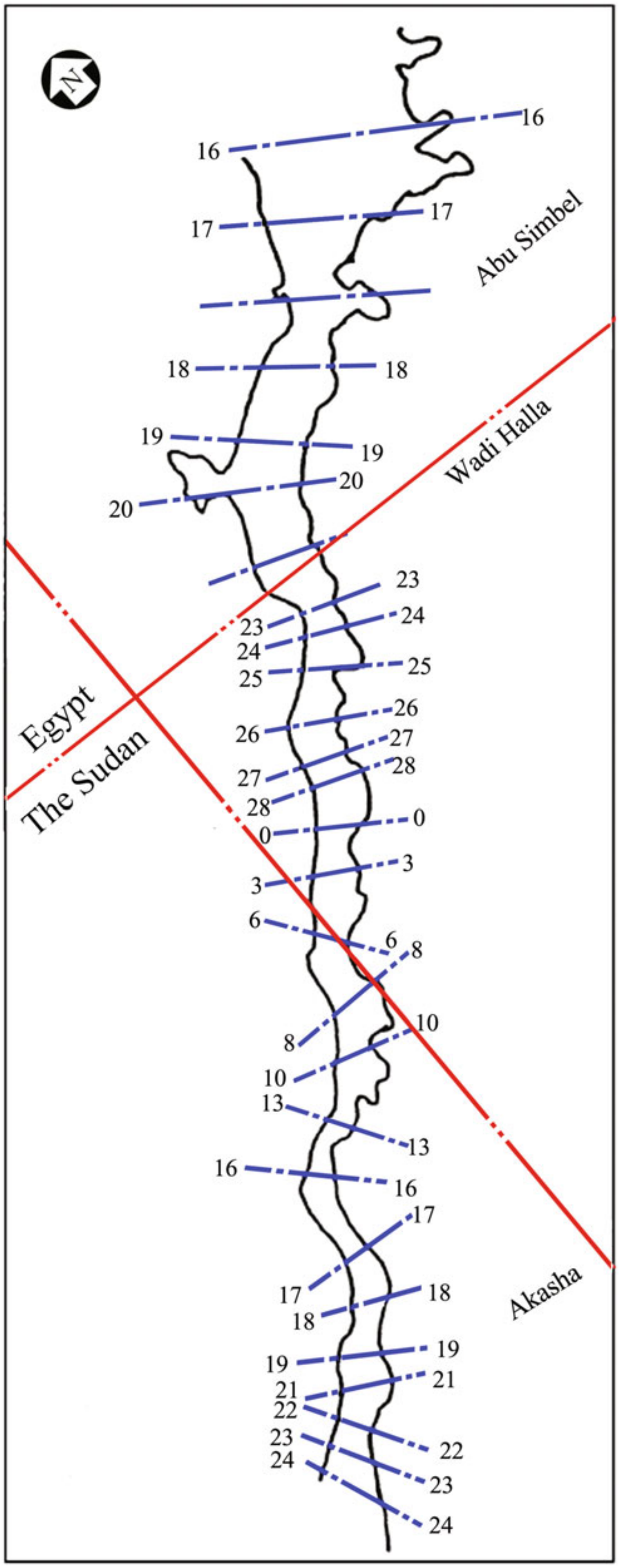


Fig. 3.3 Distribution of water quality monitoring cross-sections of the lake Nasser (Nubia) [9]

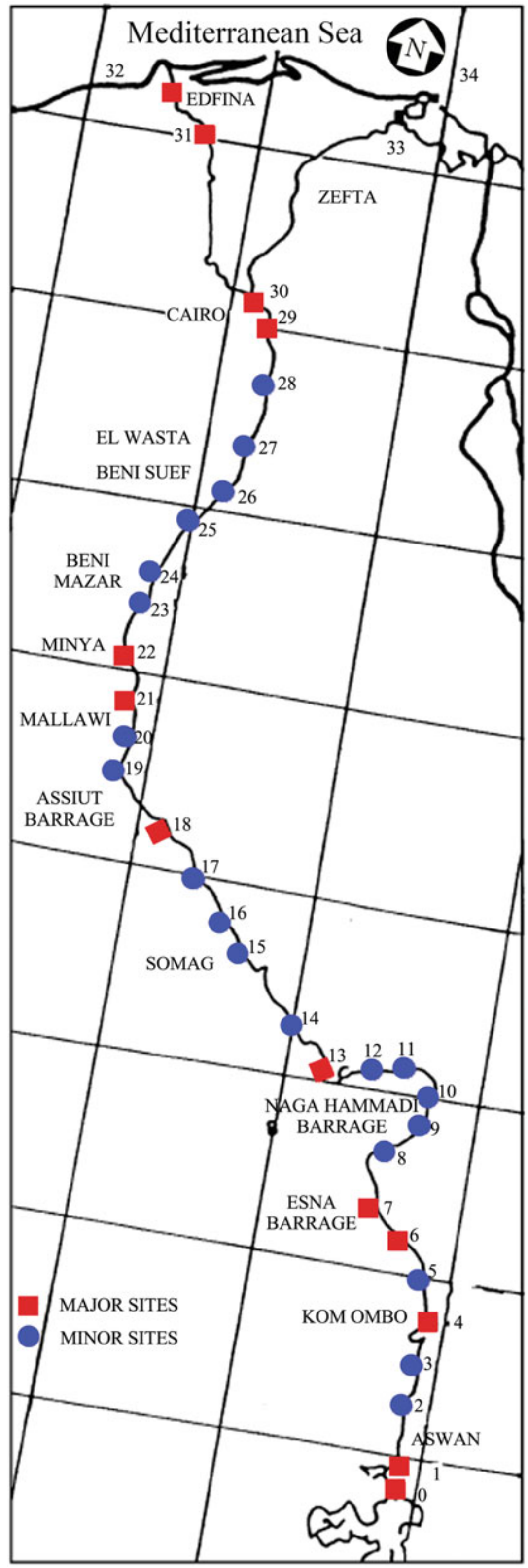


Fig. 3.4 Distribution of water quality monitoring cross-sections of the Nile downstream from the Dam [9]

from agriculture and industry nearby, the water quality is good and it has a fairly strong self-purification capability. With 98% of the sediments trapped in the reservoir, the water body downstream has less sediments and turbidity. The depth of the Sun ray penetration increased. That, along with the nutrients in the water, made algae proliferate.

Besides, the Aswan High Dam Management Board has chosen more than 500 points in the reservoir for monitoring the water quality and submitted monthly reports.

Discharge of Clear Water

The recent data from the Gaafra Hydrological Station downstream of the high dam show that the sand content of the water body has decreased from the pre-dam 3.8 kg/m^3 to the post-dam 0.1 kg/m^3. The downward discharge of clear water has broken the dynamic balance between the river bed evolution and the flow of the river downstream, thus increasing the scouring of the river bed and lowering the water level. The river regime has become more zigzagging and the hydraulic gradient has become gentle. But the three control barrages (Esna, Naga-Hammadi and Assuit), as shown in Fig. 3.2, have greatly weakened the down-cut of the river bed and gradient fall, playing a key role in regulating the river flow. The control barrages were modified after the high dam was built to meet the demand of power generation and shipping. Observation shows that the down-cut of river bed happens within a small scope of several kilometers downstream of the barrages. It was said that the biggest scouring in the past was estimated at 10 m but it was reduced to only 20 cm by 1999 and the river bed scouring has not had any harmful effect on the banks of the river downstream.

The downward discharge of clear water has had some impact on the traditional brick making industry of Egypt. For centuries, Egyptians use sand of the Nile to make red bricks. After the dam was built, the sand source was depleted, forcing brick makers to dig surface soil of the cultivated land for making bricks. Thanks to the efforts by research institutions, rock shale and clay have been successfully replaced Nile sand.

Shoreline Protection in the Estuary Area

The shoreline of the Nile Delta extends about 300 km from the Alexandra in the west to Port Said in the east. The wash or erosion of the shoreline is a natural phenomenon observed to the end of the nineteenth century. In the pre-dam period, the Nile carried a large amount of sediment during the flood season to supplement the sediment in the estuary area. But, after the dam was built, most of sediment source has gone and the shoreline erosion speed has been accelerated. In 1981, Egypt set up a shoreline protection board, which mapped out a protection plan up to the year 2000 with the assistance of UNDP. In November 1999, Dr. Huang Zhenli visited the Cleopatra seaside project in Alexandra, which is part of the plan. He saw a large amount of prefabricated members being carried to designated area to protect the banks. The project is said to be designed by a French company and undertaken by a company affiliated to the Shore Protection Authority. The Alexandra City has 25 km of shorelines that need protection. The investment per kilometer is estimated at 25,000 Egyptian pounds, all borne by the Egyptian government.

Reservoir-Induced Earthquake

There are two seismological stations at the Aswan High Dam site and at Abu Simbel by the reservoir. There are seven sets of automatic accelerators at Aswan High Dam (4), the old dam (2), and Bebel Marwa (1) to monitor the changes of earth crust. In the northern part of the reservoir, there is a remote monitoring network of pressure meter to monitor the underground water level and temperature. An earthquake with a magnitude 5.6 on the Richter scale recorded near Lake Nasser on November 14, 1981 aroused great concern for the safety of the dam. The earthquake led to a safety assessment program carried out by Egypt in cooperation with the United States. The assessment shows that even the maximum potential earthquake with a magnitude of 7 on the Richter scale is no threat to the safety and integrity of the high dam and its accessary structures.

Water Weeds Downstream

There are 47,000 km of large and small water diversion and drainage canals below the Aswan High Dam in Egypt. The completion of the high dam has created a favorable environment for water weeds to grow and proliferate in these water channels, causing such problems as blocking of water flow, interfering in shipping, affecting fisheries, boosting evaporation loss and increasing the habitats of vectors for Snail fever and malaria. Water weeds include floating plants [i.e., Common hyacinth (*Hyacinthus orientalis*)], emergent aquatic plants [i.e., Common reed (*Phragmites australis*)] and submarine plants [i.e., Pondweed (*Potamogeton sp.*)]. There are two factors contributing to the overgrowth of water weeds. One is the increase in the depth of sun penetration after the water discharged becomes clearer; the other is that the large amount of nutrients brought with water drained from the fertile crop fields or the industrial and sewage water discharged into the river untreated. The problem has aroused the full attention from the Egyptian government, which set up a Research Institute of Weed

Control and Channel Maintenance of the Water Research Center under the Ministry of Public Works and Water Resources to carry out research into countermeasures. The integrated measures adopted include weed elimination by hand, machines, biological control, and chemicals (banned after 1990). As a result, the canals overgrowing with weeds were reduced from 39,000 km (1985) to 14,400 km (1991). The coverage of Common hyacinth was reduced from 8900 hm^2 (1985) to 2670 hm^2 (1991).

Estuary Ecology

From Cairo, the Nile branches off into the Rosetta River and the Damietta River, forming a delta before they merge and empty into the Mediterranean Sea. There are two barrages on the Rosetta and three on the Damietta. Both rivers have barrages at places 10 km from the estuary, with a 1–1.5 m water difference to ward off the invasion by sea water after the runoff regulation by the high dam. During the pre-dam period, the runoff volume flowing into the Mediterranean from the two rivers was 40 billion m^3/a [9]. But such volume was reduced to about 6 billion m^3/a in the 1980s, according to Dr. Mohamed R, Abdel Bary, vice-president of the National Water Research Center and director of Institute of Nile Research. This gave us the impression that only a pitiful amount of the 84 billion m^3 annual runoff flows into the sea in Egypt and most of the water is extracted for use or stored in Lake Nasser. There is no alternative for this water-short developing country. It shows how precious water is for Egypt. No wonder it has a significant impact on the ecology at the estuary and the reduction in the catch of Sardine (*Sardinus pilchardus*).

During the pre-dam period, the Nile used to carry a large amount of sediment and nutrients into the Mediterranean Sea, which boosted the amount of floating aquatic plants and in turn fed Sardines. Although there is not a strict corresponding relationship between the amount of nutrients and the number of Sardines, the total catch of Sardine in the eastern part of the Mediterranean Sea dropped from 18,000 to 15,000 tons and Shrimps (*Decapoda*) dropped by 1/3 from 10,000 tons[11]. In contrast, the fisheries industry has increased catches in Lake Nasser. It was estimated that the fish catch in the areas close to the dam was 16,000–20,000 tons in 1965. But the fish catch from Lake Nasser exceeded 22,000 tons [11] in 1978 and reached 34,000 tons by 1981 [10].

Resettlement and Cultural Resources Protection

The Aswan High Dam involves the resettlement of about 100,000 Nubians, who are equally divided between Egypt and the Sudan. The Nubians in Egypt moved to the newly reclaimed land near Kom Ombo 45 km north of the Aswan City (600 villages merging into 43) and the 27 villages of Nubians in the Sudan moved southeastward to Khashm El Girba 600 km away from their original habitat. The Nubians of Egypt have three main subgroups: Kenuz, Fadga, and Arabs, each having its own culture tradition and language. They remain in three separate regions after resettlement. Their property has been compensated in cash by the Egyptian government. The government built new communities with better living and public facilities and provided free schools and free medical service. According to the 1959 agreement between the two countries, Egypt spent 15 million Egyptian pounds (about US$43.05 million at the then exchange rate) as compensation fees to the resettlement of the Nubians in the Sudan.

The Egyptian Nubians had experienced three rounds of major resettlement before the Aswan High Dam. The first one took place in 1902, when the old Aswan dam was built. The second took place in 1912, when the old dam was raised. The third took place in 1933, when the old dam was raised again. The Egyptian government decided to provide even better conditions in order to alleviate their pains and worries to make way for the Aswan High Dam. To make them adapt fast to the new ways of living, the Egyptian government did a lot of services and assistance to the displaced Nubians.

The Aswan High Dam was designed to submerge 17 temples of the Nubians, including the most famous Abu Simbel. The Egyptian government decided to rescue 10 of them. It got an aid from the UNESCO in relocating Abu Simbel and Philae temples and aids from France, Italy, and Germany in relocating other temples. Besides, Egypt presented Dandour Temple as a gift to the United States in return for its efforts to rescue Abu Simbel.

Egypt has a large area of desert, with scarce vegetation. The Aswan Regional Planning Centre carried out observations and studies of the aboriginals and vegetation in the areas near Lake Nasser, mainly in Wadi Allaqi on the eastern bank of the lake about 180 km south of Aswan, focusing on the monitoring of the impact of the dam on aboriginals, vegetation, and economy [14].

Public Health

Some people hold that the Awan Dam will increase the incident of bilharzia (*schistosoma*), as it used to be, ever an increase by about 10 times in Upper Egypt.

A contrast survey of 35 rural family samples in 1935, 1937 and 1955 shows [11] that bilharzia began to drop in the 1930s and dropped sharply in the 1950s thanks to preventive measures. The survey by the Alexandra University, Egypt in cooperation with the Michigan University, USA in 1976–1977 shows that the total incidence of bilharzia dropped from 83% in 1973 to 42% in 1976 and from 82% down to 27% in Upper Egypt. The incidence in some new resettlement areas is only 7.2%. This shows that bilharzia had been an old problem. Even if the incidence may increase for a time due to the favorable conditions created by the dam for the growth of hosts of bilharzia parasites, the incidence has dropped to the pre-dam level thanks to the preventive and control measures [9].

3.1.4 Causes for Arousing International Concern

The Aswan High Dam across the mighty river Nile is perhaps one of the most controversial of the existing big dams in the world, as pointed out by Egyptian experts at international conference on hydropower projects toward the end of the 1970s.[1] For a long time, reporters and authors who are not expert in technology have painted a catastrophic picture of the environmental impact of the dam. Besides, due to a limited amount of materials available, people of different professions have given different interpretations based on their own understanding.

There is no other hydropower project that has aroused such an extensive attention and played an important role in international politics. Few countries in the world are as dependent on water from a single source as Egypt. There is no other project like Aswan High Dam that has occupied such an important position in a country. Historians have that view today when describing the Aswan High Dam [15, 16]: After the "July 23" revolution in 1952, the Nasser government began to dedicate to economic development. In 1953, it took the decision to build a high dam at Aswan to solve the problem of water source and energy that have a great bearing on economic development. At that time, it was a period of confrontation between two camps of the East and the West. When the design was completed in 1954, the Egyptian government began to talk with the World Bank, the United States and the UK, hoping to get aid and loans from them. But the United States and the UK just turned a cold shoulder to it. In February 1955, Egypt came into conflict with Israel and Egypt was in a disadvantageous position. The newborn Nasser government wanted to buy advanced weapons from the West, but the western countries raised stringent strings attached, which Egypt refused. In September 1955, Egypt signed an arms sale agreement with the Soviet Union through Czechoslovakia. In November, the USA and the UK agreed to provide financing for the high dam for fear of Egypt falling into the camp of the East but the financing had harsh conditions aimed at controlling the economy of Egypt. In October 1956, the Soviet Union expressed again the willingness to provide technology, equipment, and funding, which could be repaid in kind for a maturity term of 25 years. Although the Nasser government adopted the non-alignment policy and tended to use western investment instead of over-reliance on the Soviet Union, the western countries declared that they would not support the building of the high dam on the pretext that Egyptian's financial conditions were deteriorating. This forced the Nasser government to take the final decision to rely on the Soviet Union and declared to nationalize the Suez Canal Management Company controlled by the UK and the France in July 1956 and use the revenues of the Suez Canal to pay for the dam. This touched off the Suez Canal War. Toward the end of 1958, Egypt and the Soviet Union signed an agreement on the first phase of the Aswan High Dam project and in August 1960, and signed an agreement on the second phase of the project.

It should be pointed out that in the years when the Aswan High Dam was being built, the environmental issues did not arouse attention from the world, including the western countries. Compared with the serious pollution brought about by industries, the environmental impact of hydropower projects received much less attention. Now, the whole world has become highly aware of the environmental issues, especially those brought about by hydropower projects. That has put China on the alert in building such projects, directing greater attention to environmental issues and striving to make an objective and scientific assessment and adopt measures to reduce such problems to a minimum.

[1] Changjiang Water Conservation Protection Institute and Yangtze Valley Planning Office (ed.) (1981) Impacts of Aswan High Dam on Environment. In: Translations of the environmental impact of large water projects, in September 1981.

3.2 Environmental Protection and Monitoring of the Itaipu Dam in Brazil

3.2.1 Itaipu Dam in Brazil

The Itaipu hydroelectric power project is a binational undertaking run by Brazil and Paraguay on the Paraná River on the border section between the two countries. Work started in 1973; water began to be impounded in 1982; and power generation started in 1984; 18 generating units were completed in 1991 adding up to a total generating capacity of 12,600 MW. The reservoir measures 170 km in length, with the deepest part being 170 m and a storage capacity of 29 billion m^3 of water. The reservoir water surface is 1350 m^2, with 43% belonging to Paraguay and 57% belonging to Brazil. The reservoir has changed greatly the environment of the Parana waterway, with the affected areas exceeding 30,000 km^2.

3.2.2 Environmental Impact of the Dam

An enormous amount of studies were done during the feasibility study, the construction and the 5-year operation of the project aiming at assessing and alleviating environmental impacts of the project.

In 1973, the IECO-ELC Consortium completed a report "General survey of the ecological impact by Itaipu project" and then went on to carry out detail investigations of its impact on nature, biology, and social development for the purpose of providing materials on the possible impact of the project and mapping out a guiding principles for improving

The panorama view of the Itaipu Dam (Close shot. The dam is discharging flood water)

Power plant section of the Itaipu Dam. The eighteenth 700,000 kW generating unit was completed in 1991, bringing the total maximum. Power output annually up to 93.4 billion kWh by 2000, the then biggest hydropower facility in the world. In 2005, two more 700,000 kW generating units were added, bringing the total installed capacity up to 14,000 MW

and protecting the environment in the dam site area and the affected areas.

The inevitable environmental impact comes mainly from inundation. The reservoir created has submerged 170 km of natural river section, the Sete Quedas (Guaira) waterfall, the habitats of wildlife, 700 km^2 virgin forests, 600 km^2 of farmland as well as mineral resources, and historical sites unverified.

But these unfavorable impacts on the environment have been justified by its huge amount of power generated and the social and economic benefits it has brought about. The countermeasures that have been adopted can minimize the impacts. Brazil and Paraguay have formulated preventive and protective programs for monitoring and controlling the environmental impacts.

The Itaipu Binacional, founded by Brazil and Paraguay in 1974, put forward a basic program for environmental protection in 1975, which included further environment survey (monitoring), general plan for the use of the reservoir and environmental protection measures.

3.2.3 Monitoring

Water Quality

Monitoring of the water quality upstream and downstream of the dam was done before and after the completion of the dam. Before impoundment of the reservoir, more than 40,000 data were obtained after the analysis of about 40 parameters (physical, physiochemical, chemical, biological and microorganism). With the first 5 years after the water was stored, the monitoring work continued at 22 monitoring stations, collecting about 30,000 data.

The monitoring results show that the reservoir has not led to the deterioration of the water quality of the Parana River. The river water has been found suitable as water supply source for cities and for tourism, commercial fish breeding and irrigation. The reservoir is of medium degree in nutrients and no temperature stratification. The water has not been eutrophicated. But it has been decided to control the inflow of nutrients from tributaries.

Fish Species and Fishing Resources

Investigations have been completed with classification and identification of fish species, including their composition and mutual relationship, the amount of fish in different seasons and the assessment of their habitats, such as food, spawning, and water quality. Other aspects include food chain, proliferation of fish, life cycle and migration routes, the relations among the dynamic numbers, water quality and water plant growth, with attention paid to the possibility of spreading tropical diseases by vectors such as malaria, bilharzia, and filariasis. Researches include programs of aquatic breeding station and augmenting fish resources.

In the pre-dam period, 129 fish species were established in between Monday and Yguazu estuary and the upstream of the Guaira fall. They belonged to 25 families, of which 44 species were distributed in the upstream and downstream of the Guaira fall, 13 in the upstream, 60 in the downstream, and 12 in tributaries. The amount of fish in the upstream of the Guaira fall was large in number but few in variety. But the opposite was true in the downstream. After the dam was built, 82 fish species have been identified, including 15 that were not found in the pre-dam period.

Fish breeding in the Itaipu reservoir

In order to reduce the unfavorable impacts on the downstream of the dam, the Itaipu authorities completed a Piracema Channel project to carry out migration training (3000 individuals a day). This has reduced the impact of the environment on fish and promoted fishing production downstream of the dam. The Piracema Channel project, plus the aquatic breeding stations, stimulated the studies of the natural growth and artificial multiplication of local fish species. In 1986, cage fish breeding started in the Itaipu reservoir.

Fish species in the Itaipu reservoir

Climate

The region of the reservoir has a subtropical humid climate. The annual mean temperature is 22 °C, with the highest being 40 °C in December and January and the lowest being −5 °C in July and August. The relative humidity of the air is high in all months, with an annual average of 80%. To evaluate the intensity and the extent of the eventual modification of the climate in the region, caused by the reservoir, a monitoring program has been mapped out, including the setting up of six agricultural meteorological stations connected up with the national meteorological station. Data collected over the past eight years indicate that the influence of the lake is very limited, with only a very small increase in the specific humidity and in the temperatures within the belts up to a distance of less the five kilometers from the edges. The studies also suggest that the change in the local climate is resulted from deforestation and, especially, from global variations and not from the dammed water mass.

Sediment

The average annual sand transportation of the Parana River is estimated at 5 million tons, indicating that the service life of the reservoir is at least 350 years.

Clearing of the Reservoir Bottom

As the decomposition of the plants inundated by the reservoir is a slow process, it has little impact on the water quality. So the Binacional decided not to clear the vegetation of the reservoir bottom. But to make it safer, some tall trees of about 100 km^2 at an elevation of 200–220 m were cleared. The amount of timber cleared is estimated at 200 tons, about 10% of the total.

The piracema channel (a section of the channel shown in the upper left) makes a link from the Itaipu's Reservoir with the Parana River downstream the dam. It was built in February 2002. The course, of 10 thousand meters long, uses a part of the Bela Vista River bed to reach the unevenness of 120 meters between the Parana River and the surface of the Reservoir. The Turbulent Water Channel, one of the components of the Piracema Channel, was developed for the Practical of nautical sports of competition (rafting, canoeing, slalom, and others). Photo by Zhang Dazhi

Forest Survey

The survey covered the structure and composition of trees, forest ecology and the relations between plants and animals, establishment of plant species, working out forest management plans, opening of sampling nurseries, and replacement of forests.

The survey of 3860 km^2 forests was completed in 1975. It got clear the ways of land utilization in the reservoir areas of the two countries, as shown in Table 3.1. The results show that there are big differences in the land utilization between the two countries, but the land is mainly devoted to virgin forests and agricultural land.

The natural forests in the reservoir area are of subtropical rain forest type. The survey established 110 species of commercial value, averaging 191,500 m^3/km^2 of standing stock per unit area. Species with the highest commercial value include Deodar (*Cedrus deodara*), ipe, Pau-marfim (*Agonandra brasiliensis*), Peroba (*Paratecoma perobe*), and *Camphor tree* (*Cinnamomum camphora*) as well as 103 families and 463 plant species, of which *miconia jucunda* and Condorvine (*Marsdenia sp.*) are of rare species.

Table 3.1 Land occupation in the Itaipu Reservoir area (Brazil and Paraguay)

Land occupation	Brazil (%)	Paraguay (%)
Forest	47.6	82.4
Farm land	50.5	15.7
Wetland	0.7	0.9
Water body	0.7	0.9
City	0.5	0.1

Terrestrial Animal Survey

The survey is designed to establish native and rare species of animals in the region and study their food base, habitats, migration, and reproductive cycle so as to map out a plan for relocating and rescuing wild animals in the inundated area, by establishing a center as part of a museum of natural history. As most of the virgin forests are on the Paraguay side, the activities were concentrated in Paraguay, with 61 mammals in 24 families and 9 orders, 323 birds in 58 families and 20 orders, 28 reptiles in 12 families and three orders, and 116 families of insects in 20 orders.

Plant rescuing and breeding technicians

Jaguar (*Panthera onca*) relocated for protection

Limnology

Limnological monitoring covers the formation of the reservoir, reservoir itself, water quality of the reservoir and downstream, water associated physiochemical parameters, heavy metals, toxic matters, and other matters as well as silt deposition and fish, environmental impact of the reservoir. Perennial data show that the reservoir water can satisfy the ecological and other demand of aquatic life. The analysis of aquatic life has, in addition to spawning, reproduction and nutritional dynamics, also established the ecology of major aquatic life and the differences in number between the past and present and the future trend and potential for expanded production.

Social Environment

1. Health program

The program is to investigate the health conditions before the project and formulate a health program to ensure the health of workers and residents around the project, with particular attention given to the possibility of the spread of tropical diseases.

2. Archaeological studies

The reservoir area used to be an area where the Indians of the Tupi-Guarani tribe lived in compact community in sixteenth–seventeenth centuries. There are also traces of development by Spaniards and Portuguese.

The ancient pottery discovered shows the possibility of the existence of the Preambiru trail, an ancient trading route across South America between the Indians on the shore of the Atlantic and the Incas. The potteries discovered are mainly of two types: before and after the occupation by Europeans. The investigation studied 237 ruins and collected and analyzed 171,500 pieces of objects, giving a full picture of the history of the place from 6000 B.C. to 1920.

The archaeological studies are very important for studying the area. The research achievements have been put on display in the museum of natural history and the museum of ecology near the dam.

3.2.4 Environment Protection and Improvement Measures

Belt of Protection of the Reservoir

A band of protection has been established to protect the reservoir. It is an area extending around the reservoir at an elevation of 225 m, 100–500 m on the Brazilian side, covering an area of 280 km^2, and 100–300 m on the Paraguay side, covering an area of 354 km^2. The borders of the area are a 1395 km long green belt, with more than one million trees of 50 native species planted in 1981–1982.

On the Paraguay side, about 90% of the reservoir area is covered by virgin forests, quite different from that of the Brazilian side. Most of the land on the Brazilian side has been developed for farming and only 8% are covered by virgin forests. A Gralha Azul program, named according to a kind of bird spreading tree seeds, has therefore been implemented on the Brazilian side for restoring the forest cover. If all the area is reafforested, it would require 22 million saplings. But, considering the regeneration of the existing forests, only 15 million have been planted. The reafforestation project started in 1983 and was not finished until all the protected area is covered with trees. The objective of building the green belt is to reduce erosion, siltation, and the nonpoint pollution by agriculture. The belt consists of a barrier against torrents and the wind.

In support of the reafforestation project, nurseries have been set up to cultivate native species. Over the past 11 years, the nurseries have cultivated about 20 million saplings for the reafforestation project and the environmental greening project in the residential area of the Itaipu Binacional.

Table 3.2 Itaipu natural reserves

Location	Name	Area (km^2)
Paraguay side	Limoy	148
	Ltabo	83
	Tati-Yupi	24
Brazilian side	Bela Vista	17
	Santa Helena	15
Brazil/Paraguay Border	Maracaju	14

Biological Refuge

Another measure to protect the survival of animals and plants is the creation of biological refuges. Activities in the refuges include the protection and restoration of original forests, relocation of animals, ecological studies, wildlife management, and environmental education.

The refuges are shown in Table 3.2. Five factors are taken into account in selecting the reserves: size of land area, size of natural forests, density and habitat of wildlife, population pressure, and tourism potential.

Limoy and Itabo are designated as biological refuges due to their size and natural conditions. Others are designated as protected areas due to their small size and human activities. Besides, there is a 240,000 m^2 botanical garden used as a research center, with nurseries, museum of natural sciences, regional zoo, animal hospital, and logistics center. The botanical garden is on the Paraguay side, near Ciudad del Este, which serves as a tourism spot.

The direct result of the opening of the reserves and refuges is the increase of water fowls that have never been there before.

Animal Rescue

The Binacional launched a Mymba Kuera project to rescue animals affected by the reservoir. The project involves the collection of materials about animal species and population density, rescue operation before, during and after impoundment, relocation of rescued animals, and tracking of ecological system in the reservoir area.

Aquatic Breeding

Techniques adopted include fish management (optimal fishing, restoration of fishing resources and the opening of fishing grounds), management of habitats (control of large

The green belt around the Itaipu Reservoir. Photo by Zhang Dazhi. It is 1395 km long and 100–500 m wide on the Brazilian side, covering 280 km^2 the 100–300 m wide covering an area of 354 km^2 on the Paraguay side. China has borrowed the experience and, starting in 2004, begun to build a green belt around the Three Gorges reservoir plants, water level, and artificial spawning ground), and fisheries management (management and control of commercial fishing ground and recreational fishing ground, fry, and young fish protection and fishing ban at a certain period).

In 1988, the average monthly catch in the Itaipu reservoir was 116 tons and about 840 professional fishermen operated in the reservoir, of which 57% started the work after impoundment. The common fish include Curimba (*Prochilodus scrofa*), Curvina (*Plagioscion squamosissimus*), Mapara (*Hypothalmus edentatus*), and Armado (*Pterodoras granulosus*). The amount of Curimba has been reduced after impoundment while Mapara increased. There has also been an increase in floating organisms, insects, and carnivorous fish while grass-eating and omnivorous fish has decreased.

Master Plan for the Utilization of the Reservoir

The Itaipu Binacional has formulated a master plan for the protection and utilization of the reservoir area. It has divided the area into several zones for shipping, fishing, water supply, irrigation, tourism, and recreation.

1. Reservoir zone—the water surface at an elevation of 220 m in front of the Itaipu dam.
2. Riparian zone—all the land near the reservoir bought by the Binacional. The reservoir protected zone is within the riparian zone.

The above zones have been assigned with different purposes:

- Special zone: biological protection, wildlife management, environmental protection and restoration;
- Multipurpose zone: fish breeding, shipping, and water supply;
- Recreational zone: tourism and cultural activities;
- Integrated city zone; road system, health program, telecommunications, and energy supply.

The master plan has fixed the administrative procedures and coordination with local government management departments.

In order to realize the objectives set in the master plan, the Binacional has set up an agency for implementing the plan. All activities within the reservoir area have to get the approval of the Itaipu Binacional, which will oversee the implementation of the plan.

Resettlement

The Itaipu reservoir has inundated 1460 km^2 of land. On the Brazilian side, most of the inundated areas used to be an agricultural zone, covering 1000 km^2, including 8500 blocks of real estate, 6900 in the rural area and 1600 in cities, displacing 40,000 people. 577 km of roads have been inundated, and 390 km others have to be re-routed. The rural population density is 35/km^2, averaging an area of 100,000 m^2.

About 87% of the displaced people have been resettled near the project. The new land bought is 50% more than the land area occupied by the project. The total compensation for the requisition of land is US$190 million.

In Brazil, as part of the federal government plan, some people have been resettled to other states, including Bahia (399), Acre (1193) and Parana (2930). Every resettled family has got a house and 200,000–400,000 m^2 of land and a 10-year loan from the government, with an annual interest rate of 6%.

Environmental Education

The Itaipu Binacional has formulated an environmental education program for the public, especially for local communities. The program includes the supply of equipment for environmental information and a dialogue system among the project managers, environmentalists and the public. The education program also includes two museums and the activities of the museums have been extended to biological protection zones and refuges.

The ecological museum is situated on the Brazilian side, near the dam. Covering 1200 m^2, the museum houses a 52 m^2 hothouse (with 130 species of plants affected by the dam and in the Sete Quedas area), a herbarium (820 species of plant collected in the area affected by the dam), 12 aquariums (raising 12 natural species with different water environments), several exhibition halls (for local animal specimens, ancient pottery samples and historical relics), a research lab, a library, a conference hall, and a workshop.

The Museum of Natural Sciences is on the Paraguay side, near the dam. Covering about 2000 m^2, the museum has exhibitions devoted to animals, plants, and pottery samples unearthed and a lab.

Activities of the museums include exhibitions, lectures, workshops, theatrical performances, visits by students, and eco-tourism. The museums also carry out researches in archaeology, ethnology, paleobiology, anthropology, zoology, botany, and hydrobiology.

Leisure seeking in the Itaipu reservoir

Young people visiting water fowls in the museum

3.3 Environmental Protection and Monitoring of the Glen Canyon Dam in USA

3.3.1 Glen Canyon Dam of USA[2]

The Glen Canyon Dam [19] (see Fig. 3.5) was built on the Colorado River in Arizona by the US Bureau of Reclamation in the late 1950s and early 1960 by taking advantage of the world famous Glen Canyon. The dam created a reservoir, Lake Powell, the second largest in the United States (see Fig. 3.6).

Work on the dam started in 1956 and was completed in 1963. Impoundment lasted for 17 years (1980) to reach the normal level. It is managed and operated by the US Bureau of Reclamation. The dam is 215 m high and 475 m long. Lake Powell holds 33 billion m^3 of water and its designed total discharge capacity is 7244 m^3/s through three outlets of the power plant, spillway, and bottom holes. The dam is used mainly to generate electricity and regulate the water flow and prevent flooding. The power plant has eight turbo-generating units, with a total installed capacity of 1320 MW and its annual electricity output is 5 billion kWh, directly benefiting the states of Wyoming, Colorado, New Mexico, and Utah.

The dam has aroused growing attention from the general public and federal and state governments for its unfavorable impact on the environment downstream. In July 1989, the US Bureau of Reclamation was ordered to prepare an environmental impact statement. The Glen Canyon Dam is a multipurpose project, and according to relevant regulations, it mainly undertakes to carry peak power load. But the tremendous changes brought about by water discharge have aroused extensive concern. The local people and environmentalists worried about the negative impact on recreational fishing, rafting, animals, and plants and their habitats. In 1980, when the US Bureau of Reclamation studied to expand the generating capacity, it met with a strong opposition from the public. The work had to stop. The US Bureau of Reclamation was demanded for more comprehensive environmental impact studies and disagreed with increasing power output.

In 1982–1988, the US Bureau of Reclamation started a trans-sectoral "Glen Canyon Environmental Impact Studies (GCES) (Phase I)" and went on with the work in the second phase in 1988. At the same time, the bureau organized other tests and studies. All the work has laid a foundation for the environmental impact statement.

It is generally held that the dam affects the environment in an area of the Colorado River corridor from the Glen Canyon Dam in northwestern Arizona, southward through the Glen and Marble canyons and westward through the Grand Canyon to Lake Mead. The geological conditions around the Glen Canyon are good for storing water, suitable for building a large hydropower project, as the Canyon is made up of even-textured and extra-ordinarily solid rock known as Navajo sandstones.

[2]The figures and tables in this section are supplied by the following organizations and websites: US Bureau of Reclamation; http://sbsc.wr.usgs.gov; http://www.obsessionboats.com; http://www.bransmallphoto.com; http://www.pgc.state.pa.us; http://secure.environmentaldefense.org; http://www.kaibab.org.

Fig. 3.5 Location of Glen Canyon Dam

3.3.2 Project Impact

Methodologies of Environmental Impact Determinations

The Glen Canyon Dam has, from the very beginning, affected and changed the ecology and environment of surrounding areas covering the Glen Canyon, the Marble Canyon and downstream basin of the dam. The US Bureau of Reclamation implemented in 1982 the Glen Canyon Environmental Impact Studies (GCES), focuses on two aspects: (1) whether or not the operation of the dam had an adverse effect on the environment of the Glen Canyon; (2) whether or not there were new alternatives for the operation of the dam that could protect and improve the local environment and related resources. In 1988, the GCES project group began to collect more data on the operation of the dam in preparation for an environmental impact statement (EIS). In July 1989, the Secretary of the Interior directed the Bureau to initiate an environmental impact assessment of the Glen Canyon Dam.

Alternatives for the draft Glen Canyon Dam Environmental Impact Statement (EIS) were formulated through a systematic process using public input, technical information, interdisciplinary discussions, and professional judgment.

The EIS first of all deems the following three specific operation procedures as impracticable:

- To dismantle the dam. It is not feasible according to the actual conditions.
- To build another dam at Lees Ferry downstream from the Glen Canyon Dam, it is useful for generating electricity that holds out good economic prospects. But nearly 24 km long section of the Glen Canyon will be destroyed for ever. The proposed is unacceptable.
- To operate the dam according to the pre-dam water volume. The presumption holds that the operation with the pre-dam water discharge would eliminate the environmental impacts. Such presumption did not consider the big reduction of the sand carried by the flow that will cause scour downstream and it will weaken the generating capacity of the power house, without benefiting any environmental resources.

So the EIS considers only nine specific operating procedures as shown in Table 3.3.

One view holds that the daily flow fluctuation is unfavorable to the environment in the surrounding and contends that stable flow is more favorable. Studies show that flows does not directly do harm to natural resources and cultural resources and the relations between the survival of endemic species and flow change is not clear. The stable flow should be established on the basis of accurate forecast of runoff flow and the water storage capacity available in Lake Powell and at the expense of the flexibility of power generating capacity. The current situation indicates that stable flow is not favorable to the environment of the surroundings.

Starting from 1996, EIS decided that the Glen Canyon Dam operates at modified fluctuating flows and monitor and study its impact on the environment. After 2000, the alternatives have been adjusted to seek ways of reducing the dam's impacts on the environment and resources.

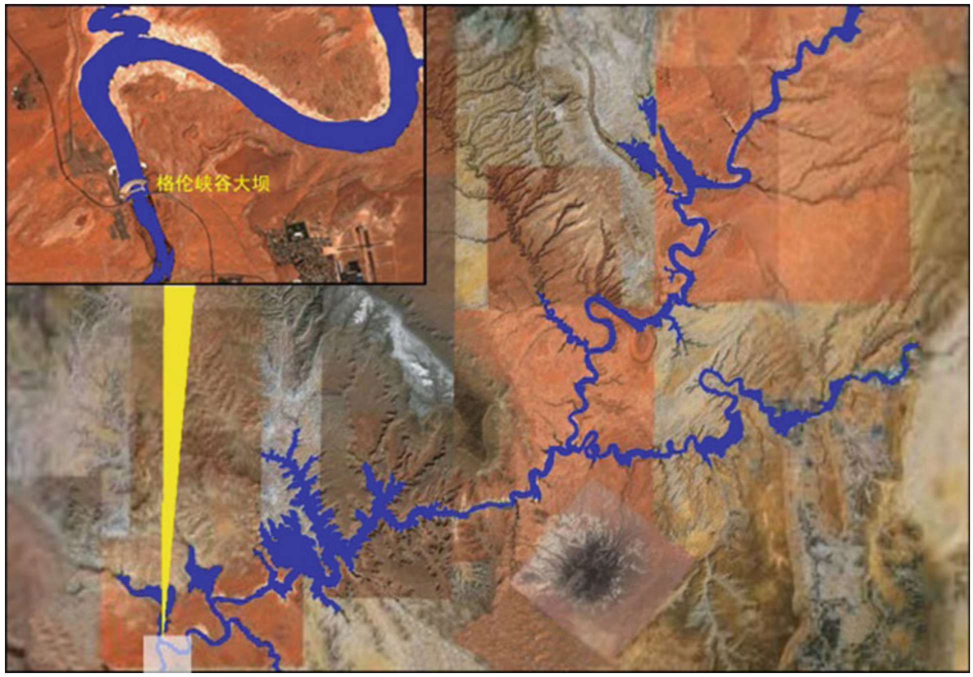
Result of Environmental Impact Assessment

GCES project collected a large amount of testing data and analyzed the impact of different operating procedures on such environmental factors as water quality, sediment, fish, aquatic plants, wildlife, cultural resources, air quality, tourism and recreation, power generation, and potential values.

Water Quality

The area of potential impacts on water quality includes the Colorado River downstream from Glen Canyon Dam, Lakes Powell and Mead, and the Upper and Lower Basin States. Computer modeling studies projected operations for 50 years to determine long-term impacts and for 20 years to determine short-term impacts. The Colorado River Simulation System (CRSS) was used in analyzing impacts on annual and monthly streamflows, floodflows and other spills, water storage, water allocation deliveries, and upper basin yield determinations for the environmental impact statement. The analysis results show that impacts of the alternatives on water issues are essentially the same as under the No Action Alternative, except for monthly flows, flood flow frequencies. Streamflows, reservoir storage, water allocation deliveries, Upper Basin yield determination, and the water quality are affected only negligibly by the alternatives. Potential impacts on water quality were assessed based on analysis of existing limited data on chemical, physical, and biological processes influencing water quality in Lake Powell. Under normal hydrologic conditions, changing release patterns under any alternative would not affect reservoir or release water quality. Under any alternative greater amount of certain constituents (salinity, nutrients, sediment, selenium, and mercury) enter Lake Powell than those out flowed. Therefore, these constituents would tend to increase in concentration, primarily in sediment and deep reservoir waters that rarely circulate. Lead

Fig. 3.6 Remote sensing image of Lake Powell



Front view of the Glen Canyon Dam

A bird's-eye view of the Corolado River downstream of the Glen Canyon Dam

Glen Canyon Dam

Lake Powell

Leeds Ferry

Table 3.3 Alternatives affecting Glen Canyon Dam environmental impact assessment

Operating procedure	Classification	Description
1. No action	Unrestricted fluctuating flow	Like the operation in 1963–1990, maintain fluctuating releases and provide a baseline for impact comparison Max. 891 m^3/s Min. 28 or 84 m^3/s
2. Maximum power plant capacity	Unrestricted fluctuating flow	Except flow, all the rest operations are like that of 1, permit use of full power plant capacity
3. High fluctuating flow	Restricted fluctuating flow	Slightly reduce daily fluctuations from historic no action levels, Max. 891 m^3/s Min. 84 or 141.5 m^3/s
4. Moderate fluctuating flow	Restricted fluctuating flow	Moderately reduce daily fluctuations from historic no action levels; includes habitat maintenance flows Max. 891.5 m^3/s Min. 141.5 m^3/s No more than 631 m^3/s in low water season
5. Modified low fluctuating flow	Restricted fluctuating flow	Substantially reduce daily fluctuations from historic no action levels; includes habitat maintenance flows Max. 707.5 m^3/s Min. 226 m^3/s (in the day) 141.5 m^3/s (at night)
6. Interim low fluctuating flow	Restricted fluctuating flow	Substantially reduce daily fluctuations from historic no action levels; same as interim operations, which is beneficial to endangered resources Max. 566 m^3/s Min. 226 m^3/s (in the day) 141.5 m^3/s (at night)
7. Existing monthly volume	Steady flows	Provide steady flows that use historic monthly release strategies Max. volume at beginning of month Min. 226 m^3/s (in the day)
8. Seasonally adjusted flows	Steady flows	Provide steady flows on a seasonal or monthly basis, with low volume in winter and high volume in spring; includes habitat maintenance flows Max. 509 m^3/s Min. 226–354 m^3/s (varying with different seasons)
9. Year-round flows	Steady flows	Provide steady flows throughout the year Max. annual flow Min. annual flow

concentrations also would continue to increase, as a result of leaded fuels used in motorized recreation on the lake. Other factors, such as future Upper Colorado River Basin depletions, development, and land use, may also influence water quality in Lake Powell and downstream.

Extended droughts cause low reservoir conditions when Lake Powell storage is lower than 1094 m. When this occurs, intakes may draw water from nearer the reservoir surface, and large areas of delta may be exposed. As a result, the release temperature may increase by 1.67 °C (3 °F), dissolved oxygen (DO) concentrations may increase, and release salinity, nutrient, mercury, and selenium concentrations may decrease.

Deposition of sediment

Sediment

The analysis of impacts to sediment resources is limited to the Colorado River corridor between Glen Canyon Dam and Lake Mead, and the deltas in Lake Powell and Lake Mead.

Table 3.4 Environmental monitoring of the Ertan hydropower station

Item	Monitoring positioning	Indicator	Frequency and time
Sediment	14 cross-sections during construction and 60 during the trial operation period	Sediment	April, 1998, September 2000
Hydrology	Nine hydrological stations and 17 precipitation stations	Water level, rainfall	Flood season: Hushantan at a flow of $Q \geq 11100$ m^3/s; water level and rainfall measured 24 times; at a flow of $Q < 11100$ m^3/s, water level and rain fall measured 8 times Low water season: Two times, the water level Trial operation started in Aug. 2000
Meteorology	2 height cross-sections, one horizontal cross-sections and 9 monitoring points	Temperature, precipitation, atmospheric pressure, wind, cloud height and shape, amount, kind of weather, evaporation, sunshine hour, geothermal temperature, and water temperature	April 1, 1996–Dec. 30, 2000, Observation at 8:00, 14:00, 20:00 and 2:00 in rainy season (June–October); Observation at 8:00, 14:00 and 20:00 in the dry season (Nov.–May)
Water quality	5 cross-sections from the tail of the reservoir to the dam, 1 at downstream and 2 on the tributaries	Compliance with surface water environmental quality standards (GB3838-1988)	Once every year during the high, normal and low water seasons in 1993, 1997–March 2000
Bottom mud	5 cross-sections from the tail of the reservoir to the dam	COD, sulfides, selenium, TAs, THg, TCu, TPb, TZn, TFe, TMn, TCr, TP, SS	Low water season in 1993
Water temperature	3 cross-sections, with 5, 6 and 6 vertical lines and measuring points at 0, 0.2, 0.7, 1 and 2 m and so on	Water temperature	From October 1999 to the present, near-dam cross-sections is observed on Tuesday every week and the Shenli cross-section and the Yumen cross-section are observed on the 1st–2nd days, the 10th–11th days and 20th–21st days
Terrestrial animals and plants	Within the watershed, with emphasis on areas with an elevation of less than 300 m in the inundated and reservoir areas	Vascular fauna, vegetative diversity and diversity of terrestrial vertebrates	October 28,1995–November 12, November 23–December 30, 1995, May 14–June 20, 1996
Aquatic plants and fish	8 cross-sections from Lizhuang of Maidigou in Mianning County to Yalong River estuary	Fish, aquatic plants and diversity of aquatic animals	Nov. 21–Dec. 19, 1996; March 20–April 18, 1997; July 8–29, 1997; Nov. 24–Dec. 23, 1997; March 9–April 9, 1998
Monitoring during construction period	*Water quality*		
	Santan Dagou	pH, chlorides, sulfate, bicarbonate, soluble solids	Dec. 1992
	Air		
	Diversion tunnel	CO, $Si0_2$, and dust	Nov. 1992
	Underground power plant	Mn, Mo, Ni, Cr, Co, $N0_2$, $Pb(C_2H_5)_4$, and dust	June, 1997
	Noise		
	Underground power plant	Noise	June 1997

Direct impacts include changes in riverbed sand storage, aggradation and degradation of sandbars, and changes in capacity to move large boulders from rapids. A comprehensive, mathematical flow and sediment transport model of the river and associated eddies were used to analyze the impacts.

Short-term impacts to sediment resources would occur within 20 years after an alternative is implemented. Flood release is assumed not to occur in the short term. In the absence of floods, sediment resources would be affected primarily by the magnitude, pattern, and duration of power plant releases from Glen Canyon Dam.

Long-term impacts would occur 20–50 years as sediment resource reaches a state of dynamic equilibrium. Dynamic equilibrium means that the average sediment load transported

Collecting sediment

by the Colorado River is in balance with the sediment loads being supplied by its tributaries. Sediment deposits (including sandbars) would change in size and number as transport capacity and tributary supply varied, but monthly and annual changes would balance out, resulting in no net change over the long term. Floodflows greater than 1273 m^3/s are assumed to occur over the long term.

Fish

Each alternative results in physical effects to the aquatic environment that alter fish habitats. Both biological productivity and physical characteristics of the environment (temperature, reliable flow, turbidity, etc.) determine the limits of fish development. The main targets of study are native fish, non-native fish, interactions between native and non-native fish and Trout (*Salmonidae*). Native fish includes Humpback chub (*Oncorhynchus gorbuscha*), Razorback sucker (*Xyrauchen texanus*), Flannelmouth sucker (*Catostomus latipinnis*), Bluehead sucker (*Catostomus discobolus discobolus*), and Speckled dace (*Rhinichthys osculus*).

Wetted parameter, hence the aquatic food base, tends to increase as the minimum reliable discharge increase. None of the alternatives change the temperature of the water released from Glen Canyon Dam. Backwaters and nearshore areas would warm somewhat during warm months under tall alternatives, but would warm more under the steady flow alternative. An insignificant increase in reproduction may occur under the steady flow alternatives in nearshore environments. However, warmwater fish would continue to rely on tributaries for reproduction under all alternatives.

Humpback chub

Razorback sucker

Speckled dace

Vegetation

Riparian vegetation mainly includes woody plants and protected wetland area. The riparian plants are sensitive to the changes in sediments and water release. Glen Canyon Dam operations affect downstream vegetation through several different mechanisms, especially daily release patterns repeated over time and major uncontrolled flood releases. Effects are reflected as changes in both plant abundance and species composition.

The short-term period of analyses is defined as the period from 5 to 20 years. The impacts of the dam operation on plants downstream are:

- Reduced frequency of major uncontrolled flood releases would result in a decline in area coverage of riparian vegetation. The vegetation shifts from riparian to desert shrub.
- The Maximum powerplant capacity alternative would result in reduced area of riparian vegetation.
- Under no action, woody plants would be maintained within state boundaries equivalent to flows between 622 and 1146 m^3/s.

The long-term period is defined as the period from 20 to 50 years. The impacts of the dam operation on plant downstream are:

- Under the No Action and Maximum Powerplant Capacity Alternatives, riparian vegetation would be set back to an earlier successional stage and woody and emergent mash plants would recover postflood to a level comparable to baseline conditions.
- All the other alternatives could maintain ecological stability flows and vegetation would be affected by changes in the weather conditions.
- Riparian vegetation supported by Lake Mead would increase under all alternatives.

Wildlife and Habitat

Dam operations affect vegetation and, in turn, habitats of wildlife. Little data about wildlife are available and the effect of the dam operations can be analyzed according to the methods applied in the effect on riparian vegetation.

Endangered Species and Other Special Status Species

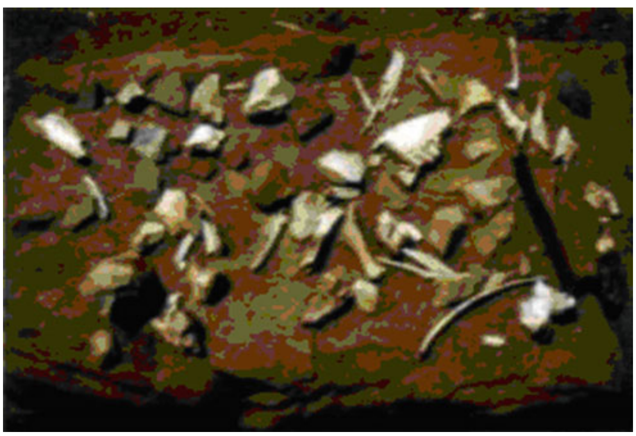
The dam operations would have indirect impacts on endangered species and other special status species. The endangered and special status fish species are influenced by factors and processes similar to native fish species. But three special status species would not be affected by changes in dam operations. They are southwestern river otter (*Lontra provocax*), Peregrine falcon (*Falco peregrinus*), and O*sprey* (*Pandion haliaetus*). A fourth species, the Kanab ambersnail (*Oxyloma haydeni kanabensis*), would be affected by maximum flows above 56.6 m^3/s. The number of Cinereous vulture (*Aegypius monachus*) is closely associated with the survival of Trout (*Salmonidae*). Belted kingfisher (*Ceryle alcyon*) live in nearshore areas suitable for making nests and they are not affected by dam operations. Only low flows make it difficult for them to catch fish. The survival of Southwestern willow flycatcher (*Empidonax traillii*) is closely associated with the amount of riparian woody plants. No data show that they are adversely affected.

Peregrine falcon

Kanab ambersnail

Belted kingfisher

Southwestern willow flycatcher



Archaeological excavation site

Pottery unearthed demonstrates traditional culture of Indians

Cultural Resources

Cultural resources in the Colorado River corridor are numerous, with 475 archaeological sites and 489 isolated occurrences documented between Glen Canyon Dam and Separation canyon. Of the archaeological sites located during the survey, 336 either have been affected by the existence and operation of the dam or have the potential to be affected by flood flows that could be released from the dam. Generally, alternatives that have the capability to maintain the sediment balance and allow for sediment distribution along the river corridor would enhance long-term preservation of cultural resources. Although sediment transport is variable and depends on flow regime, alternatives that would most likely produce net positive sand balance in the system —while maintaining a high base level of sediment deposition—would be most favorable.

Air Quality

The hydroelectric power production at Glen Canyon Dam has no direct influence on air quality, but a change in its operations would affect the electrical power system. If the alternative source of power used fossil fuel, there would be a net change in system emissions of such atmospheric pollutants as sulfur dioxide and nitrogen oxides.

Recreation

Discharge from Glen Canyon Dam affects recreation through its influence on flow-sensitive attributes or through changes in the recreation environment. Analysis of the low flows in 1989, medium flows in 1987 and high flows in 1984 indicates that the impacts on recreation are closely associated with the impact on sediment, fish and vegetation.

- Fishing: Under the fluctuating flow alternatives with a wide range of daily fluctuations, Trout would be less likely to reproduce and survive until they reach trophy size. But under the Moderate, Modified Low and Interim Low Fluctuating Flow Alternatives, the potential for catching large fish would increase. The steady flow alternatives are believed to have the greatest potential for benefiting aquatic productivity, which could result in trophy-size fish. High water velocity may present hazards to wading anglers. Downstream, angler safety is not a major issue primarily because most fishing activities take place from boats or shore.

Angling

Rafting

Camping

- Rafting: Most of boaters are anglers and they have a difficulty in navigating the 3-Mile Bar when discharge is 85 m^3/s or less, especially during morning hours, when they are unable to move up or downstream and some of those attempting to navigate the channel hit rocks. Boaters would have navigation problems under the No Action, Maximum Powerplant Capacity and High Fluctuating Flow Alternatives. The other fluctuating flow alternatives, which have minimum flows of 141.5 m^3/s would eliminate navigation and safety impacts for most day rafters and other boaters. White water rafting fluctuating flow alternatives with daily range and ramp restrictions and 141.5 m^3/s minimum flows would be all tolerable for white water rafting. The No Action and Maximum Powerplant Capacity Alternatives have the highest overall risk index because they would have more time at low flows, when accident potential is great for commercial motor and small oar-powered craft.
- Camping: Under the fluctuating flow alternatives, distribution of sites within power plant capacity would be 0.4/km in narrow reaches and 0.68/km in wide reaches. Steady flow alternatives would have 0.6/km in the narrow reaches and 0.68/km in wide reaches. The number of sites is affected by sediment erosion, deposition, and vegetation encroachment.

Hydropower

The principal values of Glen Canyon Powerplant are its ability to generate electricity without air pollution or using nonrenewable fuel resources and its flexibility to quickly and effectively respond to changes in an interconnected generation and transmission network. All the operating alternatives have a big impact on the operation of the power plant. Operational restrictions imposed by all but the No Action and Maximum Powerplant Capacity Alternatives would reduce power output.

3.3.3 Monitoring

A long-term environmental impact monitoring program started according to the requirements of the 1992 "Grand Canyon Protection Act" with the aim of bringing the Glen Canyon Dam operation under total control. The long-term environmental impact monitoring is useful to sustained assessment of the environmental impacts of the Glen Canyon Dam operations and to the ecological protection of the river basin and in reducing unfavorable effect and raising the economic benefits of the Glen Canyon National Park and the recreational areas.

Long-Term Environmental Monitoring Project Design

1. Purpose

Long-term monitoring is used for a variety of purposes including, but not limited to, assessing baseline conditions, trends of attributes, implementation of a decision, effectiveness of a decision, project impacts, model efficacy, and compliance to a set of standards. Many of these purposes are attributable to the evaluation of the impacts of Glen Canyon Dam operations.

Long-term monitoring would be designed to provide regular feedback for adaptive management. This permits mid-course adjustments in the operations of the dam to ensure achievement of the goals of the EIS and the management objectives of the resource management agencies and interests.

This proposed long-term monitoring program for the river corridor in Grand Canyon would not be considered equivalent to a long-term monitoring plan for all of Grand Canyon, or in fact for the whole river corridor ecosystem. Although the difference between the two objectives may seem to be semantic, it is critical to distinguish this program, whose intent is the monitoring of the effectiveness of the prescribed operations of Glen Canyon Dam in order to meet the objectives of the EIS, the 1992 Grand Canyon Protection Act and the management objectives of the resource management agencies and interests. Clearly, it is impossible to interpret change related to dam operations without understanding the broad range of ecological interactions. Nevertheless, the ultimate purpose of this program is to monitor ecological changes that are related to dam operations.

2. Guiding philosophy

The Glen Canyon has the function of regulating water flows and its ecology and environment are unique. In view of the particularities of the riparian ecosystem of the Glen Canyon, it is necessary to monitor the ecological parameters for a long time to come. Only by long-term monitoring it is possible to arrive at a scientific understanding of the environmental changes brought about by the dam operations. The monitoring project needs to strike a balance between two extremes: (1) to use the minimum data within the minimum scope to study the effect of the dam operations; (2) to monitor all the ecological parameters so that no parameters are missing and becoming the key factors in assessment.

The scientific community has studied the system for decades, for evaluating the effects of alternative operations of Glen Canyon Dam and identifying the targets of the long-term monitoring. They are:

- Amount and quality of water available from Lake Powell at specific times
  - Annual streamflows
  - Volume, velocity, and frequency of water release
  - Physical, chemical, and biological attributes of the water of Lake Powell and the river section from the dam to Lake Mead
- Sediment
  - Riverbed sand
  - Active width and height of sandbars
  - Erosion of high terraces
  - Debris fans and rapids
- Fish
  - Aquatic food base
  - Reproduction, recruitment, and growth of native fish
  - Reproduction, recruitment, and growth of non-native fish (including Trout)
- Vegetation
  - Woody plants and species composition
  - Emergent marsh plants
- Wildlife and their habitat
  - Riparian co-habitat of vertebrates and non-vertebrates
  - Nutrients for wintering water fowls
- Endangered and other special status species and habitats
  - Humpback chub
  - Razorback sucker
  - Flannelmouth sucker
  - Bald eagle
  - Peregrine falcon
  - Kanab ambersnail
  - Other protected species in other federal states
- Cultural resources
  - Archaeological sites directly, indirectly and potentially affected
  - Native American traditional cultural properties and resources directly, indirectly, or potentially affected
- Recreation
  - Fishing trip attributes and angler safety
  - Day rafting trip attributes and access
  - White water boating trip attributes, camping beaches, safety,
  - Net economic benefits
- Hydropower at the lowest possible cost
  - Power operations flexibility
  - Power marketing resources, costs, and rates.

This program also adopts a conservative approach of measuring attributes which reasonably might be affected by dam operations and for which no surrogate attributes exist. However, this program does not propose measurement of those attributes clearly unrelated to dam operations or which are adequately represented by other parameters. It also emphasizes use of data collected in Grand Canyon that are not field intensive. Wherever possible, monitoring, such as climate and hydrology, should be conducted using noninvasive means.

This program is designed to respond to the long-term missions, goals and management objectives of the resource management agencies and interests. A change in an attribute, determined through the long-term monitoring program, may represent a deviation from an acceptable condition (determined by management agencies and interests) that would trigger consideration of suggested changes in dam operations.

1. Scope of monitoring

The area to be monitored is primarily the Colorado River corridor between Glen Canyon Dam and Lake Mead reservoir. This area is about 362 km long, as the headwaters of Lake Mead vary with reservoir elevation. Because the overwhelming effect on the ecosystem along the shores of Lake Mead reservoir comes from operations of the reservoir and Hoover Dam, the Grand Canyon monitoring program would end at Separation Canyon, the generally accepted head of Lake Mead. However, the effects of fluctuations in Lake Mead and the influence of changes in the Colorado River below Separation Rapids resulting from dam operations might be considered as extensions of the geographical scope of the long-term monitoring program.

Many factors influence the water quality of the Glen Canyon. The pollutants from nearly everywhere of the Colorado River can move into the Glen Canyon and the sediment of the State of South Utah and Northern Arizona would all be transported to the Glen Canyon. Any chemical change in the Lake Powell will have a direct impact on the quality of water released. It is, therefore, very difficult to accurately define the upstream boundaries for long-term monitoring.

In view of the impacts of the dam operations, the appropriate upstream limit for Grand Canyon monitoring, as related to effects of dam operations, is the forebay of Lake Powell, the intake point for water into the water release structures of the dam. Because of the critical role of reservoir-scale geochemical processes in determining the quality of water at the intake sites, the separate long-term monitoring effort of Lake Powell would continue as a valuable input to this program.

2. Cooperating agencies

- National Park Service (NPS): The NPS has management objectives based upon both the ecosystem that existed prior to construction of Glen Canyon Dam and the ecosystem that has developed post-construction. Objectives are to maintain the essential dynamic elements and processes that existed pre-dam through restoration, maintenance, and protection. The NPS is committed to managing the Colorado River ecosystem and its attendant cultural resources as a coherent whole that, to the extent possible, simulates the ecosystem that existed prior to the construction of the dam.
- US Bureau of Reclamation: As manager of the Colorado River, the Bureau of Reclamation's management objectives are to strike a balance among water releases established under the "Law of the River" and the Annual Operating Plan for Glen Canyon Dam, the hydroelectric power requirements of Western Area Power Administration, and "protection" of the downstream ecosystem. The priorities given to each of these components under the EIS and long-term monitoring program are dependent on potential risk for change in Canyon resources or attributes of concern, and laws and regulations that direct the Bureau's operations.
- US Fish and Wildlife Service: The Fish and Wildlife Service provides Federal leadership to conserve, protect, and enhance fish and wildlife and their habitats, especially threatened and endangered animal and plant species.
- Bureau of Indian Affairs: The Bureau of Indian Affairs has no management role in the proposed action. However, it has management goals, among which it is fostering of self-determination of Indian Tribes.

Implementation of the Long-Term Monitoring

The completion of the Glen Canyon Dam EIS process will result in a decision by the Secretary of the Interior (Secretary) on the operation of Glen Canyon Dam. It is intended that the ROD will initiate a process of "adaptive management," whereby the effects of dam operations on downstream resources would be assessed and the requirements of the 1992 Glen Canyon Protection Act would be satisfied and the results of those resource assessments would form the basis for future modifications of dam operations.

The Adaptive Management Program (AMP) was developed and designed to provide an organization and process for cooperative integration of dam operations, resource protection and management, and monitoring and research information. The program would meet the purpose and strengthen the intent for which this EIS was prepared and ensure that the primary mandate of the Grand Canyon Protection Act of 1992 (GCPA) is met through future advances in information and resource management. The purpose of the AMP would be to develop modifications to Glen Canyon Dam operations and to exercise other authorities under existing laws as provided in the GCPA to protect, mitigate adverse impacts, and improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established. These values include, but are not limited to, natural and cultural resources and visitor use. Physical and economic conditions must also be

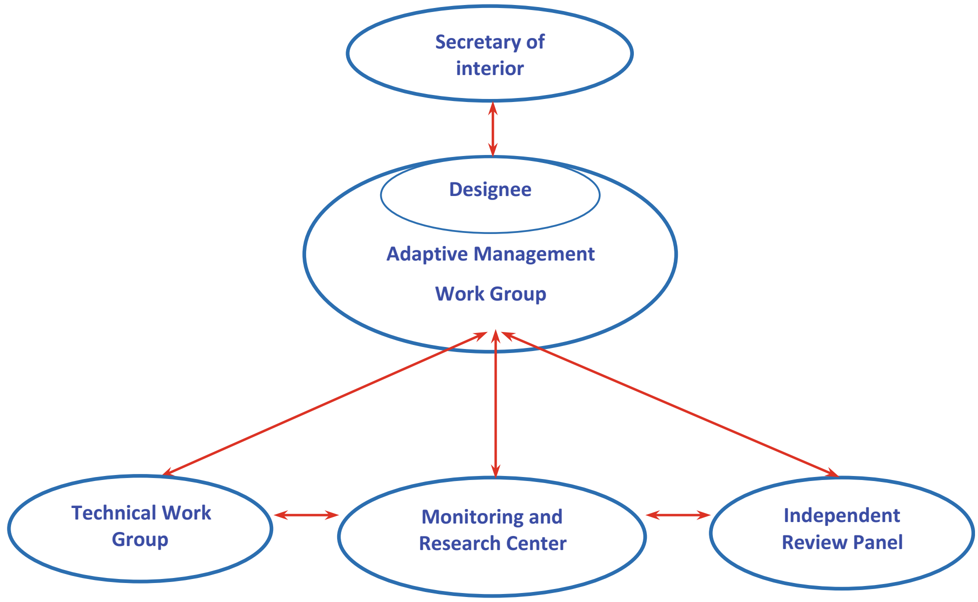


Fig. 3.7 Organizational Structure of the Adaptive Management Program

considered in any proposed modification to dam operations. Long-term monitoring and research are essential to adaptive management and would be implemented to measure how well the selected alternative meets resource management objectives.

Specific AMP goals include:

- Facilitating management response to monitoring and research information on affected resource conditions, trends, and processes;
- Ensuring compliance with related laws and the statutory purposes for Glen Canyon Dam (the " Law of the River"), Grand Canyon National Park, and Glen Canyon National Recreation Area;
- Assuring resource management obligations are defined and fulfilled in good faith without abridgment of any Federal, State, Tribal, or other legal obligation; and
- Providing a mechanism for resolving disputes.

The Adaptive Management Program would be administered through a senior US Department of the Interior official (designee) and facilitated through an Adaptive Management Work Group organized as a Federal Advisory Committee. The AMWG would be chaired by the designee and supported by a monitoring and research center and technical work group. Independent review panels would provide overview of technical studies and evaluations. Figure 3.7 shows the organizational structure of the AMP.

Adaptive Management Work Group (AMWG) membership would be appointed by the Secretary with representation from each of the cooperating agencies associated with this EIS, each of the Colorado River Basin States, and two representatives each from environmental groups, recreation interests, and contractors for Federal power from Glen Canyon Dam. It is recommended that the representation from the latter three interest groups be on a 2-year rotating basis to allow more diverse participation. The work group would provide the framework for AMP policy, goals, and direction; develop recommendations for modifying operating criteria and other resource management actions, facilitate coordination and input from interested parties, review and forward the annual report to the Secretary and his designee on current and projected year operations, review and forward annual budget proposals, ensure coordination of operating criteria changes into the Annual Operating Plan for Colorado River Reservoirs and other ongoing activities. There are three organizational elements operating under AMWG. The most important is the Monitoring and Research Center, established within the United States Geological Survey (USGS) and/or National Biological Service. The center would be responsible for developing the annual monitoring and research plan, managing all adaptive management research programs, and managing all data collected as part of those programs. The center's programs associated with long-term monitoring and research would be funded by power revenues and coordinated through the Reclamation budget process. Professional staffing for the center would be provided by USGS, National biological Service and the participating agencies in the AMWG. The specific duties of the center are to translate AMWG policy and goals into resource management objectives and establish criteria and standards for long-term monitoring and research in response to the GCPA. These would then be used by the center in developing appropriate monitoring and research. The GCPA would meet two to four times annually, as necessary. The Independent Review Panel(s) would be comprised of qualified individuals not otherwise participating in the long-term monitoring and research studies. The review panel (s) would be established by the Secretary of the Interior in consultation with the National Academy of Sciences, the tribes, and other AMWG entities. The review panel(s) would be responsible for periodically reviewing resource specific monitoring and research programs and for making recommendations to the AMWC; and the center regarding monitoring, priorities, integration, and management. Responsibilities of this review panel would include: annual review of the monitoring and research program; technical advice as requested by the center or AMWG and 5-year review of monitoring and research protocols.

1. Quality and volume of water

The quality of the discharge water may influence many of the aquatic biological processes within the Canyon, and the monitoring of the water quality in the dam intake region can better interpret the change if the quantity and quality of the discharge stream is known. Thus, the objectives of sampling in Lake Powell are to determine the quality of the water in the dam intake region in order to characterize dam discharges, and to determine whether the prescribed dam operations, especially if a selective withdrawal structure is used, affect the water in the forebay region of the dam. Sampling stations in Lake Powell as part of the long-term monitoring program would be limited to the forebay above Glen Canyon Dam. At these stations physical, chemical, and biological parameters would initially be measured monthly during studies of selective withdrawal and then quarterly in the water column at a sufficient number of locations to determine statistical variability. Physical parameters would be limited to temperature and light penetration. Chemical parameters would include pH, conductivity, nitrogen, phosphorus, dissolved oxygen, and particulate organic matter. Biological parameters would include algae (especially Blue-green algae and Diatoms), zooplankton, total chlorophyll, and chlorophyll a.

The monitoring of water quality of the mainstem of the Colorado River is focused on: dam discharge, water and sediment transport, and water chemistry. The objectives for monitoring the outputs of Glen Canyon Dam are to determine how closely dam discharge follows the prescribed operations of the dam and the extent of the variability in discharge, should it occur. These outputs, which also include discharges or spills above dam hydropower operations, would be measured both at the dam, based on power production, and at the USGS gage just downstream. Outputs to be monitored include, hourly water discharge (both flow rate and volume) and ramping rates (changes in discharge over the hour). From the above data, information on maximum and minimum daily discharges and daily fluctuations, and frequency and volume of spills, can be determined and placed in a perspective of average conditions and variance. The transport of water and sediment through the Canyon are interconnected. Sediment is the primary substrate for many Canyon biological processes as well as camping beaches. The objectives for monitoring changes in water and sediment transport are to determine whether the flux of water and sediment through the Canyon is as at the level predicted by the EIS for the prescribed dam operations, and whether the flux varies as expected within different reaches of the Canyon. Measurement objectives are: (1) continuously measure the flux of water through Grand Canyon (2) periodically measure flux of sediment through the Canyon, and (3) measure the differences in flux in different reaches. Gauging stations do not exist at the end points of each geomorphologically distinct reach in Grand Canyon, and new gauging stations would not be established through the main channel to define each geomorphically distinct reach. The emphasis of long-term monitoring would be on maximizing the analysis of data collected at existing gauges. Up to the present, the number of sand and water flow gauging stations is still not enough to calculate the sand deposit of each section. Chemistry of water in the mainstem of the Colorado influences most aquatic and riparian biological processes. Changes in water chemistry and temperature may alter physiological processes of aquatic biota potentially triggering changes in the aquatic trophic dynamics of the Canyon. Nutrient trapping by Glen Canyon Dam, changes in nutrient transport within Lake Powell resulting from changes in lake level, and in the mainstem resulting from water transport fluxes all influence the water chemistry of the mainstem below the dam. The objective of water chemistry monitoring is to determine the aquatic environment of the Canyon and evaluate this in terms of maintenance of those riverine ecosystem components. Evaluation of chemical and biological changes in the riverine ecosystem would be dependent, in part, on river discharge, water temperature, and sediment data collected at the recommended gauges on the mainstem and at the point of discharge from the dam (tailrace). Basic data on water temperature, conductivity, and pH would be measured at these gauges and the discharge point at the same time interval established for sampling discharge and/or sediment transport. Measurements of dissolved oxygen, particulate and dissolved organic matter, and nitrogen and phosphorus would be made seasonally.

Tributaries to the mainstem of the Colorado River in Glen and Grand Canyons are influenced by dam operations primarily at their confluence with the mainstem. Measurements would be continuous for discharge rates, and seasonally for chemical and biological attributes and would be taken in conjunction with these measurements at the gauges in the mainstem.

2. Sediment

Sediment in the Canyon is either in transport or in storage above or below the river surface. The prescribed dam operations would consider sediment accumulation in the riverine system, in the channel or eddies and as elevated deposits. Therefore, the objective of monitoring changes in stored sediment is to evaluate the sediment budget predictions of the EIS relative to the selected alternative. The measurement objective of the monitoring program is to determine the changes in sediment storage in different reaches of Grand Canyon. Measurement of bar changes throughout the Canyon would be made using air photo interpretation and video imaging analysis strategies.

3. Fishes and aquatic food base

Many wildlife species, including fishes, depend on the aquatic food base for their survival. Fluctuations in aquatic food resulting from dam operations or other influences would invariably cause changes in some or all of the populations of native and non-native fish species. The preferred alternative includes prediction of enhancement of the aquatic food base to ensure sufficient food for the endangered fish species and the economically valuable Trout population. For this reason, the objective of the long-term monitoring program is to determine whether the biomass, habitat, and composition of the aquatic food base are responding to dam operations as expected. Aquatic food base monitoring would be seasonal and include the mainstem, and tributaries. Quantification of changes in species survival and productivity within categories or functional groups of lower trophic levels in the ecosystem may be used as gross indicators of change. Standing crop (biomass), dominance and habitat requirements of phyto- and Zoobenthos, and phyto- and zooplankton would be measured seasonally at the dam, Lees Ferry, Little Colorado River and Diamond Creek and at least two wide-reach sites and two narrow-reach sites between the Little Colorado River and Diamond Creek. Complementing biotic sampling, the following abiotic parameters would be ascertained for comparison with abiotic data from gauge sites: water temperature, dissolved oxygen, pH, and conductivity.

Fishes are an important part of the Colorado River ecosystem because of their intrinsic value if native, the trophic role of both native and non-native taxa, and the important recreational value of non-native Trout. Fish populations depend on appropriate habitat and an adequate food base. Both of these factors may change as a result of dam operations. Operations of the preferred alternative are predicted to enhance recruitment of native fish species through reduction of "flushing" of larval fish from tributaries into the mainstem for example, and Trout through reduction in loss of spawning habitat (redds) and stranding of young. The objective of this program, therefore, is to monitor the condition and population fluxes of native and non-native fish species to evaluate their response, as predicted, to dam operations. Monitoring would include all native and non-native species.

There would be a long-term data base existing for the status of adult fishes when the long-term monitoring program is initiated; information on preadult life stages would likely be less complete. Sampling time frames would differ for different taxa and life stages. Because information on some of the fish species is not complete, adults of long-lived taxa would be sampled annually. As information becomes more complete, sampling would be on a 4-year cycle. Short-lived species and young-of-the-year of all taxa would be sampled twice annually during the period of larval fish presence (spring) and following the period of summer flooding. Sampling locations would correspond as closely as possible to those selected for monitoring of the aquatic food base, but would also include selected tributary sites.

4. Riparian vegetation (mainstem and tributaries)

Riparian vegetation along the Colorado River and its tributaries is important for streambank stability, wildlife habitat, campsite modification and aesthetic values. Riparian vegetation along the mainstem comprises three distinct communities, old high water zone (OHWZ), new high water zone (NHWZ), and near-shoreline wetlands (marshes). All of these communities are important ecosystem components; however, only the NHWZ and marshes would be impacted directly by dam operations. Maintenance of these vegetational communities for wildlife habitat is a predicted ecosystem response to the preferred alternative. The objective of this long-term program, therefore, is to monitor all three vegetation communities to determine the level of maintenance of these communities by the prescribed dam operations.

The NPS has established permanent quadrants along the mainstem and in selected perennial and ephemeral tributaries for the purpose of evaluating long-term responses of riparian and wetland communities to natural and anthropogenic influences. Equivalent quadrants have been established by the Hualapai Tribe in the riparian zone during interim flow monitoring.

Because of different response rates to changes in river dynamics, sampling procedures (particularly timing) must differ in the different communities. Marshes and low bar settings would be sampled frequently (e.g., twice a year for the first 5 years and annually thereafter, except for when there are unusual hydrological events, and then immediately again alter to twice a year for 3 years). General beach, channel margin, and debris fan settings would be sampled annually, while OHWZ settings would be sampled infrequently (e.g., every five years). Annual video- or photography of the Canyon would be used to map and quantify changes in cover of riparian vegetation in established (or expanded) GIS reaches.

5. Riparian wildlife and habitat

Determination of faunal responses to dam operations is extremely difficult and is dependent on known faunal responses to changing ambient conditions. Thus, to achieve the objective of monitoring the response of faunal assemblages to dam operations, it might be best to align these responses with sampling of riparian vegetation, recognizing that not all riparian fauna are associated with vegetation.

It is unlikely that a completed baseline of invertebrate assemblages will be available when long-term monitoring begins, although there presently exists a large database. Monitoring key taxa, when such are identified, may permit evaluation of responses to dam operations. An inventory of the invertebrate fauna would be established by the NPS and Hualapai Tribe as part of a general inventory program, but an extensive and intensive long-term monitoring program would even then disallow more than an estimate of invertebrate responses to variation in river discharges. Thus, as part of a long-term research program, it is essential to establish the invertebrate assemblages (e.g., selected taxa) that are associated with different riverine and shoreline vegetation communities. Long-term monitoring of these vegetation communities may in this way be used as a surrogate for estimating responses of Invertebrates to operational changes.

The intensity of effort required for sampling terrestrial vertebrates (herpetofauna, mammals and birds), and the low potential for distinguishing between responses to non-dam changes and those caused by dam operations, limit usefulness of long-term population studies as indicators of change in the riverine ecosystem. In addition, baseline data to support a long-term monitoring program are minimal (except for avifauna). When inventory is complete and habitat relations of selected assemblages (especially herpetofauna and birds) are established, data from long-term monitoring of vegetation and other habitat components would indicate the probable status of many terrestrial vertebrate populations. Avifaunal inventory and monitoring, if undertaken, would emphasize riparian obligate species, resident non-obligate species, migrant species in a biogeographic/geomorphic/seasonal context, listed or special status taxa (e.g., Cinereous vulture (*Aegypius monachus*), Peregrine falcon, southwestern willow flycatcher, Belted kingfisher), and wintering and breeding waterfowl. Locations of birds and nests observed would be mapped on the GIS system. Monitoring of vertebrates, if determined to be essential, would require large study sites where full descriptions of vegetation, soils, and topography are available. Spot sampling elsewhere might also be required to expand the long-term monitoring data base. For herpetofauna and mammals, a seasonal sampling schedule is recommended.

6. Endangered species

Information on the response of endangered and special status species to dam operation may be crucial to the species' recovery. In addition to their special status, these species are considered important because many were part of the pre-dam ecosystem. The objective of the long-term monitoring program is to track the populations of these species as they respond to changes in their habitat and food base caused by dam operations and other factors which are expected to enhance the chances of their survival and/or recovery.

7. Cultural resources (archaeological sites, traditional Indian tribes and historical site)

The long-term monitoring program for physical sites would adopt the Programmatic Agreement for Compliance with section 106 of the National Historic Preservation Act between the NPS, Indian Tribes, Bureau of Reclamation, the Arizona State Historic Preservation Office and the Advisory Council on Historic Preservation, as the monitoring design under this long-term monitoring program.

To effectively monitor impacts of dam operations on cultural sites, baseline information must be complete, with accurate maps, descriptions, and photographs of each site having potential of being impacted. The long-term monitoring program must be sensitive to the fragile nature of sites, the dynamic geomorphic conditions under which they persist, and the delicate situations relative to Indian Tribes and agency responsibilities for their protection and preservation. The monitoring program must be designed to identify both the present condition of sites and actual changes resulting from dam operations and other factors. Schedule for monitoring cultural sites would be dependent on the baseline condition of the site. It is assumed that all sites will have been categorized and described, including geomorphological settings, prior to initiation of the long-term monitoring program. Sites that are directly impacted by river discharges (including loss of sediment foundation) would be monitored quarterly, while a sample of other sites (ca. 20%) would be visited annually. Selection of these latter sites would be based on sensitivity, tribal concerns, and other factors determined by archaeologists, respective Indian Tribes and geologists. Sites which are not impacted by river discharges, but show impacts due to such factors as arroyo cutting, would be integrated with the long-term monitoring program. Annual aerial photo- or videographs would also be used to evaluate site changes, especially of those of sufficient size to allow remote sensing of change. This work would be coordinated with the sediment dynamics monitoring program. Sites with potential for rapid degradation would be monitored weekly through the use of oblique photography using hidden time-lapse cameras. If rapid loss is discovered, recovery archaeology and/or mitigation would immediately be initiated. Each affected Tribe should develop and implement a set of visitations on an annual basis. These visitations should include established sets of questions, determined by the Tribe and comparable over time, dealing with the Canyon resources. Questions and timing of visitations should be determined by each Tribe in cooperation with the organization responsible for the overall long-term monitoring program.

8. Tourism and recreation

Recreational use of the Canyon is of economic and environmental importance. The objectives of the long-term monitoring program, therefore, are to determine whether recreation is enhanced and safety improved over impacts of the historic operation of the dam, and whether changes in recreational patterns resulting from the selected dam operational alternative have any effect on the Canyon. Data on use and changes resulting from recreation would be compiled annually. Such data can be utilized to assess changes in use, but also may help determine causes of some changes in other resources (e.g., fish populations, and beach sizes or qualities, etc.). Data would include user days, length of trip, put-in and take-out points, beaches used, and safety (accident) records. (2) Angler uses, including commercial and private use above Lees Ferry. Data would include angler user days, fish catch data, and safety (accident) records. (3) Miscellaneous uses, e.g., birdwatching, use of riparian habitats (both mainstem and tributaries) for hiking, sightseeing within the Canyon, etc., to be evaluated through NPS and Hualapai Tribe permitting records, Game and Fish surveys, and other means. Survey results would be summarized and evaluated annually. Changes in beach camping area, above high discharge levels, can be determined through digitized video- or aerial photographs and validated on a sample basis through ground truthing coordinated with beach surveys under the sediment dynamics component of the long-term monitoring program. Recreationists' values to be monitored using surveys that deal with the relative value of Canyon experiences include: (1) satisfaction with existing discharge levels, (2) perceptions of effects of dam operations, (3) attitudes about congestion at beaches or high level visitor sites, and (4) attitudes toward researcher/monitoring teams in the Canyon. Information gathered during the pre-long-term monitoring period would be used as the baseline for comparison and evaluation of change in these values and perceptions.

9. Powerplant and economic values

Changes in power operations resulting from changes in annual dam operations would affect the power supply and its costs. The objectives of this program are to determine the impact of changes in dam operations on hydropower outputs and the concomitant power marketing and economics of the region, a concern of those agencies tied to hydropower production. A survey of power benefits would be indispensible. A more detailed review would involve assessing the significance of changes in the value or financial benefits of power and recreational uses which might impact the economic and social benefits of changes in Glen Canyon Dam (GCD) operation.

Characteristics and Future Development of Long-Term Monitoring

1. Characteristics

Essential to any long-term monitoring program is that it addresses management needs, specifically, and it would be designed to ensure that management objectives are being met. It would also be designed to recognize the temporal characteristics of the system being monitored. In the case of the Grand Canyon, long-term monitoring in response to operations of Glen Canyon Dam would continue indefinitely, or as long as the dam is operable. Periodic review of the program is necessary to determine the intensity of the monitoring program. The potential longevity of this program would be recognized in the selection or establishment of institutions that can maintain continuity while carrying out monitoring activities. Because continuity in methodology and procedures is essential to ensure comparability of data, no monitoring activity should be based on the sole contributions of any one individual but would be aligned with an agency or long-term organization.

Monitoring activities must also recognize the spatial scale of the resources. The enormity of Grand Canyon requires that projects actually be a sample, and that a hierarchy of spatial scales (e.g., nesting or representative sample units) would be used. Selection of sample units or areas would also consider the sensitivity or fragility of the system, thus methodologies would leave as small a "foot print" as possible. The type, frequency and location of measurements would, however, invariably follow from the objectives of the long-term monitoring program.

The long-term monitoring program would be sufficiently flexible to permit initiation of "new" monitoring activities to respond to transient events such as floods or tributary sediment pulses, and to changes in direction which may result from changes in management goals.

2. Data collection and management

Long-term monitoring involves a huge amount of data processing work, such as the collection of baseline original data, on-the-spot data, data input, and analysis. Scientists collecting the data would be involved with data interpretation. Although the time frame of the long-term monitoring program extends well beyond the participation period of any one scientist, it is anticipated that those who collect the data would be familiar with the Grand Canyon and may use the data as part of ongoing research programs. This connection of data collection and interpretation would result in data being collected appropriately and efficiently. Releasing and sharing data must be a requirement for every project. Those collecting original information, however, should be allowed a reasonable time for analysis and publication before releasing the data to the public. A centralized, integrated data base is necessary to avoid duplication of effort and facilitate exchanges of information among projects. Certain kinds of data and collected information are unsuitable for storage in a traditional computerized data base, such as audio and video recordings, for example, which need to be archived following procedures appropriate to their unique characteristics. Besides, GIS and remote sensing may also be used for storing and analyzing data.

3. Future development

The initial planning for long-term monitoring is very important. Each proposed monitoring activity must be reviewed by other workers prior to implementation to ensure comparability of data, prevent overlapping efforts, and to encourage interaction and integration by using comparable spatial and temporal boundaries. All participants in the long-term monitoring program must be required as a condition of participation to have their data internally and externally reviewed and entered into a common data base system on a regular and timely basis. The Bureau of Reclamation completed the Environmental Impact Assessment of Glen Canyon Dam in 1995. Since 1996, it began to test the operation alternatives based on the modified low fluctuating flow (MLFF) alternative, obtaining a large amount of data on the impacts of different operational alternatives, which will display an important role in future long-term monitoring, such as eliminating the adverse effect brought about by the dam operations. By making full use of the analytical results and improving the monitoring network, researchers went on in 1996 with the artificial flood silting experiments, obtaining the first-hand information timely and accurately. It will introduce new technologies, such as satellite remote sensing and other advanced means in the monitoring. While ensuring sufficient funding, it will add new sub-systems to fill in the gaps.

3.4 Environmental Protection and Monitoring of the Ertan Project of China

The Ertan Hydropower Station is situated in the Panzhihua City, Sichuan Province. It is part of the cascade power stations in the lower reaches of the Yalong River. Its main function is to generate power. With a total installed capacity of 3300 MW, it generates 17 billion kWh of electricity a year. At the normal pool level of 1200 m, the reservoir measures 101 km^2 and its storage capacity is 5.8 billion m^3 and its active storage capacity is 3.37 billion m^3. The work started in 1991 and was completed in 2000. The investment in environmental protection was ¥3.3613 billion.

Table 3.5 Ertan hydropower station environmental protection measures and results

Measure	Execution	Result
Trash	Apply stone lining and net concrete spray support	Brining trash and rejects under effective control
Restoration of dam site	All the trace fields leveled and covered with green, totaling 637 hm^2	Controlling new soil erosion, improving the sight of the dam site and eco-environment
Control Wastewater, waste gas and noise	Wastewater treated in a pool, low discharge equipment selected, dust fallout controlled by spraying water, low noise equipment selected, personal protection strengthened	No pollution accidents occurring during the construction period
Public health	Medical organizations set up, including clinics, first aid station and workers' hospital; physical checkup, and environmental sanitary controls	No communicable diseases breaking out during the construction period
Cultural resource protection	Excavating six ancient tombs, four stone coffin burials, 2 tomb groups of the Qing Dynasty and one Tengtiao Bridge ruins, dismantling and relocating 2 cable bridges; excavating and studying the Neolithic Age ruins in Hongxing of Yanbian county, the Han tomb and the Dazuo town ruins in Yuganyu township, building a cultural resource safekeeping room, completed in April 1998	Cultural resources excavated, well protected and studied
Reservoir shelter belt	Design of the shelter belt completed and demonstrative afforestation project covering 2403hm^2 launched in November 2000	Average survival rate reaching about 90%
Snail fever	47.76 million m^2 of snails living area verified in 1996–1997 and 16.76 m^2 of snails area eliminated; 16,682 human cases and 2153 cattle cases verified; 2315 cases treated; 47 snail habitats eliminated	Snail fever basically eliminated
Downstream warning system	Warning system composed of sirens, patrol wagons, warning signs and warning telephones	No personal or property lost

The reservoir has affected 31 townships in five counties and cities belonging to Panzhihua City and Liangshan Prefecture, involving the resettlement of 45,800 people.

3.4.1 Project Impact

The project environmental impact assessment (EIA) and environmental protection design started in 1980, undertaken by the Chengdu Hydroelectric Investigation & Design Institute (CHIDI). It completed two environmental impact reports "Environmental Impact Statement (EIS) of Ertan Hydropower Project on Yalongjiang River" and "Environmental Impact Statement of Ertan Hydropower Project on Yalongjiang River" in 1985 and 1995, respectively, which were reviewed and evaluated by the State Environmental Protection Administration (SEPA) and the World Bank. In 1993 and 1995, it completed Preliminary Action Program on Environmental Protection for Ertan Hydropower Project on Yalongjiang River and Design Report on Environmental Protection of Ertan Hydropower Project on Yalongjiang River.

The EIA finds that the project may have the following unfavorable impacts: damage of vegetation in the dam site area, a drop in the water and soil conservation capacity, reduction and change in fish resources and populations, the possibility of inducing an outbreak of Snail fever (*schistosomiasis*), threat to the safety of people working in the river course downstream by the water released by the power plant during peak operation, the inundation of culture resources, historical sites and the perception of the sights by the slag, waste gas, wastewater, noise, and leftovers in the worksites.

Double-arch dam at Ertan of the Yalong River (By courtesy of the Ertan Development Corporation)

Ertan Dam releasing floods (By courtesy of the Ertan Development Corporation)

3.4.2 Monitoring

In the project preparatory stage, surveys and assessment covering the local climate, landslides and debris flows and people's health, and seven other topics were completed. After the work started, Ertan Environmental Monitoring Center was established to undertake the monitoring and management of the environment. The center studied the waste water, waste gas and waste solids and noise pollution, the health of workers, water loss and soil erosion, and biodiversity of the reservoir area and adopted corresponding measures. According to the requirements of the World Bank, the center selected 550 relocated families as samples for following-up surveys to get an accurate picture of the life and income of the resettled people, which served as the basis for the evaluation by the World Bank. The environmental monitoring work is shown in Table 3.4 covering the construction and trial operation of the Ertan Hydropower Station.

3.4.3 Environmental Protection

The environmental protection design report put forward the following measures: build shelter belt around the reservoir, restore fish resources, control the Snail fever epidemic area, set up a warning system downstream of the dam, protect the cultural resources and historical sites in the reservoir area, process waste water, waste gas and waste solids, protect the health of workers and remove trashes in the worksites (see Table 3.5). The measures may minimize unfavorable impacts. The detailed baseline data have provided valuable materials for the Ertan Hydropower Project and the development of the cascade power stations along the Yalong River.

4 Structure of the TGP Eco-Environmental Monitoring System

The TGP is a gigantic mutipurpose hydropower project to control floods, generate electricity, and facilitate navigation, so that it has caught the attention of the whole world. It is a key project for managing and developing the Yangtze River. On the other hand, the operation of the dam will change the hydrological regime and other factors that will induce changes in the eco-environment. It will, therefore, have an extensive and far-reaching impact on the reservoir areas and even the whole Yangtze River basin.

Environmental protection is a basic national policy of China. It is also an important element to ensure that the TGP displays fully its benefits. The building of the project must strictly follow the national environmental protection law and regulations and make it a necessity to carry out a long-term sustained monitoring and research of the major ecological and environmental factors so as to discover in time problems and work out solutions, predict undesirable trend and issue timely warnings, minimize the negative impacts of the dam, optimize operation of the reservoir, ensure sustainable utilization of resources, and provide information for policy decision-making.

4.1 Eco-environmental Monitoring in the Pre-dam Period

China has set up some ecological and environmental monitoring stations along the Yangtze River since the beginning of the 1970s. Some departments concerned have also set up their monitoring networks of their specialization. All these, as shown in Table 4.1, go to form a fairly complete monitoring network in terms of water resources, environmental protection, and meteorology. Although the fishery, agricultural, communications, and land departments have not had their complete monitoring networks, they, too, have carried out irregular monitoring to meet their own needs.

4.1.1 Hydrology and Water Quality

China started its hydrological station network ever from the beginning of its founding in 1949 and carried out hydrological tests and survey on rivers, lakes, and reservoirs. By and by, it has formed a fairly complete monitoring network, which is placed in the direct service of flood regulation and water resources management. The Changjiang Water Resources Commission (CWRC) operates 13 hydrological observation stations on the mainstream of the Yangtze downstream from Chongqing. They are in Cuntan, Qingxichang, Wanzhou, Fengjie, Yichang, Zhijiang, Shashi, Jianli, Luoshan, Hankou, Jiujiang, Datong and Xuliujing. Based on that, the CWRC carries on regular monitoring of the hydrochemical elements of the river. After the 1970s, it began to monitor the water quality of the Yangtze River basin and set up a water environment monitoring center. With the establishment of environmental protection departments at all levels, all provinces and cities along the river have set up environmental monitoring stations to carry out surveys of water pollution near banks and pollution sources. There are 27 hydrological observation stations and cross-sections for monitoring water quality on the mainstream of the Yangtze and the main sections of its tributaries.

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2_4

Table 4.1 List of Monitoring Stations in the TGP-affected Areas

Department	Environmental factors	Monitoring station
Water resources	Hydrology and water quality	Wulong, Beipei, Cuntan, Qingxichang, Wanzhou, Fengjie, Yichang, Zhijiang, Shashi, Jianli, Luoshan, Hankou, Jiujiang, Datong, Xuliujing
Environmental protection	Water quality of river sections near cities	Panzhihua, Yibin, Luzhou, Chongqing, Wanzhou, Yunyang, Fengjie, Wushan, Badong, Zigui, Yichang, Shashi, Yueyang, Wuhan, Huangshi, Jiujiang, Anqing, Tongling, Wuhu, Ma'anshan, Nanjing, Yangzhou, Zhenjiang, Nantong and Shanghai
Environmental protection	Pollution sources	All districts and counties in the reservoir area
Meteorology	Local climate	Shapingba, Changshou, Wulong, Fuling, Fengdu, Wanzhou, Zhongxian, Shizhu, Kaixian, Yunyang, Fengjie, Wushan, Wuxi, Badong, Zigui, Xingshan, Yichang, and Bahekou
Fisheries	Fishing resources and environment	Chongming, Baoshan, Nantong, Jiangyin, Yangzhong, Zhenjiang, Nanjing, Wuhu, Anqing, Hukou, Wuxue, Wuhan, Hanjiang, Jiayu, Puqi, Honghu, Yueyang, Shishou, Shashi, Zhijiang, Yichang, Wanzhou, Baxian, and Yibin
Land resources	Mountain-related disasters	Yichang, Xingshan, Enshi, and Danjiangkou
Health	Public health	Anti-epidemic stations in all areas around the reservoir
Chinese academy of sciences	Ecological experiments	Wanzhou, Zigui, and Xingshan

Of those, 13 are owned by water resources departments, with monitoring done once a month and 12 times a year, and 14 operated by environmental protection departments, with sampling done three times in each of the flood, normal, and dry seasons, totaling nine times.

The water resources department mainly monitors hydrology at fixed cross-sections and water quality in selected cross-sections. The purpose is to get command of the water resources in the basin. The results of regular observation are only the flow volume and velocity and water quality at fixed cross-sections, without detail data on the water level, flow velocity field, and water quality of local river sections.

Environmental departments mainly monitor fixed cross-sections of river sections near cities in order to know the water quality indicators. Usually, they do not monitor hydrological factors. In the Yangtze, there are upper reach background cross-section, downstream pollution reduced cross-section, and sometimes pollution-control cross-sections along river sections running through large and medium-sized cities. Before 1997, when Chongqing was put under the direct administration of the central government, the Chongqing Environmental Monitoring Center, under the Chongqing Environmental Agency, began in 1979 to carry out regular monitoring of nine cross-sections in the 240.8 km Yangshi (of Jiangjin City) ~ Huangcao Gorge (of Chongqing downtown) section, Yangtze River and the 153.8 km Gulou (of Hechun City) ~ Chaotianmen (of Chongqing downtown), Jiangling River. Fuling's and Wanzhou's Environmental agencies started monitoring their respective river sections from 1984, usually in flood season (August), normal season (May), and dry season (February), 2 days in a row in each season, collecting samples 12 times a year from water at a depth of 0.5 m in the left, middle, and right sampling vertical lines.

But their monitoring time scale and distribution of cross-sections and sampling points are not representative enough, unable to reflect the general hydrological regime and water quality of the reservoir section, especially during the low water season in February, when the cross-section hydrological regime and water quality cannot be reflected to the full and the information about the riparian pollution belts and water quality is not complete. All the routine monitoring cannot satisfy the requirements of the TGP environmental impact assessment in terms of either distribution of cross-sections and sampling or the items and frequency of monitoring.

4.1.2 Pollution Sources Monitoring

Major pollution sources in the Three Gorges reservoir area come from industry and households, ships and boats, agriculture (i.e., farm chemicals, chemical fertilizer), non-point pollution of organic matters due to water and soil erosion, and the non-point pollution of urban runoff.

Most of the environmental monitoring stations of environmental department in the reservoir area were set up at the beginning of the 1980s. They have gradually developed into a network. The basic survey by the end of 1991 of 15 monitoring stations, such as Zigui, Xingshan, Badong, Wushan, Fengjie, Yunyang, Kaixian, Zhongxian, Shizhu, Fengdu, Wulong, Fuling, Changshou, and Baxian were completed by 135 engineers and technicians; each station about eight people; of the personnel, 36.3% of college education and above. They covered such disciplines as analytical chemistry, inorganic chemistry, environmental engineering, and computer science. The laboratories covered a total area of 4609 m^2, averaging about 307 m^2 per station, meeting the bottom line of the National Environmental Monitoring Management Regulations.

Before the TGP started in 1993, the pollution source monitoring was mainly undertaken by the CEMC, focusing on industrial pollution and city sewage outlets. The number of monitoring was a few and the frequency was low. There was no routine monitoring of other pollution sources, except relatively short-term monitoring and research in local areas by a few research institutions. Before Chongqing became a centrally controlled municipality in 1997, most of reservoir area was under the administration of Sichuan Provincial government. Parts of Sichuan Province had no adequate capability to monitor pollution sources. That is why there had been no systematic monitoring and research. The data of the original state are not clear; there were disorderly pollution discharge and management. It is very difficult to give an accurate estimate of the pollution source load in the reservoir area.

4.1.3 Climate

Ground manned meteorological stations, unmanned meteorological stations, high altitude sounding probe stations, acid rain monitoring station and agricultural meteorological stations, totaling 30, in the reservoir area and the surrounding areas starting from the 1950s, have observed and gauged systematically and uninterruptedly, accumulating a large amount of dada for meteorological service.

In the Hubei reservoir area and surrounding areas, there are one national baseline station (Enshi),[1] one state basic station (Yichang),[2] ten general meteorological stations (Yidu (Zhicheng), Changyang, Xingshan, Zigui, Sanxia, Tanziling, Sandouping, Sujia'ao, Badong, and Shennongjia),[3] two high altitude probing stations (Yichang and Sanxia), two acid rain observation stations (Yichang and Badong), one agricultural meteorological station (Zigui). In the Chongqing reservoir area and surrounding areas, there are 5 state basic stations (Shapingba, Fuling, Wanzhou, Fengjie, and Liangping), 7 general meteorological stations (Changshou, Dianjiang, Fengdu, Wulong, Shizhu, Zhongxian, and Wushan), 11 automatic meteorological stations (Shapingba, Changshou, Fengdu, Zhongxian, Fuling, Wanzhou, Fengjie, Liangping, Shizhu, Wulong, and Dianjiang), 4 acid rain observation stations (Shapingba, Fuling, Wanzhou, and Fengjie), 4 agricultural meteorological stations (Fuling, Liangping, Wanzhou, and Fengjie), and 1 high altitude probing station (Shapingba).

4.1.4 Fishery Resource and Environment

China's fishing affairs department and the Institute of Hydrobiology of CAS have carried out a lot of monitoring and surveys of the fish resources and other aquatic life in the Yangtze. As early as in the 1960s, the Institute of Hydrobiology carried out the taxonomic studies of fishes in the Yangtze. In the 1970s, the former State Aquatic Product General Bureau made a survey of fishery resources of some provinces in the Yangtze River basin. In January 1981, after the Gezhouba dam was built and the impoundment was finished, another full-scale survey was organized. In 1987, the Fisheries Management Bureau (MOA) set up Yangtze Fishery Resources Committee (YFRC). In 1989, YFRC organized a "Yangtze Fishery Resources Dynamic Monitoring Network" to start year-round monitoring of rare aquatic life and major economic fishes and living environment. The dynamic monitoring network has a downstream station in Wuxi City (Jiangsu Province) and a middle and upper stream station in Shashi City (Hubei Province), operating 24 monitoring points in the upper and lower

[1]National baseline station is the first class observation station in the state ground meteorological station network. It is also a backbone and standard station, with observation done 24 times a day.

[2]The State basic station is the state second class station, forming the main part of the state atmospheric and climate observation network, with observation done four times a day.

[3]General meteorological stations are the state third class observation stations, with observation done four or three times a day.

reaches. Before 1993, the geographic scope of monitoring was confined to the middle and lower reaches of the Yangtze. After 1993, more monitoring points have been added in the upper reaches. By the end of 1993, the monitoring stations had obtained more than 4000 data and established a database for River crab (*Decapoda*), four major endemic species and Chinese sturgeon.

The Institute of Hydrobiology of CAS is a state-class organization specializing in the research of freshwater life, chiefly in the Yangtze River basin. It has a freshwater fish specimen exhibition hall, which is the largest in Asia. It has a complete and most competent contingent of researchers. It has accumulated a large amount of monitoring and survey materials about fishes in the Yangtze, which have played an important role to assess the impacts of Gezhouba Dam, Three Gorges Dam and other major hydropower projects on the Yangtze River.

4.1.5 Water Loss and Soil Erosion

Toward the end of the 1980s, a large comprehensive project for controlling water loss and soil erosion with small basin areas as unit was launched. All places set up water and soil conservation bureaus or offices and designated monitoring points with standard slope runoff plot. The methodologies adopted by them are similar. However, due to lack of standards for the technologies for controlling water loss and soil erosion and the time and frequency of monitoring varied, the monitoring points are limited in representativeness. The ecological monitoring network of the CAS has carried out experiments of slope runoff plots with different gradients and different land uses. Some monitoring stations set up small basin runoff and sand transportation gaging facilities to study the loss of nutrients (non-point source pollution) due to water loss and soil erosion. Besides, forestry departments have also set up a number of monitoring stations to study water and soil conservation in the new afforested areas. Since the 1990s, two remote sensing surveys were carried, obtaining fairly accurate data on water loss and soil erosion.

4.1.6 Public Health

The Three Gorges Reservoir area has a complete medicare and health system, with cities and counties provided with general hospitals, specialized hospitals, epidemic stations, and drug inspection offices. They do not only have a large contingent of medical workers but also established a fairly complete epidemic and communicable disease reporting system.

At the beginning of the 1980s, Chinese scholars carried out surveys and experiments in the problem of Snail fever in the Three Gorges reservoir area. In the 1990s, a research group was set up to study the post-dam environment and spread of Snail fever.

4.1.7 Monitoring of Other Targets Associated with Eco-environment

(1) Mountainous disasters

It is already more than 40 years since the start of the study of earthquake that might be induced by the TGP. A large amount of monitoring and survey have been done by the former Ministry of Geology and Mineral Resources, the CWRC, the Chinese Academy of Sciences (CAS) and the State Seismological Bureau (SSB). SSB has set up an earthquake monitoring station in Yichang and Xingshan (Hubei Province). CWRC has studied the bank stability of the Three Gorges reserve for many years, accumulating a wealth of information.

(2) Construction sites

Related departments have paid a great attention to the quality of the eco-environment of the construction sites of the TGP and carried out a continuous monitoring. Since 1994, the Changjiang Basin Water Environment Monitoring Center (CBWEMC) and the Yangtze Three Gorges Hydro-Environment Monitoring Center have taken monitoring of the water, air, and noise in the construction sites on a number of occasions and obtained a batch of valuable data. At the same time, research and design departments in such areas as environmental protection, water resources, power, and health have also carried out monitoring of the ecology and environment of the construction sites.

4.1.8 Environmental Monitoring and Research

Even before the TGP started, the CAS did some experiments in probable ecological and environmental problems, such as environmental protection of the resettled area, restoration and rebuilding of deteriorating ecology, agro-ecology testing, rare aquatic life. With the project, CAS has set up ecological and environmental monitoring stations in the Three Gorges area and the Yangtze River basin. In Wanzhou and Zigui, there have been established agro-ecological experimental stations and in Xiaogang of four-lake area there established an experimental station on the swampiness and gleization of soil. The research institutes of CAS, such as the Institute of Hydrobiology, the Institutes of Botany (Beijing), Institute of Wuhan Botany (now renamed Wuhan Botonical Garden) and Institute of Oceanography (Qingdao) have carried out a large amount of research work in the Three Gorges reservoir area.

4.2 Establishment and Improvement of the TGP Eco-environmental Monitoring System

Industrial departments, such as water resources and environmental protection, undertake monitoring mainly to serve their own needs, using different monitoring systems from that directly serving the TGP, although they have technology, equipment, and personnel. So, it is, necessary for the TGP to have its own monitoring system.

4.2.1 TGP Monitoring System

The TGP eco-environmental monitoring system, fixed with its main tasks, targets, and contents, has been established according to the TGP Environmental Impact Statement (EIS) (approved in 1992), the “Environmental Protection—Preliminary Design Report on the Yangtze Three Gorges Water Control Project” (approved in 1993) and related laws and regulations of the state.

Main Tasks

The Yangtze is a big complicated system. The TGP has dynamic impacts on ecology and environment in terms of space and time, predicting the changes of both advantageous and disadvantageous factors are the basic tasks of the TGP eco-environmental monitoring system, and also an important and indispensable part of the efforts to make the project display its maximum benefits and mitigate the adverse impacts.

The monitoring system are to monitor the ecological and environmental changes of the reservoir area and in the middle and lower reaches of the river before and after the dam is built; to discover timely problems and then to put forward recommendations for mitigating the adverse effect; to predict adverse trends and then to issue timely warnings so as to serve the construction and operation of the dam; to protect the environment of the reservoir area and its surrounding areas, and to ensure sustainable utilization of resources and provide the basis for state departments to take policy decisions.

The monitoring system is mainly centered on human ecological environment, with emphasis put in the reservoir area, and if necessary, extending to upper, middle, and lower reaches of the Yangtze and its estuary area. It should be an hierarchical and comprehensive monitoring network covering different areas, sectors, and disciplines, carrying out dynamic observation and studies of the main ecological and environmental factors and collect and put information into a database for dynamic analysis so as to work out measures to display the favorable effect and avoid the unfavorables and issue timely warnings for related departments to prepare for decision makings.

The environmental impacts of the TGP involve many factors and a wide-ranging area, with different characteristics during different periods of construction. So the tasks and targets of monitoring are different during different periods of time.

The monitoring may be divided into three stages according to the construction schedule and the impacts of the dam on the ecology and environment [20].

- Before reservoir impoundment (1993–2003). The main tasks of that period are: (a) to make a comprehensive and systematic monitoring of the ecological and environmental factors that might be affected by the dam so as to obtain complete baseline data; (b) to monitor the dam–site area, resettlement areas, and other areas where the ecology and environment likely to be affected during the construction period and work out timely measures to mitigate the adverse environmental impacts in the dam site area and resettlement areas to serve the project management departments; (c) to carry out studies of countermeasures against problems that remain unresolved.
- Initial impoundment period (2003–2009). During the period from the impoundment in June 2003 to the completion by 2009, when the Three Gorges Dam has entered a period of operation and bringing benefits while construction is still going on, the main tasks are: (a) to closely watch the changes in the ecology and environment after the impoundment, with particular attention given to

the impoundment-sensitive environmental factors so as to timely regulate and perfect the monitoring plans and give timely warning; (b) To monitor the dam site area, resettlement areas and other areas where the ecology and environment might be changed during the period and adopt timely measures to mitigate adverse effect; (c) to sort out the baseline materials, make up for the missing parts and carry out comprehensive analysis and study; (d) to study the monitoring plans, methods, and technical standards, such as deep water sampling, testing of eutrophication, and water quality assessment standards of the river-type reservoir.

- After the TGP is completed (2009–). During the period when the TGP is completed (including the dam, resettlement, and power transmission projects) and beginning to enter into all-round operation and management, the main tasks are: (a) to continue the monitoring work of the previous period, with emphasis put on the long term and potentially affected factors and the results following the adoption of countermeasures, monitor, and study the accumulated environmental impacts of the cascade development of the water resources; (b) to carry out the posterior assessment of the environmental impact assessment of the TGP at appropriate time.

Main Targets of Monitoring

The monitoring system carries out regular and irregular monitoring, observation, and surveys of the important environmental factors according to the standards and procedures set in the state related technical regulations in line with the actual conditions of the TGP. According to the conclusions during the argumentation and EIA periods, the targets of monitoring should include at least the following items, concrete indicators adjustable according to the tasks and phases:

- Hydrology and water quality, covering indicators such as water level, flow volume, velocity, sediment, and COD and DO in the reservoir areas, downstream of the dam and estuary area.
- Pollution sources, including all sources that affect the water quality of the reservoir.
- Soil and environment, including soil erosion and the evolution of fertility in the reservoir area, changes due to water-logging in the middle reach and the salinization of soil in the estuary area.
- Terrestrial animal and plant diversity, with emphasis put on the terrestrial animal and plant population, composition, and their habitats below the inundated line (normal water level after the completion of TGP) and in the reservoir area.
- Aquatic life diversity, with emphasis on rare and endemic fish, fishery resources and environment from the Jinsha River in the upper reaches down to the estuary.
- Local climate, with emphasis put on the areas surrounding the reservoir and the selection of the most impoundment-sensitive climatic factors.
- Public health, especially water-related diseases and susceptible people groups.
- Estuary ecosystem, with emphasis put on the physical, chemical, and biological factors affected by the dam-regulated flow changes at the estuary, which is a complicated and most sensitive region.
- Socioeconomic changes of the resettled people, with emphasis on the changes brought about by resettlement and their impacts on the eco-environment in the reservoir area.
- Geological disasters, including disasters and earthquakes likely to be induced by the reservoir impoundment.

4.2.2 Establishment of the Monitoring System

The Action Program for the Implementation of the TGP Environmental Monitoring System was completed in 1995 by the CWRPI according to the requirements of the EIS and the comments of approval reply. The cost was listed in the total cost of the TGP.

The Action Program requires the joint efforts from water resources, environmental protection, agriculture, forestry, meteorology, health, geology, and minerals, seismology, communications, CAS, TGP Corporation, resettlement agency, related departments of Hubei and Chongqing in establishing the system. See Table 4.2, the project started in 1996 to cover the affected area from the upper reaches of the Yangtze River to the estuary, which depends on the eco-environmental indicate.

Organizational Formation of the System

The TGP environmental monitoring system is a trans-sectoral, trans-regional, and trans-discipline joint project. It is composed of a central station, major (experimental) stations, and base stations. It operates under unified planning and overall arrangements, with a clear division of labor among different departments, giving scope to the advantages in personnel, technology, and equipment of different departments.

At the beginning, due to not enough study of the indicator system, plus the non-standard management of contracts, there were much confusion about the names of stations and targets of monitoring.

Table 4.2 TGP environmental monitoring system and Monitoring units

Contract name	Sponsor
Monitoring center	China National Environmental Monitoring Center (CNEMC)
Water quality	Changjiang (Yangtze) Water Resources Commission (CWRC)
Pollution belt (now city section)	Chongqing Municipal Environmental Monitoring Center
Industrial and urban pollution sources	Chongqing Municipal Environmental monitoring Station
Floating pollution source	Environmental Protection Center, Ministry of Communications (MOC)
Farm chemicals and fertilizer non-point pollution sources	Hubei Provincial Agro-Environmental Protection Station
Main Station of Fishery Resources and Environment	Office of Yangtze Fishery Resources Committee (YFRC)
Aquatic life floating monitoring	Institute of Hydrobiology, CAS
Terrestrial animal and plant monitoring	Ecological and Environmental Monitoring Center, SFA
Local climate	National Climate Center, CMA
Public health	China Center for Disease Control and Prevention
Socialeconomic environment of Hubei reservoir area	TGP Office of Hubei Province
Socialeconomic environment of Chongqing reservoir area	Chongqing Statistics Bureau
Agro-environmental monitoring	Hubei Provincial Agro-environment Protection Station
Eco-agriculture experiments (Wanzhou, Zigui)	Institute of Mountain Hazards and Environment (Chengdu), CAS; Institute of Soil Science (Nanjing), CAS
Endemic fish experiment	Institute of Hydrobiology, CAS
Terrestrial plant experiment	Institute of Botany (Beijing), CAS
Estuary Eco-environmental Integrated experiment	Institute of Oceanography (Qingdao), CAS
Environment monitoring of dam site area	Yangtze Water Resources Protection Bureau

System Management

The monitoring system follows the management system of the TGP, which is the project owner responsibility system, opening bidding, project supervision, and contract management. Before July 1999, monitoring was organized and coordinated by the TGP Executive Office of the State Council and managed by the Three Gorges Corporation. Contracts were signed between the Three Gorges Corporation and monitoring stations.

Departments in charge of the monitoring stations exercise internal management within their subsystems, responsible for tightening technical control, providing funds, and renewing instruments and meters and equipment and workrooms. All these have ensured the fruitful operation of the subsystems.

4.2.3 Adjustment of the Monitoring System

In July 1999, the State Council TGP Construction Committee decided to shift the environmental compensation project and costs outside the dam site area from the CTGPC to the Executive Office of SCTGPCC.

In 2000, the Executive Office of SCTGPCC organized expert panel to carry out a comprehensive and systematic review and assessment of the monitoring system, getting clear about the operations of all subsystems, including execution plans, contract performance, management of archives of monitoring results, specific contents of work, and quality of each subsystem, their internal management, personnel quality, instruments, and meters and equipment. The experts deemed the operation of all subsystems was orderly and had prepared favorable conditions for monitoring in the future. But the assessment also found some problems, such as poor linkage of the monitoring targets with TGP, non-standard in contract performance, unclear in monitoring requirements, staggering quality in the management of monitoring results, irrational in expenses, quality control needing intensified, and information exchange and sharing needing strengthening.

Investigation activities and forums held before the start of the monitoring system in 1995

Li Shizhong (*left*), former vice-minister of Executive Office of SCTGPCC and Wu Guoping (*middle*), reservoir management department head presiding over a workshop aimed at summing up experience and improving management

Starting from 1997, "Bulletin on the Ecological and Environmental Monitoring Results of the TGP" (in both Chinese and English) was compiled, reporting the monitoring results and annual reports from all major stations. It is published at home and abroad on June 5 every year by the China National Environmental Monitoring Center (CNEMC). Contents include progress of TGP, social, and economic development of the reservoir area, progress in resettlement, natural environment conditions (climate, terrestrial animals and plants, fish resource, and environment), rare and endemic species of fish, agro-ecology, and geological disasters), pollution sources, water quality, public health, and progress in the ecological and environmental demonstrative projects and their benefits (photo by Huang Zhenli)

Based on the problems found, a major overall review was made with the monitoring system aimed at making it standardized, scientific, and institutionalized. Each monitoring station was required to sign their contracts again to make them more perfect and map out detailed plans for execution. The functions of some subsystems were integrated. Starting from 2001, monitoring began according to new contracts, execution plans, and management mode.

In July 2002, remote sensing dynamic monitoring started to form a spatiotemporal monitoring system. By monitoring the resources, ecology, and environment in the basin, reservoir area, and resettlement area before and after the TGP, the remote sensing monitoring system analyzed the impact of the project on resources, ecology, and environment. At the same time, it provided an information system with rich, dynamic, and large-scaled geographical information and information about resources and environment.

In July 2002, the Reservoir Management Department, Executive Office of State Council Three Gorges Project Construction Committee (SCTGPCC), and the Bureau of Resource and Environment, CAS decided to set up the "Information Center of Ecological and Environmental Monitoring Network for the Three Gorges Project (Information Center)" at the Institute of Remote Sensing Applications of CAS to realize better sharing and use of data collected. The center is responsible for building and operating the information system and providing information service for TGP.

After the adjustment, the monitoring system is composed of 12 subsystems, 20 key monitoring (experimental) stations and 58 base stations (see Table 4.3 and Fig. 4.1).

4.3 General Structure

4.3.1 Master Design of the System

The philosophy in building the system is to make full use of the existing monitoring personnel and equipment and avoid overlapping in use of people and other resources. The master design is to make it a hierarchical structure, with the general system, subsystems, major stations/experimental stations and, if necessary, base stations (Agricultural Ecological and Environmental Monitoring Stations have ordinary monitoring stations), all under standardized and orderly management and with high operability (see Fig. 4.1).

Composition of the monitoring system: The ecological and environmental experimental subsystems have four experimental stations; the hydrology and water quality and pollution source subsystems have three major stations; the fish and other aquatic life subsystem has two major stations; the reservoir area socioeconomic environment subsystem has two major stations; and the terrestrial animal and plant, local climate, agro-ecology and environment, people's health, and remote sensing subsystems each has one major station. The other four subsystems form an independent subsystem due to their importance and management lines.

Management of the monitoring system: The system is mainly managed by station owners, supplemented with sectoral management, technical management and information management. As shown in Fig. 4.2, station owners and Monitoring Center of Ecological and Environmental Monitoring Network for the Three Gorges Project (Monitoring Center), Information Center of Ecological and Environmental Monitoring Network for the Three Gorges Project (Information Center) and all major stations sign contracts and contracting parties operate according to the provisions of contracts. Sectoral departments undertake to provide technical guidance and oversight of the monitoring work. The Monitoring Center is mainly responsible for compiling the bulletin and providing technical services; the Information Center is responsible for unified management and servicing of the data obtained from monitoring; all major (experimental) stations are responsible for managing their respective base stations and submit monitoring data and monitoring reports to the Monitoring Center and Information Center.

At the very beginning, attention was paid to the scientific division, planning, and distribution of the subsystems, taking into account both operability and continuity of contract management in order to ensure the efficient operation of the system and realize the monitoring objectives. Figure 4.3 shows the distribution of major stations. For instance, the pollution source monitoring subsystem covers industrial and city pollution, ship and other floating pollution, and farm chemical and fertilizer non-point pollution. These are the tasks of certain monitoring units of different departments of different sectors. But they cannot undertake all the tasks independently. So three major stations have been established in the subsystem, namely, the pollution source (industrial and city pollution) major monitoring station, pollution source (ship and floating pollution) major monitoring station and pollution source (farm chemicals and fertilizer non-point pollution) major monitoring station. All the major stations in a subsystem are tightly linked and operate according to a unified standard so as to prevent incomparability of data.

4.3.2 Monitoring Scope

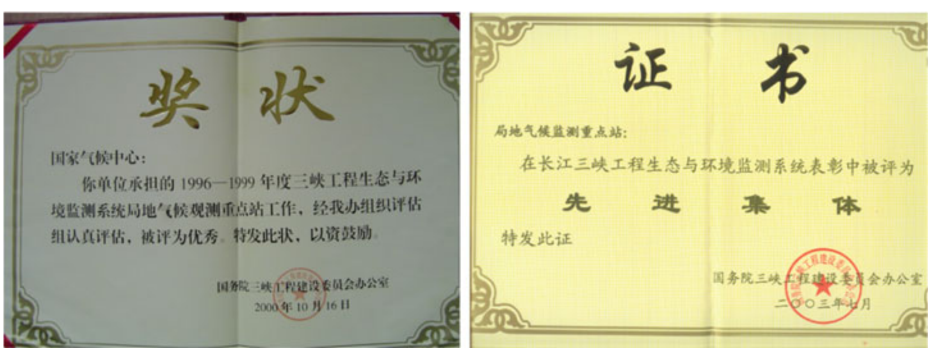
The scope of monitoring of the system covers mainly the reservoir area, with extension to cover areas affected by TGP along the river and down to the estuary. Taken as a whole, the monitoring covers most catchment areas of the Yangtze.

Experiment Base at Wanzhou eco-environment lab

Chongqing Environmental Monitoring Center. Assessment expert panel are checking monitoring archived materials. Experts are hearing reports

Experts in Institute of Hydrobiology of CAS

Executive Office of SCTGPCC organized experts to carry out the first comprehensive and systematic assessment of the monitoring system in 2000



Certificates of citations granted to monitoring stations excelled in their work

Ceremony is on cooperative agreement signing for the establishment of the TGP environmental monitoring information center at Institute of Remote Sensing Applications, CAS. Representatives of the Reservoir Management Department, Executive Office of STTGPCC, Bureau of Resources and Environment, CAS, and the Remote Sensing Applications Institute put their signatures to the instruments (*left*). Academician and former vice-president of CAS Mr. Chen Yiyu and Mr. Gao Jinbang, former vice-minister of Executive Office of SCTGPCC unveiled the name plate of the center

Table 4.3 Key monitoring stations, experimental stations, and operating units

Category	Name of station	Operating units
Key stations	Main Synchro-monitoring Station of Hydrology and Water Quality of Main Stem	Changjiang Water Resources Commission (CWRC)
	Main Monitoring Station of Typical City River Section and Pollution Belt	Chongqing Municipal Environmental Monitoring Center
	Main Groundwater (Xiaogang) Monitoring Station	Institute of Geodesy and Geophysics, CAS
	Main Monitoring Station of Industrial and Domestic Pollution Sources	Chongqing Municipal Environmental Monitoring Center
	Main Monitoring Station of Floating Pollution Sources of Vessels	Environment Protection Center, MOC
	Main Monitoring Station of Non-point Pollution of Pesticide and Fertilizer	Hubei Provincial Agro-Environmental Protection Station
	Main Station of Fishery Resources and Environment	Office of Yangtze Fishery Resources Committee (YFRC)
	Main Monitoring Station of Fish and Rare Aquatic Animals	Institute of Hydrobiology, CAS
	Main Monitoring Station of Terrestrial Animals	Ecological and Environmental Monitoring Center, SFA
	Main Monitoring Station of Local Climate	National Climate Center, CMA
	Main Monitoring Station of Public Health	Chinese Center for Disease Control and Prevention
	Main Socio-environment Monitoring Station of Hubei Reservoir Area	Office of Hubei Provincial Committee for Supporting TGP
	Main Socio-environment Monitoring Station of Chongqing Reservoir Area	Chongqing Municipal Bureau of Statistics
	Main Monitoring Station of Agro-ecological Environment	Hubei Provincial Agro-Environmental Protection Station
	Main Monitoring Station of Estuary Ecology and Environment	Institute of Oceanography, CAS
	Main Monitoring Station of Eco-environment Remote Sensing	Institute of Remote Sensing Applications, CAS
Experimental stations	Zigui Eco-environment	Institute of Soil Science, CAS
	Wanzhou Eco-environment	Institute of Mountain Hazards and Environment, CAS
	Terrestrial Plant	Institutes of Botany, CAS
	Endemic Fish Species	Institute of Hydrobiology, CAS
Special monitoring stations	Environmental Monitoring Station of Construction Site	Yangtze Water Resources Protection Bureau
	Monitoring Station of Reservoir Sedimentation and Downstream Scouring	Hydrology Bureau, CWRC
	Monitoring Station of Reservoir-induced Earthquake	Earthquake Administration of Hubei Province
	Geological Disaster Monitoring Station in the Reservoir Area	Headquarter of Geo-hazard Prevention and Control for the Three Gorges Reservoir Area
Other	Bulletin on Ecological and Environmental Monitoring Results of the Three Gorges Project (annual report)	China National Environment Monitoring Center

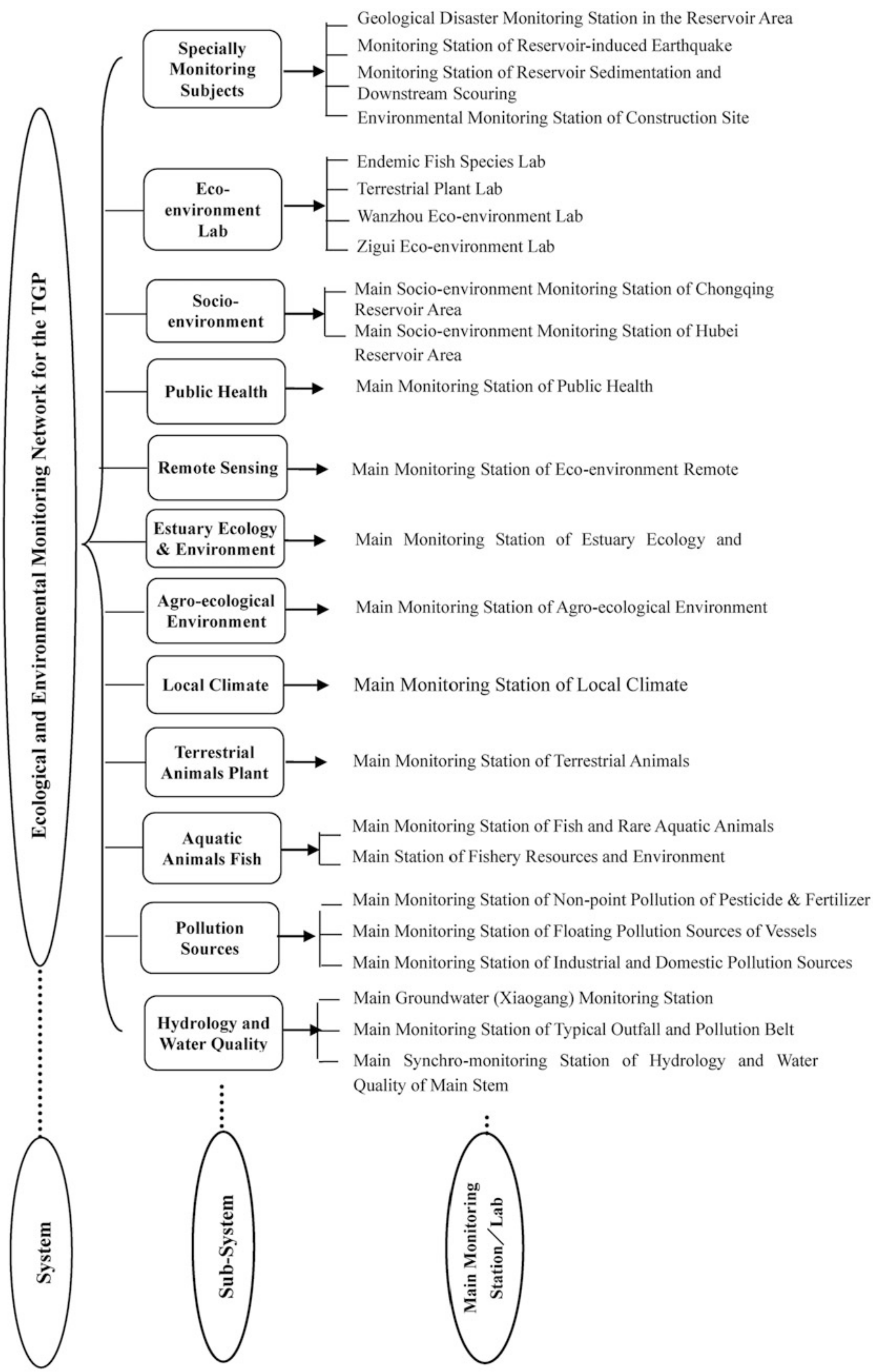


Fig. 4.1 Organizational setup of TGP eco-environmental monitoring system

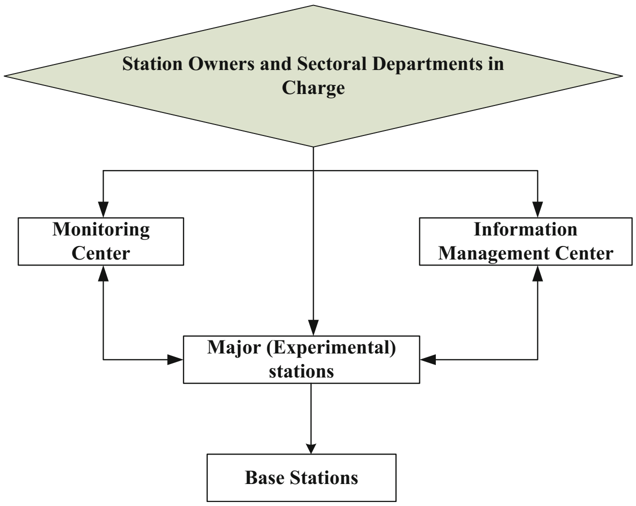


Fig. 4.2 Management flowchart of the monitoring system

But the specific monitoring scope is fixed according to the scope covered by the assessment of all factors affected by the TGP. Different monitoring elements or factors have different impacts spatially and temporally (see Table 4.4). For instance, terrestrial animals and plants are affected by inundation and the people moved back from the reservoir. So the scope of monitoring is in the reservoir area, where different monitoring points should be fixed. Local climate is affected mainly due to the rise of the water surface and the concomitant changes in evaporation and other meteorological factors mainly in the reservoir area, especially areas around the reservoir. Fish is affected due to the change in hydrological regime in regard to the spawning ground, habitats, and ecological habits and it has a direct relationship with water flow, water temperature, and texture of the river-bed. So the scope of fish and other aquatic life subsystem covers river sections from Jinsha River to the estuary area, including the Dongting Lake and Poyang Lake areas. As TGP has a big impact on the Yangtze basin, remote sensing dynamic monitoring will mainly monitor the reservoir areas while extending to the whole Yangtze basin in order to monitor the impact of TGP on the ecology and environment in the Yangtze basin from multiple scales.

4.3.3 Monitoring Indicator System

Different ecological and environmental factors require different monitoring indicators. The indicator system adopted by the system is basic for ecological and monitoring work. The TGP Eco-Environmental Monitoring Indicator System is a body of measurements used to describe and analyze quantitatively the ecological and environmental factors. It is an organic body composed of a series of interrelated, mutually independent, and mutually supplementary indicators for long-term monitoring in order to get clear about the TGP impacts on the environment and its dynamic changes.

Principles of the Indicator System

- Be complete. In the system, all factors such as ecology, environment, social, and economic development and mechanism should be seen. They include both ecological and environmental indicators of all subsystems and socioeconomic indicators under which monitoring and observation are done. The indicator system should be relatively complete, reflecting the main characteristics of ecology and environment.
- Be scientific. The indicator system should fully reflect the scientific contents of the ecology and environment. Only by establishing the indicators on ecological and environmental sciences, is it possible to correctly direct the operations of the monitoring system and realize the objectives of the system.
- Be standardized. As the indicators of different subsystems are different in nature and characteristics, it requires classification and standardization to unify the contents, scope, dimension, and computing method and keep them intact for a long time to come in order to ensure accuracy and comparability of the indicators.
- Be adaptable. The indicator system should on one hand adapt to the requirements of the different impacts of TGP on ecological and environmental characters during different periods of time and, on the other hand, if possible, should be at the proper minimum to make them easy to operate under the precondition of being capable of describing fully the ecological and environmental factors. Too many indicators would both increase costs and make them difficult to operate.
- Be operable. The indicators should be set according to the requirements of the planning and management of the monitoring system and the specific monitoring targets so as to make them more operable.
- Be independent and hierarchical. The indicator system should be of hierarchical structure of different nonrelated and independent indicators. This makes the structure of system clear and keeps the number of indicators to the optimal minimum.
- Be measurable and comparable. Qualitative indicators should have their given quantitative means. Computing methods should be clear, avoiding complexity and the data for computation should be easy to obtain and reliable.

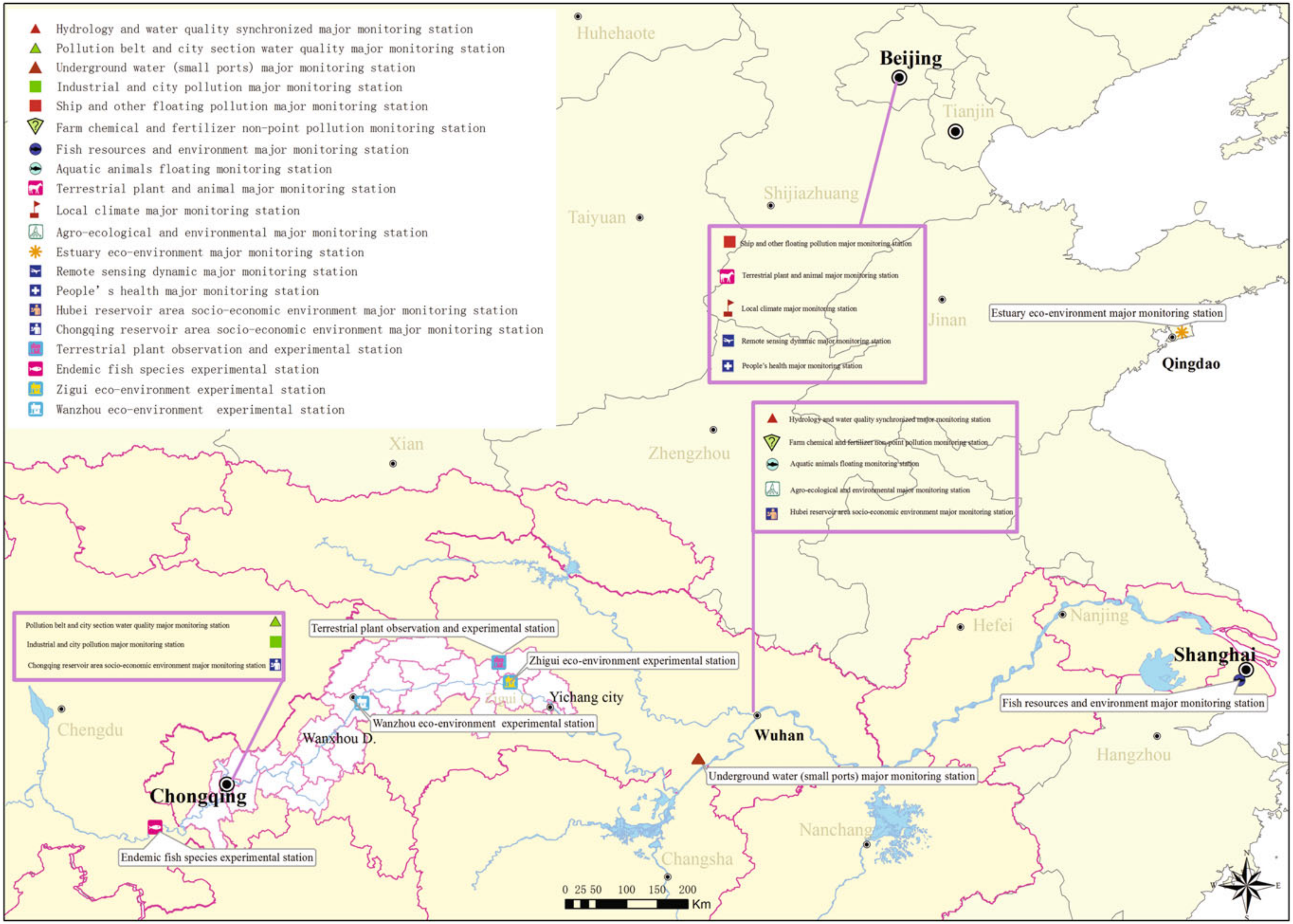


Fig. 4.3 The major stations distribution chart of the monitoring system

- Be stable. The indicators should be kept relatively stable during a given period of time so as to make it easy to compare and analyze the course of changes and development trend of the ecology and environment. But they are not absolutely changeable. There may be modifications along with spatial and temporal changes.
- Be flexible. The indicators should be made to have a certain degree of flexibility to adapt to the changes in time, space or system structure so as to fully reflect the effectiveness of policies and measures and development trend.

Monitoring Indicator System

The indicator system is designed to provide basis for review assessment of the TGP impacts by obtaining baseline information before impoundment and after, so as to prevent adverse impacts of the project and strive for a sustainable development of the reservoir area.

In the feasibility study state of the project, the environmental impact assessment was carried out at four levels, namely, general environment, environment subsystems, environment composition, and environmental factors, as shown in Fig. 2.1. The TGP Environmental Monitoring System was set up on the basis of the EIS. But the monitoring system is different from the environmental impact assessment. It has its own characteristics and it is unfeasible to copy the classification system of the environmental impact assessment. As the TGP will take a long time, the tasks and division of labor during different stages of construction would be different. At the same time, the monitoring targets, contents, and indicators of the system are massive, complicated, covering wide-ranging subjects. In the past, there was not enough study of the indicator system. That is why there was not a proper classification system at the beginning of the setup of the monitoring system. After the 2000 systematic assessment, we began to try to classify the indicators in hope of setting up a complete framework for the monitoring system.

We have divided the indicators according to the system, subsystem, classes, and subclasses as shown in Table 4.5.

The first level is the general overlooking all the ecological and environmental issues caused by TGP in an integrated way. The second level covers the subsystems, classified according to natural and social factors into 12 subsystems according to the management needs. Among them, estuary monitoring is regarded as a relative independent regime and an independent subsystem as required by supervision and management. Remote sensing is a comprehensive and macro monitoring means and, therefore, regarded as an independent subsystem. Eco-environment experimental stations are regarded as typical regional and comprehensive stations, also classified as an independent subsystem. Also relatively independent are construction area environment, sedimentation and scouring, induced earthquake, and geological disasters, which are also listed as subsystems due to their independence in management. The third level covers classes, mainly satisfying requirements of the contract management. They are divided into 24 classes (equal to 24 major stations). At the fourth level are subclasses, equivalent to major comprehensive indicators.

Major monitoring indicators and frequencies of subsystems are set according to the actual needs and possibilities of various subsystems and major stations, as shown in Table 4.6. The obtained data form the baseline data of pre-impoundment of the reservoir.

It should be pointed out that classification in Table 4.5 gives more consideration to management needs, less scientifically and comprehensively. For instance, hydrology and water quality monitoring is overlapped in the fish and other aquatic life subsystem, the estuary ecology subsystem, and the hydrology and water quality subsystem.

4.4 Characteristics of the Monitoring System

4.4.1 Project-Oriented

The TGP environmental monitoring system mainly serves TGP. It is a complete, representative, and large water project-oriented ecological and environmental monitoring system. It is different in service and functions from the ecological and environmental monitoring networks established by different sectors according to law.

4.4.2 Wide Coverage

The monitoring system covers the reservoir area and extends to the whole catchment areas of the Yangtze associated with TGP.

4.4.3 Multiple Monitoring Factors

The system is designed to monitor such factors as hydrology, water quality, underground water, pollution sources, local climate, terrestrial animals and plants, aquatic life, fish resources, agricultural ecology and environment, geological environment, people's health, socioeconomic development, and other natural and humanistic factors.

Table 4.4 Scope of monitoring of all major (experimental) stations of the monitoring system

Category	Name of station	Monitoring scope
Major stations	Main Synchro-monitoring Station of Hydrology and Water Quality of Main Stem	Areas around the reservoir and the middle and lower reaches (from Chongqing to Shanghai) of the Yangtze, with monitoring point distributed according to different cross sections
	Main Monitoring Station of Typical City River Section and Pollution Belt	Main city area of Chongqing, Fuling, Wanzhou, Zhongxian, Fengjie, Wushan, and Badong, with 50 cross sections as well as the large pollution outlets of these cities
	Main Groundwater (Xiaogang) Monitoring Station	Hubei Xiaogang farm of the four-lake areas in the middle reaches of the Yangtze and typical areas
	Main Monitoring Station of Industrial and Domestic Pollution Sources	Industrial pollution source in the reservoir area, 18 counties and cities along the reservoir section of the river
	Main Monitoring Station of Floating Pollution Sources of Vessels	Selecting typical vessels on the basis of getting clear the basic situation of operating vessels in the reservoir area
	Main Monitoring Station of Non-point Pollution of Pesticide and Fertilizer	Reservoir area
	Main Station of Fishery Resources and Environment	Yibin, Banan, Wanzhou, Jingzhou, Yueyang, Hukou, and estuary area
	Main Monitoring Station of Fish and Rare Aquatic Animals	Yangtze section from upstream Jinsha to downstream Chongming Island
	Main Monitoring Station of Terrestrial Animals	20 counties (cities) in the reservoir area, with emphasis put on inundated areas, resettlement areas, and island areas of the reservoir
	Main Monitoring Station of Local Climate	Areas around the reservoir, including main city area of Chongqing, Changshou, Fuling, Wanshou, Fengjie, Wushan, Badong, Zigui, Bahekou, and Yichang
	Main Monitoring Station of Public Health	Dam and reservoir areas
	Main Socio-environment Monitoring Station of Hubei Reservoir Area	4 districts (counties) in the Hubei reservoir area
	Main Socio-environment Monitoring Station of Chongqing Reservoir Area	22 districts (counties) of the reservoir area in Chongqing
	Main Monitoring Station of Agro-ecological Environment	Reservoir area
	Main Monitoring Station of Estuary Ecology and Environment	Estuary of the Yangtze and nearby offshore area
	Main Monitoring Station of Eco-environment Remote Sensing	Mainly the reservoir area, with extensions covering the whole Yangtze basin
Experimental stations	Zigui Eco-environment	Zigui of Hubei
	Wanzhou Eco-environment	Wanzhou of Chongqing
	Endemic Fish Species	Luzhou of Sichuan
	Terrestrial Plant	Xingshan of Hubei
Other	Environmental Monitoring Station of Construction Site	Construction area
	Monitoring Station of Reservoir Sedimentation and Downstream Degradation	Reservoir area, dam area and areas downstream of the dam
	Monitoring Station of Reservoir-induced Earthquake	Reservoir area, with emphasis on the head of the reservoir
	Geological Disaster Monitoring Station in the Reservoir Area	Reservoir area

Table 4.5 Indicator system of TGP environmental monitoring system before impoundment

System	TGP Eco-environment monitoring system											
Subsystem	Hydrology and water quality			Pollution source			Fish and other aquatic life		Terrestrial animal and plant	Local climate	Agro-ecology and environment	Estuary ecology
Class	Hydrology and water quality	Pollution belt and city section water quality	Underground water (Xiaogang) water quality	Industrial and sewage pollution	Farm chemicals and fertilizer non-point pollution	Ship and Other floating pollution	Fish resource and environment	Rare and endemic species aquatic life	Terrestrial animals and plants	Local climate	Agro-ecology and environment	Estuary ecology and environment
Sub-class	Hydrology, water quality, river-bed quality, biology	Pollution belt length, width and related hydrological conditions, city section water quality	Surface water, underground water, rainfall, soil moisture	City sewage, industrial wastewater, pollution sources of removed cities	Surface runoff, soil, farm chemical, fertilizer and animal and poultry breeding	Oil stain, sewage, garbage, noise	Major economic fish and food base, spawning ground, egg and young fish, fish water quality	Rare, endemic fish, Baijitun, river dolphin, four major endemic fish	Plant species, rare and native species, forests, vegetation, resource plants, animal species, rare and endangered species, water fowls and habitat	Regular climate, vertical climate	Farmland soil, plant diseases and pests, rural energy, farm chemical and fertilizer, soil structure and type, farm crops species	Natural environment, biological environment, fish planktons, fishing resource

System	TGP Eco-environment monitoring system											
Subsystem	People's health	Remote sensing	Socieconomic environment		Eco-environment experiment				Other subsystems			
Class	People's health	Remote sensing dynamic	Chongqing reservoir area	Hubei reservoir area	Terrestrial plant observation and experiment	Endemic fish experiment	Zigui eco-environment experiment	Wanzhou eco-environment experiment	Construction area environment	Sediment and scouring	Induced earthquake	Geological disasters
Sub-class	Life span statistics, health resources, communicable diseases and endemic diseases, bio-vector, epidemic outbreak span statistics	Land resource, soil erosion, vegetation and fauna, primary productivity and primary productivity and terrestrial biomass, plant physiological parameters	Population, resources, environment, economy, social development and resettled people		Species migration and preservation, sample belt monitoring	Endemic fish habitat and reproduction survey, artificial breeding technology experiments	Soil fertility monitoring, eco-agricultural experiments, follow-up survey of resettled people	Hydrology, water quality, air quality, noise, people's health	Sediment, scouting, account and position	Earthquake magnitude and position	Collapse, landslide and high-cut slopes	

Table 4.6 Monitoring frequency of major indicators (2001)

Subsystem	Major indicators and monitoring frequency
Hydrology & water quality subsystem	For 10 Yangtze mainstream cross-sections and 3 tributary cross-sections: once every month for observing three hydrology indicators; twice every year for 16 indicator water quality monitoring (seven analyzed separately by clear and turbid water) and ten indictors river–bed quality monitoring 5 Yangtze mainstream cross-sections and five indicators: four times biological monitoring a year Six times a year for synchronized hydrology and water quality monitoring of 4 typical city sewage outlets and 7 city riparian pollution belts in the reservoir area, and for 16 cross-sections and 29 indicators in 11 reservoir area cities and countries Underground water level monitoring, water balance factor observation, 4 indicator soil gleization monitoring, 8 indicator gleyed soil fertility monitoring, 8 indicator gleyed soil fertility monitoring
Pollution source subsystem	Once a year for 10 indicator city sewage survey of 63 sewage outlets in 18 riparian districts and counties in the reservoir area, 4 indicator garbage survey; 48-hour continuous monitoring, 2-hr. interval, twice a year for 7 indicator sewage verification monitoring of sewage outlets of 7 large cities; twice a year for industrial wastewater discharge of 60 industrial pollution sources in the reservoir area; 6-indicator pollution source survey of 124 resettled cities and towns Once every year for 7-indicator farm chemical and fertilizer application survey in 182 townships in the reservoir area; once a year for four-indicator surface runoff monitoring and 11-indicator runoff surface soil sample monitoring at four areas and 16 monitoring point of the reservoir area; measurement of farm chemical and fertilizer loss 9-indicator operating vessel information and 6-indicator pollutants discharged by ships survey; monitoring of typical vessel pollutant discharge density and amount; 4-indicator vessel oil leak emergency monitoring; vessel sewage and noise monitoring
Fish and other aquatic life subsystem	24 times a year survey of major economic fish catch composition, ratio and amount at 7 monitoring points of the Yangtze mainstream; 60 times a year survey of spawning conditions and spawn (fry) amount of four major endemic fishes in the Yichang-Chenglingji section of the Yangtze at 2 cross-sections; annual survey of the lake area, food base for fish and carp spawning ground distribution and scale at 18 cross-sections of the Dongting and Poyang lakes. 15 times survey of fish catch composition, ratio of catches and total amount of catches at 6 monitoring points 14-indicator water quality for fish monitoring, three times a year at 7 monitoring points on the Yangtze mainstream 20-indicator endemic fish and rare fish monitoring at 6 sections of the Yangtze mainstream, 6-indicator resources utilization survey; 10-indicator environmental factor monitoring, twice a year
Terrestrial animal and plant subsystem	140 sample land blocks for terrestrial plants, 4 sample plant belts, 19 sample animal travel routes, 18 random sampling routes, 48 random sample survey points, 17-indicator plant species, typical fauna and ancient and famous tree monitoring at below 175 m water level, once every 2 years Survey of the species, distribution and habitat of terrestrial animals; year-found non-point monitoring of the species and habitats of rare and endangered species; annual survey of species and number of water fowls
Local climate subsystem	Regular climate observation at fix time, four times a day at 10 base stations around the reservoir, two contrast stations outside the reservoir area, 13 indicators Four-month vertical meteorological observation at two cross-sections at Fuling and Yichang in 2002–2003, totaling 21 ground observation points, 8 times a day, six factors, four more factors in some stations, 2 low altitude observation, four factors, twice a day, totaling 14 factors
Agro-ecology and environment subsystem	Cropping system and plant structure survey at 182 townships of the reservoir area, once a year; 5-indicator farm crop pests and diseases and 5 indicator rat infestation and losses survey, once a year; 5-indicator reservoir area rural energy structure survey, once a year; 7-indicator agricultural biodiversity survey and monitoring in the inundated area, once and for all; 17-indicator reservoir area soil baseline monitoring, twice a year
Estuary ecology and environment subsystem	9-point, 31-indicator soil salinization monitoring in the estuary area, once every five days; 30-point, 31-indicator estuary ecology and environment survey, once a year; 15-point fishing resources monitoring, once a year
People's health subsystem	10-county, 4-indicator base materials survey, once a year; 7-indicator population materials survey, once a year; 4-indicator health organization and staff survey, once a year 18-township, 35-communicable diseases and 6-indicator survey, 12 times a year; 3-indicator endemic diseases monitoring, once a year; 3-indicator serum monitoring, once every 2 years 5-indicator rat monitoring, twice a year; 6-indicator mosquito monitoring, 8 times a year; epidemic outbreak report
Reservoir socioeconomic environment subsystem	4-county, 101-indicator comprehensive monitoring, once a year; 20-resettlement villages, 73-indicator survey, once a year 15-district (counties), 101-indicator comprehensive monitoring, once a year; 7-main city integrated statistical indicator monitoring; 10-resettlement villages, 73-indicator survey in the Chongqing reservoir area, once a year

(continued)

Table 4.6 (continued)

Subsystem	Major indicators and monitoring frequency
Ecology and environment experimental station	Wanzhou: 5-sample point soil nutrients and organic matter monitoring, once and for all; 2-sample point soil runoff flow and sand generating monitoring, once a year; arid slope land water and soil conservation efficiency observation, three times a year; 5-peasant households, 5-indicator resettlement survey, once a year; arid slope land ground film water blocking experiment; arid slope land grain-cash crop-fruit composite model experiment; vegetation (grass) restoration and plant fence experiment on the slope land returned from farmland Zigui: 63-point, 16-indicator soil fertility monitoring, once every 2 years at cultivate layer and once every 5 year at sub-cultivated layer; 15-point, 4-indicator water and soil loss monitoring; 17-indicator ecological factor monitoring, three times a day; 10-resettlement and non-resettlement contrast households, 8-indicator survey, once a year; arid slope land integrated consolidation and soil fertility experiment and demonstration; crop vertical optimal plant model experiment and demonstration; cropping system optimization experiment and demonstration; cash crop industrialization, clean production and standardization experiment Luzhou: survey and monitoring of the living and reproduction environment of 3–5 endemic species of fish to study the reproductive ecology and biology to explore ways of artificial reproduction technology Xingshan: removing and preservation of 30-species of plants in the reservoir area; 48-indicator fauna monitoring; 3-sample belt biodiversity monitoring in the reservoir area, once belt a year; 6-indicator soil characteristics monitoring, once every 3 years; climatic factors observation within the experimental stations, three times a day
Remote sensing dynamic monitoring subsystem	Reservoir area and resettlement area ecological and environmental baseline survey, once every 5 years; reservoir area land resources and quality dynamic monitoring; reservoir area soil erosion intensity dynamic monitoring; reservoir area vegetation resources and fauna biotope quality dynamic monitoring; reservoir area monthly primary productivity and annual terrestrial biomass monitoring; city land use dynamic monitoring, resettlement progress monitoring; returning land reclaimed from grassland/forests/natural shelter belts monitoring; monthly plant physiological parameter remote sensing monitoring
Other subsystems	Construction area (water quality, hydrology, meteorology, air quality, noise and people's health); induced earthquake; geological disaster, sediment and scouring

In 2005, the Executive Office of SCTGPCC organized experts to acceptance check the monitoring contracts of 19 major stations, marking the completion of the TGP environmental monitoring system before impoundment of the reservoir

Members of the expert panel (from *left* to *right*): Ao Lianggui, Wu Guoping, and HuangZhenli at the review meeting

4.4.4 Systematic and Long Term in Nature

As the ecological and environmental problems the TGP in concern are very complicated and cover all aspects, both potential and long term in nature, the monitoring system has its objectives of obtaining the baseline materials about the ecology and environment, post-dam assessment, and serving TGP management departments, focusing on the monitoring of natural, economic, ecological, environmental, and social factors with emphasis on the reservoir area. Some factors change fast due to the reservoir impact, such as water quality; some factors change slowly, difficult to reveal in a short time, such as the ecological changes for plants and fish; some are hard to predict, such as the impact on climatic changes. So the monitoring is complicated and of long term in nature.

4.4.5 Involving Multiple Areas, Sectors, Disciplines and Levels

The monitoring system is China's only trans-regional, trans-sectoral, multidisciplinary, and multi-leveled monitoring network. The targets for monitoring include hydrology, water quality, pollution sources, fish, and other aquatic life, terrestrial animals and plants, local climate, agricultural ecology and environment, estuary ecology and environment, people's health, reservoir areas socioeconomic environment, ecological and environmental experiments, and other areas, involving sciences in hydrology, water conservancy, geology, environment, ecology, biology, chemistry, physics, agro-science, medicine, demography, economics, sociology, statistics, and others of natural and social sciences.

As is mentioned in Chap. 3, comparing with Aswan, Itaipu and Ertan projects, the Three Gorges project has the monitoring targets, scope, and scale, far larger, more comprehensive and complete, which were established during the construction period and obtained pre-dam baseline materials and carried out regular monitoring.

4.4.6 Integration of Monitoring and Experiments/Demonstration

The monitoring system has integrated monitoring work with application of countermeasures to mitigate the adverse impact of the TGP, carrying out experiments and demonstration aimed at coordinated development of the economy and environment, by which to promote the application and service in improving the ecology and environment. It carries out experiments and application studies on problems hitherto remaining unclear. It has put forward specific measures and policies concerning ecological restoration and building in areas associated with the Yangtze River in hope of bringing about synchronized development of the environment and economy.

4.4.7 Information Management

The monitoring data are processed and managed by the information management center. The center has become a comprehensive information platform for public information service, sharing, publishing, integrated analysis and dynamic information gathering. Management departments may, through the information management center, issue work directives and technical standards and obtain the latest monitoring information. All the stations will submit their data, analytic reports to the information management center, which will process the information and store them in the databank, ready for comprehensive analysis and publishing.

5 Sub-systems of TGP Eco-Environment Monitoring System

The TGP Eco-Environment Monitoring System consists of the hydrology and water quality sub-system, fish and aquatic life sub-system, terrestrial animal and plant sub-system, local climate sub-system, agro-ecology and environment sub-system, estuary ecology and environment sub-system, sub-system of socioeconomic environment for the reservoir area, remote sensing dynamic monitoring sub-system, and ecological and environment experimental station. There are 11 sub-systems, with 20 major (experimental) stations and 58 base stations. This, plus the other special target monitoring, totals 12 sub-systems.

5.1 Hydrology and Water Quality Sub-system

The hydrology and water quality sub-system includes a hydrology and water quality synchronized monitoring, the Main Monitoring Station of Typical City River Section and Pollution Belt and underground water (Xiao Gang) monitoring stations, as shown in Fig. 5.1.

The TGP has its impact on general water quality and local water quality, such as riparian pollution belt, city section water quality, and tributary water quality as well as underground water quality.

The TGP has changed the hydrological regime of the reservoir area and the middle and lower reaches of the Yangtze and affected the water quality chiefly in the reservoir area. In order to get clear the TGP impact on water environment and resources, it is necessary to carry out synchronized monitoring of the hydrology and water quality at multiple cross-sections on the mainstream and tributaries from the tail of the reservoir to the estuary so as to master the laws governing the changes of the water environment, assess the TGP impact on water environment, and put forward measures to mitigate the adverse impacts.

The river sections in cities are both areas of extracting water for daily life and industrial use and areas that receive city sewage and industrial wastewater. The TGP's effect on the city section water in the reservoir area has a direct bearing on the living and agricultural and industrial production. All cities in the reservoir area lack adequate infrastructure and discharge their sewage and industrial wastewater directly to the Yangtze, which form conspicuous pollution belts near the banks. Monitoring of the water quality of the selective riparian pollution belts and the city river sections at fixed points and during regular intervals may help get clear the pre-dam features of the sprawling pollution belts, predict the post-dam changes in water quality, analyze the laws governing the sprawling of the

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2_5

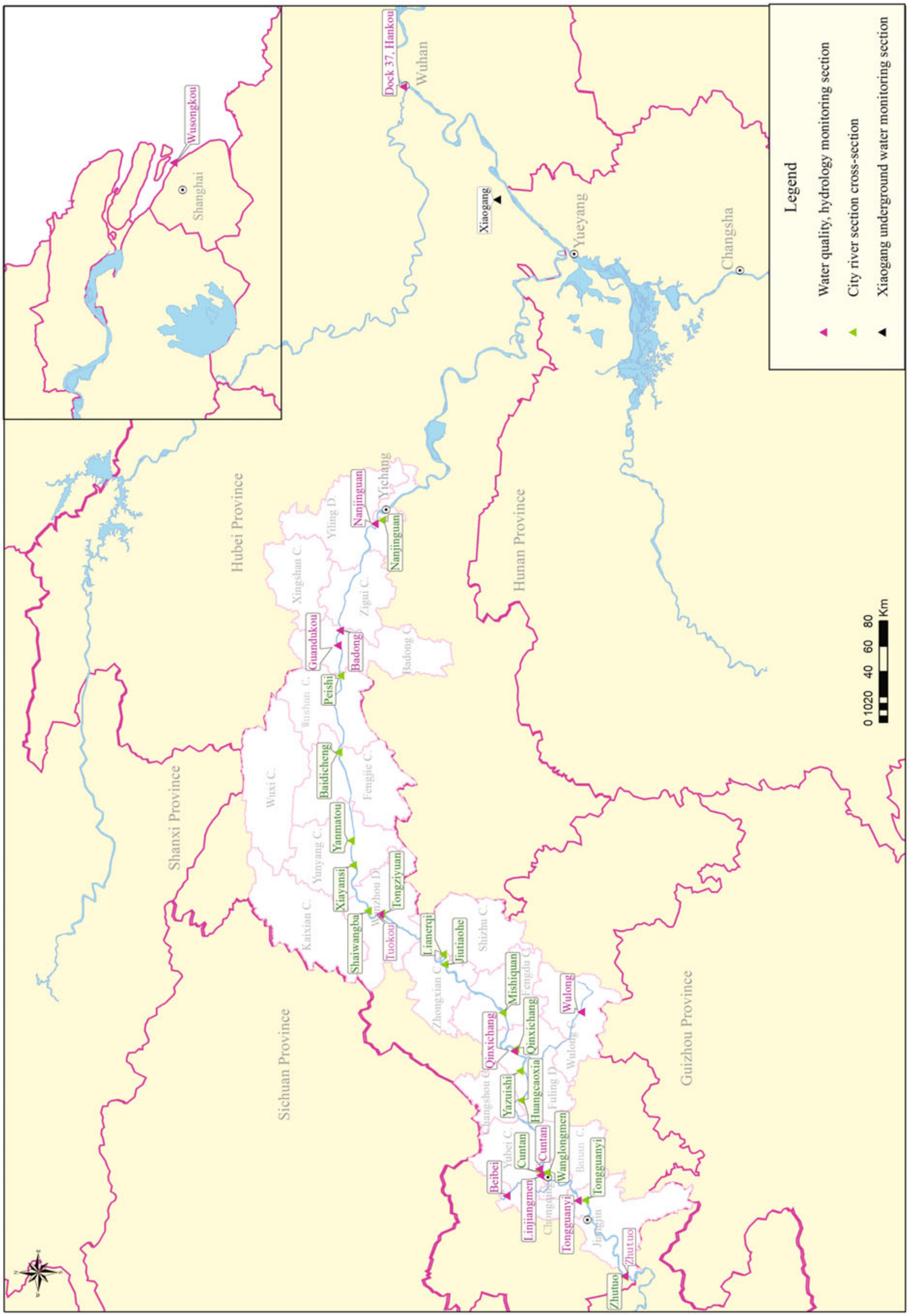


Fig. 5.1 Distribution of hydrology and water quality sub-system

pollution belts during different periods of time before and after the dam is built, and provide scientific basis for the protection of the water environment of the city river sections in the reservoir area and the management of the water resources of the reservoir.

The change in the water level of the Yangtze will inevitably affect the changes in the pressure water head on the plains in the middle reaches of the river. As the phreatic and underlying pressure water is closely associated, the rise in pressure water will in the end be reflected in the phreatic level. The groundwater table affects the whole process of gleization and swamping of the soil. With the rise in the ground water table, the soil has a strong condition of restoration, thus aggravating the gleization process. The monitoring of the effect of lateral infiltration of the Yangtze water on soil gleization may provide quantitative indicators for measuring the threat of gleization to soil on the plains in the middle reaches of the river and provide the basis for ameliorating the gleyed soil.

5.1.1 Main Synchro-Monitoring Station of Hydrology and Water Quality of the Mainstem

Targets and requirements of monitoring

(1) Monitoring scope and targets

Hydrology and water quality (clarity and turbidity samples), riverbed quality, and aquatic life in the reservoir area and the river section from Chongqing to Shanghai.

(2) Sampling cross-sections and vertical layout

- Monitoring cross-sections of hydrology, water quality, riverbed:
  Yangtze mainstream: Zhutuo, Tongguoyi, Cuntan, Qingxichang, Tuokou, Guandukou Badong Gauging Station, Nanjinguan, Hankou, Wusongkou, totaling 10 cross-sections (see Table 5.1);
  Main tributaries: Beipei and Linjiangmen of the Jialing River, Wulong of the Wujiang River, totaling three cross-sections.
- Aquatic life monitoring cross-sections:
  At Cuntan in Chongqing, Qingxichang of Fuling, Tuokou of Wanzhou, Guandukou of Badong, and Nanjinguan of Yichang.

(3) Monitoring indicators and frequency

- Hydrological observation: At Zhutuo, Cuntan, Qingxichang, Tuokou, Nanjinguan, Hankou, Wusongkou, Beibei of Jialing River and Wulong of Wujiang River, totaling nine cross-sections for observing water level, flowrate and mean velocity, one every month, 12 times a year; At Tongguanyi, Guandukou,, Badong Gauging Station and Linjiangmen of Jialing River, totaling four cross-sections, adopting hydrological computing method to calculate flowrate. All the 13 cross-sections were required to be observed once before December 31, 2003.
- Water quality monitoring: Water temperature, pH, redox potential, conductivity, SS, total salinity, total hardness, ArOH, THg, TAs, Cr^{6+}, TCd, TCu, TPb, Oil,

Table 5.1 Distribution of cross-sections for hydrology and water quality monitoring

Name of cross-section	Location of cross-section	Position of cross-section	Water quality monitoring points	
			Vertical line	Monitoring point numbers
Zhutuo	400 m upstream of Zhutuo Town Port	105°51′ E, 29°41′ N	3	6
Tongguanyi	Tongguanyi Town of Jiulongpo	40 km upstream of the place where Jialing River flows into the Yangtze	3	3
Beibei	Bei Wenquan, Beibei District	106°25′ E., 29°50′ N	3	6
Linjiangmen	Chaotianmen, Yuzhong District	200 m upstream of the confluence of Yangtze and Jialing River	3	3
Cuntan	Town of Cuntan	105°36′ E, 29°37′, N	3	9
Wulong	Xiangkou Town, Wulong County, Fuling District	107°43′ E, 29°17′ N	3	6
Qingxichang	Qingxichang Town, Fuling district	107°27′ E, 29°48′ N	3	9
Wanzhou	Tuokou, Wuqiao Town, Wanshou District	108°25′ E, 30°45′ N	3	9
Guandukou	West end of Guandukou Town, Badong County	111°30′ E, 31°02′ N	3	7
Badong Gauging Station	Badong Gauging Station, Badong County town	111°26′ E, 31°02′ N	3	7
Nanjinguan	Hydrological cross-section of the Nanjinguan Hydrological station, Yichang	111°13′ E, 30°44′ N	3	7
Hankou	Dock No. 37, Hankou	114°17′ E, 30°35′ N	3	9
Wusongkou	(1–V sample points) 23 km downstream of Wusongkou	121°43′–121°45′ E, 31°17′–31°17, N	5	10

total colibacillus, total bacteria, DO, BOD_5, COD_{Mn}, NH_3-N, NO_3-N, NO_2-N, TN, and TP. For COD_{Mn}, TP, TAs, THg, TCu, TPb, and TCd are subject to analysis in clarity and turbidity, Wusong monitoring once at tide and at ebb every odd-number month, totaling 6 times. For the rest of the cross-sections, once a month, totaling 12 times.

- Riverbed monitoring: THg, TAs, TCu, TPb, TMn, TK and TP, organic matters, organic chloride farm chemicals (8 components), organic phosphorous farm chemicals (5 components), twice a year, in January and July.
- Aquatic life monitoring: Phytoplankton, zooplankton, zoobenthos, periphyton algae, aquatic vascular plant; 4 times a year, in January, April, July, and October.

Monitoring units (1996–2003)

The hydrology and water quality monitoring sub-system is made up of one leading station and seven base stations. The leading station is at the Changjiang Water Resources Commission (CWRC). The seven base stations are in Chongqing, Fuling, Wanzhou, Bandong, Yichang, Hankou, and Shanghai.

Fuling station (Qingxichang cross-section)

Wanzhou station (Wanzhou cross-section)

Fixed cross-section monitoring vessel

Ready for sampling

Lead fish going into the water

Collecting water samples

Fixed cross-section hydrology and water quality synchronized monitoring (Photo by Huang Zhenli)

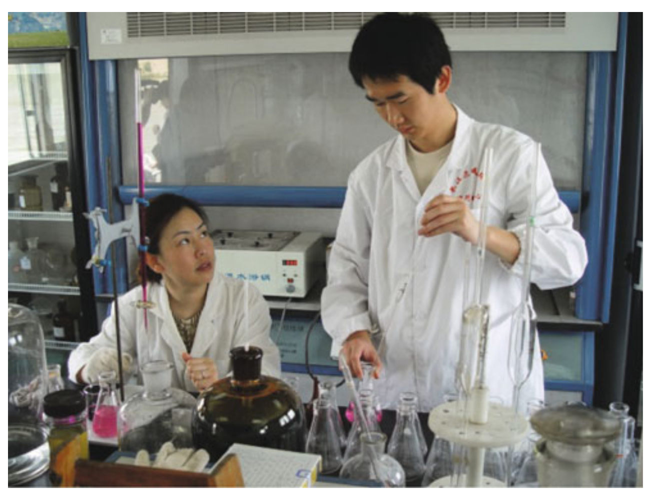
Floating monitoring vessel

Water sampling

Collecting plankton samples

Geological sampling


Velocity testing


In-vessel Lab

Floating monitoring of hydrology and water quality

Chongqing Municipal Environmental Monitoring Center

5.1.2 Main Monitoring Station of Typical City River Section and Pollution Belt

Monitoring targets and requirements

(1) Riparian pollution belt monitoring

- Monitoring requirements: Typical pollution belt monitoring was done in 1997–2000 in the main city districts of Chongqing (Taohuaxi, Huangshaxi and the confluence of the Yangtze and Jialing), Fuling, Wanshou, and Wushan. In 2001–2003, 50 cross-sections were designated in seven cities: main city districts of Chongqing, Fuling, Wanshou, Zhongxian, Fengjie, Wushan, and Badong. Monitoring was conducted in February–March and October–November. Monitoring was also conducted of the pollutants discharge outlets of cities as contrast to the changes in the riparian pollution belts.
- Monitoring cross-sections: 12 in Chongqing city districts, 6 in Fuling city districts, 8 in Wanshou city districts, 4 in Zhongxian districts, 4 in Fengjie City districts, 4 in Wushan city districts, and 4 in Badong city districts.
- Monitoring indicators: Hydrological indicators include flowrate, mean velocity, water level, and shape of river course. Water quality indictors include major indicators for different sections of the river such as COD_{Mn}, TP, and TN.
- Technical requirement: Each cross-section has 5–6 vertical lines and water samples are collected at a depth of below 0.5 m at each vertical line.
- Monitoring time and frequency: In 2001 at Badong, Wushan, and Fengjie; in 2002, at main city districts of Chongqing; in 2003, at Fuling, Wanzhou, and Zhongxian. Each cross-section is monitored twice a year in February–March (low water season) and October–November (normal water season). Each sampling point is sampled twice at an interval of 5–10 min., with the samples analyzed separately.

(2) City river section water quality monitoring

- Monitoring scope: Cities in the reservoir area along the mainstream of the Yangtze: Jiangjin, main city district of Chongqing, Changshou, Fuling, Fengdu, Zhongxian, Wanzhou, Yunyang, Fengjie, Wushan, and Yichang, in total 11 cross-sections.
- Monitoring indicators: water temperature, pH, DO, COD_{Cr}, BOD_5, NH_3-N, NO_3-N, NO_2-N, TP, THg, ArOH, chluorides, As, Cr^{6+}, Cd, Pb, Cu, colibacillus, bacteria, and Oil, totaling 29.
- Technical requirement: Samples are collected at a depth of 0.5 m in three points: left, middle, and right.
- Monitoring time and frequency: Monitoring is done in February, May, and August (during high, normal, and low water seasons), twice a month, totaling 6 times a year.

Monitoring units (1996–2003)

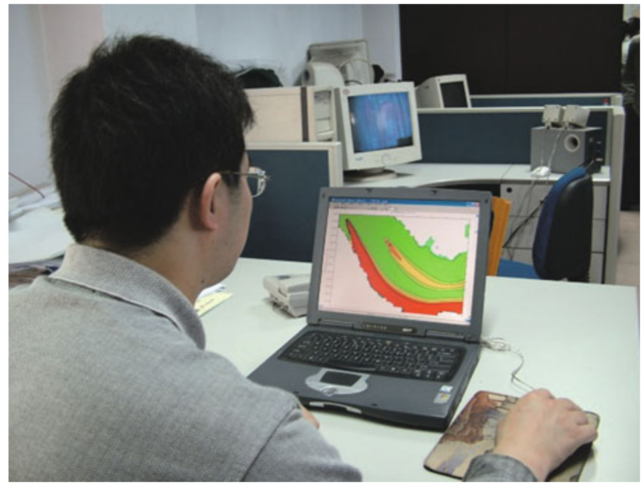
The leading monitoring station is set in the Chongqing Municipal Environmental Monitoring Center, without base stations. Part of the work is entrusted to district and county environment monitoring stations.

Industrial pollutant belt. This is one of the most serious problems in the reservoir area. The discharge of sewer and industrial wastewater without treatment has had a serious consequence on water, cityscape, and hydro-ecology. The monitoring is aimed at getting clear the sprawling and distribution of such belts by computing through mathematic models so as to provide basis for adopting countermeasures

Collecting samples

Water sample

Water quality analysis in lab



Mathematic model simulation of pollution belt

5.1.3 Main Groundwater Monitoring Station (Xiaogang)

Monitoring targets and requirements

(1) Monitoring targets

- Yangtze lateral infiltration replenishment observation system (pressure water and phreatic level monitoring);
- Supplementary water balance elements observation;
- Soil gleization monitoring;
- Gleyed soil fertility monitoring.

(2) Monitoring indicators

- Underground water level: pressure water, phreatic, and water temperature;
- Other water balance observation: rainfall, evaporation;
- Gleyed soil: pH, redox potential, active reduction matter, and total reduction matter;
- Soil fertility: Characteristics of soil cross-section, pH, organic matters, pernitrogen, perphosphorous, perpotasium, base hydrolyzable N, fast-acting phosphorous, and fast-acting potassium;
- GPS position of observation hole.

(3) Monitoring frequency

- Underground water table monitoring: 10 holes in five groups, once a day;
- Other water balance observation: Observing rainfall and evaporation according to the conventional meteorological method, three times a day.
- Gleyed soil: three soil cross-sections (corresponding to different types of gleyed soil) twice a year, in May and November.
- Soil fertility: once every 5 years.

Monitoring units (1996–2003)

The monitoring station is situated at Xiaogang in the "Four-Lake" area, operated by the Institute of Geodesy and Geophysics, CAS.

Water injection at the Xiaogang observation port

Phreatic observation port at Xiaogang

Serious gleyed soil cross-section

Lotus growing: plantation model of gleyed soil at Xiaogang

5.2 Pollution Sources Sub-system

The pollution sources sub-system includes industrial and city pollution sources monitoring, floating pollution sources monitoring, farm chemicals, and fertilizer non-point pollution source monitoring, totaling three leading stations, as shown in Fig. 5.2. The purpose of monitoring is to get clear about the wastewater discharge volume, frequency of discharge, regional distribution before discharge, density of major pollutant discharge, and pollution load so as to provide data of dynamic measuring and surveys for reference in water pollution prevention and control in the reservoir area.

5.2.1 Main Monitoring Station of Industrial and Domestic Pollution Sources

Monitoring targets and requirements

As industrial enterprises and cities and towns are widely distributed in the reservoir area, it is impossible to monitor each and every enterprise and city. What is feasible is to get representative and scientific data from industrial wastewater and city sewerage and get a general picture of the pollutants discharge. First of all, it is necessary to carry out a survey of industrial enterprises and city pollution sources and then fix the number pollution sources and corresponding indicators for monitoring. Then, it is necessary to carry out on-spot monitoring of typical outlets of major industrial wastewater and typical city sewerage. For other enterprises and cities and rebuilt cities and towns, data may be obtained by way of survey.

(1) City sewerage

- City sewerage survey
  - Scope of survey: 18 districts (counties and cities) along the Yangtze in the reservoir area, namely, Jiangjin, Banan, Dadukou, Jiulongpo, Yuzhong, Nan'an, Jiangbei, Yubei, Changshou, Fuling, Fengdu, Zhongxian, Wanzhou, Yunyang, Fengjie, Wushan, Badong, and Zigui.

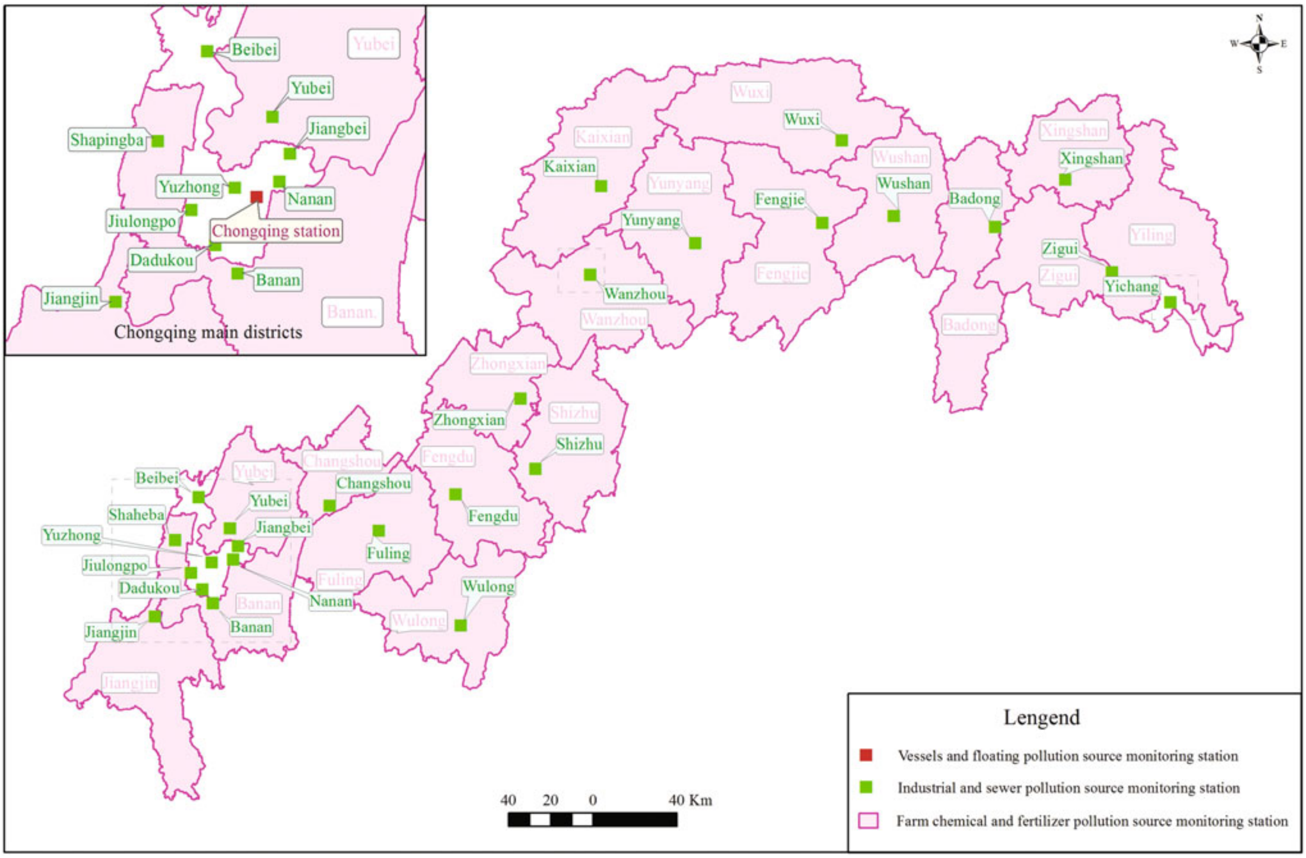


Fig. 5.2 Distribution of major monitoring station of the pollution sources monitoring sub-system

- Targets of survey: Large city sewerage outlets fixed during the 1997 survey (totaling 63), city district population, city area, tap water supply, sewerage discharge, and annual discharge of BOD_5, COD_{Cr}, TP, NH_3-N, ArOH, and Oil; Generation of garbage, volume of discharge, cumulative amount, and position of piling.
- Survey time and frequency: A comprehensive survey is conducted once a year in October–December.

- City sewerage monitoring (check)
  - Scope of monitoring: The seven most representative large city pollutant discharge outlets selected in 2002 in the 18 city districts (counties, cities) in the reservoir area, including Ba'nan (1), Chongqing main districts (2), Fuling (1), Wanzhou (1), Fengjie (1), and Badong (1).
  - Monitoring indicators: flowrate, BOD_5, COD_{Cr}, TP, NH_3-N, ArOH, and Oil.
  - Monitoring time and frequency: One 48-h nonstop monitoring of the seven pollutants discharge outlets in April and September 2002, with flow measured once every two hours, with samples collected once every two hours and mixed the 4-h samples for analysis.

(2) Industrial waste water

- Survey of industrial pollution sources
  - Coverage of survey: 60 major industrial pollution sources controlled by the state or cities in the reservoir area.
  - Targets of survey: Industrial wastewater discharge and density and volume of major water pollutants.
  - Monitoring time and frequency. Once in October–December every year in 2001–2003.
- Industrial pollution sources monitoring
  - Number of pollution sources under monitoring: selecting six major pollution sources controlled by the state or cities every year.
  - Monitoring indicators: amount of industrial wastewater discharge and density of major pollutants.
  - Monitoring time and frequency: twice a year in the first and second half of the year in 2001–2003.

(3) Pollution sources of resettlement cities and towns

- Survey of pollution sources of newly built cities and towns

- – Coverage of survey: 361 townships rebuilt due to inundation of the reservoir.
- – Targets of survey: sewerage, industrial wastewater, garbage, industrial solid waste discharged annually, and load of major pollutants.
- – Monitoring time and frequency: A detailed survey of the 361 townships was carried out in August–December 2001 and a general survey of major pollution sources that accounted for 80% of the pollution load in the inundated areas was carried out in 2002 and in February–December 2003.
- – Methods of survey: questionnaires survey, on-the-spot sample survey, and telephone inquiry.

- Verification of pollution sources
  - – Number of cities and towns checked: five big cities and towns are selected for check every year.
  - – Targets of check: city sewerage and industrial wastewater discharge and density of pollutants, garbage, industrial solid wastes generation, and discharge.
  - – Check time and frequency: once a year in September–December.
  - – Method of check: sampling, field survey, calculation of materials used or pollutant discharge coefficient estimation.

Monitoring units (1996–2003)

The leading station is set in the Chongqing Municipal Environmental Monitoring Center, without base stations. Part of the work is entrusted by contracts or agreements to qualified district (county, city) environment monitoring stations.

5.2.2 Main Monitoring Station of Floating Pollution Sources of Vessels

Monitoring targets and requirements

(1) Survey of the basic substances due to vessels operating in the reservoir area.

There are many types of vessels in the reservoir area, and their large individual numbers and the wide distribution make it impossible to monitor each type and every boat. What can be done is to obtain data that are representative and scientific and able to give a general picture of the pollutant discharge. It is, therefore, necessary to carry out a basic survey of the types of vessels operating in the Yangtze so as to fix the number of typical vessels for monitoring.

Investigation indicators should include the following:

- Basic information of operating vessels: shipping companies, types, number, power, tonnage, displacement, main navigation routes, passenger vessels, and freight vessels;
- Pollutant discharge: amount of pollutants generated, the amount treated, amount discharged, the installation and use of pollutants treatment facilities, garbage collection and treatment, monitoring and management of vessels by shipping departments.

(2) Monitoring of the pollutants discharged by operating vessels.

- Monitoring indicators: pollutants discharged by typical vessels, the density, and total amount.

Field survey by major monitoring station

Measuring discharge at pollutant outlet

Ready for sampling

Taohuaxi sewage outfall of Chongqing

Pollution source of Chongqing farm chemicals group

Haitangxi pollutant outlet of Chongqing before the reservoir impoundment

Biggest garbage heap of 412,000 tons on the bank of the Yangtze in Fengjie County. It was removed in June 2003 before the reservoir impoundment

Ultraviolet spectrophotometer

Fourier ultrared spectrometer

- Main targets of monitoring: oil-containing sewerage (cabin water and ballast water), sewerage, noise, and garbage.
- Monitoring time and frequency: once a year in February–November.
- Starting and ending time: annual survey of oil-containing water and garbage during the 3 years in 2001–2003. Starting from 2002, annual monitoring is done on oil-contaminated water, sewerage, and noise of vessels.
- Number of vessels monitored: According to the July 2000 assessment proposal, the number of vessels subject to monitoring should be about 300–400 every year from 2001 to 2003. Among them, most representative and typical vessels should be chosen to monitor sewerage, noise, and garbage. The number remains to be decided according to the Review Report on the Number of Monitoring Vessels against Floating Pollution.
  During the 3 year from 2001 to 2003, 1160–1560 vessels were monitored, as shown in Table 5.2.
- Monitoring indicators: as shown in Table 5.3.

(3) Emergency monitoring of oil spill in reservoir area

- type of pollutants, spilled amount, and areas affected;
- Density of pollutants in water body, with indicators including oil, pH, COD, and BOD_5;
- Possible effect.

Monitoring units (1996–2003)

The leading station is set at the Environment Protection Center, MOC, with base stations scattered in Chongqing, Wanzhou, and Three Gorges (Yichang), as is shown in Table 5.4.

Table 5.2 Number of vessels under monitoring

Pollutants	Monitoring frequency/(time/a)	Number of vessels monitored/(num./a)	Monitoring time	Total number of vessels monitored in 2001–2003
Oil-containing water	1	300–400	2001–2003	900–1200
Sewerage	1	10–30	2001–2003	30–90
Noise	1	10–30	2002–2003	20–60
Garbage	1	20–30	2001–2003	60–90

Table 5.3 Vessel pollution source monitoring indicators

Pollutant	Indicator
Oil-containing water	Petroleum
	pH
	SS
Sewerage	SS
	BOD_5
	COD_{Cr}
	Bacillus
Noise	
Garbage	Collection and whereabouts, estimated total amount

Table 5.4 Division of work among monitoring stations

Monitoring station	Monitoring targets			
	Oil-containing water	Sewerage	Noise	Emergency monitoring
Chongqing	Yes	Yes	Yes	Yes
Wanzhou	Yes	Yes	Nil	Yes
Sanxia (Three Gorges)	Yes	Nil	Yes	Yes

Spot monitoring at the Chongqing base station

Sampling

Measuring oil content in lab

5.2.3 Main Monitoring Station of Non-point Pollution of Pesticide and Fertilizer

Monitoring targets and requirements

Monitoring the contents of nitrogen, phosphorous, and potassium in the surface runoff, analyze and estimate the losses of farm chemical and fertilizer, and build a non-point load estimation system.

(1) Distribution of monitoring stations

- Leading station: Wuhan City, Hubei Province.
- Base stations: Chongqing, Wanzhou (Tiancheng), Badong, Yichang, and Honghu.
- Ordinary stations: Jiangjin, Banan, Yubei, Changshou, Wulong, Fuling, Fengdu, Shizhu, Kaixian, Zhongxian, Yunyang, Fengjie, Wushan, Wuxi, Badong, Zigui, Xingshan, Yiling, and Jingzhou.

(2) Targets of monitoring

- Scope of monitoring
  Surface runoff and runoff surface soil at Shizhu, Wanzhou (Tiancheng), Xingshan, and Yiling, with four monitoring points in each, totaling 16 points (see Table 5.5).
- Monitoring indicators:
  Water body: pH, N, P, Organic P(methamidophos, isocarbophos, dichlorvos, and dimethoate);

Table 5.5 Points for monitoring farm chemical and fertilizer non-point pollution sources

Area name	Number of points for sampling				
	5° slope land	15° slope land	25° slope land	15° terraced field	Total
Shizhu	1	1	1	1	4
Wanzhou (Tiancheng)	1	1	1	1	4
Xingshan	1	1	1	1	4
Yiling	1	1	1	1	4
Total	4	4	4	4	16

  Soil: organic matter, total nitrogen, total phosphate, total potassium, base hydrolyzable N, fast-acting phosphate, fast-acting potassium, mercury, and cadmium.
- Monitoring frequency: Once a year, depending on typical rainfall.
- Monitoring time: Sampling for a month from May to August every year.

Monitoring units (1996–2003)

The leading station is set at the Agro-Ecology and Environment Protection Station of Hubei Province, with five base stations and 19 minor stations.

Land utilization rate along the Yangtze is high and pollution caused by farm chemicals and fertilizer non-point pollution sources occupies a significant proportion

Runoff after rainfall

Sampling collecting

5.3 Fish and Aquatic Life Sub-system

Fish and aquatic life sub-system has two leading stations, one for fish resources and environment monitoring and one being a floating monitoring of aquatic life, as is shown in Fig. 5.3. The endemic fish experimental station in Luzhou, Sichuan Province also undertakes part of the monitoring work of rare and endemic species.

The Yangtze abounds in aquatic life and genetic diversity. It is held up as a treasure house of China's freshwater fish germplasm resources. The fish fauna on the upper reaches has its unique history of evolution. The endemic fish in the upper reaches is the species that has been evolved by adapting to the ecology and environment of the water body, especially the hydrological regime and food base conditions. They are of great significance in studying zoogeography and systematic development of fish. Some species have entered the list of animals for state first and second class protection due to their narrow areas of distribution, fewer in number or damaged habitat. The middle and lower reaches of the Yangtze are a composite ecosystem with rivers and lakes. It has its special aquatic life fauna. Many of the species have formed the habit of seeking food and growing and recruiting in lakes and return to mainstream and tributaries for reproduction. They include the four major endemic species, which are the pillar of the natural fisheries in the region.

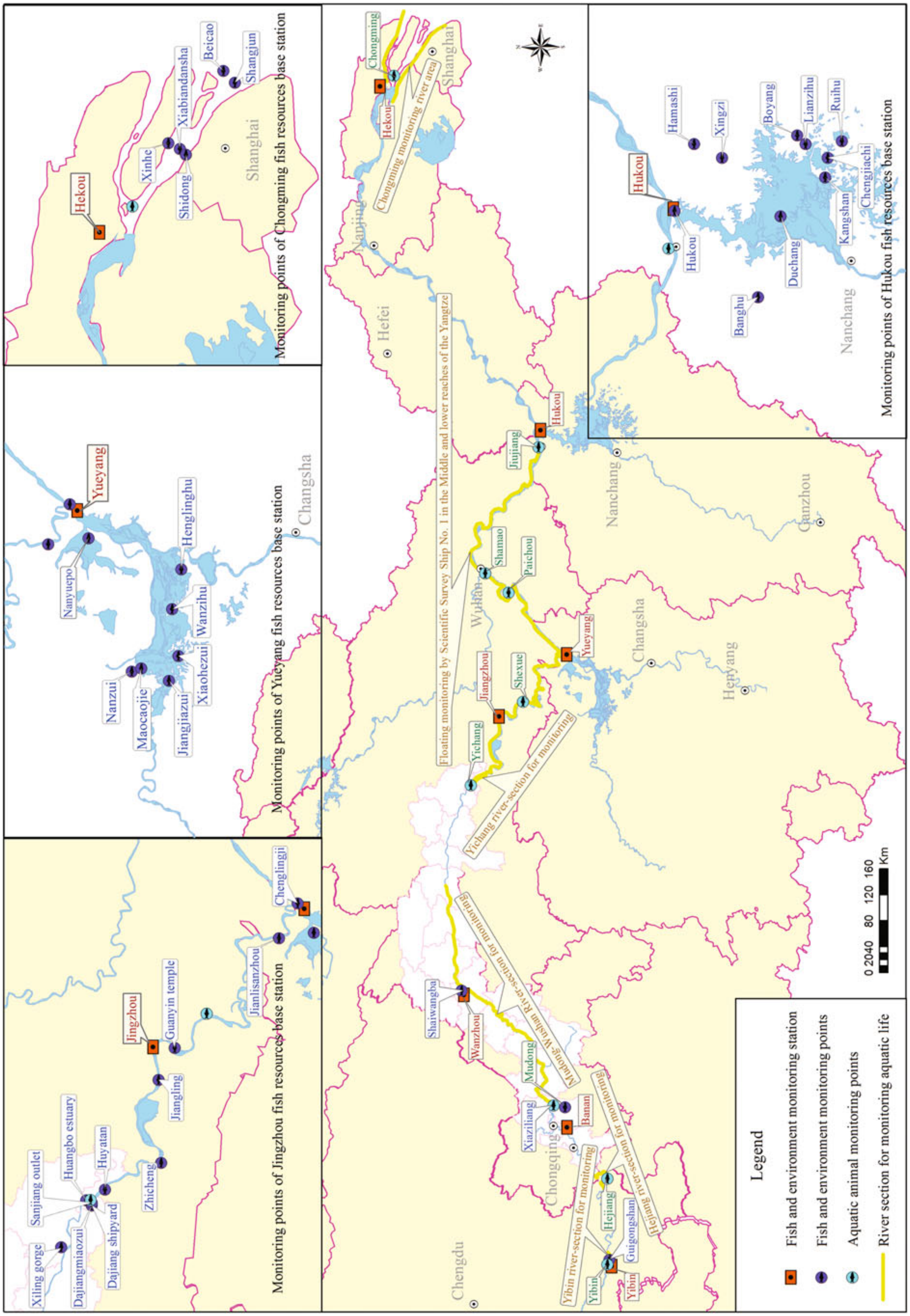


Fig. 5.3 Distribution of monitoring stations in the fish and aquatic life sub-system

For years, due to environmental evolution (such as water projects construction, water surface shrinking, and outbreak of disasters), unregulated catching, water pollution, plus the weak sense of resources protection on the part of human beings and poor management means, the fish resources of the Yangtze have been dropping steadily. The habitat of endemic species has been reduced and the number of such species has become less. Some rare species has been threatened in their survival. After the TGP, the original rapids of the reservoir area have become gentle flows, thus forcing the fish fauna to change in their composition. More than 40 species of fish have been adversely affected, of which 2/5 are of the upper stream endemic species. The seasonal changes in the runoff distribution in the middle and lower reaches have brought about many changes in the habitats of fish and other aquatic life, their reproductive grounds and spawning conditions, adversely affecting their survival and even threatening the survival of some rare species.

In view of the situation, we have set up monitoring stations to trace the endemic and rare species and the resources of fish of important economic values to accumulate scientific data and analyze the impacts of environmental changes brought about by the TGP on the structure of aquatic life fauna and the survival pressure of rare species so as to provide prompt reports and adopt prompt measures to mitigate the adverse effects and provide scientific basis for protection, management, and making laws. Long-term monitoring may reveal the movement of resources and the sustained impacts on environment and the self-regulatory abilities of aquatic life to environmental changes.

5.3.1 Fish Resources and Environment Monitoring Leading Stations

Monitoring targets and requirements

(1) Composition of fish catch, proportions of different species, and total catch

- Monitoring positions: seven points along the Yangtze, see Table 5.6.
- Monitoring indicators: Composition, ratio and catch of fish.
- Monitoring frequency: twice a month, 24 times a year (Biological monitoring of River crab (*Decapoda*), Eel and Tapertail anchovy (*Coilia mystus*) during the fishing season in the Hekou area.
- Monitoring time: on the 10th and 26th of every month.

(2) Spawning conditions and egg (fry) number of four major endemic species in the Yichang–Chenglingji section of the Yangtze.

- Monitoring positions: Jianli Sanzhou (112°55′25″ E, 29° 32′47″ N) and Guanyin Temple in Jingzhou (112°14′52″ E, 30°11′06″ N).
- Monitoring indicators: spawn (fry) generation and spawning conditions of four major endemic species.
- Monitoring frequency: 60 times in total.
- Monitoring time: once a day in May–June.

(3) Lake area, fish food base, and carp spawning ground

- Monitoring positions: Monitoring points are mainly distributed in the Dongting and Poyang lakes, see Table 5.7:
- Monitoring indicators: Lake area, foodbase, and carp spawning ground.
- Monitoring frequency: Once a year (Monitoring started from 2003 in Poyang Lake).
- Monitoring time: April 15, every year.

(4) Composition, species ratio, and amount of catch

- Monitoring positions: three points each in Dongting and Poyang lakes, see Table 5.8.
- Monitoring Indicators: Composition, ratio of species, and total catch.
- Monitoring frequency: 15 times a year (Monitoring started in Poyang Lake in 2003).
- Monitoring time: Autumn fishing season (about October 11–25).

(5) Fish water quality

- Monitoring positions: the same as for major cash fish, see Table 5.6.
- Monitoring indicators: water temperature, pH, DO, COD_{Mn}, TCu, TZn, TPb, TCd, Cr^{6+}, THg, ArOH, TP, NH_3-N, and oil.
- Monitoring frequency: three times a year.
- Monitoring time: Reproductive period, recruitment period, and wintering period every year.

Table 5.6 Monitoring points of major cash fish in the Yangtze

Name	Position	East longitude	North latitude
Yibin	Guangongshan	104°42′50″	28°47′30″
Banan	Xiaziliang	106°49′30″	29°24′28″
Wanzhou	Saiwangba	108°26′15″	30°50′03″
Jingzhou	Guanyin Temple	112°14′52″	30°11′06″
Yueyang	Sanjiangkou	113°08′18″	29°25′17″
Hukou	Dukou	116°12′01″	29°44′48″
Hekou	Hengsha	121°10′–122°30′	31°10′–31°35′

Table 5.7 Monitoring positions of lake area fishing grounds

Lake	Monitoring point	East longitude	North latitude
Dongting Lake	Sanjiangkou	113°08′18″	29°25′17″
	Nanyuepo	112°57′14″	29°19′28″
	Wanzihu	112°28′11″	28°05′42″
	Henglinghu	112°47′12″	28°49′27″
	Jiangjiazui	112°11′53″	28°53′25″
	Xiaohezui	112°19′36″	28°50′10″
	Nanzui	112°14′30″	29°05′42″
	Maocaojie	112°15′05″	29°02′05″
Poyang Lake	Dukou	116°12′01″	29°44′48″
	Duchang	116°10′48″	29°06′30″
	Poyang	116°39′12″	29°00′48″
	Ruihu	116°37′01″	28°44′12″
	Hamoshi	116°36′12″	29°37′12″
	Xingzi	116°31′24″	29°27′12″
	Kangshan	116°24′01″	28°50′01″
	Lianzihu	116°36′02″	28°57′48″
	Chengjiahu	116°31′01″	28°49′02″
	Benghu	115°41′02″	29°14′48″

Table 5.8 Monitoring positions for fish catch in the lake area

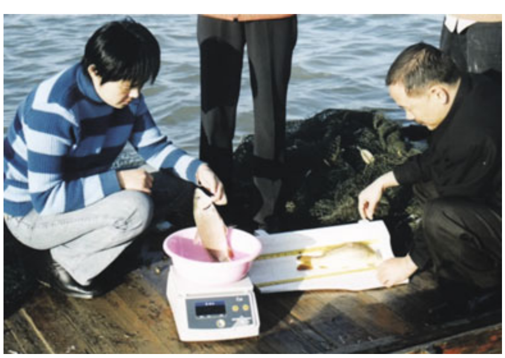
Lake	Monitoring point	East longitude	North latitude
Dongting lake	Nanyuepo	112°57′14″	29°19′28″
	Wanzihu	112°28′11″	28°05′42″
	Jianjiazui	112°11′53″	28°53′25″
Poyang Lake	Duchang	116°10′48″	29°06′30″
	Poyang	116°39′12″	29°00′48″
	Ruihu	116°37′01″	28°44′12″

Monitoring units (1996–2003)

The leading station is set at the Office of Yangtze Fishery Resources Committee (YFRC), with base stations in Yibin, Banan, Wanzhou, Jingzhou, Yueyang, Hukou, and Estuary.

Fishing boats on the Dongting lake, a major feeding ground or fishing place of Yangtze economic fishes

A banned traditional fishing tool, named Mihunzhen, trapping all sized fish by encircling gear



Biological measuring of fish

Collecting egg or fry of four major endemic species

Water sampling in fishing area

Pretreatment of water samples

5.3.2 Main Monitoring Station of Fish and Rare Aquatic Animals

Monitoring targets and requirements

(1) Monitoring scope

The mainstream section is from the lower Jinsha River to Chongming Island.

(2) Distribution of monitoring stations

- Lower reach of the Jinsha River (Yibin)
  - Monitoring targets: Number of population and natural reproductive conditions of Dabry's strugeon, China paddlefish and Chinese Sucker and local endemic species.
  - Time and frequency: March–May, September–October; 10 days a month.
- Middle section (Hejiang) of the upper reach of the Yangtze
  - Monitoring targets: composition, number of population, and natural reproductive conditions of local endemic species; resources of Dabry's strugeon, China paddlefish.
  - Time and frequency: March–May, September–October; 10 days a month.
- Reservoir area (Mudong–Wushan)
  - Monitoring targets: Composition, population, and natural reproductive conditions; resources of Dabry's strugeon, China paddlefish and Chinese Sucker.
  - Time and frequency: April–June, September–November, 10 days a month.
- Section (Yichang) downstream of Gezhouba
  - Monitoring targets: Number of population and natural reproductive conditions of Chinese strurgeon, Chinese paddlefish and Chinese Sucker.
  - Time and frequency: March–May, October–November, depending on bycatch and reproductive conditions.
- Middle and lower reaches of the Yangtze (Scientific Survey Ship No. 1)
  - Monitoring targets: Population of Baiji (Chinese river dolphin), Finless porpoise, composition of species, number and quality of early resources of rare fish, and four major endemic species.
  - Time and frequency: May–August, repeating every day. Information summation is filed once every 3 years for Baiji dolphin and Finless porpoise.
- Yangtze River mouth (Chongming)
  - Monitoring targets: Resources of young Chinese sturgeon and Chinese paddlefish.
  - Time and frequency: May–September, depending on miscatch.

(3) Monitoring indicators:

- Resources Status: Composition and distribution of species, relative ratio in number of different species, relative ratio in weight, range of change in length and weight and age structure; ratio in number and absolute amount of early resources of different species, composition, distribution of early resources, sex ratio, minimum sex maturity, fecundity and reproductive season of different species, the number and eating-lasting duration of egg-eating fish, ratio of the number and composition of egg-eating fish aimed at Chinese sturgeon spawning, ratio of artificially released young Chinese sturgeon in the Yangtze mouth, number of Chinese sturgeon detected by sonar; observation number of Baiji and Finless porpoise.
- Utilization of resources: Investigating types and number of fishing gears; catch per unit of effort by different fishing gears; miscatch amount and bycatch ratio of fish banned.
- Environment: Investigating topography and terrain of surrounding areas; climate, water temperature, velocity, substrate, clarity, pH, DO, and water level (water depth).

Monitoring organizations (1996–2003)

The leading station is set in the Institute of Hydrobiology of the Chinese Academy of Sciences, with six base stations (including Survey Ship No. 1).

Statistical catches at Hejiang station

Tools for measuring length and weight of catches

Dissecting egg-eating fish—Bronze gudgeon and Largemouth bronze gudgeon, an indirect method for measuring eggs of the Chinese sturgeon

Conical net used in early resource survey

Filtering fry barrel used in early resource survey

Fishing boats in anchor in Yichang

Part of photos of monitoring stations of fish and rare aquatic animals

Fishing net

Bait fishing gear

Drift net

Part of fishing gears used in the upper reaches of the Yangtze

5.4 Terrestrial Animal and Plant Sub-system

The terrestrial animal and plant sub-system has one leading monitoring station as is shown in Fig. 5.4. The experimental station in Xingshan County of Hubei Province undertakes monitoring of terrestrial plant diversity. The sub-system is targeted at changes in terrestrial animals and plants caused by the TGP for the purpose to know the time and spatial laws governing the changes in the ecosystem of the reservoir area before and after impoundment and also for the purpose

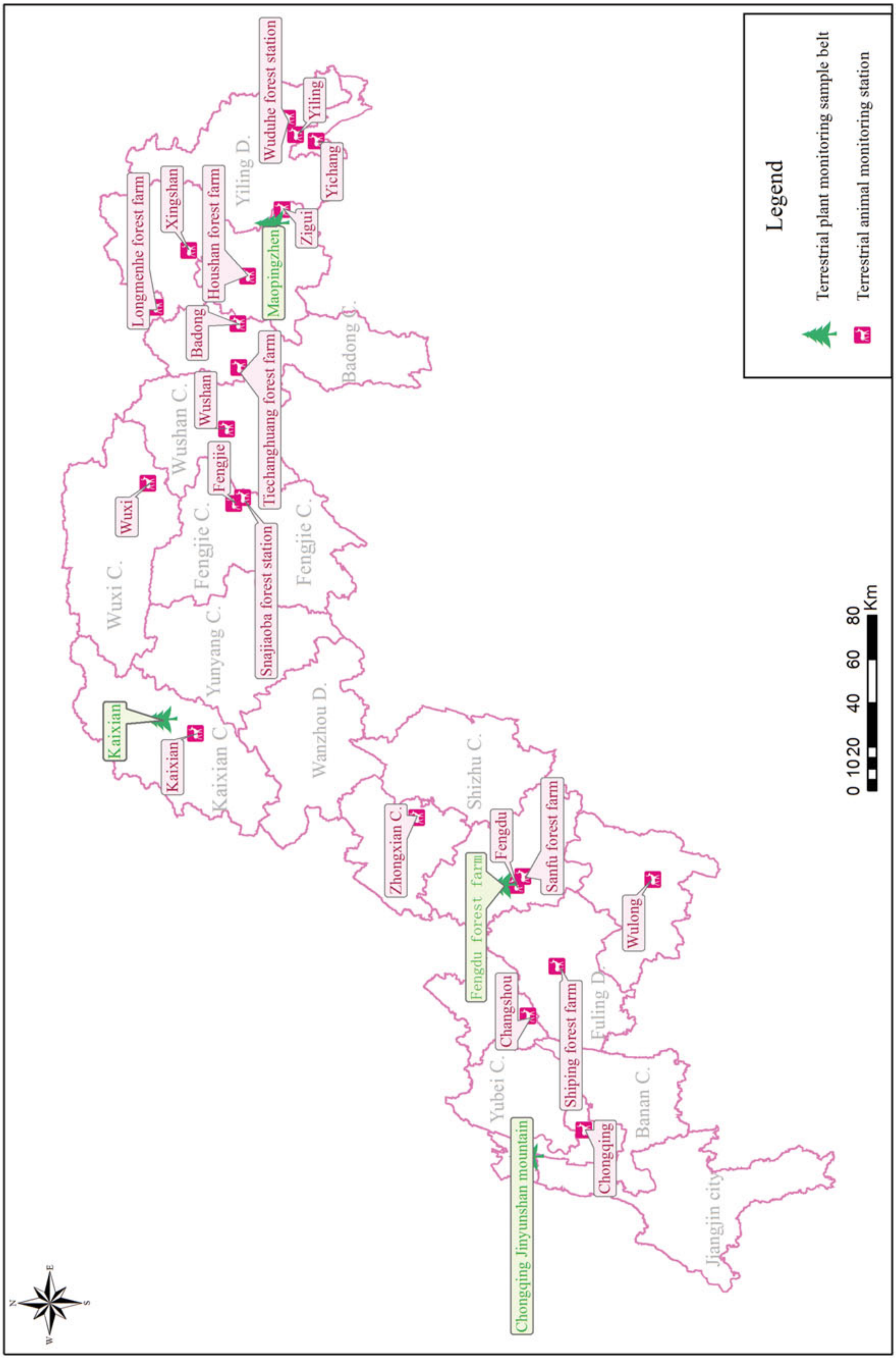


Fig. 5.4 Distribution of monitoring stations in the terrestrial animal and plant sub-system (including layout of monitoring sample belt)

Hardworking field surveyors having a lunch break

Drafting of a sketch of vegetation in the field

China yew (*Taxus wallichiana var. chinensis*) under state first class protection

Silver fir, under state first class protection

Besta sparrow hawk (*Accipiter virgatus*)

Spotted dove (*Streptopelia chinensis*)

of providing the basis for future environmental impact review and assessment, verification and review of assessment results, and for the construction, supervision and management of the environment in the reservoir area. The monitoring results will yield corresponding protection measures so as to make the project more favorable and mitigate adverse impact.

5.4.1 Monitoring Targets and Requirements

Scope of monitoring

Monitoring covers 20 districts (counties, cities) covering a total area of 55,000 km^2 in the reservoir area (actually inundated), with emphasis on areas below an elevation of 175 m and resettlement area possibly affected (an area above the elevation of 175 m and below 800 m) as well as intending island areas of Fuling, Yuyang, and other areas likely to be inundated in the future.

Distribution of monitoring stations

Base stations within the monitoring area are required to do routine monitoring and fill in survey table about animals and plants. More than 140 pieces of fixed sample blocks for terrestrial plants have been set up. In addition, four plant monitoring sample belts and 19 fixed survey sample lines for terrestrial animal survey, 18 random survey lines and 48 random survey points have been set up in Chongqing's Jinyunshan, Fengdu's Siping Forest Farm, Zigui's Maoping Town, and Kaixian.

Monitoring indicators

(1) Terrestrial plants

- Main plant species, regional flora area, distribution, including main species composition, elevation, gradient, gradient position, topography, amount or coverage of major species in the sample monitoring area and belts, species and distribution of resource plants, rare and endangered plants and endemic plants in the reservoir area as well as species, amount and distribution of ancient and famous trees.
- Terrestrial plants below 175 m, with emphasis on endemic species and typical population affected by the dam and activities of people relocation.

(2) Terrestrial animals

- Species, distribution, and habitat of terrestrial animals.
- Species and habitat of major rare and endangered species as well as the amount and distribution of such major species as Snub-nosed monkey (*Rhinopithecus roxellanae*), Francois'langur (*Presbytis francoisi*) and black bear (*Ursus thibetanus*).
- Water fowl species and number in the process of the changes in the wetland before and after impoundment.

(3) Time and frequency

From January 2001 to December 2003, all the targets before the reservoir impoundment, monitoring of terrestrial plans was done in every growing season. Monitoring of terrestrial animals was done mainly in spring and winter. Monitoring and survey of water fowls were done mainly in the winters from December 2001 to January 2002 and from December 2002 to January 2003.

Setting up fixed monitoring and survey sample lines and blocks, all-round monitoring once every 2 years and all-round monitoring once every year. If necessary, sample lines and sample blocks may be added or extended.

5.4.2 Monitoring Units (1996–2003)

The Ecological and Environmental Monitoring Center, SFA, is the main station, with base stations to be set up by administrative departments under the Chongqing Forestry Department (Science and Technology Division) and Hubei Forestry Department (Afforestation Division), which will be responsible for routine monitoring and coordination.

5.5 Local Climate Sub-system

This sub-system has one leading station, which undertakes regular monitoring and vertical monitoring, as is shown in Fig. 5.5. The sub-system selects representative points to monitor air temperature, humidity, precipitation, evaporation, and sunshine hours in order to get full information about the basic climate of the area, which can serve as the basis for analyzing the impact of wider water surface and higher water level after the reservoir is completed on the local climate and provide services for the TGP project, reservoir area ecological restoration and rational utilization of climatic conditions for resettlement by development.

5.5.1 Regular Monitoring

Scope of monitoring

Mainly it is the reservoir area, with emphasis on (within a radius of a dozen kilometers) where TGP has clear impact.

Climate is a very complicated natural phenomenon. Apart from the impact brought about by the reservoir, the large-measure climate itself also changes. In order to analyze the climatic changes before and after the reservoir is built, it needs comparative observation by a number of meteorological stations.

Distribution of stations

The existing meteorological stations along the reservoir banks have been made the basic stations, with an additional base station built near the construction site.

There are 12 local climate base stations, of which ten sets around the reservoir. They are Chongqing, Changshou, Fuling, Wanzhou (Longbao), Fengjie, Wushan, Badong, Zigui, Bahekou, and Yichang. The first six are within the territory of Chongqing Municipality and the last four are in Hubei Province. Six are in the industrially developed Chongqing, Fuling, Wanzhou, Fengjie, Badong, and Yichang for regular monitoring and acid rain monitoring. Liangping and Enshi on the northern bank of the Yangtze some distance from the reservoir have been selected as contrast stations. The distribution of the stations is shown in Table 5.9.

Monitoring and statistical indicators

Monitoring indicators include air pressure, temperature of the maximum, minimum and the mean, relative humidity, wind velocity, wind direction, precipitation, evaporation, sunshine hours, weather phenomena (fog and thunderstorm), pH, and conductivity of natural rainfall.

Statistical indicators are monthly average air pressure, mean temperature, average highest temperature, average lowest temperature, average relative humidity, average wind velocity, frequency of wind directions, precipitation, evaporation, sunshine hours, foggy days, thunderstorm days, mean pH of rainfall, and average conductivity of rainfall.

Monitoring frequency and time

According to the requirements of Ground meteorological observation standards, observation is done regularly at 2:00, 8:00, 14:00, and 20:00 h every day. Collection of basic meteorological factors started in 1996 and the collection of data on pH and conductivity of natural rainfall started in 1997.

5.5.2 Vertical Climate Monitoring

Objectives of observation

Two representative river course cross-sections were selected for vertical monitoring with hope of carrying out research of the local climate, before and after impoundment of the reservoir by using climatic statistic methods and local climate model on the basis of data accumulation, to simulate the local climate effect of the reservoir water body so as to provide scientific basis for the development and utilization of the natural resources and ecological protection.

Targets of observation and technical indicators

(1) Position selection[1]

Yichang cross-section has ten ground observation points from Yichang to Zigui east of the reservoir including Tanziling, Sandouping, Sujiaao (as the low altitude observation point), Zigui, Xiaoxita, Changyang, Xingshan, Shennongjia, Yidu, and Yemuping.

[1]The site selection for monitoring points is an initial plan. The ultimate choice of monitoring points should be fixed according to the report after investigations and discussion.

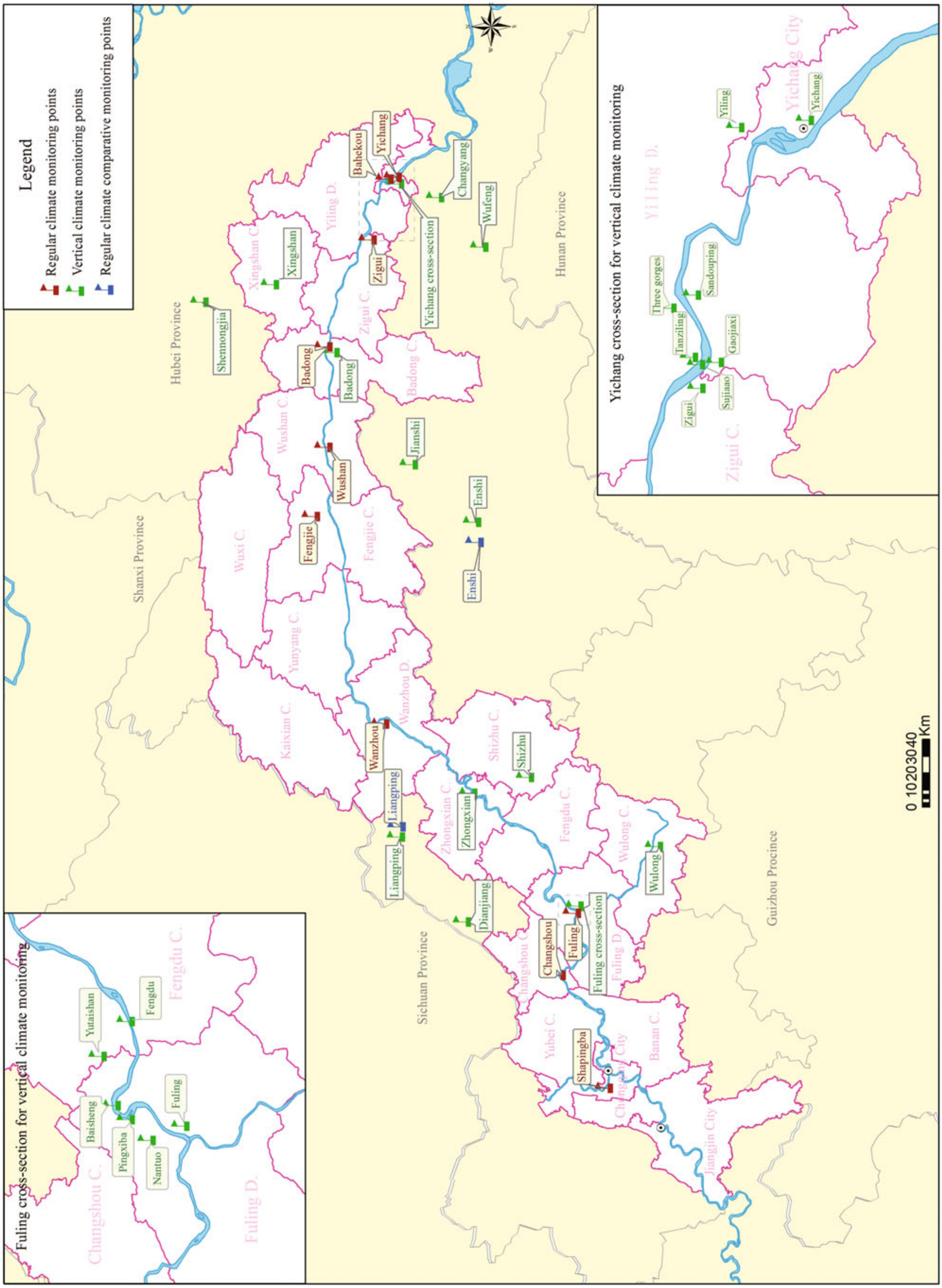


Fig. 5.5 Distribution of monitoring stations in the local climate sub-system

Table 5.9 Distribution of local meteorological base stations

Name	Position	Starting time	Monitoring target
Shapingba	Shapingba District, Chongqing	1996	For all stations: Air temperature and humidity, wind direction, and velocity and sunshine hours, precipitation, evaporation, air pressure, weather phenomena, observing at 2:00, 8:00, 14:00, and 20:00 h every day Shapingba, Fuling, Wanzhou, Fengjie, Badong, and Yichang stations monitoring pH of acid rain, one sample for every rainfall (Starting from 1997)
Changshou	Changshou District, Chongqing	1996	
Fuling	Fuling District, Chongqing	1996	
Wanzhou	Wanzhou District, Chongqing	1996	
Fengjie	Fengjie County, Chongqing	1996	
Wushan	Wushan County, Chongqing	1996	
Badong	Badong County, Hubei Province	1996	
Zigui	Zigui County, Hubei Province	1996	
Yichang	Yichang City, Hubei Province	1996	
Bahekou	Bahekou, Yichang City, Hubei Province	1996	
Liangping	Liangping County, Chongqing	1996	
Enshi	Enshi City, Hubei Province	1996	

Fuling cross-section has 11 ground observation points on the plain area (near Fuling) west of the reservoir area, including Zhongxian, Shizhu, Wulong, Dianjiang, Fengdu, Fuling, Liangping, Pingxiba (as the low altitude observation point on Island in the river), Baisheng, Nantuo, and Yutaishan.

(2) Weather observation indicators

For all the ground observation points, they are air temperature, humidity, wind direction, wind velocity, precipitation, weather phenomena (fog and thunderstorm); for part of the stations, air pressure, evaporation, sunshine hours, and geo-temperature are added (for details, see Table 5.10).

(3) Observation time

Daily observation was carried out in July and October 2002, January and April of 2003 before the reservoir was impounded (2003). Observation frequency: 8 times a day on ground weather observation; twice a day on low altitude observation. The observation time is the same as the regular weather stations.

5.5.3 Monitoring Organizations (1996–2003)

The leading station is set at the National Climate Center, CMA, with 12 regular monitoring base stations.

Table 5.10 Plan for the distribution of automatic weather stations for vertical observation

Cross	Name	Position			Targets of observation for automatic weather stations
		Elevation (m)	East longitude	North latitude	
Yichang, Hubei	Tanziling	300	111°00′	30°49′	Air pressure, temperature, humidity, wind velocity, wind direction, and precipitation
	Sandouping	340	111°03′	30°49′	
	Zigui	200	110°41′	31°00′	
	Xiaoxita	280	111°19′	30°46′	
	Changyang	144	111°11′	30°28′	
	Xingshan	275	110°47′	31°19′	
	Shennongjia	937	110°40′	31°45′	
	Yidu	100	111°27′	30°23′	
	Yemuping	1200	110°56′	30°49′	
	Sujiaao, Yichang	300	110°59′	30°51′	With altitude observation, geo-temperature, evaporation, and sunshine hours added
Fuling, Chongqing	Zhongxian	232	108°02′	30°18′	Air pressure, temperature, humidity, wind velocity, wind direction, and precipitation
	Shizhu	569	108°07′	30°00′	
	Wulong	406	107°45′	29°19′	
	Dianjiang	418	107°21′	30°20′	
	Fengdu	214	107°41′	29°52′	
	Liangping	454	107°48′	30°41′	With geo-temperature added
	Fuling	274	107°25′	29°45′	
	Baisheng	354	107°29′	29°54′	Temperature, humidity, wind velocity, wind direction, and precipitation
	Nantuo	300	107°24′	29°49′	
	Yutaishan	810	107°36′	29°56′	
	Pingxiba (Island)	185	107°27′	29°52′	With altitude observation, geo-temperature, evaporation, and sunshine hours added

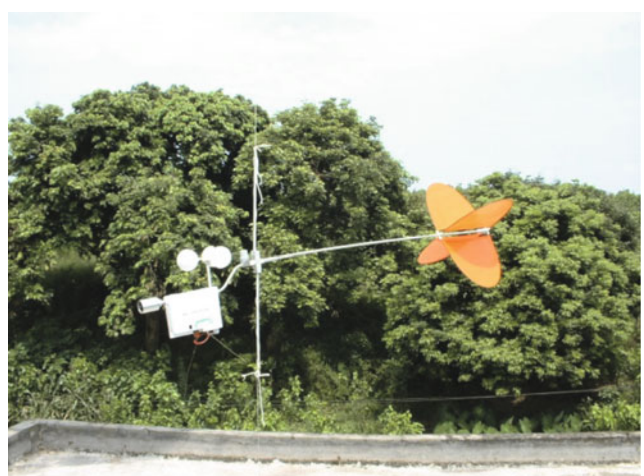
Exchanging experience at major station

Yichang station, one of the base stations

Irradiation observation meter

Evaporation observation instrument

Air probe balloon



Weather monitoring

Regular weather observation

Observation plan under scrutiny

Tanziling automatic monitoring station


Sandouping observatory

Letianxi sounding radar


Gaojiaxi sounding radar

Pingxiba (island) observation station

Vertical climatic observation

5.6 Agro-Ecology and Environment Sub-system

This sub-system has one leading station as is shown in Fig. 5.6 to collect data and study the TGP impact, especially, on resettlement of the displaced people in terms of agricultural ecology and environment and agricultural production, as the basis for policy decision taking that will protect and improve the ecology and environment in the reservoir area and promote a sustainable development of agricultural production.

5.6.1 Monitoring Targets and Requirements

Monitoring targets

They include survey of the cropping system and crop structure around the reservoir area, plant diseases and pests, Rodent infestation and the harm to be done, rural energy structure, agro-diversity in the inundated area, the use of farm chemicals and fertilizers, and soil baseline materials monitoring.

Distribution of monitoring stations

The leading station is in Hubei Province;

The base stations are Chongqing, Wanzhou (Tiancheng), Badong, Yichang, and Honghu;

The ordinary stations are Jiangjin, Banan, Yubei, Changshou, Wulong, Fuling, Fengdu, Shizhu, Kaixian, Zhongxian, Yunyang, Fengjie, Wushan, Wuxi, Badong, Zigui, Xingshan, Yiling, and Jingzhou.

Scope of monitoring

It covers Jiangjin, Banan, Yubei, Changshou, Wulong, fuling, Fengdu, Shizhu, Kaixian, Zhongxian, Wanzhou (Tiancheng), Yunyang, Fengjie, Wushan, Wuxi, Badong, Zigui, Xingshan, and Yiling, totaling 19 districts (counties and cities), 194 townships.

Monitoring indicators:

(1) Cropping system and crop structure
(2) Plant diseases and pests, rat infestation, and the harms done. They are areas infested by rice blast, rice borer, late blight of potato, corn blight, leaf blight and leaf spot and rats, areas under control, disastrous areas, output, and economic losses.

(3) Rural energy structure survey

They are average number and distribution of biogas pits per household, and the total number in rural areas and firewood forest areas and the total number.

(4) Agro-diversity of the reservoir area

They are species, distribution and growing areas, cropping system, output of farm crops (especially rare and endemic species) and soil, weather and other environmental factors.

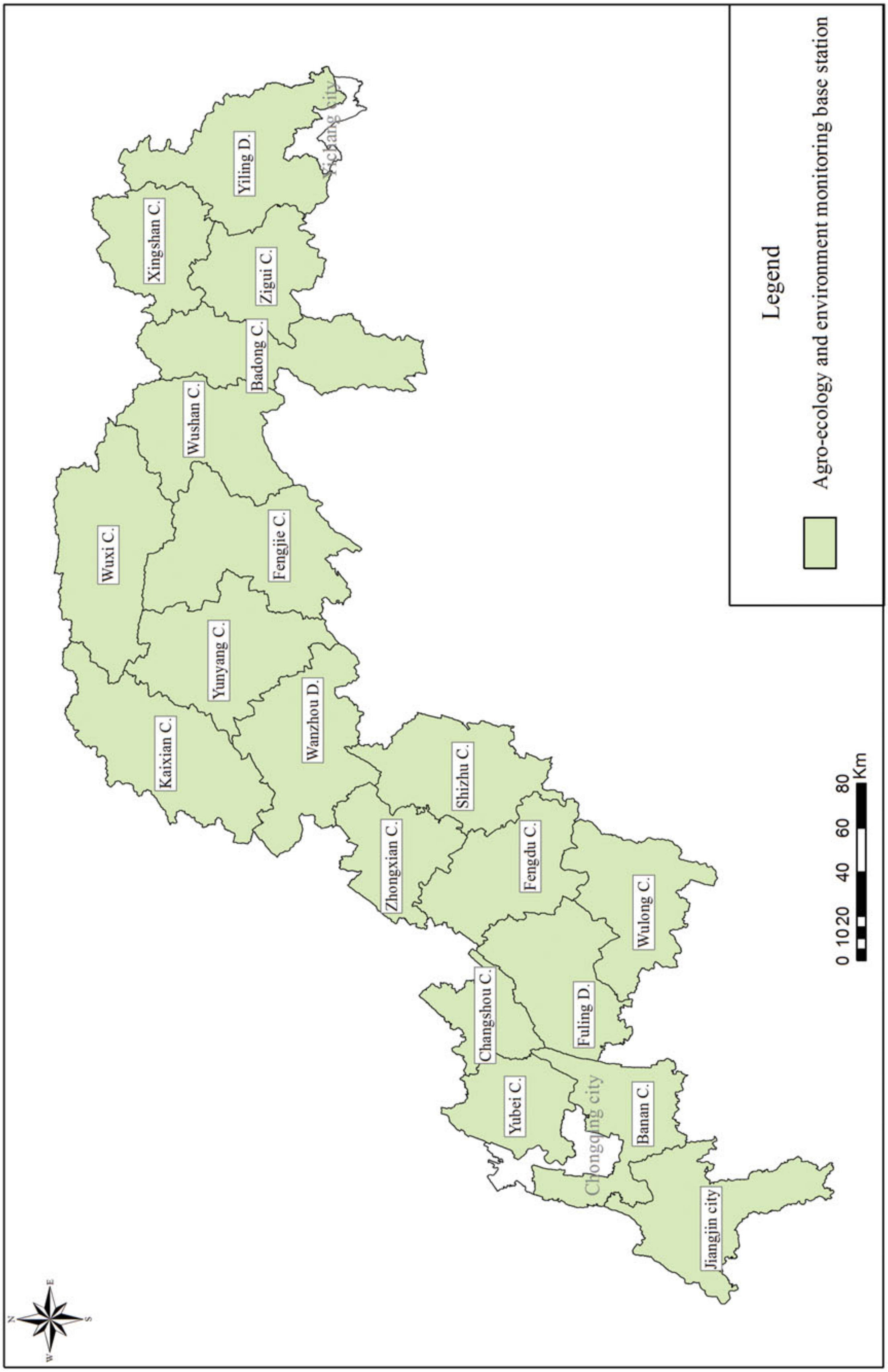


Fig. 5.6 Distribution of monitoring station of the agro-ecology and environment sub-system

(5) Farm chemicals and fertilizers application

They are total amount use and average application per unit of farm chemicals and fertilizers; and the total area, types and the folding purity of farm chemicals and fertilizers used.

(6) Soil baseline materials collection

They are total phosphate, total nitrogen, total potassium, base hydrolyzable N, fast-acting phosphate, fast-acting potassium, copper, zinc, lead, cadmium, mercury, arsenic, methamidophos, isocarbophos, dichlorvos and dimethoate.

Monitoring time and frequency

Agro-diversity monitoring was completed in May 2001–December 2002. For other indicators, monitoring is carried out once a year, in October.

5.6.2 Monitoring Organizations (1996–2003)

The Hubei Provincial Agro-Ecology and Environment Protection Station is the leading station and under it there are five base stations and 19 ordinary stations.

5.7 Estuary Ecology and Environment Sub-system

This sub-system has one leading station as is shown in Fig. 5.7. It undertakes to carry out dynamic monitoring and systematic analysis of the salt contents in the ecology and environment of the Yangtze estuary area and determine the scope of the salt dynamic changes and soil salination in the area and find out the laws governing the salt content dynamic changes and seasonal changes before and after the

Annual meeting of agro-ecology and environment major monitoring station dam construction. It monitors and surveys at fixed time and fixed points a number of factors of ecology and environment and biological resources systems in the estuary and the coastal areas and gives objective assessment of the impacts of the TGP on the eco-diversity and sustainable utilization of biological resources in the area.

5.7.1 Monitoring Targets and Requirements

Soil salination in the estuary area

(1) Monitoring targets

They include background survey and analysis of the surface and underground water and salt content in soil, monitoring of the typical river sections near the estuary and underground water and salt contents; monitoring of the law governing dynamic changes of salt contents in soil of typical sections in the estuary area; tracking survey and monitoring of soil evolution characteristics of typical and sensitive areas in the estuary.

(2) Scope of monitoring and distribution of monitoring stations

There are three monitoring cross-sections in the northern part of the Yangtze mouth, two on the northern bank and one on the southern bank. The three cross-sections are situated in the Yinyang Town, Daxing Township, and the Xinglongsha Township agricultural breeding farm in Qidong City, Jiangsu Province. The Yinyang cross-section is 4 km from the river mouth, Daxing, 22 km and Xinglongsha, 35 km. In order to make them align in a straight angle with the river dyke and parallel with main inland waterways, each cross-section has three monitoring points from south to north (for Xinglongsha, from north to south), which are 200, 500, and 1000 m from the river dyke. All the nine monitoring points are installed with six groups of salt content transducers at depths of 10, 20, 40, 60, 80, and 120 m. Three groups of tensile meters are installed at depths of 20, 50, and 100 cm. The observation wells of ground water level and quality are installed at a depth of about 200 cm.

(3) Monitoring indicators and frequency

Monitoring indicators include water quality of the northern mainstream of the Yangtze and near the inland river sluice gates, soil conductivity (six measuring depths for each point) in the three monitoring points, soil negative pressure (3 measuring depths for each point), underground water table, and conductivity.

The indicators for all cross-sections are the same in number and date. The measuring cycle is five days, namely, 5th, 10th, 20th, 25th, and 30th of every month (28th or 29th in February).

Water samples for measuring water quality are collected at a place at least 200 m north of the inland river sluice gates (south in Xinlongsha); samples are collected from the river side at the cross-section to measure the water quality of the Yangtze; underground water samples are collected for measuring the underground water level; measurement is also done on soil conductivity; soil salt contents are monitored regularly; soil negative pressure is gauged at three layers. Besides, meteorological data and Yangtze water level data are also collected.

Estuary environment and fish resources

(1) Monitoring targets

They include hydrophysical environment, hydrochemistry environment, major biological environment, fish resource structure, dynamic changes of economic species and their ecological indices; the building of comprehensive experimental data for the estuary environment and fish resources.

(2) Scope of monitoring and distribution of monitoring stations

Monitoring scope covers 121°10″–123°30″ east longitude, 30°45″–32°00″ north latitude. Samples for environmental indicators should be collected from no less than 30 observation points. Sampling of trawler net should be collected from no less than 15 observation points.

(3) Monitoring indicators

- Hydrophysics: temperature, salt content, water depth, transparency, water color, frontal surface, and cross layer.
- Sediment environment: SS.
- Hydrochemistry: PO_4-P, SiO_3-Si, NH_3-N, NO_3-N, NO_2-N, total salinity, TON, granulated organic carbon, pH, DO, COD, BOD, TN, and TP.
- Chlorophyll a and primary productivity.

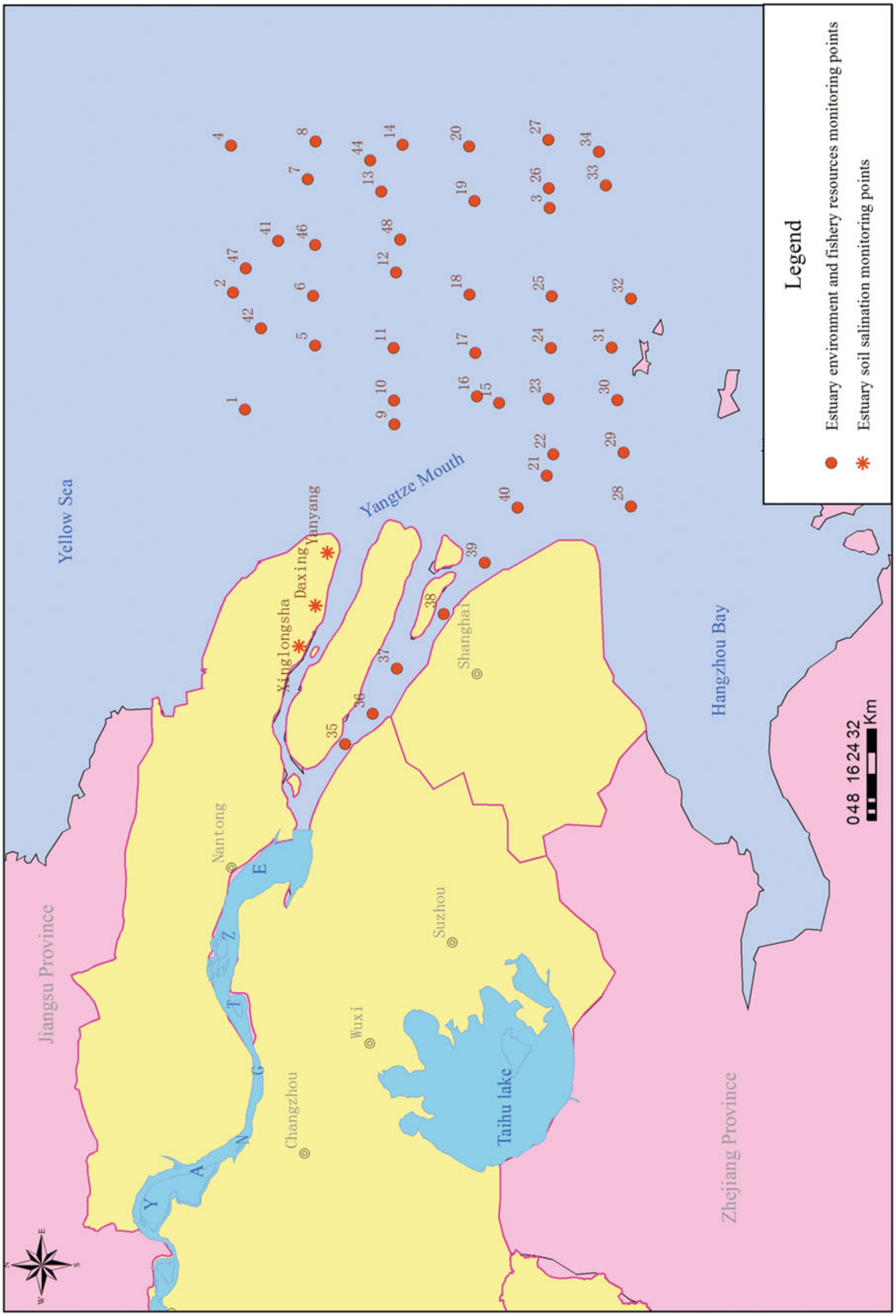


Fig. 5.7 Distribution of monitoring points of the Yangtze estuary ecology and environment sub-system

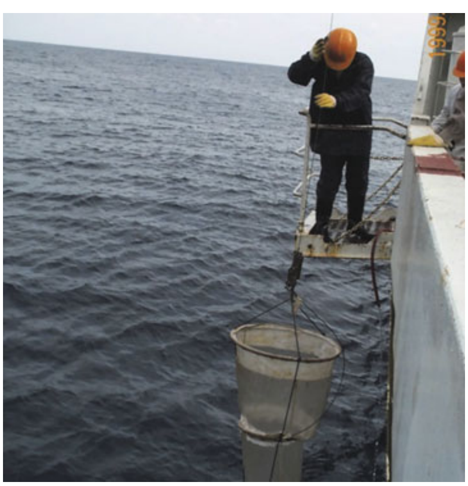
- Planktons (plant and organisms).
- Fish-type planktons (egg, larve and juvenile).
- Benthos.
- Necton [fish, Shrimp (*Decapoda*) and Crab (*Decapoda*)].

(4) Monitoring frequency: It is once every year, in May or November.

5.7.2 Monitoring Organizations

The leading station is set up in the Institute of Oceanography, CAS, with the Institute of Soil Science, CAS, as the main cooperation partner. The CAS Institute of Oceanography undertakes monitoring, experiments and survey of the environment and fish resources in the offshore waters and the Institute of Soil Science undertakes the monitoring and experiments of salination on the boundary of land and sea.

Offshore survey



Sampling

Dissection analysis

Monitoring point for soil salination

Maintenance of soil salination monitoring point

Rape (*Brassica napus*) field soil sampling

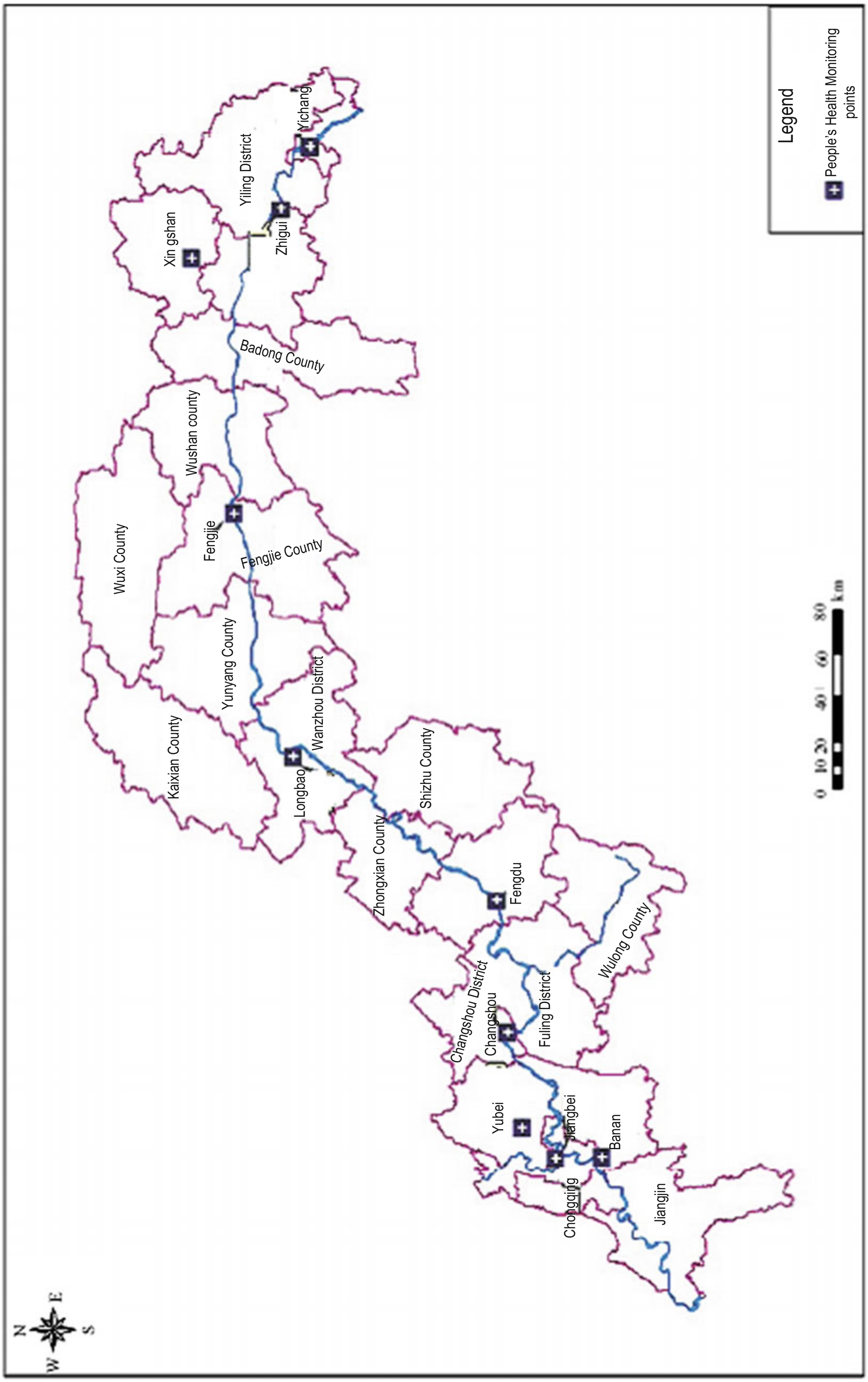


Fig. 5.8 Distribution of people's health monitoring sub-system

5.8 People's Health Sub-system

This sub-system has one leading monitoring station as is shown in Fig. 5.8. The purpose is to prevent and control the outbreak and spreading of major communicable and endemic diseases, assess the impact of TGP on health of the people and provide scientific basis for taking policy decisions.

5.8.1 Monitoring Targets and Requirements

Scope of monitoring

There are four monitoring points at the dam site and in the reservoir area and nearby resettlement centers, that is, Jiangbei District, Banan District, Yubei District and Changshou District, Wanzhou District (Longbao), Fengdu County of Chongqing and Yichang City (Xingshan County, Zigui County, and Yiling District of Hubei Province, each point covering a population of about 100,000. According to the monitoring project interval assessment and expert proposals, the Yichang monitoring point was adjusted starting from 2001, replacing Sandouping and Letianxi in the Yiling District by the Dam area and Shizhenxi of Zigui County. It was planned to add Fengjie County of Chongqing to the list, because of the technical conditions and the size of population, which is 21,000, with 20,000 resettled people. For details, see Table 5.11.

Monitoring targets and requirements

(1) General materials

- Basic materials
  Identified the county as a unit, they are information on Gross National Product (GNP), per capita income, urban and rural population, to be obtained from local governments or statistical departments.
- Population
  - population: total population, including, births, deaths and migrants and immigrants, at the beginning of a year, to be obtained from the local police stations, in categories of the annual's total age, sex, and predictions of the following year.
  - Birth: Annual number of births covers time from January 1 to December 31. The newborn list can be got from the police station and from hospitals or maternal and child care monitoring points.
  - Death: Annual number of deaths refers to deaths from January 1 to December 31. The monthly list can be copied from the local village health centers; calculation should include age-group-specific deaths, causes of death (according to international classification ICD-9).
- Health organizations and staff members
  They can be obtained from local health departments, with inpatient beds, staff members listed at county, township, and village levels.

(2) Disease monitoring

- Communicable diseases: 35 communicable diseases, classified in A, B, C types, including pestis, cholera, virus hepatitis, dysentery, typhoid fever, paratyphoid fever, AIDS, clap, syphilis, polio, measles, whooping cough, epidemic cerebrospinal meningitis, scarlet fever, epidemic hemorrhagic fever, rabies, leptospirosis, Brucellosis, anthrax, typhus fever, encephalitis B, black fever, malaria, dengue fever, TB, Snail fever, filariasis, echinococcosis, leprosy, flu, mumps, rubella, acute hemorrhagic conjunctivitis (AHC), and infectious diarrhea.
  Materials to be collected should include reports on communicable diseases produced by medical organizations and private practitioners; reports on infectious diseases A, B, and C discovered by medical organizations in the monitoring points; epidemic situation of monitoring points in epidemic reports collected from the county health and anti-epidemic stations. Monthly reports by village health centers; monthly epidemic reports by hospitals; epidemic left out in the hospital reports.
- Endemic diseases: Survey is of endemic goiter, endemic fluorine deficiency and paragonimiasis within the monitoring points. For endemic goiter and endemic fluorine deficiency, 400 primary and middle school students from one or two schools are selected for monitoring, once a year.
- Serology monitoring: Antibody serum examination is carried out among people susceptible to encephalitis B, leptospirosis, and epidemic hemorrhagic fever in July and at the beginning of September every year, dividing into three age groups (7～, 15～, and 30～). Targets are randomly selected according to statistical science, with no less than 50 people in one age group, once every 2 years.

(3) Biological vector monitoring

- Rat monitoring
  - Rat catching once in April and September every year, between 10th and 20th.
  - Points for rat catching should be fixed. If change is necessary, they should be situated near original monitoring points, with all the conditions similar to the original monitoring points.
  - Rats shall not be preserved after lab tests, but specimens may be preserved for the record in special circumstances.
  - Rat catching rate should be made the indicator for rat density. Rat density = (number of rats caught/effective clips) $\times$ 100%.

Table 5.11 Coverage of people's health monitoring points

Base stations	Monitoring point resident county	Township, town and neighborhood covered by the monitoring points	Population (10,000)	Resettled population	Notes
Yichang	Xingshan	Jianyangping	1.00	500	
	Zigui	Guojiaba	3.62	10,200	
		Shazhenxi	3.99	20,000	
	Yiling	Dam area	2.50	Construction site	
	Subtotal		11.11	30,700	
Wangzhou	Longbao	Gaofeng Town	2.18	1370	
		Longbao Town	2.02	1428	66,158 people relocated in
		Baiyan neighborhood	3.65	–	
		Sipai neighborhood	3.99	–	
	Subtotal		11.84	2798	
Fengdu	Fengdu	Mingshan Town	6.92	40,792	
		Shuanglu Township	1.08	627	
		Huinan Township	2.28	1937	
		Zhanpu Town	1.06	734	
	Subtotal		11.34	44,090	
Chongqin	Jiangbei district	Dashiba neighborhood	4.83	0	
	Changshou District	Jiangnan Town	1.38	476	
		Shantuo Township	0.78	422	
	Yubei district	Luoji Town	2.53[a]	1873	
	Banan district	Yudong Town	2.92[a]	2077	
	Fengjie	Wansheng Township	2.13	20,103	
	Subtotal		14.57	24,951	
	Sum total		48.86	102,539	

[a]The actual monitoring population

- Mosquito monitoring
  - Monitoring time is May–August every year, once in the former half and once in the latter half of a month, 6th–10th days and 20th–24th days in the month.
  - Mosquito catching points should be fixed. If changes are required, the new points should be as near the original points as possible, with all the conditions similar to the original points.
  - Mosquitoes should be identified: culex pipiens pallens, Southern house mosquito (*Culex quinquefasciatus*), *Culex tritaeniorhynchus*, *Anopheles hyrcanus*, *A. obturbans* and, for other species, they may be accounted together.
  - Statistically required mosquito density = (total number of Mosquitoes caught/rooms caught) × 4, with room.h as the unit.

(4) Epidemic breakout report

Breaking epidemics and health events with unknown causes should be reported at any time. On receiving the reports, working personnel and related professional people should rush to the scene to carry out epidemic survey to find out the causes and adopt such measures as blockading the epidemic points, sterilizing, handing out preventive medicine, emergency inoculation, and on-the-spot sampling to control the spread.

5.8.2 Monitoring Unit (1996–2003)

The leading station is set at the Chinese Academy of Preventive Medicine, with four base stations.

Reviewing people's health monitoring project and rewarding advanced persons

Expert at the Chongqing base station in November, 2003

Deploying rat clippers

Catching mosquitoes

Having a serology check

Pathogen testing

Station staff training

5.9 Sub-system of Socioeconomic Environment for the Reservoir Area

This sub-system has two leading stations, one in Hubei and one in Chongqing, both in the reservoir area, as shown in Fig. 5.9.

The purpose of the system is to get a comprehensive and systematic picture of the changes in social, economic, and environment caused by the TGP and their development trend so as to provide regularly information serve the TGP construction and the government for policy-making to protect the ecology and environment and sustain utilization of the environmental resources.

This monitoring sub-system has the tasks of regular comprehensive monitoring, to add some indicators to the existing statistical data, and the typical tracking monitoring. The second is to select typical and representative resettled households to work out an indicator system and carry out scientific, systematic and continuous monitoring of their changes in production and life after resettlement, and study changes in income and quality of living as well as existing problems, so as to serve formulating resettlement policies.

5.9.1 Socioenvironment Monitoring Station in the Hubei Reservoir Area

Regular comprehensive monitoring

(1) Scope of monitoring covers Yiling, Zigui, Xingshan, and Badong in the Hubei reservoir area.
(2) Monitoring targets include 101 indicators:

Land, population, and labor: Total arable land area (actual crop area at the end of year), per capita cultivated land area, year-end population, agricultural population, nonagricultural population, average annual population, new births, birthrate, natural population growth rate, people employed (agriculture, industry, and services), and year-end total employees (registered unemployment in cities and towns and registered unemployment rate).
Economy: GDP (agriculture, industry, and services), labor productivity, total fixed asset investment, local budgetary revenue, local budgetary expenditure (spending in education and public health), total output value (current price) of agriculture, forestry, livestock breeding and fisheries, major agricultural products output (grain, oil-bearing crops, flue-cured tobacco, meats and aquatic products), total industrial output value (current price), production/sale ratio of manufactured goods produced by enterprises at and above the township level, integrated economic efficiency index of enterprises practicing independent accounting, ratio of pre-tax profits to total capital, newly added length of highways, length of roads open to traffic, total freight transportation, total passenger transport, total postal services, total retail sales of social consumption, total import and export value (export), total foreign capital utilization, and energy consumption per 10,000 yuan output value.
People's living: Urban and rural consumption level, average monetary wage per worker (per capita disposable income and per capita living expenses of urban residents, per capital net income and per capital living expenses of rural residents), urban and rural bank savings, consumer price index, retail price index, newly built houses (per capital use area in cities and towns and per capital use area in rural areas), rural population with safe drinking water, and ratio of such people in total rural population.

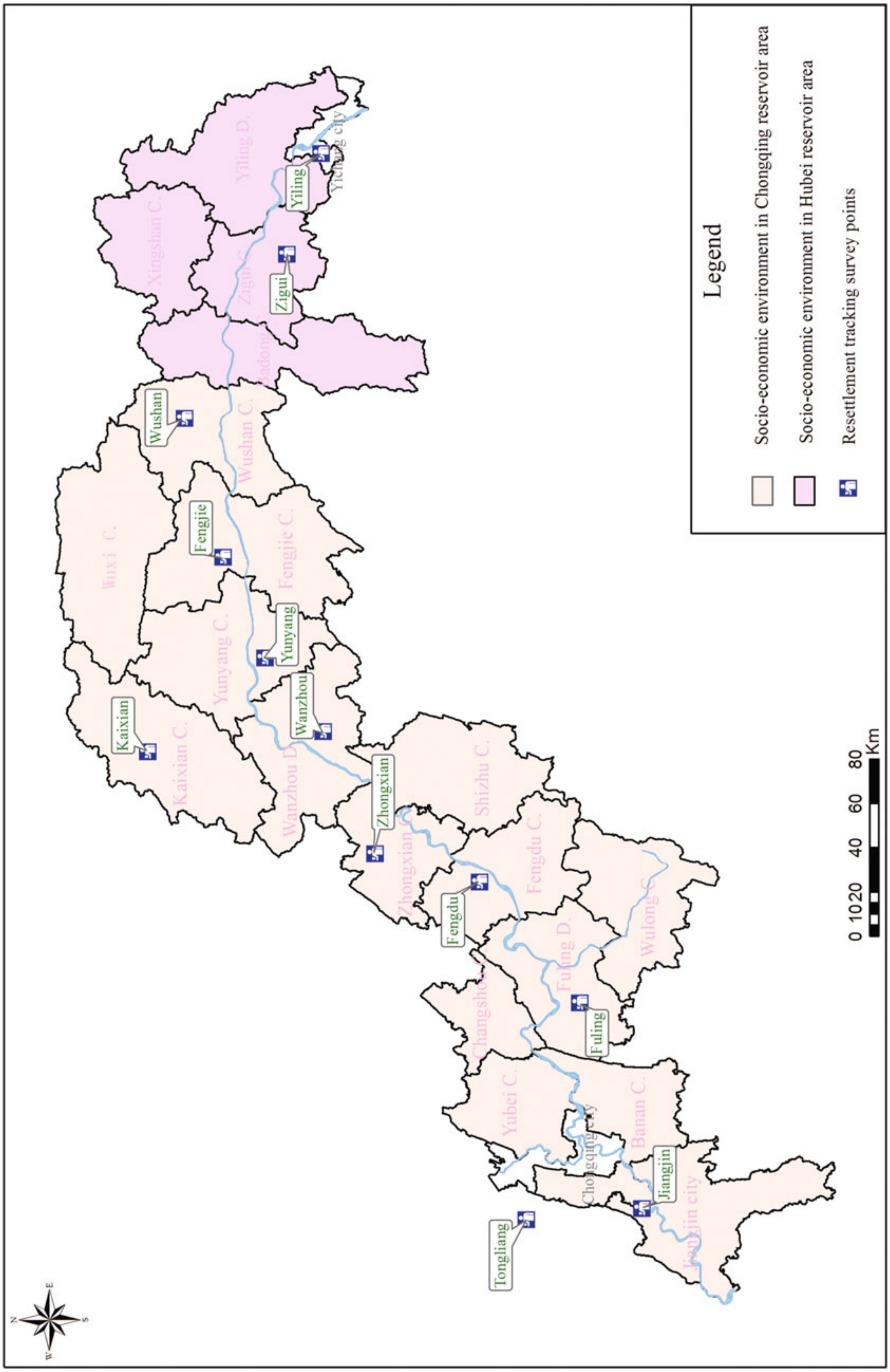


Fig. 5.9 Socioeconomic and environment monitoring sub-system in the TGP reservoir area

Ecology and pollution control: per capita public green areas in cities and towns, ratio of garbage harmless treatment, areas suffering from water loss and soil erosion, industrial wastewater discharge compliance rate, the reduction rate of waste gas discharge, the comprehensive utilization of industrial solid waste, and investment in pollution control.

Science, education, culture, health, and social security: number of professional technicians, book collection of public libraries, population coverage by radio, population coverage by TV, number of middle and primary schools, number of students in primary and middle schools, number of teachers in primary and middle schools, primary school enrolment rate, primary school completion rate, number of hospital beds, number of health technicians, number of criminal cases, number of beds in social welfare institutes, year-end population living in poverty, major relief targets, frequency of receiving state relief, number of people enjoying temporary state relief, number of people enjoying fixed term and fixed amount of relief, number of community service facilities, number of townships that have rural social security net, and coverage of rural social security net.

Resettled people: Investment made for resettlement, investment in the year, areas of housing removed for resettled people, number of urban residents removed; number of rural residents removed, number of people resettled elsewhere, investment by partnership program, and number of partnership projects.

Typical resettled household tracking

(1) Scope of monitoring: Yiling District, Zigui County, Xingshan County, and Badong County in the Hubei reservoir area and 20 resettled households from typical villages selected in Yiling and Zigui County for tracking the production and life of the resettled people.
(2) Monitoring indicators: There are 73 indicators, including the basic situation of resettled rural families, their income, and expenditures, both before and after the resettlement and their problems in production and life, see Table 5.12.
(3) Methods of survey: Random sampling of resettled households, recording family production, living consumption and income, cash and in kind accounts, and sorting them out on the monthly basis to collect the book accounts of the households surveyed.

Monitoring unit (1996–2003)

The leading monitoring station is set in the office of Hubei Provincial Committee for Supporting TGP, with base stations distributed in four counties.

5.9.2 Socioenvironment Monitoring Station in the Chongqing Reservoir Area

Regular comprehensive monitoring

- Scope of monitoring: There are 15 districts (counties, cities) in the Chongqing reservoir area and seven districts on the outskirts of Chongqing Municipality, totaling 22 districts (counties and cities).
- Monitoring indicators: The same is as of the Hubei reservoir area.

Typical resettled households tracking

- Scope of monitoring: As the number of resettled people is large and widely distributed, only sample survey of most representative families is adopted, with a selection of 90 households resettled locally from eight districts and counties including Wushan, Fengjie, Yunyang, Wanzhou, Kaixian, Zhongxian, Fuling, and Fengdu and 10 households resettled outside of their counties but within Chongqing administrative city from Jiangjin city and Tongliang County to follow their changes in production, life, and other aspects.
- Monitoring indicators: The same is as of Hubei reservoir area.
- Methods of survey: It is identical with Hubei reservoir area.

Monitoring unit (1996–2003)

The leading monitoring station is set in the Statistical Bureau of Chongqing Municipality, with base stations distributed in the reservoir areas and various districts and counties and cities.

Table 5.12 Monitoring indicators for 20 households and 100 rural households in the Hubei reservoir area

No.	Indicator	Unit	No.	Indicator	Unit
1	Resident family member	Person	23	#Income from local township enterprises	Yuan/person
2	People on the job	Person	24	Income from working outside hometown	Yuan/person
3	#No. of migrant workers	Person	25	Other wage income	Yuan/person
4	Original value of per capita productive fixed assets	Yuan	26	Family business income	Yuan/person
5	#Per capita houses or structures	Yuan	27	Farming	Yuan/person
6	Area of per capita housing and other structures	m^2	28	#Plant culture	Yuan/person
7	Motor vehicle	Unit	29	Forestry	Yuan/person
8	Large and medium-sized tractor	Unit	30	Animal husbandry	Yuan/person
9	Small and walking tractor	Unit	31	Fisheries	Yuan/person
10	Per capita cultivated land		32	Industry	Yuan/person
11	#Per capita family land		33	Building trade	Yuan/person
12	Per capita living area	m^2	34	Transportation and posts and telecom	Yuan/person
13	Households with health facilities in houses	Household	35	Wholesale, retail sale and catering	Yuan/person
14	Electricity used in daily life	kWh	36	Social service	Yuan/person
15	Households using safe drinking water	Household	37	Culture, education, and health	Yuan/person
16	Households using LPG	Household	38	Other family business income	Yuan/person
17	Households using coal	Households	39	Income from property	Yuan/person
18	Households using firewood	Household	40	Transfer income	Yuan/person
19	Per capita family income	Yuan/person	41	#Relief funds, disaster relief funds	Yuan/person
20	(–) wage income	Yuan/person	42	Resettlement compensation	Yuan/person
21	Income from non-enterprises	Yuan/person	43	Per capita family spending	Yuan/person
22	Income from local enterprises	Yuan/person	44	Family business expenses	Yuan/person
45	Farming	Yuan/person	60	Tax	Yuan/person
46	#plant culture	Yuan/person	61	Other direct tax payment	Yuan/person
47	Forestry	Yuan/person	62	Village retainment	Yuan/person
48	Animal husbandry	Yuan/person	63	Payment to township pool	Yuan/person
49	Fisheries	Yuan/person	64	Other expenses	Yuan/person
50	Industry	Yuan/person	65	Consumption spending	Yuan/person
51	Building trade	Yuan/person	66	Spending on food	Yuan/person
52	Transportation, posts, and telecom	Yuan/person	67	Spending on clothing	Yuan/person
53	Wholesale, retail sale, and catering	Yuan/person	68	Spending on housing	Yuan/person
54	Social service	Yuan/person	69	Family equipment, daily use articles, and services	Yuan/person
55	Culture, education, and health	Yuan/person	70	Spending on medicine and health care	Yuan/person
56	Other family business expenditure	Yuan/person	71	Transportation and telecom spending	Yuan/person
57	Spending on productive fixed assets	Yuan/person	72	Articles used in culture, education, recreation, and services	Yuan/person
58	Depreciation of productive fixed assets	Yuan/person	73	Other goods and service spending	Yuan/person
59	Tax payment and fees	Yuan/person			

December 13-15 meeting of the Chongqing socioeconomic and environment monitoring station

Cross-checking questionnaires

Household survey

Urban household survey

5.10 Remote Sensing Dynamic Monitoring Sub-system

Remote sensing technology is used to carry out baseline surveys and dynamic monitoring of the ecology and environment of the reservoir area. The analysis of the data obtained will serve as basic materials and scientific basis to get to know the basic conditions and trend of change of the ecology and environment in the reservoir area.

5.10.1 Monitoring Targets and Requirements

Scope of monitoring

Focus monitoring is of the reservoir area, supplemented by the monitoring of land resources and land productivity of the Yangtze basin.

Monitoring targets and requirements

(1) Baseline data on ecology and environment

To set up ecology and environment databank with a ratio of 1:50,000 for the reservoir area and 1:10,000 for the resettlement areas to reflect the features of ecology and environment before and after the impoundment to satisfy the need for assessing the TGP impact on ecology and environment.

(2) Soil erosion and non-point pollution monitoring system

To set up a soil erosion intensity remote sensing quantitative assessment model and water loss and soil erosion control result remote sensing monitoring technology system, analyze the ways and volume of non-point pollution load into the reservoir, study the remote sensing computing model of pollutant load, and set up non-point pollution load estimation and analysis system based on geo-information system and with the support of the remote sensing monitoring baseline databank and related experimental observation databank.

(3) Land ecological quality monitoring system

To set up remote sensing and GIS-based land ecological quality monitoring indicators, study and develop corresponding methods and technical route and integrate into a monitoring system, estimate the load of different types of land, and study land environment capacity of different scales so as to provide scientific basis for resettlement area development and policy formation and for ecological restoration by returning farmland to forests and grassland.

(4) Land productivity monitoring

To set up a remote sensing model for net primary productivity and land biomass, through certain estimation methods and technical routes, with 10-day, 30-day and annual monitoring for an analysis of the primary productivity and biomass factors, according to the time and spatial changes to get an ecological security situation of the reservoir area.

(5) Flora quality monitoring

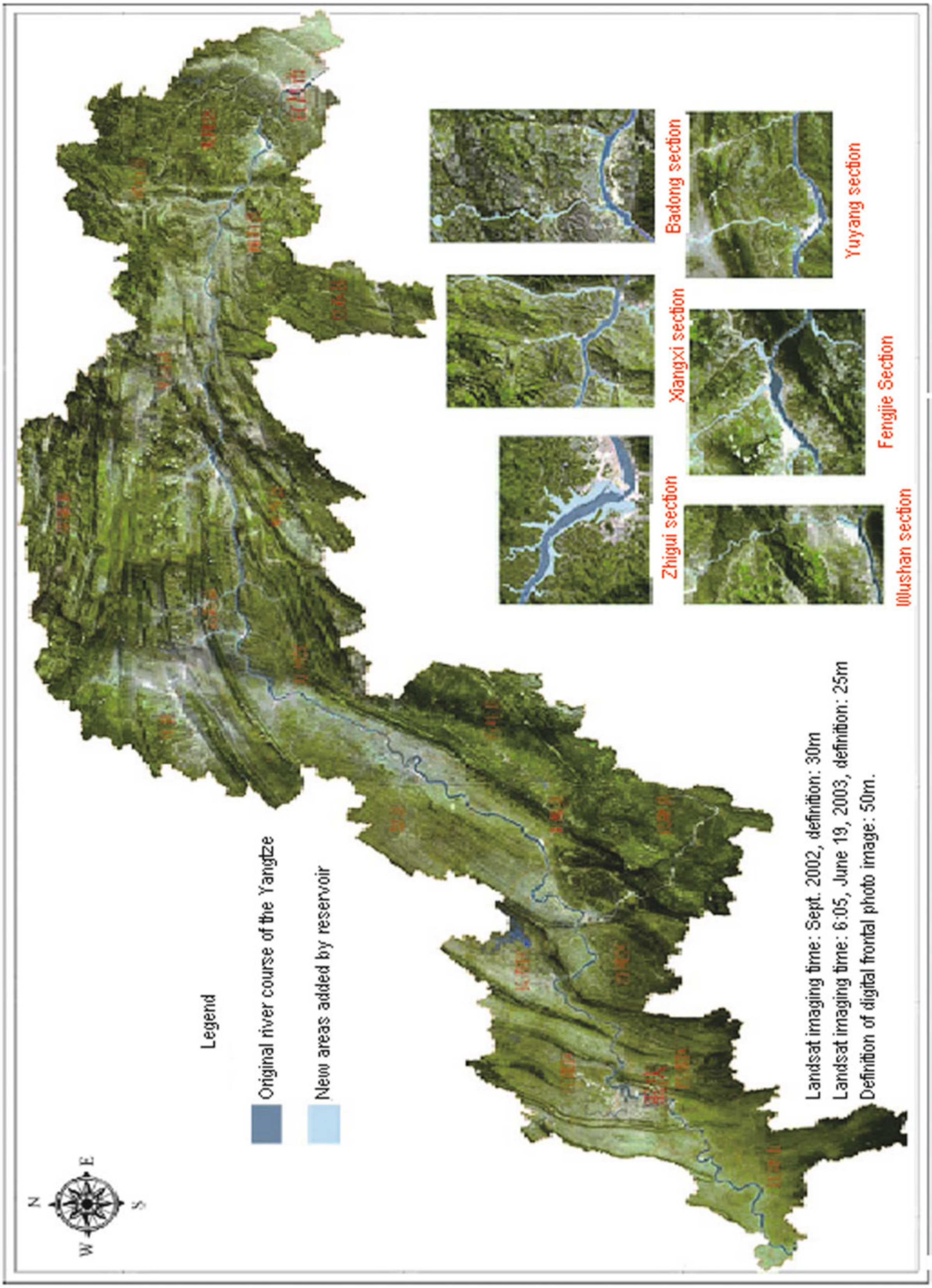
To set up plant flora biotope quality remote sensing monitoring indicators, study and develop corresponding remote sensing technology and methods and integrate them into plant flora biotope monitoring system, to monitor the dynamic changes of flora biotope changes in the reservoir area, and, on the basis of assessing the TGP impact on the ecosystem, explore for a mechanism for the plant flora to respond to the ecological and environmental changes.

(6) Dynamic land resources monitoring

Dynamically monitor the land resources by remote sensing of the reservoir area, analyze the total amount and changing trend of slope land so as to provide the backing for implementing the plan to return farmland back to forests and grassland; by annual remote sensing sample survey, carry out dynamic monitoring of land used by cities and towns and by resettlement so as to provide basis for ecological and environmental assessment and formulating policies for resettlement.

5.10.2 Monitoring Unit (1996–2003)

The leading station is set in the Institute for remote sensing applications of CAS.



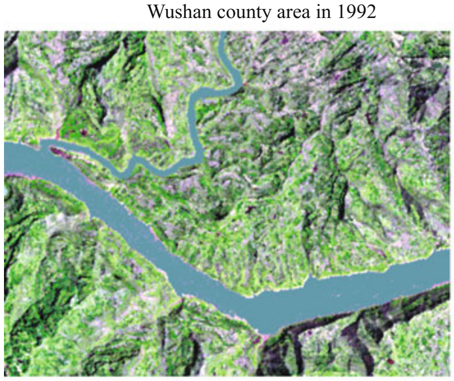
Comparison of Landsat images before and after impoundment in 2003

Three Gorges Dam area in 1992

Three Gorges Dam area in 2002

Wushan county area in 1992

Wushan county area in 2002



Yunyang county area in 1992

Yunyang county area in 2002

Wanzhou district area in 1992

Wanzhou district area in 2002

Landsat remote sensing images of some areas in 1992 and 2002

5.11 Ecological and Environment Experimental Station

Ecology and environment experimental stations include those of terrestrial plant observations, endemic fish experimental, Zigui Ecological and Environmental Experiments, Wanzhou Ecological, and Environmental Experiments, as shown in Fig. 5.10.

The purpose is to timely discover problems and put forward corresponding countermeasures with regard to changes in ecology and environment to be brought about by the TGP. Some impacts are apparent but short-lived; but some are latent and lasting. Both should be taken into account in planning and designing the monitoring system. The experimental stations will focus on the study of apparent but short-lived impacts and carry out experiments to demonstrate how to mitigate the effects. On the other hand, long-term monitoring should be put in place on the latent and lasting effects.

The terrestrial plant observation and experimental station mainly undertakes to (1) remove and multiply rare, endemic, and endangered species to maintain their diversity; (2) carry out long-term monitoring of the dynamic changes in biodiversity in the reservoir area, analyze the pattern and process of biodiversity, and use the indicative function and feedback function of biodiversity on the environment to assess the changing process and trend of changes in the environment.

The endemic fish experimental station mainly undertakes to get clear about the habitat, food base, and reproductive conditions of endemic fish species, monitors the development of the fish reproductive environment and resources, and explores for artificial reproduction and release technology and protect the habitat so as to protect species and biodiversity.

Zigui and Wanzhou ecological and environment experimental stations mainly undertake to track the dynamic changes of the natural ecosystem and the environment and social and economic system caused by the TGP and resettlement and, through a series of experimental demonstration, explore for ways of solving the ecological and environmental problems brought about by the project and put forward practicable policies for the development of eco-agriculture and restoration of the degenerated mountain ecosystem.

5.11.1 Terrestrial Plant Observation and Experimental Station

Monitoring targets and requirements

(1) Plant preservation: Remove and reproduce rare, endangered, and endemic species, fixing 30 species for preservation.

(2) Monitoring indicators

- Environment: coenotype, place name, boundaries, area, elevation, topography, slope face, gradient, position, local terrain, geological conditions, bed rocks, moisture, interference, dominant species, surroundings, sketch, and photos of plants;
- Arborous layer: coverage, height, name of trees, positioning of each tree, photos, crown projecting sketch, gaps distribution, layer cross-section chart, and trunk diameter and tallness;
- Shrub layer: coverage, height, name of plants, height, coverage, multi-dimension, growth period, and photos;
- Herb layer: the same as the shrub layer;
- Chinese kidney maidenhair (*Adiantum reniforme var. sinense*) and Looseflowered falsetmarisk (*Mayricaria laxiflora*): growth rate, death rate, density, dominant plants, and size of population.

(3) Sampling biodiversity monitoring belts: there are three such belts.

- Monitoring frequency: once every 3 years for each of them;
- Monitoring method: fixed sample belt.

(4) Soil characteristics of biodiversity monitoring cross-section

- Soil monitoring: organic matter, total nitrogen, total phosphate, total potassium, major heavy metals, and pH value;
- Monitoring frequency: once every 3 years;
- Monitoring methods: in the same time as biodiversity monitoring.

(5) Weather factors

- Weather monitoring frequency: three times a day;
- Monitoring method: by manual observation.

Monitoring unit (1996–2003)

The leading experimental station is set at Longmen River, Xingshan, Hubei Province, undertaken by the Institute of Botany of CAS.

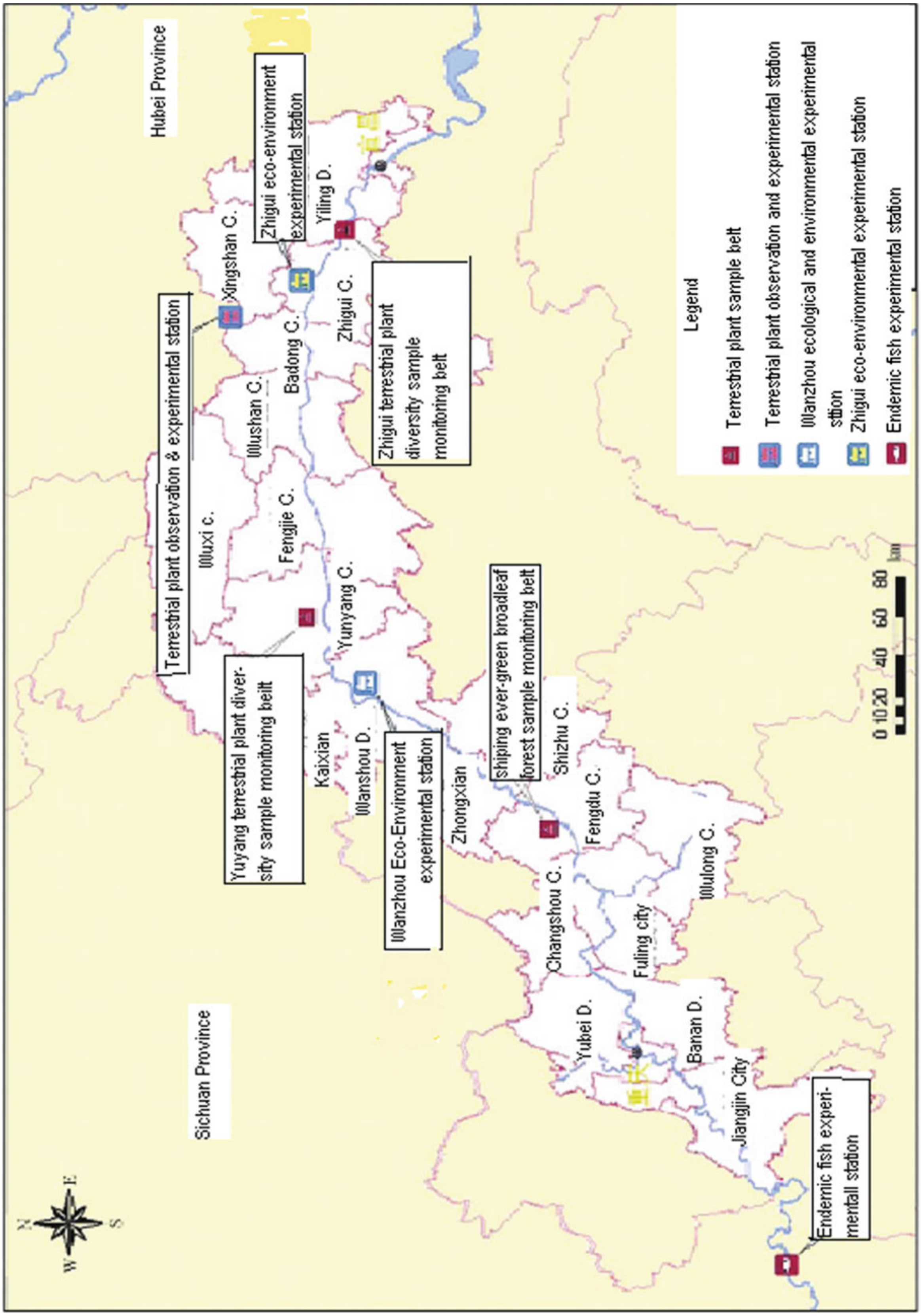


Fig. 5.10 Distribution of ecological and environment experimental stations

Terrestrial plant observation and experimental station

Sims's azalea (*Rhododendron simsii*)

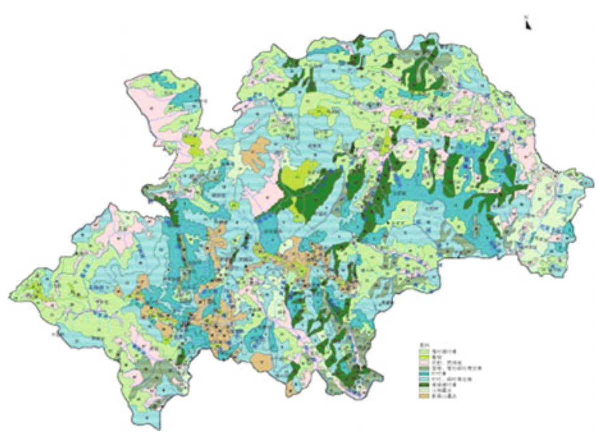
Experiment of plant protection in a new place

Monitoring mark of terrestrial plant samples

Chinese Barberry (*Berberis julianae*)

Soil samples of the terrestrial plant sample area

Representative view of broad-leaved forest



Xingshan Longmenhe terrestrial plant types map

Luzhou on the upper reaches of the Yangtze, where the endemic fish experimental station is situated

5.11.2 Endemic Fish Experimental Station

Monitoring targets and requirements

(1) Scope of monitoring and experiments

More than 40 species of endemic fish, with emphasis on the study of Elongate loach (*Leptobotia elongate*), Redlip loach (*Leptobotia rubrilabris*), *Megalobrama pellegrini*, Large-mouth bronze gudgeon (*Coreius guichenoti*), *Rhinogobio ventralis*, *Ancherythroculter nigrocauda, Bangana rendahli*, Rock carp (*Procypris rabaudi*) and *Jinshaia sinensis* or much more species if possible.

(2) Distribution of monitoring stations

As the experimental stations focus on endemic species, comparative studies are not required. The stations are mainly fixed stations. A fixed outdoor experimental station is set up at Luzhou City, Sichuan Province, which has its own breeding and reproduction facilities and carries out most of the experiments. It will be supplemented, if necessary, by the Wuhan laboratory.

(3) Monitoring and experiment contents

Survey and monitoring of the habitats and reproduction environment factors of endemic species affected by the TGP, reproductive ecology and biology, impact on fish reproduction and artificial breeding technology of endemic fish.

(4) Time and frequency

Monitoring is done twice a year, in March–June and September–October. Artificial breeding experiments in the reproductive season (March–June), annual collection of artificial feed and biology, with biological materials collected in large samples at least on the quarterly basis.

(5) Monitoring indicators and experimental factors

- Environment: ecotype description, air and water temperature, transparency, DO, pH, water level, and velocity.
- Biological and reproductive ecology: miscatch of rare species, natural reproduction, age structure of different species, sex ratio of different species, food composition, gonadal development, reproductive season and reproductive conditions, composition of reproductive population, fertility, and special habits.
- Artificial breeding: domestication and post-spawning care, water temperature, oxytocin dose and effective time, environmental factors and embryo development, development of larval and juvenile and growth, young fish feeding habit, nutritional demand, and artificial feed of different species and at different growth stages.

Monitoring organization (1996–2003)

The leading experimental station is in Luzhou, Sichuan, undertaken by the Institute of Hydrobiology of CAS.

Endemic fish breeding experiments in 2001 in Luzhou

Yangqiao of Luzhou, 2002-2003 endemic fish breeding

Expert directing work at the endemic fish experimental station.

Check the development of fish bred

Fish fry and egg collection

Endemic fish development observation

Endemic fish experiments

Ancherythroculter nigrocauda, 2001

Megalobrama pellegrini, 2002

Rock carp, 2003

Laixi river, tributary of Yangtze, habitat of *Ancherythroculter nigrocauda Wu* and *Megalobrama*

Longxi river, primary tributary of Yangtze,
Spawning ground of *Megalobrama pellegrini*

Tang river, tributary of Yangtze, habitat of rock carp

Artificial breeding experiments at endemic fish experimental station

5.11.3 Zigui Ecological and Environment Experimental Station

Monitoring targets and requirements

(1) Soil fertility monitoring

The experimental station is made of the base and three representative layers (low mountainous area at an elevation of about 300 m around the experimental station, semi-high altitude area at an elevation of about 700 m, and a sub-high mountainous area at an elevation of about 1100 m) are selected at different elevations and at each layer; different plant systems [Washington navel (*Citrus sinensis* "Washington Navel") orchard and vegetable garden at low elevation; arid slope land and rice fields at semi-high elevation; timber woodland and arid slope land at sub-high elevation] are selected and land blocks of different fertility at the same elevation and with the same vegetation are selected for monitoring three times at each selected points, in addition to farmland that is not all devoted to the plantation of Washington navel but has the same conditions as in the experimental station (one sample point, three fertility levels and three repeated times), totaling 63 monitoring points, positioned by GPS, collecting soil samples from the cultivated layer (0–20 cm), sub-cultivated layer (20–40 cm) for measurement of total nitrogen, total phosphate, total potassium and organic matter as well as fast-acting nitrogen, phosphate, and potassium. Then biennial monitoring is conducted of the cultivated layer; monitoring of the sub-cultivated layer is conducted once every 5 years. The data on the output of each block of land are recorded in order to get clear about the relationship between soil fertility and output on the one hand and ecological factor changes on the other. Data about fertilizer application, type of fertilizer applied, the time of fertilizer application and crop output, biomass of woods, and main management means will be recorded every year. The data about soil fertility and biomass output and biomass of woods will be recorded and supplied every year.

(2) Water loss and soil erosion monitoring

The runoff plot in the experimental station is made the base to monitor surface runoff flow, soil erosion amount, nutrient losses, and their contribution to the eutrophication of the water body under different vegetations (different plans and different methods of cultivation). Three gradients (27°, 25°, and 23°) of runoff plots, totaling 15 treatments, including different arid crop systems [wheat, sweet potato (*Ipomoea batatas*), corn, and grazing grass], optimized land utilization mode (tree–crop intercropping, tree–grass interplanting, grain–grass intercropping, grain–grass rotation, grass–grass rotation) returning farmland to from forests and grassland, prevention of water loss and soil erosion, results of controlling and mitigating agricultural non-point pollution on the water body of the reservoir and improving land output, and measures for improving the living quality of the resettled people; analyzing the relationship between rainfall and runoff as well as the relationship between different vegetation cover and water loss and soil erosion; and monitoring the relationship between soil humidity and water loss and soil erosion.

(3) Ecological factor monitoring

With the makeshift meteorological observation point of the experimental station as the base, measure the dry-bulb and wet-bulb temperatures, highest and lowest temperatures and highest and lowest land soil surface temperatures, soil temperatures at different depths (0.5, 10 and 20 cm), precipitation, evaporation, frost-free days, disastrous weather records, and moisture of soil at different depth as well as the changes in the micro-climate of different vegetations, three times a day (at 8:00, 14:00 and 20:00 h), and a summary analysis every year.

(4) Tracking the social and economic conditions of resettled people

Select 10 resettled households and corresponding non-resettled households as the contrasting group in the resettled area at Longkou of the Shuitainba Township to track the changes in the family economic conditions. Targets of monitoring include annual family income and expenditure, per capita net income, changes in land of farm households, changes in labor and means of production, employment of farm household labor, and family income structure. Monitoring is done once a year, with an analytical statistics attached according to the income reason of farm households.

Experiments and demonstration

(1) Integrated control of arid slope land and fertilization of soil for high, stable, and quality yields

Experiments and demonstration are carried out on land at elevations of 300 and 700 m for the purpose of spreading eco-agriculture in the mountainous areas. And it is to apply principles of ecology and economics, use advanced and adaptive techniques to protect and improve agricultural economy and environment, increase income of farmers by optimizing production structure, make full use of locally available natural resources, realize multiple utilization of organic matters by employing all kinds of processing means so as to create more utilizable products, and create more beautiful living environment. The utilization of land mainly focuses on orchards at low elevations and farmland at medium elevations. It is to apply different control measures (returning land to forests and grassland technology, contour plant filtering belt technique, biological controlled green food technology) and fertilize the soil (planting grass and returned the animal manure to the fields, stalk cover, and deep burying technique). What merits attention is that returning farmland to forests and grass is but only one means for integrated control of arid slope land and restoring the ecology and environment. The underlying problem is how to turn trees and grass into farm produce and accelerate the pace of making the local people prosperous and stimulate the local economic development. It is, therefore, necessary to carry out production and operation in multiple ways according to local actual conditions. Monitoring of the soil fertility is done once every 3 years.

(2) Vertical crop (including economic forests) planting mode, fertilizer application technical system, and economic efficiency

It is carried out experiments and demonstration of vertical planting mode (fruit–vegetables, fruit–grass, and grain–grass) around the experimental station, set up fertilizer application technique system (new fertilizer, new methods of application, new fertilizing schemes, fertilizer application of soil-based formula) and economic efficiency, and timely sum up the achievements of the experiments and demonstration for popularization in the localities. Annual monitoring should be conducted of the plant structure, investment, output, income structure of households that are carrying out experiments, and make comparative analysis with normal households and, on this basis, recommend planting models best suited to local conditions.

(3) Optimization of cropping system and improvement of farmland productivity

It is to introduce fine strains of crops, adopt rational fertilizer application technology, and improve the farmland output level by optimizing the cropping system (to change the high sloping land into terraced land, introduce rational interplanting and rotation and protective planting).

(4) Factory, clean, and standard production of such cash crops as Washington navel and Houttuynia cordata

It is to introduce new varieties of Washington navel, clean and standard cultivation and factory management on experimental areas of 50–100 mu (1mu=666.7m^2); carry out experiments and demonstration of water and fertilizer-efficient methods in growing Washington navel (including dripping irrigation, injection, deep hole cover) by selecting 3–5 households; carry out experiments in artificial cultivation of Houttuynia cordata by introducing technologies for high output of superior quality on 1–2 mu of land.

Monitoring unit (1996–2003)

The experimental station is set in Shuitianba of Zigui County, Hubei Province, undertaken by the Nanjing Soil Science Institute of CAS.

Experimental plot of the Zigui experimental station

Contrasting corn plots at Zigui experimental station

In-situ of Zigui experimental station

5.11.4 Wanzhou Ecological and Environment Experimental Station

Monitoring targets and requirements

(1) Soil fertility monitoring at experimental sample blocks

Experimental blocks: rice field, arid sloping land, terraced field converted from sloping land, vegetable plots, and orange planting zone at Xiao Chenjiagou, with dynamic monitoring points set in each plot (totaling five typical pieces of land).

Monitoring indicators are nitrogen, phosphate, potassium, and organic substance.

Time and frequency: once every 5 years. The second monitoring was done in October 2003, with ten samples.

(2) Monitoring of flow and sediment generation at runoff plots

Distribution of monitoring stations: two standard runoff plots;

Monitoring indicators are precipitation, runoff flow, and sediment generation.

Time and frequency: all rainfall and flow generation process of a year.

(3) Monitoring of technical measures for controlling water loss and soil erosion in arid slope land (three times during the rainy season every year).

Experimental plots: experimental plots of arid and ridge culture;

Monitoring indicators are precipitation, runoff flow, and sediment.

Time and frequency: three rainfall and runoff flow (sediment) processes during the rainy season of a year.

(4) Dynamic tracking of resettled people and local economic and social development.

Scope of monitoring: 50 resettled farming households in the town of Changling and Lingshui Township.

Monitoring indicators are employment structure, land utilization structure, income structure, living quality, and health conditions of local residents and resettled people.

Time and frequency: once a year in January or October the following year.

Experiments and demonstration

(1) Water-efficient technology for arid sloping fields

Experimental plots: 5–10 mu in the experimental station and Xiao Chenjiagou, small basin sloping land of aged soil.

Experiments: underground film water blocking wall.

(2) Grain-cash crop and fruit combined furrow planting model and optimization in arid sloping land

Experimental plots: 5–10 mu in the experimental station and Xiao Chenjiagou, small basin sloping land of aged soil.

Experiments: grain (wheat, corn and sweet potato), cash crops, and fruit furrow planting model.

(3) Vegetation (grass) restoration and hedgerow technology on land returned to forests and grassland

Experimental plots: 5–10 mu in the experimental station and Xiao Chenjiagou, small basin sloping land of aged soil.

Experiments: growing of Hybrid Giant Napier (*Pennisetum hydridum*) and other plants on land returned to forest and grassland and hedgerow technology.

Monitoring unit (1996–2003)

The experimental station is situated in Wuqiao of Wanzhou District of Chongqing, undertaken by the Institute of Mountain Hazards and Environment, CAS.

Runoff observation plot (July 2001)

Film water blocking wall experiment at Lishu Village, town of Changling, Wanzhou district (May 1999)

Hybrid Giant Napier hedgerow at Tangpu village in the town of Changling (May 2000)

Reclamation of sloping land with a gradient bigger than 40 degrees at Tangpu village in the town of Changling

Grass bundle ridge plus Hybrid Giant Napier Sampling (May 2000), technique for sloping land returned for afforestation at Tangpu village of Changling town

Composite furrow planting method (corn plus soybean *(Glycine max)*) spread in Tangpu Changling town (July 2000)

Giving lecture to local farmers

Xinwu group 5 in the town of Changling, experimenting in crop-tree ecosystem.

Chinese yam (*Dioscorea opposita*) demonstrating plot at Longhu village of Zhuxi town, Kaixian County

5.12 Other Ecological and Environment Monitoring Sub-systems

Apart from the above monitoring sub-systems, there are some other specialized monitoring projects. For instance, the dam may cause changes in the ecology and environment of the construction site. It is, therefore, necessary to list it exclusively in order to place monitoring results in direct service of the big dam project. Induced earthquake, geological disasters, reservoir sedimentation, and downstream degradation are usually the main technical issues for a big dam project and it is, therefore, merits special attention.

5.12.1 Monitoring of the Construction Site

The Three Gorges Dam has the fastest and most direct impact on the economy and environment of the construction site. But the impact is limited in scope, confining it to an area of only about 15.28 km^2. In order to reduce the impact of construction on the ecology, environment, and people's health, the targets of monitoring should include water quality, hydrology, meteorology, air quality, noise, and people's health.

The purpose is to get clear the pollutant discharge and dynamic changes of the environmental quality, air quality and noise, and other environmental factors of the construction site and discover promptly the possible environmental problems so as to provide scientific basis for the ecological and environmental construction and management, have a systematic command of the environmental quality during the construction period and put in place measures of environmental protection so as to maintain a sound state of the ecosystem and realize synchronized development of both the project and environmental protection.

Monitoring targets and requirements

(1) Water quality: This includes the mainstream and tributaries, riparian water, sewerage, industrial wastewater, water supply, and burying ground of garbage.
(2) Hydrology: It includes flow, water level, and sand content of the Yangtze.
(3) Meteorology: It includes meteorological features, wind velocity, and wind direction.
(4) Air quality: The monitoring covers routine monitoring of construction sites and sensitive points.
(5) Noise: Noise monitoring covers office and living areas, engineering sites, roads, and outside the borders of the construction site.
(6) People's health: The monitoring should focus on communicable diseases caused by etiologic biological vectors and diseases of natural focus.

Monitoring undertaker

The Three Gorges Corporation has entrusted the task to the Changjiang Basin Water Environment Monitoring Center (CBWEMC).

Construction site environment protection seminar (photo by Sun Zhiwei)

Monitoring flying dust in the construction pit of the third phase coffer dam (photo by Huang Zhenli)

Air quality monitoring point at Tanziling construction site (photo by Huang Zhenli)

The noise testing on the road of construction sites (photo by Huang Zhenli)

Collecting water samples from the mainstream of the Yangtze at the construction site

Waste water treatment of sand washing and reclaimed water recycling pools

5.12.2 Sedimentation and Scouring Observation

Sediment involves a series of important and complicated technical issues that concern the service life of the reservoir, reservoir inundation, navigation channel at the reservoir tail, evolution of port area, normal operations of the shiplock and the power station, scouring of the riverbed downstream, water level, and the impact of changes in riverbed on flood control and shipping. In order to optimize the design and the water depth and flow conditions for the normal operation of the reservoir and shipping and provide basic materials for the construction and development of ports and docks and ensure thoroughfare of the shipping channels, it is necessary to carry out all-round study of the sediment issue in the dam area, downstream of the dam and backwater of the reservoir and observe the sediment prototype of the future reservoir area and downstream. The observation area covers the reservoir area, dam area, and river course downstream.

Monitoring targets and requirements

(1) Reservoir area: The scope of monitoring covers an area from Zhutuo to the dam, including all-year-round backwater area and fluctuating backwater area. Main targets of monitoring are as follows:

- Underwater topography;
- Fixed cross-section observation;
- Reservoir bed sand composition;
- Evolution of riverbed in the fluctuating backwater area;
- Reservoir area water level;
- Testing of water and sand entering the reservoir.

(2) Dam area: The scope of monitoring covers the 17 km section from the dam site to Miaohe and the 14 km section from the dam site to Letianxi. Targets of monitoring include the following:

- Evolution of riverbed in the dam area;
- Sedimentation at navigation structures;
- Sedimentation at the power plant;
- Water current and suspended sediment at the dam area; and
- Water current and suspended sediment at the coffer dam and the open channel.

(3) Downstream of the Dam: The river section between the Three Gorges Dam and the Gezhouba Dam as well as the section in the middle reach of the Yangtze from Gezhouba to Hukou. Targets of monitoring include the following:

- Riverbed evolution between the Three Gorges Dam and the Gezhouba Dam;
- Underwater topography of the mainstream of the middle reach of the Yangtze and the Dongting Lake;
- Fixed cross-section on the mainstream of the middle reach of the Yangtze and the Dongting Lake;
- Flow and sand diversion at the Jingjiang;
- Water level of the section between Yichang and Wuhan;
- Riverbed composition of the section from Yichang to Chenglingji;
- Bed load of the section downstream of the dam; and
- Riverbed evolution of major sections in the middle reach of the Yangtze.

Monitoring undertaker

The Three Gorges Corporation has entrusted the task to the Hydrology Bureau, CWRC.

Hydrological survey vessel at Cuntan station, a cross-section in the upper reach of the Yangtze

Collecting water samples to detect suspended particles and their size

5.12.3 Induced Earthquake Monitoring

Monitoring targets and requirements

(1) Digital remote control seismological station network

The network is made up of 24 digital remote control seismological stations, 3 relay stations and one digital remote control station, with eight mobile digital seismological stations as standby. Besides, there are two non-remote controlled strong quake observation stations. Monitoring targets include the following:

- **Type I major monitoring area** (40 km upstream from the dam), having the location accuracy of ML0.5 earthquake at the lowest, the epicenter location accuracy of 1 km, and the source depth accuracy of 2 km.
- **Type II major monitoring area** (an area about 90 km upstream of the dam), having the location accuracy of ML0.5 earthquake, the epicenter location accuracy of 2 km and the source depth accuracy of 5 km.
- **General monitoring area** (Wushan–Wanzhou), having a small quake monitoring capacity of ML2.5.
- **Medium-type earthquake detecting capability:** At least four sub-stations can record the complete seismographic waves of an earthquake measuring Ms5.0 in the major monitoring areas and record the basic parameters of earthquake above Ms5.0 in the reservoir area.
- **Strong earthquake instant reporting capability**: Capable of processing the data of an earthquake above ML2.5 in the major monitoring area and above ML4.0 in the middle section of the reservoir within 15 min and instantly reporting them to the headquarters of the monitoring stations and related departments.

(2) Earth crust change monitoring network

This monitoring network includes GPS for horizontal deformation, with two fixed base stations, the Yichang station, and 21 mobile stations and vertical deformation precision level network. The first class standard monitoring network has a circular line of about 800 km; gravity network has the same routes and precision as the precision level network, with 48 gravity monitoring points, uniformly distributed. Trans-fault deformation monitoring network, with a three-dimensional network distributed on the major faults (Jiuwanxi fault, Xiannushan fault, Tianyangping fault, Shuitainba fault, and Gaoqiao fault), together with precision level line, extensimeter in the chamber and static force level observation of reservoir basin sinking and reservoir basin bottom width. The above earth crust deformation monitoring networks have brought the whole dam area and the major fault activities under tight scrutiny.

(3) Underground water dynamic monitoring well network

It is composed of eight observation wells, four in the dam area, and four near the Jiuwanxi and Xiannushan faults. Monitoring indicators include water level, water temperature, soil radon, air pressure, air temperature and precipitation; dynamic observation of the water temperature, water level and gas radon of the wells is the important means for monitoring the signs of earthquakes and for obtaining important information about changes in earth tide.

(4) General earthquake monitoring station

The structure of the earthquake monitoring system is shown in Fig. 5.11. The general station undertakes data transmission, processing and management, besides data collection and storage and databank management, computer network communication, system service and integrated development of processing software in all disciplines; compiling and editing express earthquake reports, monthly report, annual report, and provide related organizations with monitoring reports and trend development.

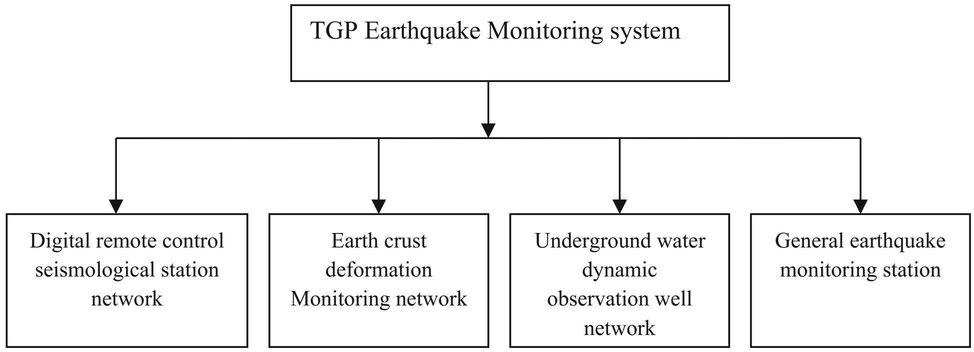


Fig. 5.11 Structural framework of TGP earthquake monitoring system

Monitoring undertaker

The Earthquake Research Institute, CSB is entrusted to take the task.

5.12.4 Geological Hazards Monitoring

Geological hazards in the reservoir area mainly include avalanche, landslide and mudflow, bank collapse, which may occur as well as at high cut slopes and super-deep basements for rehabilitation of special facilities such as towns and roads. The geological hazard monitoring and precautionary system is specialized with monitoring, mass participation, and information systems.

Monitoring targets and requirements

(1) Specialized monitoring and precautionary system

- GPS monitoring: It is undertaken by a three-tier monitoring network in the whole reservoir area to keep a close watch on the 129 points prone to avalanche, landslide and mudflow, and the reservoir bank; and carry out emergency monitoring of breaking out geological hazards in the reservoir area. The A-level control network is made up of 15 control points; the B-level network is of 193 base level points; and the C-level deformation monitoring network is 925 monitoring points.
- Integrated three-dimensional monitoring: The 136 points prone to avalanche, landslide and mudflow and collapse are put under integrated three-dimensional monitoring. Indicators include surface movement, deep deformation, landslide thrust, and underground water.
- Remote sensing monitoring: Remote sensing devices are used to monitor the whole reservoir area, a construct a three-dimensional landscape model, and simulate a flight to provide perceptive stereoscopic visualized dynamic platform.

(2) Mass participation system

There are 20 county-level monitoring stations, with monitoring points of 1216 unstable slopes and banks selected by geologists team and with local people participation. For different monitoring targets, carrying out physical indicator surveys and planning evacuation routes. The stations put up makeshift monitoring poles at points chosen by geologists, assign spot monitoring personnel, and issue unified record forms and spot monitoring personnel do the actual operation.

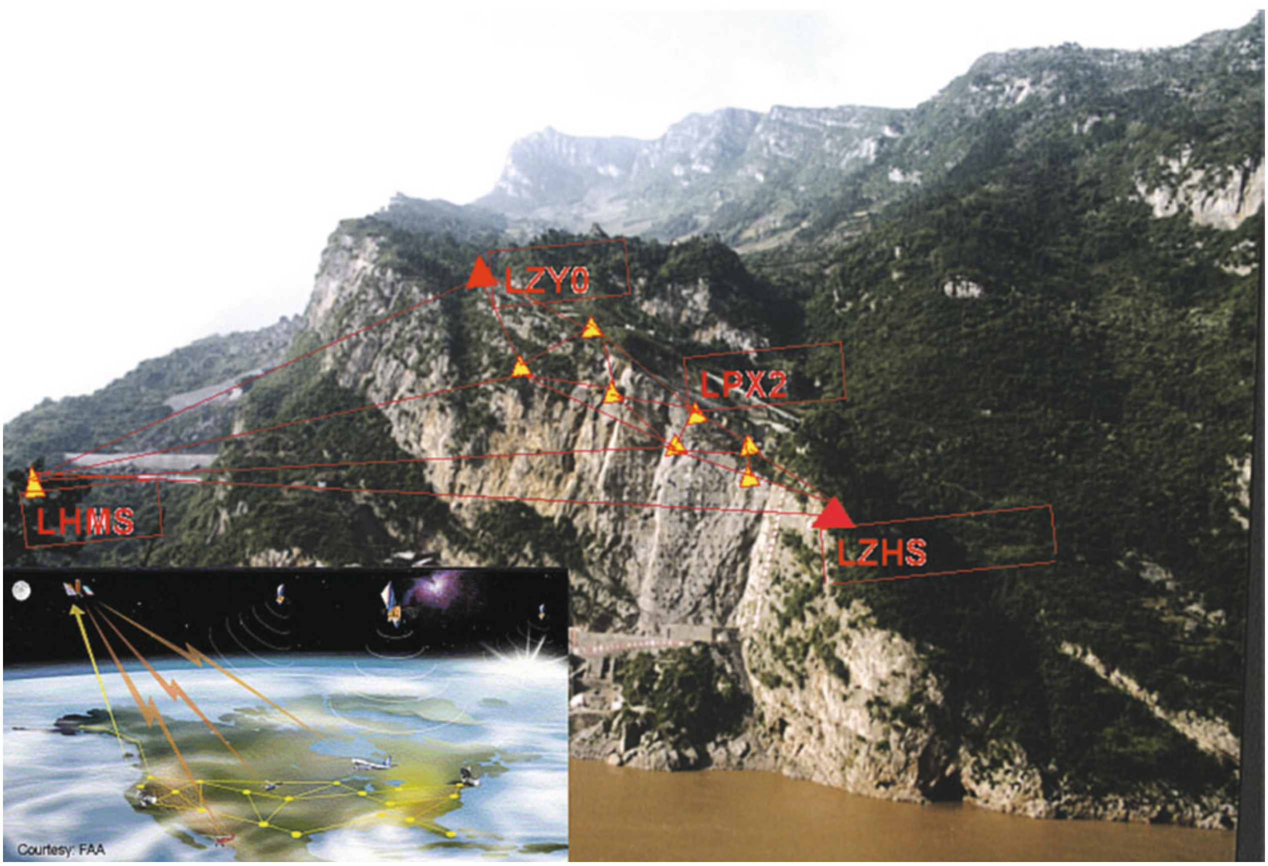
(3) Information system

- Network system: The reservoir area has 20 county-level monitoring stations and a command headquarters LAN system, forming a WAN system.
- Information system: It is composed of a geological hazard information system and a disaster policy-making support system, undertaking to collect and store information in a databank and exercise management of the information, provide information retrieval service, execute graphic programming, spatial model analysis, make integrated analysis and assessment, achievement output and information release in the service of disaster prevention, control and management.

Monitoring undertaker

Headquarter of Geo-hazard Prevention and Control for the Three Gorges Reservoir Area, MLR undertakes the monitoring.

Distribution of monitoring points of A-level control network



Distribution of dangerous rock body GPS monitoring network at Lianziya,

Observation pier of A-level GPS control network

Monitoring porous water pressure, physical pressure force, moving water pressure and physiochemical characteristics of underground water

6 TGP Eco-environmental Monitoring Information System

6.1 Orientation of the Information System

In order to get the ecological change mechanism along the Yangtze River and better support TGP construction and management work, large amounts of data and information have been collected by the TGP ecological and environmental monitoring system, which is build up based on the existing ecological and environmental monitoring system, with large-scale real-time remote sensing monitoring, effective use of sharing resources and management information (hereinafter referred to as the "Three Gorges Information System").

The information system is an important component of the TGP ecological and environmental monitoring system. The purpose is to collect, store, manage, and apply the data and other information collected by the monitoring system and serve the owner units and all monitoring undertakers as well as related government departments. It also serves to accumulate data for future retrospective environmental impact assessment.

The system mainly serves owner units and all leading monitoring stations as well as base stations, related units, and the general public. The building up of the system needs active participation of all sub-systems. It will not only provide data obtained from monitoring but also share the database with other sub-systems.

6.2 Objectives of the Information System

The general goal of the information system is to become an integrated information platform that provides information service, sharing, releasing, comprehensively analyzing, and managing.

Public Information Service Platform

The information system will make public information about the environment of the Three Gorges area. People have access to the website to keep pace with the progress of the TGP and the updated information about the population, social and economic development and resettlement, and the natural ecological and environmental conditions of the reservoir area.

It also provides the owner, the major monitoring stations, experimental stations with public information service, such as geographical information, standards and norms, etc.

Besides, it also provides to others free or paid information service, such as information query, data download, and purchase of data CDs.

Information Distribution

The project owner's departments, the leading monitoring stations, experimental stations, and research organizations, may reach the information collected in the system. The owner departments may collect and sort out all kinds of detailed information on a particular subject obtained from monitoring; all the leading monitoring stations and experimental stations may share the information and analytical reports; research organizations in all related disciplines may carry out researches based on the massive original data and statistical analyses accumulated in the system.

The units may also share analytical methods and experiences with one another through the system.

Information Release

The system undertakes to release TGP environmental impact monitoring reports and related information, including

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progresses in environmental protection and monitoring reports on particular areas, research achievements, and public information. Information release may be available in the form of report, graphics, image, and data.

Integrated Analysis

The system provides data searching service on any particular area and integrated monitored data, statistical analyses and developments, and trend analyses.

The system also has a section devoted to policy decision analysis and information on the ecology and environment impact of TGP based on the databank and provides advanced analytical information service to the owner and organizations of all disciplines.

Dynamic Information Management

The system will also work as a platform for the management of all dynamic information, such as follow-up monitoring and release of breaking events, monitoring of the development of the ecosystem and environment, and put them into the databank for concentrated management.

6.3 Architecture of the Information System

The system has three tiers as is shown in Fig. 6.1. The core operation is treated together with related services through the middle layer, namely, the operation logic. The main functions are to accept service demand from the users and then carry out data interaction with the data server before providing the users with monitored information, spatial data, and texts. It carries out complicated mathematic operations and processing (such as spatial query, analysis, reprocessing of operational data). The end user is responsible for interface expression and interacting with the users, such as query data obtained from monitoring, displaying, browsing and graphic display of query results. The database tier is responsible for the management of monitored data, spatial data, and text information.

The whole system is based on network and realizes communications with major monitoring stations and experimental stations through IP. Upload of data is done through the web server of the center. The cost of the network is low and the DDN connection between the owner units and information management center can ensure smooth information exchange. That is the optimal network model for the future. On the whole, the information system has satisfied the principles of being advanced, universal, unified, scalable, secure and manageable.

6.3.1 The Middle Layer

The middle layer is devoted to the technology itself of the database platform and geographical information platform to provide instrumental interface for the application and development of the upper layer and, by using advanced middleware to provide interface for development tools, quickly transplant and construct the application systems. The middle layer includes a web server, a GIS server, and some applicable middleware shared by the system. That is the core operation for the system to realize all functions.

The system uses IIS (Internet Information Service) as web server. IIS is a powerful web server that provides a highly reliable, manageable, and scalable web application infrastructure for all versions of Windows, a feature that makes it the first choice for Windows platform server. Closely integrated with Windows systems, IIS may use the embedded security mechanism to protect itself. Customer demand is first received by IIS, which will execute a certain program or transfer the demand to GIS server or other middleware.

GIS server mainly includes online geographical information system (WEBGIS) server and spatial data server for releasing, storing, querying, and analyzing spatial information and data.

WEBGIS provides the basis for GIS data distribution and applications on the Internet. Working together with Web server, it distributes spatial data. The same as Web server, WEBGIS is also operating in the background. Its core functions realized by WEBGIS include browsing spatial data, inter-query between spatial data and attributes data, spatial analysis, and theme map layout.

The spatial data server expands spatially on the basis of the existing relationship or the object-based database management system (DBMS), capable of integrating spatial and nonspatial data into most commercial Relational Data Base Management System (RDBMS), that is, integration of multisource spatial data and spatial and attribution data. After RDBMS is infused into spatial data, the spatial data server may provide highly efficient database service operations for spatial and nonspatial data. It stores and retrieves data in tandem with RDBMS server. Spatial data server interprets spatial data for RDBMS, converts customer data demand into SQL to enable RDBMS to read, and stores geographical spatial data in the database forms.

The use of middleware of the TGP information system arises from the specific system applications. They include unified data access to middleware, unified graphic middleware, user management service, and some industry-oriented application middleware, all of which operate in the server to take out data on demand or execute corresponding operations.

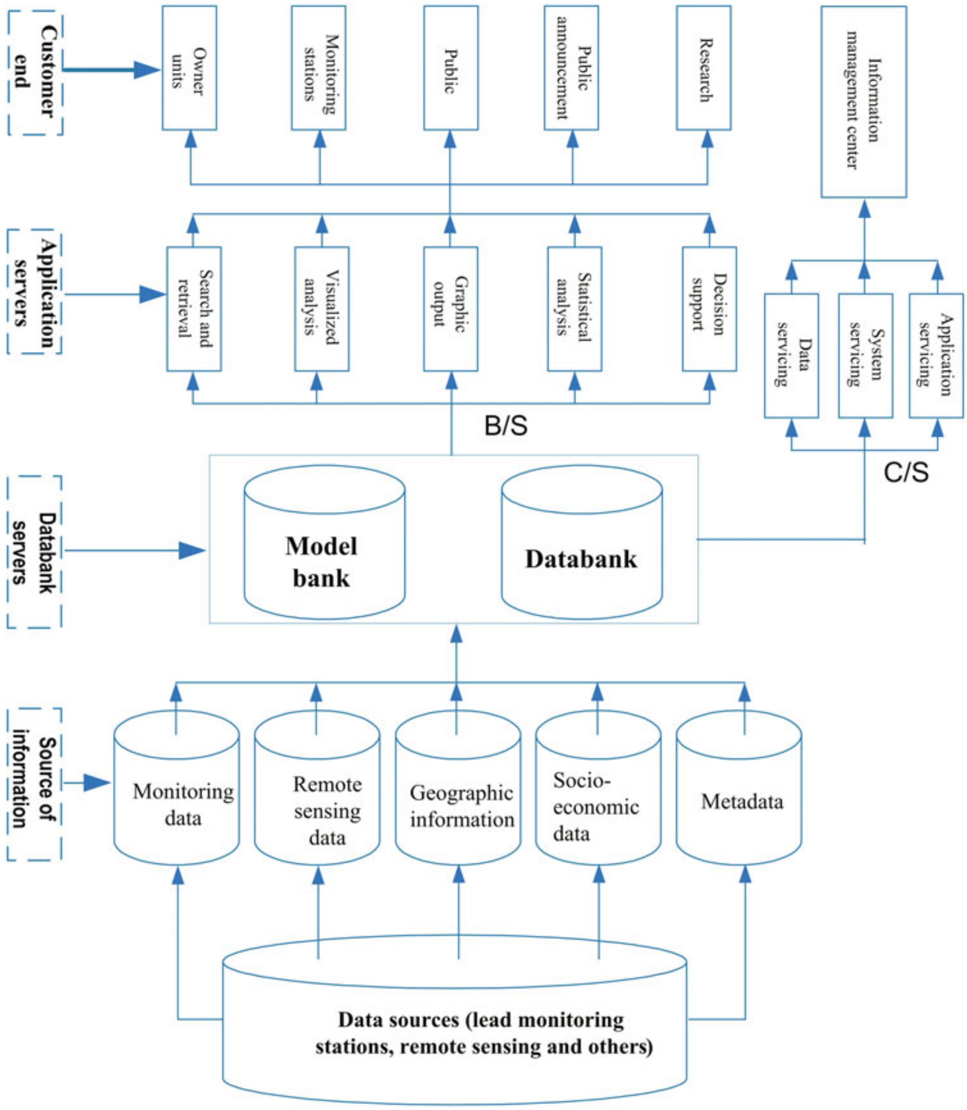


Fig. 6.1 General Structure of the TGP Information System

6.3.2 Database

Database construction is the base during the process of an information system development, especially for the TGP information system, which is so large-scale data that the database is very complicated. Generally speaking, the database server layer is made up of model database and sub-databases.

Data Source and Data Analysis

The collection and sorting out of monitored data determines the success or failure of an information system. Data from monitoring come from 19 leading stations and experimental stations, with data available in a diversity of forms that have developed according to the habits of their respective trades and services. The information management center has collected and analyzed the monitoring data since the system started operation in 1996, mainly from telephone calls, fax information, emails and conferences and visits of the related stations, analyzing technical reports, monitoring annual reports and quarterly reports, operational procedures with hope of reaching common understanding. Through incessant data collection and analysis from November 2001 to April 2004, the Information Center of Ecological and Environmental Monitoring Network for the Three Gorges Project (Information Center) has made fruitful achievements, such as data assessment reports, standard data and data form structure, physical relationship charts, and metadata. Up to the beginning of 2004, the information management center had basically collected all the baseline data about the ecosystem and environment before the reservoir impoundment, thus laying the foundation for building up of the information system.

The information management center has also achieved independently monitoring data, basic geographical data, remote sensing data, and interpretative information. The data process can be used directly in building the database.

Characteristics of Data

The key to realizing the functions of the information system lies in the data stored and managed by the system. The data in the system assume the following characteristics:

The data come from wide-ranging sources in multiple formats. There are mainly eight types of data: image data, matrix data of particular subjects, graphic data, statistical data, sample data, multimedia data, text data, metadata, and other nonstructured data, such as models. The data are available in huge amounts. It is estimated that the ultimate amount could reach 3 TB (including newly added data from remote sensing). The monthly amount is about 12 GB. The amount of data added monthly to the base data after sorting out is about 2 GB. The data are available in all kinds of formats. They require different processing and analytical technologies. There are image treatment, GIS, statistical analysis system, text processing system, and database management system. The software required is available in multiple types and versions. The data are of multi-temporal phase and multiple scales. In timescale, the time resolutions are different, ranging from 12 times a year to once a year and even once several years; in spatial scale, the biggest may reach 1:5000 and the smallest, 1:50,000.

The monitoring data come from 19 leading monitoring stations and experimental stations. The formats are diversified, originating from the demand and habits of different industries and trades. It is therefore necessary to convert all the data of different formats into a format required by the database, that is, the two-dimensional table form required by relational database. As part of the information is sourced in operational system, they have to be extracted and integrated into the database.

Completeness and accuracy of data is of utmost importance. They concern the analysis and policy decision taking on the TGP environmental impact. So, before entering the database, the data have to go through the checking for completeness and accuracy to ensure that they are error-free.

Finally, the integrity of the database determines the operation of other sub-systems. The analysis of data must be purpose-oriented. It requires integrated analysis, knocking down isolation among all sub-systems. The data must be attributed and integrated and put into different sub-systems such as pollution source, hydro-environment, declining wetland ecosystem, terrestrial ecosystem, hydro-ecosystem, social environment system, experimental stations and comprehensiveness.

Model Database

The model bank includes policy decision analysis model, methodology, and processes used in the process of monitoring, research, and remote sensing. The information in the bank mainly includes model name, provider, date, applicable conditions, analytical method, model formula, analysis process, and model description. In the model bank are spatially distributed models, time sequential models, multi-element analysis models, multi-element analysis and spatially analyzed integrated models, and time and space data models. The building of the model bank is the most complicated. All the monitoring stations and points and research units have to join hands in building and improving the multi-model bank.

Data Warehouse

The database contains all the information about the ecology and environment obtained from monitoring, remote sensing, and GIS.

(1) Monitoring data

They include all data obtained by all monitoring stations and points and experimental data from experimental stations.

(2) Remote sensing data

They include the basic ecology and environment data of the reservoir area (1:50,000) and resettlement area (1:10,000) renewed every 5 years; the dynamically renewed data about land resources and quality of the reservoir area in the three years of 1992, 2002, and 2005; spatial data about soil erosion intensity and areas in the reservoir area and monitoring results of the annual dynamic changes of soil erosion; data about the quality and changes in vegetation and habitats; data about the monthly primary productivity and annual terrestrial biomass of the reservoir area; data from dynamic monitoring of the areas of land used for building cities and towns; data from the monitoring of the progress of resettlement; data from the monitoring of the project of returning farmland to forests and grassland and natural shelter belts; and remote sensing data about biodiversity and monthly remote sensing of biophysical parameters.

(3) Basic geographical information

They include the resource environment baseline data of the Yangtze basin at a scale of 1:100,000 of 1985, 1995, and 2000; the baseline data of the second phase reservoir area at a scale of 1:50,000 of 1992 and 2002, and the baseline data about the third phase resettlement at a scale of 1:10,000.

Metadata are those of the above three types of data.

The above data form the database of the TGP information system as is shown in Fig. 6.2. As the monitoring stations

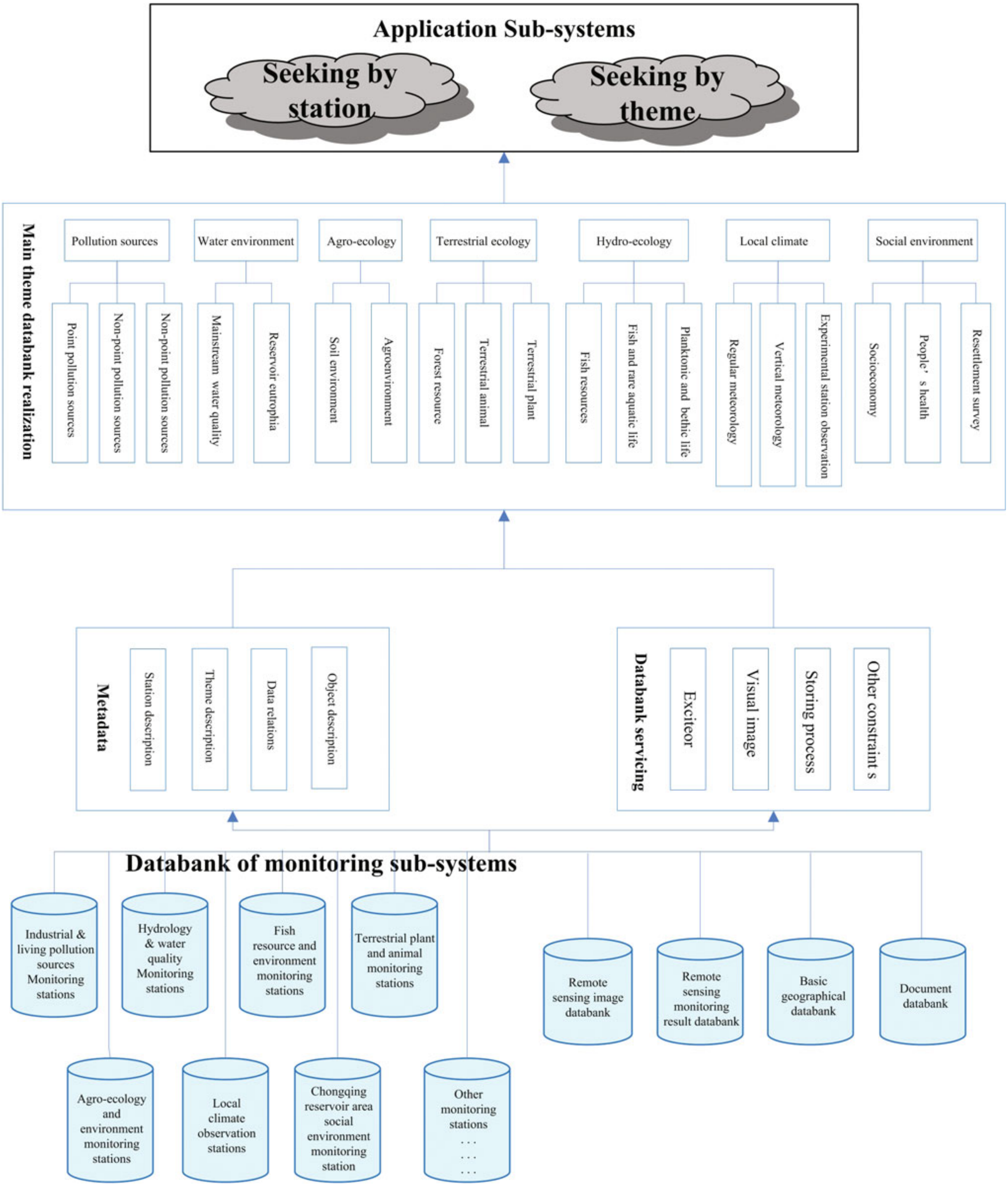


Fig. 6.2 Conceptual architecture of the databank of the TGP information system

are relatively independent and the data can be serviced, the database is divided physically according to different monitoring stations. The designing of the database has to take into consideration higher goals. The division of themes and expressions are realized mainly by two ways: one is the programs of the application systems; the other is the inner mechanism of the database system. The design of the themes at the database level may reduce greatly the development work of the application systems, which, in turn, may develop and expand the functions that cannot be realized or hard to be realized at the database level.

6.4 Functions of the Information System

6.4.1 Functional Modules of the System

The system is made up of six functional modules of data transmission, data processing, servicing system, searching and analyzing, policy decision support and information release, as is shown in Fig. 6.3. The data transmission sub-system is based on a kind of C/S system on the WAN; the data processing sub-system and system servicing sub-system are similar in structure, which is of the C/S of the LAN of the information management center. Searching and analyzing sub-system, the policy decision support sub-system, and information release sub-system are of the B/S system, with the former two providing information service according to the user authorities and the later two being the public-oriented websites. The following is a detailed description of the functional modules of the TGP information system:

6.4.2 Data Transmission Sub-system

This sub-system is to solve problems of data sharing, exchange and transmission among the owner departments, various monitoring stations and experimental stations, information management center and all base work stations to make their data transformation quick and easy, and support the owner technically in getting to know promptly the ecological and environmental conditions of the TGP area.

The data transmission system is of the C/S structure, with the information management center as the server and owner units, information management center, and all monitoring stations as the customer end. In view of the module composition, it mainly includes the following:

- User management module: user log and system log management module;
- Information transmission module: information release module, information receiving module and information management module;
- Work task transmission, receiving, and management modules;
- Official document transmission module: official document release, transmission, receiving and management modules;
- Materials transmission module: materials and data receiving and management modules.

The relations between the data transmission sub-system's functional modules and the user ends are shown in Figs. 6.4, 6.5 and 6.6, which respectively, interfaces the owner units' customers and those of the information management center.

6.4.3 Data Processing Sub-system

In Sect. 6.4, we have listed the characteristics of the data of the information system. They include not only monitoring data, reports and photos from 19 leading monitoring stations and experimental stations, the contracts signed between owner units and various stations, and information open to the public but also spatial data from remote sensing and GIS. They are widely divided in types and methods of processing. Conversion and import of those data are very complicated and low in efficiency. The data processing system is designed to raise the work efficiency and processing capability, making streamlined the processing, conversion, import of different formats of the six major types of information, and making it systematic through interaction between machine and man.

The data processing sub-system is made up of five major modules to process monitoring data, reports, photos, contracts, and public information. Specifics are shown in Fig. 6.7.

Monitoring Data Processing

Most of the data from monitoring are available in the tabular form, which is a kind of analysis result, different from the tabular structure of the database. There are also some data coming from the operational system. These forms have to be converted and integrated between the operational database and the database of the system.

The data processing function may realize standardization of data submitted, making them conform to the tabular

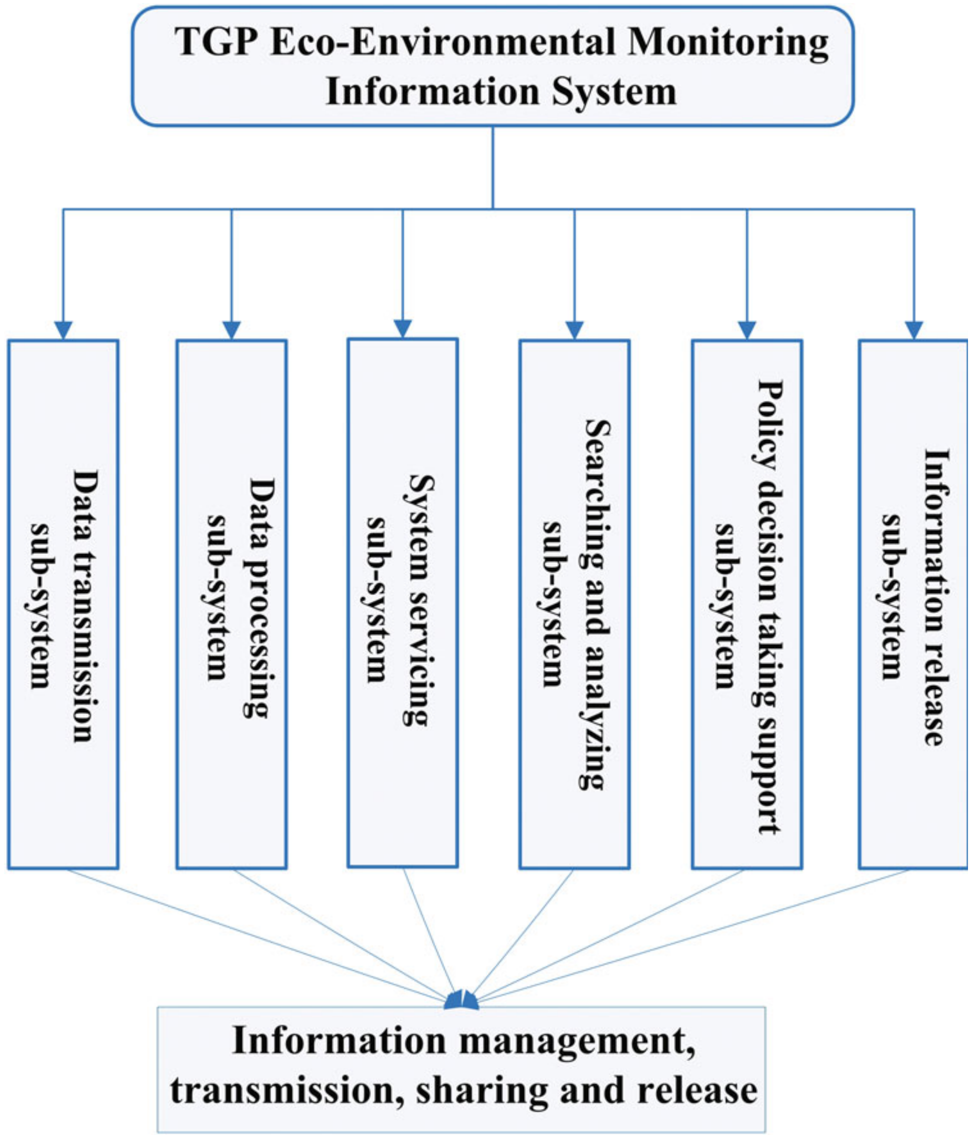


Fig. 6.3 Functional modules of the information system

structure of the database. They include title conversion, line and column conversion, data item merger, title merger, data item split, similar contents of merger, title data item conversion, Xiaogang data item split and data processing, totaling eight formats. The system requires that the processed data must conform to the data import format defined by the above eight formats. The system is capable of processing Excel documents, ODBC data source (DBF document, ACCESS document, and all regular data sources). Besides, the system also provides data entry functions and models, including additions and renewals.

Picture Processing

The formats to be processed include JPG, TIF, and BMP. Through the system interface, the basic caption information may be captured, including name, time, contents, unit code, attributive theme, automatic numbering and recording the photos and basic information in one entry. Besides, the system will compress large photos (>300 k) according to a certain proportion to facilitate WEB search while retaining the original and the compressed version of the photos. The function of photo browsing is also available.

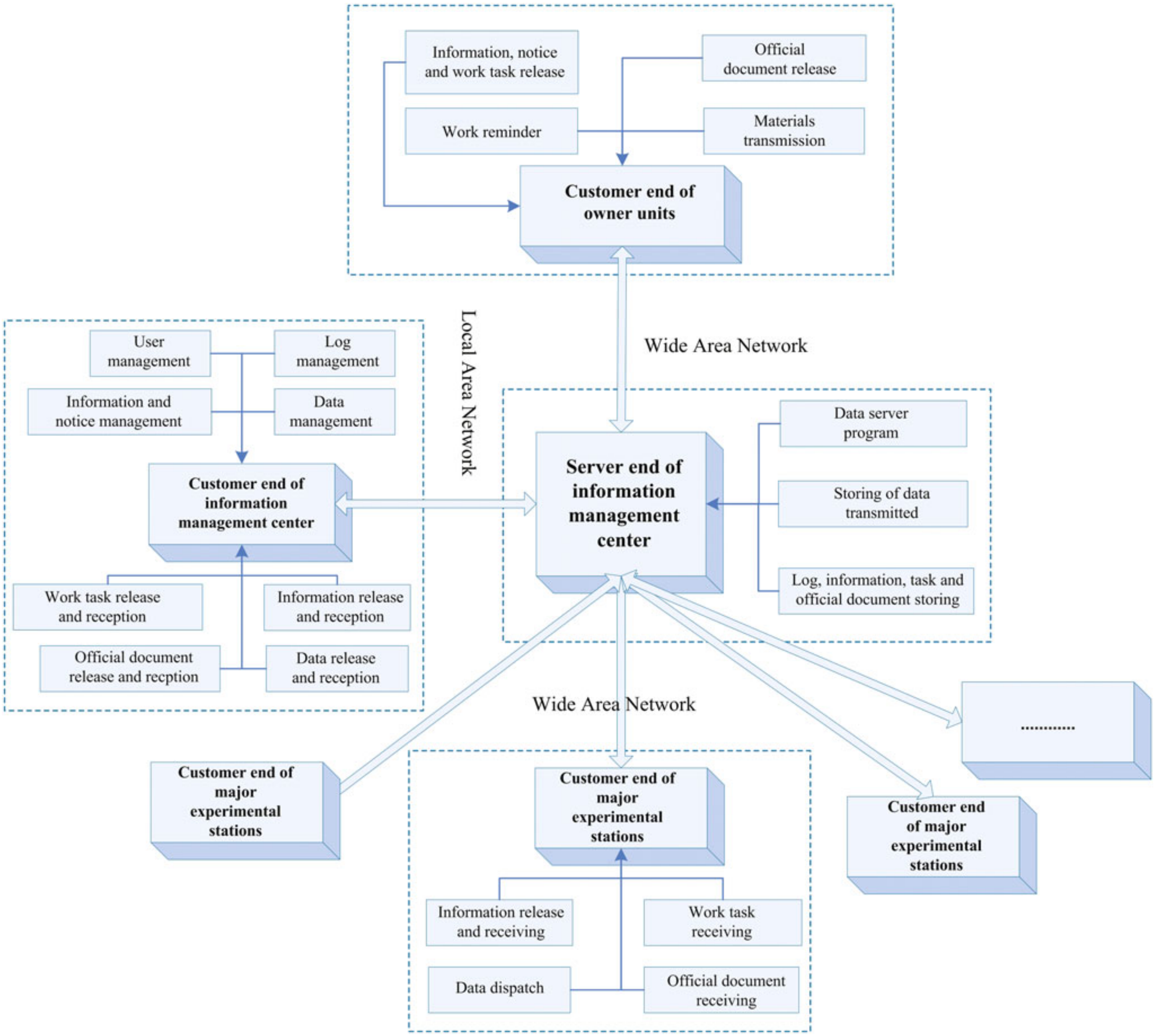


Fig. 6.4 Functional modules of data transmission sub-system

Report Processing

The system can process all kinds of documents, including reports, contracts, and public information. The process includes collection of basic document information, such as serial number of document, selection of document type, and selection of units that provide the document, import of document, and basic information into the database in the duplicated form in the formats of Word and PDF. The system requires that the processed documents must meet the following requirements: Word document must have a standard page layout and be converted into PDF format with content box added.

Contract Processing

Contract processing includes page layout design, format conversion, contract document content making, contract document renaming, and contract abstract information collection.

Public Information Processing

Public information is mostly available in document and tabular forms. The processing includes text input, editing, page layout design, classification, and abstract extraction. The processing is similar to that of contracts and reports as shown in Fig. 6.8.

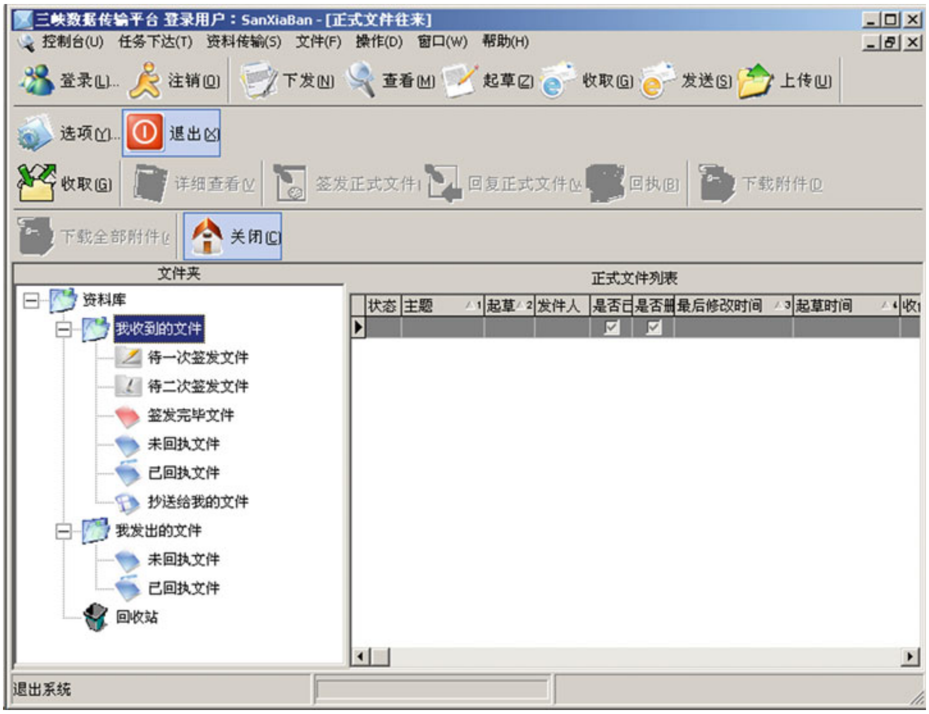


Fig. 6.5 Customer end of the owner units of the data

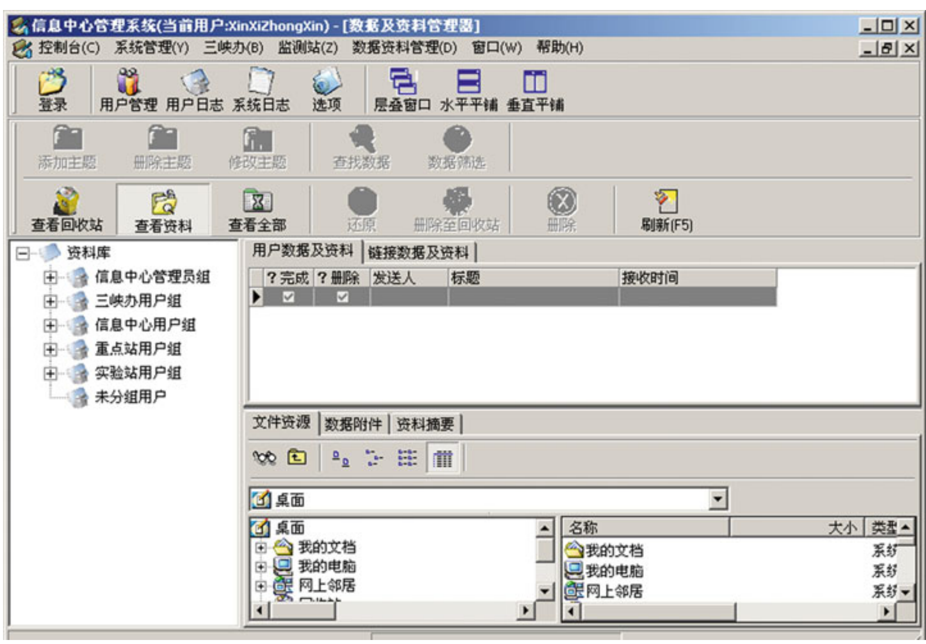


Fig. 6.6 Customer end of interface of the data

Basic geographical spatial information mainly includes image data, graphic data (vector data), and grid data. Most of the processing is done in the background by specialized analytical software with Erdas, PCI, ArcInfo, Ecognition as the platforms. The results of analysis are put under the management of database and released through the web. In the data processing system, it is completed according to demand by specialized analysis of the basic geographical spatial data and its maintenance is carried out in the system maintenance sub-system.

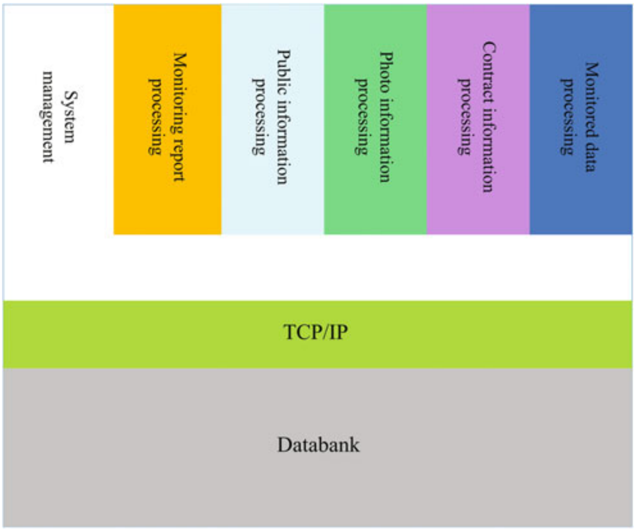


Fig. 6.7 Structure of the data processing

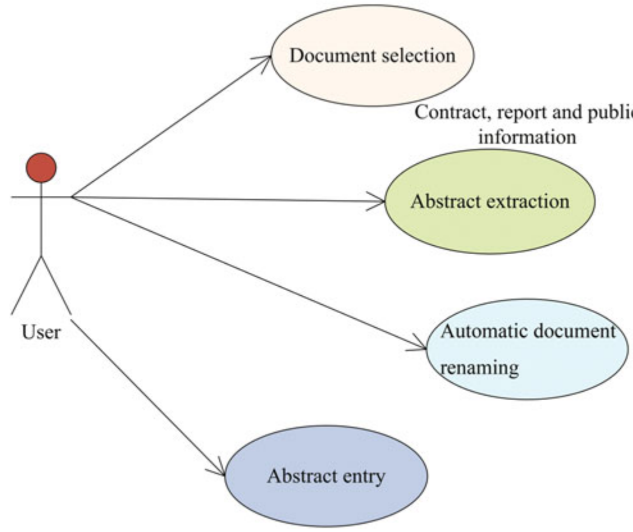


Fig. 6.8 Contract, report, and public information processing modules

6.4.4 Information Release Sub-system

The information system serves as an information release platform, with the user sub-systems, leading monitoring stations and experimental stations, owner units, scientific experiment units and the public as the main targets. Information released includes public information, information for sharing, integrated analysis information, dynamic information, and environment bulletin. The information is released on the web. It also serves as monitoring reports and related information about the ecosystem and environment in the TGP area, such as progress of eco-environmental protection and monitoring, monitoring reports on a particular subject, research achievements, and other information open to the public. Information released may be in the form of report, graphics, and image or table. The main interface of the sub-system is shown in Fig. 6.9. The website of the TGP information system is www.tgenviron.org. The information release structure is made up of three parts.

Information Service Column

The zone displays all façades of the monitoring system, including introduction to the system, history and progress of TGP, main eco-environmental issues on the upper and lower reaches of the Yangtze, people resettlement, monitoring achievements for all years, laws and regulations and standards concerning monitoring, papers, publications on the analysis and study of the monitoring data, communication and information sharing among monitoring personnel, contracts of units and responsible persons, and websites addresses of all related units. The area has the authority configuration for protecting the intellectual property rights of monitoring and management units.

Monitoring Sub-stations and Points Column

This covers owner units, monitoring bulletin, leading monitoring stations, experimental stations, and other specialized monitoring units. The main contents are introduction, news and staff members, research projects in progress, research achievements, and instruments and meters as well as upload and download of monitoring data, reports, proposals, and suggestions and management information. While giving brief introductions to all units, the system provides online work platform to facilitate owner units to issue commands, plans, and manage monitoring.

Three Gorges Column

The zone covers important news, landscapes, cultural relics and historical sites, natural conditions and biotope, general pictures of counties and cities around the TGP, and the magnificent work sites of the project.

6.4.5 Query and Analysis Sub-system

The sub-system is made up of user management module, monitoring information search module, document information search module, three-dimensional and multimedia demonstration module, and spatial information search module. The maintenance and management interface of the user management module is built in the system maintenance sub-system. It is of the C/S structure. The user information

Fig. 6.9 Main page of the TGP information system website

and related service program are installed in the server. The other four modules realize secure visits of the search system through user information and service program. The other five modules are the core information search and analysis modules of the B/S structure.

User Management

The user management module functions to add and delete users, modify code, and control authorities. These functions are realized through the middleware in the development server end. The middleware has integrated some public service functions, such as unified data visit interface. The service name of the middleware is "sanxiaservice". The system maintenance module provides start and stop service functions. The user management module provides the search system and policy-making support service with basic security assurance and empowers different users with corresponding access authority.

Monitoring Information Query

The monitoring information search module mainly provides users with information and analysis from 19 monitoring stations, divided into different levels. The 19 monitoring stations are of the first level virtual module. As each station has different monitoring targets and analyses, the monitoring information module is divided into three levels, with the third level being the real module. Table 6.1 shows the composition of the module of leading stations for monitoring local climate. The other module divisions are similar. There are about 100 sub-modules. We shall not go into them one by one.

The main functions of the monitoring information search modules include information search, statements on particular subjects, time and spatial dynamic statistical analysis, statistical forms and graphics, development trend analysis, and prediction. Figure 6.10 shows the module.

Document Query

The document search module is mainly to seek, browse, and download required documents based on the artificially preprocessed documents and abstracts in the data processing sub-system. These documents include environment announcement, technical reports, annual reports and quarterly reports by all monitoring stations during different periods of time, contracts signed with owner units, and some documents containing public information such as laws and regulations. The abstracts of all kinds of reports include serial number, name, date of submission, time of completion, report providers, name of special subjects, type of reports, catalog of document saved, and directions. Users just input some search conditions and retrieve the desires reports.

Three-Dimensional and Multimedia Demonstration

The three-dimensional and multimedia demonstration module includes six sub-modules on TGP, three-dimensional and

Table 6.1 Module composition of major stations for monitoring local climate

First level virtual module	Second level virtual module	Third level module	Third level module code
Local climate leading monitoring station (CLLM)	Regular weather	Monthly change	CLIM01
		Quarterly change	CLIM02
		Annual change	CLIM03
	Meteorological disaster statistical analysis	Rainfall days	CLIM04
		Max. wind velocity	CLIM05
		Strong wind days	CLIM06
		Rainstorm analysis	CLIM07
		Drought analysis	CLIM08
		Low temperature & rainy days analysis	CLIM09
		High temperature analysis	CLIM10
		Acid rain analysis	CLIM11

Fig. 6.10 Monitoring information query module

video images, current conditions of the reservoir area, resource of the reservoir area, ecological environment, and monitoring system.

"TGP" covers background, general picture, features, and environmental impacts;

"Current conditions of the reservoir area" covers general introduction to the social economic conditions of counties and districts, geological foundation, soil types, people's health, and resettlement of displaced people.

"Resource of the reservoir area" covers land, water, plant culture, vegetation, fish, minerals, and tourism.

"Ecological environment" covers hydrology, water quality, environmental pollution, local climate, hydrobiology, terrestrial life, land cover, and vegetation physiological parameters.

"Three-dimensional and video images" is a basic layer and baseline layer of the ecology and environment, such as three-dimensional pictures, laminated images, waterway systems, roads, and community centers generated by DEM from the topographical data, which vividly display the ecological and environmental shape of the reservoir areas from different angles and, through video technology, enables users to browse DVD and photos, with voice-over introductions.

"Monitoring system" displays the general introduction of the monitoring system and its sub-systems in the forms of text, photo, voice, video, and visual images.

Spatial Information Query

Spatial information module is used to search remote sensing data and basic geographical data. By using ArcIMS software, through secondary development with HTML and JavaScript, the module offers browsing, enlarging, contracting, roaming, attribute search, and spatial positioning of the spatial data layer (Fig. 6.11).

6.4.6 Decision Support System

The service occupies an important position in the system. It mainly serves owner units by providing information in support of policy-making. The purpose of the sub-system is to provide leadership with the results of the comprehensive analysis of the TGP ecological and environmental monitoring data, including the causes, future development trend, the impacts on the entire ecosystem and environment of the reservoir area in addition to amassing monitoring data. The service integrates all kinds of analytical models for analyzing the ecology and environment in the service of policy-making, carries out spatial, multi-factor and model analysis and computation to arrive at some conclusions for reference in taking policy decisions.

Based on ArcIMS platform, the sub-system uses ASP. Net, HTML, JavaScript, and other development language and environment to realize real-time information service, comprehensive searching service, and analysis of information in particular areas (trend analysis, statistical analysis, and eco-environmental analysis). The sub-system has the following functional modules:

(1) Reservoir area eco-environmental baseline and dynamic change analysis (mainly on land resources);
   - Dynamic changes of the amount and quality of land resources;
   - Total areas of existing slope land >25° and the annual changing trend;
   - Monitoring of farmland reclaimed from forests and grassland and natural shelter belts;
   - Dynamic monitoring the changing trend of land used for building up cities and towns.
(2) Dynamic changes of vegetation and wildlife habitat quality;
(3) Estimation of water loss and soil erosion and non-point pollution load;
(4) Assessment and trend analysis of biodiversity;
(5) Assessment and environmental analysis of fish resources;
(6) Hydro-environmental assessment and trend analysis; and
(7) Monitoring of the progress of people resettlement.

The policy decision support sub-system involves wide-ranging industries and many problems have to be analyzed and resolved through scientific research. The monitoring stations have different scopes and targets for monitoring. So, the policy decision analysis concerning the TGP's impact on the ecosystem and environment has to be completed by joint efforts of related research organizations and units. Research institutions and various sub-systems must first carry out their own analyses and the results are collected for review before arriving at comprehensive information for reference in taking policy decisions.

6.4.7 System Maintenance and Management

The information system contains a large amount of information. It takes a long time to build and it is very busy in processing data. It is, therefore, very important to keep the system operation stable, efficient, reliable, and secure. Maintenance mainly covers software and hardware maintenance and upgrading, website servicing, user management, authority management, backup and restoration of service, log recording, and auditing. Some of the work has to be done

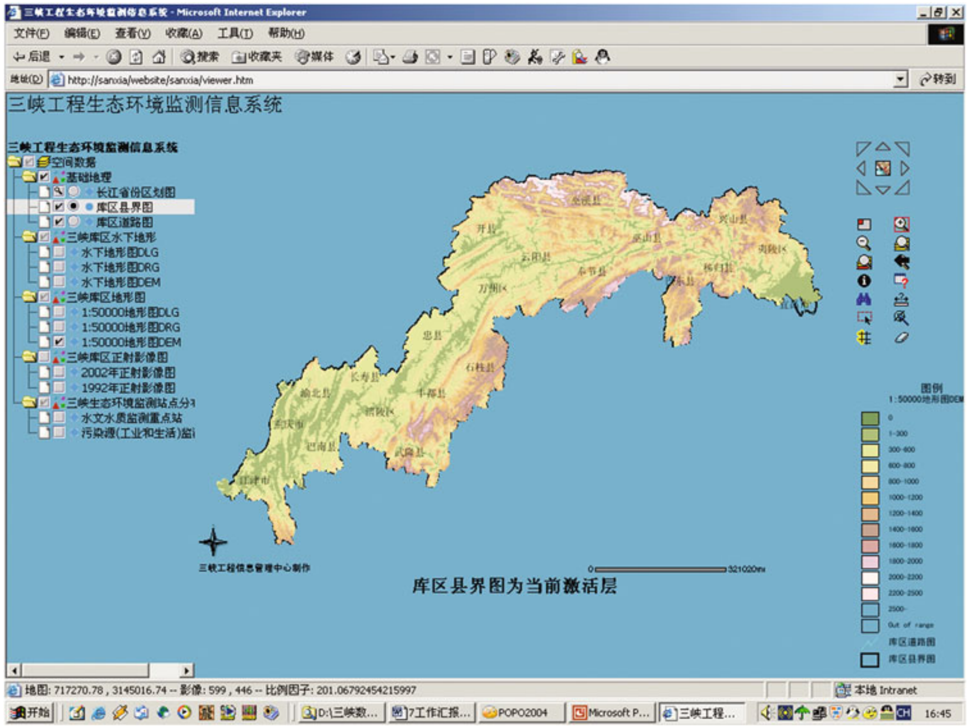


Fig. 6.11 1:50,000 search result display

by special modules developed and some by the functions of the software.

Software and Hardware Maintenance and Upgrading

This includes the mainframe, network system, database system, and application development platform. The mainframe maintenance includes the hardware environment and operating system. Work includes routine maintenance, professional maintenance, and upgrading. Web system includes exchangers, routers, and Internet access. Work includes network configuration, resources application, properties analysis and trouble shooting, up scaling, replacement, and upgrading of network system equipment.

Database Maintenance and Management

The information management center has developed modules to carry out maintenance of the monitoring data, remote sensing data, and basic geographical spatial data. The functions of the modules include the following:

(1) Data input: spatial data uploading, nonspatial data entry and photo entry;
(2) Data renewal: nonspatial data renewal and spatial data renewal;
(3) Data retrieval and browsing: the browsing of form data, standard frame, and spatial data by layer;
(4) Spatial data version management: vector data version management, grid data version management, and form data version management.

Figures 6.12 and 6.13 show the form data (monitoring data) and spatial data maintenance interface.

Website Maintenance

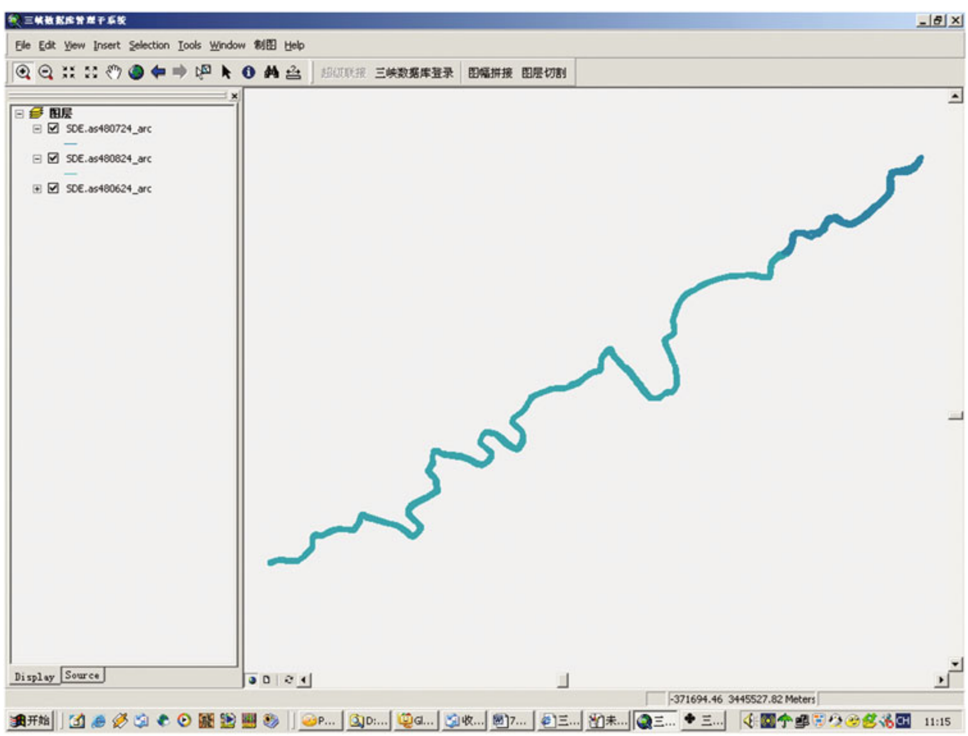
(1) Website style renewal: Sometimes, website style has to be changed to meet demand of the system and make the website more attractive.
(2) Column adjustment: Sometimes the website should add new columns and sometimes cut others to better satisfy demand of the system development.
(3) Static page maintenance: The static page maintenance involves a large amount of work, including introductions of topics, units, liaison methods, notice, news, standards or norms, technical directions, and interpretation of terms and glossaries.
(4) Maintenance of the main page of various special topics (including leading monitoring stations and experimental stations).

User and Privilege Management

As the purpose and objects of service of the five sub-systems of the TGP information system, the users and their authorities

Fig. 6.12 Monitoring data maintenance interface

Fig. 6.13 Spatial data maintenance interface



are also different. The users and their authority control modules of the data processing and transmission sub-systems are integrated with their corresponding application systems; the users and their authority control modules of the searching and analyzing sub-systems and policy decision taking support sub-systems are relatively independent C/S modules.

Backup and Restoration

Backup and restoration include system environment, application data, and applied system.

The system environment includes the operating system and database system. The system environment is usually backed up regularly to a tape or other storing media. When troubles occur with the system, the system environment could be copied back to the original system. In backing up the system environment, it is essential to record the key information, such as name of system and root information.

Data backup and restoration mainly refer to the data of the application system. They are usually backed up regularly by hand or automatically to other storing media in case of troubles with the server medium. There should be a tight backup strategy in order to reduce losses and restore the original data.

The backup and restoration of the application system are relatively simple. When the application system is renewed, the whole system may be copied to other media, with the record of the application system well kept. In restoring the application system, it is first of all restoring the application system environment and copying the application system into the system.

Security Control

The information system is a complicated systems engineering. Its demand for security cannot be resolved by any one unit technology. It requires a complete system and adopts all kinds of security technology and means for all layers of data and in all links. The security of the system is ensured in its hardware support environment, system software support environment, and application system.

The security of the hardware support environment is realized through firewall and router. There is a firewall between the LAN of the information management center and the public network to prevent vicious attacks by illegal access or hackers. The router supports security monitoring and control mechanism. When any security loophole occurs and the system is attacked, it reminds the management personnel and automatically adopts proper protective measures.

The software support environment includes the operating system and database system. The operating system protects the document system, Internet protocol, and cookies against virus invasion. The database system, Oracle, provides a strong security. When allowing users to access to the system via Internet, it selects multiple standard-based and through verified data encryption to certify users to access to the database and web server.

The application system security is realized through one-off code verification, information encryption, and authority control. The data transmission has to go through encryption and decryption to ensure security.

Log and Audit

In order to ensure security of the system, it requires the recording of system operation log and user operation log. Once the system gets into trouble, logs analysis should be made so as to find out where the problem lies.

7 TGP Ecological and Environmental Impact Monitoring Achievements Before Impoundment

The TGP eco-environmental monitoring system was set in motion in 1996. Since then, all the sub-systems and major stations have carried out regular or irregular monitoring, observation and surveys of natural, ecological, environmental, and economic factors in the TGP affected areas from multiple perspectives in line with the standards published by the State or industries. They have accumulated a lot of data and obtained the baseline materials of the dam affected areas. This chapter gives a general picture of the monitoring achievements (not including sedimentation and degradation, earthquake induction, and geological disasters) by major stations before the impoundment of the reservoir in June 2003. Readers interested in details may read related technical reports.

7.1 Hydrology and Water Quality Monitoring[1]

The Hydrology and Water Quality sub-system carried out monitoring of the Yangtze hydrology and water quality, water quality at cities, pollution belts, and groundwater in the midstream to see the possible changes in the hydrological regime of the river after impoundment. Baseline data have been obtained on hydrology and water quality before impoundment.

[1]Changjiang Water Resources Commission (CWRC). Technical Report of Main Synchro-monitoring Station of Hydrology and Water Quality of Main Stem (1996–2003); Chongqing Municipal Environmental Monitoring Center, Technical Report of Main Monitoring Station of Typical Outfall and Pollution Belt (1996–2003); Institute of Geodesy and Geophysics, CAS. Technical Report of Main Groundwater (Xiaogang) Monitoring Station (1996–2003).

7.1.1 Yangtze Monitoring Results

Hydrology and water quality

By analyzing the hydrology and water quality (both clear and turbid samples), bed quality and aquatic life in the middle and lower reaches of the Yangtze and the reservoir area before impoundment, they have obtained the baseline materials and the features of their changes.

The perennial average value of all indicators used in water quality assessment was between Type II and III, GB3838-1988 Standards, see Table 7.1, well meeting the requirements for multiple water uses. The water quality was generally good.

In terms of spatial distribution, part of the indicators had some changes at all monitoring cross-sections due to local environmental impacts on different river sections, such as sea water invasion, which caused the conductivity of the Wusongkou section to be higher than other river sections. But, in terms of water quality assessment, there was no essential difference between the reservoir section and sections downstream of the dam.

In terms of time scale distribution, the indicators in all cross-sections were relatively stable, with small annual changes. Except the Wanzhou cross-section, which exceeded the total leading standards (0.057 mg/L), for which the water was rated as Type V, the water of all other cross-sections was rated as Type II or III for all years. However, due to great differences in the suspended substances during different water seasons, substances that were easily absorbed by sediment flowed into the river, thus causing COD_{Mn} and heavy metals and other pollutants to be higher in high flow season than normal and low flow season.

The main pollutants in the reservoir area and in the middle and lower reaches of the river were organic matters. The main indicators affecting the water quality in different

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2_7

Table 7.1 Integrated assessment of the water quality in the monitoring cross-sections in the reservoir area and in the middle and lower mainstream of the Yangtze

Area	Cross-section	Item	DO	COD_{Mn}	BOD_5	NH_3-N	NO_3-N	NO_2-N	ArOH	Cyanide	Arsenide	Cr^{6+}	TCu	TCd	TPb	Integrated assessment
Mainstream in reservoir area	Chuntan	Mean value (mg/L)	8.5	3.86	1.15	0.229	1.421	0.029	0.001	0.001	0.004	0.0044	0.029	0.0030	0.033	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	31.9	1.4	4.3	0	0	1.4	0	0	0	0	0	26.1	
	Qingxichang	Mean value (mg/L)	8.4	3.67	0.91	0.203	1.427	0.031	0.001	0.001	0.004	0.0044	0.026	0.0032	0.033	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	29.0	0	2.9	0	0	1.7	0	0	0	0	0	42.0	
	Wanzhou	Mean value (mg/L)	8.4	3.81	0.91	0.184	1.489	0.029	0.001	0	0.004	0.0044	0.027	0.0031	0.036	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	37.3	0	1.5	0	0	6.0	0	0	0	0	0	29.9	
	Guandukou	Mean value (mg/L)	8.8	2.71	0.73	0.208	1.011	0.032	0	0	0.002	0	0.021	0.0025	0.013	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	10.1	0	0	0	0	0	0	0	0	0	0	5.8	
	Badong station	Mean value (mg/L)	8.7	2.77	0.83	0.222	1.034	0.031	0	0	0.002	0	0.023	0.0024	0.012	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	10.6	0	0	0	0	0	0	0	0	0	0	4.5	

(continued)

Table 7.1 (continued)

Area	Cross-section	Item	DO	COD_{Mn}	BOD_5	NH_3-N	NO_3-N	NO_2-N	ArOH	Cyanide	Arsenide	Cr^{6+}	TCu	TCd	TPb	Integrated assessment
Tributaries in reservoir area	Linjiangmen	Mean value (mg/L)	8.3	3.67	1.37	0.405	1.760	0.053	0.001	0.001	0.004	0.0081	0.009	0.0030	0.021	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	I	II	II	
		Above standards (%)	0	28.7	7.5	23.9	0	0	7.5	0	0	0	0	0	0	
	Wulong	Mean value (mg/L)	8.7	2.13	0.71	0.107	1.688	0.012	0.001	0	0.002	0.0027	0.007	0.0027	0.016	II
		Water quality classification	I	II	I	I	I	I	I	I	I	I	I	II	II	
		Above standards (%)	0	8.8	0	0	0	0	2.9	0	0	0	0	0	0	
Middle and lower mainstream	Nanjinguan	Mean value (mg/L)	8.8	2.74	0.78	0.216	0.986	0.031	0	0	0.002	0	0.022	0.0025	0.012	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	10.1	0	1.4	0	0	0	0	0	0	0	0	5.8	
	Hankou	Mean value (mg/L)	9.0	2.97	1.19	0.298	1.235	0.026	0	0	0	0	0.016	0.0018	0.018	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	II	
		Above standards (%)	0	11.6	0	11.6	0	0	0	0	0	0	0	0	2.9	
	Wusongkou	Mean value (mg/L)	8.0	3.84	1.51	0.348	1.479	0.037	0.002	0.004	0.012	0.0041	0.016	0.0031	0.006	II
		Water quality classification	I	II	I	II	I	I	I	I	I	I	II	II	I	
		Above standards (%)	0	40.3	0	20.0	0	0	0	0	0	0	0	0	2.9	

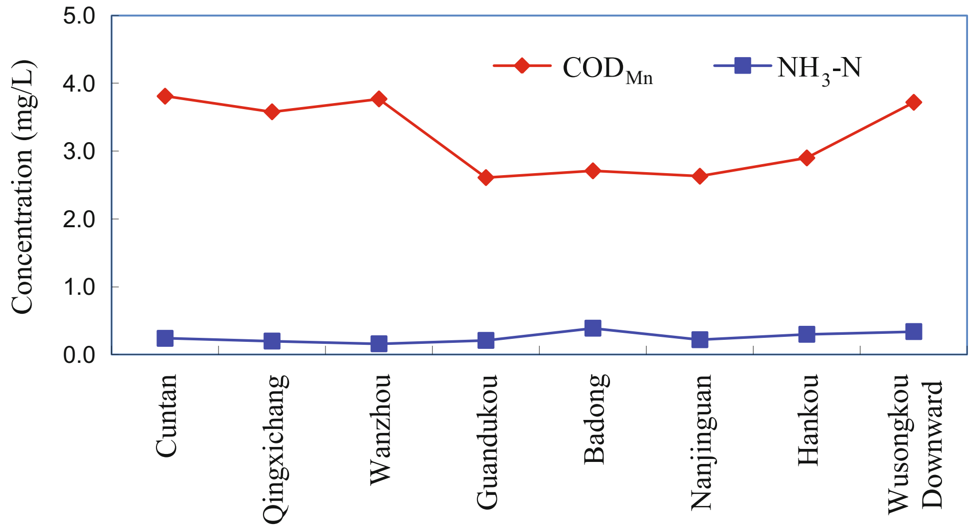


Fig. 7.1 Distribution of years' average value of COD_{Mn} and NH_3-N in the mainstream of the Yangtze in 1997–2003

monitoring sections were COD_{Mn} and NH_3-N, but changes were not big along the river. See Fig. 7.1.

Comparison of the monitored value of COD_{Mn}, TP, THg, TAs, TCu, TPb, TCd of both clear and turbid water samples showed that they were visible in all the 10 monitoring cross-sections, with that in the turbidity samples being higher than clear samples, such as the contents of COD_{Mn}, TP, and TCu in the turbidity samples are 0.41–0.85 times, 1.25–3.45 times and 1.11–3.28 times higher than in the clear samples. As the contents of TPb, TCd, TAs, and THg were low, there was not much difference between turbid and clear samples.

Water quality trend analytical statistics shows that there was no significant change in the density and transmission rate in the parameters of water quality, indicating that the water quality and pollution load were basically stable.

River bed quality

(1) The deposit monitoring results of all monitoring cross-sections in the mainstream and tributaries of the reservoir area and in the middle and lower reaches of the river show that, apart from total mercury, the annual contents of other items in all cross-sections were at the same level or at similar levels, with the total mercury contents at the Wulong cross-section significantly higher than other cross-sections due to the high mercury contents of the Wujiang River.

(2) The monitoring result of organic farm chemicals in the deposits shows:

Organic chloride farm chemical universally existed in the deposits of the mainstream and tributaries in the reservoirs area. It was found in all the five cross-sections in the mainstream of the reservoir area in 1997 and 2001. But it was found in all the cross-sections in 2002 except at the Badong water table station.

Organic phosphorous farm chemicals are not significant. It was found in all the five cross-sections in 1997, but it was found in the remaining two cross-sections in 2001. But it was not found in all the cross-sections in 2002. This might be associated with the characteristics of the farm chemical, which is non-stable in the environment and easy to be degraded.

The detection probability of ethion and dimethoate among the organic phosphorus farm chemicals was higher than that of ethyl parathion and malathion, but neither has a high detection rate, with the methyl parathion never detected.

Biology

Monitoring results show that the general characteristics of phytoplankton, zooplankton, zoobenthos, and attached algae in all the river sections monitored in the reservoir area were: fewer types detected, basically no predominating species found and biomass was small.

The phytoplanktons and biomass at the Cuntan cross-section were basically at the same level; those at Linjiangmen and Wulong cross-sections were higher than the mainstream cross-sections. See Fig. 7.2.

The distribution of plankton in the reservoir area was mainly influenced by its life history and hydrological regime, with the density and biomass assuming significant seasonal changes as shown in Figs. 7.3 and 7.4. The density is the biggest in winter, when the Yangtze is in a low flow season and the water current was warm and clarity was relatively higher. When spring comes, with the water temperature rising, zoobenthos, large phytoplanktons, and zooplantktons begin to grow in large numbers, with the biomass being the biggest of all seasons, and there is even the emergence of

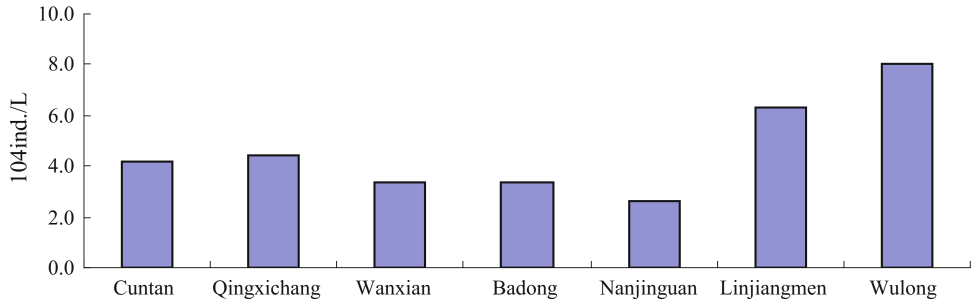


Fig. 7.2 Average density of planktonic plants in the reservoir area in 1999–2002

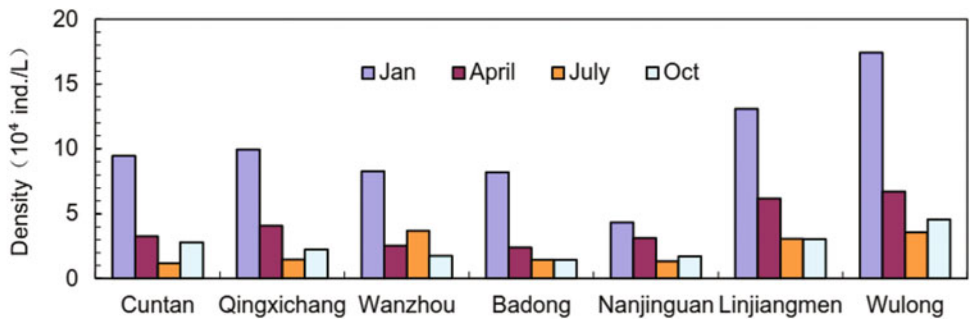


Fig. 7.3 Density of planktonic plants during different seasons in 1999–2002

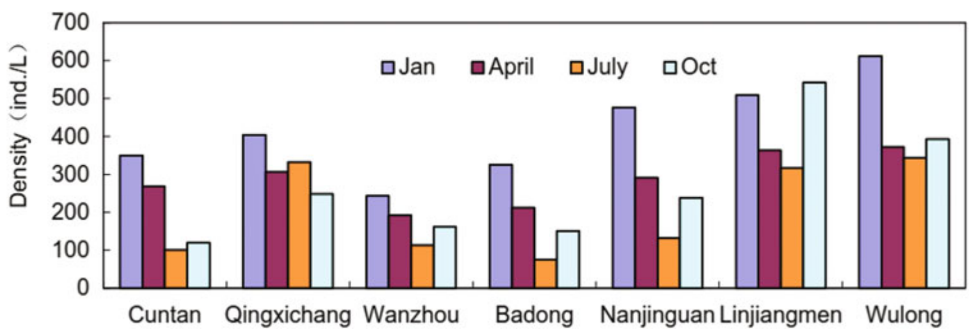


Fig. 7.4 Density of Planktonic animals during different seasons in 1999–2002

epistylis and other pollution resistant species. But the density and biomass are the lowest in summer, when the high flow season sets in and the water flow and sediment increase, making it unfavorable for planktons to grow. Zoobenthos is mainly influenced by its life history rather than by water flow. It has the biggest seasonal changes, available in the biggest number in spring and the least in autumn.

According to the water quality assessment standards GB3838-2002 and using the monitoring results of the aquatic life species composition and number to make the assessment, the water quality in the reservoir area was generally good, with the pollution resistant species found in the monitoring cross-sections upstream. This merits attention. Analysis should be made concerning its relations with the environment.

7.1.2 Pollution Belts Monitoring Results

Water quality of city river sections

During the 1996–2003 dry seasons before impoundment, the water quality of city sections in the reservoir area reached or was even better than Type III standards, as is shown in Fig. 7.5. The cross-sections where water quality reached or even better than Type II standards up to 81.8, 92.3, 100, 81.2, 87.5, 86.7, 86.7, and 86.7%, indicating that the water quality in most city river sections during the low water season is good in general.

During the normal flow season, the water quality of all the cross-sections in all years, except 1997 that reached 100%, with the cross-sections whose water quality reached

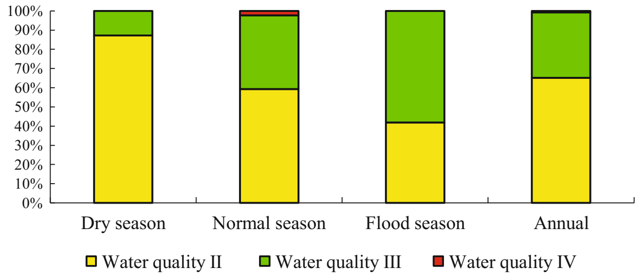


Fig. 7.5 Time scale of different water qualities during different water seasons in the city river sections of the reservoir area

or even better than Type II standards being 81.8, 69.2, 53.3, 46.7, 50, 66.7, 53.3, and 80%, indicating that about half of the cross-sections able to meet the requirements of Type III standards, but being worse during the dry water season.

During the high flow season, water quality of all the cross-sections in all years reached 100%, with that of all cross-sections reaching or better than Type II standards reaching 81.8, 38.5, 33.3, 31.2, 50, 30, 53.3, and 46.7%, indicating that about 2/3 of the cross-sections unable to meet the Type II standards, the worst of all the water seasons.

The results of the water quality assessment of city river sections during the low, normal and high water seasons were made without considering the TP and oil indicators. If TP and oil are taken into consideration, the water quality in most of the cross-sections in most of the years would have been of Type III and even Type IV instead of type II and the changes have poor regularity in time and space. In the past, the pretreatment of water samples was not standard in the monitoring of TP and Oil and the testing methods were not unified, thus resulting in a big divergent factor in the value of density, making it poor in comparability. So, their impact on water quality is not taken into account.

In 1996–2003, the indicators of water quality in the city sections of the river in the reservoir area that failed to meet Type II standards-included TP, COD_{Mn}, COD_{Cr} and NH_3-N. There were only isolated cases when DO, BOD, and ArOH exceeded Type II standards. AS for heavy metal Pb, which exceeded Type II standards during normal and high water seasons, it was seen mainly in the river sections passing through the main city districts of Chongqing. The density of oil was between “not detected” and “0.05 mg/L” in most cross-sections in recent years. If 0.05 mg/L is taken as the basis for classifying Type III standards, the indicator of oil in most cross-sections in the reservoir area belonged to Type III, failing to meet Type II standards. See Table 7.2.

Pollution belt monitoring result

The riparian water quality monitoring at Fengjie, Wushan, and Badong city districts found significant pollution belts. The length and width were associated with the pollution load and water flowing into the river. They were also associated with the quality of water flowing into the river. The above-background pollution belts of the three cities in 2001 were 7.9 km during the low flow season and 9.2 km during normal flow season, occupying 63 and 73% of the total city sections of the river. The corresponding above-background water quality pollution belt was 20–40 and 20–80 m in width, only about 10–20% of the width of the river. Among the three monitoring indicators, there is no water quality standard for TN, making it unable to determine the range above the standards. As the entry flow background density is low in COD_{Mn}, no significant above-standard pollution belts were found near the banks of the city sections of the river. In Badong and Wushan, as the entry flow background density was high during the low flow season, the TP density in the whole city section of the river exceeded standards, but it was not caused by the city itself. The above-standard pollution belts in the low flow season in Fengjie, which were caused by the pollution discharge by the city itself, and the riparian pollution belt in Badong city district section during the normal flow season were not so long and wide. They appeared in the lower part of the city sewerage discharge outlet.

Before the impoundment of the reservoir, there were 66 sewerage discharge outlets along the banks of the Yangtze in the reservoir area and 164 direct wastewater discharge outlets. The above-background pollution belts formed by typical city sewerage discharge outlets were about 25–32.2 km long and 10–150 m wide. As the city sewerage discharge changes annually, the pollution belts caused also vary in length, width, and area. The pollution belts caused by city sewerage discharge mainly appear in the main city districts of Chongqing, Wanzhou, Fuling, and other central cities where the sewerage discharge is heavy. There are very few concentrated pollution belts in other places. The pollution belt caused by city sewerage in the city districts of Chongqing accounted for 65–77% of the total pollution belts in the reservoir area and those in Wanzhou and Fuling, accounted for 13–21%. The above-standard (Type III standard) pollution belts caused by typical city sewerage outlets were short, about 1.7–2.0 km in length and about 5–10 m in width in 1997–2000, the same as the distribution of above-background pollution belts, which were mainly distributed in the main city districts of Chongqing and Wanzhou, of which the total length in Chongqing city districts accounted for 48–62% of the total pollution belts and that in Fuling and Wanzhou, 20–22%.

The changing trend of the city riparian pollution belts in the reservoir area is mainly determined by the city sewerage discharge and industrial wastewater discharge when the hydrological regime and the quality of incoming flow into the reservoir do not change much. If the pollution discharge

Table 7.2 Mean value of water quality of the city river sections in 1996–2003 (mg/L)

Monitoring factor	Dry season	Normal season	Flood season
pH	7.88 ± 0.24	7.81 ± 0.16	7.90 ± 0.18
DO	9.02 ± 0.68	7.38 ± 0.28	7.11 ± 0.34
COD_{Mn}	2.33 ± 0.27	2.82 ± 0.37	3.11 ± 0.42
COD_{Cr}	9.40 ± 1.54	10.38 ± 1.80	11.57 ± 1.99
BOD_5	1.60 ± 0.37	1.81 ± 0.35	1.73 ± 0.39
NH_3-N	0.27 ± 0.04	0.28 ± 0.06	0.25 ± 0.04
ArOH	0.001 ± 0.0002	0.001 ± 0.0004	0.001 ± 0.0004
CN	0.002 ± 0	0.002 ± 0	0.002 ± 0
TP	0.114 ± 0.079	0.121 ± 0.078	0.128 ± 0.034
Oil	0.036 ± 0.018	0.031 ± 0.013	0.037 ± 0.020
As	0.004 ± 0.0005	0.004 ± 0.0005	0.004 ± 0.0005
Hg	0.00003 ± 0	0.00003 ± 0	0.00003 ± 0
Pb	0.005 ± 0.001	0.006 ± 0.003	0.009 ± 0.006
Cd	0.001 ± 0.0008	0.0014 ± 0.0010	0.0010 ± 0.0006
Cr^{6+}	0.005 ± 0.005	0.005 ± 0.005	0.006 ± 0.006

continues to increase, the pollution belts would be expanding. As the hydrological regime will change greatly after the impoundment of the reservoir, the river of gorges, where the water flow velocity used to be rapid, will become a reservoir, where the flow velocity would be slowed. Such change is unfavorable for dissolution, diffusion, and degradation of pollutants. The pollution belts would be lengthened in some places and shortened in others. But the total width and area would increase significantly. The fundamental way of arresting the worsening trend after impoundment is to cut the pollution load entering the river.

7.1.3 Groundwater (Xiaogang) Monitoring Result

Features of groundwater

In the Xiaogang monitoring area in the "four-lake area" in the midstream of the Yangtze, the groundwater table is high, with the phreatic water level at below 0.5 m in the high water season and generally at 1–2 m during the low water season, and bearing water level slightly bigger than phreatic water depth. The perennial average phreatic water level ranges 21.8–22.5 m and bearing water level, 21.3–22.5 m. The monthly average value of groundwater table changes in an annual cycle, with the maximum appearing in July or August, more often in August, and the minimum in March. The underwater table changes little annually, except some abnormal years, which is not exceeding 0.1 m. For unit change in the water level, the corresponding change in pressure water table is more significant in the low flow season than in high water season.

According to monitoring results, if the release discharge of the reservoir is cut to less than 4000 m^3/s in the high water season, the groundwater in the four-lake area would not change much; if the reduced discharge is more than 4000 m^3/s, the groundwater level would drop to a certain extent, but not too much, not exceeding 0.1 m in general. If the increased release discharge is less than 1500 m^3/s during the low flow season, it has little impact on the groundwater in the four-lake area. If it is more than 1500 m^3/s, it has a significant impact on the groundwater in the four-lake area. If it exceeds 6000 m^3/s, the pressure water table in the sensitive areas would rise by at least 1 m, thus knocking out of balance the dynamic pattern of the groundwater, having a strong impact on the temporal and spatial distribution of water table. The effecting intensity (K) of the Yangtze on the confined water in weakened with the increase of distance (Fig. 7.6).

Soil gleization indicators

The soil gleization reflects the quantity of soil that has become gleyed due to the impact of such factors as organic

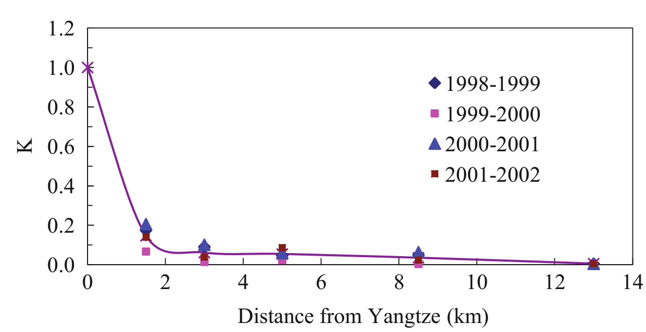


Fig. 7.6 Relationship between K and distance from the Yangtze

Table 7.3 Measured value of the indicators of gleyed soil

Season	Statistical parameter	pH	Eh (mv)	Active reducing agents (cmol/kg)	Total reducing agents (cmol/kg)	Ferrous iron (cmol/kg)	Manganite (cmol/kg)
Summer	Average	7.04	304.6	4.85	8.06	0.47	0.026
	Max.	7.87	628	15.5	17.8	1.03	0.092
	Min.	5.82	68	0.184	0.626	0.0183	0
	Standard error	0.52	131.3	4.49	4.41	0.32	0.025
Winter	Average	7.15	328.1	1.9	3.88	0.42	0.091
	Max.	8.09	751	12.1	13.7	3.09	0.526
	Min.	4.59	13	0	0.097	0	0.002
	Standard error	0.59	151.3	2.27	3.08	0.59	0.112

matters, moisture, temperature, and biological activities. The Eh value, the total reduced matter, the active reduced matter, ferrous iron and manganous acid, and other soil gleization indicators are determined directly by the soil types (different degree of gleization). The more seriously the soil is gleyed, the more significant the indicators. Gleization of soil changes with seasons, see Table 7.3.

The utilization of land also has a significant impact on the soil gleization indicators. Take Eh as an example, the sequence from high to low in winter and spring is vegetable field, winter crop field, lotus field, winter idle field, and pool mud field. The indicators vary greatly during different seasons. In winter, the major indicators, such as total reduced matter, active reduced matter, and manganous acid are significantly smaller than in spring, but the opposite is true with Eh.

Soil fertility monitoring

The organic matters and TN contents of gleyed soil is associated with the mother materials and process of soil-forming. As the rice soil originated from hydric soil in the area is at the different de-swamping and de-gleyed stages, the organic matters and TN contents vary significantly. The sequential order from big to small is: heavy gleyed soil, half-gleyed soil, and gleyed soil. The gleization of soil is favorable for soil to maintain a fairly high content of organic matters and TN and therefore high fertility.

The percentage of organic phosphorus in TP is in positive correlation with the contents of organic matters. The transformation and loss of phosphorus in drenching under the long-term reduction conditions under the action of gleization may minimize TP and contents of effective phosphorus of the heavily gleyed rice soil. The factors influencing the fertility of rice soil in the four-lake area are mainly high groundwater table and water-logging. The phosphorus content of heavily gleyed rice soil is on the low side, especially the surface soil. The gleyed soil features soil puddling, pastiness, poor permeability, and bad physical characters.

7.2 Pollution Sources Monitoring Results[2]

7.2.1 Industrial and City Pollution

Annual change of industrial pollutants discharge

In 1997–2001, the wastewater and COD discharge into the Yangtze by major industrial pollution sources assumed a general trend of annual drops as is shown in Table 7.4, Figs. 7.7 and 7.8. This is because that during that period, all the industrial enterprises in the reservoir area were in a period of reformation, with many old enterprises on the verge of shifting production, stopping production or going bankrupt due to unmarketability of products they produced with backward technology and processes. At the same time, the state strengthened control over industrial pollution sources in 2000 and 2001. But the wastewater and COD discharge rose again in 2001, when many enterprises restored to normal production after completing restructure and reformation.

Regional variations in industrial pollutants discharge

There is no significant change year-on-year in the wastewater discharge into the Yangtze by industrial enterprises in terms

[2]Chongqing Municipal Environmental Monitoring Center. Technical Report of Main Monitoring Station of Industrial and City Pollution Sources (1996–2003); Environment Protection Center, MOC. Technical Report of Main Monitoring Station of Floating Pollution Sources of Vessels (1996–2003); Hubei Agro-Environment Protection Station. Technical Report of Main Monitoring Station of Non-point Pollution of Pesticide and Fertilizer (1996–2003).

Table 7.4 Annual industrial pollution load directly discharged into the Yangtze from the reservoir area in 1997–2003

Year	Number of major pollution sources	Total Industrial wastewater discharge (100 Mm^3)	Total discharge of pollutants 10^4/t	Major pollutants and total discharge					
				COD_{Cr} (10,000t)	NH_3-N (t)	ArOH (t)	Cr^{6+} (t)	Oil (t)	CN (t)
1997	94	1.12	3.77	3.22	3100	108	4.69	106	9.95
1998	110	1.27	2.94	2.82	/	52	1.67	933.9	9.6
1999	124	1.84	2.27	2.15	912.7	0.04	0.23	177.3	0.17
2000	97	1.28	1.52	1.47	271	0.17	0.04	142.7	0.67
2001	60	1.08	0.8	0.76	324.8	0.05	0.03	77.5	0.04
2002	60	1.44	0.995	0.94	440.6	0.044	0.065	68.7	0.002
2003	54	1.84	2.502	2.41	848.9	0.467	0.95	84.4	0.076

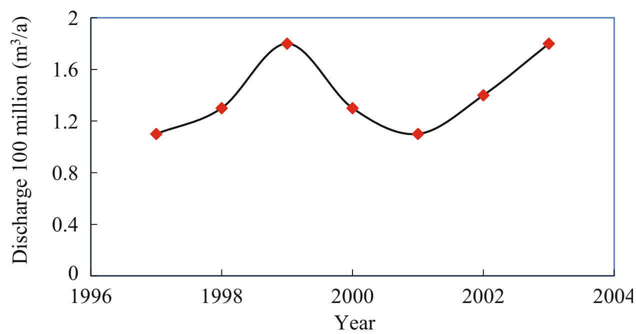


Fig. 7.7 Annual changes in direct wastewater discharge from major industrial pollution sources into the Yangtze

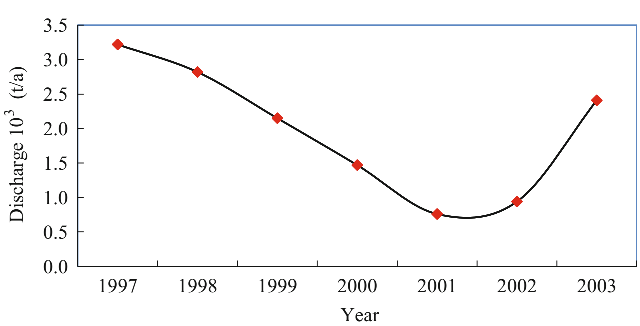


Fig. 7.8 Annual changes in direct COD discharge into the Yangtze in the reservoir area

of both total discharge and discharge by region, as is shown in Table 7.5 and Fig. 7.9. Main city districts of Chongqing, Changshou, and Fuling are the main areas that discharge industrial wastewater directly into the Yangtze.

Main sources and composition of industrial pollutants

Polluting sources that directly charged pollutants into the Yangtze were mainly chemical raw materials and chemicals manufacturing industry and industries of machine-building, electric and electronics manufacturing, power and coal gas and water production and supply, tobacco processing, food and beverage and pharmaceutical manufacturing.

Before the impoundment of the reservoir, the leading polluting sources were the chemical industry (36.4%), the power industry (30.3%), metallurgical industry (11.1%), and pharmaceutical industry (3.0%).

Main pollutants directly discharged into the Yangtze were COD, NH_3-N, TP, and Oil, with COD being the largest in amount.

Annual change and regional variations of city sewage discharge

The total direct discharge of city sewage into the Yangtze ranged 295 million–404 million m^3 before the impoundment, as is shown in Table 7.6 and Fig. 7.10, averaging 340 million m^3. Leading dischargers were such central cities as Chongqing, Wanzhou, and Fuling, whose discharge accounted for 84.2% of the total. This is mainly associated with the amount of city sewage and human and economic activities. The more populous and the more developed in economy and the more sewage a city discharges.

Variations in the composition and density of city pollutants

Principal city pollutants include COD, BOD_5, NH_3-N and TP. In the 7 years from 1997 to 2003, the four main pollutants accounted for, respectively, 88.2, 87.4, 95.4, 87.6, 88.4, 93.86, and 94.37% of the total. TP is one of the main sources of nutrients in the water body of the reservoir.

City sewage in the reservoir area includes both industrial wastewater and domestic sewage. There is a big change in the pollutant density of sewage discharged from cities that discharge a bigger proportion of industrial wastewater; there is a small change in the pollutant density of sewage discharged from cities that discharge a smaller proportion of

Table 7.5 Regional distribution of wastewater discharged directly into the Yangtze in 1997–2003 (100 million tons)

Area	Item	1997	1998	1999	2000	2001	2002	2003	Total
Chongqing City Districts	Discharge volume	0.81	0.58	1.1	0.75	0.5	0.49	0.6	4.83
	%	72.3	45.8	59.9	58.1	43.3	34.2	32.8	48.9
Jiangjin City	Discharge volume	–	0.08	0.12	0.14	0.07	0.33	0.34	1.08
	%	–	6.4	6.7	10.5	6.9	23.1	18.3	10.94
Changshou District	Discharge volume	–	0.33	0.32	0.25	0.29	0.24	0.35	1.78
	%	–	25.8	17.3	19.8	26.5	16.9	18.9	18.03
Fuling District	Discharge volume	0.2	0.13	0.1	0.07	0.2	0.27	0.3	1.27
	%	17.9	9.8	5.6	5.7	18.9	18.8	16.5	12.87
Wanzhou District	Discharge volume	0.1	0.09	0.08	0.04	0.03	0.03	0.1	0.47
	%	8.9	6.9	4.5	3.4	2.8	2.1	5.5	4.76
Other Districts and Counties	Discharge volume	0.01	0.06	0.01	0.03	0.3	0.08	0.15	0.64
	%	0.9	5.2	6.1	2.3	1.6	5.6	8	6.48
Total	Discharge volume	1.12	1.27	1.84	1.28	1.08	1.44	1.8	/

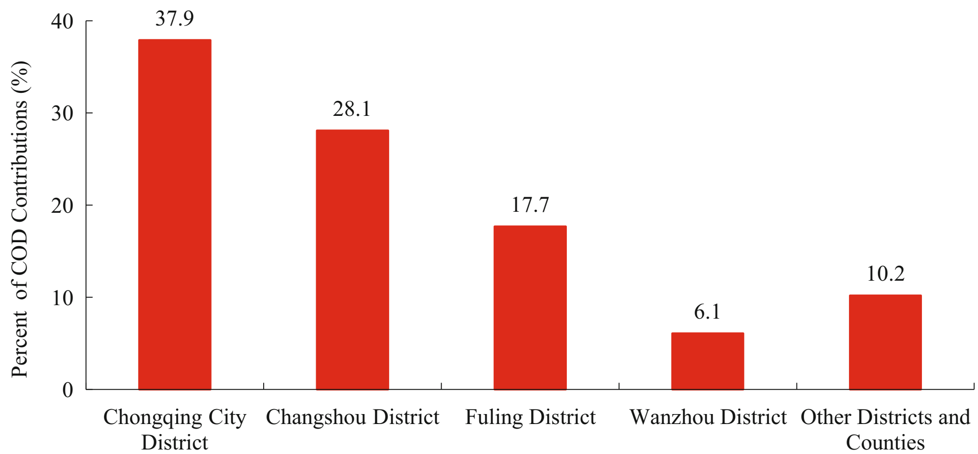


Fig. 7.9 Regional distribution of COD industrial sources discharged directly into the Yangtze

Table 7.6 Regional distribution of the annual changes in city sewer discharged into the Yangtze in the reservoir area in 1997–2003 (100 m M^3, %)

Year	Chongqing main districts		Fuling District		Wanzhou District		Other districts and counties		Total
	10^8 M^3	%	10^8 M^3	%	10^8 M^3	%	10^8 M^3	%	10^8 M^3
1997	2.98	78.6	0.17	4.5	0.23	6.1	0.41	10.8	3.79
1998	2.64	76.5	0.17	4.9	0.23	6.7	0.41	11.9	3.45
1999	2.25	69.6	0.2	6.2	0.29	9	0.49	15.2	3.23
2000	1.98	67.1	0.21	7.1	0.32	10.8	0.44	14.9	2.95
2001	1.99	63.6	0.23	7.3	0.34	10.9	0.57	18.2	3.13
2002	1.91	59.9	0.23	7.2	0.35	11	0.7	21.9	3.19
2003	2.53	62.6	0.29	7.2	0.44	10.9	0.78	19.3	4.04
Average	2.32	68.6	0.21	6.26	0.31	7.69	0.54	15.8	3.40

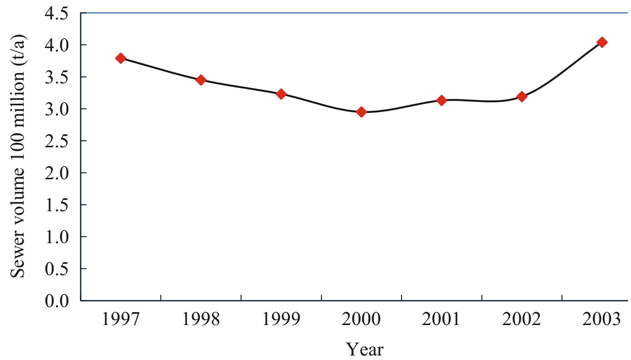


Fig. 7.10 Annual changes in the volume of sewer directly discharged into the Yangtze from the reservoir area

industrial wastewater. In 1997–2001, the average density of COD, BOD_5, NH_3-N, and TP discharged from cities in the reservoir area was 406.5, 146.4, 24.3, and 2.61 mg/L respectively, by and large similar to the sewage density discharged by other cities in the country.

Sewage discharged by relocated towns

The annual discharge of sewage by the 124 relocated towns surveyed in 2001 totaled 62 million m^3, including 21,200 tons of COD, 9400 tons of BOD, 1900 tons of NH_3-N and 374 tons of TP. The garbage produced totaled about 440,000 tons. A review in 2002 of 92 townships, which discharge 80% of the pollutants in the reservoir area, shows that the annual sewage discharge totaled 69 million tons, including 23,800 tons of COD, 11,200 tons of BOD, 2100 tons of NH_3-N, 416 tons of TP, and 460,000 tons of garbage. The increase is attributed to the rise in population and urbanization level. The 2003 review of 89 relocated towns showed that the annual sewage discharge was 740,000 tons, including 25,400 tons of COD, 11,900 tons of BOD, 2200 tons of NH_3-N, and 400 tons of TP, indicating a slight increase.

7.2.2 Pollution by Floating Vessels

General trend of pollution by vessels

Vessel pollution assumes a rising trend with the development of shipping in the reservoir area, see Table 7.7. But the speed of increase has been slowing down due to the control efforts over the past few years.

Vessel pollution load

There are many types of vessels operating in the reservoir area. They mainly include tourism boats, passenger ships, freight ships, passenger/freight ships, roro ships, towing boats, and engineering ships. Passenger and freight ships are the main pollution sources whose annual equal standard pollution load ratio combined accounts for over 70%. Furthermore, the passenger and freight ships are operating in large numbers and discharge a large amount of oil and contaminated water as is shown in Fig. 7.11.

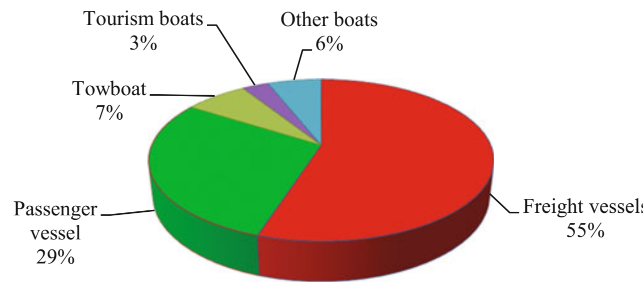


Fig. 7.11 Average ratio of equal pollution load of various vessels

Main pollutants discharged by vessels

Vessel pollutants include bilge water, sewage, garbage, waste gas, noise, fuel oil, and machine oil leaked, and suspended matters in the oil-stained water discharged and pH.

1997–2003 monitoring of oil, SS, and pH in the vessel oil-contaminated water found that the petroleum equal standard pollution load value and equal standard pollution load ratio was the highest, see Table 7.8. Petroleum is, therefore, the main pollutant generated by vessels.

Vessel pollution accidents

Pollution incidents happen every year and major pollution accidents happen from time to time, due to traffic accidents and improper operations, causing serious consequences, especially oil spills and release of toxic and harmful chemicals.

7.2.3 Farm Chemicals and Fertilizer Non-point Pollution

Amount of chemical fertilizers applied

The 19 districts (counties and cities) in the reservoir area applied 921,000 tons (in purity terms) of chemical fertilizer in the 8 years from 1996 to 2003. They included 676,000 tons of nitrogen, 194,000 tons of phosphate and 51,000 tons of potassium. 2002 saw the biggest amount of 136,000, 31,000 tons more than in 1996, see Table 7.9. But in 2003, the amount of chemical fertilizers applied dropped by 26,000 tons as compared with 2002. This was the result of the inundation of cropland due to reservoir impoundment and starting of dam operation in June that year.

Table 7.7 Number of vessels and tonnage in the reservoir area in 1997–2001

Year	1997	1998	1999	2000	2001	2002	2003
Number of vessels	9500	8327	8755	7437	7066	7289	9700
Passenger transport volume (10^4/a)	479	303	315	270	266	263	203
Freight volume (10^4/t)	1386	1037	1057	1200	1514	2214	3085

Table 7.8 Pollutants discharged by vessels into the reservoir area (tons)

Year	Types of vessel									
	Tourism vessel		Passenger vessel		Freight vessel		Towboat		Other vessels	
	Oil	SS	Oil	SS	Oil	SS	Oil	SS	Oil	SS
1997	0.70	2.87	15.9	42.5	11.8	22.9	6.53	14.4	1.34	1.34
1998	1.46	2.83	12.2	37.8	26.3	2.39	5.35	7.41	1.54	1.25
1999	0.44	0.62	18.3	33.6	49.7	15.8	6.24	3.04	10.4	9.15
2000	3.49	5.54	10.2	96.7	35.6	8.66	1.82	9.21	4.63	9.01
2001	0.2	2.40	16.7	59.5	13.7	1.60	1.10	2.70	1.50	2.80
2002	0.10	1.00	9.60	8.7	45.1	11.3	0.60	0.80	0.80	1.20
2003	0.04	0.17	5.85	5.15	58.9	7.00	1.10	3.30	0.12	1.07
Average	0.92	2.2	12.7	40.6	34.4	9.90	3.20	5.80	2.90	3.70

Table 7.9 Total amount of chemical fertilizers applied in 1996–2003 in the reservoir area (tons)

Year	1996	1997	1998	1999	2000	2001	2002	2003
Nitrogen	69,459	80,274	85,452	87,778	89,995	90,681	94,523	77,909
Phosphate	18,982	20,425	22,494	25,509	27,660	28,390	29,003	22,028
Potassium	2654	4648	4806	4600	5344	5593	12,701	10,343
Total	91,095	105,347	112,752	117,887	122,999	124,664	136,228	110,279

Nitrogen is the principal chemical fertilizer applied in the reservoir area. But the soil in the area mainly lacks phosphate and potassium. So the fertilizer application is in general not rational, with potassium extremely lacking. The imbalance in the ratio of potassium to nitrogen and phosphate has already affected the absorption of nitrogen by crops. The demand for potassium is even more urgent for crops if high yield is to be achieved. On the other hand, the excessive application of nitrogen often causes the soil to be hardened and fertility to drop. If the soil structure is spoiled, nitrogen would lose its effectiveness.

There is a significant regional disparity in spatial terms. The chemical fertilizer application in 1996–2003 was averaged 473.5 kg/hm^2, higher than the national average. The leading location in the chemical fertilizer application was Zigui, with 757.6 kg/hm^2 per unit. It was followed by Fengdu, Zhongxian, Tiancheng, and Xingshan. The biggest in the intensity of nitrogen application were Wushan, Tiancheng, and Xingshan, about 500 km/hm^2. The biggest in the intensity of phosphate application were Zigui, Fengdu, Zhongxia, and Wushan, averaging more than 100 kg/hm^2. The biggest in the intensity of potassium application were Zigui, Wulong, Xiangshan, Badong, and Fengjie reaching 50 kg/hm^2.

Farm chemicals applied

The total amount (in purity terms) of farm chemicals applied in the reservoir area assumed a declining trend in 1996–2003. It was 548.7 tons in 1996 and 560 tons in 1997, with that in 2003 the least, only 476.2 tons, 84.9% that of 1997, see Table 7.10. Farm chemicals applied include organic phosphorus (59.04%), organic nitrogen (16.02%), Pynethroids (5.35%), herbicides (3.80%), and others (15.78%).

In terms of total amount applied, Zigui County used the biggest amount, averaging 91.91 tons a year. It was followed by Yunyang and Kaixian, averaging more than 50 tons a year. The above three counties used 42.93% of the total farm chemicals, the main source of farm chemicals pollution.

Chemical fertilizer and farm chemical residue and losses monitoring results

1996–2003 monitoring results show that the annual crop nitrogen catch rate averaged 35.16%, with its residue averaging 30.31%, surface runoff rate being 9.45%; the eluviations rate in the groundwater being 0.54%; and evaporation rate being 24.46%. The annual crop phosphate catch rate

Table 7.10 Total volume of farm chemicals applied (tons)

Farm chemicals	1996	1997	1998	1999	2000	2001	2002	2003
Organic nitrogen	86.35	80.76	88.04	96.31	95.48	84.17	85.4	68.81
Organic phosphate	371.39	318.45	316.99	315.93	304.63	318.67	310.78	269
Methyl chrysanthemate	21.92	24.97	26.16	30.8	26.99	32.62	30.72	34.92
Herbicides		18.55	19.54	20.41	23.8	25.72	25.11	29.63
Other	69.03	117.85	78.26	89.08	85.49	83.7	78	73.88
Total	548.69	560.58	528.99	552.53	536.39	544.88	530.01	476.24

was 34.16%, with its residue rate being 13.18%, surface runoff rate (loss rate) being 5.25%, underground eluviations rate being 0.75%, and soil catch rate being 13.19%.

Data show that organic phosphorus residue accounted for 10% of the total farm chemicals applied. If calculated according to rate of 10% washed into the water body by runoff, the organic phosphorus farm chemical eluviations index is very high in all counties in the reservoir area, see Table 7.11.

Chemical fertilizer pollution load in soil

Nitrogenous fertilizer retaining in the soil may generate harmful nitrogen (source intensity) through nitrification and denitrification. The total nitrogen (source intensity) averaged 24073.5 tons a year in 1996–2003. The soil pollution load averaged 89.2 kg/hm^2 and it rose year by year until it reached the maximum by 2003, 42.7 kg/hm^2 more than in 1996.

In recent years, due to a fairly high level of phosphate fertilizer application, the phosphorus applied has been much higher than the amount of loss. The surplus phosphorus in the agro-ecosystem has made TP and OP level rise steadily. The enrichment of phosphorus in soil due to its strong fixation effect has increased the possibility of phosphorus loss from the soil. Monitoring shows that in 1996–2003, the phosphorus source intensity that causes soil pollution averaged 3125.6 tons and the perennial phosphate fertilizer pollution loan in soil averaged 9.8 kg/hm^2. Although the heavy metal of cadmium causes less pollution to the soil, its accumulation effect merits full attention.

Table 7.11 Estimates of organic phosphate loss in all counties

County	Total loss (kg)	Unit loss (g/hm^2)
Jiangjin	829.4	101.8
Banan	3145.4	289.1
Yubei	2260.3	210.7
Changshou	2192.2	280.4
Wulong	1218.4	145.8
Fuling	2371.5	83.0
Fengdu	691.7	32.6
Shizhu	835.1	229.1
Kaixian	7818.6	556.8
Zhongxian	3165.5	195.0
Tiancheng	1943.6	558.5
Yunyang	5946.2	165.8
Fengjie	2792.8	186.9
Wushan	3758.3	229.0
Wuxi	291.1	161.8
Badong	462.5	35.5
Zigui	9191.2	478.9
Xingshan	2667.8	621.5
Yiling	1897.2	441.0

Water pollution load caused by the application of chemical fertilizers

Monitoring and calculation show that in 1996–2003, the actual drain of nitrogenous fertilizer assumed an upward trend, averaging 8009.1 tons a year. 1997–2001 monitoring data indicate that the total nitrogen discharged from agriculture non-point pollution sources accounted for 47–70% of the total discharged into the Yangtze, see Table 7.12. The nitrogenous fertilizer flowed into the Yangtze in the form of NO_3-N, NO_2-N, and NH_3-N through surface runoffs, thus causing pollution of the water.

The actual annual loss (source intensity) of phosphate fertilizer in 1996–2003 averaged 1252.8 t/a. The 1997–2001 monitoring and calculation show that the total phosphorus discharged by the agricultural non-point sources accounted for about 50% in 1997 and it rose to 77% by 2000.

One of the main factors to the agricultural non-point pollution is the excessive application of chemical fertilizer per unit area, which reached 473.5 kg/hm^2, with that in Zigui County being the highest, reaching 757.8 kg/hm^2. As the crop uptake is limited, a large amount of fertilizer would get lost.

In 1996–2003, the perennial average nitrogenous fertilizer eluviations were 440.0 t/a. The fertilizer then entered the groundwater through the surface runoff in the form of NO_3-N, NO_2-N, and NH_3-N, thus causing pollution. The actual eluviations of phosphate fertilizer in the reservoir area averaged 169.3 t/a.

The excessive use of chemical fertilizers would inevitably lead to some nitrogen and phosphorus penetration into the groundwater body. As the reservoir is situated in a mountainous and hilly area, part of the groundwater flows out through fountains and springs, which are the main drinking water sources of the people in the area. The excessive application of chemical fertilizers, especially nitrogen when entering into the groundwater, will affect the water quality.

Pollution caused by domestic animal and poultry farming

The animal and poultry farming in the reservoir area produces about 12,368,000 tons of faeces. Of this amount, 10,143,000 tons or 82.0% are produced by Pigs and 1,325,000 tons or 10.7% are produced by large livestock, 592,000 tons or 4.8% are produced by poultry, and 307,000 tons, or 2.5% are produced by Sheep. The phosphorus loss from poultry and animals averaged 463.9 t/a in 1996–2003 and nitrogen loss averaged 12,500 t/a, all higher than the actual losses from chemical fertilizers as is shown in Fig. 7.12. Thanks to the efforts to render the faeces harmless, the losses of phosphorus and nitrogen have been on the decline.

Most of the faeces in the reservoir area are directly discharged or piled up without harmless treatment, that is, the farm households use faeces as manure. There is also a considerable part of phosphorus and nitrogen that have found their way into the water body of the reservoir through surface or subterranean water.

Impact of farm chemical and chemical fertilizer non-point pollution on water quality

Pollution of the Yangtze River was almost ignorable in the pre-dam period, when the water flowed fast and the large volume of flow had the great power of self purification. But after the dam is built, the velocity of the flow has dropped and water surface has been expanded, giving rise to many bays and backwaters, where it is not easy for pollutants to disperse. The application of chemical fertilizers mainly has its impact on the water body of the Yangtze in the following two aspects: One is the excessive use of nitrogenous fertilizer resulting in the loss of a large amount of nitrate, which

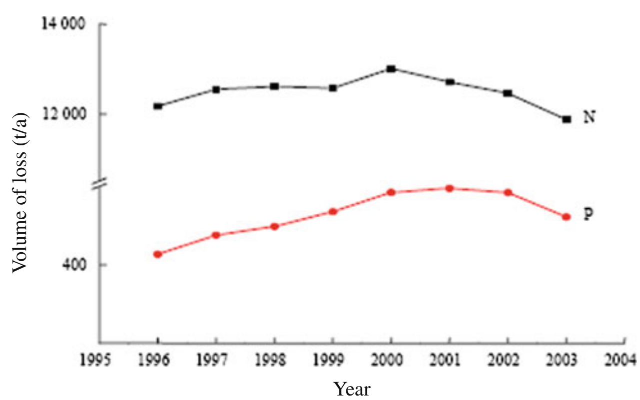


Fig. 7.12 Faeces nitrogen and phosphate losses of domestic livestock and poultry in the reservoir area

Table 7.12 Contribution of farm fertilizer non-point pollution sources to nitrogen and phosphate contents of the water body in the reservoir area

Year	Nitrogen import (10^4 t)	% in total	Phosphate import (10^4 t)	% in total
1997	0.74	47	0.10	52
1998	0.79	44	0.12	57
1999	0.82	59	0.13	64
2000	0.84	70	0.14	77
2001	1.01	49	0.19	52

enters into the water body of the Yangtze, thus raising its content of nitrate; the second is a large amount of nitrogen, phosphorus, and organic matters that are washed into the water body by the surface runoff, thus causing eutrophication of the water body of the reservoir or occupying a certain proportion in the nutrients of eutrophication.

7.3 Fish and Other Aquatic Life Monitoring Results[3]

The Fish and Aquatic Life Sub-system has two major monitoring stations: fish resources and environment, and aquatic life, one for monitoring the amount and development trend of major economic fishes, the biological indices of all species and the habitats, and the other for the development of the population and habitats of rare and endemic species.

7.3.1 Fish Resource and Environment Monitoring

In 1996–2003, the natural annual catch in the reservoir area, areas downstream of the dam, the Dongting Lake, the Poyang Lake, and the estuary area averaged 94,500 tons, with the fluctuations ranging 66,900–149,000 tons, all assuming a downward trend except in 1998, when flood pushed up the natural catch, as is shown in Fig. 7.13. The proportion of semi-migrant fish in the total catch dropped and that of resident species rose. The trophies tended to be smaller and younger.

The hydrological conditions in May–June, 1996–2002 were favorable for the four major endemic species to spawn and reproduce normally. Compared with the 1980s, the spawning grounds and positions did not change much, but spawns were smaller in scale and amount, indicating a slow downward trend.

In 1996–2003, the general quality of water in the major fishing grounds in the reservoir area, areas downstream of the dam, the Dongting Lake, the Poyang Lake and the estuary area was good, with only a few monitoring indicators exceeding the prescribed limit, indicating that local water bodies were polluted to a certain extent.

Upstream and reservoir area

The natural catch averaged 4488 tons in the upper reaches of the Yangtze and the reservoir area in 1996–2003, with the fluctuation range being 2935–11,000 tons. Major catches included Bronze gudgeon, Largemouth bronze gudgeon, Large mouth catfish (*Silurus meridionalis*), Common carp (*Cyprinus carpio*), Yellow catfish (*Pelteobagrus fulvidraco*), Grass carp (*Ctenopharyngodon idellus*), and Silver carp (*Hypophthalmichthyys molitrix*), accounting for 89%, of which the catch of Bronze gudgeon and Largemouth bronze gudgeon accounted for 34.7%, that of Large mouth catfish 18.9% and that of Common carp, 12.7%.

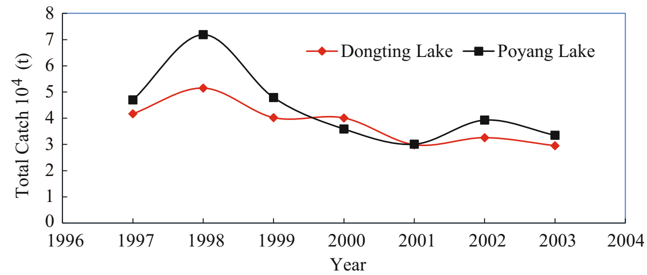


Fig. 7.13 Total catch from natural fish resources in typical area

Monitoring results show that large mouth catfish and Largemouth bronze gudgeon caught are small in scale and younger, with 1-year fish accounting for 56 and 50%, respectively. The catch of Grass carp, Common carp, and Yellow catfish are mainly of 2–3 years old, accounting for 78, 71 and 58%, respectively. The Bronze gudgeon caught averaged 2.4 years in age (ranging between 1 and 6 years). Grass carp caught averaged 2.4 years (with a fluctuation range between 1 and 5.4). Silver carp caught averaged of 2.2 years (with a fluctuation range between 1 and 6). The Common carp caught averaged of 2.8 years (with a fluctuation range of 1–6). The Yellow catfish of 3.2 years (fluctuating between 1 and 7).

The principal pollutants in the water of fishing grounds of the reservoir area are un-ionized ammonia (NH_3-N), TCu, Oil, and TCd; The mean value of TCu assumed a downward trend while that of un-ionized ammonia was on an upward trend. The other indicators were within the standards.

Areas downstream of the dam

The natural catch in areas downstream of the dam in 1996–2003 averaged 10,169 tons (with a fluctuating range between 2450 and 23,000 tons). Major catches were four major endemic species, Bronze gudgeon, Yellow catfish and Common carp, which accounted for 81%, of which the catch of Bronze gudgeon accounted for 36.7% and the four major endemic species, 24.6%.

Monitoring results show that the catch of largemouth gudgeon, Bronze gudgeon, Yellow catfish, longsnout catfish, and catfish was small in scale and the preys were

[3]Institute of Hydrobiology, CAS. Technical Report of Main Monitoring Station of Fish and Rare Aquatic Animals (1996–2003); Office of Yangtze Fishery Resources Committee (YFRC). Technical Report of Fish resources and environment monitoring leading stations (1996–2003).

young. Among the catch, the 1-year largemouth guedgeon and catfish accounted for 92 and 87%, respectively; the 1–2 year Bronze gudgeon, longsnout catfish, and bullhead catfish accounted for 80, 68, and 64%. The average age of Black carp (*Mylopharyngodon piceus*) was 2.6 years (with a fluctuating range of 1–5); that of Grass carp, 2.8 years (ranging between 1 and 6); that of Silver carp, 1.7 years (ranging between 1 and 5); that of bighead carp, 2.5 years (ranging 1–6); that of Bronze gudgeon, 1.8 years (ranging 1–6); that of catfish, 1.4 years (ranging from 1 to 6); that of Common carp, 2.7 years (ranging 1 and 7), and that of Yellow catfish, 2.2 years (ranging 1–6).

The principal pollutants in the fishing waters downstream of the dam were oil and TCu, with TZn, TPb, and TP exceeding the limit in some years. The other indicators were within the range of standards.

Spawning grounds of four major endemic species

The 1997–2003 monitoring shows there were ten spawning grounds for the four major endemic species in the about 400 m section from Yichang to Chenglingji, with those in Yichang, Zhijiang, Jiangkou, Haoxue, and Tiaoguan being the largest. Compared with those in the 1980s, there was not much change in size. But the number of eggs was fewer, with the fry in the monitored section in 2003 being about 4% of that in 1986.

In 1997–2003, the amount of young fish of the four major endemic species in the Jianli cross-section monitored averaged 2.524 billion (ranging from 1.9 to 3.587 billion) as is shown in Fig. 7.14. The average fry composition of the four major species were Black carp, 17.33%, (ranging from 7.10 to 23.90%), Grass carp, 75.41% (ranging from 67.50 to 85.30%), Silver carp, 2.53% (ranging from 0.30 to 35.62%) and Bighead carp (*Aristichthys nobilis*), 4.73% (ranging from 2.13 and 8.50%).

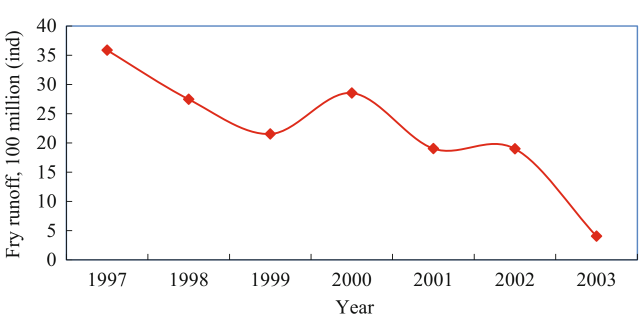


Fig. 7.14 Annual changes in fry runoff of four major endemic species at the Jianli cross-section

The principal pollutants affecting the water quality of the young fish passage was TCu, which exceeded the standards in mean value in all the five monitoring years, without improvements. TP contents exceeded Type III surface water standards. Other indicators were within the range of standards. In general, the water quality of the Jianli section could well satisfy the requirements for normal growth of fry of the four major species.

Dongting Lake

The annual natural catch of fish in the Dongting Lake in 1996–2003 averages 40,060 tons, with a fluctuating range of 29,516–55,000 tons. The principal catches included Black carp, Grass carp, Silver carp, Bighead carp, Common carp, Goldfish (*Carassius auratus*), Oriental sheatfish, and Yellow catfish. The first three catches were Common carp, catfish Oriental sheatfish (*Silurus* spp.), and crucian carp, which accounted for 32, 19, and 15%, respectively. The catches were mainly made up of 1–2-year-old fish, which accounted for over 60%. But the body length and weight did not change much except in 1997.

There were about 46 spawning grounds for Common carp and Goldfish, averaging 260 km^2 (fluctuating from 212 to 305 km^2) each, assuming an upward trend. This might be associated with the efforts of returning reclaimed land to the lake.

The spawning size of Common carp and Goldfish was 228,000 for Common carp (fluctuating from 185,000 to 280,000) and the number of eggs averaged 5.895 billion (fluctuating from 5.325 to 6.776 billion). It was 300,000 spawning Goldfish (fluctuating from 278,000 to 350,000) and the number of eggs averaged 3.942 billion (a fluctuating range of 3.594–4.461 billion).

The lake had about 32 feeding grounds, 831 km^2 (ranging from 751 to 886 km^2) and the population fed is about 10.2 billion (ranging from 6.8 to 18 billion). Fish species fed in the grounds are Common carp, Goldfish, Silver carp, Bighead carp, Black carp, Grass carp, Mandarin fish (*Siniperca chuatsi*), Oriental sheatfish, and other fish species of economic value.

Eight-year water quality monitoring shows that it has been good in recent years, with none of the 22 physiochemical factors, such as pH, temperature, $BOD^{inferior}$, total cynides, NO_3-N, NO_2-N, nonionic ammonia, Cr^{6+}, TZn, TCd, and TAs, which accounted for 50.0%, exceeding the limits set. The contents of TCu, TPb, COD_{Mn}, ArOH, NO_2-N, NH_3-N, and DO, which accounted for 31.8%, exceeded the standards sometimes. Besides, TN, TP, total colibacillus group, and suspended matters, which accounted for 18.1%, were far above the standards.

Poyang Lake

The natural catch in the Poyang Lake in 1996–2003 averages 43,700 tons (ranging from 30,100 to 71,900 tons). The main catches included Black carp, Grass carp, Silver carp, Bighead carp, Common carp, Goldfish, Bream (*Parabramis pekinensis*), Oriental sheatfish, Yellow catfish, Mandarin fish, and Shrimp (*Decapoda*).

The spawning grounds for Common carp and Goldfish averaged 520 km^2 (ranging 200–700 km^2), with the biggest being in 1998, when a big flood struck to raise the water level of the lake and expand the effective spawning grounds to 700 km^2. The amount of eggs averaged 4.94 billion (2–9 billion).

The feeding grounds are distributed in the middle and southern parts of the lake, averaging an area of 626 km^2 (a range from 460 to 955 km^2) each. The young species included Common carp, Goldfish, Black carp, Silver carp, Bighead carp, Mandarin fish, and Oriental sheatfish, with the Common carp and Goldfish occupying 30–50%.

The principal pollutants in the water during the fish wintering period was TP, with the water quality monitored in 1998–2000 exceeding Type II or Type III standards for surface water.

Estuary area

Osbeck's grenadier anchovy (*Coilia mystus*) is the principal species of economic value in the estuary area, occupying about 50% of the total catch in the area. In 1997–2003, the total natural catch averages 952 tons, ranging from 510 to 1257 tons. Biological indices of the species show no significant change in body length and weight; neither were there any significant differences in fullness and relative egg-carrying capacity. One-year-old fish was the main catch, without significant change in history. The total catch during the monitoring period was no different from previous years in history. There was no significant decline in resources.

In 1997–2002, the natural catch of Chinese mitten-handed crab averages 0.89 tons a year, with the lowest at 0.77 tons and the highest, 1.20 tons. The 6-year monitoring shows no significant change and difference in shell length, shell width and weight. The reproductive area and catching area showed no signs of change, without any change in flood season. The catch intensity was not closely related with the amount of catches, indicating that the resources were not plentiful, serious shortage as compared with previous years. During the 5-year monitoring, the catch remained stable and showed steady recovery.

In 1997–2003 the natural catch of Eel fry averages 2.96 tons annually, with the lowest being 0.83 tons and the highest being 8.90 tons. The 7-year monitoring shows that the catching area showed no signs of shifting, with no significant change during the floor season. The Eel fry catch assumed an upward trend in 1997–2003, with the total catch in 2003 registering a big increase, indicating that the Eel fry resources were recovering.

The environmental quality in the estuary area was generally good, with only TP and ArOH contents exceeding the prescribed limits. In 1999, the monitored value of ArOH came above the water quality standards. Except 2003, the TP value in all years exceeded Type II or Type III water standards.

Pollutant residue in the fish body

The 1997–2000 survey of 404 samples covering more than 50 fish and Shrimp species shows the pollutant residue in the fish body was all lower than the related standards set or recommended by food hygiene or other related administrations of the state, with only some individuals having residues slightly above the set standards, but still well meeting the requirements set by the state.

7.3.2 Aquatic Animal Mobile Monitoring

Endemic species of fish

(1) Composition of species and distribution

There are 64 endemic species of fish in the water between the lower Jinsha River and the other parts of the upper Yangtze, among them 19 inhabiting only above Yibin, four of which were collected during field surveys, accounting for 21.05%; 16 species inhabiting only downstream from Yibin, eight of which species were collected during field survey, accounting for 50%, and the rest 29 species found both upstream and downstream from Yibin, 26 of which were collected in the field survey, accounting for 89.66%.

The abundance and availability of the endemic species is in positive correlations with the range of distribution. The narrower the distribution range, the smaller the population and the lower availability. It also has a strong dependence on the impact of projects on the water.

(2) Feeding habits

The 64 endemic species may be divided into five types according to their food intake. (1) Algae-eating fish, such as *Xenocypris*, *Onychostoma sima*, *Bangana rendahli,* and some species of Snow barbels (*Schizothorax*); (2) fish feeding on zooplanktons, such as *Anabarilius*, Ditterling (*Acheilogthus*), and small fishes mostly living in lakes that are connected with rivers; (3) fish mainly feeding on bottom-living Invertebrates, such as most of the Loaches (*Cobitidae*) family, Hillstream loach (*Homalopteridae*), *Amblycipitidae,* and part of Snow barbels (*Schizthorax*) as well as Dabry's sturgeon and Rock carp; (4) fish feeding on other fishes, such as Japanese sea bass (*Lateolabrax japonicus*) and Common carp; (5) omnivore fishes, such as *Megalobrama pellegrini*, *Megalobrama elongata*, largemouth bronze gudgeion (*Coreius guishenoti), Rhinogobio cyldricus, Rhinogobio ventralis*.

Apart from the major species feeding on zooplanktons in the lake, all the other four species feed on algae growing on stream stones and organic matters brought into the water by riparian surface runoff.

(3) Reproductive habits

Apart from a few species that are adapted to the lake environment, all the endemic species mentioned above mostly reproduce in the flowing water, where water temperature is the biggest influencing factor. Reproduction requires the minimum temperature of 16–18 °C.

There are gravel benchlands in all the mainstream and tributaries in the upper reaches, suitable for most of endemic species to spawn. During the reproductive season, species lay sink eggs and some, adhesive eggs. The eggs sink into stone seams or stick to the surface stone. Some endemic species lay floating eggs in the rapids during the flood season in the mainstream and large tributaries. The early fry float with the water. When they grow strong enough, they swim upstream to stay in shallow or gentle flows.

(4) Economic value

Yibin section: There are 14 common endemic species: medium-size species include Largemouth bronze gudgeon, Elongate loach, *Rhinogobio ventralis*, Finescale schizothoracin (*Schizothorax chongi*), and *Rhinogobio cylindricus*. Small fish species include *Xenophysogobio boulengeri*, Redlip loach, *Paracobitis potanini*, *Platysmacheilus nudiventris*, *Xenophysogobio nudicorpa*, *Liobagrus marginatoides*, Kunming nase (*Xenocypris yunnanensis*), *Jinshaia sinensis, and Hemimyzon yaotanensis.*

Taking a fairly high proportion in the weight of the total catches, they are Largemouth bronze gudgeon, *Rhinogobio ventralis* and *Xenophysogobio* boulengeri, accounting for 0.83–46.12, 0.2–23.34, and 0–14.17%, respectively. Taking the biggest proportion in number they are Largemouth bronze gudgeon, *Rhinogobio ventralis,* and *Xenophysogobio* boulengeri, accounting for 0.96–53.9, 0.1–20.19, and 0–12.45%, respectively. The most frequently seen species are Largemouth bronze gudgeon, *Rhinogobio ventralis*, *Xenophysogobio*, *leptobotia elongate,* and *leptobotia rubrilaris*. But the show-up rate in 2001 was less than in 1997. For instance, the show-up rate of largemouth bronze gudgeon, which had a large population, dropped from 100% in 1997 to about 50% by 2001.

The total annual catch in the Yibin section was 607,000 pieces, weighing 17,000 kg in 1997–2000, with endemic species accounting for 7.09%, totaling 215,183 pieces, weighing 5688.2 kg; In 2001, the total catch was 626,000, weighing 166,000 kg, with endemic species accounting for 3.64%, totaling 113,932, weighing 7556.4 kg.

In the Hejiang section of the river, 26 species endemic to the upper reaches of the Yangtze were found in the total catch, with the total weight taking up as much as over 60% and the number percentage as high as over 80%. Among them, Largemouth bronze gudgeon and *Rhinogobio ventralis* were in the largest number, followed by rock carp, *Rhinogobio cylindricus*, and *leptobotia elongate*.

In the Mudong section of the river, the 1997–2001 survey showed that Largemouth bronze gudgeon, Bronze gudgeon, Darkbarbel catfish (*Pelteobagrus vachelli*), and Longsnout catfish (*Leiocassis longirostris*) were the main targets of catch in spring; Largemouth bronze gudgeon, Bronze gudgeon, Darkbarbel catfish, longsnout catfish, *Rhinogobio ventralis*, and *Rhinogobio cylindricus* were the main targets of catch in autumn. Among them, Largemouth bronze gudgeon, *Rhinogobio ventralis*, and *Rhinogogio cylindricus* were species endemic to the upper reaches.

(5) Survival threat

Although fishing-closed season has been imposed and the protection areas have been demarcated, the total catch and the fishing gears used are not limited, resulting in indiscriminate catching, even the young without escape. Excessive catch plus late sexual maturity poses, as it would take longer time for reproduction. Besides, building of dams has fragmented the habitats of some species.

Rare fish species

(1) Chinese sturgeon (*Acipenser sinensis*)

Chinese sturgeon is a large migrant species passing through the estuary to live in the offshore areas of China and Japan and returning to reproduce in the lower section of the Jinsha River in the upper reach of the Yangtze (2850 km from the Yangtze estuary) or the upper reach of the Zhujiang River. The fish lays eggs in mid-October–mid-November. The Gezhouba dam has obstructed its migrating route, forcing it to stay in the river section downstream of the dam, where a new spawning ground has taken place. Survey shows that the spawning ground was the only one found and also the main habitat of the fish species. After the completion of the Gezhouba dam, the reproduction age of the fish was increased for males in the mid- and late 1990s and the number of the female was assumed an upward trend.

According to calculation with the catch-marking-recatch method it shows that in 1981–1990 the number ranged 1022–2879, averaging 2079. The sonar detection estimated that the number of the fish in the river section between the Gezhouba dam and Zhenjiang was 680 in 1998, 601 in 1999, 343 in 2000, 257 in 2001, 308 in 2002, averaging an annual 470.

There are three types of spawning grounds for the Chinese sturgeon downstream the Gezhouba dam: the stable one in the section from the dam to Zhenjiangge, with reproductive activities occurring every year; the instable in the section from Mojishan to Wulong and in the Yanziba section 9 km downstream the dam and the occasional spawning type in the Huyatan section. Surveys since 1997 has shown that these spawning grounds still exist but it tends to shrink to the 4.8 km section between the dam and Zhenjiangge.

The Chinese sturgeon is not so hypercritical about water level, flow velocity and sediment in the spawning ground. But temperature is the restrictive factor. The optimum water temperature for spawning is 17–20 °C.

(2) Chinese paddlefish (*Psephurus gladius*)

The Chinese paddlefish is mainly found in the mainstream of the Yangtze, from Leibo in Sichuan to the estuary and some tributaries with big flows and lakes connected with the river. It has the habit of migrating upstream before the reproductive period. It is a ferocious species, feeding on other fish. It grows fast and big. The spawning season is in late March to early May. Its spawning ground is in the upper reaches of the Yangtze upstream from Chongqing, with the main spawning ground in the section between Pingshan County and Luzhou City in Sichuan Province. The spawning ground bed is sand or gravel. The egg is of the adhesive type. The absolute spawning capacity is 178,000–787,000, averaging 359,000.

It was estimated that before 1976, the annual catch of the fish from the Yangtze was about 25,000 kg and it had been dropping year by year since then, with a drop very significant after the Gezhouba dam was completed. In 1997, there were only three accurate records of discovery of the fish in the upper reaches, one for each in the Town of Xinshi, Luzhou section and Chongqing section. It was no longer spotted after that. In the Yichang section, 94 of such fish were caught accidentally in 1981–1985. The figure for 1986–1990 was 50; 14 for 1991–1994. No accidental catch has ever been reported since 1995. The largest number of fry was collected in the Chongming area in 1983 and it began to drop after that. All those show that during the 10 years after the Gezhouba dam operation, the natural reproductive activities did not stop and its spawning grounds still exist.

The main threat to the Chinese paddlefish comes from the water conservancy projects and wanton catch. In the estuary, there are hundreds of such fish caught accidentally. The Mihunzhen for catching fish in all sections, lift net and other fishing gears as well as small-eye net are fatal killers of the young.

(3) Dabry's sturgeon

Dabry's sturgeon is distributed in the mainstream and tributaries of the Yangtze. Usually, it does not travel long distances to seek food or lay eggs. It usually inhabits a section of the river and travels within the area. Its main food is living things at the bottom and occasionally small fish and water plants. The 1-year-old fish is 25–35 cm long and 0.4–0.6 kg in weight. Up to 8 years, it could grow to 99–110 cm and weigh 12.5–16.0 kg. The spawning season starts from late March and ends in late April. A male reaches sexual maturity when it is 4 years old while the female reaches sexual maturity when it is 6 years old. The absolute spawning capacity is 60,000–130,000 eggs. The eggs are of strong adhesive type, usually sticking to the gravel in the river bottom. The spawning ground is in between Maoshui of the Jinsha River and Hejiang of the Yangtze, usually on the gravel benchland in the mainstream, where the flow velocity is 1.2–1.5 m/s and water clarity is about 33 cm and the water temperature ranges 14–18 °C.

Before the mid 1970s, there was a considerable presence of the fish in such river sections as Yibin, Luzhou and Hejiang in the upper reaches. In 1972–1975, the Sichuan Aquatic Resources Survey Group collected 208 samples.

After 1980, the catch of such fish diminished. In the 13 years from 1980 to 1993, the total catch was 344, averaging 26.5 a year. A sharp drop occurred after 1995, averaging only 3.6 a year. Few were caught in the Yichang section. Since 1982, only 10 have been caught in the section downstream of the Gezhouba dam. No catch of the fish has been reported since 1996.

Excessive catching is the main factor accounting for the dwindling of the rare fish. Artificial reproduction of the species is the only effective way of protecting and rescuing such fish.

(4) Chinese sucker (*Myxocyprinus asiaticus*)

This species of fish has the habit of anadromous migration, often found in the mainstream and tributaries of the Yangtze and in the Dongting and Poyang lakes. The Chinese sucker feeds on invertebrates at the bottom of the river. It grows very rapidly, with a 13-year old as long as 98.5 cm. The reproductive period is between late March and late April. The spawning grounds are distributed in the section between Yibin and Chongqing in the upper reaches of the Yangtze and the downstream of such tributaries as the Jinsha River, the Minjiang River, and the Jialing River. It takes about 8 years for a female to get mature sexually and about 6 years for a male to get mature sexually. The absolute fecundity ranges 211,000–390,000. When the water temperature reaches 13 °C, it is time for natural reproduction. The optimum water temperature for spawning is 14–16 °C. It lays adhesive eggs in the flowing water. The spawning grounds are mostly distributed in the sandbars of rapids.

The total catch of such fish (caught accidentally) in 1982–2000 was 294, indicating that it had maintained a considerable population in the upper and middle reaches of the river after the Gezhouba dam was built. The reproduction scale in the Yichang spawning ground is small. The main population is in the upper reaches of the Yangtze.

Early resources of fish

Since 1997, 55 types of fry have been collected in the field survey in the upper and middle reaches of the Yangtze. They belong to 12 families and 7 orders, including 38 species of Cypriniforms (*Cypriniformes*). The distribution of fry in the cross-sections shows that the number was declining gradually from the bank to the middle of the mainstream, but there were no significant differences in terms of fry density in different depths of water.

But the fry density in different collecting points in the middle reaches varied greatly. The general trend was that the fry density was higher in the upper than in the lower reaches. The change in runoff matched changes in fry density. Since the 1960s, it has assumed a generally downward trend in the middle reaches. In 2003, most of the four major endemic species were artificially hatched in July, without any birth of juvenile fish during the impoundment of the Three Gorges Reservoir.

Baiji dolphin and Finless porpoise

(1) Baiji (Chinese river dolpin)

Baji (*Lipotes vexillifer*) is native to the Yangtze of China, visible in the mainstream from Zhicheng of Hubei Province to Liuhekou of Taicang in Jiangsu Province. The riparian-obligate species is distributed in groups. At present it is distributed only in the about 1400 km mainstream in the lower reaches of the Yangtze from Jiangyin to Jingsha.

In 1985, a winter survey discovered about 300. But the number was reduced to less 100 during the 1991–1995 monitoring. No such fish was discovered in April–August in 1996 and in October 2–10, 1997. Monitoring was conducted on three occasions from November 1999 to December 2000 and only one big and one small Baji dolphins were discovered moving upstream. From May to July 2002, 10 rounds of monitoring were conducted in the section from Yichang to Wuhan and only one was discovered.

It is, therefore, necessary to designate natural protection river sections and set up a base of water with superior conditions for increasing the reproduction and protection of Baiji dolphin.

(2) Finless porpoise

Finless porpoise is distributed in subtropical and tropical offshore area and some rivers. In the Yangtze, it is found in the 1700 km section downstream of Yichang. It lives in the middle and lower reaches of the Yangtze by groups, often near banks, gentle flow sandbars and river bends. The monitoring results in recent years and comparison with historical materials showed that the population density dwindled from 0.55 per km in 1994 to 0.12 per km and further down to 0.05 per km by 2000, nearing extinction. Remedial measures must be adopted.

It reaches sexual maturity at 4–5 years with a corresponding body length being about 133 cm. Sexual activities usually happen from late February to mid-June, mostly in March–May. It feeds on carp, Yellow catfish (*Pelteobagrus fulvidraco*), Goldfish, Shrimp, rice, and other cereals.

Measures for protection mainly include the setting up of artificial breeding center in the old river course of the Yangtze, using available breeding facilities and establishing dolphin protection areas in river sections where the dolphin is like to concentrate.

Ancherythroculter nigrocauda (Hejiang Station)

Chinese sucker *(Myxocyprinus asiaticus)* (Hejiang Station)

Rhinogobio cylindricus (Hejiang Station)

Rhinogobio ventralis (Yibin Station)

Jinshaca sinensis (Yibin Station).
Its belly is like a sucker disc firmly fixed to the rock in water in order to adapt to the rapid shallow currents.

Chinese sturgeon (Yichang Station)

Some endemic species of fish collected by grassroots monitoring stations

7.4 Terrestrial Animals and Plants Monitoring Results[4]

7.4.1 Terrestrial Plants in the Reservoir Area

Plant species and rare and special plants

The reservoir area abounds in terrestrial plant resources, with species and number of plants of higher order always claiming the focus of attention from all quarters. Related departments and experts have carried a number of surveys. With surveys going deeper, more species could be found. The terrestrial animals and plants monitoring station announced in 2000 that there were 6088 species of vascular plants in the reservoir area, belonging to 1428 families in 208 orders [21]. But this has aroused differences of views among experts. Chen et al. pointed out in 2003 [22]: Jin and Yang discovered 1389 species of plants of higher order [except Moss (*Bryophyta*)] (not published) before 1987. Verification in 1990 found 3012 species. What was published in 2000 was 6088 species. The 2000 catalogue is extraordinary, featuring all-inclusiveness. But the regional scope is possibly different from the previous directories published. One of the reasons for the big increase in the number of species is the inclusion of imported plants, plants growing in parks, botanical gardens and medicinal herb gardens) or in farm house courtyards and some species have different names. Chen et al. estimated according to the materials available in provinces around the reservoir area that the total species number in the reservoir area, plus the naturalized species, should be about 3500.

In 1997–2003, a survey found dovetree (*davidia involucreata*), a plant coming under the state first-class protection in Zigui, a county-level distribution area in Hubei Province, and a new distribution point at Xingshan County, Hubei Province for Vilmorin dovetree (*Davidia involucrata var. vilmoriniana*), a new distribution point, Jiangdong town of Jicheng, Fuling county for Spiny alsophila (*Alsophila spinulosa*), a plant coming under the state first-class protection, a new county-level distribution points (Zhongxian and Xingshan counties) for China yew (*Taxus wallichiana var. chinensis*), plant under the state first-class protection, and its community and a number of points with the distribution of relic plants, which were reported for the first time in China. The Xingshan County discovered a rare relic plant community made up of mainly China yew, Farges torreya (*Torreya fargesii*), Fortune plumyew twig and leaf (*Cephalotaxus fortune*), Chinese plumyew (*Cephalotaxus sinensis*). Badong discovered a dozen rare and endangered species, including Cercidiphyllum *japonicum*, *davidia involucreata*, Henry emmenopterys (*Emmenopterys henryi*), *Tetracentron sinense*, Chinese falsepistache (*Tapiscia sinensis*), Glabrousleaf epaulettetree (*Pterostyrax psilophyllus*), Wilson buckeye, China coinmaple (*Dipteronia sinensis*), China filbert (*Corylus chinensis*), and Chinese stewartia (*Stewartia sinensis*). Also discovered were a large expanse of *Securinega wuxiensis*, a native species on the banks of the Yangtze west of Guandu Town, Badong county new distribution points at Zigui and Yichang County in Hubei Province for *chuanmingsen*, and *Adiantum feniforme var. sinense* communities covering 20 and 0.1 hm^2 at Wuqiao of Wanzhou and Shizhu County.

Vegetation and forest resources

The Three Gorges reservoir area is situated in the northern part of the mid-subtropical belt. Influenced by the subtropical monsoon, its zonal vegetation mainly features Farges chinkapin (*Castanopsis fargesii*), Nanmu (*Phoebe zhennan*) and other evergreen broadleaf forests. In the low elevation area below 1000 m, it is hard to find original vegetations apart from small communities that are free from strong artificial intervention. There are some natural forests in the areas above the elevation of 1300 m. Most representatives are Yiziliang of Kaixian, Maocaoba of Fengjie, and Baiguo of Wuxi, where the forest vegetation has been well preserved. Most extensively distributed in the reservoir area are Pine (*Pinus massoniana*), cypress forest and their open forests, shrubs, meadows, and farmland.

Survey shows that there are more than 78 types of vegetations, including more than 44 arbor, distributed in areas 195–2700 m above the sea level, 16 shrubs at an elevation of 90–2700 m and 22 herbosa. Below the inundation line there are also *securinega wuxiensis* shrubs, *Maytenus variabilis* shrubs, Thinleaf adina (*Adina rubella*), and *Faber bauhinia* (*Bauhinia brachycarpa*) shrubs, which are commonly distributed in the riparian low elevation area.

Survey shows that there are 208 species of plants under the state level protection and are native to the reservoir area. Listed in the catalog under state protection are 155 species, including Dawn redwood (*Metasequoia glyptostroboides*), Cathay silver fir (*Cathaya argyrophylla*), Spiny alsophila, Buckwheat (*Fagopyrum dibotrys*), Dove tree (*Davidia involucrata*), China bretschneidera (*Bretschneidera sinensis*), Silver orchid (*Cephalanthera erecta*), Common cuckoo-orchis (*Cremastra appendiculata*), and China yew. There are 54 species native to the reservoir area, including *Meliosma thomsonii*, Thinleaf maple (*Acer tenellum*), Chongqing camellia (*Camellia chungkingensis*), Spineless oilnut (*Pyrularia inermis*), and *Zanthoxylum echinocarpum*.

[4]Ecological and Environmental Monitoring Center, SFA. Technical Report of Main Monitoring Station of Terrestrial Animals, (1996–2003).

Table 7.13 Species of likely to be affected plants and endemic plants under state class protection

Classification	Total	Basically innudated	Partially innudated	Resettlement area
State Protected plant	103	–	5	98
Endemic Plant in Reservoir Area	25	5	2	18

The reservoir may affected 128 species (Table 7.13). A large-scaled transplantation and research have been done with regard to such rare and native species have aroused the biggest attention as *Adiantum feniforme var. sinense*, Looseflowered falsetamarisk (*Myricaria laxiflora*), *Chuanmingsen*, and *Securinega wuxiensis*. In addition, new distribution points were discovered in the 1997 survey. The plants under state protection and plants native to the reservoir area are sparsely distributed and few in number. Over 60% of them are distributed in the resettlement areas, which need protection.

Principal resource plants

Survey shows that there are more than 4500 species of resource plants, including more than 3500 species that may be used as medicine, 610 species that are edible, 566 species that bear oil, more than 500 species as ornamental plants, more than 250 species of fiber plants, more than 300 species of timber trees, 136 shelter belt trees, and green manure plants, more than 50 plants that may be used to make dyes, 41 species of rubber plants, and 480 plants of other purposes (such as aroma oil, tannin, fruit trees, rosin, and pigment).

There are many wild plants that may be developed and utilized. The most extensively distributed are coptis root (*Rhizoma Coptidis*), buckwheat, Eucommia, *magnolia* officinalis, Fiveleaf gynostemma (*gynostemma pentaphyllum*), Fragrant spicebush (*Lindera fragrans*), China magnoliavine (*Schiandra* spp.), Cercidiphyllum *japonicum*, Liquidambar (*Liquidambar formosana*), *Konjac* (*Amorphophallus rivieri*), Beetor (*Beta vulgaris*), Oiltung (*Vernicia fordii*), Mountain spicy tree (*Litsea cubeba*), Giant dogwood (*Cornus controversa*), China sumac (*Rhus chinensis*), Dye tree (*Platycarya strobilacea*), Pine, hemp, and Western brackenfern (*Pteridium aquilinum var. latiusculum*). There are also timber trees, ornamental plants, and nectariferous plants (honey plants).

Famous ancient trees

There are, in the reservoir area, 4514 ancient trees of 157 species, belonging to 112 families and 54 orders of which 50% are Cypress Tree (*Platycladus orientalis*), Pine, Ginkgo (*Ginkgo biloba*), and China honeylocust (*Gleditsia sinensis*).

Of these ancient trees, only a small number of non-rare species such as Fig tree (*Ficus virens*) are distributed at an elevation below 175 m, accounting for about 7% of the total number of ancient trees. The TGP does not pose any threat to most of the ancient trees.

The 2003 survey shows that all the ancient trees in the reservoir area were cultivable species, not falling into species for protection.

7.4.2 Terrestrial Animals in the Reservoir Area

Survey data show that there are 561 species of terrestrial vertebrates in the reservoir area, including 9 under the state first-class protection, 64 of the state second class protection, accounting for 13.01% of the total animal species. Listed in the red book of endangered species (including many under the state class protection) are 119, accounting for 21.21%. There are 87 native species, including 53 distributed in China and 34 mainly distributed in China (including those under the state class protection and listed in the red book), accounting for 15.51%, totaling 164 species in 53 families and 22 orders, accounting for 29.23% of the total. Compared with the total vertebrates of the country and those under priority protection, the reservoir occupies an important position in terms of species and number.

The number of bird species in the reservoir area is 390 in record, close to the theoretical analysis (about 400), including 3 [Black stork (*Ciconia nigra*), Golden eagle (*Aquila chrysaetos*), and Imperial eagle (*Aquila heliaca*)] under the state first-class protection, 47 under the state second class protection and 58 under the provincial class protection. There are 103 mammal species, including 6 under the state first-class protection [Snub-nosed monkey (*Rhinopithecus roxellanae*), Clouded leopard (*Neofelis nebulosa*), Lepard (*Panthera pardus*), tiger, Asiatic golden cat (*Felis temmincki*), and Sika deer (Cervus nippon)]; 16 under the second class protection and 20 under the provincial level protection. There are 36 reptile species and 32 amphibian species, with one under the state second class protection.

Monitoring results show that living in places with an elevation ranging 800–1000 m are Black-leaf monkey (*Presbytis francoisi*), Snub-nosed monkey and tiger under the state first-class protection, and under the state second class protection are Rhesus monkey (*Rhesus macaque*), *Macaca tibetana*, Black bear, Tufted deer (*elaphodus cephalophus*), Goral (*naemorhedus goral*), Crimson-bellied tragopan (*tragopan temminskii*), Koklass pheasant (*pucrasia macrolopha*), White-crowned long-tailed pheasant (*Syrmaticus reevesii*), and Golden pheasant (*Chrysolophus pictus*). Rare and endangered species such as Rhesus macaque, Black bear, Chinese muntjac (*muntiacus reevesi*), and Serow (*Capricornis sumatraensis*) have been found in large numbers. They are easily observed.

There are also 44 wild animals newly recorded. They include 12 mammals, 21 of avifauna, and 6 of herpetofauna and 5 of the amphibeans. *Macaca tibeta*na, Cinereous vulture (*Aegypius monachus*), and *Chinese tiger frog* (*Rana rugulosus*) come under the state second class protection.

Golden-haired monkey is also existent in the reservoir area. At least 2–3 colonies are living within the boundaries of Badong and Xingshan counties in Hubei Province, with at least a population of 400. The large areas of biotope breaks separated the golden-haired monkeys in Badong and Xingshan from those in the Shennongjia protection zone.

The Black-leaf monkey in Wulong-Pengshui in Chongqing and those in Nanchuan all belong to the white-cheeked subspecies on the northern fringe of the geographical location of this colony. Isolated from each other, the fragile colonies could reproduce the rehabilitative number in a short period of time.

Also found in the reservoir area are two wintering habitats of a considerable scale for Mandarin ducks (*Aix galericulata*). It is in the Furong River valley in Wulong County and the Yanduhe of Badong County. Wintering mandarin ducks have also been found in the Daning River (little Three Gorges) between Wushan and Wuxi counties. The 1999 survey was carried out in a radius of 18 km and at least six mandarin ducks were spotted. It was estimated there were at least 100. There was also a considerable number of mandarin ducks in the Madu River, a tributary of the Daning River. After the reservoir is built, great changes have taken place in the habitats of mandarin ducks. More surveys and monitoring are needed.

Tiger, Leopard (*panthera pardus*), Clouded leopard, and Golden cat are also on or nearing the verge of extinction.

Rhesus macaque (*macaca mulatta*) is frequently seen near the Daning River in Wushan County, the Yandu River in Badong County, the Furong River in Wulong County, and Longhe River in Fengdu County. But the distribution of Tibetan macaque (*Macaca thibetana*) has not been confirmed.

Species living near the inundated line affected by the impoundment of the reservoir include Mandarin ducks, Rhesus monkey, Otter, Serow, and Golden pheasant.

Other rare water fowls, according to sample monitoring and survey, include Black stork, White spoonbill (*Platalea leucorodia*), Black-faced spoonbill (*Platalea minor*), Whooper swan (*Cygnus cygnus*), and Whistling swan (*Cygnus columbianus*). The stable wintering habitats of considerable size are no longer existent. The birds of the *anatidae* family are dwindling in number in the Changzhou Lake and the Dahong Lake. Lophura nycthemera is a newly recorded species in the survey. It is available in a limited number, only occasionally seen.

7.5 Local Climate Monitoring Results[5]

7.5.1 Features of the Local Climate in the Reservoir Area

The Three Gorges reservoir is situated in the middle latitude, with a subtropical wet monsoon climate. Under the control of climate in the south and north and due to geographical conditions, the area features warm winter, early spring, hot and dry summer, rainy autumn, high humidity, small wind force, and obvious vertical changes.

Precipitation

The reservoir area has a plenty of rainfall, averaging 1120 mm a year. But the time and spatial distribution is uneven, with a descending order from the west to the east, as is shown in Fig. 7.15. Precipitation is mainly concentrated in May–October, with that in June accounting for at least 78% of the annual total. There are frequent rainstorms. Annual changes are also big, with the average relative change of 9.3%, with the maximum annual rainfall reaching more than 1800 mm and the minimum annual rainfall being less than 750 mm, a difference of 2.4 times. The rainfall in 1961–2003 did not change much in general, as is shown in Fig. 7.16. The rainfall days in the area reached 143, mainly in spring and autumn. But a slight declining trend has been recorded in the number of rainfall days.

Air temperature

The mean annual temperature ranges 16.3–18.2 °C, which increases progressively from east to west due to the influence of the geographical location and the Yangtze River, see Fig. 7.17. The maximum temperature appears in the summer month of August while the minimum temperature appears in the winter month of January. In 1961–2003, the mean annual temperature in the reservoir area did not change much, with that of 1960–1970 being close to normal, that of the early

[5]State Meteorological Center. Technical Report of Main Monitoring Station of Local Climate (1996–2003).

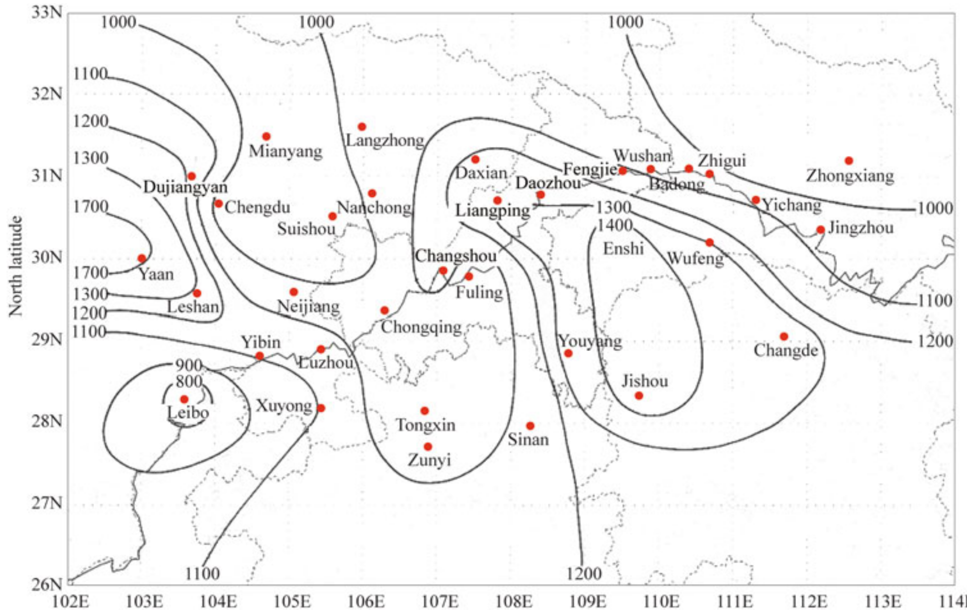


Fig. 7.15 Annual precipitation distribution of the reservoir area

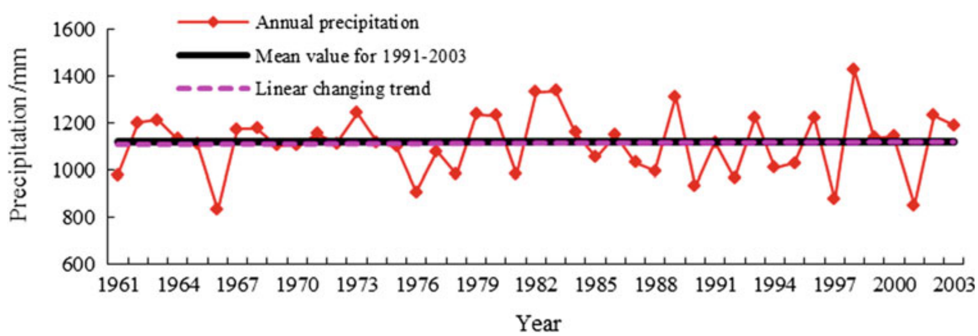


Fig. 7.16 Annual precipitation changes in the reservoir area 1961–2003

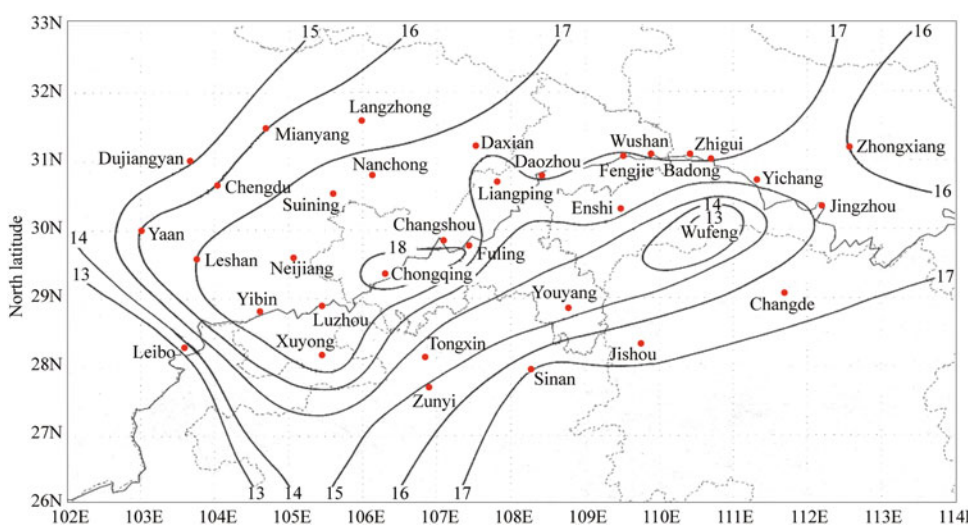


Fig. 7.17 Annual mean temperature distribution of the reservoir area

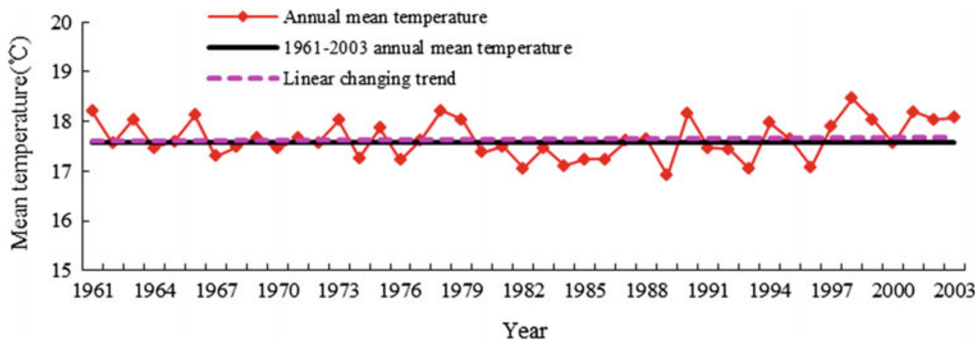


Fig. 7.18 Annual mean temperature changes in 1961–2003 of the reservoir area

and mid-1980s being relatively lower and that of the late 1980 s till present being relatively higher. The seasonal mean temperature in spring, autumn, and winter have been rising to a certain extent and the mean temperature in summer have been falling slightly. See Fig. 7.18.

Relative humidity

The mean annual relative humidity is generally high in the reservoir area, with the range of change being 70–82%. The minimum mean relative humidity is registered in spring and the maximum difference is registered in winter. In general, the humidity is higher in the eastern part than in the western part and low in the middle part, as is shown in Fig. 7.19. In the recent 43 years from 1961 to 2003, the mean relative humidity has been on the rise, but the range of change is not big, as is shown in Fig. 7.20.

Sunshine hours

The sunshine hours in the reservoir area are small in number, ranging mostly from 1200–1600 h in most areas, with the spatial distribution assuming a descending order from east to west. Chongqing has the minimum sunshine hours, about 1125 while Yichang has a maximum 1608. The annual change in sunshine hours is big, with the biggest difference being 560–850 h. In the 1960s–1970s, there were more sunshine hours, but in the 1980 s, the number of sunshine hours was on the low side. See Fig. 7.21.

Wind

Due to topographical reasons, the wind force in the reservoir area is small and the calm wind frequency is high. The annual calm wind frequency in Wanzhou and Fuling accounts for over 60% and the annual wind velocity is generally 0.5–2.0 m/s, one of the smallest wind areas in the country. Influenced by the general circulation and complicated topography, the prevailing wind direction and wind direction frequency vary greatly in the area, with the partially northerly wind prevailing in Chongqing, Changshou, Fuling, and Wanzhou in the western section of the reservoir, partially northerly wind and partially easterly wind prevail in Fengji and Wushan in the western part of the middle section

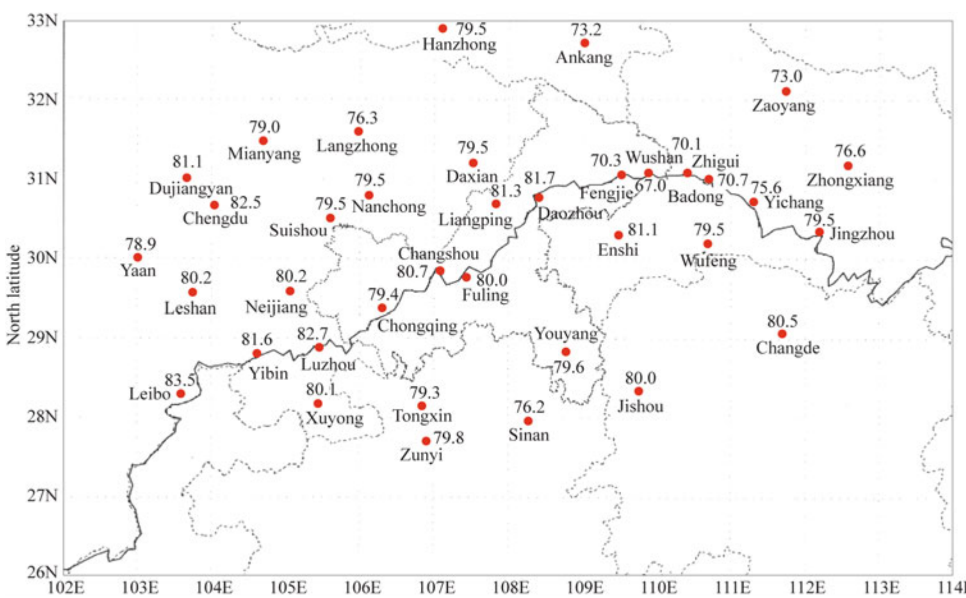


Fig. 7.19 Annual mean relative humidity of the reservoir area (1961–1965)

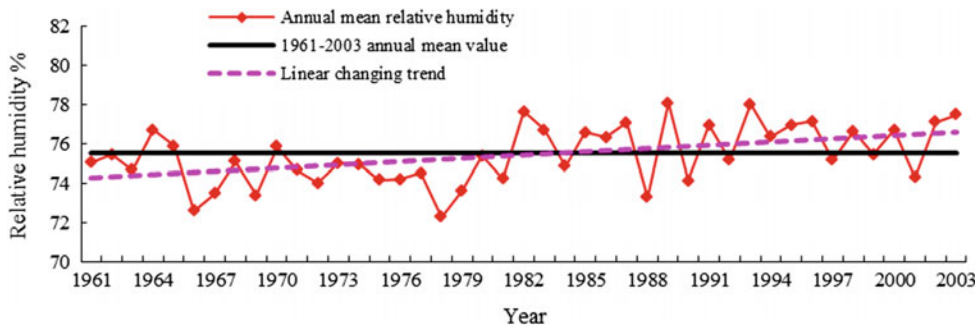


Fig. 7.20 Annual mean relative humidity changes in 1961–2003 of the reservoir area

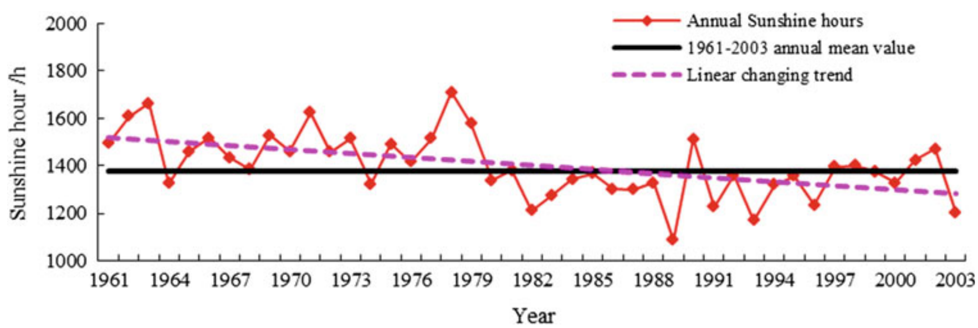


Fig. 7.21 Annual sunshine hour changes in the reservoir area

of the reservoir and mostly southeasterly wind in Badong, Zigui, and Yichang east of the Wushan Mountain. The average velocity change in the recent 43 years is significant, with the average velocity being big in the 1960s–1980s, significantly dwindling in the 1980s–1990s and on the upward trend since the late 1990s. See Fig. 7.22.

Evaporation

The average annual evaporation in the reservoir area is 1322.6 mm, varying greatly from year to year and in different time scales. The evaporation was on the big side in the 1960s–1970s and vice versa since the 1980s.

The change in the local climate is similar to the climatic change of southwest China, the whole nation the whole world. It is, therefore, a change based on the general climate. The annual mean temperature rise is basically identical with global and national temperature changes. The same is true with the temperature change in winter and summer. However, the changes in the trend and scope of climatic factors are different in different places, signifying the importance of the impact of local topography and the underlying surface.

7.5.2 Principal Meteorological Disasters

The main meteorological disasters in the reservoir area include rainstorm and flood, drought, low-temperature rainy spell, hailstorm, high temperature and fog. Rainstorm and flood are the most destructive. They happen almost every year. The annual average rainstorm days are 2–4, with those in the east more than in the west as is shown in Fig. 7.23. Rainstorm strikes mainly in April–November, with those in June and July being the more frequent, accounting for 22.2%

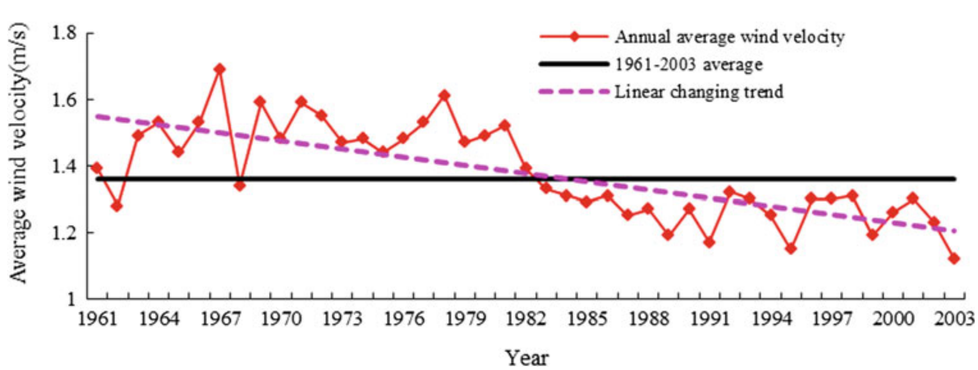
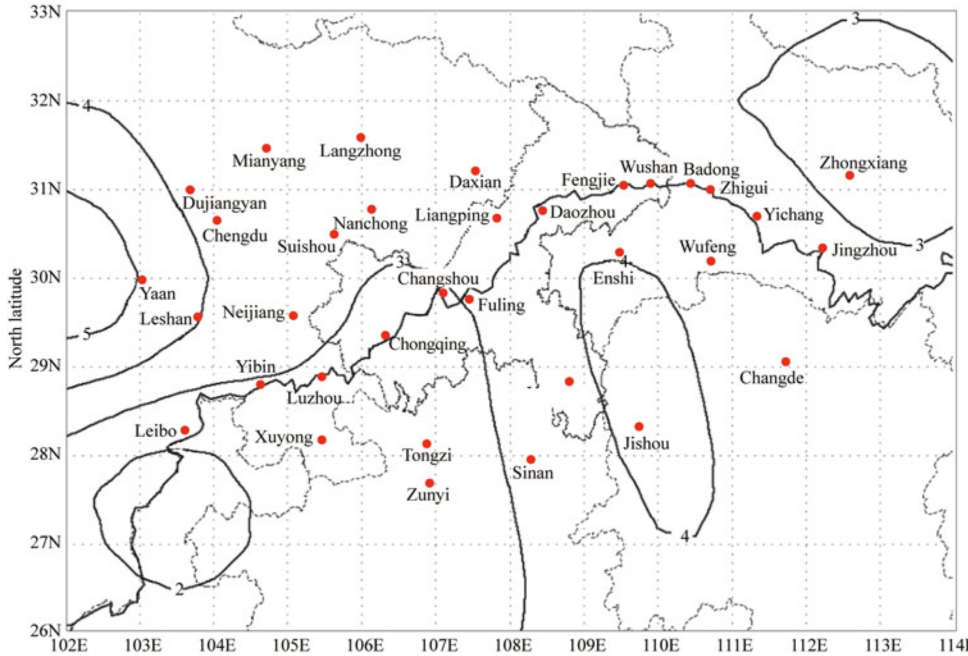


Fig. 7.22 Change in annual average of wind velocity in the reservoir area

Fig. 7.23 Annual rainstorm days in the reservoir and surrounding areas



and 26.4% of the total rainstorm days. Rainstorm is the main factor that induces mud flow, land slide, and crumbling in the reservoir and surrounding areas.

Drought and flood

Due to uneven spatial distribution of precipitation and topographic factors, drought is one of the main meteorological disasters, with an average annual frequency of 52.8%, happening in all seasons of the year. Summer drought is frequent in the western part of the reservoir, averaging over 60% in the main city districts of Chongqing and most part of Zhongxian County. The early summer drought is concentrated in mid-July; the second summer drought often occurs in mid- and late August. Autumn drought mainly occurs in the eastern part of the reservoir area, but with the frequency and intensity not as often and strong as the summer drought. Drought frequency was high in the 1980s and the 1990s, as is shown in Fig. 7.24. Flood is next to drought, with frequency varying from place to place, ranging from 17 to 40%, with that being higher in places south of the Yangtze than in places north of the Yangtze. There is little difference between the east and the west. Flood occurs mainly in summer. The intensity and losses caused by floods in recent years tend to increase in severity.

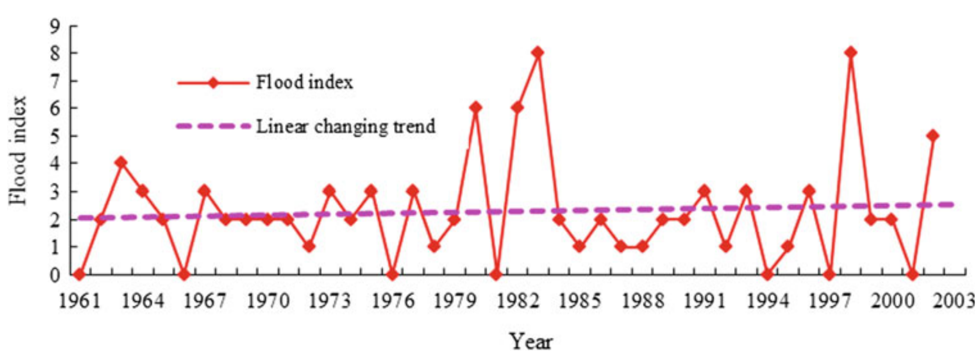
Thunderstorm

The number of thunderstorm days is more in the eastern part of the reservoir than in the western part, with that in the eastern part averaging 48.3 days and that in the western part averaging 32.7 days a year. Thunderstorm occurs most frequently in April–August but little in autumn and winter.

High temperature

High temperature affects not only the growth of crops but also the health of the people. Temperature higher or equal to 35 °C mainly occurs in the western part of the reservoir area,

Fig. 7.24 Change flood index in the reservoir area



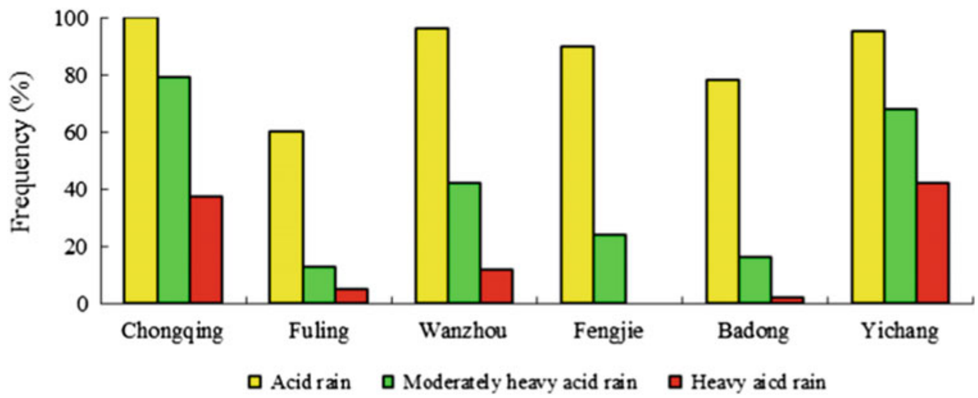


Fig. 7.25 Frequency of acid rains in six stations in the reservoir area

averaging 22.8 days a year, with that in Yunyang, Kaixian, Wushan, Wuxi, Fengdu, and Wanzhou averaging over 33 days a year. The number of high temperature days in Yunyang could reach 40.7 days. Such high temperature days are likely to occur anytime in March–October, but mostly in August, when it accounts for 45.5% of the total high temperature days. The next month with the most frequent high temperatures is July, when the high temperature days account for 34.7%.

Heavy fog

The number of annual foggy days in the reservoir area averages 30–40, with that in the western part being more than in the eastern part. Fuling has an average 72.6 foggy days while Zigui has only 1.2 days. The annual change in foggy days is also big. In Fuling, 1987 witnessed the largest number of foggy days of 118 but 1976 saw the least foggy days of 30. Fog appears mostly in autumn and winter east and west of the valley between Fengjie and Badong. The number of foggy days is the least in summer. But contrary is true in the Gorges sections, where it is foggy in summer and less foggy in winter.

Acid rain

Acid rain is the most frequent and the severest in the reservoir area. The acid rain frequency in all the monitoring stations in the reservoir area ranges 60–100%, over 90% in most stations. The severest are Yichang and Chongqing on the eastern and western end of the reservoir, with the frequency of heavy acid rain being 42% and 37%. But that in other areas is less than 15%. Acid rain is the severest in December and it is slightest in May–August, as shown in Fig. 7.25. pH value is closely associated with precipitation. It is also associated with the wind velocity. It has some relations with foggy days but not so significantly.

7.5.3 Vertical Climate Before the Reservoir Impoundment

What affect the climate of the reservoir area are the changes brought about by impoundment to the underlying surface. The local climate monitoring sub-system selected Yichang and Fuling cross-sections to observe the changes in the vertical climate in order to provide the baseline materials for comparative studies.

Observation results at Yichang

(1) Observation time

Ground observation station at the head of the reservoir: On the right bank are the Fengxianggou Meteorological Station, Maoping Meteorological Station in Zigui County and Taiyangbao Station; on the left bank are Sujia'ao Meteorological Station, Tanziling Meteorological Station. Observation time: July and October in 2002 and January and April in 2003.

(2) Temperature

The average temperature at the head of the reservoir features significant annual changes, with that in January being the lowest and that in July, the highest. The monthly and annual mean temperatures dropped and the average lowest temperature rose with the rise of elevation. Figure 7.26 shows the changes in the annual average temperature at elevations of 140 m (Letianxi), 300 m (Maoping), and 1000 m (Taiyangbao). This shows that the annual temperature change curves at different elevations are in the same phase, all reaching the highest in July and the lowest in January. When elevation rises, the monthly and annual average temperature drops. The January average temperature in Letianxi and Taiyangbao is 5.1 and 1.5 °C, with a difference of 3.6 °C. The July average temperature is 27.6 and 23.2 °C,

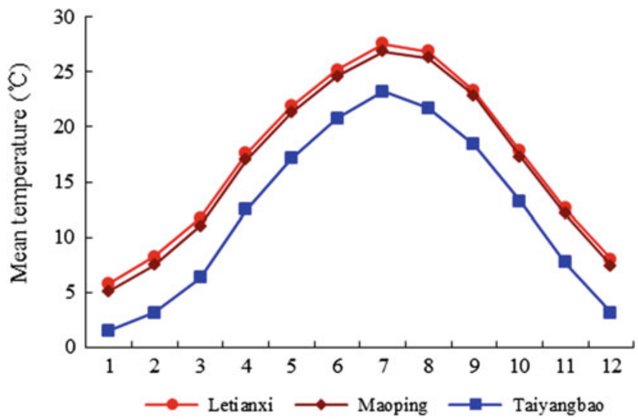


Fig. 7.26 Annual change curve of mean temperature at different elevations (1961-1965)

with a difference of 4.4 °C. The water body has a significant effect on lowering the temperature in the day, by about 0.1–0.7 °C. But at night, the water body has the effect of increasing temperature by about 0.1–0.7 °C. As is shown in Table 7.14, the temperature boosting effect at 20:00 h is more significant than at 08:00 h. The range of temperature increase is the biggest in the Fengxianggou group, followed by Letianxi group and it is the smallest in Tanziling. This is in reverse relationship with their distances from water bodies. The shorter the distance from the water body, the bigger the increase in temperature.

The thickness of the mixed layer and daily change at the head of the reservoir have significant regional features, with that in spring being the biggest in average thickness, followed by that in summer and winter. That in autumn is the smallest. Figure 7.27 shows that the annual average is 754 m.

(3) Relative humidity

The average relative humidity at the head of the reservoir is 76%, with that in most years fluctuating above and below the average value, in a positive distribution, as is shown in Fig. 7.28. The monthly change is not big, about 5% but with a strong seasonal characters. It is the highest in spring, followed by summer and autumn and it is the lowest in winter. The daily change in low elevation areas is big, but it is getting lower with the rise of elevation.

(4) Precipitation

Rainfall in the reservoir area is concentrated in May–October, accounting for 82–91% of the annual total, with the monthly precipitation reaching over 50 mm. The higher the elevation is, the bigger the precipitation will be, See Fig. 7.29. There is little rain in winter and spring, without significant changes with the rise in elevation. Besides, water body inhibits rainfalls of the neighboring areas.

(5) Wind

Due to local topographical reasons, the average wind speed at the headstream of the reservoir rises with the rise in elevation, with average velocity in March–April and October–November being the biggest and that in February and May being relatively small. Apart from Letianxi, where northwest north wind prevails, all the other stations witnessed the prevalence of easterly wind. In Yichang downstream of the reservoir, southeasterly wind prevails. Wind speed is the slowest before sun rise and it increases in the day and slows down again after sunset, with the biggest happening around dusk.

Table 7.14 Temperature difference at 8:00 and 20:00 among the three contrasting group (°C)

	08:00				20:00			
Contrasting groups	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
Tanziling (1)	0.3	0.3	0.1	0.3	0.4	0.4	0.6	0.6
Letianxi (2)	0.5	0.9	0.7	1.0	−0.1	0.5	0.7	0.5
Fengxianggou (3)	0.8	0.1	0.0	0.4	1.1	1.5	1.6	0.8

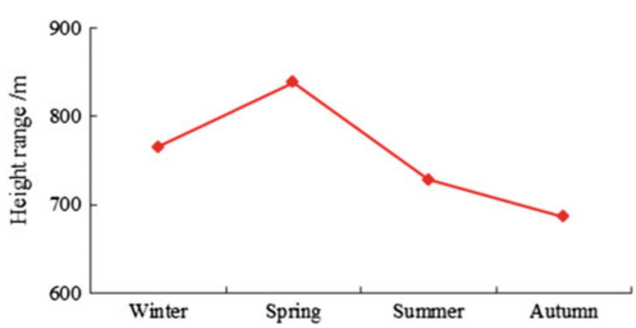


Fig. 7.27 Annual change of average height in the mixed layer

Figure 7.30 shows the distribution of wind direction frequencies at representative elevations in all months. At elevations of 200 and 700 m, the wind directions in all months are identical, with wind blowing along the Yangtze Valley direction as a result of the local mountain valleys. But the wind directions above the elevation of 900 m begin to change. At the elevation of 1300 m, the wind direction distribution is dispersed, increasing with the rise of elevation, less influenced by the local topography. At the

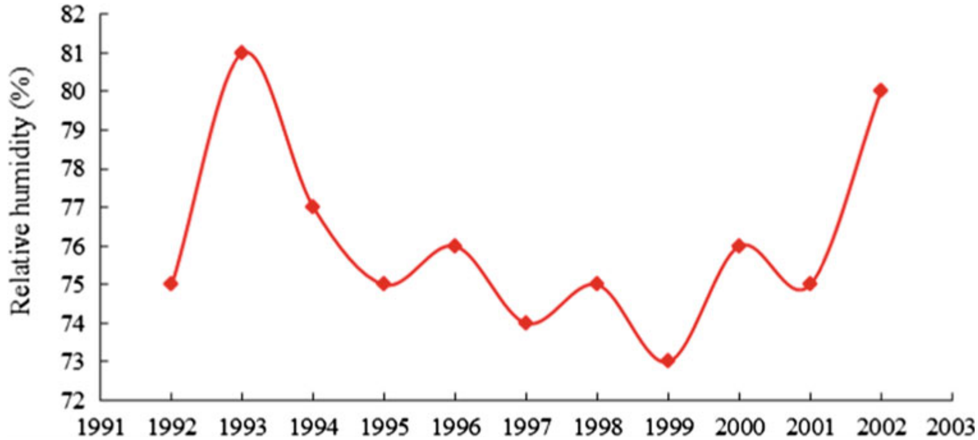


Fig. 7.28 Change in relative humidity at Bahekou (dam-site) regular meteorological station

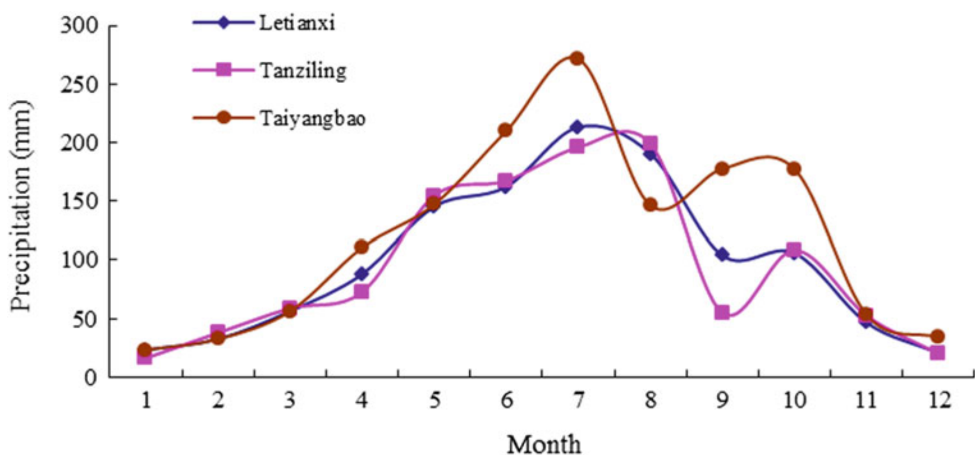


Fig. 7.29 Annual precipitation change curve of the dam area

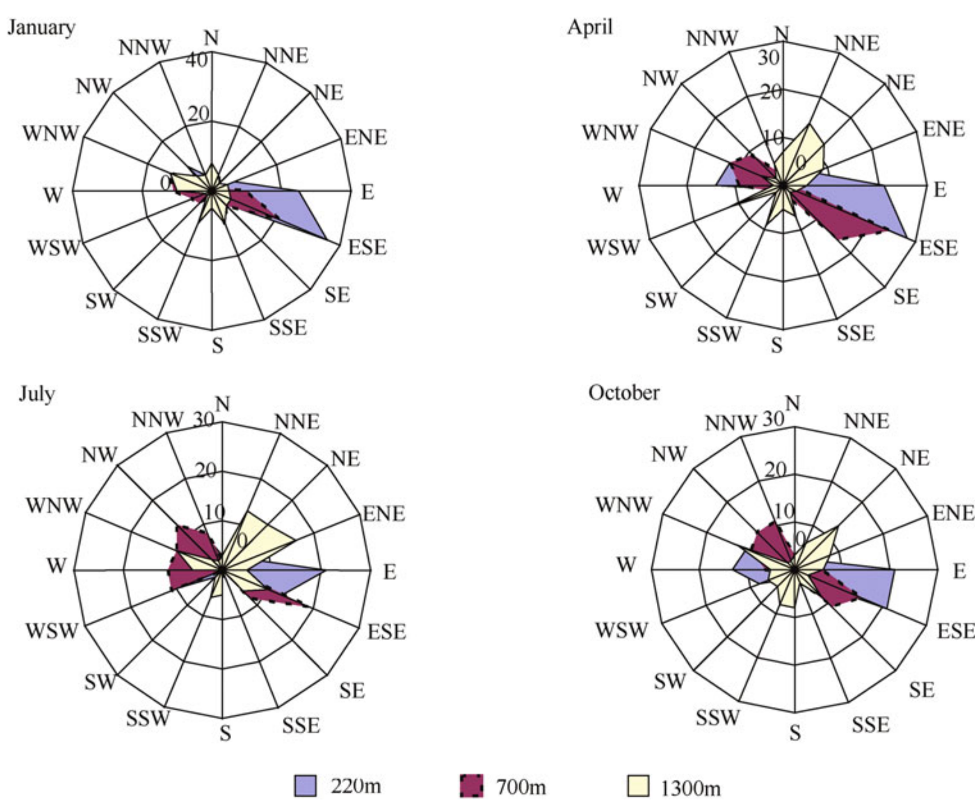


Fig. 7.30 Wind direction frequency distribution at representative heights

elevation of 1300 m, it is close to the top of the boundary layer, which has some influence on the activities of weather scale system. Apart from January, northeasterly wind frequency is big in all the other months.

(6) Heavy fog

Heavy fog appears in all months of the year in the reservoir area, usually from October to May the following year, see Fig. 7.31. The number of heavy fog days upstream the tail of the reservoir is less than that of the upper reach of the reservoir, and the number of heavy fog days in the dam area (Tanziling) is more than those both upstream and downstream of the dam.

Observation of vertical climate at the Fuling Cross-section

(1) Observation time

The Fuling Cross-section consists of 11 observation stations: Zhongxian, Shizhu, Wulong, Dianjiang, Fengdu, Fuling, Liangping, Baisheng, Nantuo, Yutaishan, and Pingxiba (Jiangxin Island). Observation was made on the daily basis in the representative months of July and October in 2002 and January and April in 2003.

(2) Temperature

The mean, maximum, and minimum temperatures all change with the rise of elevation, all assuming a downward trend. There is an inversion temperature layer in the annual mean temperature at elevations ranging from 500 to 600 m, with the maximum mean temperature having two turns at elevations of 200–300 and 300–400 m. There are seasonal differences in the progressive reduction with the change in elevation, with that in April being the biggest and that of October the smallest, see Fig. 7.32. The maximum temperature at all elevations mostly appears at 14:00–17:00 while the minimum temperature mostly appears at 05:00–08:00 h. The biggest temperature change occurs in summer.

Boundary layer temperature and ground surface temperature follow the same annual and daily changing pattern. Temperature rises significantly in the layer near the ground in the day of the summer months, but the temperature rising effect in winter is far from that in summer. The occurrence of inversion temperature layer in the area is 72.6% in the whole year, with the highest happening in October. The difference in other months is not as much as in October.

(3) Surface temperature and shallow layer geotemperature

The surface temperature generally drops with the rise in elevation, but not much. The annual change of surface temperature and shallow layer geotemperature assumes the single peak pattern, with the peak appearing in July and the trough appearing in January. The geotemperature rises with the increase in depth in January and October at the layer from the surface to 20 cm or 50 cm deep layer. The monthly geotemperature drops with the increase in the depth of the layer in April and July. See Table 7.15.

(4) Vertical structure of the boundary layer temperature

The boundary layer and surface temperatures follow the annual and daily change patterns. Temperature rise significantly in places close to the layer in the days of summer months, but the temperature boost effect in winter is far from summer. Apart from January, when the mean temperature profile at 19:00 h in representative months is below 100 m, there is a close-surface inversion temperature layer in April, July, and October, which assumes a drastic dropping trend at 100–800 m. There is no close-surface inversion temperature layer at 7:00 in all months, but there is a suspended inversion layer at different elevations. The vertical lapse rate from the surface to an elevation of 800 m is bigger in the evening than in the morning. The direct lapse rate at 7:00 and 19:00 h are seasonal in nature. See Figs. 7.33 and 7.34. The atmosphere at 7:00 and 19:00 in all representative months is at a stable or neutral state. The inversion temperature frequency reaches 72.6% in the whole year, with that in

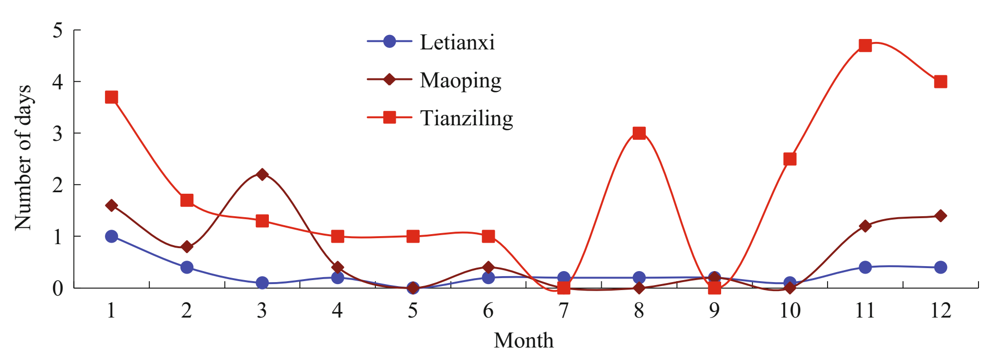


Fig. 7.31 Number of foggy days by month in the first year of reservoir operation

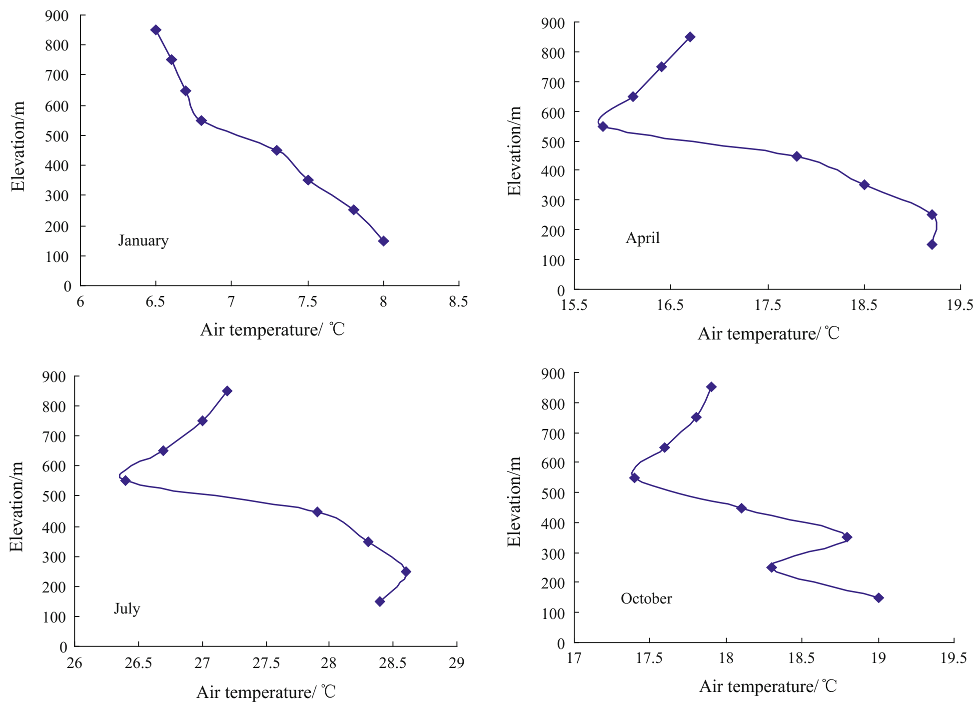


Fig. 7.32 Mean air temperature change curves at different elevations

Table 7.15 Average shallow geotemperature at related monitoring stations in representative months (°C)

Station name	Layer depth (cm)	Jan.	Apr.	July	Oct.
Pingxiba	0	9.4	19.8	31.7	20.3
	5	9.4	19.6	30.6	20.5
	10	9.7	19.4	30.5	20.9
	20	10	18.9	29.9	21.1
	50	10.9	18.1	28.4	21.7
Fuling	0	8.3	21	31.8	19
	5	8.7	20.3	30.3	19.2
	10	9	20.1	29.9	20
	20	9.7	20	29.3	20.4
	50				
Dianjiang	0	7.6	19.5	33	20
	5	8.2	18.5	30.5	20
	10	8.6	18.3	30.1	20.4
	20	9.1	17.7	28.8	20.7
	50				

October being the highest and not much different in other months. The average inversion temperature intensity at 7:00 and 19:00 h in all months is all above 1 °C/100 m, with that at 7:00 h in January being the smallest and that at 19:00 h in April being the biggest. The inversion temperature at the highest of the mixed layers changes seasonally, with the bigger-than-800 m frequency being the highest in July and the lowest in January.

(5) Surface relative humidity

The annual mean relative humidity at the 100–800 m sloping surface changes in a range from 74 to 86%. But the annual change of humidity is not big at different heights, with the biggest being 9–10%, at an elevation of 100–300 m. The trend of change with elevation in all representative months is basically similar to the annual mean relative

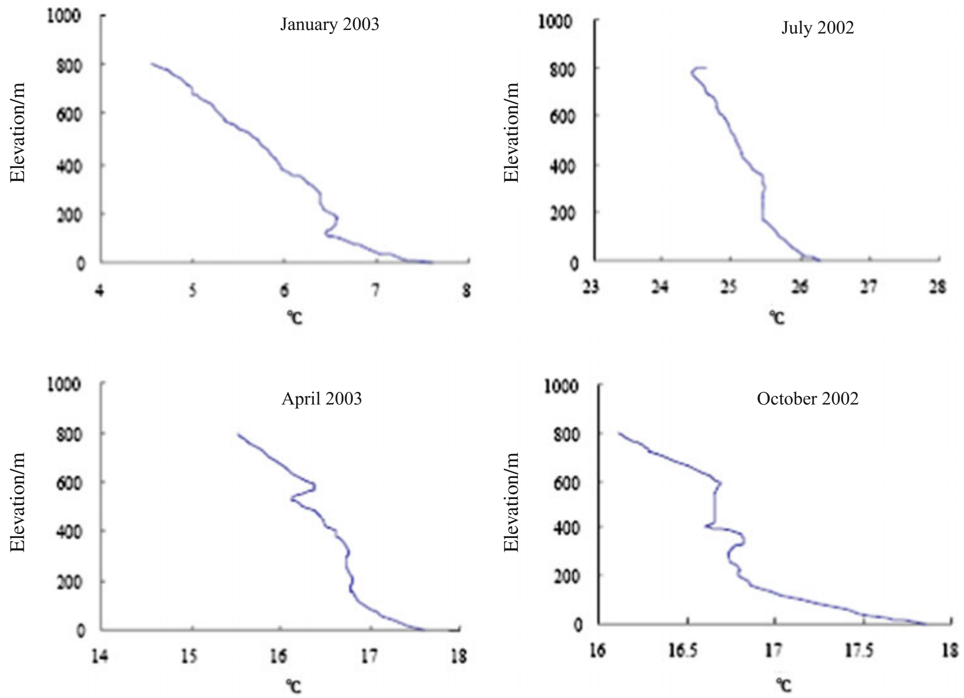


Fig. 7.33 Average temperature vertical profiles at 07:00 of representative months

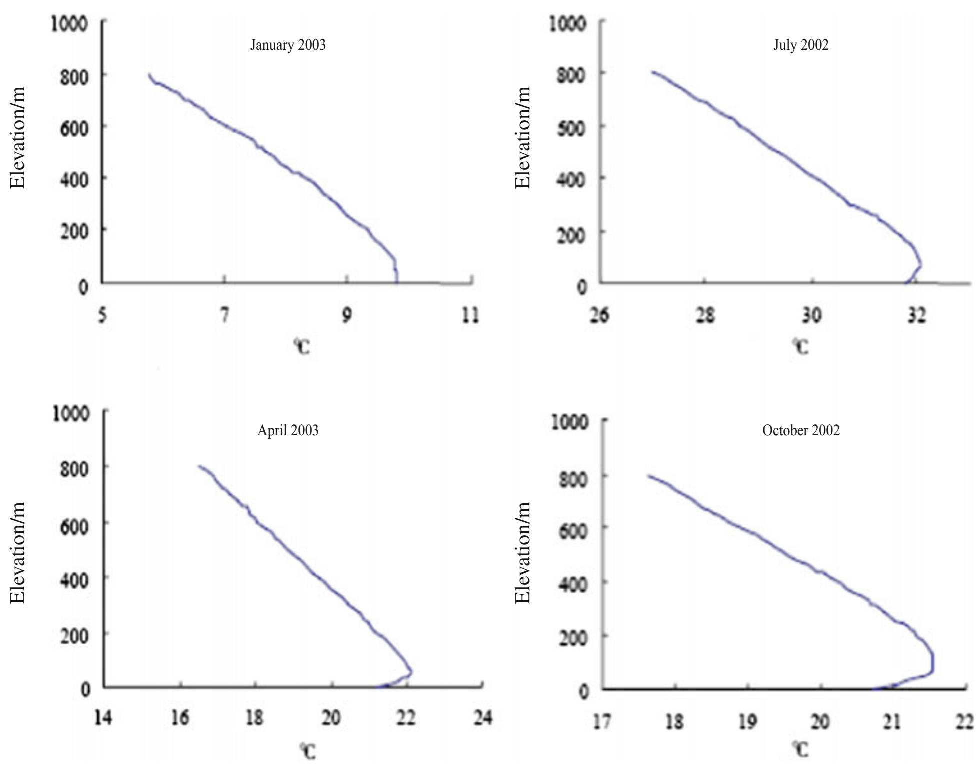


Fig. 7.34 Average temperature vertical profiles at 19:00 of representative months at different elevations

humidity, as is shown in Table 7.16. The biggest change at elevations ranging 100–800 m in all representative months happens in January and the smallest change happens in April and something in between occurs in July and October.

The seasonal changes in relative humidity follow the same pattern at 7:00 and 19:00 h, with the biggest change occurring in January and the smallest in April, October and July, but the seasonal difference at 19:00 h is more significant than

Table 7.16 Average relative ground humidity and max changes (%)

Elevation (m)	Jan.	Apr.	July	Oct.	Year	Annual max change
100–200	87	78	78	84	82	9
200–300	79	71	71	81	75	10
300–400	90	82	85	87	86	8
400–500	80	75	74	78	77	6
500–600	75	74	74	73	74	2
600–700	78	77	77	75	77	3
700–800	81	79	80	77	80	4
800–900	84	81	82	79	82	5
Vertical max change	15	9	14	14	12	–

at 7:00 h. The relative humidity in the whole boundary layer is higher in the morning than in the evening. But such differences change with the reasons, with that in summer being the biggest and that in autumn the next and that in winter the smallest. Vertical lapse appears from the surface upward in all the months, except in January, when there is a thin layer of isothermal layer at 40–60 m at 7:00 h. But it assumes a downward trend with the rise of elevation in all representative months at 19:00 h. From 140 to 300 m and above, there is a 420–660 m isothermal layer or inversion layer.

(6) Ground wind

The wind velocity is slow in the area. The annual mean velocity is 0.7–1.6 m/s at elevations of 100–800 m. There is not much change in average wind velocity at 100–400 m. But the wind velocity drops rapidly at 400–600 m and it increases in a linear manner with an elevation from 500 to 900 m. The monthly average wind speed is the biggest in April, the next biggest in July, still next biggest in October and the slowest in January. The maximum daily wind velocity usually appears at 14:00–17:00 h. But the slowest wind speed occurs in an intermittent manner. The maximum annual wind velocity in all cross-section stations does not have much to do with elevation. See Table 7.17. Maximum annual wind speed often occurs in spring and autumn and sometimes in summer, but little in winter. The calm wind frequency in the area is big, with the annual calm wind frequency at 200–600 m slopes reaching 19–54%. The prevailing wind directions vary greatly in all stations.

(7) Low altitude wind

The vertical distribution of boundary layer wind features similar velocity at 7:00 and 19:00 h in all representative months, with the minimum wind speed all occurring on the ground while wind velocity rises with elevation until it reaches its peak at a certain elevation before it remains almost unchanged or it repeats slightly. Seasonal changes in wind velocity show that it is the fastest at 7:00 and 19:00 h in April and the slowest in July. But the wind speed at 7:00 in October is bigger than in January but the reverse is true at 19:00 h. (See Figs. 7.35 and 7.36). The vertical distribution of the frequency of wind directions features no obvious daily change at the low layer below 100 m in January. At 7:00 h at an elevation of 200–800 m, southeasterly wind prevails, but

Table 7.17 Average value of average ground wind velocity at different elevations (m/s)

Elevation (m)	January	April	July	October	Year
100–200	1.1	1.4	1.1	1.1	1.2
200–300	0.9	1.5	1.2	1.1	1.2
300–400	1.2	1.5	1.4	1.2	1.3
400–500	0.8	1.3	1.1	1.0	1.1
500–600	0.6	0.8	0.6	0.6	0.7
600–700	0.9	1.1	1.0	0.9	1.0
700–800	1.2	1.5	1.3	1.2	1.3
800–900	1.5	1.8	1.6	1.5	1.6
Average	1.0	1.4	1.2	1.1	1.2

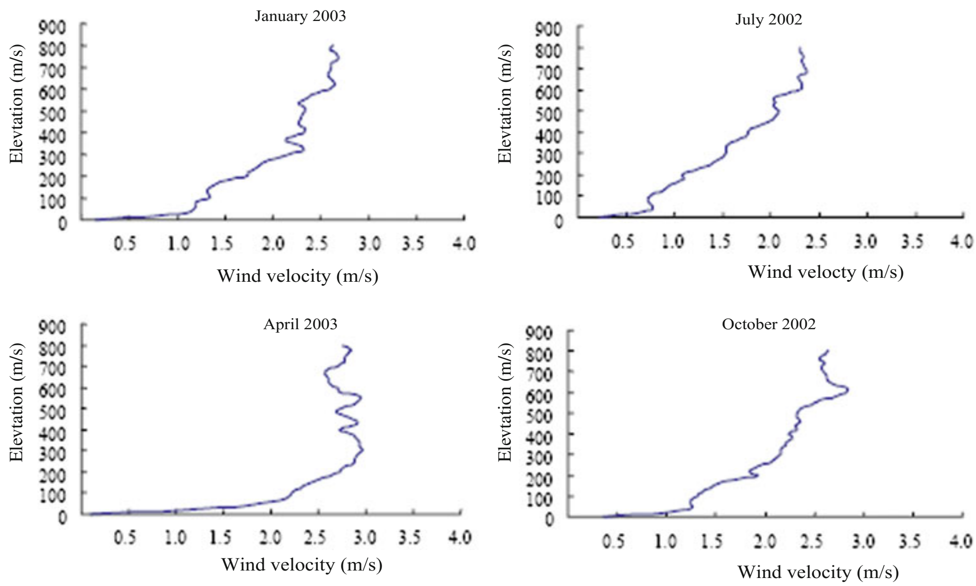


Fig. 7.35 Average wind velocity vertical profile at 07:00 of representative months

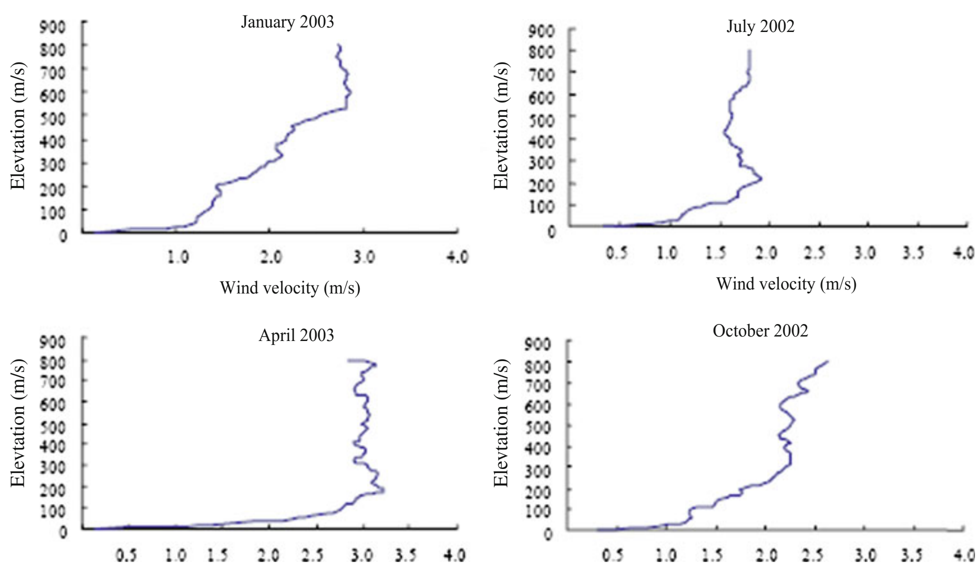


Fig. 7.36 Average wind velocity vertical profiles at 19:00 of representative months

at 19:00 h, the northeasterly-easterly wind prevails, with significant differences in wind direction early in the morning and in the evening. But wind directions are similar at 7:00 and 19:00 h at a layer below 100 m in April. On the ground, southeasterly and southeast-easterly wind prevails and northerly wind prevails at 50–100 m, but above 200 m, the prevailing winds are quite different. The prevailing wind directions at 7:00 h in July change within a narrow angle of EN-E–SE-E from the ground to an elevation of 800 m, but the wind directions are more scattered at 19:00 h. The prevailing wind directions are generally similar at 7:00 and 19:00 h in October, with NE-N prevailing wind at 50 m. The prevailing wind directions at the two time scales at elevations of 150–800 m mostly appear within the three directions of NE-E to SE-E.

7.6 Agro-Ecology and Environment Monitoring Results[6]

7.6.1 Soil Ecosystem in the Reservoir Area

Soil fertility monitoring in the reservoir area

Monitoring by 29 fixed stations shows that the TN content of the soil was 0.118–2.22 g/kg, with the average at 0.966 g/kg, generally very low. The TP content was 0.098–2.602 g/kg,

[6]Hubei Provincial agro-environmental protection station, Technical Report of Main Monitoring Station of Agro-ecological Environment (1996–2003).

with the mean value at 0.544 g/kg, also very low. TK content was 0.827–23.0 g/kg, averaging 9.40 g/kg, fairly low. The Total dissolved N (TDN) was 5.83–115.6 mg/kg, averaging 46.3 mg/kg, fairly low. The content of fast-acting phosphorus was 1.02–90.17 mg/kg, averaging 15.2 mg/kg, at the middle level. The content of fast-acting potassium was 0.01–366.0 mg/kg, averaging 95.0 mg/kg, all fairly low.

Fixed point monitoring of soil fertility shows that the organic matters in the dry land soil basically remained unchanged, with TN increasing slightly, TP basically stable and TK assuming a downward trend. Of the effective nutrients, the TDN increased significantly due to the application of large amounts of nitrogenous fertilizer. Organic phosphorus increased, but not too much. Fast-acting potassium decreased.

Monitoring at 14 fixed points in the rice paddies of the reservoir area shows that TN content in paddy soil was 0.242–2.04 g/kg, with the average value at 0.885 g/kg, fairly low. The TP content was 0.075–1.798 g/kg, averaging 0.433 g/kg, fairly low; TK content was 0.459–27.3 g/kg, averaging 6.96 g/kg, fairly low. TDN was 5.24–112.9 mg/kg, with the average value at 47.1 mg/kg, very low. The content of fast-acting phosphorus was 1.02–40.74 mg/kg, averaging 13.9 mg/kg, at the middle level. The content of fast-acting potassium was 11.0–249.2 mg/kg, averaging 89.2 mg/kg, all fairly low.

Monitoring results showed that the soil organic matter content remained unchanged, TN and TP content increased, but TK content decreased. It shows that the farmers are inclined to fertilize heavy nitrogen and less potash. For the soil available elements state, the available N and P content increased significantly and the available K increased slowly.

Heavy metals contents

Monitoring of dry land at 25 fixed points in the reservoir area shows that Cd content of the soil is 0.08–0.40 mg/kg, with the average value at 0.158 mg/kg; Hg, 0.02–0.287 mg/kg, averaging 0.101 mg/kg; As, 3.16–10.52 mg/kg, averag-ing 6.03 mg/kg; Pb, 10.8–29.1 mg/kg, averaging 19.0 mg/kmg/kg, averaging 18.7 mg/kg; Zn,60.8–135.1 mg/kg, averaging 5.4 mg/kg. The contents of Hg, Cd, Pb, Cu, Zg; Cu, 7.00–30.2n. As are all within the scope of background value, meeting the first-class standards for the quality of soil environment.

Monitoring of rice paddies at 14 fixed points shows that Cd content of the soil is 0.05–0.40 mg/kg, with the average value at 0.112 mg/kg; Hg, 0.072–0.778 mg/kg, averaging 0.179 mg/kg; As, 1.07–11.1 mg/kg, averaging 5.98 mg/kg; Pb, 11.2–27.2 mg/kg, averaging 17.7 mg/kg; Cu, 6.38–26.3 mg/kg, averaging 14.7 mg/kg; Zn, 77.2–140.6 mg/kg, averaging 96.0 mg/kg. All these indices are within the scope of background value, meeting the first-class standards for the quality of soil environment.

Dynamic changes of land in the reservoir area

The wooded land in the reservoir area is 679 368 hm^2, accounting for 62.95% of the total land area; cultivated land is 252 529 hm^2, accounting for 23.39%; land for livestock breeding is 79,916 hm^2, accounting for 7.41%; tea plantation and orchards are 37,638 hm^2, accounting for 3.48%; and orange orchards are 29,756 hm^2, accounting for 2.75%.

Monitoring shows that the total cultivated land basically remains unchanged. Of the total cultivated land, dry land is 154,628 hm^2, accounting for 64.1%; and rice paddies, 86 575 hm^2, accounting for 35.9%.

The cultivated areas of different fertilities dropped in general as is shown in Table 7.18. The area with moderately low fertility is increased by 4.4%; the areas with low fertility increased by 3.2%; the area with middle level fertility drops by 10.7%. As the fertile land is situated mostly below 180 m water level, the resettled people have to reclaim new land and the fertility is therefore poor. The quality of land in the reservoir area has decreased on the whole.

Dynamic changes of cropping pattern in the reservoir area

Monitoring of the crop-growing areas shows that the total sowing area in the reservoir area increased by 6.9% from 1996s 530,590 to 567,391 hm^2 in 2003 as is shown in Table 7.19. The areas devoted to cash crops increased by 57.49% from 1998s 89,841 to 141,494 hm^2 by 2003. The multiple cropping index rose slightly from 213% in 1997 to 233% in 2003.

7.6.2 Dynamic Monitoring of Plant Diseases and Pests

Diseases and pests of major farm crops in the reservoir area

The areas infested by major diseases and pests in 1996–2003 assumed an upward trend, as is shown in Table 7.20. 1997 witnessed the least affected, 371 350 hm^2/times. 2001 witnessed the severest plant diseases and pests, which occurred on 596 233 hm^2/times, 60.6% more than in 1997. In 2003, diseases and pests occurred only on 342 430 hm^2/times.

Table 7.18 Composition of cultivated land of different fertility in the reservoir area (%)

Year	Number of townships survey	High	Hairly high	Middle	Fairly low	Low	Total
1996	179	12.22	25.69	33.20	18.52	10.37	100
1997	183	9.76	25.46	37.89	18.67	8.21	100
1998	182	10.90	20.08	36.89	21.75	10.92	100
1999	190	13.50	19.71	31.58	22.45	13.30	100
2000	194	13.47	19.24	30.31	22.78	14.20	100
2001	194	13.79	19.39	27.23	22.92	13.52	100
2002	194	14.85	19.84	31.99	21.05	12.26	100
2003	181	15.66	20.78	28.83	22.95	11.78	100
8-year average		13.02	21.27	32.24	21.39	11.82	100

Table 7.19 Change in total crop-growing area in the reservoir area (hm^2)

Year	Number of township survey	Total growing area	Grain crops area	Cash crops area	Total (%)
1996	179	–	–	–	–
1997	183	530,590	–	–	213
1998	182	541,696	420,882	89,841	231
1999	190	580,593	452,757	99,896	240
2000	194	606,096	465,470	113,706	239
2001	194	620,287	465,084	135,595	231
2002	194	567,391	439,856	127,535	241
2003	181	531,599	390,106	141,494	239
8-year average		568,322	439,026	118,011	233

Table 7.20 Major plant diseases and pests occurrence among major crops and area brought under control

Year	Number of townships survey	Infested area (hm^2/times)	Areas under control (hm^2)
1996	179	464,150	382,200
1997	183	371,350	370,480
1998	162	515,693	559,367
1999	190	514,387	648,613
2000	194	542,367	583,987
2001	192	596,233	444,833
2002	192	247,613	261,080
2003	181	342,430	325,930
8-year average		449,278	447,061

Major Rodent infestation and control

The areas infested with Rodents increased somehow, but the changes are not big. No outbreak of Rodent infestation was reported. But the actual losses due to Rodent infestation are on the increase. The actual losses were 4.04 million yuan in 1996 and 13.10 million yuan by 2001, increasing by 224.3%, averaging an annual rise of 37.4%. But the pest showed a declining trend in 2002 and 2003. See Table 7.21.

Rice diseases and pests infestation and control

Areas infested with rice blast were on the increase, with the lowest occurring in 1996, 11,430 hm^2/times and the highest

Table 7.21 Major rat infestation and control

Year	Number of townships surveyed	Area infested (hm^2/time)	Areas brought under control (hm^2/time)	% of control	Loss prevented (10^4 yuan)	Actual loss (10^4 yuan)
1996	179	135,850	–	–	3476	404
1997	183	144,420	124,550	86.2	5248	494
1998	162	203,173	198,307	97.6	5102	536
1999	190	194,673	191,387	98.3	5067	556
2000	194	190,007	150,713	79.3	2470	707
2001	192	181,513	117,213	64.6	4363	1310
2002	192	226,866	101,426	44.7	6652	1028
2003	181	144,200	57,980	40.2	3325	658
8-year average		177,587	134,511	73.0	4463	712

occurring in 2000, 36,473 hm^2/times. But it has been on the decline after 2001. The areas infested with rice sheath blight (*Thanatephorus cucumeris*) were on the decline, with the slightest occurring in 1997, 36,330 hm^2/times, and the severest occurring in 1999, 48,473 hm^2/times. Areas infested with paddy snout moth's larva were on the decline, with the slightest occurring in 1997, 77,490 hm^2/times, and the severest occurring in 1999, 101,993 hm^2. Areas affected by planthopper vary greatly, with the slightest occurring in 1996 with 59,450 hm^2. It reached its peak in 1999, with 101,447 hm^2, before it dropped to 33,090 hm^2 by 2003. See Fig. 7.37.

Of all the diseases and pests, the prevention and control of rice blast was the most effective. But the changes over the years were big. The prevention and control of the other pests and diseases remained stable. See Fig. 7.38.

Other crop diseases and pests

Areas infested with wheat scab varied greatly, with the slightest occurring in 2003, 11,050 hm^2 and the severest happening in 2000, with 35 427 hm^2. Areas infested with late blight of potato remained unchanged (except 1997 and 1998, where it was severer), with about 23,000 hm^2 affected. See Fig. 7.39. 2000 suffered the biggest losses, about 7.06 million yuan, and 2003 witnessed the least losses of 1.03 million yuan. The prevention and control remained at a steady level, without much change. See Fig. 7.40.

Citrus red and yellow spider mites and control

1998 witnessed the severest infestation of citrus red and yellow spider mites, with 83,107 hm^2 affected; 2003 saw the lightest infestation, with 20,750 hm^2 affected. But in general, the pests were on the decline. See Fig. 7.41.

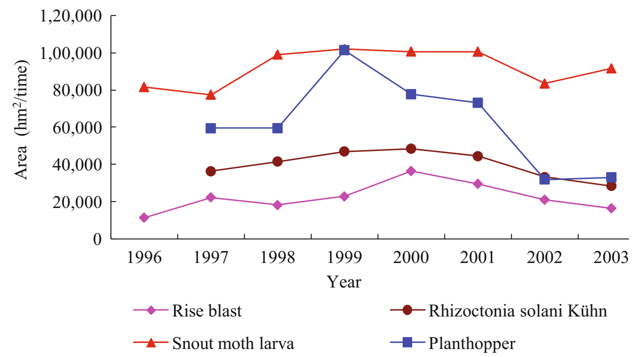


Fig. 7.37 Change in areas infested with plant diseases and pests

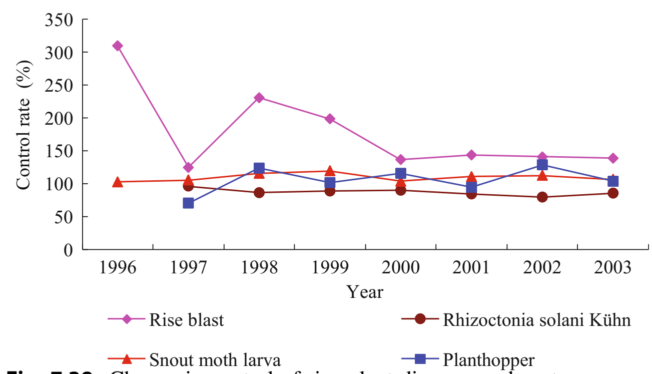


Fig. 7.38 Change in control of rice plant diseases and pests

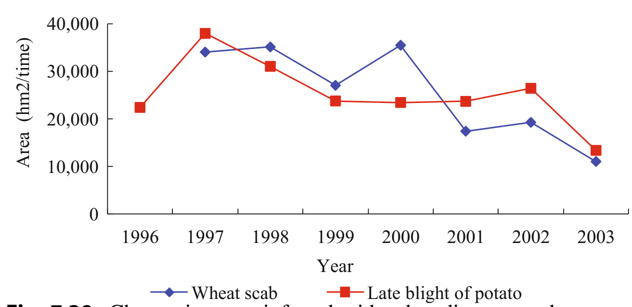


Fig. 7.39 Change in areas infested with other diseases and pests

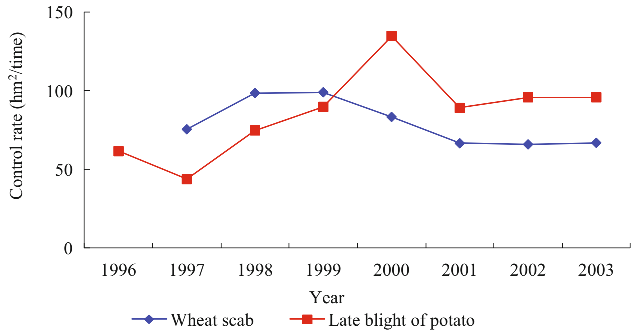


Fig. 7.40 Change in the control of other diseases and pests

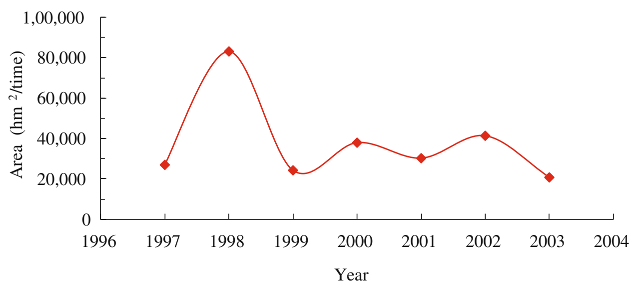


Fig. 7.41 Change in area infested with citrus red mite (*panonychus citri Mc Gregor*) and citrus yellow mite (*Eotetranychus kankitus Ehara*)

7.6.3 Impact of Eco-Environmental Changes on Orange Belt in the Reservoir Area

Orange growing areas and quality of different grades of orange

Monitoring results show that the areas of the five grades of orange have not changed much over the past 8 years. In general, the Three Gorges Dam does not have any significant impact on areas of different grades of orange. The general average of the eight observation years is: 10.65% for the high grade, 17.60% for the next high grade, 38.14% for the middle grade, 23.2% for the moderately low grade and 10.90% for the low grade.

Grade A orange was on the rise, from 32.99% in 1997 to 42.56% in 2002, rising by 9.57%, averaging 1.36 percentage points a year. Grade C orange was dropped by 9.72% from 28.40% in 1997 to 18.688% by 2002, averaging an annual decrease of 1.38%. Grade B orange remained unchanged.

Analysis of agrochemical factor in the soil for growing orange

Monitoring of orange field soil fertility at 16 fixed points shows that the organic matters, TN, TP, and TK have basically maintained unchanged while the fast-acting nutrients rose to varying degrees, especially alkali-hydrolyzed nitrogen, which increased significantly, followed by fast-acting phosphorus. But the fact-acting potassium did not increase as much. This indicates a fertilizer structure mainly featuring nitrogen, followed by phosphorus and potassium.

Monitoring in 1997, 1999, and 2001 of heavy metal elements in the soil of orange fields shows that the contents of heavy metal elements have been in the range of the background value, conforming to the requirements of the first-class standards of soil environmental quality. The heavy metal contents in soil were balanced between that taken away by crops harvested and that put in. Survey also shows that the stone coal area in the reservoir area contained fluoride, selenium, arsenic, and mercury. Care must be taken in exploiting the stone coal and coal dust in order to prevent them from polluting the soil.

7.6.4 Dynamic Changes in Rural Energy Demand and Supply

Rural energy structure

Firewood and crop stalks are the main sources of energy in the rural area. As is shown in Table 7.22, the general trend in the 8 years was that crop stalks accounted for 37.22–43.92%, averaging 41.11% and coal accounted for 18.50–31.78%, averaging 25.92%. As the small coal pits are widely distributed in the Three Gorges area, rural people all use locally available coal. Electricity generated by small hydropower stations accounted for 17.57–24.00%, averaging 18.96%. Firewood accounted for 10.78–14.03%, averaging 12.15%. Biogas made up a very small proportion, only about 0.82–2.81%, averaging 2.44%.

The proportion of firewood and electricity from small hydropower stations has been on the rise in areas with abundant land resources. Biogas use has also risen, but the range of rise is not very big. The proportion of crop stalks and coal has been on the decline.

Biogas use has been declining sharply in Fengjie, Tiancheng, Kaixian, Shizhu, and Yubei, but it has increased sharply in Yichang, Zigui, Badong, Zhongxian, Fengdu, Fuling, and Wulong.

As the land resources are limited in the reservoir area, the areas of firewood forests have not changed much. But in hilly areas where land use is relatively not so intensive, such as Badong, Kaixian, and Changshou, the areas of firewood forests and charcoal output have increased. But in areas where the land utility is intense, such as Wanzhou and

Table 7.22 Composition of rural energy in reservoir area (%)

Year	Number of townships surveyed	Firewood	Crop stalks	Small hydropower	Coal from Small pits	Biogas	Total
1996	179	–	–	–	–	–	–
1997	183	10.78	43.92	24.00	18.50	2.81	100
1998	162	10.96	43.55	17.57	28.71	0.82	100
1999	190	12.32	37.22	17.04	31.78	1.63	100
2000	194	14.03	40.51	18.21	25.05	2.10	99.9
2001	192	12.64	40.34	17.98	25.56	2.63	99.15
2002	192	13.28	37.33	18.44	27.28	3.68	100
2003	181	14.60	37.29	18.17	26.49	3.44	100
8-year average		12.66	39.88	18.77	26.11	2.44	99.87

Yichang, the firewood forests and charcoal output have been dwindling.

Changes in major energy sources

The number of households that have biogas pits was maintained at 1048,400–1231,900 from 1996 to 2003, averaging 1138,000. But the number of biogas pits was on the rise, increasing by 532.8% from 14,404 in 1996 to 76,742 by 2003, averaging an annual growth of 27%. Biogas output also increased from 1996s 6.707 million m^3 to 28.945 million m^3 almost 431.6%, averaging an annual growth of 23.2%. This is attributed to the launch of high-efficient eco-agricultural demonstrative projects by the Ministry of Agriculture in the reservoir area. The development of biogas provided an effective way of rendering nightsoil and animal droppings harmless and controlling non-point pollution sources.

The area of firewood forests ranged 28,558–58,540 hm^2, with the 8-year average being 43,750 hm^2, which peaked in 1997, with 58,540 hm^2, and bottomed in 1999, with 28,558 hm^2. The change of the firewood output ranged 1,383,000–5,928,000 tons, averaging 2,494,000 tons, with the highest being 5928,000 tons in 2003 and the lowest being 1383,000 tons in 1999. Firewood can satisfy only 12.15% of the rural energy needs.

7.6.5 Crop Diversity in the Reservoir Area

Crop diversity

Monitoring results show that there were 143 species (variations), 94 genera and 39 families of farm crops in the inundated area. See Table 7.23. Included are 5 families, 13 genera, and 15 species of cereal crops; 3 families, 4 genera, and 5 species of oil-bearing crops; 11 families, 20 genera, and 30 species of fruits; and 22 families, 48 genera, and 77 species of vegetables. Other crops include 11 families, 14 genera, and 17 species.

Famous and rare crops

The given climatic conditions in the inundated area of the reservoir have generated some rare and native species of plants, which feature superior quality and marketability. Survey shows that the special fruits include red orange (*Citrus reticulate*), Washington navel (*Citrus sinensis "Washington Navel"*), sweet orange, and pickled mustard. Widely planted species include *Musa basjoo* and *Edible Canna*. Widely planted rare species in history include various longan and litchi.

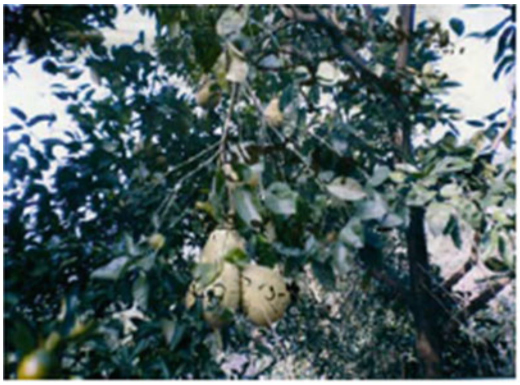
Characteristics of plant diversity in the inundated area of the reservoir

A survey of inundated area at low elevations shows that with the accelerated rate of the application of research achievements, many of the selected species and alien fine varieties have been introduced into the reservoir area since the 1980s, especially over the past dozen years and the local species have been reduced and some of them have become rare or even disappeared. For instance the China Barley Genetic Resources Catalogue compiled more than 20 years ago recorded such low elevation local species as Four-edged hulled barley and Six-edged Hulled barley of Xingshan, Hulless barley of Wanxian, Needleless barley of Wanxian, and Needleless six-edge barley of Jiangjin. But the recent

Table 7.23 List of farm crop species in the reservoir inundated area

Crop	Species (variations)
Grain crops	Rice (*Oryza sativa*), Wheat (*Triticum aestivum*), Barley (*Hordeum vulgare*), Corn (*Zea mays L.*), Sorghum (*Sorghum bicolor*), Millet (*Panicum miliaceum*), Broad Bean (*Vicia faba*), Pea (*Pisum sativum*), Mung bean (*Vigna radiata*), Rice bean (*Lablab purpureus*), Red bean (*Vigna angularis*), Yam (*Pachyrhizus erosus*), Sweat potato (*Ipomoea batatas*), Buckwheat (*Fagopyrum dibotrys*), and Amaranth (*Amaranthus paniculatus*)
Oil-bearing crops	Youbaicai pakchoi (*Brassica rapa var. oleifera*), Rape (*Brassica napus*), Sesame (*Sesamum indicum*), Peanut (*Arachis hypogaea*) and Soybean (*Glycine max*)
Fruit	Tangerine (*Citrus reticulata*), Sweet Orange (*Citrus sinensis*), Pomelo (*Citrus maxima*), Lemon (*Citrus limon*), Hardy Orange (*Poncirus trifoliata*), Chinese sur cerry (*Prunus pseudocerasus*), Japanese plum (*Prunus salicina*), *Prunus glandulosa Thunb*, Yuantao (*Prunus persica 'Yuantao'*), Flat peach (*Prunus persica 'Compressa'*), nectarine, *Prunus persica* (*Linn.*) *Batsch*, Common plum (*Prunus armeniaca*), Loquat (*Eriobotrya japonica*), Chinese pear (*Pyrus pyrifolia*), Ma pear (*Pyrus serrulata*), White pear (*Pyrus bretschneideri*), Hornthaw (*Crataegus pinnatifida*), Strawberry (*Fragaria ananassa*), Date (*Ziziphus jujuba*), Grape (*Vitis vinifera*), Persimmon (*Diospyros kaki*), Walnut (*Juglans regia*), Chestnut (*Castanea mollissima*), Fig (*Ficus carica*), Spine wild pomegranate (*Punica granatum*), Sweet banana (*Musa sapientum*), longan and litchi
Vegetables	Cabbage (*Brassica oleracea var. capitata*), Cauliflower (*Brassica oleracea var. botrytis*), Kohlrabi (*Brassica oleracea var. gongylodes*), Chinese Cabbage (*Brassica rapa var. glabra*), Chinese rapa (*Brassica rapa var. chinensis*), Brassica narinosa bailey (*Brassica rapa var. narinosa*), False pakchoi (*Brassica rapa var. parachinensis*), Xuelihong Leaf-mustard (*Brassica juncea var. multiceps*), Tuber mustard (*Brassica juncea var. tumida*), Chinese kalem (*Brassica juncea var. megarrhiza*), Radish (*Raphanus sativus*), Shepherdspurse herb (*Capsella bursa-pastoris*), Common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata* (*Linn.*) *Walp*), Purple haricot (*Lablab purpureus*), Garden pea (*Pisum sativum*), Sword bean (*Canavalia gladiata*), Wax Gourd (*Benincasa hispida*), Water melon (*Citrullus lanatus*), Pumpkin (*Cucurbita moschata*), Summer squash (*Cucumis pepo*), Cucumber (*Cucumis sativus*), Cucumis melo (*Cucumis melo*), Vegetable Sponge (*Cucumis melo var. conomon*), Bottle gourd (*Lagenaria siceraria*), puberrulous glochidion, Edgeless suakwa vegetable sponge (*Luffa cylindrical*), edged suakwa vegetable sponge, Balsum (*Momordica charantia*), Turtle gourd (*Sechium edule*), Snake gourd (*Trichosanthes anguina*), Hot pepper (*Capsicum annuum*), Cherry Redpepper (*Capsicum annuum var. conoides*), Ornamental Chinese Lantern Pepper (*Capsicum annuum var. grossum*), Eggplant (*Solanum melongena*), Potato (*Solanum tuberosum*), Tomato (*Lycopersicon esculentum*), Coba Aspiragus (*Zizania latifolia*), Moso bamboo shoot (*Phyllostachys edulis*), Water bamboo shoot (*Phyllostachys heteroclada*), Ginger (*Zingiber officinale*), Spinach (*Spinacia oleracea*), Oakleaf goosefoot (*Beta vulgaris*), China Toona (*Toona sinensis*), Axillary Southern Wildjujube (*Malva verticillata var.* crispa), Celery (*Apium graveliens*), Carrot (*Daucus carota*), Coriander (*Coriandrum sativum*), Sweet Fennel (*Foeniculum vulgare*), Lotus Root (*Nelumbo nucifera*), Arrow-head (*Sagittaria trifolia* ssp. *leucopetala*), Waternut spikesedge (*Eleocharis dulcis*), Coco yam (*Colocasia esculenta*), Copperleaf (*Amaranthus tricolor*), Water spinach (*Ipomoea aquatica*), Asparagus lettuce (*Lactuca sativa var. angustata*), Lettuce (*Lactuca sativa*), Glass lettuce (*Lactuca sativa var. crispa*), Hawksbeard velvetplant (*Chrysanthemum coronarium*), Erusalem artichoke (*Helianthus tuberosus*), Citron Daylily (*Hemerocallis citrina*), Common asparagus (*Asparagus officinalis*), Chinese chives (*Allium tuberosum*), Garlic (*Allium sativum*), Leek (*Allium fistulosum*), Red onion (*Allium ascalonicum*), Shallot (*Allium ascalonicum*), Chive (*Allium schoenoprasum*), Onion (*Allium cepa*), Scallion (*Allium chinense*), Common garden coleus (*Perilla frutescens*), Fineleaf shizonepeta (*Nepeta cataria*), Purslane (*Portulaca oleracea*), White Vinespinach (*Basella alba*), Edible fungus (*Lentinula edodes*), Edible black fungus (*Auricularia auricular*)
Other	Pricklyash (*Zanthoxylum bungeanum*), Little-fruit citrus (*Fortunella margarita*), Chintan (*Fortunella margarita 'Chintan'*), Yichang Orange (*Citrus ichangensis*), Fingered citron (*Citrus medica*), Bergamot –calabrian (*Citrus medica var. sarcodactylis*), Agastache (*Agastache rugosa*), Mulberry (*Morus alba*), Konjac (*Amorphophallus rivieri*), Sugar Cane (*Saccharum officinarum*), Tea (*Camellia sinensis*), Tobacco (*Nicotiana tabacum*), Indian Mallow (*Abutilon theophrasti*), Ramie (*Boehmeria nivea*), Edible Canna (*Canna edulis*), and Chinese yam (*Dioscorea opposita*)

surveys have discovered that no barley is planted at all in the area. This is the result of the change in grain demand. On the contrary, historically, the local area grew only Red orange, Jin cheng (*Citrus sinensis 'Jin Cheng'*), and a few varieties of Pomelo (*Citrus maxima*). But now there is a full range of varieties of such citrus fruits, replacing the original species. This is not the result of the changes in agro-ecology but the result of technical extension in fruit growing. With time passing by, the old varieties are sure to be replaced by other new varieties. The plant diversity is also influenced by agricultural policies, such as adjustment of crop culture structure and market competition.



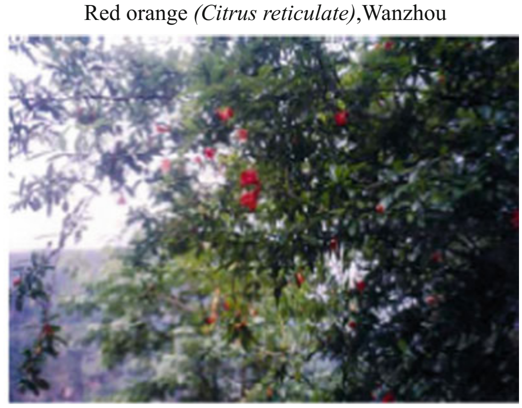
Red Pummelo *(Citrus maxima 'Hongxin You')*, Fengdu

Longan, Shizhu

Musa basjoo,Wanzhou

Red orange *(Citrus reticulate)*,Wanzhou

Loquat,Wanzhou



Wild pomegranate, Wulong

Part of species from the biodiversity survey in the reservoir area


Taro *(Colocasia esculenta 'Honggeng-yu')*, Yunyang


Edible canna,Yunyang


Sweet Banana *(Musa sapientum)*, Zigui


Washington navel No.35, Zigui


Bampeiyu, Zigui

Part of species from the biodiversity survey in the reservoir area

7.7 Estuary Eco-Environment Monitoring Results[7]

7.7.1 Soil Salinization

Dynamic features of water and salt contents of soil in the estuary

The groundwater depth in the estuary area is usually less than 1 m, with little hydraulic gradient and poor conditions for water and salt discharge. In recent years, the groundwater level has assumed a rising trend. In general, the dynamic pattern of the salt content in the soil within a year is: salt leaching efficiency drops in summer and salt content rises and accumulates in winter and autumn. The salt content of cultivated layer of the soil appears to drop, in a natural leaching state.

The general trend of the changes in water and salt contents of the soil is that the mineralization of the river water is in negative correlations with the water level, rising with the drop of water level. The river water of the Yangtze and other rivers both affect the groundwater and salt contents in the sensitive areas of the estuary. The Yangtze River water has main effect on water 500 m from the dyke. Outside this area, the groundwater and salt contents are in close relationship with other inland waterways.

Dynamic impact of TGP on the water and salt contents of the soil in the estuary

As the reservoir regulates the Yangtze flow in different seasons, the Yangtze River flow changes thus affect the water and salt contents of the soil in the estuary. During spring (January–May), the released flow increases, raising the water levels of the Yangtze River and other inland waterways and groundwater, making it unfavorable for the soil to desalt. At the same time, the mineralization of the water drops, making it favorable to desalt. In autumn and winter (October–December), released water decreased, causing the levels of the Yangtze River and other inland waterways and groundwater levels to drop, making it favorable to desalt, but the mineralization of the water rises and salt wave invades, making it unfavorable to desalt. Analysis of data shows that the monthly release flow increases by 1154 m^3/s in January–May at the Datong Station, causing the water level in the section from Santiaogang to the Datong River to rise by about 2–23 cm. The average release flow in October–December decreases by 2313 m^3/s, causing the water level in the section from Santiaogang to the Datong River to drop by an average 3–46 cm.

[7]Institute of Oceanography, CAS. Technical Report of Main Monitoring Station of Estuary Ecology and Environment (1996–2003).

Simulated experiments

Indoor simulated experiments show that when the conductivity is 0.4, 0.8, and 1.6mS/cm and the groundwater level is 0.85, 1.05 m, salt cumulates fast in the soil. When the evaporation conditions are 150d and 260d, the salt entering the cross-section is in a stable state, that is, the salt in the mineralized groundwater is only equal to the accumulation in the surface soil and the salt in the underlying soil maintains a dynamic balance. When the accumulated salt is in a stable state, the conductivity of the groundwater is 0.8mS/cm and the soil conductivity in the cross-section treated is 10mS/cm. Take the mineralization of groundwater as 0.8mS/cm, when the simulation experiments lasted into the end of the three months, the depth of groundwater is 0.85 m and 1.05 m, the average salt content of the soil is 3.5 and 3.9 times the initial salt contents. So, under the current conditions, the salt accumulation is already very fast. When there is little rainfall, the salt accumulation would be much faster. After the TGP is completed, the water level in spring would rise, thus raising the groundwater level in the estuary area. When water level of the Yangtze drops in autumn and winter, the mineralization of the water would rise. The changes in the water and salt contents are likely to cause drastic dynamic changes in the water and salt contents in the estuary area, thus changing the original salinization trend or even leading to strong secondary salinization of the soil. But the ultimate impact on the water and salt contents of the soil in the estuary area will have to be confirmed by further monitoring and testing.

7.7.2 Ecological Environment and Fish Resources

Natural environment

Monitoring results show that Yangtze diluted water is thinning off from the estuary outlet to the east. In general, diluted water may reach the bottom of the sea near Nangang and Beigang at ebb time. The maximum depth of diluted water outside Nancao mouth may reach 38 m. The distribution of water mass in spring and autumn changes significantly from year to year. Such interannual change does not only reflect the changes in the distribution of Yangtze diluted water during transitional seasons, but also the seasonal characters of sea water invasion.

The plain distribution of the loss on ignition at the estuary is basically identical with the plane distribution of suspended mass. The loss on ignition is relatively high near the river mouth, but the suspended content is still low, indicating that the suspended matters near the Yangtze mouth are mainly sediment. Although the loss on ignition in the sea water east of 122°30′E is low, the suspended mass is high, indicating little effect of sediments. But the organic matters and zooplanktons occupy a big proportion.

The annual outlet of nutrient salts to the sea is higher than the estuaries of other rivers. Statistics show that the total inorganic nitrogen is 8.81×10^5t, PO_4-P is 1.36×10^4t and SiO_3-Si is 2.04×10^6t. The distribution of nutrient salts is decreasing progressively from the estuary to the sea, identical with the direction of diluted water tongue. The nutrients are different in density and gradients. SiO_3-Si and nitrate have the biggest gradient and the highest density, with the former averaging 192 μmol/L (November) and the latter, 81.6 μmol/L (May). Phosphorus and nitrate have the lowest gradient and density, with the former at 0.88 μmol/L (August) at the maximum and the latter averaging 0.33 μmol/L. The comparison expression obtained from statistics of the transport flux of different nutrients and the runoff flow Q(m^3/s) is shown in Table 7.24, which shows the transport flux of nitrogen and phosphorus in all forms is in significant or fairly significant positive correlations with the runoff flow. Nutrient transport flux can be obtained from the runoff flow.

Biological environment

Four voyage surveys of chlorophyll and primary productivity show that chlorophyll-a content averaged over 1.900 mg/m^3 in the two voyage surveys in May, obviously higher than that obtained by the other two voyages conducted in November. Chlorophyll-a content is low in all the survey points near the estuary outlet and in the river course. This is associated with the turbidity and low clarity, which affect the growth of Phytoplankton. Chlorophyll-a content in the same quarter at the Yangtze River mouth does not change much from year to year, with that in November 1998 remaining the same as in November 2000 and that in May 1999 remaining the same as in May 2001. See Fig. 7.42. The level of primary productivity fluctuates greatly from year to year, with that in May higher than that in November. The surveys also show that chlorophyll-a content of sea water in May is higher than in November.

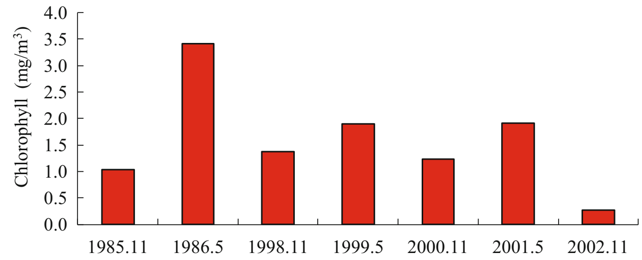


Fig. 7.42 Change in the chloroplhyll-a in the Yangtze estuary

Phytoplankton in 1998 was one order of magnitude higher than in 2000, with quite different concentration zones, with that in the autumn of 2000 just outside the Yangtze River mouth and that in 1988 far from the estuary outlet and closer to the monitoring area. That is the result of the extraordinary floods in the summer of 1998. The huge runoff carried a large amount of nitrogen, phosphorus, and other nutrients and inorganic matters into the sea. See Fig. 7.43.

What was the same during the two surveys was that *skeletonema costatum* was found to be the most important dominant species, with the dominance rate of over 95%. The average amount of Phytoplankton found in the two voyages in spring was close to each other, with the skeletonema costatum dominating but the position of concentration quite different.

Comparison of the Phytoplankton result surveys in recent years shows that the biomass peaked in around May, but the distribution was uneven, in the mottled shape. It reaches its bottom in November, evenly distributed. See Fig. 7.44. The seasonal distribution pattern of biomass in the sea area at the estuary is the same as those in the 1950s and 1980s, with the biggest amount appearing in the northeastern part and the next biggest amount in the southern part and the smallest amount in the waters west of Hengsha and near the banks of the Yangtze estuary. Besides, the 2001 survey discovered

Table 7.24 Comparison expression of nutrient salt output and runoff in the Yangtze estuary

Nutrient salt (kg/s)	Comparison expression Q (m^3/s)	r^2	p
NO_3–N	8.519 + 0.001249 Q	0.976	<0.01
NO_2–N	0.570 + 0.000028 Q	0.883	<0.05
NH_4–N	4.710 + 0.000333 Q	0.850	<0.05
DIN	13.781 + 0.001654 Q	0.962	<0.01
TON	11.857 + 0.001120 Q	0.908	<0.05
TN	25.638 + 0.002774 Q	0.960	<0.01
PO_4–P	0.556 + 0.000031 Q	0.926	<0.01
TP	1.493 + 0.000134 Q	0.944	<0.01

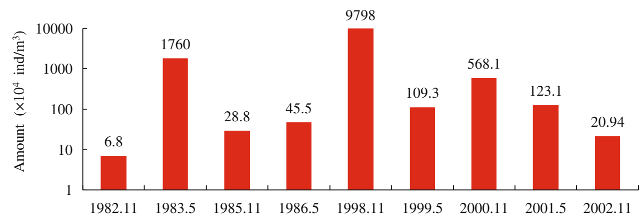


Fig. 7.43 Annual change in the amount of Phytoplankton in the Yangtze estuary

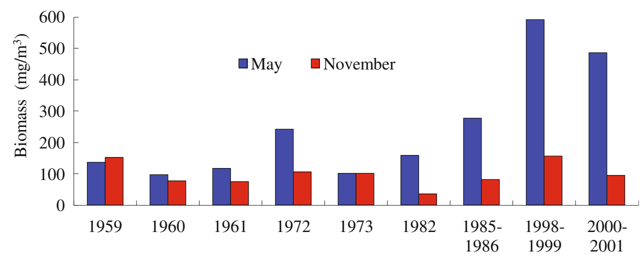


Fig. 7.44 Comparison of average zooplankton biomass

changes in biomass, which was less than the previous few years. That should be the results of changing species, fewer amounts of dominant species and little dominance. The changes in the biomass of Phytoplankton basically reflect the quantitative change of all zooplankton and secondary productivity level in the sea area.

The total average biomass of benthos in spring is more than in autumn (November), because the water temperature at the Yangtze River mouth rises in May, when the flood season comes, there are abundant nutrients and organic bits and ends, making it favorable for benthos to reproduce. The diversity of benthos population assumes the following features: in the open seas near the Yangtze estuary (east of 122° E), the H′ value that indicates diversity index is high, reaching over 2.8. But in November and May, there is a seasonal difference in the distribution of biodiversity in the waters. During the autumn low water season (November) the planar distribution of high H′ value converges to the open seas while during the May flood season, when the water temperature rises, the high H′ value extends to near the Yangtze River mouth, especially along the coasts of Qidong in northern Jiangsu. The Shannon-Wiener index H′, the abundance rate index D and the evenness index J in the waters east of 122°E are all higher than those near the Yangtze estuary. This shows the basic pattern of the distribution of benthos population. It also shows that the distribution of benthos is closely associated with the physiochemical environment of the waters.

Ichthyoplankton

Survey shows there is a variety and large amounts of ichthyoplankton in spring in the Yangtze estuary, but the species and amount of fish eggs and young larval and juvenile fish caught in winter are less than in spring.

In May 1999, there were 22 species and 16 families of ichthyoplankton in the Yangtze estuary. In the vertical and surface water bodies, the ichthyoplankton of the anchovy family occupies an absolute position in both number and the scope of distribution. Analysis by the index of relative importance (IRI) shows that in the ichthyoplankton in the spring of 1999, Japanese anchovy (*Engraulis japonicus*) is the absolute dominant species while Pinkgray goby (*Amblychaeturichthys hexanema*), and Redlip mullet (*Liza haematocheilus*) are the dominant species.

In the May 2001 survey area, there were 32 species, of which 26 species have been verified and the rest six have been verified to family. Tapertail anchovy and Pinkgray goby are the largest in number among ichthyoplankton in the surface and vertical water bodies while Japanese anchovy are the widest distributed and the IRI value of Tapertail anchovy is the highest, in an absolute dominating position.

The November 1998 survey caught five species of young fish. Stone moroko (*Pseudorasbora parva*) was found in the largest number in the surface water. It was followed by Commerson's anchovy (*Stolephorus commersonnii*). But in the vertical water bodies, Tapertail anchovy was the largest in number. In the 1998 winter dominant inchthyoplankton community, Tapertail anchovy was dominant, with the highest IRI value.

The November 2000 survey caught 11 species of eggs and young fish, with ten having been identified as species and one having been identified to genus. Japanese anchovy and Ice fish (*Hemisalanx brachyrostralis*) were available in the largest number in the vertical and surface water bodies. But the widest spread was still Japanese anchovy, which has the highest IRI value. The IRI value of Ice fish and Bombayduck (*Harpadon nehereus*) was bigger than 100, belonging to the absolute dominant species.

Fish resources

Comparison with historical data shows that the Shannon-Wiener index H′, abundance rate D and evenness J of Invertebrates in the estuary area were generally high, indicating a good ecology. But due to excessive catching, the fish resources were assuming a declining trend. Compared with historical data, the importance of carnivorous fish in the community was on the decline while species living on plankton was on the rise, indicating an evolution toward short food-chain in order to maintain community stability.

During the survey period, the number of species, density, biomass density, and single average biomass were all higher in autumn than in spring. But there were not many differences between spring and autumn in biodiversity, but the differences among different stations were big. It was water depth rather than salt content that had the biggest impact on these indices. In the waters east of 123°E and south of 31°30′′N, Shannon-Wiener index and abundance rate were fairly high, reaching over 2.8. The area is beyond the Yangtze diluted water tongue. But the deciding factors (nutrient and plankton) leading to such distribution remained to be further studied.

The total biomass ecological density (BED) in the autumn of 2000 was 19.4% lower than that in 1998. See Table 7.25. That of 2002 was only 44.2% that of 1998. Of this, the BED of fish in 2000 dropped by 28.7%. But the BED of Invertebrates increased by 1.4 times as compared with 1998. The fish BED in 2002 was only 17.5% that of 1998, but the BED of Invertebrates was 5 times more than in 1998. The Islands and reefs in the southern part near the shore were the low distribution areas. But the autumn of 2000 survey reported even distribution in the BED. But in 2002, the distribution developed toward open seas. The total number ecological density (NED) in 2002 was 18.3% less than in 1998, with that in 2002 being 14.4% that of 1998. Of this, fish NED in 2000 dropped by 13.1% and the NED of Invertebrates dropped by 48.0%. The 2002 NED of fish was dropped by 82.5%. The NED of Invertebrates in 1998 was 19.6%. The seaward side in the central part of the survey area was the high distribution area. In terms of the amount of resources, a downward trend was recorded from 1998 to 2000 and further to 2002. The resources were reduced by 19.4% in 2000 and by 55.8% in 2002. Mainly, the fish resources were reduced. But the resources of Invertebrates increased significantly.

The 2001 spring BED was 18.3% less than that of the spring of 1999 (see Table 7.25). BED of fish was dropped by 25.7%. The 2001 BED high value zone was near the shore, tending to move northward as compared with 1999. 2001's NED was 25.2% more than in 1999. Of this, fish NED increased by 34.8% and that of Invertebrates dropped by 26.7%. 2001's NED high value zone was mainly near the

Table 7.25 NED, BED, average size and total amount in the Yangtze estuary and its offshore area

Item		Autumn 1998	Autumn 2000	Autumn 2002	Spring 1999	Spring 2001
NED (1000 ind/km^2)	Invertebrata	90.99	47.32	17.87	24.09	17.65
	Fish	513.68	446.46	69.25	32.51	53.20
	Total	604.67	493.78	87.12	56.60	60.85
BED (kg/km^2)	Invertebrata	286.38	676.81	1416.58	72.60	94.79
	Fish	4825.67	3442.94	843.15	480.39	356.95
	Total	5112.05	4119.75	2259.73	552.99	451.74
Average size (g)		7.15	10.44	25.94	11.97	11.78
Total amount ($\times 10^4$ kg)	Invertebrata	406.8	961.4	1197.69	103.1	134.6
	Fish	6854.9	4890.7	2012.25	682.4	507.0
	Total	7261.7	5852.1	3209.94	785.5	641.6

shore. The individual size in 2001 was smaller than in 1999. The number ecological density of fish resources increased but the biomass ecological density dropped, indicating smaller individual size. The total resources and fish resources in 2001 were less than in 1999 but the resources of Invertebrates increased by 30.6%.

According to the 1998–2002 survey, the dominant species among the fish resources in the estuary in spring were Silver pomfret, Little yellow croaker, *Setipinna taty*, and Bombay-duck. Dominant species in autumn were Bombay-duck, *Setipinna taty*, and Little yellow croaker. There were six dominant species in 1998 with the IRI value topping 1000 while there were only three in 2000. Among the Invertebrates, Blue crab (*Portunus trituberculatus*), Chinese ditch prawn (*palaemon gravieri*), and Squid (*Loligo japonica*) were the dominant species in spring while Mantis shrimp and Two-spot swimming crab (*Charybdis bimaculata*) were the dominant species in autumn.

7.8 People's Health Monitoring Results[8]

7.8.1 Population Life Statistics and Health Resources

The 1996–2003 population monitoring shows some changes every year. See Table 7.26. But the annual population at each monitoring station was 127,964, identical with the general requirements for establishing disease monitoring points and conforming to the general statistical requirements for population, suitable for use in the health statistics computation associated with population, environment and health. The proportion of resettled people in the population monitored increased year by year since 2000, rising from 13.55% to 17.41%. The ratio of rural to urban population monitored was 93:100, without a big bias.

The birthrate and death rate at the monitoring points assumed a slow downward trend. See Table 7.27. Infant mortality rate assumed a slight upward trend, but lower than the national average. The average life expectancy was 68–71 for males and 73–75 for females, close to the national level. The figure obtained by some monitoring stations (such as Changshou District of Chongqing) was higher than national level.

The 1997–2003 survey of causes of death showed that the main causes of death were cancer of the circulating system, respiratory injuries, poisoning and digestive system diseases, highly identical with the national data.

[8]Chinese Center for Disease Control and Prevention (CDC). Technical Report of Main Monitoring Station of Public Health (1996–2003).

The number of medical organizations in the monitoring points increased year by year, averaging an annual increase of 287, with that in 2003 reaching 314. The number of medical workers averaged 4078, with that in 2003 reaching 4307. The annual average number of hospital beds was 3098, averaging 6.11 per thousand patients.

7.8.2 Communicable and Endemic Diseases and People's Serology

An eight successive years of monitoring showed that the incidence of communicable diseases was the same as the national average. The reported incidence of 25 kinds of Type A and Type B infectious diseases were 388.22–574.07 per 100,000 people. See Table 7.28. The first five infectious diseases were virus hepatitis, dysentery, gonorrhea, TB, and measles, which remained stable. But after 2001, syphilis edged into the first five. All monitoring points reported rare Type A infectious diseases, indicating that the monitoring points are not the source of plague or cholera. The incidence of epidemic hemorrhagic fever, leptospirosis, epidemic encephalitis B, and malaria, which are natural epidemic focused diseases, was dropping in a sustained manner. There was not much change with the incidence of infectious diseases during the 8 years of dam construction, people resettlement, and construction of new settlement areas, indicating that the TGP project and resettlement do not have any impact on the incidence of natural epidemic foci that are closely related with environmental changes. But it merits attention. During the 8 years, there were no outbreak of Type A or Type B infectious diseases. But in 2001, Type C infectious diseases such as flu and epidemic parotitis broke out in local areas, indicating the necessity of strengthening monitoring and controlling measures.

The endemic diseases monitored were endemic goiter, endemic fluorine poisoning, and paragonimiasis. Monitoring results show that the areas of all the four monitoring stations were goiter epidemic zones, but with a low intensity of prevalence. 20% of the 8–12 children suffered from goiter. But the disease was more serious in Fengdu and Chongqing, where the average iodized salt coverage was 86.80%, the qualification rate of iodized salt was 86.80% and the coverage of qualified iodized salt was an average level of 70.02%. Of the four monitoring stations, only Fengjie of Chongqing found endemic fluorine poisoning, with a positive rate reaching 33.50%, indicating that Fengjie County was an endemic fluorine poisoning area. Paragonimiasis was seen only in the Yichang station in 2000, with a positive rate of 2.03%.

The serology monitoring was mainly targeted at anti-body level against endemic hemorrhage fever, leptospirosis and epidemic encephalitis B, and the infections of

Table 7.26 Population size monitored in 1996–2003

Monitoring point	1996	1997	1998	1999	2000	2001	2002	2003	Average
Chongqing	142,855	145,580	180,402	158,416	155,156	138,443	117,851	141,971	147,584
Wanzhou	104,840	106,438	109,888	115,068	121,027	127,821	132,127	134,685	118,987
Fengdu	130,038	118,451	108,861	109,905	111,677	114,359	114,978	114,453	115,340
Yichang	104,071	138,531	135,942	130,678	133,364	129,332	104,803	99,523	122,031
Total	481,804	509,000	535,093	514,067	521,224	509,955	469,759	490,632	503,942

Table 7.27 Births and deaths in 1996–2003

Year	Number of births	Birthrate (‰)	Number of deaths	Death rate (‰)
1996	4692	9.70	2966	6.16
1997	4239	8.33	2524	4.96
1998	4330	8.09	2759	5.16
1999	4093	7.96	2821	5.49
2000	4102	7.87	2610	5.01
2001	3832	7.51	2914	5.71
2002	3345	7.12	2754	5.86
2003	3766	7.68	2918	5.95
Total	25,288	8.04	22,266	5.52

the diseases among people with indirect reactions. The 1997–2003 monitoring results showed that the positive rate against epidemic hemorrhagic fever averaged 2.50%, that against leptospirosis averaged 26.03% and that against epidemic encephalitis B was 29.00%. There was no much change from year to year.

7.8.3 Monitoring of Rodents, Mosquitoes, and Pathogen Carried by Rodents

Disease vector monitoring results showed that the Rodent density indoors was higher than outdoors, similar in all years. See Table 7.29. The Rodent density dropped significantly in 1998 and 1999, due to floods. But it rose again in 2001. Indoors were mainly Brown rat (*Rattus norvegicus*), followed by House mouse (*Mus musculus*). This indicates that the emphasis of monitoring epidemic hemorrhagic fever was that carried by rats at home. Outdoors were mainly Common shrew, with Brown rat and Striped field mouse (*Apodemus agrarius*) ranking second and third, indicating that hemorrhagic fever among wild rats is not the main threat to humans. What merits attention is that Striped field mouse (*Apodemus agrarius*), the main vector of epidemic hemorrhagic fever and leptospirosis, was becoming less year by year. Close attention should also be paid to the impact of reservoir impoundment on the rat density and variety so as to come out with countermeasures and strategies against diseases.

The mosquito monitoring results showed that the mosquito density was in a relative stable state. The mosquito density in animal sheds was 183.44 ind/(room·h), higher than human houses, which was about 60.04 ind/(room·h). In houses were mainly *amigeres subalbatus* and *culex pipiens fatigans*. The latter may spread epidemic encephalitis B and filariasis. It merits close attention. In the animal sheds were mainly *Amireres subalbatus* and *Anopheles sinensis*, which can spread malaria. They also merit attention with regard to their density. See Table 7.30.

Pathogen testing results show that the positive rate of mouse pneumonias epidemic hemorrhagic fever was 1.60% and the positive rate of the mouse kidney leptospirosis was 0.98%, at a very low level, hence the low level of incidence of such diseases among humans. See Table 7.31. The dam and reservoir will have some impacts on the activities of Rodents. It is, therefore, necessary to test the pathogens carried by rats and once signs of epidemic are discovered, countermeasures should be produced immediately in order to ensure the health and safety of the people.

Table 7.28 Incidence of legally reported communicable diseases in 1996–2003 (per 100,000)

Disease	1996	1997	1998	1999	2000	2001	2002	2003
Cholera	0	0	0	0	0.19	0	0.68	0
Viral hepatitis	123.91	147.15	123.71	156.12	106.67	106.48	101.56	100.28
Dysentery	208.80	168.57	166.70	100.46	78.08	92.20	99.51	60.33
Typhoid fever	4.77	1.57	0.19	0.57	0.19	0.78	1.19	1.63
Gonorrhea	118.93	150.88	156.23	103.13	86.34	83.93	48.22	37.5
AIDS	0	0	0	0	0	0	0.43	0.2
HIV	0	0	0	0	0	0	0.21	0
Syphilis	1.04	0.39	0	1.53	4.99	10.00	4.59	3.87
Measles	0	25.15	0.56	7.43	5.56	7.65	15.17	14.88
Whooping cough	0	0.20	0	0	0	0.20	0	0.2
Epidemic cerebrospinal meningitis	1.04	0.39	0	1.33	0.19	0.40	0.34	0.2
Scarlet fever	0.83	0.39	2.24	1.33	1.15	0.80	2.04	1.63
Epidemic hemorrhagic fever	1.87	1.18	0	0.57	0.19	1.40	0.51	0.61
Leptospirosis	1.25	1.18	1.50	0.95	2.88	1.00	0.68	0
Epidemic encephalitis B	2.08	1.18	1.12	1.14	1.54	1.80	1.36	0.61
Malaria	2.28	1.38	0.37	0.38	0.38	0.20	0.34	0
Tetanus of Newborn	0	0	0	0	0	0.20	0	0
TB	88.00	75.64	78.86	90.74	99.96	143.93	128.48	145.73
Flu	0	3.93	91.39	0	1.92	20.59	1.49	9.17
Epidemic parotitis	6.02	40.86	8.22	8.20	18.80	90.52	21.93	1.23
Rubella	1.04	3.34	0.56	0.19	3.07	24.71	39.38	20.99
Hemorrhagic	0	2.16	8.78	0	0.38	1.60	22.14	38.11
Infectious diarrhea	0	26.13	11.77	9.34	16.88	89.40	136.24	141.04
Total	561.85	650.49	650.73	495.20	429.37	676.79	581.75	589.04

Table 7.29 Indoor and outdoor small animal density in April and September in 1998–2003 (%)

Time		Indoor		Outdoor	
		Number of effective clamps	Density	Number of effective clamps	Density
1998	April	1821	4.23	1862	4.62
	Sept.	1893	5.92	1346	5.5
1999	April	1346	6.91	1496	4.81
	Sept.	1997	4.61	2532	1.42
2000	April	680	4.85	2303	5.12
	Sept.	1046	4.88	2317	5.01
2001	April	773	3.75	2449	4.57
	Sept.	2270	2.47	3651	4.41
2002	April	2078	2.07	4241	3.42
	Sept.	1843	2.17	3480	4.25
2003	April	2100	1.33	3355	3.4
	Sept.	1949	1.08	2726	3.74
Total	April	8798	3.44	15,737	5.71
	Sept.	10,978	3.89	16,052	4.01

Table 7.30 Composition of Mosquitoes under different habitats in 1997–2003(%)

Habitat	Year	Number of rooms	*Culex pipiens pallens*	*Culex pipiens quinqusfasciatus*	*Culex tritaeniorhynhus Giles*	*Anopheles sinensis*	*Armigeres subalbatus*	Other
Residential houses	1997	300	16.85	6.10	0.24	5.84	70.59	0.39
	1998	320	16.98	4.45	0.37	2.39	74.50	0.77
	1999	320	13.26	4.52	0.28	2.22	78.80	0.92
	2000	360	14.25	5.45	0.87	3.8	74.69	0.93
	2001	520	1.84	37.09	13.14	4.23	43.49	0.21
	2002	520	5.3	30.54	7.96	6.48	49.06	0.34
	2003	94	3.60	28.06	3.35	13.51	49.68	1.88
Total		2434	10.45	16.93	4.63	4.31	62.95	0.59
Livestock barns	1997	300	7.43	1.73	0.78	10.88	79.10	0.08
	1998	320	7.47	1.52	0.75	5.44	84.22	0.61
	1999	320	6.65	1.56	0.33	4.94	86.07	0.45
	2000	360	4.31	4.46	2.66	7.95	79.93	0.68
	2001	520	2.84	12.21	4.42	7.66	72.07	0.81
	2002	520	6.15	18.10	8.33	15.62	50.82	0.99
	2003	94	4.90	11.95	2.15	33.01	47.66	0.32
Total		2434	5.54	7.00	3.00	9.13	74.72	0.62

7.9 Socioeconomic Environment Monitoring Results[9]

7.9.1 Socioeconomic Environment of Hubei

Economic development level

Thanks to the building of the dam, the social and economic development in the reservoir area in Hubei Province has been surging ahead at a rapid clip and the living standards of the people have improved. Industrial structure has been further optimized. The partnership program has been very fruitful, with a number of top-flight enterprises and famous brands settling down in the reservoir area, boosting and forming a number of pillar industries. But the internal development is extremely uneven. Yiling is one of the most developed areas among all counties (cities and districts) in the province while Zigui and Badong counties are poor, receiving state relief. The general development of the reservoir area lags behind the average level of the whole province.

In 1996–2003, with the construction of TGP and the launching of the drive for poverty relief and the drive of western China development, the economy in the four counties of the reservoir area in Hubei has maintained a good momentum of growth. In 2003, the GDP of the four counties reached 14.795 billion yuan. See Table 7.32.

Social and cultural development

The reservoir area of Hubei Province has since 1996 strictly controlled the population growth and achieved great successes in improving the quality of the population. The population natural growth rate has dropped below the natural replacement level. But illiteracy rate is relatively high, making it unfavorable for social and economic development.

The four counties have since 1996 implemented the strategy of invigorating the economy by relying on science and education, which helped improve the education of children and young people and improve the living standards in both urban and rural areas. The people have realized the leap from poverty to enough food and clothing. The urban and rural income has increased steadily.

Infrastructure construction

Due to historical reasons, the infrastructure in Hubei reservoir area was poor, becoming a serious bottleneck to economic and social development. Since work started on the

[9] Office of Hubei Provincial Committee for Supporting TGP. Technical Report of Main Socio-environment Monitoring Station of Hubei Reservoir Area (1996–2002); Chongqing Statistics Bureau. Technical Report of Main Socio-environment Monitoring Station of Chongqing Reservoir Area (1996–2002).

Table 7.31 Rat-carried pathogen testing in 1997-2003

Year	Mouse pneumonitis Epidemic hemorrhagic fever testing			Mouse kidney pathogenic Leptospira testing		
	Number of samples	Number of (+)	(+)%	Number of samples	Number of (+)	(+)%
1997	–	–	–	310	1	0.33
1998	963	14	1.45	1039	13	1.25
1999	312	2	0.64	498	2	0.40
2000	271	6	2.21	272	6	2.21
2001	307	8	2.61	279	6	2.15
2002	191	3	1.57	309	0	0
2003	14	0	0	242	1	0.41
Total	2058	33	1.60	2949	29	0.98

Table 7.32 GDP of Hubei reservoir area (*unit* 10^4 yuan)

Year	1996	1997	1998	1999	2000	2001	2002	2003
GDP	611,929	646,675	749,690	697,404	760,211	1,294,664	1,398,015	1,479,498

dam, the state has launched a number of infrastructure projects and given great support to Yiling, Zigui, Xingshan, and Badong counties in their infrastructure construction. All these have helped improve the investment environment and stimulated the harmonious development of social, economic, and ecological environments.

Resettlement

TGP preparations started in 1993. In 2 years, 25,700 mu of land were delivered for construction purposes and 4490 households, totaling 13,445 people were resettled. This, plus the people displaced by access roads and material yards, brought the total people to be resettled to 16,671. Starting from 1995, reservoir people of the first phase construction were started to move to ensure the construction river closure on November 8, 1997.

The second stage of resettlement started in 1997. By the end of September 2002, the investment in resettlement reached 5.941 billion yuan, resettling 137,400 people, accounting for 89.5% of the total due to move out. A total of 5.7 million m^2 of new houses were built, 88.8% of the total areas planned. Resettlement, rebuilding of cities and towns, and reconstruction of special projects all went as scheduled.

Living standards of resettled people

In the four counties in the Hubei reservoir area, three county seats had to be relocated. In 2001, the rehabilitation of Zigui county seat was completed. The rebuilding of Badong and Xingshan county seats was completed before October 1, 2002. All the 10 inundation affected county townships at the 135 m level had been resettled. They are Taipingxi, Quyuan, Guojiaba, Shanzhenxi, Xietan, Cherangkou, Yanduhe, Guanduhe, Guizhou, and Xiakou.

For the resettled people, everything has been done to ensure that they get the same amount of contracted land and household plots and plots for building houses as before. The government also helped them develop market-oriented production. For people who are resettled up from the reservoir, the land is allocated according to the number of people and sign resettlement and production contracts and issue new “Land operation certificates.” For people listed as in dire poverty by the civil affairs department of the local governments, funds are appropriated from the land occupation tax for building new houses. For places where there is not space for resettlement or the land available is limited, they are encouraged to move out of the reservoir area and be resettled somewhere in the country.

According to a sample survey, the quality of living of most people resettled has improved. The 5020 people who moved from Chongqing to Hubei have all moved to new houses and each person has got 1.5 mu of cultivated land and the children of the resettled families go to nearby schools. A sample survey of 20 resettled people in Xingshan and Zigui showed that the 2002 per capita net income was 2123 yuan, 58 yuan more than the per capita net income in the four counties in the reservoir area. The per capita living space is 38 m^2, 7 m^2 more than the rural areas in the reservoir area. The per capita cultivated land is 1.15, 0.04 mu more than in the rural area of the reservoir area.

7.9.2 Social Environment in Chongqing

Major social and economic indicators

The population growth in the Chongqing reservoir area has been brought under effective control, rising from 17.5843 million in 1996 to 18.1427 million by 2002, averaging an annual growth of 0.5%. GDP rose from 72.113 billion yuan in 1996 to 128.323 billion yuan by 2002 (see Fig. 7.45), averaging an annual growth of 10.7%. The proportion of the primary industry has become smaller, down from 21.7% in 1996 to 13.2% by 2002. The tertiary industry has increased fast, rising from 33.9% to 40.4%. The secondary industry has also increased slightly, but not much, by only 0.7%. The industrial structure in the whole reservoir area is developing in a good direction.

Developing the fastest is postal service, growing by an annual 46.1%. Indicators that increased over 20% a year include local budgetary fiscal expenditure (26.5%), urban and rural bank savings (21.6%), per capita bank savings (21.0%), added value of township and village enterprises (21.0%), and fixed asset investment (20.7%). Of major farm products, grain and cured tobacco have been decreasing at an average annual rate of 1.1% and 5.5%, respectively. Edible oil, meats, and aquatic products have all increased, especially aquatic products, which has been increasing at an annual rate of 7.7%.

Integrated assessment of the social and economic development of the Chongqing reservoir area

In 2002, the integrated index of social and economic development of the Chongqing reservoir area was 197.0%, 97.0% more than that in 1996. Of this, population and employment levels rose by 27.9%; economic development level rose by 88.2%; social development level rose by 54.0%; environment and communications level rose by 206.7%. 1996–2002 was a period in which the social and economic development in the reservoir areas was the fastest in history. See Table 7.33. During this period, GDP grew 80.1%; fixed assets investment grew by 2.5 times; local budgetary fiscal receipts rose by 1.08 times; local budgetary expenditure increased by 3.02 times; consumer goods retails increased by 76.2%; urban per capita disposable income increased by 56.1%; rural per capita net income rose by 37.1%; the urban and rural bank savings grew by 2.35 times. The development is uneven, with that in economy, communications facilities and environmental protection developing fast, while the population, employment, and social undertakings developing slower.

Social and economic conditions of resettled people

The integrated contrast index of the rural resettled families is 98.74%, 1.26 percentage points lower than the rural average level of the city. See Table 7.34. But the family economy of resettled people has come strong, more promising than other farm households and it will get above the city average level in terms of development momentum.

The integrated index for the living standards of the resettled people is 122.63%, 22.63% higher than the rural

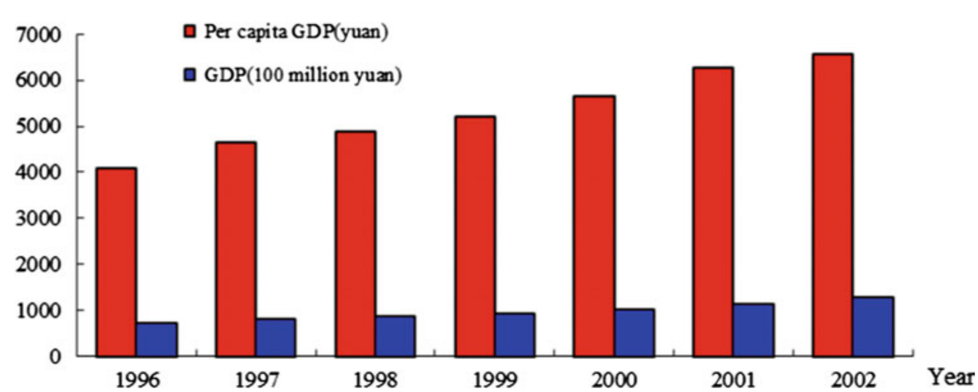


Fig. 7.45 Chongqing reservoir area GDP and per capita GDP in 1996–2002

Table 7.33 Social and economic growth in the reservoir area

Year	1997	1998	1999	2000	2001	2002	Average net growth
GDP	113.8	110.5	109.1	108.5	109.7	110.5	10.3
Fixed assets investment	117.4	121.3	133.3	115.2	121.5	128.0	23.3
Local budgetary fiscal receipt	126.2	111.9	108.8	113.0	110.2	108.8	13.0
Local budgetary fiscal expenditure	124.0	120.4	112.0	115.9	135.9	147.5	26.1
Consumer retail sales	113.4	107.2	107.5	109.3	109.4	112.8	9.9
Freight transport volume	93.1	99.4	105.5	104.1	115.7	120.2	6.5
Passenger transport volume	120.8	110.4	103.9	104.7	111.3	111.5	10.3
Postal service volume	145.4	147.3	141.4	140.7	128.3	115.2	35.9
Urban per capita disposable income	106.2	106.1	104.7	107.0	110.9	111.5	7.7
Rural per capita net income	115.1	107.4	100.6	101.2	102.6	106.2	5.4
Urban and rural bank savings balance	126.0	122.6	127.0	121.2	115.8	117.3	22.3

Table 7.34 Comprehensive assessment of economic development level of resettled rural people

Serial No.	Item	Unit	Weight	Actual Level		% of resettled people in city average	Index score	Difference
				City average	Resettled people			
A	B	C	1	2	3	4 = (3/2)	5 = (4 × 1)	6 = (5 − 1)
1	% of labor in total population	%	5	69.80	71.30	102.15	5.10	0.10
2	Educational level of labor	Year	10	6.73	7.01	104.16	10.42	0.42
3	Per capita productive fixed assets	Yuan	8	615.61	788.98	128.16	10.25	2.25
4	Per capita building structures for production purposes	m^2	5	7.40	5.15	69.59	3.48	−1.52
5	Ratio of income from industry and services	%	8	40.90	50.10	122.49	9.80	1.80
6	Commodity rate of agriculture	%	10	40.00	30.90	77.25	7.73	−2.27
7	Efficiency of family operations	%	12	69.10	71.10	102.89	12.35	0.35
8	Per capita total income	Yuan	10	2709.49	2488.90	91.86	9.19	−0.81
9	Per capita net income	Yuan	20	1971.18	1895.35	96.15	19.23	−0.77
10	Per capita cash income	Yuan	12	1752.07	1633.43	93.22	11.19	−0.81
11	Integrated index of economic development level	%	100	–	–	–	98.74	−1.26

Table 7.35 Integrated assessment of the living standards of the rural resettled people

No.	Item	Unit	Weight	Real level		% of resettle people in city average	Index point	Difference
				City average	Resettled people			
A	B	C	1	2	3	4 = (3/2)	5 = (4 × 1)	6 = (5 − 1)
1	Per capita family income	Yuan	12	2709.49	2488.90	91.86	11.02	−0.98
2	Percapita family net income	Yuan	18	1971.18	1895.35	96.15	17.31	−0.69
3	Per capita living space	m^2	10	31.00	40.73	131.39	13.14	3.14
4	Per capita electricity used	kW h	10	38.62	57.97	150.10	15.01	5.01
5	% of households using LPG	%	8	1.50	3.00	200.00	16.00	8.00
6	% of households accessing to safe drinking water	%	8	42.44	55.00	129.59	10.37	2.37
7	Per capita consumption spending	Yuan	10	1475.16	1660.47	112.56	11.26	1.26
8	Per capita spending on medical and health care	Yuan	8	86.05	63.59	83.18	6.65	−1.35
9	Per capita spending on culture, education and recreation and services	Yuan	8	157.10	172.52	109.82	8.79	0.79
10	% of per capita net income in total income	%	8	72.75	76.15	104.67	8.37	0.37
11	Integrated comparison index of living standards of the resettled people	%	100	–	–	–	117.92	17.92

average level. See Table 7.35. The higher living standards are merely due to moving into new houses, with a temporary and superficial feature.

7.10 Remote Sensing Dynamic Monitoring Results[10]

The satellite remote sensing was carried out in 1992 and 2002 in order to get the baseline data. The 1:50,000 reservoir land coverage/utilization map reflects the land resources and their changes 10 years before and after the TGP. See Fig. 7.46.

7.10.1 Time and Space Characters of Land Coverage

The Three Gorges reservoir covers 20 districts (counties and cities), 16 of them in the Chongqing reservoir area and 4 in the Hubei reservoir area. Calculated by 1:50,000 topographic map borders, the total area are 58,544.65 km^2. Due to natural conditions and human activities, the land cover assumes the general pattern that features (1) high-yielding cultivated land and industrial belt in the hilly urban/rural border area west of Yunyang in eastern Sichuan; (2) Shrubs and cultivated land in the medium- and high-mountainous areas from Yunyang to Zigui New Seat; (3) cultivated land, orchards, and hydropower projects in the piedmont broad valley east of Zigui New Town.

In 1992, the cultivated land was 43.33% of the total land area. This included dry land, which accounted for 30.63% and rice paddies, which accounted for 12.70%, wooded land, 49.90% (coniferous forest, 1.38%, broadleaved forest, 1.38%, shrubs, 19.47%, and mixed forest, 0.88%), grassland, 2.28%; water body, 2.03%, land used for construction purposes, 1.56%; and land for other purposes, 0.90%. In 2002, the cultivated land was 42.9% of the total land area, including dry land (30.21%), paddies (12.69%), wooded land (49.39%), including coniferous forest (27.60%), broadleaved forest (1.44%), shrubs (19.51%) and mixed forest (0.84%), grassland, 2.89%, water body, 2.02%, land for construction purposes, 1.89%, and land for other uses (0.81% (Fig. 7.46).

The Three Gorges is a mountainous area. Due to population pressure and excessive land reclamation, the land is mainly cultivated, with dry land dominating. The ratio of dry land to paddies is 2.38:1. Most cultivated land is on gentle mountain slopes and mountain ridges and raised land. The fragmentation of land blocks is the main reason for water loss and soil erosion. Dry land east of Wanzhou is more than in the western part while paddies east of Wanzhou are more than in the western part. See Fig. 7.47a, b.

[10]Institute of Remote Sensing Applications, CAS. Technical Report of Main Monitoring Station of Eco-environment Remote Sensing.

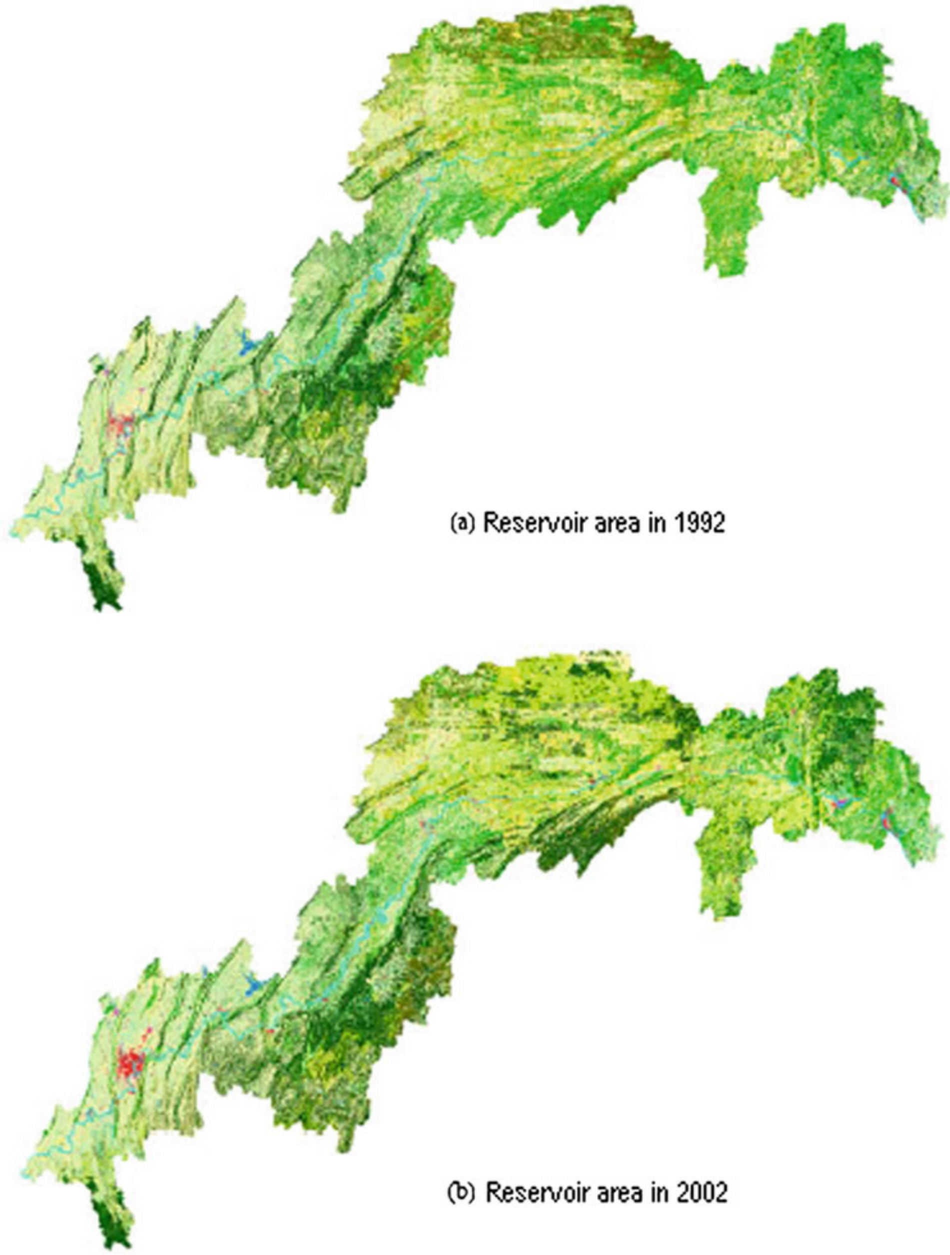


Fig. 7.46 Coverage Changes of reservoir area over past 10 years

Wooded land, just like cultivated land, is the main land cover. They cover 92% of the total land area. High forest is mainly distributed in counties east of Fuling, such as Fengdu, Shizhu, Wanzhou, Fengjie, Badong, Xingshan, and Yichang. Shrubs are mainly distributed in between Yunyang and Badong. See Fig. 7.47c, d. There are two types of land for construction purposes. One is for building roads and the other is for building structures. Land used for building roads are mainly distributed in Chongqing, Wanzhou, and Yichang and their surroundings. Land for building structures are also distributed in these areas. See Fig. 7.47e, f.

In the 10 years before and after the TGP, tremendous changes took place in the land cover. There have been great changes in the dry land, grassland, high forests, and shrubs in areas east of Kaixian. The cultivated land in the poor mountainous counties, such as Wuxi, Dadong, and Shizhu, is still at the reclamation stage and cultivated land is still increasing. But the cultivated land in other counties has been yielded to shrubs, grassland and high forests. There is a big change in high forests in Yunyang, Wuxi, Badong, Zigui, mainly coming from dry land and high forests, with that in Yunyang and Zigui increasing and that in Wuxi and Badong

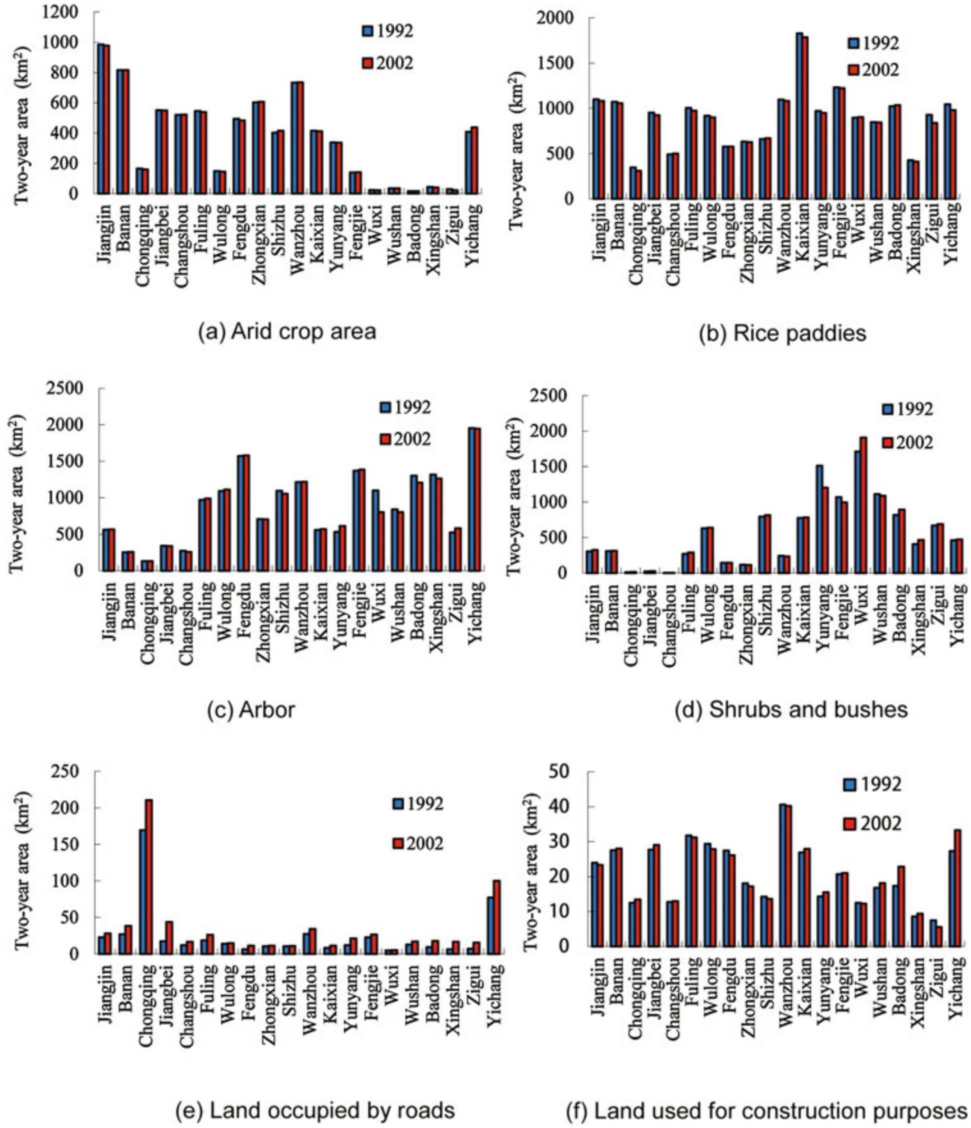


Fig. 7.47 Distribution of land cover in the reservoir area. **a** Arid crop area. **b** Rice paddies. **c** Arbor. **d** Shrubs and bushes. **e** Land occupied by roads. **f** Land used for construction purposes

reduced, replaced by grassland and high forests. Big changes in grassland took place in Yunyang, Fengjie, Wushan, and Wuxi, with that in Yunyang, Fengjie, and Wushan increasing, mainly coming from shrubs, and that of Wuxi reduced, mainly becoming shrubs. The changes in land for construction purposes and paddies are evenly distributed, with big changes taking place in the rice paddies in Fengdu, Shizhu, Zigui, and Yichang. Of the land used for nonlinear construction purposes, big changes took place in Chongqing, with that in counties along the Yangtze increasing. Land for linear construction purposes changed greatly in Yichang and Badong as well as on the outskirts districts and counties of Chongqing.

7.10.2 Land Cover Dynamic Changes in the Reservoir Area

Land utilization is the way and conditions of use of the land by humans and its spatial change is, therefore, mostly clear in borders and its time change entirely depends on the rate of change in the way of utilization. The GIS and remote sensing-based statistical analysis of the land utilization over the past 10 years shows that 5536.15 km^2 of land have changed in the type of land utilization and land cover according to the four-level classification, accounting for 9.48% of the total land cover in the reservoir area, with each having increases and decreases. See Table 7.36. Increasing

Table 7.36 Land Utilization and Land Cover in 10 Years (km^2)

Item	Herbal plant area	Aquatic plant area	Grassland	City green area	Non-construction use land	Nonlinear land use for construction purposes	Linear land use for construction purposes
Areas added	1008.92	285.84	810.10	10.33	0.02	213.39	50.37
Areas reduced	1384.58	290.37	445.46	1.40	0.00	33.71	37.65
Change	−375.66	−4.52	364.64	8.93	0.01	179.68	12.72
Item	Lakes	Shrubs	Arbor forest	Arbor plantation	Reservoir	Hard surface	Rivers
Areas added	1.78	1847.03	1175.10	38.52	28.82	4.17	60.69
Areas reduced	1.67	1689.79	1513.56	36.55	11.88	3.86	85.67
Change	0.11	157.24	−338.47	1.96	16.93	0.31	−24.98

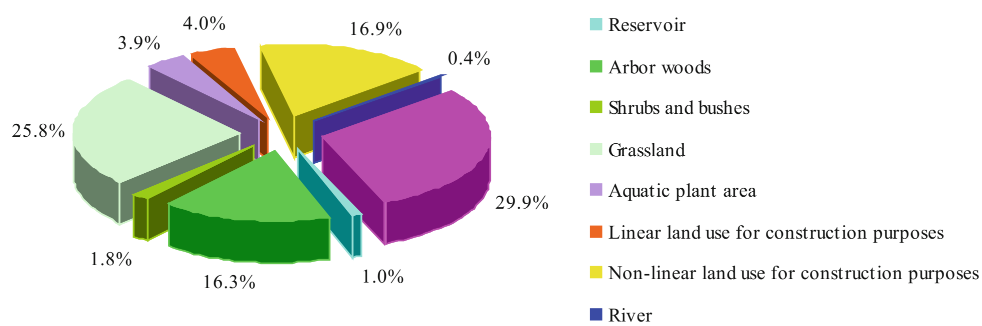


Fig. 7.48 Absolute value and ratio of land use by type in 1992–2002

is the transformation of other types of land utilization/land cover to a certain type of land utilization/land cover; decreasing is the transformation of a certain type of land utilization/land cover to other types of land utilization/land cover. The amount of changes is the absolute change of the land use in the reservoir area over the past 10 years.

Table 7.36 shows that the 10-year absolute increase in area is grassland, land use for construction purposes (non-linear construction and linear construction), city greens, and reservoir. The grassland increased 364.64 km^2; land for construction purposes increased 192.4 km^2; city greens increased 8.93 km^2; and reservoir increased 16.93 km^2. The 10-year absolute decrease in areas is dry land, paddies and high forests, with dry land decreasing by 375.66 km^2; paddies, by 4.52 km^2; and high forests, by 338.47 km$^{2.}$ The general trend is the steady reduction of arable land and wooded land and the gradual increase in grassland and land for construction purposes. See Fig. 7.48.

7.10.3 10-Year Land Use and Land Cover (LULC) Change and Causes

LULC change and TGP

The changes in LULC affected by TGP are the land occupied by the projects, residential quarters, and roads. From the start to 2002, the construction area in Maoping Town was 7.6 km^2, residential quarters, 9.7 km^2; and roads, 85 km. Two-thirds of the work volume of the dam have been completed. The Xiling Bridge downstream from the dam and access roads has been completed.

LULC has already had some impacts on the TGP. A survey shows that the annual soil erosion upstream of the Yangtze and the reservoir area has reached 1.56 billion tons. The amount of silts entering into the Yangtze averages 40 million tons a year. Sedimentation problem of existing water conservancy projects is common and serious. It is calculated that sedimentation of the TGP reservoir would reach a balance in about 80 years. But in the first 10 years, most of the sediments would be deposited in the reservoir.

At present, soil erosion changes due to the change of LULC, especially in Yunyang and Zigui, where the gradients are big and LULC plays a deciding role. During the past 10 years, the areas of slope land have been reduced, but not in wide areas, contributing little to lessening soil erosion. The cultivated land cover still occupies 25–40%, mainly slope land. In summer, when rainfalls are concentrated, the land would lose a lot of sand and mud. The high forests in the area have partly become shrubs and grassland, with limited impact on the land cover or the surface erosion. But the vegetation biomass has been reduced and decreased rainfall interception effect but, resulted in gullies. In general, the high level of water loss and soil erosion has basically remained unchanged.

Correlation between LULC and resettlement

The resettlement of a million people holds the key to the success of the TGP. The economy is underdeveloped and the natural ecological environment is fragile in the reservoir area. The displaced people are mainly scattered in areas along the Yangtze, cities and towns spreading along the mainstream of the Yangtze and farmland mainly along the tributaries. In the 10 years from 1992 to 2002, the newly built cities and the old ones co-existed simultaneously, including county seats of Xingshan, Zigui, Badong, Wushan, Fengjie, Yunyang, and Fengdu. The areas occupied by residents have increased rapidly, scarifying: 1200 km^2 of shrubwood and high forests in 10 years, and accounting for 5% of the cultivated land, certainly. Not all that for people resettlement purposes.

Besides, the building of houses for resettled people cost 1/4–1/3 of all the standing timber. It is one of the reasons for the dwindling of forests. The reduction of wooded land will threaten more forests and grass on mountain slopes and increase the probability of mud flow, landslide, drought, and floods.

LULC and regional economic development

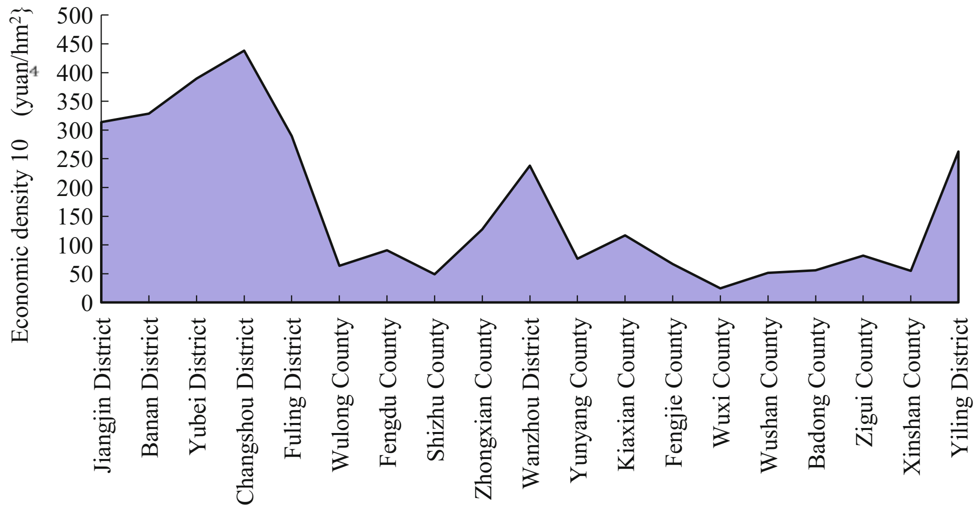
Administratively, the reservoir area has two regions: Chongqing reservoir area and Hubei reservoir area. The Hubei reservoir area is administered jointly by Yichang City and Enshi Prefecture. As the administrative jurisdictions are different, policies are different, too. In the Chongqing reservoir area, there has formed an economic development belt centered round Chongqing, Fuling, and Wanzhou. Since Chongqing was made a municipality under the direct administration of the central government on March 14, 1997, the city has accelerated the pace of urban construction. In 1998, Chongqing was positioned as one of the centrally administered municipalities and an important central city in southwest China and in the upper reaches of the Yangtze, a nationally important industrial base, a communications hub and a trading port. In order to further display the geographical advantage, the “flagship” and “window” role, and the diffusion effect in stimulating the economic and social development of southwest China and the upper reaches of the Yangtze, Chongqing is designed to develop mainly energy, communications, raw materials and tourism resources and deploy development projects along the communication lines. In addition, it has concentrated its efforts on the building of such central cities as Wanzhou, Fuling, and Qianjiang in the hope of making them the growth poles. Yichang City in Hubei Province will mainly develop hydropower and tourism resources and accelerate the pace of the development of new service industries. The city will make tourism as its “flagship” industry and make great efforts to develop exhibition industry, housing and logistics, transportation, information service, financial and insurance industry, real estate industry, culture, sports and health services, and community services, making the city “capital of hydropower.” It has vowed to rationally develop and protect resources and raise the land utilization rate and make great efforts in environmental protection and pollution control.

The economic density (GDP per km^2) of the reservoir area was 1.4452 million yuan/km^2 in 2002. See Fig. 7.49. The economic density at the tail end of the Chongqing reservoir was the highest, with 3.5344 million yuan per km^2, equal to 3.35 times in the middle section of the Chongqing reservoir area, where economic density was the lowest, with 1.0552 million yuan per km^2. The economic density of the Hubei side was in the middle, with 1.2322 million yuan per km^2. Each area has an economic density peak. The peak at the tail end of the Chongqing reservoir area was at Changshou District (4.3816 million yuan); the peak in the middle section of the Chongqing reservoir area was at Wangzhou (2.3799 million yuan). The peak at the head section in Hubei was at Yiling District (2.6260 million yuan). But the industries in Wulong, Fengdu, and Shizhu counties were relatively less-developed as the main communications line between Wanzhou and Chongqing bypassed the reservoirs. Yunyang and Xingshan were in the fringe of the two economic zones and therefore enjoyed no geographical advantages and the development speed was slow. Chongqing and Yichang and their surrounding areas have increased fast in the urban areas.

LULC and state policies

The state promulgated the “Basic Farmland Protection Regulations” in July 1994 with a view to strengthening the protection of high-yielding farmland while exercising control for a dynamic balance in the cultivated land resources. The regulations require that if some places occupy farmland

Fig. 7.49 GDP of districts and counties in reservoir area in 2002



for construction purposes, they have to reclaim the same size of land in remote areas in order to keep grain production stable. In 1997, the state came out with a new policy with regard to the management of forests and launched six major forestry projects. From August 1998 to January 2000, the excessive felling of trees, logging theft and reclaiming forests were brought under control thanks to the policies of "banning the destruction of forests to reclaim land or collect seeds" and "returning land to forests, grassland and lakes in a planned way and step by step."

The project of returning land to forests resulted in the co-existence of ecological projects and expansion of farmland due to population growth. Most of the rural population is distributed in remote mountainous areas and the actual reduction of farmland was not much. According to the population size of 19.7207 million in the reservoir area in 2002, the per capita cultivated land was 1.9 mu. If calculated in purity terms, the farmland averaged about 1.5 mu per person, striking a basic balance between people and land.

7.11 Achievements of Eco-Environmental Experimental Stations[11]

7.11.1 Terrestrial Plant Experimental Stations

Terrestrial plants and vegetation of the Longmenhe area

Longmenhe area is situated on the border of the central Asian tropical zone and the north Asian subtropical zone. Broadleaf evergreens are the zonal vegetation. But the primary vegetation has virtually been depleted by human activities. The broadleaf evergreens on the vertical belt, the mixed evergreen and deciduous broadleaved forest and deciduous broadleaved forest are of the secondary forests in nature. According to field survey data, the vegetation of the area is divided into 15 formations, belonging to three types of vegetations of broadleaf evergreens, mixed evergreen and deciduous broadleaved forest and deciduous broadleaved forest.

The broadleaf evergreens belt: It is situated below the elevation of 900 m (the highest is 1300 m). As it is at a low elevation where human activities are intense, there are only a few pieces of secondary broadleaf evergreen forests, such as Large-leaf spicebush (*Lindera megaphylla*) at Mendongzegou. Others are mostly man-made forests or mixed forests on the basis of the destroyed primary vegetation. In some places with unique biotope are distributed *sclerophyllous* broadleaved evergreen forests, such as Wugang oak (*Quercus phillyraeoides*) forests.

Mixed evergreen and deciduous broadleaved forest and deciduous broadleaved forest: The belt is situated at an elevation ranging from 900 (1300) to 1600 m. It borders on deciduous broadleaved forest above and on broadleaf evergreens down below. Due to human activities, the evergreens have gradually been replaced by deciduous forests, thus reducing the areas of the mixed forests and forming a deciduous and broadleaf forest with multiple deciduous trees dominating. Such mixed forests are available in large area, with the dominating species being *Quercus glandulifera*, Dye tree, Farges hornloeam (*Carpinus fargesiana*), and Shiny-bark birch (*Betula luminifera*).

Deciduous broadleaf forest belt: The belt is mostly distributed at elevations ranging from 1600 (1300 m the lowest) to 2200 m. This belt is little affected by human activities and there are still some natural vegetation, with Oriental

[11]Institute of Soil Science, CAS. Technical Report of Zigui Eco-environment Experimental Station (1996–2003); Institute of Mountain Hazards and Environment,CAS. Technical Report of Wanzhou eco-environment Experimental Station (1996–2003); Institute of Hydrobiology, CAS. Technical Report of Endemic Fish Experimental Station (1996–2003); Institutes of Botany, CAS. Technical Report of Terrestrial Plant Observation and Experimental Station (1996–2003).

white oak (*Quercus aliena*) and Serrate oak (*Quercus glandulifera var. brevipetiolata*) low growing forests distributed on the slopes facing the sun while Engler beech (*Fagus engleriana*) and Shining-leaf beech (*Fagus lucida*) Forest are growing on the back slopes. There are also small expanses of dovetree forests near Fujiawan.

The plant communities of the area have undergone great changes due to human activities. What left are mostly types with human interference or secondary type. There are no large expanses of shrubs. This may be attributable to the following three reasons: (1) The natural conditions are suitable for tall trees to grow and even the tall trees are destroyed, the young trees grow so rapidly that they soon grow to the top layer to occupy a dominant position; (2) the population density is not big and the forest cover is high, without sustained strong interference; and (3) local residents often cut shrubs as firewood, thus preventing the shrubs from growing. The management ways of the Longmenhe Forest Farm has, to a large extent, affected the current conditions and evolution of the vegetation.

Fixed sample belts for monitoring terrestrial plant diversity

In 2001–2003, three biodiversity monitoring sample belts were designed in the reservoir area. They were Fengdu, Zigui, and Yunyang.

(1) Fengdu belt

The Fengdu sample belt is centered round the Shipping Forest Park on the border of Pingxingling Valley in eastern Sichuan and the eastern part of the basin, belonging to the Fengdu County Shiping Forest Farm. The geographical location is 29º47′40″N, 107º37′40″E, with an elevation of 350–1050 m. It covers 1800 hm^2, mostly covered with secondary natural forest dominated by evergreen broadleaf trees. The annual mean temperature is 18.3 °C and annual mean precipitation is 1267.5 mm. The soil is of the yellow and yellow brown type developed on the mother rock of sand shale, with pH value being less than 5.0.

The sample belt is made up of seven fixed quadrates with continuous change of gradient and one 1 hm^2 fixed monitoring sample plot. Each plot is positioned by GPS according to international standards, with cement poles planted in the four corners.

The whole sample belt features eight different vegetations that appear in the following order from up and down: *Form.* Yellow bramble (*Vitex negundo*), Readlike sugarcane, (*Sacceharam arundinaceum*) grassland, Cypress Tree forest, Pine, Farge's chinkapin forest, Oiltea camelia (*Camellia oleifera*), Fortune firethorn (*Pyracantha fortuneana*), and Dye tree. They are the true reflection of the vegetation under the action of human activities. The preliminary results show that there are more than 120 species of plants of higher order in the sample belts and those appearing in large numbers are plants of the Honeysuckle family (*Caprifoliaceae*), *Fagaceae*, Grass family (*Gramineae*), Sedge (*Carex* sp.) family (*Cyperaceae*), Waxmyrtle family (*Myrsinaceae*), Laurel family (*Lauraceae*), Rose family (*Rosaceae*), Sweetleaf family (*Symplocaceae*), and *Rubhceae*.

The Cypress Tree forest, Pine forest, and Oiltea camelia are artificial forests, but they are mixed with many natural broadleaf evergreen trees, such as Fortune firethorn and Sawtooth Oak (*Quercus acutissima*), indicating that they used to be broadleaf evergreen forests. In order to better protect what is left of the evergreen broadleaf forests, it is necessary to seal up the mountains for cultivation, return land to forests and launch a natural forest protection project.

(2) Zigui fixed sample belt

This sample belt is situated in the Shuitianba Town of Zigui County in Hubei Province. At an elevation of 208–1045 m, it lies at a point of 31º04′N and 110º40″E. Human activities have depleted the area of forests, leaving only a few *Pinus tabulaeformis*, Pine, Chinese fir (*Cunninghamia lanceolata*), and Cypress Tree above the elevation of 800 m. Natural vegetation (shrubs and grass) below 600 m is rare. Most of them have been turned into farmland or orchards. In recent years, many mountainous areas were demarcated as "No logging zones." As the natural vegetation used to subject to serious artificial interference, it is of certain value to study how to restore the natural terrestrial vegetation. The emphasis of monitoring this belt is put on the impact of human activities on the terrestrial plant vegetation and the process of restoration.

The preliminary analysis results show that there are more than 60 species of plants of higher order. The most frequently seen are plants of the Gramineae (*Poaceae*), Rose family, Sedge family, Waxmyrtle family, *Symplocaeae, and Rubhceae.*

Distributed from the lower up to the higher of the sample belts are in the sequential order young Chinese fir forest, Locust (*Robinia pseudoacacia*), Fortune firethorn shrubs, Cypress Tree forest, Purpus privet (*Ligustrum quihoui*), *Pinus tabulaeformis* forest, Nepal coriaria (*Coriaria nepalensis*) shrubs, and Contorted yellowquitch (*Heteropogon contortus*) grass growth, a true picture of the vegetation under the action of human activities in the reservoir area.

Young Chinese fir forest: It is an aerial-seeded forest, with the canopy density being 70% and the tallness of trees ranging 3–6 m. Apart from Chinese fir, there are many *pinus* *tabulaeformis* as well as *Quercas glandulifera* and China sumac saplings. The shrub layer cover is 30%. They are mainly Fortune firethorn, Sims's azalea (*Rhododendron simsii*), Oiltea camelia, Common smoketree (*Cotinus coggygria var. cinerea*), rose, Chinese gooseberry (*Fructus Actinidiae Chinensis*) and Cotoneaster (*Cotoneaster* sp.). The herbaceous layer is 40%, including Japanese silvergrass (*Miscanthus floridulus*), Sedge, Cutleaf bushclover (*Lespedeza cuneata*), Threevein aster (*Aster ageratoides*), and *Pteridophyta*.

Young Locust forest: It is situated at Chenjialing of Tianshuiba, with purple sandstone as the base rock. The Locust forest is artificially planted, about 6–8 years old, with the tallness ranging from 50 to 250 cm, interwoven with many China Sumac and Chinese pine (*Pinus tabulaeformis*) saplings. Shrubs are few and far between. They include Twinflower abelia (*Abelia biflora*) and China loropetal (*Loropetalum chinense*). The herbaceous layer cover is 50%, mainly dominated by contorted yellowquitch.

Fortune firethorn shrubs: they are situated at Hengniushi of Shuitianba, growing in yellow brown soil developed from lime. The shrub cover has reached 35%. Species include Fortune firethorn, *Spiraea X bumalda* and Honeysuckle family. The herbaceous layer cover is 30%, including Contorted yellowquitch, Cutleaf bushclover, and Wormwood (*Artemisia* sp.).

Cypress Tree forest: secondary natural forest growing in purple sandstone, with the canopy density being over 90%. Among the arbor are some Chinese pines. Shrubs and herbs are rare, with the cover being less than 1.

Purpus privet shrubs: It is situated at Laohudun of Shuitainba, growing in the purple shale rock. The shrub layer cover is 35%. Species include mainly purpus Privet, Chinese clovershrub (*Campylotropis macrocarpa*), *Coriaria nepalensis*, Flue arrowwood (*Viburnum utile*), WUK, Cherokee Rose (*Rosa laevigata*), and Chinese box (*Buxus sinica*). There are also saplings of Dye tree, China tallowtree (*Sapium sebiferum*) and China sumac. The herbaceous layer cover is 15%. Species include Ungeargrass (*Arthraxon hispidus*), White Cogongrass, Contorted yellowquitch, and Wormwood.

China pine forest: It is situated at Huopaoling of Shuitianba, a secondary natural forest restored a dozen years ago. The base rock is lime. The canopy density is 80%. The shrub layer cover is 60%. Species include China loropetal, Africa myrsine (*Myrsine Africana*) and Spiraea (*Spiraea* sp.). The herbaceous cover is 8%, mainly including Japanese silvergrass and *Arthraxon hispidus*.

Nepal coriaria (*Coriaria nepalensis*) shrubs: Base rock is lime. The shrub layer cover is 40%, with species covering *coriaria nepalensis*, Chinese clovershrub, *a*nd China fevervine (*Paederia scandens*). The herbaceous layer cover is 40%, mainly including such species as White Cogongrass, Contorted yellowquitch, Ungeargrass, and Wormwood.

Contorted yellowquitch: It is situated northeast of Yanshuihe Bridge in Shuitianba, a barren slope returned from reclaimed farmland. The base rock is of purple shale. The herbaceous layer cover is about 70%, mostly Contorted yellowquitch, with some Ungeargrass and Cutleaf bushclover in between.

(3) Yunyang fixed sample belt

This sample belt is situated in the Nanxi Town of Yunyang County, Chongqing Municipality, at an elevation of 290–1040 m. The geographical location is at 31º04′N, 108º51″E, the same latitude as the Zigui sample belt and about in the middle of the Zhiping sample belt and Zigui sample belt in longitude. As the reservoir area is a narrow strip extending from east to west, the three sample belts are in the eastern, middle and western parts, making it strongly representative. They cover areas that used to be subject to strong interference by human activities, with primary vegetation completely gone. The low elevation areas are mainly farmland and orchards, with only some degenerating shrubs visible on some slopes. There are some Pine forests and Cypress Tree at an elevation above 700 m. The main forests are artificial and only some are likely to be secondary natural forests.

The preliminary analysis result shows that there are 54 species of plants of higher order. The most frequently seen are plants of the *Gramineae*, Rose family, *Cyperaceae*, *Asteraceae,* and *Pteridophyta*. There are altogether six different types of vegetations in the whole sample belt.

Pine forest: It is situated as areas with an elevation above 900 m, with sandstone as the base rock. It was aero-seeded in 1984, with the canopy density being 85% and tallness ranging from 4 to 6 m, the only species counted as arbor. Next frequently seen are saplings of China sumac and *Quercas glandulifera*. The shrub coverage is 30%. They are mostly tea bushes, Sims's azalea, China loropetal, *Eurya nitida var. aurescens* and Raspberry (*Rubus* sp.). The herbaceous coverage is 70%. Species mainly include Common wedgeler fern (*Sphenomeris chinensis*), Dichotomy forked fern (*Dicranopteris pedata*), White cogongrass, and Cudweed (*Gnaphalium affine*).

Cotinus shrub: It is situated at an elevation of about 770 m, with lime as the base rock. The shrub coverage is 80% and tallness ranges about 1.2 m. Species include mainly *Cotinus coggygria var. cinerea* and Africa myrsine as well as *Lespedez quihoui.* The herbaceous coverage is 20%. Species mainly include contorted yellowquitch, Japanese silvergrass, and *Arthraxon hispidus*.

Young Cypress Tree forest: It is situated on the lime stone mountains above the elevation of 700 m. It is mostly artificially planted, with the tallest being 3 m, not yet in the arbor layer. The shrub layer coverage is 25%. Species is mostly Cypress Tree, followed by common smoketree (*continus coggygria*), Fortune firethorn and Digua fig (*Ficus tikoua*). The herbaceous layer coverage is 40%, with species including mostly contorted yellowquitch and Awngrass (*Miscanthus sinensis*).

Coriaris nepalensis shrub: It is available in two quadrants, at an elevation of 440–630 m, with limestone as the base rock. The shrub layer coverage is 55–70%. Plants mainly include *coriaris nepalensis*, *continus coggygria*, *Myrsine africana*, Wild prickleyash (*Zanthoxylum simulans*), Digua fig, Fortune firethorn, and Rose family. The herbaceous layer coverage is 30–60%, mostly including Japanese silvergrass, *Arthraxon hispidusand*, White cogograss (*Imperata cylindrical*), and Contorted yellowquitch.

Contorted yellowquitch shrub: It is also a degenerated grass growth commonly seen in the reservoir area. There are two sample quadrants at an elevation of 360–410 m, with the purple shale rock as the base rock. The soil is purple in color, lean and dry, with little humus. The grasslands have been formed after the farmland was abandoned. It has no shrub layer or artificially planted saplings. The herbaceous layer coverage is 55–70%. Species are mostly Contorted yellowquitch and a small amount of *Arthraxon hispidus*, Wormwood, and Bitter fleabane (*Erigeron acre*).

White cogongrass shrub: It is situated at an elevation of about 300 m, with lime as the base rock. The herbaceous layer coverage is about 35%. Main species include cylindrical imperata and *arthraxon hispidus*. Frequently seen are also Contorted yellowquitch, Wild Chrysanthemum (*Dendranthema indicum*), Green bristlegrass (*Setaria viridis*), and Dandelion (*Taraxacum mongolicum*).

Conservation ex situ of rare and endangered species of plants in the reservoir area

By the end of 2003, 51 species of rare and endangered species of plants had been introduced (see Table 7.37). Among them, 43 species have been listed in China's Red Data Book (Volume 1) and one species, that is, Looseflowered falsetamarisk, has been inundated. Seven have been listed under provincial level protection. They are Deinanthe (*Deinanthe caerulea*), *Taxus chinensis*, Manyleaf paris (*Paris polyphylla*), Cyclocarya (*Cyclocarya paliurus*), Wilson buckeye (*Aesculus wilsonii*), Bloodbark maple (*Acer griseum*), and China umbrellaleaf (*Diphylleia sinensis*). Among them 42 species are native and 9 are alien.

Most of the rare plants cultivated ex situ are growing well. But some species not well against cold are not growing so well. According to the observation of *phenophases*, survival rate and growth speed, part of the rare and endangered species conserved may be divided into five grades: very good, fairly good, good, normal, and poor.

7.11.2 Endemic Fish Experimental Stations

Starting from 2001, experiments have been carried out on the breeding of such endemic species of fish as *Ancherythroculter nigrocauda* and *Megalobrama pellegrini* to collect biological data about *Megalobrama pellegrini*, *Rhinogobio*, Rock carp, analyze the biological features of *Megalobrama pellegrini* and focused on the study of *Ancherythroculter nigrocauda*, *Megalobrama pellegrini*, Rock carp, and *Bangana rendahli. Ancherythroculter nigrocauda* and *Megalobrama pellegrini* have been successfully bred in pools and laboratories. Attempts have also been made to domesticate Rock carp, *Leptobotia elongata*, Redlip loach (*Leptobotia rubrilabris*), *Jinshaia sinensis*, *Coreius*, *Rhinogobio ventralis*, *Rhinogobio cylindricus,* and *Bangana rendahli*.

Artificial breeding of *Ancherythroculter nigrocauda*

Ancherythroculter nigrocauda is of Minnows or carps (*Cyprinidae*), *Cultrinae* and *Ancherythroculter*, mainly inhabiting in the slow current waters in the mainstream and tributaries of the Yangtze. Such small tributaries as the Longxi River, the Laixi River, the Xishui River, and the Mutong River have the favorable conditions for it to grow and reproduce. The fish mainly feeds on small fish and Shrimps, very simple in its community structure. The main reproductive fish are 2-year and 1-year individuals. The reproductive period is 4–8 months. Its spawning needs the stimuli of rising and flowing water, changing temperature, and water weeds, like spawning in groups.

The key technique in artificial breeding of *ancherythyoculter nigrocauda* is the correct selection of parent fish, best to select those that have been domesticated for a long time. The one-off injection method should be adopted and the idealist dose is 3 μg LRH-A + 2500 international units of HCG. 2–3 mg PG may be added to parent fish with poor gonadal development. The dose for male fish shall not be 1/2 less than that for females. In the critical period of alevin development, when the fish begins to inflate its swimming bladder and to seek food, suitable baits should be given.

Four times of artificial breeding experiments has been carried out with the artificial insemination to parent fish, obtaining 50,000 fry. 18 artificial breeding experiments have been carried out with the drug method, obtaining more than 50,000 fry. The size of dose for artificial stimulation has been established. On the basis of artificial breeding, observation and description have been carried out in the early stage of development.

Table 7.37 List of rare and endangered species relocated from the reservoir

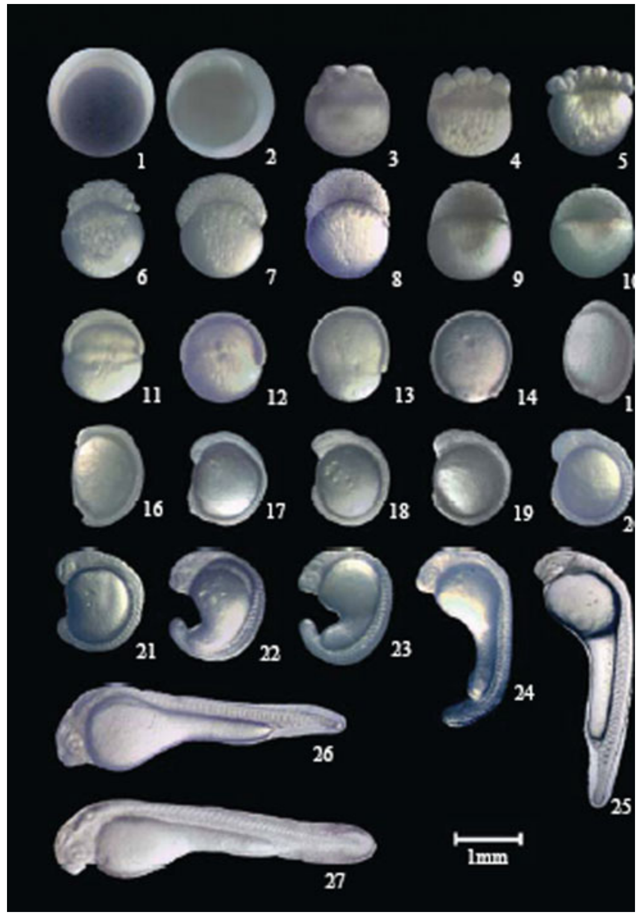
Latin name	Status	Source	Time of plantation	Amount
Davidia involucrata	Rare	Longmen River	1997	16
Ginkgo biloba	Rare	Beijing Botanic Garden	1997	30
Metasequoia glyptostroboides	Rare	Longmen River	1997	9
Amentotaxus argotaenia	Vulnerable	Longmen River	1997	5
Pteroceltis tatarinowii	Rare	Longmen River	1997	3
Euptelea pleiospermum	Rare	Longmen River	1997	22
Dysosma versipellis	Vulnerable	Longmen River	1997	8
Magnolia officinalis	Vulnerable	Longmen River	1997	5
Eucommia ulmoides	Rare	Longmen River	1997	18
Dipternonia sinensis	Rare	Longmen River	1997	15
Stewartia sinensis	Vulnerable	Longmen River/Shennongjia	1997	35
Sinojackia xylocarpa	Vulnerable	Beijing Botanic Garden	1997	6
Cephalotaxus oliveri	Vulnerable	Longmen River	1997	5
Coptis chinensis	Rare	Longmen River	1997	12
Glycine soja	Vulnerable	Longmen River	1997	>200
Myricaria laxiflora	Submerged	Zigui/Badong/Chongqing	1996	600
Adiantum reniforme var. *sinense*	Vulnerable	Wanzhou	1996	300
Phellodendron chinense traditional glabriusculum	Vulnerable	Longmen River	1997	20
Abies chensiensis	Vulnerable	Shennongjia	1998	4
Corylus chinensis	Vulnerable	Longmen River	1998	3
Cercidiphyllum japonicum	Rare	Longmen River	1998	4
Liriodendron chinense	Rare	Beijing Botanic Garden	1998	1
Manglietia patungensis	Vulnerable	Wuhan Botanic Garden	1998	3
Tetracentron sinense	Rare	Longmen River	1998	6
Tapiscia sinensis	Rare	Xiangping, Maogu	1998	3
Emmenopterys henryi	Rare	Longmen River	1998	12
Phoebe zhennan	Vulnerable	Longmen River	1998	2
Trillium tschonoskii	Vulnerable	Longmen River/Shennongjia	1998	5
Changnienia amoena	Rare	Longmen River	1999	30
Pseudolarix amabilis	Rare	Hunan	2000	15
Sinowilsonia henryi	Rare	Wuhan Botanic Garden	2000	5
Pterostyrax psilopermum	Vulnerable	Wuhan Botanic Garden	2000	5
Davidia involucrata var. *vilmoriniana*	Rare	Longmen River	2000	3
Cathaya argyrophylla	Rare	Hunan	1999	3
Eurycorymbus cavaleriei	Rare	Wuhan Botanic Garden	2000	5

Artificial breeding of *Megalobrama pellegrini*

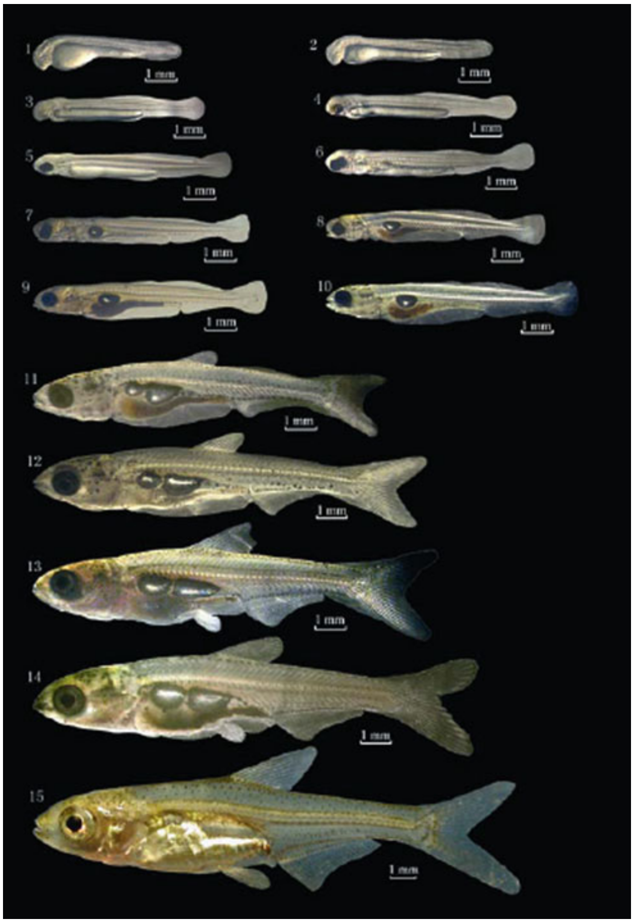
Megalobrama pellegrini is of Minnows (*Cyprinidae*), *Cultrinae,* and *Megalobrama*. It is a kind of big-sized endemic fish of high economic value, inhabiting in the mainstream of the upper reaches of the Yangtze and its main tributaries such as the Minjiang, Tuojiang, Chishui, Jialingjiang, and Wujiang rivers. Although the fish is widely distributed, the past catches were not reflected in the quantitative analysis. The resources are limited. The reproductive season is April–July. The fish requires deep water to hide itself and to tide over the winter. It also requires hydro-biological communities. Reproduction needs flowing water with a temperature of over 18 °C. Despite its adhesive eggs, the fish often spawn in rapids with stone as bottom. Flowing water is essential for its reproduction.

The highlights of artificial breeding are: use two injections to stimulate spawning, with an interval of 8–10 h. The dose is 3 mg PG+3 μg LRH-A2 per kilogram of fish. The first injection is 1/6 of the total and the second, 5/6. The same dose applies to both male and female. The action time is 10–12 h at a temperature of 21 °C and only 6.5 h when the temperature is 27 °C.

In 2001–2003, 16 experiments were carried out to stimulate spawning, averaging a stimulating rate of 62.5%. Of the 16 experiments, 12 succeeded to stimulate female fish to spawn and nine obtained fertilized eggs. The average fertility rate was 62.1% and hatching rate was 44.7%, obtaining 300,000 fertilized eggs and hatching 16,800 fry. During the course, the development atlas of the fish was recorded.



Megalobrama pellegrini development atlas



Megalobrama pellegrini development atlas

Artificial breeding of Rock carp

Rock carp is of *Cyprinidae*, *Cultrinae,* and *Procypris*, distributing in the mainstream of the upper reaches of the Yangtze and such tributaries as the Minjiang, Tuojiang, Chishui, and Jialingjiang rivers. It is a kind of big-sized endemic fish, with high economic value. Study results show that the fish is composed of nine age groups from 0 to 8. But the proportion of fish of 4 years and above has been reduced from 64.8% in the 1970s to 37.8%. Part of it reaches maturity in 2 years. But there are still 5-year old whose gonad development is still not complete. The reproductive season is March–May. In the reproductive population, 2- and 3-year-old make up 60%, with the female and male ratio being 1:1.08. Rock carp is a typical omnivorous fish, feeding on Shellfish (*Limnoperna lacustris*), *Snail* (*Gastropoda*), Aquatic insects (*Insecta*), water weeds, and algae. The habitat of the fish is the rock-bedded deep water. Young fish often appears in groups in big bay or downstream of tributaries and river mouths in spring and autumn.

According to reports on artificial breeding of Rock carp, there has not been any breakthrough or at least it has not reached the stability stage, although there is a certain scale of artificial breeding.

The endemic fish laboratories have carried out six experiments in artificial breeding and failed in five. There are still many technical details that need further study. The key to successful artificial breeding lies in the domestication of parent fish. Observation shows that when meeting interference (catching, transportation, and injection), the fish often crashes and suffers from spasm, which will cause death. When anaesthesia is applied before interference, it may raise survival rate. So anaesthesia application is necessary before the fish is domesticated, transported, and stimulated to spawn. The situation is similar to the "training" of fry in cultivation. While domesticating Rock carp, it is necessary to give regular interference so that it will get used to it.

After the reservoir is impounded in 2003, the endemic fish experimental station and the Chongqing Wanzhou Aquatic Research Institute purchased more than 400 such fish, also known as Chinese ink carp, averaging 800 g each. After 8–10 months of domestication, 350 survived by 2004. The experimental station selected those weighing over 1200 g and having apparent secondary sex characters, to carry out seven experiments in artificial insemination. It succeeded in four, obtaining about 60,000 fry.

Artificial breeding of *Spinibarbus sinensis*

The endemic fish experimental station has carried out six experiments in artificial breeding of *Spinibarbus sinensis.* Five were carried out in 2003. Of which, three were successful, one was effective in stimulating spawning and one failed. The average successful rate was 56.0%, averaging a fertility rate of 70.3%.

The fish, also popularly known as "Qingbo," is regarded as a noble fish in the upper reaches of the Yangtze. Since the 1980s, many places in the country, especially in the Chongqing area, have listed it as a new variety for development. In the past, there were people who specialized in catching the fish in the Jialingjiang, Tuojiang, and Chishui rivers for sale. There were also units or individuals in Chongqing and Luzhou who carried out artificial breeding. Yet, no breakthrough has ever been reported. In 1999–2002, the 3–3.6 cm long fish sold for 1–3 yuan. In 2003, the endemic fish experimental station succeeded not only in artificial breeding of *Spinibarbus sinensis* but also helped the Luzhou Jiangyang Seed Fish station and Wuhan Xianfeng Aquatic Technology Co. in carrying out a large-scaled development of *Spinibarbus sinensis*. If there is a breakthrough in scale breeding and fry cultivation, all the fish of


Collecting eggs

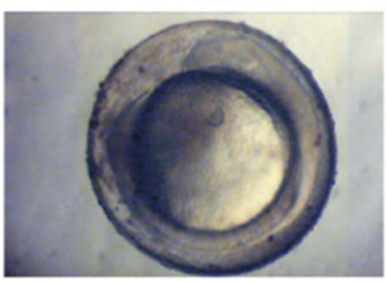

Collecting semens


Mixing up semens and eggs


Putting fertilized eggs on net


Collecting fertilized eggs for observation


Observing growth of fertilized eggs


Fertilized eggs


Young fish


Growing bigger

Process of artificial breeding of *Ancherythroculter nigrocauda* high economic value may be utilized by artificial breeding. This has not only reduced the pressure on natural catching but also made planned artificial release a possibility.

Artificial breeding of other endemic fish species

The Endemic Fish Experimental Station carried out three very successful experiments in artificial breeding of *Bangana rendahli* in 2004. The spawning stimulating rate was 100% in two experiments and was 90% in one. The insemination rates were 70, 51, and 80%. The hatching rates were 25, 15, and 25%, obtaining about 1.08 million fry. Apart from those sold and for development observation, the experimental station bred about 1000 larval and juvenile fish.

The laboratory also carried out 20 experiments in artificial breeding of Darkbarbel catfish (*Pelteobagrus vachelli*) and other species. It conducted 13 experiments with Darkbarbel catfish and succeeded in nine, failed in two and was effective in one. It conducted two experiments in the breeding of *Leiocassis crassilabris* but neither was successful. The experiment with *Mystus macropterus* was effective but the experiments with *Leptobotia elongata* (*Bleeker*) and Bronze gudgeon (*Coreius heterodon*) failed.

7.11.3 Zigui Eco-environment Experimental Station

The station has its goal of restoring ecosystem and expanding environmental capacity of the areas for the resettled people. It has carried out experiments and demonstration projects in controlling water loss and soil erosion by biological measures, ameliorating the soil and rational application of fertilizer for Washington navel, crop production and rational application of fertilizer, vegetable production, and courtyard economy. At the same time, it carried out monitoring of dynamic changes of land resources, water loss, and soil erosion in dry slope land and non-point pollution, dynamic changes of soil fertility and the social and economic development of the rural resettled people.

Experiments and demonstration of biological measures for controlling water loss and soil erosion

(1) Contents and conclusions of experiments and demonstration projects

The experiments in hedgerow in four types of slope land on the purple sandstone at Shuitianba Township of Zigui County show that different types of hedgerows have the effect of preventing water loss and soil erosion on slopes of different gradients, directions and on different degenerated land. The nutrients in soil is lost with the loss of soil and the main measures for maintaining soil fertility should be to prevent soil erosion, which should be made the main orientation for preventing water loss and soil erosion and for restoring land productivity potential. Experiments show that the maximum critical gradients for erosion was 25°–30°, which should be made the focal section for utilizing, ameliorating and preventing soil erosion in slope land. When the vegetation cover reaches 30%, it can prevent soil erosion; when it reaches 60%, it can basically control soil erosion; when it reaches 80%, it can bring soil erosion under complete control.

(2) Ecological efficiency analysis

- Blocking the soil from being washed away. The longer the hedgerows grow, the better the result in blocking the soil from being washed away. The size of benefits depends on the raised part of the hedgerow. Take *Leucaena leucocephala*, Yellow bramble, and *Vetiveria zizanioides* as examples. From the 3rd year on, the hedgerow would all be above 60 cm in height, which can totally bring the soil erosion under control and make the fields gently sloping terraced fields.
- Making the slopes gentler. As the soil is blocked, the gradients of the slope would by and by become gentler. The gradient of Yellow bramble hedgerow may be reduced from 34° to 22°; the gradient of *leucaena leucocenphala* hedgerow may be reduced from 29° to 21°; the gradient of *vetiveria zizanioides* hedgerow may be reduced from 32° to 21°; the gradient of Rose of sharon (*Hibiscus syriacus*) *hedgerow* would be reduced from 33° to 24°. Ultimately, the land would become terraced fields with gentle slopes or even contour terraced fields.
- Shortening the slope length. With hedgerows growing higher, the gradients would become gentler and the slope length would be shortened. The 4-year nugundo chastetree hedgerow would shortened the slope length from 344 to 246 cm; the *leucaena leucocephala* hedgerow may shorten the slope length from 378 to 243 cm; and the *vetiveria zizanioides* hedgerow may shorten the slope length from 388 to 342 cm; the Rose of Sharon hedgerow may shorten the slope length from 270 to 246 cm. In about 10 years, the slope land would become contour terraced fields.
- Green manure output. The branches and leaves trimmed from the hedgerows may be used as green manure for

enhancing the fertility of the soil. Some varieties such as *leucaena leucocephala*, which is of the bean family, may fix nitrogen in the soil. If calculated by the belt distance as 3.5 m, the *leucaena leucocephala* hedgerows may provide 24,000 kg/hm^2 of branches and leaves; negundo chastetree may provide 31,500 kg/hm^2, *coriaria sinica*, 8400 kg/hm^2 (output is low due to pests). If the above values are converted into nutrient elements, the per hectare *leucaena leucocephala* green manure is equivalent to 351 kg of ammonia sulfate, 126 kg superphosphate, and 126 kg potassium sulfate; the green manure of *leucaena leucocephala* would be equal to 924 kg ammonia sulfate, 48 kg of superphosphate, and 504 kg potassium sulfate.

- Enhancing soil fertility. Take the experimental plots for instance. In 1993, when the experiments started, the organic matters in the surface soil was 9.0 g/kg, alkaline-hydrolysable nitrogen (AHN), 49.51 mg/kg, TP, 0.40 g/kg, fast-acting phosphate, 4.18 mg/kg, TK, 22.7 g/kg, and fast-acting potassium, 130.7 mg/kg. Three years later, the organic matters increased to 9.6 g/kg, AHN, to 104.73 mg/kg, TP, to 0.42 g/kg and fast-acting phosphate, to 153.3 mg/kg.

(3) Economic efficiency analysis

- Output of the alley cropping of arid hedgerow plus grain crops. Take No. 4 experimental plot as an example. The area was 337 m^2. The Yellow bramble and *leucaena leucocephala* hedgerows were laid in May 1996. If the output is calculated by the unified purchasing price of grain, the harvest in the year was converted into 168.2 yuan. It rose to 178.8 yuan by 1997 and up to 211.7 yuan by 1998.
- Output of Washington navel planted in between hedgerows and in stone terraced fields. Take No. 3 experimental plot, which was planted to orange in between hedges. On the left side was the orange planted in stone terraced fields. The gradient of the experimental plot was steeper than the contrast field. Experiments started in 1993, when orange in the experimental plot was visibly poor than the plot on the left side but similar to the right side, which was a slope land. But when coming to the 4th year, the output in the experimental plot was 20% higher than the left-side plot and about 25% higher than the right-side plot.
- Investment in building and maintaining hedgerows and stone terraced fields. In 1993, 1 hm^2 of stone terraced field required 24,298.5 yuan while planting hedgerow required only 2290.5 yuan, saving 22,008 yuan. The plant hedgerows do not need maintenance in 5 years. But stone terraced fields had to be maintained every year. According to a survey in August 1993 of 10 stone hedges totaling 500 m in length the July 22 rainstorm of 74.3 mm flattened 17.76 m of the stone hedges, 3.55% of the total length. It cost 14.5 yuan to restore the stone hedges. There are at least two strong rains of over 50 mm/d in Zigui County. This, plus weathering effect, made the stone hedges non-stable. It is quite costly to maintain.

Experiments and demonstration of soil conditions and rational application of fertilizer for the growth of Washington navel

(1) Experiments, demonstrations and conclusions

The optimum soil conditions for Washington navel are: soil layer: over 60 cm; soil nature: neutral, with pH value being 5.5–6.5. When pH value is less than 5, it requires 3000–3450 kg of lime per hectare; when pH value ranges 5.0–5.4, 1500–1950 kg of lime are needed; and when pH value ranges 5.5–6.0, 750–1050 kg are needed. The application of calcium magnesium phosphate may also enhance pH value. Lime or calcium magnesium phosphate should be spread into the soil in winter. The best formula of fertilizer is: N: P_2O_5:K_2O = 1:(0.55–0.70):(0.75–0.90). The application of nitrogen during the fruit picking period accounts for 50% of the total for the growth period; the application of phosphate, 50% and potassium, 15%. The nitrogen for fruit consolidation accounts for 30% for the growth period; phosphate, 40% and potassium, 75%. The formula can raise output by about 15% as compared with sole application of fertilizer during fruit picking period or during fruit consolidation period or too much fertilizer during the spring sprouting period or fruit fixing period. It can also raise the sugar–acid ratio by 1.5–2. The spray of leaf-surface fertilizer containing Zn and B during the flowering and fruit fixing periods can raise output by 14–16%. It can also control natural falling of fruit in May, reducing fruit falling by about 30–40%.

(2) Eco-economic efficiency analysis

- The optimum fertilizer formula cannot only raise the output by 20–30% but also improve quality, size and color of products, thus making the products more competitive on the market.

- The application of different amounts and composition of fertilizers during different periods of growth can raise output by about 15% more than conventional methods of fertilizer application and raise the sugar/acid ratio by 1.5–2.
- Rational application of fertilizer can effectively prevent waste and non-point pollution compared to excessive application of fertilizer, and it can also reduce economic losses compared to inadequate application of fertilizer, thus improving the eco-economic efficiency.
- Fertilizer manufacturers may produce fertilizer according to the optimum formula, which will not only help raise economic efficiency but also increase jobs, helping farmers in solving difficulties in fertilizer application, thus achieving both economic efficiency and social benefits.
- As rational application of fertilizer can raise economic efficiency and reduce pollution, it can help increase income of the resettled people and expand the environmental capacity, thus achieving not only economic and ecological efficiency but also social benefits.

Experiments and demonstration in crop culture and rational application of fertilizer

(1) Experiments, demonstration and conclusions

The application of fertilizer in Zigui County is in an imbalanced state. Its best fertilizer formula for rice is N:P_2O_5:K_2O = 1:0.40:0.50; that for wheat is N:P_2O_5:K_2O = 1:0.50:0.44; that for corn is N:P_2O_5:K_2O = 1:0.40:0.40. The optimum amount of fertilizer for summer and autumn is about 28 kg of nitrogenous fertilizer per mu per quarter; the best formula for tea is N:P_2O_5:K_2O = 1:0.60:0.40.

(2) Eco-economic efficiency analysis

- The use of the optimum fertilizer formula can, first of all, raise output by 30–40% more than that by the habitual methods of fertilizer application; secondly it can improve quality of grain, with higher weight per 1000 grains (>26 g/1000 grains) and lower rate of empty and blighted grains (<17%); third, it can reduce the loss of nitrogen by 5–10% and phosphate by 3–5%. It cannot only improve economic efficiency but also reduce non-point pollution, hence higher eco-economic efficiency.
- The use of best formula for wheat can increase output by 17–26% as compared by the local habitual method of fertilizer application. It can also enhance disease-resistance of crops, especially resistance to head blight at the beginning of May when the wheat is fast maturing. On the other hand, it can reduce the loss of nitrogen by 15%.
- The application of best formula for corn can increase output by 20–23%.
- The best formula for tea can increase output by 13–20%. Output increase is not so obvious for high-yielding plantations, generally below 15%. But the output increase for medium- and low-yielding plantations ranges above 16%. On the other hand, it can increase the quality of tea leaves, with the contents of amino acid, tea polyphenols, and caffeine all increasing significantly.
- The production of fertilizer according to the formula cannot only increase economic efficiency of manufacturers but also expand production scale, thus offering more jobs for the resettled people. The comprehensive efficiency in raising output and improving quality and reducing non-point pollution has thus maximized.

Experiments and demonstration in vegetable production

(1) Experiments, demonstration, and conclusions

Vegetable production in the reservoir area enjoys comparative advantages. (1) Advantage in climatic resources. The vegetable production on high mountains over 1000 m may make up for the supply shortages in the slack seasons of spring and autumn in the Yangtze River basin. (2) Advantage in vegetable germplasm resources. The area boasts not only rich in vegetable varieties but also rich wild vegetable resources. The planted vegetables are available in 18 families, 37 species, and more than 200 varieties. Wild vegetables are available in 53 families, 118 genera, and 169 species. All these are favorable for developing vegetable production, especially in the production of anti-season vegetables and specialty vegetables. (3) Advantages in reclaimable land resources. The high mountain areas over an elevation of 1000 m are sparsely populated but the land resources are rich, especially the vast expanses of barren hills and grass slopes that are lying idle. (4) The TGP has pulled up market demand, creating unrivaled development opportunities.

The vegetables planted in the river valleys and platform land ripe 11–21 days earlier than in other areas of the same latitude. They are suitable for the following three ways of cultivation: (1) Early spring sowing. The vegetables planted may be harvested and put on market in the slack seasons of March–April; (2) Summer sowing. This way of cultivation may advance the harvest period to the eve of the National Day (October 1). (3) Late autumn sowing. This way of cultivation may extend the supply period to the New Year's Day or around the traditional Chinese Spring Festival.

The high altitude areas are suitable for growing anti-season vegetables, especially varieties for supply during the spring and autumn slack seasons.

(2) Eco-economic efficiency analysis

- Economic efficiency analysis: The 1380-mu vegetable production base at Chenjiaba was all converted from rice paddies. This has added annual output value by 1.76 million yuan. The vegetable production base at Shiya Village is of reclaimed terraced fields and converted from corn fields. The vegetable production has added an annual output value by 2 million yuan. The 500-mu old vegetable production bases at Kaziwan of Xiangxi Town and Longwanmiao Village have increased output value by 250,000 yuan by applying new technologies and new varieties. These vegetable production bases have given additional output value of 5 million yuan to the County and an additional income of 3.5 million yuan to vegetable growers.
- Ecological efficiency analysis: The river valley and high mountain vegetable production bases can fully display the advantages of light, temperature, water, and soil. The rotation of rice paddies and vegetables in the river valleys can help improve the soil structure and reduce the hazards of plant diseases and pests. After converting rice paddies into vegetable gardens, especially after using plastic green houses, the organic matters in soil have increased. The organic matters in soil in the Shiya high mountain vegetable production base increased from 1.74 to 2.15% after 3 years of vegetable production. The contents of nitrogen, phosphate, and potassium also increased to varying degrees. The 2–3 years of successive plantation of anti-season vegetables is the most effective and quickest way of making the newly reclaimed land ripen.
- Social benefits analysis: It has brought about a balanced supply of vegetables on the market. The two vegetable production bases in Zigui County have not only eased the vegetable shortages and enriched variety at the dam construction site and the new county town of Zigui but also made the vegetable prices more reasonable.

  It has accelerated the pace of poor mountain villages to shake off poverty and embark on the road to wealth. Shiya used to be a typical poor mountain village. Thanks to the growing of anti-season vegetables in large areas, the income of the villagers has risen sharply. The per capita income in 1994 was only 398 yuan. By 1996, after growing anti-season vegetables, the per capita income reached 860 yuan and up to 1020 yuan by 1998. There are 14 households whose annual income has exceeded 10,000 yuan.

  It has expanded the capacity for accepting resettled people and improving their living standards. Vegetable production is a labor-intensive industry. The two major vegetable production bases have not only expanded the capacity for accepting relocated people but also helped improve their living standards. Part of the resettled people can earn at least 1000 yuan from growing vegetables alone. The income from vegetable growing is accounted for 64–92% of their annual total income.

Experiments in courtyard economy

The reservoir area is suitable for developing courtyard economy, especially for growing fruits and vegetables. But the courtyard economy is subjected to constraints of funds, technology, personnel, and management expertise in addition to the influence of plant culture, breeding culture and processing industry. Only by coordinating well the internal structure and the relations between internal and external sources is it possible to display fully the comprehensive efficiency of the courtyard economic system. The area should display to the full its comparable advantages and build the optimal structure that covers biocirculating mode, vertical cultivation mode and farm and sideline primary processing. The biocirculating mode should be centered round biogas pits to realize the material and energy circulation and multistage utilization, such as grazing grass growing, farm and sideline products—Pig raising, Sheep raising-biogas pit-farmland, and orchards. Vertical cultivation model should be rationally distributed with Washington navel growing dominating, such as Washington navel–grazing grass-Pig (Chicken, Sheep) farming, navel–water melon–vegetables, grape-strawberry, Sheeppan–sechium. The courtyard primary processing of farm and sideline products should cover such areas as preservation, storage, and packaging of Washington navel and bean sprout processing.

7.11.4 Wanzhou Eco-environmental Station

The station started in 1998. It has carried out experiments in water-efficiency agriculture in arid land, the composite furrow cultivation of grain, cash crops and fruits on dry slope land, vegetation restoration, and plant hedgerows of land returned from farmland and the domestication of famous, specialty fruits and medicinal herbs. It has monitored soil fertility, runoff, and sediment yields of the runoff plot of the station, climatic and ecological factors, water and soil conservation measures on dry slope land and social and economic developments of resettled people. The aim is to restore the ecosystem and expand the environmental capacity for resettlement.

Experiments in the technology for domesticating fine strains and highly efficient ecological cultivation

The station has introduced 141 plants of fine strains, including vegetables, fruit trees, medicinal herbs, and grazing grass. They include 16 wheat varieties, 29 corn varieties, 35 rice varieties, 13 potato varieties, 18 vegetable varieties, 27 fruit tree species, 9 grazing grass varieties, and two medicinal herbs. It has also carried out corresponding year-round vegetable and anti-season vegetable cultivation, GRC green house facilities, and intercropping of grain and cash crops—fruit and grain, fruit and vegetables, fruit and grazing grass, and medicinal herbs. Successfully domesticated included such wheat varieties as Chuanyu-21688, Mianyang-335, Chuanyu-12, and Chuanyu-33976, such middle and late ripening rice varieties as II-you-746, II-you-906, II-you-838, Jinyou-10 and II-you-448; new corn varieties of Chengdan-2065, Yayu-2, Chengdan-16, and Chengdan-14; such find grazing grass as Hybrid Giant Napier (*Ponnisetum hydridum*) and Ryegrass (*Lolium perenne*), high-valued medicinal herbs of Yellow yam (*Dioscorea panthaica*), Peltate yam rahizome (*Dioscorea zingiberensis*), such fruit trees as Japanese sweet nectarine (*Prunus persica*), Zhonghua shoutao (*Prunus persica* '*Zhonghuashoutao*'), Winter Peach (*Prunus persica*), Fengshui pear (*Pyrus* sp.), Qiuhong pear (*Pyrus* sp.), Nachi Pear (*Pyrus* '*Atagonashi*'), and Big Five-star Loquat (*Eriobotrya japonica* '*Dawuxing*'); as well as hybrid water melon, green pepper, and pumpkins. All these have been widespread in the reservoir area.

Experiments in the technology for water-efficient agriculture with underground plastic sheet water wall in dry slope land.

Experiments show that the technique can effectively block part of the interflow in the dry slope land, raise, and conserve soil moisture, and therefore ease and mitigate the hazards of seasonal drought and raise crop output. The plastic sheet water walls laid at the bottom and middle part of the slope land are the most effective way of increasing crop output.

Experiments in technology of composite ridge culture on slope land or agro-forestry technique of slope cropland

Experiment results show that the integration of the ridge culture with agro-forestry intercropping and the breeding of "short, dense, high-yielding and early-ripening" fruit trees can turn slope-wise cultivation into horizontal checkerboard ridge cultivation and turn single cropping into multi-cropping cultivation. The observation of soil thickness, pores, moisture, and water and soil loss in the experimental plots showed that the thickness of cultivated soil increased by 24.8 cm on average; the volume-weight of soil was reduced by 19.58%; pores increased by 19.15%; the water content of soil was raised by 60.72%; Nutrients of soil were raised sharply, with organic matters increasing by 18.95%, TN, by 11.57%, TP, by 11.48% and TK, by 7.07%, AHN, by 13.46%, fast-acting phosphate, by 16.62% and fast-acting potassium by 10.29%. The soil erosion has been reduced by over 90% at the maximum. The output of wheat was increased by 17.57%; corn, by 9.45%, peanuts, by 13.16%; and Soybean, by 15.38%. Usually, the economic results may be doubled and redoubled after 3 years.

Experiments in the technology of plant hedgerows in slope cropland

Plant hedgerow in slope cropland is one of the most effective measures for conserving soil and water. They have the functions of conserving water, fixing soil, increasing soil fertility, and increasing output and income.

Famous new fruits introduction and eco-cultivation technology (Wanzhou eco-environmental station)

Fruit and grass mixed cropping mode (Wanzhou eco-environmental station)

Plant hedgerow experiments were carried out by selecting suitable plants and applying proper laying techniques, agro-forestry management techniques, and cultivation and management of farm crops (cash fruit trees, medicinal herbs, and grazing grass), supplemented by such mini-engineering measures as laying straw ridges and stalk covering. Then quality farm crops, fruit trees, medicinal herbs, and grazing grass were planted in between the hedgerows. Plus animal husbandry and breeding industry, they all go to achieve the purpose of cyclic and sustainable utilization of ecological and economic resources.

Observation showed that in 2 years, the gradients in between hedgerows were reduced from 25° to 22°. The plant hedgerows separated the slope cropland into smaller slope land, thus shortening the slope length. The branches and leaves of the hedgerows can be put on the upper side of the hedgerows and be used as green mature that can improve the physiochemical characters of the soil in between the hedgerows. The soil layer can increase by 4.6 cm in thickness; the soil volume-weight can be reduced by 10.34%; the total porosity can increase by 16.12%; the water content of the soil can increase by 65.31%. The organic matters, TN, TP, TK, AHN, fast-acting phosphate and fast-acting potassium increased by at least 10%, with the maximum at 21.50%; the soil erosion was cut by over 90%.

Table 7.38 Water quality assessment of the mainstream cross-section of the Yangtze in the construction site in 1994–2002

Cross-section	1994	1995	1996	1997	1998	1999	2000	2001	2002
Taipingxi	III	III	III	III	II	II	III	III	II
Dongyuemiao	III	III	III	III	II	II	III	III	II
Letianxi	III	III	III	III	II	II	III	III	II

7.12 Construction Site Monitoring Results[12]

7.12.1 Water Quality

The monitoring of the construction site shows that the water quality of the construction site section of the Yangtze has been maintained at Type II–III class standards (GB3838-1988). The same is true with the riparian water quality.

Water quality at the mainstream cross-section

In the 9 years from 1994 to 2002, the water quality of the mainstream cross-section basically remained at Type II–III class standards. The changes in water quality of the controlled cross-section (Dongyuemiao) and attenuation cross-section (Letianxi) were basically identical with that of the contrast cross-section (Taipingxi). See Table 7.38.

The TGP may affect the pH value of water. The monitoring of the annual characters of the comprehensive indices of petroleum and organic matters shows that the water quality in the mainstream of the Yangtze is controlled within standards, without significant differences in the contents of monitored factors between the contrast cross-section (Taipingxi) and controlled cross-sections (Dongyuemiao and Letianxi), indicating no obvious unfavorable effect of the project on the general water quality of the Yangtze mainstream.

Quality of riparian water

In 1994–2002, the annual average assessment results by all monitoring points show that the water is of Type II–III class standards, basically the same as the mainstream cross-sections. See Table 7.39. But, affected by the flow from the upper stream, the water quality in the third quarter of every year is poorer than the other quarters, where the TPb and COD_{Mn}.contents are higher.

The COD_{Mn} content and suspended matters in the riparian water during the first phase project (1993–1997) are obviously higher than in the water body of the cross-section, but there is no obvious difference in the COD_{Mn} content and suspended matters during the second phase of the construction (1997–2003). This shows that the project has strengthened pollution control and the impact on the riparian water environment has been minimized.

[12]China Three Gorges Corporation (CTGC). Technical Report of Environmental Monitoring Station of Construction Site (1996–2003).

Aquatic life

(1) Phytoplankton

The total Phytoplankton collected belongs to 87 genera in eight phyla, including 28 genera of Diatoms (*Bacillariophyta*), 35 genera of Green algae (*Chlorophyta*), 14 genera of Cyanobacteria (*Cyanophyta*), 2 genera of Dinoflagellate (*Pyrrophyta*), 3 genera of Euglenoids (*Euglenophyta*) and 3 genera of Yellow-green algae (*Xanthophyta*), one genus of Cryptomonads (*Cryptophyta*), and one genus of Golden-brown algae (*Chrysophyta*). Diatoms, Green algae, and Cyanobacteria are the main Phytoplankton in the construction site, making up 32.2, 40.0, and 16.1% of the total.

The frequently seen species of Phytoplankton are mainly *Melosira*, *Cyclotella*, *Tabellaria*, *Diatoma*, *Fragilaria*, *Synedra*, *Navicula*, *Cymbella*, *Gomphonema*, *Nitzschia*, *Surirella*, *Cocconeis*, *Gyrosigma* and *Pinnularia* of Diatoms, *Pediastrum*, *Scenedesmus*, *Closterium*, *Uloothrix*, *Spirogyra,* and *Staurastrum* of Green algae and *Oscillatoria* of Cyanobacteria.

The density of Phytoplankton is high in spring, ranging 13,500–18,510 ind/L. It is low in autumn, ranging 1900–54,000 ind/L. Diatoms is the main component part of the density of Phytoplankton, with the density in spring being 12,300–121,400 ind/L and that in autumn being 1300–51,000 ind/L.

(2) Zooplankton

Collected are 69 genera in four major categories of zooplankton, including 29 genera of Protozoa, 26 genera of Rotifer (*Rotifera*), 9 genera of Cladocera, and 5 genera of Copepod. Protozoa and Rotifera are the main zooplankton, making up 42.0% and 37.7% of the total.

The most frequently seen are Amoebas (*Difflugia*), *Centropyxis*, *Arcella*, *Phryganella*, *Vorticellidae* and Epistylidis, *Brachionus* (angularis, calyeiflorus) and *Keratella* (cochlearis, quadrata, valaa) of Rotifer, *Bosminidae*, *Alona* and *Chydoridae* of Water flea (*Branchiopod*), and *Cyclopoidea* of Copepod (*Copepoda*).

The density of zooplankton is high in spring, ranging from 60 to 3300.2 ind/L. But it is low in autumn, ranging

Table 7.39 Riparian water quality assessment at the Yangtze mainstream in the construction site in 1994–2002

Sampling point		Year								
		1994	1995	1996	1997	1998	1999	2000	2001	2002
Left bank	Upper cofferdam					II	II	II	III	II
	Lower cofferdam					II	II	III	III	II
	Downstream approach channel						II	II	II	II
	Bahekou	III	III	III	III	II	II	II	III	II
	Yingzizui	III	III	III	III	II	II	II	III	II
	Ziniuwan						II	II	III	II
	Xia'anxi							III	III	II
Right bank	Lao Maoping Zhen					II	II	II	III	II
	Mouth of Maopingxi					II	II	III	III	II
	Gaojiaxi	III	III	III	III	II		III	III	II
	Baimiaozi	III	III	III	III	II	II	II	III	II
	Yangjiawan	III	III	III	III	II	II	II	III	II
	Daishi	III	III	III	III	II	II	III	II	II

from 0 to 2103.0 ind/L. Protozoa is the main body of zooplankton, whose density is 60.0–2300.0 ind/L in spring and 0–2100 ind/L in autumn.

(3) Benthos

Benthos collected belong to 22 genera in five major categories, including 5 genera of Oligochaete (*Oligochaeta*), 7 genera of aquatic insects, 5 genera of *Crustacean*, 4 genera of Mollusk (*Mollusca*) and 1 genus of Flat-bodied plankton.

Most frequently seen are Tubifex (*Limnodrilus*) of Oligochaete, Shrimp, and larva of Aquatic insects.

Quantitative sampling of artificial base materials by using basket sampler (18 cm in diameter and 20 cm in height) shows that the number of benthos in the construction site ranges from 5 to 1100 ind.

(4) Basic statuses of aquatic life

1996–2002 monitoring shows that there are 87 genera of Phytoplankton in the mainstream of the Yangtze in the construction site, with a density being 1900–185,100 ind/L. Diatoms is the most frequently seen population. There are 69 genera of zooplankton, with a density being 0–3399.2 ind/L; 22 genera of benthos, few in number. In general, there is a rich variety of Phytoplankton. But the plankton and benthos in the Yangtze mainstream of the construction site are few and far between, with density and biomass being small. This is associated with the ecological conditions characterized by high velocity and high contents of suspended matters.

Phytoplankton density comparison among all cross-sections in the construction site shows that during the construction period, the composition of Phytoplankton is stable, with the total density of Phytoplankton and Diatoms density being identical in Dongyuemiao (controlled cross-section), Letianxi (subduction cross-section), Taipingxi (contrast cross-section and Gaojiaxi cross-section). This indicates that the construction of the dam has not had any significant impact on the structure of aquatic life.

7.12.2 Air Quality

By using the daily mean value of SO_2, NO_x, and TSP (NO_x has been changed into NO_2 starting from 2000) as assessment parameters, the monitoring of the air in the construction site in 1994–2002 shows that the air quality is good.

- During the first phase of construction, SO_2 in the air of the office and living area of the construction site conformed to Type II standards; that in the operational area conformed to Type I–II standards. In the second phase of construction, SO_2 in the air conformed to Type I standards in both the office and living area and the engineering area. See Fig. 7.50.
- In the first phase of construction, NOx in the air of the office and living area conformed to Type I–III standards and NOx(NO_2) in the air of the operating area conformed to Type I–III standards. But in the second phase of the project, NOx (NO_2) conformed to Type I standards in both office and living area and the engineering area (see Fig. 7.51).
- In the first phase of the project, TSP in the office and living area and engineering area reached Type I and

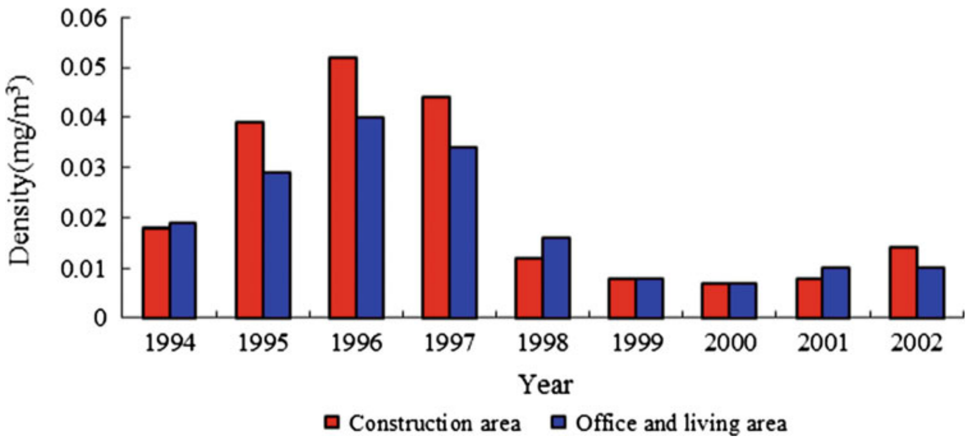


Fig. 7.50 Annual changes in SO_2 in the construction area in 1994–2002

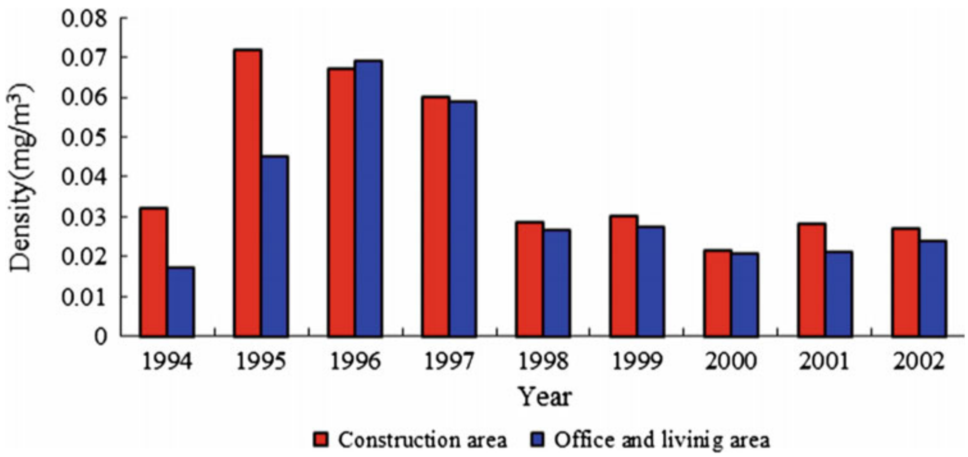


Fig. 7.51 Annual changes in NOx (NO_2) in the construction area in 1994–2002

super Type III standards; but in the second phase of the project, TSP remained the same in all area, but the amount above the standards assumed a downward trend. See Fig. 7.52.

- Monitoring results show that there is slight pollution of the air in the construction site, with the main pollutant being TSP. But the air quality in the second phase of the project is improved, with the contents of SO_2, NOx(NO_2) and TSP reduced in general. This indicates that with the reduction in excavation and land leveling work, the air quality improved.

7.12.3 Noise

1996–2002 monitoring of the noise pollution in the construction site shows that noise changed greatly in the day and at night in the office and living area. In 1996–1999, it was identified as Type 0–4 area. But up to 2000, it was identified as above Type IV. In 2001, it was identified as Type 0–3 area, and by 2002 it became a Type 0–2 area, indicating a turn for the better. But there was little improvement in the engineering area.

Office and living area

In 1996–2000, the high value of Ld (equivalent sound level) conformed to Type IV standards. In 2001, Ld conformed to Type 0–3 standards. In 2002, it conformed to Type 0–2 standards. Except 2001 when Ld conformed to Type 0–4 standards, the Ld of all the other years was above Type IV standards.

Construction site

The noise in the construction site conformed to the 90 dB standard set for workshops and operational sites (in contact with noise for 8 h in succession) in the state "Noise Control Design Standards for Industrial Enterprises" (GBJ87—1985). See Table 7.40.

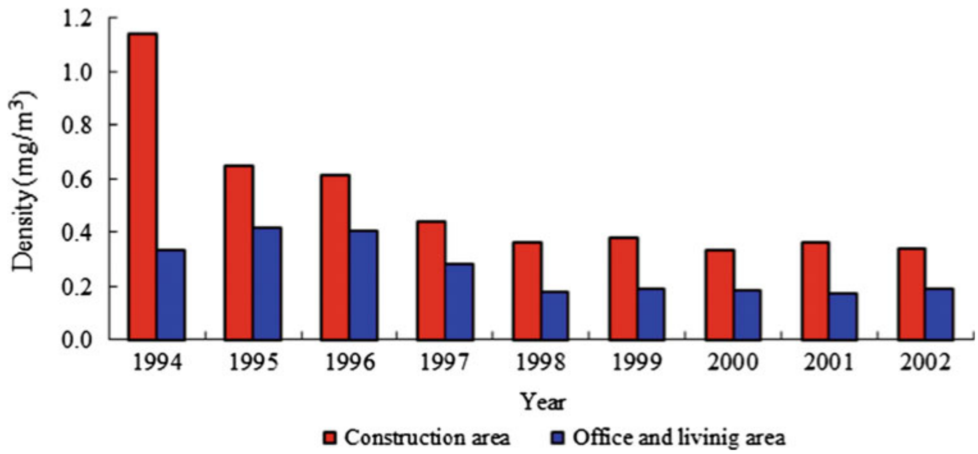


Fig. 7.52 Annual changes in TSP in the construction area in 1994–2002

Table 7.40 Noise assessment in the construction area

Year	Office and living area		Construction area	Construction roads
	Day	Night		
1996	1–4	2–Above 4	Conforming to standard	2–Above 4
1997	2–4	2–Above 4	Conforming to standard	4–Above 4
1998	0–4	0–Above 4	Conforming to standard	1–Above 4
1999	0–4	0–Above 4	Conforming to standard	2–Above 4
2000	1–Above 4	2–Above 4	Conforming to standard	4–Above 4
2001	0–3	2–4	Conforming to standard	4–Above 4
2002	0–2	1–Above 4	Conforming to standard	4–Above 4

Noise on roads
Noise on the two sides of the Jiangxia and Xiling roads was seriously above the standards and was assuming an upward trend. The noise was mainly caused by moving vehicles. There were more vehicles, especially the big tonnage vehicles, the severer the noise would be

7.12.4 Conclusions

Since the start of the project in 1992, the Three Gorges Project Corporation has conscientiously implemented the Program of Action for the Protection of the Environment of the Construction Site. It has adopted a series of measures to control and protect the environment. It has basically realized its goal. The environmental quality has been good and all the controlled indices have been kept stable since the damming of the river.

The water quality in the construction site section of the river has been kept at Type II–III standards (GB3838-1988, single factor assessment method). The water quality in the contrast cross-sections, controlled cross-sections, attenuation cross-sections and the riparian water has basically been kept identical. The water sources for waterworks and water supply conform to the standards for drinking water. The air quality in the construction site is also good. NO_2 and SO_2 all conform to Type I standards (GB3096-1996). The main pollutant in the air is TSP. There has been a turn for the better in recent years, with that in the office and living areas conforming to Type I–II standards and construction area conforming to Type I–II standards in 66% of the tests. The noise pollution in the construction site has met the requirements by the state and it has been reduced year by year. The water and soil loss has been brought under effective control. Water and soil conservation and greening projects have been fruitful. The public sanitation conditions are good. There has been no outbreak of infectious diseases.

8 Ecological and Environmental Monitoring After Reservoir Impoundment

8.1 Necessity of Updating

The Three Gorges reservoir began to store water in June 2003. By November 5, the water level had risen to El.139 meters. As the formation of the reservoir has a certain impact on the hydrological regime of the Yangtze, the monitoring system and emphasis of monitoring should also change correspondingly according to the changes in natural environment conditions. At the same time, since 1995, with the changes in overall environment and policies, the shift of functions of the government, the building of major ecological projects, technical progress and the readjustment of the goals of the monitoring system itself, great changes have taken place in the environment where the monitoring system is being operated. So, all those as above require necessary modification of the monitoring program.

Changes in Environment of the Reservoir Area

After the impoundment of the reservoir in June 2003, it has brought about changes in the natural hydrological regime. The water surface of the reservoir has been widened; the flow velocity has slowed down and sediment has deposited. With the progress of the project and the rise of the water level, the TGP began to display its function of flood control. The operation of the reservoir determines that there would be a water-level fluctuating zone to the banks of the river in the reservoir area, where there would be a unique ecosystem with terrestrial and aquatic ecosystems acting upon each other. While, downstream of the dam, due to changes in the water flow during high and low seasons, there would be scouring to a certain extent, thus changing the river regime evolution.

In addition, the natural environment has also improved due to much state investment in such projects as returning farmland back to forests, protecting natural forests and building green belts around the reservoir. The water pollution control projects in the reservoir area and its upstream will lighten the pollution load of the reservoir and improve the water quality.

Now that construction and operation are going on simultaneously and will last for some time, but by the end it will be mainly on the stage of operation, the monitoring points and requirements will have to be changed according to the features of the new environment. The central task of the monitoring system should also be shifted from mainly collecting baseline information to serving reservoir management, safety operation, and sustainable development of the reservoir area and to serving the purpose of retrospective review of the environmental impact. The whole monitoring system must adapt itself to the changes of the new situation.

Changes in Policy

Since 1996, with China entering into the WTO and the development of the socialist market economy, the government has taken new steps to bring its administrative behavior and environmental standards in line with those of the world and changed its policies and rules and regulations by which the monitoring system operates. Not only have the original policies and rules and regulations been changed and modified and becoming more demanding, but also new policies and new rules and regulations have been formulated. The new "Water Law" was put into effect on October 1, 2002; Law on Environmental Impact Assessment has also been promulgated. The state has modified the standards for surface water (GB3838—2002).

It also needs further study as to how to draw on and apply the owner responsibility system, the bidding system, the project supervision system, and the contract management

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system introduced for the TGP in line with market rules. In reality, apart from the contract management system, the other three systems have not been effectively implemented especially the project supervision system. The traditional administrative management still dominates the implementation of project management, making the monitoring system unable to meet the requirements of the developing situation, thus affecting the efficiency and capability of the monitoring system.

Changes in Technology

The technical progress, especially the heightening of the ecological awareness of the people, has raised higher demand on ecological and environmental monitoring. The missing out contents have to be added and such technical means as monitoring instruments and meters have to be improved.

The original system mainly does monitoring at selected points and lines. With the application of remote sensing technology, the vertical dynamic monitoring system has become a possibility so that the monitoring system may get a full picture of TPG impacts on the environment in an integrated manner and from a macroscopic angle.

The progress in the IT technologies, such as Internet, has made information exchange much easier and the databank technology has made the integrated management of tables, charts and graphics and images a possibility and made the information sharing more convenient. The data accumulation has raised higher demands on the monitoring system with regard to integrated analysis, forecast, application, and development of pre-warnings.

Necessity of the Improvement in the Monitoring System Itself

Following 8 years of operation, the TPG environmental monitoring system has completed baseline surveys and has to deal with new problems and new situations after the impoundment of the reservoir. The water quality monitoring has to be changed according to the post-impoundment hydrological regime; the pollution sources monitoring has to know the changes of discharge outlets of the new wastewater treatment plants and garbage disposal sites. The monitoring of eutrophication has to be undertaken in the backwater zones of tributaries; there are problems of repetition and drawbacks in monitoring targets among different monitoring stations.

The purpose of updating is to make the monitoring targets more complete and system management sounder, so as to make it better adapt to the administrative system and raise the efficiency and capabilities onto a new level.

8.2 Adjustment of the Monitoring Indicator System

The guideline for the modification is to proceed step by step under a unified planning and strive to bring the monitoring system to perfection according to the trans-regional, trans-sectoral, multi-disciplinary, and multilevel characteristics to make it well matched with the progress and requirements of the TGP so that it is put in better service of the eco-environmental protection and the operation of the reservoir.

The original monitoring system started operation in 1996. After it was adjusted in 2000, it has become what it is today, with 19 major monitoring (experimental) stations, each station having its own monitoring objectives and targets and their own indices. They first established the targets of monitoring and then, according to different targets, set up major monitoring stations at authoritative units and sectoral departments, which fixed their base stations and indicators systems according to their respective monitoring targets. The whole monitoring system has, through many years of continuous work, obtained a large amount of previous baseline data on the TGP impact on the ecology and environment. But with the monitoring going into depth, some indicators have fallen short of the requirements, making it difficult to realize the monitoring goals for future development. The main drawbacks are:

The original monitoring indicator system was designed to suit the ecology and environment conditions of a given period of time before the reservoir was built. The classification was more to meet the requirements of traditional management. But changes have taken places in all the natural, social, and economic conditions in the areas affected by the TGP, which dictates the corresponding changes in the indicator system. For instance, when the preliminary water storage and power generation started in June 2003, the reservoir brought about changes in the hydrological regime and natural conditions and the pollution and eutrophication of major tributaries emerged as a major problem, hence the necessity of corresponding adjustments in the indicators for monitoring.

As the indicator system was designed according to the monitoring capabilities and habitual requirements of all major stations, a small part of the indicators were repetitive and unsystematic, with some satisfying only the requirements of the current industrial management instead of the requirements of the TGP impact or the requirements of the reservoir management. Besides, some items for monitoring were missing. It is, therefore, necessary to design a new indicator system to raise the monitoring abilities of the system, to make it capable of carrying out integrated monitoring of the TPG impact on the environment. The indicators for non-point pollution source monitoring represented fewer types of land and the scope of distribution of monitoring points is limited, falling short of the requirements for overall monitoring. The existing terrestrial plants monitoring system did the work by using points and lines quadrates, which are not so representative with regard to monitoring scope. In addition, the frequency of monitoring is not enough and poor in synchronization. It is, therefore, necessary to add more representative land and increase the monitoring frequency and synchronization.

The monitoring indicator system after the reservoir water storage was divided into four levels: system, sub-systems, classes and subclasses. We have made further studies of the system according to the monitoring objectives. In the classification mentioned in Chap. 4, we gave more consideration to the traditional mode of management and practical needs, thus rendering the system less scientific. For instance, the "Sub-system in Table 4.5 was made both according to scientific classification such as hydrology and water quality and according to the regional classification such as estuary ecology. It is also classified according to ways of monitoring such as remote sensing and according to the work nature of stations such as eco-environmental experimental stations. In a word, the way of classification is complicated and confused, not so scientific.

With these problems in mind, we have in this section made some improvements in the indicator system, doing away as far as possible with crossed and repetitive monitoring in different sub-systems at the same level or among different classes such as is shown in Fig. 8.1.

The first level is the system, which reflects the general situation of the monitoring system.

The second level covers the sub-systems, which has been integrated from 12 before the impoundment into nine in line with the new natural and social conditions. They are pollution sources, hydro-environment, aquatic life, terrestrial ecology, wetland ecology, climate conditions, social environment, integrated, and other sub-systems. The 11 sub-systems mentioned in Chap. 4 have been reclassified into six sub-systems, with (water-level fluctuating zone) wetland ecology and the integrated sub-system added.

The third level covers classes, which are divided into 26 according to the nature and characteristics of issues.

The fourth level involves subclasses. It has 52 subclasses, giving prominence to the comprehensive monitoring indicators.

Below the fourth level are specific monitoring indicators selected according to the state standards and the actual conditions of the TGP.

The integration and monitoring of the sub-systems are shown as follows:

The pollution source sub-system remains unchanged in both sub-system and classes, with additions made only to the subclasses according to the changes following the water storage of the reservoir.

The hydro-environment sub-system has integrated hydrology and water quality sub-systems and the water quality for fisheries in the "Fisheries and Aquatic Life Sub-System" and the estuary water quality and salinization in the "Estuary Eco-Environment Sub-system" in Table 4.5 of Chap. 4. Besides, "temperature stratification of the reservoir" and "Eutrophication of Tributaries in the reservoir area" has been added.

The aquatic life sub-system has integrated the "Fisheries and Aquatic Life Sub-System", the aquatic life part of the "Hydrology and Water Quality Sub-System" and the estuary plankton and benthos life in the "Estuary Eco-Environmental Sub-system" in Table 4.5.

The terrestrial ecology sub-system has integrated the "Terrestrial Animal and Plant Sub-System", the "Terrestrial Plant Observation and Experimental Stations" and the water and soil loss in the "Remote Sensing Sub-System" in Table 4.5 and adjustments have been in line with the needs of the reservoir after impoundment.

The wetland sub-system has been added according to the changes of water level and the emergence of the water-level fluctuating zone, an issue that has caught extensive attention at home and abroad and is therefore very important for the reservoir as a scenic spot. After water storaged, the water-level fluctuating zone has become an anti-season wetland ecosystem, with low water level in the high water season but high water level in the low water season. As a sub-system, it merits special attention.

The climatic sub-system remains unchanged as the "Local Climate Sub-System" in Chap. 4.

The social environment sub-system has integrated the "Socio-Economic Sub-System" and "People's Health Sub-System" in Chap. 4, with the sample surveys of urban resettlement added.

The integrated sub-system gives prominence to the importance of comprehensive analysis and information integrated management in studying the impact of TGP.

Other sub-systems have not been integrated and adjusted as they belong to different management departments. They remained the same as in Chap. 4.

The third and fourth levels may be divided into sample monitoring and typical monitoring according to methods of work. Sample monitoring includes point pollution sources, floating pollution sources, terrestrial animals, people's health and follow-up survey of the resettled people; typical monitoring includes non-point pollution sources, mainstream water quality, and eutrophication of reservoir water and local climate, which require a long-time and continuous monitoring at fixed points.

There are also regular monitoring and specialized monitoring according to monitoring frequency and organizational method. Specialized monitoring is applicable to that with low frequencies, such as pollution sources, terrestrial

System	Sub-Systems	Class	Sub-classes
TGP Ecological and Environmental Monitoring System	Other	Geological hazards	Specialized monitoring and precaution,mass participation
		Induced earthquake	Seismological station,earth crust deformation,underground water dynamic observation well
		Sediment deposit and scouring	Hydrology, underwater topography and sediment
		Construction site monitoring	Hydrology and water quality, air, noise, people's health
	comprehensiveness	Information management and release	Websites
			Reporting
			Information system
		Integrated analysis and assessment	Sustainable development capability
			Ecology and environment security
			Socio economic environment
			Biodiversity
			Hydro-environmental
	Social Environment	Follow-up survey of resettled people	Sample survey of urban resettled people
			Sample survey of resettled rural people
		Socio-economy	Socio-economy
		People's health	People's health
	Climatic	Local climate	Vertical climate
			Regular climate
	Wetland Ecology	Landscape ecology of the water-level fluctuating zone	Soil pollution
			Land utilization
		Animals and plant in water-level fluctuating zone	Plants
			Animals
	Terrestrial Ecology	Water and soil loss	Soil erosion
		Terrestrial places	Habitat Quality
			Vegetation physiological parameter
			Vegetation
		Terrestrial animals	Terrestrial animals
		Forest resources	Forest resources
		Agricultural ecology	Productivity of nearly reclaimed land in reservoir area
			Agricultural eco-environment in reservoir
	Aquatic Life	Plankton and benthos	Plankton and benthos at estuary
			Planktons and benthos of mainstream
		Rare and endemic species	Rare species of fish
			Endemic species of fish
		Fishing resources	Fish resources at estuary
			Fish resources downstream of dam
			Fish resources in reservoir area
	Hydro-Environment	Underground water	Salinization at estuary
			Gleyed soil in midstream
		Tributary hydro-environment	Eutrophication of tributaries in reservoir area
		Mainstream hydro-environment	Water quality at estuary
			Water quality for fish resources
			Stratification temperature of reservoir
			Pollution belts
			Synchrony of hydrology and water quality
	Pollution Sources	Floating pollution sources	Pollution by vessels
		Non-point pollution sources	Farm chemical and breeding industry pollution
			Small catchment area
			Runoff ground
		Point pollution sources	Sewage and garbage treatment plant outfall
			Daily life pollution sources
			Industrial pollution sources

Fig. 8.1 Indicator system of the TGP eco-environmental monitoring system after reservoir water storage

animals and plants, water loss soil erosion, which does not change much annually. Limited financial resources are unable to ensure the quality of monitoring if they spread over scattered targets. So they do not need to be monitored every year. Annual monitoring may be carried out in a few years' interval.

This classification is the result of our study and exploration, taking into account the scientific nature and practical management convenience. But it is not hard and fast rule. In fact, during the monitoring by major stations, there are both sample monitoring and typical monitoring and both specialized monitoring and regular monitoring. It is up to various major stations to decide what kind of monitoring to be conducted according to actual circumstances.

The indicator system in this book is designed for use in assessing the TGP impact, with the main purposes of avoiding unfavorable effects. This is the characteristics of the system and the requirements of management. The developments of river management in the world show that the establishment of an indicator system for monitoring the health of an ecological system and for facilitating management, by making river, reservoir and lake as "organisms", has gradually become a hot spot in river monitoring, study, and management [28, 29]. It is, therefore, a future development trend to monitor and assess the impact of water projects on ecology and environment by determining the health of the ecological system. So, it is that of the Three Gorges reservoir as the main objective, a monitoring indicator system has been set up.

8.3 Targets of Monitoring of All Sub-systems After Impoundment

This section mainly gives a general description of the scope and targets for monitoring by the eight sub-systems. It does include the other four specialized monitoring targets as they have their own program of action.

8.3.1 Pollution Sources Sub-system

Purpose: to get clear about the major pollutant loads and sources as well as the total pollution loads of the reservoir so as to provide the basis for controlling the pollution and protecting the water quality.

Point Pollution Sources

In order to ensure the water quality of the reservoir, the state started in 2001 to invest heavily in building a series of sewage and garbage treatment plants, which would be completed one after another after the impoundment of the reservoir in June 2003. After that, fish culture in net pen (cage culture) appeared in some places. It is, therefore, necessary to intensify monitoring of the completed sewage and garbage plants in addition to the industrial and urban sewage monitoring, so as to estimate the contributions to pollution by the cage culture.

(1) Monitoring scope

Industrial pollution sources, urban sewage outlets, outlets of sewage treatment plants, garbage dump sites and fish breeding cages.

(2) Indicators

Industrial pollution sources: industrial wastewater discharge, density and amount of major pollutants, new polluting enterprises and main pollution load and the number of enterprises passing through environmental assessment.

Urban sewage outlets: Number of urban people, urban area, tap water supply, sewage discharge and annual discharge of BOD_5, COD_{Cr}, TP, NH_3-N, ArOH, Oil; amount of daily sewage generated and discharged, and cumulative stock and position of garbage dump sites.

The third and fourth levels may be divided into sample monitoring and typical monitoring according to methods of work. Sample monitoring includes point pollution sources, floating pollution sources, terrestrial animals, people's health and follow-up survey of the resettled people; typical monitoring includes non-point pollution sources, mainstream water quality and eutrophication of reservoir water and local climate, which require a long-time and continuous monitoring at fixed points.

Sewage treatment plants: sewage collection rate, discharge amount, and density of BOD_5, COD_{Cr}, TP, NH_3-N, ArOH, and Oil discharged.

Garbage dump sites: garbage collection rate, annual amount dumped, leakage and treatment.

Fish cage culture: type, composition and amount of baits used and their contributions to pollution.

To prevent water pollution in the Three Gorges Reservoir, the state invested a lot to build sewage treatment plant. How much sewage can be treated actually by the sewage treatment plants in the area? How much is the pollution load? Would cage culture bring about water pollution? And how about are landfill, large-scale livestock and poultry pollution, etc.? The water pollution pattern in the area has changed, so it is necessary to adjust the content to adapt to this change with the monitoring need. The picture shows the cage culture in the reservoir (Photo by Huang Zhenli)

Non-point Pollution Sources

Before the reservoir impoundment, surveys were carried out only on the use of farm chemicals and chemical fertilizers, paying not much attention to animal and poultry farming. With rise in scale of animal and poultry farming, pollution caused cannot be ignored. Farm chemicals, chemical fertilizers as well as animal and poultry farming pollute the reservoir in the form of non-point pollution. Runoff and small catchment area monitoring is important in estimating the load of non-point pollution sources. Some work was done before June 2003. But as the work was not standardized, typical or representative, it affected the accuracy of the estimation of the non-point pollution source loads. It is, therefore, necessary to carry out runoff plots observation in representative areas together with the agricultural non-point pollution sources survey and small catchment area monitoring, thus completing the non-point pollution load estimation system in the reservoir area.

(1) Monitoring of runoff plots

- Monitoring scope: It covers 64 runoff plots, including 16 existing runoff experimental plots and 48 new ones in Yiling, Xingshan and Zigui of Hubei Province, Jiangjin, Fengdu, Shizhu, Kaixian, Wushan, and Wanzhou in Chongqing.
  It is required to set up runoff plots according to different vegetations (different species and different ways of culture), different types of soil and different types of land use (village and urban area). They should be divided into three different slopes (5°, 15°, 25°), covering different types of landscapes, ecosystems, and arid crop systems (wheat, sweet potato, corn, and grazing grass), different modes of land utilization (forest-grain intercropping, forest-grazing grass cropping, grain-grass intercropping, grain-grass rotation, grass-grass rotation) and areas where farmland reclaimed from forests or grassland has been returned.
- Monitoring indicators
  – Runoff plots: longitude and latitude, length, width, gradients, slope length, photo, and annual loss in thickness;
  – Soil fertility in runoff plots: soil type, porosity, relative density, pH, characteristics of soil cross-section, grain size (three levels), organic matters, ammoniacal nitrogen, AHN, granulated phosphate, fast-acting phosphate, fast-acting potassium, TN, TP, TK,

cooper, zinc, lead, chromium, cadmium, mercury and arsenic, lasting organic pollutants (decomposed matters from farm chemicals and herbicides)

– Daily rainfall: maximum and continuous 10, 20, and 30 min heavy rains; surface runoff and sediment content in runoff.
– The precipitation of each rainfall and lasting time; maximum continuous 10, 20, and 30 min heavy rain; surface runoff; sediment content of runoff; vegetation covered by rainfall.
– Indicators for surface runoff: pH, TN, TP, ammoniacal nitrogen, soluble phosphate, soluble potassium; persistent organic pollutants (decomposed matters of farm chemicals and herbicides).
– Monitoring indicators for surface runoff sediment: organic matters, ammoniacal nitrogen, AHN, granulated phosphate, fast-acting phosphate, quick -acting potassium, TN, TP, TK, copper, zinc, lead, chromium, cadmium, mercury, arsenic, and farm chemical remnants.

There are 48 additional runoff areas, with different soil types, planting modes and gradients to monitor the non-point pollution load of slope land. The picture shows the runoff plot (*yellow* soil, *orange*-grazing grass intercropping and 5° of gradient) at Longtanping village, Taipingxi Town, Yiling District of Yichang City. Photo by Huang Zhenli

A brick-and-cement sand deposit pit is build below each runoff plot, which measures 1 m^3 in volume, 1 m deep and has a cover to prevent rainwater from falling directly into the pit. The picture shows the runoff plot (*yellow* soil, vegetable-potato intercropping, 15° in gradient) at Longtanping Village, Taipingxi Town, Yiling District of Yichang City. Photo by Huang Zhenli

Runoff plot in Kaixian of Chongqing (*purple* soil, rape-Ipomoea batatas intercropping and 25° in gradient)

Runoff plot of Wanzhou, Chongqing (*lime* soil, corn-Ipomoea batatas intercropping, 25° in gradient). Photo by Huang Zhenli

- Monitoring frequency: Monitoring is referred to each rainfall of a year.

(2) Small catchment area monitoring

- Monitoring cross-sections: Three hydrological control cross-sections and four side-stream current measuring weirs in the small catchment area of Laoyinggou, Tianba Township, Zigui County and a control observation cross-section at the river mouth.
  Three hydrological control cross-sections and four side-stream current measuring weirs at Laotu side-stream and Chenjiagou in the small catchment area of the Wuqiao River in Changling Town of Wanzhou District, two side-stream current measuring weirs in the Laotu catchment area and two in the side-stream at Tangpu Village, with the controlled observation cross-section at the confluence of the Chengjia Stream and the Wuqiao River at Chengjiagou, a controlled observation cross-section in the Wuqiao River before it flows into Changling Town and another controlled observation cross-section in the river before it empties into the Yangtze.
- Monitoring indicators: 1:10,000 scale DEM of small catchment area, soil atlas and land cover atlas, and cross-section longitude and latitude.
  Soil fertility: longitude and latitude, soil name, porosity, relative density, pH, character of soil cross-section, grain size (three levels), organic matters, ammoniacal nitrogen, AHN, granulated phosphate, quick-acting phosphate, quick-acting potassium, TN, TP, TK, copper, zinc, lead, chromium, cadmium, mercury, arsenic and persistent organic pollutants (decomposed matters of farm chemicals and herbicides).
  Precipitation of each rainfall and lasting time; maximum continuous 10, 20, and 30 min heavy rain; surface runoff; and sediment content of runoff.
  Precipitation of each rainfall and lasting time; maximum continuous 10, 20, and 30 min heavy rain; surface runoff; sediment content of runoff; nutrient loss; maximum continuous 10, 20, and 30 min heavy rain; surface runoff; and vegetation covered (major crops) by rainfall.
  Indicators for surface runoff: pH, TN, TP, ammoniacal nitrogen, soluble phosphate, soluble potassium; persistent organic pollutants (decomposed matters of farm chemicals and herbicides).
  Monitoring indicators for surface runoff sediment: organic matters, ammoniacal nitrogen, AHN, granulated phosphate, quick-acting phosphate, quick-acting potassium, TN, TP, TK, copper, zinc, lead, chromium, cadmium, mercury, arsenic, and farm chemical remnants.
- Monitoring frequency: Everyday and each rainfall in the whole year.
- Other requirements: Monitor 1–3 soil cross-sections for each type of soil, with the location of the cross-section marked on the soil atlas. Mode of culture should be marked in the land cover atlas.

(3) Farm chemicals, chemical fertilizer and livestock breeding pollution sources

- Scope of monitoring: 182 townships in Jiangjin, Banan, Yubei, Changshou, Wulong, Fuling, Fengdu, Shizhu, Kaixian, Zhongxian, Tiancheng, Yunyang, Fengjie, Wushan, Wuxi, Badong, Zigui, Xingshan, and Yiling Disrict (county, city).
- Indicators: Application of farm chemicals and chemical fertilizers by townships, unit area application; areas where farm chemicals and chemical fertilizers are applied, type of farm chemicals and chemical fertilizers, and in purity terms, with township as unit; unit area farm chemical and chemical fertilizer loss, ammonia loss, N_2O loss, runoff loss, nitrification denitrification loss; number of pits, large animals (cattle, mule, horse and donkey), Sheep, poultry (Chicken, duck and goose), faeces generated a year, proportion used as manure, nitrogen loss, and phosphate loss.

Mobile Pollution Sources

There are many vessels, large in number and widely distributed and strong in mobility, very difficult to monitor. In order to obtain representative and scientific data, it is necessary to carry out investigation and analysis of vessel types, number and pollutants discharged on the basis of getting clear about the basic situation of operating vessels and fix the number of different types of vessels put under monitoring and carrying out sample monitoring at different levels.

- Monitoring targets
  Major targets: oil-contaminated water, cabin water and ballast water, sewage water, garbage and waste gas.
  Sample number: 5–15%, with vessels having oil-contaminated water being no less than 350 and sample vessels with sewage, noise, garbage and waste gas being no less than 50 for each type.
- Indicators
  Basic situation of operating vessels: name of shipping company, type of vessel, number, power, tonnage, passenger and freight transportation on major navigation routes;
  Pollutant discharge: amount generated, amount treated, amount discharged, installation and use of waste disposal facilities; garbage reception and treatment at ports,

supervision and management of vessel pollution by marine departments.
Oil-contaminated water: pH, oil, and SS;
Sewage: SS, BOD_5, COD, TP, TN, and Bacillus coli;
Garbage: investigating the reception amount and whereabouts and estimating the total amount generated;
Waste gas: soot, NO_2, and SO_2;
Noise.

- Emergency monitoring of oil pollution accidents
  Pollution accidents by vessels may cause great damages to the hydro-environment and have a great impact on the people's life. In order to mitigate the impact of such accidents and provide the basis for emergency treatment, it is necessary to carry out emergency monitoring.
  Indicators should include
  Survey of basic conditions of operating vessels, type of pollutants involved, overflow of pollutants, and areas of waters affected;
  Indicators should include Oil, pH, COD, BOD, and major pollutants loaded by culprit vessels;
  Judgment of possible effects on the water body and impact of accident.

8.3.2 Hydro-Environment Sub-system

Purpose: to get clear about the changes of hydro-environment, accumulate data for assessment and development analysis and provide the basis for formulating control plans.

The Hydro-Environment Monitoring Sub-System was relatively sound before the reservoir impoundment. But after the impoundment, the river course has become a reservoir and there are corresponding changes in the distribution of monitoring points and the water function zoning and management and operation require unified arrangements. There should also be corresponding arrangements with regard to the monitoring targets as the water in the tributaries and reservoir bays is easy to be eutrophicated and stratified in temperature. This requires full study.

Mainstem Hydro-Environment

(1) Synchronized monitoring of hydrological regime and water quality

- Hydrological observation
  Cross-sections: 12 in all in Zhutuo, Tongguanyi, Linjiangmen of the Jialing River, Cuntan, Qingxichang, Tuokou, Guandukou, Nanjinguan, No. 37 dock of Hankou, Datong, Beipei of the Jialing River, and Wulong of the Wujiang River.
  Indicators: water level, flow volume, and average velocity at cross-sections.
- Water quality monitoring
  Cross-sections: Nine in all in the mainstream: Zhutuo, Tongguanyi, Cuntan, Qingxichang, a point 1 km downstream of Wanzhou, Guandukou, Nanjinguan, No. 37 dock of Hankou, and a point 23 km downstream of Wusongkou; Seven in all in the major tributaries: Beipei and Linjiangmen of the Jialing River, Wulong and Yulinhe of the Wujiang River, the Xiaojiang River, the Daning River, and the Xiangxi River.
  Vertical line and sampling points: nine monitoring points on three vertical lines of six cross-sections in Cuntan, Qingxichang, a point 1 km downstream of Wanzhou, Guandukou, Nanjinguan and No. 37 dock of Hankou, with three vertical sampling points on each vertical line, that is, at a point 0.5 m under water, 1/2 depth of water and 0.5 m from the river bed; seven monitoring points on three vertical lines in two cross-sections at Zhutuo and Tongguanyi, with one sampling point on each of the left and right vertical lines at a depth of 0.5 m and at 0.5 m from the river bed, with one sampling point at 0.5 m underwater, 1/2 of water depth and 0.5 m from the river bed on the mid-depth vertical line; 10 monitoring points and five vertical lines in the cross-section 23 km downstream of Wusongkou, with one sampling point on each vertical line at 0.5 m under water and 0.5 m from the river bed; three vertical lines and six monitoring points in the three cross-sections at Beipei of the Jiangling River, Linjiangmen and Wulong of the Wujiang River, with one sampling point 0.5 m under water and 0.5 m from the river bed of each vertical line; two vertical lines and two monitoring points in the cross-section of the mouths of the four tributaries of the Yulin, Xiaojiang, Daning and Xiangxi rivers, with one sampling point as a depth of 0.5 m under water.
  Indicators: temperature, pH, oxidation-reduction potential, conductivity, SS, DO, COD_{Mn}, BOD_5, NH_3-N, TN, TP, Total alkalinity, total hardness, Hg, Cr^{6+}, As, Cd, Cu, Pb, Oil, *B. Coli* in faeces, totaling 21, with COD_{Mn}, TP, TAs, THg, TCu, TPb and TCd analyzed in both clear and turbid water.
- Bottom mud monitoring
  Cross-sections: the same as for water quality monitoring, with samples collected from the river bed of each vertical line of the 16 cross-sections.
  Indicators: THg, TAs, TCu, TPb, TMn, TK, TP, organic matters, organic chloride farm chemical (eight elements), and organic phosphate farm chemical (five components).

(2) Monitoring of pollution belts

- Locations: pollution belts of typical pollution discharge outlets in the reservoir area.
- Indicators: flow, velocity, water level, shape of river course of the starting cross-sections; 2–3 indicators for water quality monitoring according to the special circumstances of pollutant discharge outlets.
- Cross-sections: 5–7 each time (including background water quality cross-section), 5–7 vertical lines, with samples collected from 3 to 5 levels of each vertical line.
- Other requirements: draw a pollution belt spatial distribution map.

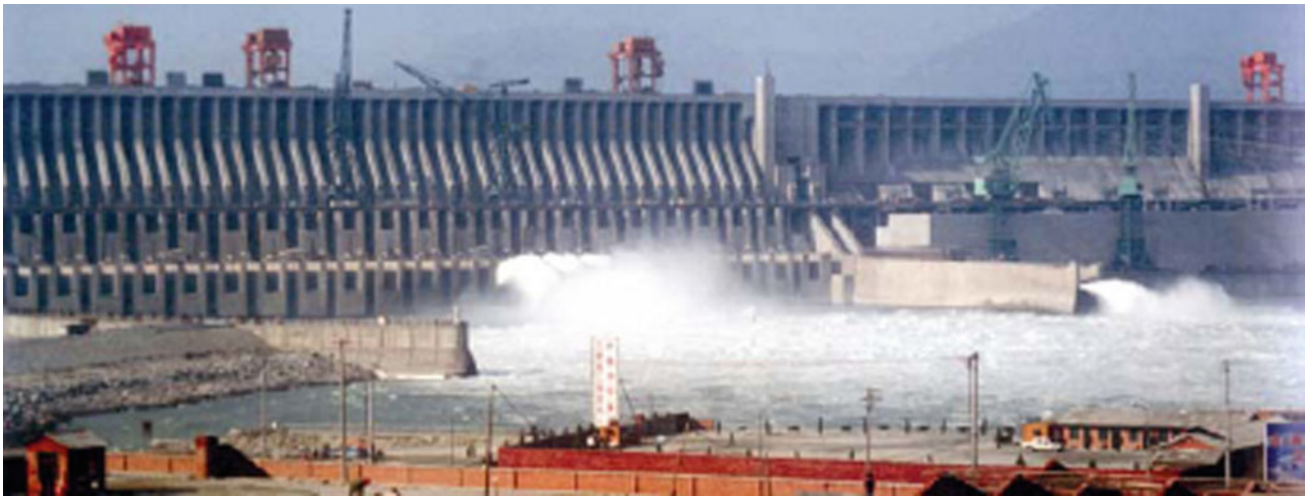
(3) Water temperature stratification monitoring

On the basis of the monitoring cross-sections of major stations that do both hydrology and water quality monitoring at the same time, it is to add vertical elements. The monitoring points are determined by local water depth and actually temperature observed, with 5–9 points in each vertical line.

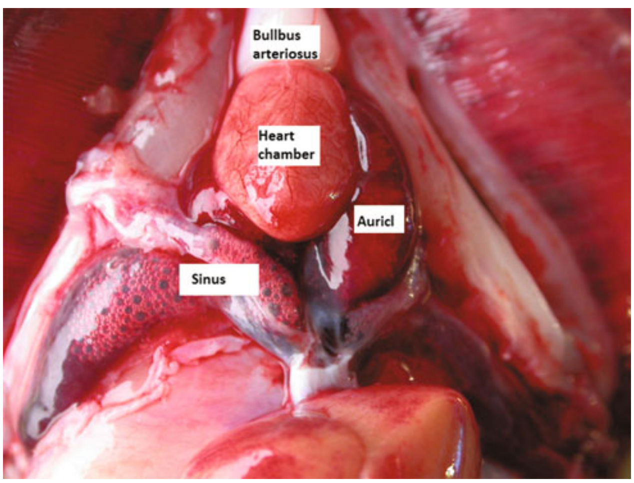
Monitoring is done for a complete hydrological year in major areas where temperature stratification is likely to appear based on a mathematical model. Sampling points are required to be distributed according to the size of measuring area before the dam and in reservoir bays. Sampling points on the vertical line should be distributed at 0.5–1 km intervals, which should be smaller if thermocline appears in actual measuring.

(4) Monitoring of water quality for fish

- Monitoring of fishing environment in reservoir area
  Locations: Yibin, Banan, Wanzhou, and Wushan.
  Indicators: temperature, pH, DO, COD_{Mn}, Cu, Zn, Pb, Cd, Cr^{6+}, Hg, ArOH, TP, NH_3-N, Oil, cyanides, SS, and As, totaling 17; heavy-metal remnants include Cu, Zn, Pb, Cd, Cr^{6+}, Hg, ArOH, and As, totaling eight.
- Spawning ground of Chinese sturgeon
  Locations: Mainstream Power Station, ship-lock, Miaozui, third-channel outlet, and Huyatan.
  Indicators: Temperature, pH, DO, COD_{Mn}, Cu, Zn, Pb, Cd, Cr^{6+}, Hg, ArOH, TP, NH_3-N, Oil, cyanides, SS, As, totaling 17.
- Spawning grounds of four major endemic species
  Locations: Zhicheng, Longzhou, Sanzhou, and Wuxue.
  Indicators: Temperature, pH, DO, COD_{Mn}, Cu, Zn, Pb, Cd, Cr^{6+}, Hg, ArOH, TP, NH_3-N, Oil, cyanides, SS, As, totaling 17.
- Spawning grounds in the lake areaLocations: East Dongting Lake, West Dongting Lake, South Dongting Lake, Poyang Lake (Duchang, Poyang and Xingzi).
  Indicators: Temperature, pH, clarity, SS, cyanides, DO, COD_{Mn}, NH_3-N, TN, TP, BOD_5, ArOH, sulfides, Cr^{6+}, As, Pb, Zn, Cd, Cu, chlorophyll-a, totaling 20.
- Estuary
  Locations: Tuanjiesha–Hengsha Island, Xinhe–Beicao, and Changxing–Jiuduan.
  Indicators: pH, DO, SS, salinity, inorganic nitrogen, TN, active phosphate, TP, COD_{Mn}, ArOH, Oil, Cu, Zn, Pb, Cb, Cr^{6+}, Hg, cyanides and As, totaling 19.
- Air supersaturation: When the dam releases water, a large amount of air would penetrate into the water, causing oversaturation of nitrogen and oxygen. That affects the growth of aquatic life, especially fish and may even cause death in serious cases. In the 2004 flood season, as only part of the power stations was operating, a large amount of water had to be discharged through the bottom outlets, causing death of fish due to oversaturation of nitrogen and oxygen. It is, therefore, necessary to intensify the monitoring of nitrogen and oxygen contents of water so as to discover problems timely and adopt corresponding measures.
  Scope of monitoring: to be decided on the flood release situation.
  Targets of monitoring: nitrogen and oxygen contents of the water body, saturation, respiratory and blood of fish, and the environmental factors for hydrology and water quality.



Gas oversaturation appeared in part of the downstream area in June, 2003 when the dam released water, causing significant fish biological effect



Dissection of dead fish discovers a large amount of bubbles in the heart and other organs

(5) Estuary water quality

- Monitoring scope and distribution of monitoring stations: 121°10′E–123°30′E, 30°45′N–32°00′N. Samples should be no less than 30.
- Indicators
  Hydro-physics: temperature, salinity, water depth, clarity, color, frontal surface, thermocline, and SS.
  Seawater chemistry: PO_4-P, SiO_3-Si, pH, DO, TN, TP, COD_{Mn}, BOD_5, NH_3-N, total salinity, TON, granulated organic carbon.

Hydro-Environment of Tributaries (Eutrophication of Tributaries in Reservoir Area)

(1) Monitoring scope

Select ten first level tributaries each with a catchment area larger than 1000 km^2 (Xiangxi, Daning, Meixi, Changtan, Modaoxi, Tangxi, Xiaojiang, Longhe, Longxi, and Yulin rivers), with three cross-sections set in each tributary: entry into the reservoir (175 m in water level), river mouth and in the middle.

(2) Requirements for sampling points distribution

Number of vertical lines and sampling points is determined by river width and depth, with one mid-depth vertical line in rivers less than 50 m wide; two in rivers with width ranging 50–100 m; and three for rivers with width bigger than 100 m. Each vertical line should have a sampling point 0.5 m under water surface on each vertical line with a depth less than 5 m; two sampling points 0.5 m under water and 0.5 m from the river bed in vertical line with a depth of 5–10 m; and three sampling points 0.5 m under water, 1/2 depth and 0.5 m from the river bed in vertical line deeper than 10 m.

(3) Indicators

- Hydrology: flow volume and flow velocity.
- Water quality: pH, color, temperature, clarity, turbidity, SS, DO, COD_{Mn}, BOD_5, NH_3-N, Cr^{6+}, TP, TN, TK, Carbon, TCu, TPb, THg and TAs, totaling 19.
- Bottom mud: color, granule size, organic matter content, TN, TP, TK, THg, TAs, TCu, TPb, TMn, organic chloride farm chemicals (eight components) and organic phosphate farm chemicals (five components), totaling 13.
- Phytoplankton: chlorophyll-a, population, biomass, and algae amount.
- Zooplankton: species and numbers.
- Microorganism: Total bacteria (number/L), B. coli (number/L)
- Net primary bio-productivity (C) [mg/(m^3 · d)].

Ground Water

(1) Soil gleization in midstream

- Monitoring scope: Four lakes area in Hubei: two groups of observation points from Xiaogang Farm of Honghu City to Stone Dock.
- Indicators
  Ground water: pressure water level, phreatic water level, and temperature.
  Meteorology: atmospheric temperature and geo-temperature (5 cm).
  Water balance: rainfall and evaporation.
  Gleization of soil: pH, oxygen reduction potential, active reduction matters, and total reduction matters.
  Soil fertility: pH, characters of soil cross-section, organic matters, NH_4-N (ammonium nitrogen), AHN, granulated phosphate, quick-acting phosphate, quick-acting potassium, TN, TP, TK, copper, zinc, lead, chromium, cadmium, mercury, arsenic, lasting organic pollutants (decomposed farm chemicals and herbicides).

(2) Soil salinization at estuary

- Monitoring scope: Three cross-sections are set in Yinyang Town, Daxing Township and Xinglongsha Township of Qidong city, Jiangsu Province, with three monitoring points at each cross-section.
- Targets of monitoring: Regular survey and analysis of surface water, ground water and soil salinity. Dynamic monitoring is done of water level and salinity and of inland waterways and ground water at the typical sections. Dynamic change pattern is followed of moisture and salinity of typical sections. Follow-up survey and monitoring of soil evolution is done at typical and sensitive sections.
- Indicators
  Moisture and salinity: EC of mainstream, EC of inland waterways, EC of soil (nine monitoring points, six levels at each point), negative pressure of soil (nine points, three levels in each), ground water table and EC of ground water.
  Soil salinization: EC of soil, pH and salt ion composition.
  Soil fertility: name of soil, porosity, relative density, characters of cross-section, grain size (three levels), organic matters, NH_4-N, AHN, granulated phosphate, quick-acting phosphate, quick-acting potassium, TN, TP, TK, copper, zinc, lead, chromium, cadmium, mercury and arsenic, lasting organic pollutants (decomposed farm chemicals and herbicides).
  Hydrology and meteorology: daily meteorological data of Qidong city, including rainfall and evaporation and daily water level (tide position) data of the Yangtze at Santiao Port and Qinglong Port.

Expert seminar on August 29, 2002 discussing eutrophication of Three Gorges Reservoir, an issue that had been the focus of attention. (Photo by Huang Zhenli)

Short-time waterbloom appeared in some reservoir tributaries of Daning, Xiangxi and Shenu after impoundment in June 2003. The picture shows the sight of water bloom, with part of the water body turning *black* and *dark*

Collecting water samples

Collecting suspended matters from water

8.3.3 Aquatic Life Sub-system

Purposes: To know the current conditions and annual changes of aquatic life and assess the TGP impact on aquatic ecology and aquatic life so as to provide the scientific basis for policy decision taking.

Fish Resources

(1) Fish resources in the reservoir area

- Monitoring scope: Yibin, Banan, Wanzhou, and Wushan.
- Indicators: Composition, ratio and amount of catches, biological features of major fish species of economic value (body length, weight and age); composition of fish fauna, fish community structure, and resource amount.

(2) Resources of the four major endemic species in Yichang–Hukou section

- Monitoring scope: Jianli, Sanzhou, Wuxue, Zhicheng, and Longzhou.
- Indicators: Production of spawner (fry) and conditions of spawning.

(3) Spawning ground and fish resources in the lake area

- Monitoring scope: Dongting Lake (east, west and south), Poyang Lake (Duchang, Poyang, and Xingzi)
- Indicators
  Spawning ground: area of lake, area and habitat of the four major endemic species.
  Catches: composition, ratio and amount of catches, biological features of major fish species of economic value (body length, weight and age);

(4) Fish resources in the estuary

- Monitoring scope: 121°10′E–123°30′E, 30°45′N–32°00′N, trawler sampling should be done in at least 15 monitoring stations.
- Indicators
  Swimming life: community structure, species composition, and fauna features.
  Characteristics of resources: Catches, resources and biomass of major species [Crab (*Decapoda*)] of economic value.
  Characteristics of fishing grounds: Fish catch and resources developments in the fishing zones.

Rare and Endemic Species of Fish

(1) Endemic species

- Monitoring scope: Yibin, Hejiang, Mudong, and Wushan sections of the Yangtze.
- Indicators: Fish species, type, amount, weight structure, total catch, and annual change in the resources of endemic species; food base composition and their habit of reproduction and the relations with the environment; artificial breeding of endemic species.

(2) Early resources of fish

- Monitoring scope: Yidu section of the river.
- Indicators: Composition and ratio of species of early resources; time and spatial distribution of early resources, fishing season of the four major endemic species, runoff of early resources; sources of early resources of endemic species (contribution by major spawning grounds).

(3) Survey of rare species

- Monitoring scope: Mainstream section from the lower reaches of the Jinsha River to the Chongming Island at estuary, including two fixed points in Yichang and Chongming.
- Indicators: Resources of white sturgeon, Dabry's sturgeon and Chinese sucker (*Myxocyprinus asiaticus*), number and size and location of fish caught accidentally. Number of Chinese sturgeon breeding, time and scale of reproduction, composition and amount of egg-eating fish and egg-eating intensity, resources of Chinese sturgeon larval and juvenile at Yangtze estuary.

Plankton and Benthos Community Survey

(1) Mainstem plankton and benthos communities

- Monitoring cross-section (points)
  Mainstream: two sampling points at Cuntan, Qingxichang, and a point 1 km downstream of Wanzhou, Guandukou, and Nanjinguan.Tributaries: two sampling points, one on the left and one on the right, at Jialingjinag mouth and the Wujiang River mouth and one sampling point in the mouth of four tributaries of the Yulin, Xiaojiang, Daning, and Xiangxi rivers.
- Indicators: Chlorophyll-a, Phytoplankton, zooplankton, benthos animals, attached algae and aquatic vascular plants.

(2) Plankton and benthos community at estuary

- Monitoring scope: 121°10′E–123°30′E, 30°45′N–32°00′N. Survey and sampling should be done in at least 30 monitoring stations.
- Indicators: Chlorophyll-a and primary productivity; zooplankton, Phytoplankton, benthos; fish type zooplankton: fish egg, larva and juvenile.

8.3.4 Terrestrial Ecology Sub-system

Purposes: Terrestrial ecosystem covers agricultural ecology, forest resources, terrestrial plant and water loss and soil erosion, which are interdependent and mutually influencing each other. The monitoring of the TGP impact on the five types of ecological factors and finding out their mutual relationship and influence will help put forward policy recommendations for improving and protecting the terrestrial ecosystem.

It is suggested that the monitoring of agricultural ecology and environment should increase the monitoring and survey of productivity of newly reclaimed land for the resettled people on the basis of the monitoring of rural energy structure, cropping system, planting structure, pests and plant diseases and gleyed soil so as to adopt timely measures to raise land productivity while protecting the ecology and environment and help farmers achieve wealth and prevent new problems to be caused by newly reclaimed land.

The monitoring of terrestrial animals and plants before the impoundment of the reservoir mainly focused on species, amount and distribution of animals and plants, with emphasis on rare, endangered, and endemic species, famous ancient trees and typical communities in the reservoir area below the 175 m water level. It is, therefore, necessary to add forestry survey on the basis of what has been done and use remote sensing technology to monitor the plant physiological parameters and habitat quality and strengthen the survey of flora in the reservoir area, especially surveys of the impact of the reservoir on the terrestrial ecology.

Agricultural Ecology

(1) Agricultural ecology in the reservoir area

- Monitoring scope: 182 townships, including Jiangjin, Banan, Yubei, Changshou, Wulong, Fuling, Fengdu, Shizhu, Kaixian, Zhongxian, Tiancheng, Yunyang, Fengjie, Wushan, Wuxi, Badong, Zigui, Xingshan, and Yiling.

- Indicators
  - Rural energy structure: area and amount of firewood forests; number, distribution and per-household number of biogas pits.
  - Cropping system and plant structure.
  - Pests: areas affected by rice blast, Rice borer, late blight of potato, corn leaf blight, big and small scab and rats, areas under control, areas of disaster, output and economic losses.

(2) Productivity of newly reclaimed land

- Monitoring scope: Shuitianba Township of Zigui County, Changling Town of Wanzhou District, totaling five monitoring points.
- Distribution of monitoring points: Monitoring points should be evenly distributed at different elevations; each point should be no less than 100 mu (some six hectares), made up of 5–10 sampling points, including different cropping systems.
- Indicators
  - Survey: plant pattern and cropping system, crop (fruit) types, crop (melon) output.
  - Monitoring: phenology calendar, leaf area index, biomass and pests and plant diseases.
  - Monitoring of soil fertility: soil name, porosity, relative density, pH, characteristics of soil cross-section, grain composition (three levels), organic matters, NH_4-N, AHN, granulated phosphate, fast-acting phosphate, fast-acting potassium, TN, TP, TK, Cu, Zn, Pb, Cr, Cd, Hg, As and lasting organic pollutants (decomposed farm chemicals and herbicides).

Forestry Resources

- Monitoring scope: 55,000 km^2 administrative area in 18 counties (city) and districts actually inundated.
- Indicators: Forest land area by county, forests (natural and artificial), open forests, shrubs (evergreen and deciduous) area and coverage, standing stock of timber, forest area and standing stock by type of forests, forest area and standing stock by age-group, annual artificial afforestation area and survival area of artificially created forests.
  Area and standing stock of timber forests, economic forests, green belt, firewood forests, and bamboo groves by county and areas suitable for afforestation.
  Logging area and amount by county, area affected by pests and fire, and areas of regeneration.
  Growing stock and growth rate of major forest types;
  1:50,000 forest type atlas and forest zoning atlas;
  Major rare and endangered plants and species and distribution of endemic plants in the reservoir area;
  Major species under protection, type, amount, and distribution of famous ancient trees.
  Impact of resettlement activities and construction of endemic species and typical communities.

Terrestrial Animals

- Monitoring scope: 55,000 km^2 administrative area in 18 counties (city) and districts, with 30 fixed sampling lines, 20 random sampling lines and 50 random survey sampling points.
- Indicators: Type, distribution, number, and habitat conditions of terrestrial animals.
  Types, distribution, amount and habitat conditions and changes of animals, birds, amphibious reptiles, especially rare and endangered species (animals include leopard, cloud leopard, golden-haired monkey, black-leaf monkey, Tibetan macaca, Rhesus macaque, and black bear; birds include crimson-bellied tragopan, koklass pheasant and golden pheasant; amphibious reptiles include giant salamander, *Wushan salamander*, *Tylototriton wenxianensis*, *Oreolalax lichuanensis* and *Oreolalax rhodostigmatus*.)
  Types, distribution, and number of water fowls in wetland.

Terrestrial Plants

(1) Plant community in reservoir area

- Monitoring scope: Sampling fields are arranged according to plant communities and sampling is done by sampling at every layer, totaling about 300, each measuring 100 m × 100 m, with five arbor sample blocks each measuring 20 m × 20 m, 10 shrub sample blocks each measuring 5 m × 5 m and 10 herb sample blocks, each measuring 1 m × 1 m. Each sample block has a lasting mark, such as cement pile, including the three water-level fluctuating zones at Shuitianba Township in Zigui, Wuqiao River in Wanzhou and Xiaojiang in Kaixian.

- Indicators
  - Sample fields: longitude and latitude, place name, area, surroundings, sampling point chart and photos.
  - Environment: Name of plant communities, types, elevation, topography, slope orientation, gradient, slope position, local topography, geological conditions, base rock, moisture conditions, interference and dominant species.
  - Soil: organic matters, pH, TN, TP, TK, fast-acting nitrogen, fast-acting phosphate and fast-acting potassium.
  - Arbor layer: three layers, recording top canopy, height, average age, height and chest diameter, number of tree species, amount and abundance, dominant species, gaps distribution map, forest layer cross-section map, leaf area index, biomass, photos of constructive species, name of each tree, positioning of each tree, canopy projection map, canopy layer area, size of canopy, chest diameter, height, age, and photos.
  - Shrub layer: canopy, layer height, average age, name and number, leaf area index, biomass, constructive species photos, name and number of each species, average height, average cover, abundance, growth period, average leaf area index, average biomass, and photos.
  - Herbal layer: canopy, height, leaf area index, biomass, constructive species photos, name of species and amount, height, canopy, abundance, growth period, and photos.
  - Profile charts of plant community structure, average leaf area index and total biomass.

(2) Plant physiological parameters

- Monitoring scope: 55,000 km^2 administrative area in the upper reaches of the Yangtze above Yichang.
- Indicators: Monthly plant physiological parameters such as NDVI, LAI, fCover and fAPAR; monthly net primary productivity and net ecology productivity.

(3) Habitat quality

- Monitoring scope: 55,000 km^2 of 18 counties (cities) which are actually affected by inundation.
- Indicators: Area and ratio of arbor, shrub and grassland, age of arbor, plant coverage, abundance, complexity, and surface biomass.

Water Loss and Soil Erosion

- Monitoring scope: One million km^2 in the upper reaches of the Yangtze, with emphasis on the reservoir area.
- Targets of monitoring: Area, spatial distribution, intensity of water and soil loss, harm and development trends of water loss and soil erosion, implementations of water and soil conservation projects and results.

8.3.5 Wetland Sub-system

To ensure flood control capacity and sediment discharge, the reservoir operates at the 145 m level in the June–September flood season in normal year. After October, the reservoir operates at the normal pool level of 175 m. When the inflow is smaller than the release flow, the water level drops but does not drop lower than 155 m before May. So, there is a 145–175 m water-level change, which is very important to the water and ecology as well as landscape. Before the impoundment, the monitoring system carried out overall baseline material surveys of animals and plants at/below the 175 m inundation line and of land utilization. After the impoundment in June 2003, the area below the 175 m inundation line has become a wetland ecosystem with water-levels fluctuating. The evolution and development of this ecosystem has become an important issue of public concern and in reservoir management. It is very important to carry out special monitoring.

Monitoring scope: 145–175 water-level fluctuating zone of the mainstream and tributaries in the reservoir area.

Targets of monitoring: species of animals and plants and the evolution of their communities, changes in the way of land utilization, especially the pollution of water caused by the agricultural utilization and cultivated land soil leaching.

The reservoir impoundment has given rise to a water-level fluctuating zone, with water level being higher in winter than in summer. When the water level of the reservoir reaches 175 m, the ecology and environment issues of the 30 m high water-level fluctuating zone have caught attention. (Photo by Huang Zhenli at the Little Three Gorges of Daning River in Wushan County on July 16, 2005)

8.3.6 Climate Sub-system (Local Climate)

Conventional Climate

(1) Monitoring scope and distribution of monitoring stations

Reservoir area, with emphasis on areas relatively seriously affected by TGP (a dozen kilometers around the reservoir); choose a number of weather stations to carry out contrast observations in order to analyze and compare the climatic changes before and after the reservoir is built.

There are 16 local meteorological stations. They are Chongqing, Changshou, Fuling, Wanzhou (Longbao), Fengjie, Wushan, Badong, Zigui, Bahekou, Yichang, Zhongxian, Fengdu, Yunyang, Jianshi, Liangping, and Enshi. Among them are ten base stations along the river and the reservoir, with Jianshi, Liangpin, and Enshi as the contrast stations.

The six stations of Chongqing, Fuling, Wanshou, Fengjie, Badong, and Yichang, where industrial pollution is concentrated, have to monitor acid rain in addition to routine monitoring.

(2) Indicators and statistical indices

- Monitoring indicators: air pressure, maximum temperature, minimum temperature, mean temperature, relative humidity, wind velocity, wind direction, precipitation, evaporation, daily sunshine hours, and weather Phenomena (fog, thunderstorm).
- Statistical indices: average monthly air pressure, mean temperature, average maximum temperature, average minimum temperature, average relative humidity, average wind speed, wind direction frequency, precipitation, evaporation, daily sunshine hours, foggy days, and thunderstorm days.
- Acid rain indices: pH value and electricity conductivity, monthly average acidity of rains and average conductivity of rain.

Vertical Climate

(1) Monitoring scope and distribution of monitoring stations

- Yichang cross-section: Tanziling, Sandouping, Sujia'ao, Guizhou, Xiaoxita, Changyang, Xingshan, Shennongjia, Yidu and Taiyangbao, totaling ten observation points.
- Fuling cross-section: Zhongxian, Shizhu, Wulong, Dianjiang, Fengdu, Fuling, Liangping, Pingxiba (Jiangxin Dao), Nantuo, Baisheng and Yutaishan, totaling 11 observation points.
- Low altitude observation points: Sujia'ao of Yichang and Pingxiba of Fuling.

(2) Observation indicators

- Ground observation: temperature, humidity, wind direction, wind speed, precipitation, weather phenomena (fog and thunderstorm), as well as air pressure, evaporation, daily sunshine hours and geo-temperature.

- Low altitude probing indicators: Air pressure, air temperature, humidity, wind direction and wind speed.

8.3.7 Social Environment Sub-system

Purposes: To analyze the TGP impact and other influencing factors on the economic and social changes, study the people's work and life before and after their resettlement, centering round the goal of people relocation, "Not only being able to move and stay steadily in new place but also embark on the road to wealth", healthy economic and social development; provide a scientific basis for the government at all levels to formulate strategies and supportive measures for the development of the reservoir area after resettlement; and modify policies and plans for economic and social development of the reservoir area.

The pre-dam social environment monitoring focused mainly on the general survey and the follow-up monitoring missed out the follow-up monitoring of the resettled urban people. It is suggested that this be added in the monitoring system after reservoir impoundment by selecting 500 urban households as samples to carry out surveys in 89 statistical indices, including family structure, population structure and employment, housing and living conditions, income and expenditure in order to reflect the work and life of the resettled urban people.

Socioeconomic Monitoring

(1) Monitoring scope

Four counties in the Hubei reservoir area, five towns of Xiaoxita, Sandouping, Taipingxi, Letianxi, and Maoping around the dam area, 15 districts and counties (cities) and seven major urban districts of Chongqing in the reservoir area.

(2) Indicators

- District (county, city): population, resources, environment, economy, social development, and resettled people, totaling 104 statistical indices and 40 assessment indicators.
- Dam area: basic situation, integrated economic development, people's life, science, education and culture and health, social security and others, totaling 86 indicators.

Survey of Resettled People

(1) Sample survey of resettled rural people

- Scope of survey: Sample survey of 300 rural households resettled.
- Indicators: Population, environment, economy and social development, resettled people (totaling 236).

(2) Sample survey of resettled urban people

- Scope of survey: Samples survey of 500 resettled urban households.
- Indicators: Family structure, population structure and employment, housing and living conditions, durable consumer goods, income and expenditure, totaling 89 statistical indices.

(3) Follow-up survey of resettled people

- Scope of survey: 50 households in the Changling Town of Wanxian and Liangshui Township; 10 resettled households and 10 non-resettled household in Longkou of Shuitianba Township of Zigui County as contrast.
- Indicators: Family financial situation, including annual income, expenditure, per capita net income and family income structure, agro-household labor employment structure, land use structure, changes in the cultivated land and means of production, quality of living and health conditions of original residents and the resettled people.

Monitoring of People's Health

(1) Monitoring scope

Five disease monitoring points along the Yangtze and surrounding resettlement areas in the reservoir area: They are Chongqing City (Jiangbei, Banan, Yubei and Changshou districts), Wanzhou district (Longbao district), Fengjie

County, Fengdu County and Yichang City of Hubei Province (Xiangshan County, Shazhenxi and dam area of Zigui County), each point covering about 100,000 people.

(2) Indicators

- Population data, total population, birth, death and immigrants and emigrants at the initial year, annual average population and age and sex structure, annual birth and annual death, death by age-group, and causes of death (according to the ICD-9).
- Medical organizations and staff: Number of medical organizations, number of hospital beds and number of medical workers to be listed separately at county, township, and village levels.
- Disease monitoring
  Infectiously diseases: 36 types of communicable diseases of the A, B, and C categories, including plague, cholera, virus hepatitis, dysentery, typhoid fever and paratyphoid fever, AIDS, gonorrhea, syphilis, polio, measles, whooping cough, diphtheria, epidemic cerebrospinal meningitis, scarlet fever, epidemic hemorrhagic fever, rabies, leptospirosis, brucellosis, anthrax, typhus, epidemic encephalitis B, black fever, malaria, dengue fever, neonatal tetanus, TB, schistosomiasis, filariasis, echinococcosis, leprosy, flu, epidemic parotitis, rubella, acute hemorrhagic conjunctivitis, infectious diarrhea and SARS.
  Endemic diseases: Endemic goiter, endemic fluorosis, and paragonimiasis.
- Bio-vector monitoring
  Rats: Rats include Brown rat (*Rattus norvegicus*), House mouse*, Rattus flavipetcus, Rattus losea Swinhce,* Striped field mouse (*Apodemus agrarius*), and others, taking catch rate as the density index; rat density = (catches/effective rat-catching devices) $\times$ 100%.
  Mosquitos: Identify such species as C*ulex pipiens pallens, Culex pipiens quinquefasciatus, Culex tritaeniorhychus, Anopheles sinensis* and A*rmigeres subalbatus* and other species for integrated statistics. Mosquito density = (total mosquito caught/number of room) $\times$ 4, Unit: number/room $\cdot$ h).
- Epidemic breakout report
  File timely report on epidemic outbreak and public health events with unknown causes and carry out epidemiological surveys after receiving reports, find out causes and isolate the epidemic points, sterilize the surroundings, give out preventive medicines, carry out emergency inoculation and spot sampling to control the spread of epidemic.

8.4 Comprehensive Analysis

TGP environmental monitoring system is a complicated and massive system, with most sub-systems covering multiple disciplines and sectors and all sub-systems are mutually influencing and relating to each other directly or indirectly. The TGP ecological and environmental problems are very complicated, too, with many influencing factors, both engineering and non-engineering. It is, therefore, necessary to carry out comprehensive analysis of the changes in ecology and environment at a higher level of the whole system on the basis of the analysis by different sub-systems in order to identify accurately the causes for the changes in the ecology and environment and make both quantitative and qualitative, both objective and accurate judgments. Otherwise, it is easy to arrive at biased conclusions and make unreasonable judgments without support of monitoring data.

In line with the objectives, functions and monitoring targets as well as the monitoring work that has been done and the achievements, and in consideration of the constant accumulation of materials in the future, the framework of comprehensive analysis and requirements should cover the following:

8.4.1 Hydro-Environment

Analysis of Pollution Load

On the basis of the hydrology and water quality monitoring and the monitoring of pollution sources in both the mainstream and tributaries in the reservoir area, it is necessary to calculate the load of all pollutants that enter the reservoir every year, get clear about the load and its distribution in both time and space, know the types of pollutants, density and pattern of discharge so as to provide a scientific basis for controlling pollution sources in a comprehensive manner, and assessing the hydro-environmental quality and protecting the water sources.

The following special analyses are needed to make a comprehensive estimation of the pollution load:

(1) Based on the data of urban sewage, industrial wastewater, urban garbage, industrial solid waste and other major point pollution sources, it is to calculate the sources, total amount and changing pattern of different pollutants from all point pollution sources (all urban industrial pollution, sewage and removed and newly constructed pollution sources) and estimate the total

pollution load in the reservoir area, analyze the annual change of pollution load and regional distribution pattern.

(2) Based on the data from the actual measurement of agricultural runoff zones and small catchment area and the survey data about the application of farm chemicals and chemical fertilizers and the data about the LULC, together with the analytical technology of remote sensing and geographical information system (GIS), it is to construct a non-point pollution calculation model on the basis of land used as landscape units, estimate the total pollution load of agricultural zones, cities and towns and poultry farms and the non-point pollution sources in the reservoir area and analyze the annual change and regional distribution pattern; demarcate areas for controlling non-point pollution and put forward countermeasures for managing and controlling non-point pollution in the reservoir area.

(3) Based on the data about the number and structure of vessels and pollutant types and amount discharged by all types of vessels in the reservoir area, it is to calculate the sources, total amount and changing patterns of different pollutants from floating sources, estimate the total floating pollution load and analyze the annual change of the floating pollution load.

(4) On the basis of estimating the load of point, non-point and floating pollution sources, it is to estimate the total pollution load in the reservoir area and, according to the development trend of different pollution sources, to use model to analyze the pollution situation and forecast the changing trend.

(5) On condition of satisfying the reservoir water quality control objectives and according to the total pollutants control scheme and in line with the principle of fairness, rationality, economic optimization and the actual local conditions, it is to calculate the allowable load of controllable pollution sources and construct related optimization and distribution dynamic model to distribute the pollution load as the scientific basis for formulating water pollution control plans.

Hydro-Environment Quality Analysis and Assessment

It is to devise a unified assessment method, select indicators that can give an overall picture of the water quality and carry out mathematical and physical calculation of the data obtained from monitoring to get the all kinds of statistical characteristic values and representative values of environmental quality and use the water quality monitoring databank to assess the water quality.

The focus of hydro-environmental quality assessment should be:

(1) Use the data obtained from the synchronized monitoring of hydrology and water quality and in line with the water functions and protective goals, carry out assessment of the water quality as a whole in the reservoir area; make goal-attaining assessment of individual indicators according to different water seasons, carry out classified assessment (natural, organic and toxic), and adopt different models in comprehensive assessment (such as water quality co-efficient, comprehensive pollution index, organic pollution comprehensive assessment value, Ross water quality index) and analyze the current conditions of water quality and annual changing trend.

(2) In conjunction with the monitoring of pollution belts, assess the water quality of typical areas (such as city river sections) and analyze the impact of pollution sources on the water quality of the area and the influencing pattern.

(3) Analyze and assess the TGP impact on the sources of drinking water.

(4) Assess in a comprehensive manner the water quality of the reservoir area, analyze the bearing capacity of water sources and hydro-environment, construct hydro-environmental bearing capacity control model so as to provide the scientific basis for protecting and utilizing the hydro-environment in a sustainable manner.

Analysis and Assessment of Eutrophication

Eutrophication is one of the major water pollution problems in the reservoir area. It is, therefore, necessary to put forward major control indices for preventing and controlling eutrophication on the basis of analyzing the mechanism, set up a complete set of comprehensive assessment indicator system covering water quality and flow pattern, analyze the mechanism and conditions for eutrophication, carrying out multi-objective prevention and control studies.

The occurrence and development of eutrophication of the reservoir is the result of the concerted action by many factors. It is planned to carry out the following analyses according to the characteristics of the reservoir area:

(1) Current condition analysis. Eutrophication is caused by such nutrients as nitrogen and phosphate when they exceed a certain limit, thus causing algae to proliferate extraordinarily under a given hydrological and climatic conditions. Chlorophyll-a is a comprehensive index that reflects the amount of algae and often used as a leading factor for assessing eutrophication. But the changes in chlorophyll-a are closely associated with TP, TN, COD, transparency (SD), and other pollution indices. So, the analysis of eutrophication of the reservoir should include distribution pattern of nutrients, assessment of the state

of nutrients, indicators of zooplankton to the state of nutrients.

(2) Assessment of the harm done by eutrophication. Analyze the impact of eutrophication on the physiochemical features, hydro-ecological balance, aquatic life, fish breeding and people's health and estimate the economic losses.

(3) Analysis of mechanism of eutrophication. Eutrophication is a process in which the imbalance of the whole hydro-environment system has led to excessive proliferation of some dominant algae. It is, therefore, necessary to analyze the expression of eutrophication according to the geographic features, natural climatic conditions, aquatic ecosystem and pollution to get to know the different dominant algae communities that have caused the imbalance of different types of aquatic life and, according to the necessary conditions for eutrophication, analyze the distribution and changing patterns of such nutrients as TP and TN, the flow pattern such as velocity and water depth and the suitable temperatures for eutrophication.

(4) Analysis of the development trend of eutrophication and measures against it. Based on the mechanism of eutrophication and analysis of the changing patterns of nutrient sources, it is to forecast the development trend of eutrophication, devise anti-eutrophication measures and comprehensive monitoring and assessment systems so as to provide the scientific basis for the building of an ecology-friendly reservoir.

8.4.2 Biodiversity

Diversity of Terrestrial Animals and Plants

TGP will change some ecological and environmental factors, such as climate, moisture and soil, which will, in turn, affect the biodiversity of terrestrial animals and plants. The analysis of the diversity of terrestrial life at all levels and objective assessment of the TGP impact on the terrestrial animals and plants and their habitats will be helpful in taking measures to mitigate the unfavorable effects.

(1) Diversity of terrestrial animal communities and plant communities: This mainly includes the types, number, habitats, and distribution of such animals and plants and their succession under the influence of the changes in the environmental factors.

(2) Diversity of species of terrestrial animals and plants: this covers the analysis of the relationship between their spatial distribution and environmental factors, abundance and diversity and evenness and spatial and gradient distribution of diversity of species and development trends.

Diversity of Aquatic Life

The habitats of aquatic life would be affected to varying degrees by the reservoir as it would bring about big changes in the hydrological regime. The comprehensive analysis of the current conditions of aquatic life and their annual change pattern and assessment of the TGP impact on the aquatic ecology and biological resources will provide the scientific basis for taking policy decisions.

(1) Diversity of aquatic ecosystem: This includes a comprehensive analysis of the communities of aquatic animals, Phytoplankton, microorganisms or their community structures, number, habitats, population and their annual change patterns and the characteristics of the habitat change after the reservoir is built.

(2) Species diversity: This includes analysis and forecast of species structures of aquatic life, level of diversity, diversity index, richness and abundance and construction of mathematical model.

Diversity of Rare Animals and Plants

Animals and plants are rare because of their narrow biotopes, weak migration ability and high sensitivity to environment. The TGP and corresponding human activities will bring about changes to the ecosystem and corresponding damage and interference in the biotopes of rare animals and plants. It is, therefore, necessary to get clear the changing trend of the types, habitats, and number of the species of rare animals and plants so as to work out specific measures for protecting species endangered.

(1) Eco-diversity of rare and endemic animals and plants: This mainly includes analysis of the scales, biotopes, density, community diversity and their changing patterns and forecast the development trends of community structures and number.

(2) Analysis of the species composition, existing number, speed of reduction in population, distribution area, threat they face and protective measures.

Diversity of Agricultural Ecosystem

Agricultural ecosystem is an agricultural production system of different forms and development levels established in a given time and area under an artificial regulation and control by engaging in agricultural production and by utilizing the relationship between agricultural life and nonlife environment and among different species. Like natural ecosystem, it is also a material circulation and energy conversion system composed of four major basic factors, namely, environment, plants, animals, and microorganisms. It has three major characteristics of productivity, stability, and continuity. The analysis of the diversity of agricultural ecology, knowing the mutual influence of agricultural environment, production model, and hydro-environment of the reservoir will provide the basis for raising agricultural ecological productivity and adjusting the agricultural production structure and serve the purpose of sustainable development of agriculture and grain security in the reservoir area.

(1) Diversity of agricultural environment: This includes analysis of the changes of the non-biological factors in the agro-ecosystem, including soil, irrigation water, air, sunshine, and temperature and other natural factors as well as land degeneration, water loss and soil erosion, pollution of water for agricultural use and soil pollution resulting from it and the pollution by farm chemicals and chemical fertilizers.
(2) Diversity of agro-ecosystem. This is an analysis of the diversity of agricultural planting system, such as single cropping, mixed cropping, crop-domestic animal mixed system, crop-tree intercropping, crop-silk worm-livestock breeding system, aquatic breeding, pasture, grazing ground, and optimal control policy.
(3) Diversity of crop species in cultivation. This is mainly an analysis of the plant species diversity (including semi-domesticated cultivation, cultivated breed, and managed wild breeds), pests and plant disease management and high-efficient utilization of plasma resources.

8.4.3 Socioeconomic Environment

An in-depth analysis and study of the economic and social changes and their influencing factors, determination of the trend and degree of the influence of various factors and giving a comprehensive assessment of the social and economic development level of the reservoir area are of great significance in revealing the economic and social development pattern and ensuring the smooth-going of the TGP and a healthy and stable economic and social development. They are also of very high application value for the governments at all levels in working out development strategies, improve economic and social development policies and plans.

People's Health Analysis

The changes in the natural environment due to the dam and reservoir would cause occurrence of diseases and public health problems. A comprehensive analysis of the data obtained from monitoring and an accurate assessment and forecast of the TGP impact and timely discovery of problems and finding-out solutions will provide the basis for controlling diseases and for local health administrative departments in working out health development plans.

(1) Effect of TGP on infectious and other diseases of natural epidemic foci. This is an analysis of the incidence and causes of virus hepatitis, dysentery and typhoid fever and other water-borne infectious diseases, leptospirosis, epidemic hemorrhagic fever, epidemic encephalitis B, anthrax, Brucellosis, typhus, relapsing fever, Lyme disease and black fever, the impact of ecological and environmental change on the spread of infectious sources and epidemic foci, vectors (rat and mosquito) breeding places and biotope of epidemic foci and measures for controlling infectious diseases.
(2) Impact of TGP on schistosomiasis, malaria, and other worm spread diseases. This is an analysis of the possibilities of an outbreak of schistosomiasis and malaria that might be caused by the expansion of the mosquito breeding habitats.
(3) TGP impact on endemic diseases. This is an analysis of the distribution, harm and preventive measures of such endemic diseases as fluorosis, goiter and Keshan Disease and their changes after the change of natural factors.

Analysis of Socioeconomic Development

This aims to sort out data obtained, analyze comprehensively the speed, quality, and coordination of social and economic development so as to find out the constraining factors, reflect the impact of TGP and resettlement of one million people on the social and economic environment and give a quantitative comprehensive assessment of the social and economic environment of the reservoir area.

(1) Analysis of the basic conditions of social and economic development, covering population and population density, industrial structure, economic aggregate, economic structure, regional disparities, financing and investment, social environment, people's living standards, and mineral reserves.
(2) Comparative analysis of economic development space, covering economic aggregates of different areas,

economic development levels, economic development quality, and economic strength.
(3) Historically comparative analysis of social and economic development, covering development speed, quality, and economic strength of different historical periods.
(4) Comprehensive assessment of social and economic development, covering population and employment, economic and social development, environment and basic conditions, people's life and resettled people by the comprehensive index method.
(5) Analysis of the socioeconomic conditions of the resettled people, mainly covering their production, living and other changes as well as problems still existing with their life and production.

Distribution and Utilization of Resources

A comprehensive mastery of the distribution, changes and utilization of resources in the reservoir area, and an in-depth study of the resources and industrial development will facilitate the working out of policy recommendations on the reasonable and effective utilization of resources for reference by the governments at all levels in formulating correct industrial policies for realizing sustainable development of the economy. It is planned to carry out studies in the following aspects:

(1) Spatial distribution and change of resources. This is an analysis and study of the spatial distribution and changes of mineral resources, ecological resources, and tourism resources and advantages and disadvantages of resources in the reservoir area.
(2) Rational utilization of resources. This is aimed at putting forward policies for the rational utilization of resources and for industrial development based on the resource advantages and advantageous and disadvantageous industries.

Studies of Human Resources Development Strategy

The massive number and low-quality human resources are the most outstanding problem in the reservoir area and the root cause for its difficulty to shake off poverty and backwardness and also the biggest obstacle to the current and future economic and social development.

(1) Carefully investigate into the number, quality, and distribution structure of human resources in the reservoir area and correctly understanding the supply and demand gaps.
(2) Use Chinese and Western human resources management theories, new economic growth theories and labor and employment theories to analyze the relations between human resources and economic growth of the reservoir area.
(3) Use the research achievements to help governments and departments at all levels to formulate regional human resources development strategy and improve the general quality of human resources.

8.4.4 Assessment of Ecology and Environment Security

Analysis of Geological Disasters

The land surface of the reservoir area has been cut up seriously; the topography varies greatly in elevation; rainfalls are concentrated; the land is fragmented, eroded and easy to be weathered; and eroded rocks are extensively distributed. This, plus faults, especially active faults, makes the geological environment very fragile. It is one of the areas where geological disasters are easy to occur. This problem has become even more outstanding after the reservoir is built. A comprehensive analysis of the types, features, distribution pattern of geological disasters and their impact on water storage of the reservoir would be conducive to working out policy recommendations for preventing and controlling geological disasters after the operation of the dam and reservoir.

(1) Determination of the types of geological disasters. The aim is to find out such disasters as earthquakes, landslides, collapses, dangerous rocks, mudflows, cave-ins, fractures and unstable slopes and make an overall analysis of these disasters with the support of geographical information.
(2) Analysis of the distribution pattern of geological disasters. This mainly includes the spatial distribution of disasters and concurrence, non-stable cycle and lagging nature and the assessment of possible harm done on the basis of differentiation of disasters.
(3) Analysis of major patterns of geological disasters. This is to mainly analyze the place, magnitude, and damages of the past geological disasters and the relations between geological disasters and other natural factors and the operation of the reservoir.
(4) Studies of measures against geological disasters. This includes studies of measures for controlling existing disasters, anti-disaster GIS construction and assessment of the possibilities of the reservoir induced earthquakes.

Water and Soil Loss Analysis

The reservoir area is one of the areas with strong water loss and soil erosion, which has not only damaged the local ecology but also seriously threatened the service life and efficiency of the reservoir. The aim is to get a complete picture of the current conditions and development trend in water and soil loss through comprehensive analysis and analyze the results of the water and soil conservation facilities so as to provide the scientific basis for controlling water loss and soil erosion.

(1) Assessment of the current conditions of water and soil loss. The task is to build a soil erosion amount estimation system based on the existing geographical information and monitoring data and draw maps on water and soil loss and damages that it has caused and, on this basis, estimate the total amount of soil erosion.
(2) Analysis of water and soil loss pattern. This is to analyze water and soil loss pattern of different types of vegetations, land covers, land utilization, topographical types, and landscape types under different intensity of rainfall and carry out assessment of the potential danger of water and soil loss and build a databank accordingly.
(3) Analysis of the result of water and soil conservation projects. This is to analyze the progress of water and soil conservation projects and results already obtained and carry out monitoring of such projects.
(4) Water and soil loss control plans. The aim is to work out measures for controlling water and soil loss according to different influencing factors.

Climate Analysis

Climatic changes have a direct impact on social and economic development and on the ecosystem. It will bring either harm or opportunities for economic and social development. Climatic changes have affected or will seriously affect the resources and ecosystem on which people depend on for survival and development and will have a great impact on different sensitive areas or resources, such as water sources, biodiversity, wetland, natural reserves, forests and grassland.

In order to carry out studies of the impact of climatic changes on the reservoir and the impact of reservoir on the local climate, it is suggested to do specialized analysis in the following aspects:

(1) To set up a time sequence of major climatic factors over the past century and built a basic database and information management system concerning climatic changes according to the facts and causes on the annual to century scale.
(2) To develop local climate model. This is to study how to use the medium-scale regional climatic pattern and local climatic model by the nesting method to carry out the changing mini-climate forecast, carry out minute climatic resources zoning and, in conjunction with the climatic resources and changing patterns in the reservoir area, map out development plans for agriculture, forestry and livestock breeding and rationally developing the climatic resources.
(3) To study the impact of climatic change on the frequency and intensity of climatic disasters and get clear the impact of climatic changes on the anti-flood and power generation capabilities of the reservoir so as to do a good job of climatic risk assessment of the operation in low water seasons.
(4) To develop methods and models for comprehensive assessment of the impact of climatic changes. This includes the setting up of the climatic change bearing capacity assessment indicator system, the study of the comprehensive assessment information system on climatic change bearing capacity and forecasting of the possible impact of different climatic changes during different time scales on the ecology of the reservoir area.
(5) To carry out studies of climatic disasters and their impact. This includes forecast and warning of mountain torrents induced by rainstorms, the impact of fog on road and shipping traffic and the impact of high temperature, drought, thunderstorms, and hailstorms on agriculture and ecology.
(6) To carry out comprehensive assessment of the climatic, ecological, and environmental resources. This means to use the general advantage of the TGP environmental monitoring system to carry out studies of the mutual relationship between climate and hydro-environment, terrestrial plants and agricultural ecology and establish a system for assessing the impact of climatic, ecological, and environmental resources.

Soil Environment Analysis

The changes of the original natural biotopes with the formation of the reservoir will bring about corresponding changes in soil, which is the dynamic reflection of the soil nature in time and space. It is, therefore, necessary to know the differences in characteristics of the soil during different periods of time on the basis of the monitoring data obtained and use them to judge the impact of TGP on the soil of the reservoir area, assess the soil fertility, land utilization, and degeneration. It is suggested to carry out the following analyses based on the data obtained.

(1) Conditions of soil salinization of the soil at the estuary. This is mainly to analyze the secondary salinization and dynamic situation of the soil due to backflow of sea water as the result of the changes in hydrological regime after forming the reservoir.
(2) Analysis of soil gleization on the plains in the middle and lower reaches of the Yangtze. This mainly covers soil gleization and dynamic development that might be caused by the increased replenishment of the ground water and the rise of phreatic water level during the natural low water seasons with the reservoir full of water.
(3) Assessment of the changes of soil nature. This mainly covers analysis of such indicators as organic matters, nitrogen, phosphate, potassium, salt-based saturation, acidity, nutrients and organisms in soil, assess the soil changes quantitatively and establish a databank on soil change and draw a soil change atlas.
(4) Assessment of the change in soil quality. This should cover analysis and assessment of the current conditions of soil quality and dynamic development on the basis of natural characteristics by selecting representative assessment factors, such as soil layer thickness, texture, gradients, organic matter, TN, HN, fast-acting phosphate, fast-acting potassium, TP, TK, ion exchange, and pH.
(5) Analysis of factors causing soil change. This should cover analysis of the causes of soil degeneration based on the ecological and environmental factors and the ways of land utilization and the working out of measures for preventing soil degeneration, improving soil fertility and protecting ecology and environment, which can serve as the basis for taking policy decisions on sustainable development.

Comprehensive Analysis of Terrestrial Ecosystem

(1) Analysis of the historical background and evolution process of the formation of the terrestrial ecosystem, covering ancient geography, ancient climate and relations between man and land.
(2) Analysis of landscape structure of the terrestrial ecosystem, mainly including spatial relations between different ecosystems and factors, that is, the distribution of energy, materials and species associated with the size, shape, amount, type, and structure of the ecosystem.
(3) Analysis of the functions of terrestrial ecosystem, mainly including mutual action of spatial factors, that is, the movement and changes of energy, materials, and species of the ecosystem.

8.4.5 Remote Sensing Analysis of the Ecology and Environment

The purpose is to use remote sensing technology to carry out baseline survey and dynamic monitoring of the ecology and environment of the reservoir area and accumulate a large amount of basic geographic information, baseline data about the ecology and environment and, through comprehensive analysis of the spatial data, get to know the basic conditions of the Three Gorges ecology and environment and their dynamic changing trend, which can serve as the basic materials and scientific basis for related research and for taking policy decisions by related departments. The remote sensing analysis should cover the following aspects:

(1) Estimation of soil erosion and non-point pollution. The aim is to set up a soil erosion intensity assessment model and a soil erosion control result remote sensing monitoring technical system and, in conjunction with the studies and analysis of the non-point pollution load and the ways of its entry into the reservoir by ecological laboratories and the influx, study the pollutant load remote sensing calculation model and establish a GIS-based non-point pollution load estimation and analysis system with the support of the remote sensing monitoring baseline databank and related databank of experimental monitoring.
(2) Analysis of the quality of terrestrial ecosystem. This is to study and develop monitoring methods and a technical line based on remote sensing and GIS-based terrestrial ecosystem quality monitoring indices, estimate the bearing capacity of different types of land, study land environmental capacity on different scales so as to provide the scientific basis for the development of the resettlement areas and for restoring of the ecology mainly by returning farmland to forests and grassland.
(3) Analysis of the changes in land productivity. This is to set up a remote sensing estimation model for net primary productivity and terrestrial biomass, develop methods for estimating the net primary productivity and terrestrial biomass and integrate them to become land productivity monitoring system and carry out ten-day, monthly, and annual changes of primary productivity and regional difference analysis and the comprehensive factor analysis of primary productivity and biomass, monitoring the spatial annual changes of biomass and the development trend of ecological security of the reservoir area.
(4) Analysis of the biotope quality of plant communities. This is to set up a remote sensing monitoring indicator

system for the biotope quality of plant communities, study and develop remote sensing monitoring methods and technology for monitoring indicators, develop dynamic change monitoring of the biotope quality of plant communities and, on the basis of the assessment of the impact of TGP on the vegetation ecosystem, explore the responsive mechanism of plant communities to the ecological and environmental changes in the region.

(5) Dynamic analysis of land resources. This should cover the remote sensing dynamic monitoring of the land resources in the reservoir area, analysis of the total cultivated land and dynamic changes and, through annual remote sending sample survey, carry out dynamic monitoring of the areas of land use by cities and towns and by the resettled people so as to provide the scientific basis for the eco-environmental assessment of the resettlement areas and for formulating land resources policies.

8.4.6 Development Sustainability

Analysis and Assessment of the Environmental Capacity of the Resettlement Areas

The analysis and assessment of the resettlement capacity should cover the following aspects as backed up by resources and socioeconomic environment data:

(1) Analysis of resource bearing capacity. This includes the current conditions of climate, cultivated land, grassland, wood land and exploitable water quality and potential production capacity and the spatial distribution pattern of minerals and tourism resources and the bearing capacity of resources in different types of natural zones under the current economic and technical levels.

(2) Analysis of pollution-bearing environmental capacity. This mainly includes analysis of the pollution load under the current living and economic operational model, and whether or not it is harmful to the water quality of the reservoir and the constraining conditions on the population, resources and the ways of living and production in line with the environmental bearing capacity.

(3) Forecast of economic development and population growth. The resettlement capacity will change with the change in economic development levels and living standards and it is necessary to use a dynamic view to analyze the changes of the resettlement capacity so as to provide the basis for mapping out and adjusting resettlement plans and policies.

(4) Analysis of the development of the regional resource environment. This is an analysis of the changes in environmental capacity resulting from the changes in natural and artificial factors and the ways of adjusting and expanding the resettlement capacity by making full use of locally available resources.

The above analysis would result in an objective assessment of the environmental capacity for resettlement and answer the questions on how to improve or raise the living standards of the resettled people under the current policies and how to carry out post-resettlement support and its impact on the ecology and environment.

Assessment of Development Sustainability

The objective of sustainable development is the harmony between man and nature. The poor basic conditions, the fragile natural economy and environment and limited environmental capacity will greatly restrict the economic and social development. The reservoir area will face a stern situation as to how to protect the ecology and environment in its future development.

The assessment of the development sustainability in the reservoir area should cover the following:

(1) To set up a time and spatial information databank of the assessment indicators. This databank should be built on the basis of databanks on specific topics and by constructing a spatial model to mix the nonspatial natural resources environment and social and economic data with the basic geographical spatial information to make them acquire the attribute of spatial distribution and at the same time, integrate all the spatial resources data so that they all go to form a basic databank for the assessment of development sustainability. Based on the established database, it is necessary to use the comprehensive assessment model to develop indicators for sustainable development, such as vulnerability index, capacity building index, sustainable development comprehensive index and the index of the change in future scenes of sustainable development, which are used to describe sustainable development. They can also serve as the basis for further comprehensive assessment of sustainable development.

(2) Spatial analysis of the overall state of sustainable development. This requires the construction of a vulnerability index model based on the irrational utilization of land (reclamation of slope land), vegetation damage, water and soil loss and pollutants discharge, which is used to assess the vulnerability of the development sustainability. Second, it also requires the construction of a capacity building index model according to the enhanced development sustainability such as infrastructure, socio-economic development, rehabilitation of ecology, and improvement of the environment, which is

used to make a comprehensive assessment of the capacity building for development sustainability. Then, it is necessary to make a comprehensive analysis and assessment of the vulnerability of development sustainability and capacity building. The assessment results are used to classify the state of vulnerability, capacity building and general development into different levels of sustainable development, such as non-sustainable development zone, feeble sustainable development zone, moderate sustainable development zone and strong sustainable development zone.

(3) Analysis of the future scenes of sustainable development. This includes the construction of a simulated model of sustainable development scenes to simulate the spatial pattern of future scenes of sustainable development, the determination of different simulation schemes and compare them to seek the optimal scheme.

(4) Comprehensive zoning of sustainable development. This is the integration of the above analysis results to construct a sustainable development zoning model, which covers vulnerability index, capacity building index, comprehensive development index, dynamic change index and future scene simulation and then carry out spatial cluster analysis on the basis of ecological landscape unit or administrative unit to do the zoning of sustainable development.

(5) Comprehensive analysis of sustainable development policy recommendations. Policy recommendations for sustainable development should be put forward on the basis of the comprehensive assessment and zoning. These recommendations should include assessment and modification of the policies and measures concerning resettlement, returning farmland to forests and grassland, natural forest protection, adjustment of agricultural structure and pollution source control to evolve into a series of new policy recommendations and measures.

Planning of Sustainable Comprehensive Utilization

It is an arduous task for a long period of time to come to promote economic development, protect and improve the environment and strive for sustainable development. The basic work to ensure sustainable development in the reservoir area is to analyze all the factors of the ecology and environment in a given period of time in the future, divide the ecological function zones and plan for sustainable development of different landscape units and, on this basis, ensure correct implementation by effective management.

The planning of sustainable comprehensive utilization work should include:

(1) Analysis and assessment of the current conditions of the ecology and environment in the reservoir area. This involves a comprehensive assessment of the current conditions of the ecology and environment of the reservoir area and the zoning of ecological functions.

(2) Fixing the objectives and principles for the comprehensive utilization and management, such as ensuring reservoir security, the display of the anti-flood, power generation, and shipping functions of the project, ensuring the security of the ecology and water quality and sustainable development of the reservoir area, rationally utilizing the water and soil resources and tourism resources. The objectives may be divided into immediate future, medium-term and long-term.

(3) Fixing the scope of comprehensive utilization and management, such as incorporating the surrounding land, river banks, water-level fluctuating zone and water surface of the reservoir into reservoir planning.

(4) Planning by county. It requires the planning of resources utilization with county as the basic unit so as to facilitate management and operation.

(5) Planning of functional zoning. This requires the functional zoning of the surrounding land, river banks, water-level fluctuating zones and water surface to determine the ecological functions of every small zone, the way of development and utilization and technical requirements. For instance, the limitation of the application of chemical fertilizer, land development and prevention of landslide, scope and scale of fish breeding in cages, and the scope of the natural or ecological landscape protection zones. Only with detailed functional zoning is it possible to formulate corresponding and operable management system.

(6) Utilization of recreational (including tourism) resources. After the formation of the reservoir, the area is bound to become a new type of tourism attraction, with the tourism pattern mainly featuring sightseeing likely to be turned into one featuring mainly recreation and vacationing. It is, therefore, necessary to attach much importance to the value in recreation of the reservoir area and give it full consideration in planning.

(7) Fixing the major areas and projects for priority implementation of the ecological restoration and environmental improvement, such as the fixing of such projects as water and soil loss control of all ecological functional zones, green belt around the reservoir, returning farmland to forests and grassland, and natural forest protection and the determination of the purposes of the use of the land and bank lines, water-level fluctuating zone and water surface in a given scope.

Formulation of policies and laws concerning sustainable comprehensive utilization. This includes the formulation of the “Three Gorges Reservoir Management Regulations”, which should make clear the objects, scopes, and principles of management, the management system after the reservoir is completed, including management organization and related departments and their relations with related provinces, cities and departments and their division of responsibilities and powers. In addition, it is necessary to formulate Planning on the Sustainable Comprehensive Utilization of TGP Reservoir, planning of the functional zones and special resources utilization, which should be matched with specific management system, such as “Management Rules on Riparian Land Utilization of Three Gorges Reservoir”, “Management Rules on the Utilization of Water-Level Fluctuating Zone of the Three Gorges Reservoir”, “Management Rules on the Utilization of the Water Surface of the Three Gorges Reservoir” and “Management Rules on the Extraction and Use of Water from the Three Gorges Reservoir.”

9 TGP Eco-Environmental Protection Measures

The TGP is a project that has both advantages and disadvantages with regard to environment. It is good to the environment when it helps raise the anti-flood capabilities in the middle and lower reaches of the Yangtze to protect the property and life of millions of people and ensure the space of survival for the people. Hydropower is regarded as clean energy by its supporters. The TGP power station can replace seven 2.6 million kW of thermopower plants and can save 50 million tons of coal annually and cut the discharge of CO_2 by about 100 million tons, SO_2 by two million tons, CO by about 10,000 tons, N_2O by about 370,000 tons as well as a large amount of industrial waste. The project will play a key role in mitigating acid rains, soot and other environmental pollutions in China and its neighboring countries and reducing the global hothouse effect caused by CO_2 discharge. The project will also ease the sedimentation and shrinking of the Dongting Lake and improve the water quality in the lower reaches of the Yangtze during the low water season.

Of course, like any other large projects, it has its disadvantages, especially its unfavorable impacts on the surroundings and the social and economic development and environment. China attaches much importance to protecting the environment in constructing this mammoth project. It has compiled an environmental impact report and the preliminary design report that devotes a whole chapter to environmental protection. Since the start of the project, the state has adopted a series of measures to protect the ecology and environment of the reservoir area and other areas likely to be affected.

9.1 Special Environmental Protection Measures

9.1.1 Adjustment of Resettlement Policies

The number of people and materials affected by the super large project is rare in Chinese history and even in the world. According to the normal 175 m operation scheme, the areas to be inundated include 28,000 km^2 of farmland, orchards and wooded land in 20 counties (cities and districts), involving 840,000 people. If the natural growth of population is taken into account, a total of 1.13 million people have to be relocated by 2009 when the project is completed.

In order to improve the ecosystem and the living of the people, the State Council made two major adjustments to the resettlement policy, that is, increasing the number of rural people moving out of the reservoir area and intensifying the restructuring of enterprises to move out of the reservoir area in order to effectively ease the conflicts between man and land and reduce industrial pollution.

By the end of June 2004, 166,000 people had moved out of the reservoir area and been resettled in some other parts of China. Among them, 96,000 people moved to 11 other provinces and cities, including Shanghai, Jiangsu, Zhejiang, Shandong, Fujian, Guangdong, Hunan, Hubei, Jiangxi, Anhui and Sichuan. Restructuring had been done with 1222 industrial enterprises, including forced bankruptcy, shutting-down or shifting to other areas of production, that major policy decision has a long-term and profound impact on the sustainable economic and social development in the reservoir area.

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2_9

9.1.2 Water Pollution Control Plan for the Reservoir Area and Upper Reaches of the Yangtze

In order to protect the water quality of the reservoir and reduce pollutant discharge into the reservoir and upper reaches of the river, the State Council held a resettlement and partnership support work conference in Yichang in July 2001. The meeting demanded the State Environmental Protection Administration (SEPA) and other related departments and the governments of related provinces and cities to compile a plan for the control of water pollution of the reservoir. On November 2, 2001, the State Council approved the implementation of the plan. The plan covers three areas: reservoir area and major cities districts of Chongqing and 20 districts, counties and cities (including four districts and counties in Hubei and 15 districts, counties and cities and major cities districts of Chongqing), 42 districts, counties and cities affected by the reservoir (including four districts, counties and cities in Hubei province, 15 districts, counties and cities of Chongqing City, 20 districts and counties in Sichuan and three cities and counties in Guizhou), 214 districts and counties of 38 prefectures and cities in the upper reaches of the reservoir area (including 7 prefectures and cities in Yunnan, 7 in Guizhou, 21 in Sichuan and 3 in Chongqing). The total areas covered are 790,000 km^2, with a total population of 154 million, 60% of the people involved are in agriculture. In fact, all the areas in the upper reaches of the Yangtze have been incorporated into the plan.

The general plan is to be implemented in two stages, with 2000 as the base year. Goal for the first stage, that is, up to the end of 2005, is to bring the surface water quality of major controlled sections in the reservoir area and the upper reaches of the Yangtze to hit Type III standards and by 2010, to bring the water quality up to Type II standards. The total investment is estimated at 39.22 billion yuan. Of this amount, 21.65 billion will be used to build urban sewage treatment plants; 7.75 billion will be used to invest in landfill for urban garbage; 2.48 billion will be used to control industrial pollution; 4.47 billion will be used for ecological protection projects, 700 million yuan is scheduled for the basic capacity building and 1.47 billion will be used to control pollution caused by vessels.

By the end of 2004, the urban sewage treatment and garbage landfill projects had been going on smoothly. The plan requires the completion by the end of 2005 of 80 sewage treatment projects, with a combined treatment capacity of 5 million tons a day. Now 20 have been completed, adding a 725,000 tons/day capacity; 34 are in progress and 26 others are yet to be started. The reservoir area had completed 29 sewage treatment projects, with a combined treatment capacity of 1.975 million tons. Of these, 15 had been completed, adding a 520,000/t treatment capacity, eight are in progress and six others are yet to be started.

The plan requires the completion of 91 garbage treatment projects before the end of 2005. Of these, 17 have been put into operation; 51 are scheduled for completions by 2005; and 22 others are yet to be started.

The industrial pollution control projects have been getting on slowly. Of the 147 major industrial polluting projects, 56 have been shut down; 29 have reached the required objectives after control; 11 are working on the project and 51 others have not started yet. According to the requirements of the plan, 304 enterprises below the required scale have been shut down and, of the 242 heavily polluting enterprises, 15 have completed their control tasks.

Fengdu Sewage Treatment Plant

Outlet of the Fengdu sewage

Fengdu garbage landfill
Sewage treatment plants and garbage landfill in the reservoir area. Photo by Huang Zhenli

9.1.3 Geological Disaster Prevention and Control Plan and Its Execution

The Three Gorges Dam site enjoys superior geological conditions, but the reservoir area is a place suffering from landslides and mudflows. On slope of the two banks of the mainstream and tributaries bellow 600 m, 4719 hazardous spots have been identified. They pose serious threats to the life and property of the people and the resettlement projects. The State has invested greatly to prevent and control geological disasters.

In January 2002, the State Council approved the general plan for the prevention and control of geological disasters in the reservoir area compiled by the Ministry of Land Resources (MLR) and allocated four billion yuan for the project and for building a geological disaster monitoring and pre-warning system. The tasks that are required by the plan to be completed before June 2003 when the water level reaches 135 m are: control of about 198 crumble-slide prone bodies (56 in Hubei and 142 in Chongqing), protection of 81 river bank sections from collapsing (22 in Hubei and 59 in Chongqing), relocation of people from 232 hazardous sites (55 in Hubei and 177 in Chongqing), protection of 214 high-cut slopes (34 in Badong, 90 in Wushan and 90 in Fengjie) and reinforcement of deep foundation in 803 sites (178 in Hubei and 625 in Chongqing) and rockfall and landslide monitoring and pre-warning projects and research projects. After surveying and designing adjustment, Hubei and Chongqing actually completed the following projects: control of 163 rockfall and landslide hazardous sites (44 in Hubei and 119 in Chongqing), protection of river banks in 71 sections (22 in Hubei and 49 in Chongqing), protection of 147 high-cut slopes (34 in Badong, 64 in Wushan and 49 in Fengjie) and reinforcement of 803 deep foundations (178 in Hubei and 625 in Chongqing) and relocation of people from 180 hazardous sites (19 in Hubei and 161 in Chongqing). The rest existing hazards are subject to risk management by adopting such measures as intensifying monitoring and issuing warnings. A monitoring and pre-warning system made up of professional monitoring systems, prevention systems with mass participation and information system has initially taken shape to keep a professional watch on 129 sections for major potential rockfall, landslide and bank collapse, leaving 1216 other sections to monitoring by a network with mass participation, thus completing the formation of a GPS three-tier monitoring network made up of 1337 monitoring points and 20 district (county) local area networks.

In November 2003, the MLR organized the compilation of a plan for preventing and controlling geological hazards and disasters at the third stage of water storing of the reservoir. Incorporated into the plan were the engineering control of 372 sections, protection of 408 bank sections, totaling 169.5 km, relocation of people from 373 sites, 1977 sites subject to monitoring and warning and control of 1198 high-cut slopes. In order to ensure the goal of storing water up to a level of 156 m, it required the completion of 195 emergency control projects with regard to rockfall and landslide, protection of 92.8 km of bank sections prone to collapse and relocation of people from 258 hazardous sites.

Pictures of Badong Huangtupo before and after treatment control (*Above* before control; *Below* after Control)

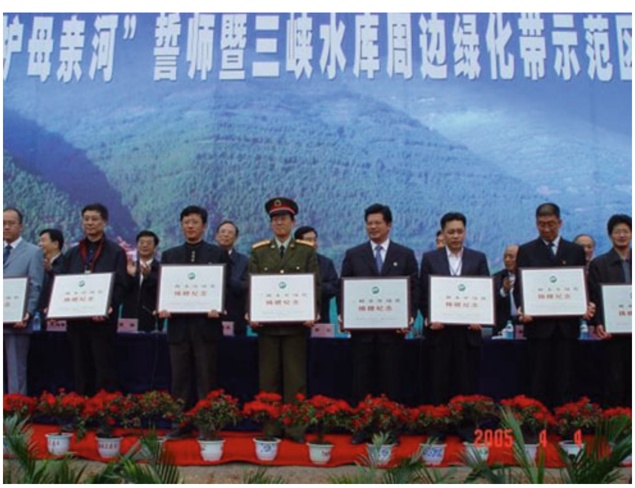
Project for protecting the reservoir bank at the Town of Taipingxi, Yiling District of Yichang City

9.1.4 Green Belt Project Around the Reservoir and Its Execution

By drawing on the experience of Brazil in building green belt around the Itaipu Dam, China plans to build green belts around the reservoir as a natural ecological screen to protect terrestrial animals and plants and safeguard the ecological security. In June 2003, when the second phase of the dam project was completed and water began to store, permanent shiplock opened and the first power generating unit went on operation, the central authority re-stressed the restoration of the ecosystem and environment of the reservoir area. In September 2003, Premier Wen Jiabao presided over the 13th conference of the Three Gorges Project Committee. The conference decided to compile a Construction Program for Green Belt Surrounding the Three Gorges Reservoir. In April 2004, the State Council approved the program worked out by experts organized by the National Development and Reform Commission. The planned total investment was

1.79 billion yuan. The project covered four counties and districts in Hubei and 22 counties and districts in Chongqing, where 733,000 mu (48,866.6 ha) of farmland once claimed from forests and grassland were to be reafforested (including 5000 mu or about 333 ha of slope land to be converted into terraced fields), 179,000 mu (about 11,933 ha) of barren hills and wasteland were to be planted with trees, 180,000 mu (12,000 ha) of mountains to be sealed up for cultivating woods and irrigation and drainage facilities in 764,000 mu (about 50933 ha) of farmland are to be improved. By the end of 2004, all the projects had started, with project survey and planning, operational designs and annual execution plans put in place.

The Central Committee of the Communist Youth League, the Executive Office of SCTGPCC, the Ministry of Water Resources (MWR), the SEPA and the State Forestry Administration (SFA) started in March 2004 to jointly launch activities for beautifying the Three Gorges and protecting the mother river. The activities have inspired the awareness of environmental protection in the whole society. All the youth league members took an active part in planting and protecting trees and the environment. In March 2005, the five ministries and administrations jointly issued a Notification on the "beautifying the Three Gorges and protecting the mother river" and actively mobilize the social forces to support and participate in the project. The call received enthusiastic response from the Central government units and departments, Chinese Peasants' and Workers' Democratic Party, the People's Liberation Army, partnership aid provinces and cities, and Chinese and foreign enterprises. People from all quarters donated actively. In April 2005, a demonstrative project was launched jointly in Yunyang County of Chongqing.



On April 4, 2005, activities of beautifying the Three Gorges and protecting the mother river and the demonstrative project were launched in Yunyang. People from all quarters actively donated for the project (Photo by Huang Zhenli)

Former Vice-Premier Zeng Peiyan wrote an inscription for the demonstrative green belt project, which reads: "In Memory of the Greening Project Around the Reservoir". The table with the inspection is planted in the demonstrative project of Yunyang County (Photo by Huang Zhenli)

9.2 Ecological and Environmental Protection Project Covered by the Project Estimates

9.2.1 TGP Eco-Environmental Monitoring System

The system has been dealt with in detail from Chap. 4 through Chap. 8.

9.2.2 Protection of Terrestrial Animals and Plants and Aquatic Life

The most effective measure to protect the biodiversity is to set up natural reserves that will protect species and their habitats. China has designated a number of protection zones to protect terrestrial and aquatic life affected by TGP (Table 9.1). The protection zones planned are mainly in the high mountain areas such as Dalaoling of Yichang and Longmenhe of Xingshan, as there are not the conditions for building natural reserves in low altitude areas directly affected by the project. Looseflowered falsetamarisk (*Myricaria laxiflora*) is a species to be inundated. The original plan for the protection should be readjusted and ex situ cultivation in similar habitat has been tried. Study is also under way on the possibilities of cultivating the plant in the 30 m water-level fluctuating zone to improve its landscape. Chinese kidney maidenhair (*Adiantum reniformevar. sinense*) is a species to be partially inundated. But as the community is scattered and narrowly distributed at places above the 175 m water level, the only way of protecting it is to designate protection points.

Table 9.1 TGP Natural Reserves

	Name	Targets of protection	Area or length	Progress
Terrestrial life	Hubei Yichang Dalaoling Plant Diversity Protection	Sub-tropical mountain natural forest ecosystem, some rare and endangered species moved in	5936 hm^2 (Core area: 1530 hm^2)	Approved as state forest park in 1992, Design work started in 1995 and construction from 1997 to June 1999. Plant checklist completed
	Hubei Xingshan Longmenhe sub-tropical evergreen broadleaf forest protection project	Sub-tropical evergreen coniferous forest, natural vegetation, plant and species diversity and rare plant communities	4644 hm^2 (Core area: 873 hm^2)	Designing completed in 1999 and construction from 2002 to 2004. Plant checklist completed
	Chongqing Wushan Little Three Gorges landscape and ecology protection zone	Natural landscape, ecosystem and environment, cultural relics and ancient cultural ruins	2000 hm^2	Already a tourism attraction, under strict protection
	Chongqing Wanzhou Xinxiang *Adiantum reniformevar.sinense* protection point	Original habitat and community	To be decided	Artificial cultivation and ex situ preservation completed
	Hubei Zigui *Myricaria laxiflora* protection point	Original habitat and community	To be decided	Ex situ conservation, artificial multiplication completed
	Hubei Yichang Chuanminshen protection point	Original habitat and community	To be decided	Artificial cultivation and ex situ conservation completed
	Reservoir area ancient tree protection	Ancient trees and environment (totaling 199)	Single tree	44 ancient trees protection project completed in 1998
Aquatic life	Yangtze upstream rare and endemic fish natural reserve	Chinese paddlefish, Dabry's sturgeon, Chinese sucker, and Yangtze endemic species	250 km (Hejiang–Pingshan)	Approved as state class natural reserve in 1999, plan adjusted in 2005 (including Chishui Rare and Endemic Fish Protection Zone)
	Chinese sturgeon natural reserve downstream the Gezhouba Dam	Chinese sturgeon, spawning ground, habitat	80 km (Gezhouba–Zhijiang)	Approved as Hubei Provincial natural reserve in 1996 and protection project completed in 2004
	Baiji Dolphin protection in the Xinluojiang section of the Yangtze	Bi Dolphin, and Finless Porpoise	135 km (Luoshan–Xintankou)	Approved as state class natural reserve in 1992
	Chinese sturgeon juvenile reserve in the Yangtze Estuary	Chinese sturgeon juvenile	21 km (East of Chongming)	Approved as Shanghai municipal class natural reserve
	Tian-e-zhou semi-natural reserve	Baiji Dolphin and Finless Porpoise	21 km (Yangtze River) 89 km (Shishou)	Approved as state class natural reserve in 1992

For aquatic life, there will be five natural/semi-natural reserves. It is very difficult to set up rare fish natural reserves, as the Yangtze is China's main inland waterway for shipping and the human activities on both banks are frequent, which would inevitably interfere in the life of fish in the reserves, especially in the core areas. This, plus the inadequate management of illegal fishing operations in the river, will sabotage the habitats of fish. On the other hand, China is preparing for the Xiangjiaba and Xiluodu and other large water projects, which will cover the Hejiang-Pingshan rare and endemic fish protection zone. Now review work is going on concerning the conflict between the projects and the protection zone. As it is very important to protect the endemic species of fish in the Yangtze and yet the country has already decided to develop the cascade power stations on the Yangtze mainstream, it is suggested the selection of one or two tributaries in the upper reaches of the Yangtze that will not be used for power development as natural ecological rivers that will exist for a long time to come and protect the upstream endemic fish species to the maximum. In 2005, the State Council approved the plan of building an endemic fish protection zone in the main tributary—the Chishui River.

Plant diversity protection project in the Dalaoling state forest park in Yichang, Hubei Province

The targets of protection are the sub-tropical mountain natural forest ecosystem, rare species and big ancient trees. Subprojects include plant diversity protection, research,

Plate (*left*) and introduction (*right*) of the iongmenhe sub-tropical evergreen broadleaf forest protection zone in Xingshan

Xingshan Longmenhe sub-tropical evergreen broadleaf forest protection station

Three Gorges Arboretum in Xinshan, which protects rare trees in the reservoir area (Photo by Huang Zhenli)

Chishui River, a major tributary of Yangtze in the upper reaches where there is no dam and natural ecosystem has been preserved, is honored as “Eco-River”, “Wine River”, “Beautiful River” and “Hero River” for Maotai liquor, famous spirit brand in China and its revolutionary tradition [31–32]. In 2005, the State Council approved it as a rare and endemic fish protection zone. According to a survey by the Institute of Hydrobiology of CAS, the river boasts 116 species of fish, belonging to 71 genera, 17 families and 7 orders. 31 of them are endemic species in the upper reaches of the Yangtze. They include (*onychostoma*), *spinibarbus sinensis* and rock carp (Procypris rabaudi). Many of the species produce floating eggs, which need a long flowing distance to complete incubation (Photo by Huang Zhenli)

low-yielding forest transformation and infrastructure. Work started in May 1997 and was completed in March 1999. The cost was estimated at 4 million yuan.

Longmenhe sub-tropical evergreen broadleaf forest natural reserve in Xingshan of Hubei Province

The reserve mainly protects the fairly complete sub-tropical evergreen broadleaf communities and their ecosystem, species diversity and rare plants in the reservoir area. Work started in January 2002. It included civil engineering and plant engineering. Plant engineering included addition of trees, the building of rare tree gardens and forests of economic value. The whole protection project had been completed by the end of 2004, with a cost of 4.67 million yuan.

Rescuing protection of Looseflowered falsetamarisk and Chinese kidney maidenhair

The two kinds of plants are species endemic to the reservoir area, having great value in research and protection. They have been listed into the TGP environmental compensation project. They will be inundated totally or partially by the reservoir. The protection project that includes ex situ conservation, facility conservation and domestication and returning to nature will ensure their lasting survival and proliferation. The work cycle is scheduled for five years (September 2002–September 2007) at an estimated cost of 2.4 million yuan.

Captive rearing of rare fish species with release to the wild

The technology for artificial breeding of Chinese sturgeon (*Aclpenser Sinensis*), Dabry’s sturgeon and Chinese sucker (M*yxocyprinus asiaticus*) has become mature. The captive rearing of species with release to the wild has become one of the main means of multiplying the Chinese sturgeon after the building of the Gezhouba Dam. The work started in 1984. According to reports [30], 4.258 million fry and 62,800 3–5 g young fish were released in 1983–1998. Dabry’s sturgeon and Chinese sucker were also released. According to the preliminary arrangements, investment will be made in building three new stations for captive rearing of species with release to the wild in Chongqing, Wanxian and Yichang.

In carrying out the work, it is necessary to draw on Chinese and foreign experience and lessons, paying more attention to assessment of the results. The Gezhouba Dam released more than 4 million fry, but it is not clear about the multiplication results, that is, how many have entered the sea for recruitment and how many have migrated into the Yangtze. The result is not too optimistic. Secondly, there is excessive catch of parent fish for artificial breeding. According to incomplete statistics [30], 663 Chinese sturgeon (455 females and 208 males) were caught for research and breeding purposes in 1984–1998, but the number actually used for artificial breeding was only 107, thus causing losses in resources. This merits full attention. Thirdly, it is necessary to draw on Chinese and foreign management experiences to introduce the market competition mechanism so as to raise the efficient use of funds for captive rearing of species with release to the wild. Fourthly, the technology, such as non-fatal egg extraction and post-spawning parent restoration and the artificial breeding of Chinese paddlefish (*Psephuyrus gladius*) needs to be further improved.

Summing up the past experiences and lessons and in order to fully display the role of the existing research institutes that do captive rearing of species with release to the wild and improve the efficiency in the use of funds for such purposes, it is suggested to use the funds originally established for the construction of three artificial breeding and releasing stations to finance the existing breeding bases by introducing the market mechanism under the precondition that the original objectives are kept unchanged and, at the same time, strengthen the studies of technologies for breeding and releasing rare species of fish.

9.2.3 Strengthen TGP Ecological and Environmental Research

Studies of reservoir water pollution control

In 1995–2003, the Technology and International Cooperation Department, Executive Office of the SCTGPCC organized Tsinghua University, the China Institute of Water Resources and Hydropower Research (IWHR), Sichuan University, the Yangtze Water Resources Protection Bureau and the Chongqing Environmental Sciences Institute to study the water pollution control of the Three Gorges reservoir. The range of study covered survey and observation of the current conditions of the water quality of the Three Gorges reservoir, construction of a mathematical model to calculate and analyze the water quality in the late period of project construction and the beginning of the operation of the reservoir, comparing the changes of the hydro-environment of the reservoir before and after its formation, zoning the functions of the reservoir water body, determining the hydro-environmental capacity of the riparian and total water body and putting forward a scheme of optimal distribution of pollution load and water pollution control measures and establishing a pollution information management system. The main conclusions of the studies are as follows:

The water quality of the mainstream of the Yangtze in the reservoir area is good as a whole, although there are riparian pollution belts in some city sections of the river. The main pollutants are TP, COD_{Cr} and NH_3-N.

Release of marked Chinese sturgeon in 1997. *Left* Chinese sturgeon fry. *Right* Fluorescent marking of Chinese sturgeon

(1) The general water quality has no change with the water storage but the riparian water quality would be poorer than before.
(2) The water temperature at the head of the reservoir is clearly stratified in May and June and becomes uniform in July and August, with the mass density evenly distributed vertically in months when the temperature is not stratified.
(3) The hydro-environmental capacity after the formation of the reservoir is generally bigger than before its formation, but the riparian hydro-environmental capacity has become less.
(4) A water pollution control information management system has been established and there should be a scheme for controlling the total amount of COD_{Cr} and NH_3-N.

With the research project going into depth, a special topic on principal pollutants and sediment coupling action and its impact on water quality started in 2003. The research groups studied how sediment absorbed pollutants and carried out numerical simulation studies of the pollutants transportation and movement pattern under the concerted action of water flow and sediment and quantitatively assessed the impact of sedimentation on the water quality of the reservoir after its completion.

Studies of biodiversity protection

(1) Aquatic life
- Study of Chinese sturgeon (*Aclpenser Sinensis*) by ultrasound wave remote sensing technology. Major breakthrough has been made in the study of the scale, position and conditions of the spawning grounds for Chinese sturgeon downstream of the dam.
- Studies of the protection of endemic fish species in the lower reaches of the Yangtze. The environmental impact report requires the investigations into the fish species in the upper reaches and tributaries of the Yangtze. The research group has carried out in-depth investigations of fish species and their habitats in the Chishui River and put forward protection schemes seeking solutions to the conflict between cascade power station development project on the Jinsha River and fish protection.
- Studies of the protection of Baiji dolphin. It has got clear about the number (less than 100) of Baiji dolphin and put forward countermeasures for protection.
- Studies of the assessment of captive rearing of Chinese sturgeon with release to the wild. The first assessment of the results has been carried out, which has an important role to play in directing future capital rearing with release.
- Verification of the early resource investigating methods and fish fry species. For the first time, the work has been completed on the early resources investigation methods and atlas of fish development in the Yangtze, which serves as a technical document for verifying fish species by the monitoring system.
- Studies of rescuing protection of *craspedacusta* in Zigui County. More than 40,000 such species have been domesticated in Zigui and other waters and on the experimental farm in Wuhan. There have been clear conclusions about *craspedacusta* with regard to its distribution and multiplication.

(2) Terrestrial plants
- Studies of the protection of rare plants in the Dalaoling forest park in Yichang. While the protection work is being done, a plant directory within the protection project has been compiled.
- Studies of domestication of Chinese kidney maidenhair, Looseflowered falsetamarisk and *Chuanmingsen* with transplantation in the wild. Work has been completed for multiplying three species. Problems of domestication and transplantation in the wild have been solved. The domestication and transplantation in the wild in Sixi of Zigui County have basically been successful.
- Studies of the protection of big ancient trees in Hubei. Work has been completed on the protection of 40 ancient trees in the Hubei reservoir area.
- Studies of plant diversity of evergreen broadleaf forests at Longmenhe of the reservoir area. While protection work is being done, a plant directory has been compiled.

Endemic and rare plant multiplication base at Sixi of Zigui County (Photo by Huang Zhenli)

Myricaria laxiflora growing well in the Endemic and rare plant multiplication base (Photo by Huang Zhen li)

(3) Studies of ecological restoration

In the process of TGP project, the government encouraged the people in the reservoir area to move out and carry out developmental resettlement to ease the conflict between man and land. For those remaining in the area, they are encouraged to carry out experiments, demonstration and spread of eco-agriculture and consolidate the achievements in controlling water loss and soil erosion.

For instance, the Wanzhou eco-environmental station has carried out experiments in building underground plastic sheet wall to block water from being lost, in intercropping of grain and cash crops on the slope land and in utilizing the land with outcropping rocks and in building biological hedgerows, spread fine strains of seeds and domestication of vegetables, fruit trees, medicinal herbs and grazing grass. The Zigui station has tried out technical research and demonstration in water and soil conservation in resettlement areas and small catchment area and experiments and demonstration of comprehensive control of water loss and soil erosion of slope land.

The demonstrative projects have provided guidance to changing the plant cultural patterns, the agricultural product mix, planting technology and water and soil conservation technology, thus giving an impetus to the rural economic development and the improvement of the ecological environment.

(4) "Chunhui Program" of Chongqing

Chongqing Municipality has launched a program of action known as "Chunhui" (Spring Glory). It has four subprojects: Comprehensive control plan for solid waste in the reservoir area and major cities in the area and the studies of related technologies, applied research in fine grassland construction and the industrialization of beef cattle in vitro fertilization (IVF) technology in the reservoir area, and studies of steep land forest ecosystem restoration model in the reservoir area, which are undertaken by Chongqing University, and the studies of the impact of major environmental factors on sediment generation in the reservoir area undertaken by the Chongqing Jiaotong College. The studies of the solid waste removal directly serve the work of clearing the reservoir. Based on the research achievements, part of the districts and counties have cut greatly the amount of garbage that has to be removed, thus saving a lot of investment.

9.2.4 Environmental Protection in the Construction Site

In August 1994, the Yangtze Water Resources Protection Bureau compiled a program of action on the environmental protection of the TGP construction site, which was examined and approved by an expert panel organized by the SEPA and the State Council TGP Office. The program outlined specific measures and provided the scientific basis for environmental management in the construction site. This has enabled the environmental protection of construction site to reach the first class in the world. The program has analyzed the water quality, air, noise, rejects, garbage, greening, people's health and stone material piles and their impacts on the environment, especially the material piles at Huyatan downstream of the dam and its impact on the spawning ground of Chinese sturgeon and put forward corresponding protection measures.

The TGP Corporation, following the requirements of the program, formulated the rules of management of TGP construction site and formed an environment and cultural relics protection committee and an environmental protection center, built an environmental monitoring system to monitor the quality of the environment regularly to keep the ecosystem and environment in shape. The corporation also restored the sites for construction purpose by planting trees and grass. The sewage water in the construction site all has gone through the secondary deep processing. The water discharged from the basement and sand and stone material processing systems and oil-containing wastewater have all reached the state standards for discharge. All the engineering facilities have been equipped with devices to reduce pollution to the air, including advanced dust-free drilling machines. The water sources for the construction site have been brought under priority protection. There is a tap waterworks in the construction site and people working in the site can have safe and healthy water to drink. There is also an emergency treatment center to exercise strict supervision and management of food hygiene. All the people working in the site have to go through regular physical checkup. At present, the construction site has become a tourist attraction. It has won high appraisal from Chinese and foreign tourists.

9.3 Eco-Environmental Protection Program Incorporated into the Resettlement Estimates and Its Implementation

9.3.1 Environmental Protection in the Resettlement Areas

In order to avoid people resettlement from causing environmental problems, special arrangements have been made with regard to environmental protection. Work has started to experiment in spreading high-efficient ecological agriculture in areas for rural resettlers in order to expand the environmental capacity and prevent water and soil loss. In building new towns, all places have proceeded from the actual situation to plan their sewage treatment plants and designated green areas and parks, and shut down polluting enterprises. In addition, they have strengthened monitoring of the drinking water sources and strengthened anti-epidemic measures and monitoring of the people's health to prevent major outbreak of epidemics. The governments at all levels in the reservoir area have all adopted measures to reduce pollution by enterprises by having their product mix adjusted and strictly forbidding polluting enterprises from entering the reservoir area.

9.3.2 Reservoir Bottom Clearance

Before the second stage of water storage, the state organized related departments and the two provinces concerned to formulate strict technical documents, standards and requirements concerning the clearing of the bottom of the reservoir and structures, woods, garbage and solid waste to be cleared under the inundation line to ensure the water quality security and people's health.

By the end of June 2003, what had been removed or cleared from the bottom under the 135 m water storage line included 1528 infectious pollution sources, 38,803 graves, elimination of rats in 160.161 million m^2 of land, 2.38 million tons of garbage in 314 sites and 2.42 million tons of solid waste in 217 sites, 16,300 tons of dangerous waste in 141 sites, 19 waste radioactive sources, 14.9605 million m^2 of building structures, 83,300 mu (5553.33 ha) of forests and 2.9 million scattered trees. The second stage of bottom cleaning was completed in high quality and accepted by the state.

9.3.3 Protection of Cultural Relics

Historical sites and cultural relics are the precious legacy of the Chinese nation. The Chinese government sets great store by protecting them. The massive excavation had postponed the TGP construction twice. Starting from 1993, cultural relic's protection workers from about 30 units carried out overall surveys and excavations. In 1998, the State Council TGP Committee approved 1087 sites for protection (752 in Chongqing and 335 in Hubei). Among them, 723 needed excavation (506 in Chongqing and 217 in Hubei) and 364 historical sites on the ground need protection (246 in Chongqing and 118 in Hubei).

The people's governments of Chongqing and Hubei and related departments have conscientiously implemented the decisions to protect cultural relics, clearly defined their duties and responsibilities, adopted new measures and strengthened management. Related cultural relics and resettlement departments have done a huge amount of work according to the principle of making protection the main means, rescue first and carrying out protection and excavation of key projects. That has insured the progress in the fulfillment of the annual plans. The cultural relics protection sites are well managed, without any accidents happening. The lagging of the translocation of historical sites was corrected. The management work has gradually been put on track. The objectives of cultural relics protection in the reservoir area is surely realized so long as the objective management is tightened up.

9.4 Supervision and Management of Eco-Environmental Protection

All related departments of the State, including water resources, environmental protection, agriculture, forestry, construction, communications and health, have strengthened supervision and management of the ecological and environmental protection of the reservoir area. They have adopted all possible measures and enforce strictly of the environmental protection law. At the same time, while intensifying their partnership program, they have strengthened the capacity building and personnel training of environmental protection units in the reservoir area. TGP will bring about unfavorable impacts on the ecology and environment of the reservoir area. The vulnerable ecosystem, the growing economic development and human activities will also bring unfavorable impacts on the water quality security and ecological security in the reservoir area. It is, therefore, of special importance and urgency to manage the ecology and environment well in the reservoir area. The strengthened supervision and management have helped enhance the environmental awareness of the governments at all levels and local people and brought about significant improvements to the environmental protection facilities in the reservoir area. It has become the common understanding of the governments at all levels and local people to strengthen environmental protection and embark on the path of sustainable development. This section is devoted to the supervision and management of the reservoir area by such departments as environmental protection, communications, fisheries and forestry.

9.4.1 Supervision and Management by Environmental Protection Departments

The SEPA holds the main responsibilities. Since the TGP started, it has strengthened its supervision and management. In 2001, it formed a leading group for the prevention and control of water pollution in the reservoir area. Together with other departments, it also organized the drafting of technical conventions for clearing garbage and floating objects in the reservoir area and carried out law enforcement and implementation checks concerning the treatment of sewage water, industrial wastewater and pollution caused by vessels. It examined and approved the program of action on the environmental protection in the TGP construction site and organized supervision over its implementation. It organized its affiliated water quality monitoring organizations to set up a monitoring network that covers the whole Yangtze River and the reservoir area.

The environmental protection departments of Hubei Province and Chongqing Municipality strengthened supervision and management within their jurisdictions. Chongqing environmental protection department strengthened air pollution control in the main city districts and announced the ban on the sale and use of detergents containing phosphorus.

9.4.2 Supervision and Management by Industrial Departments

Communications departments

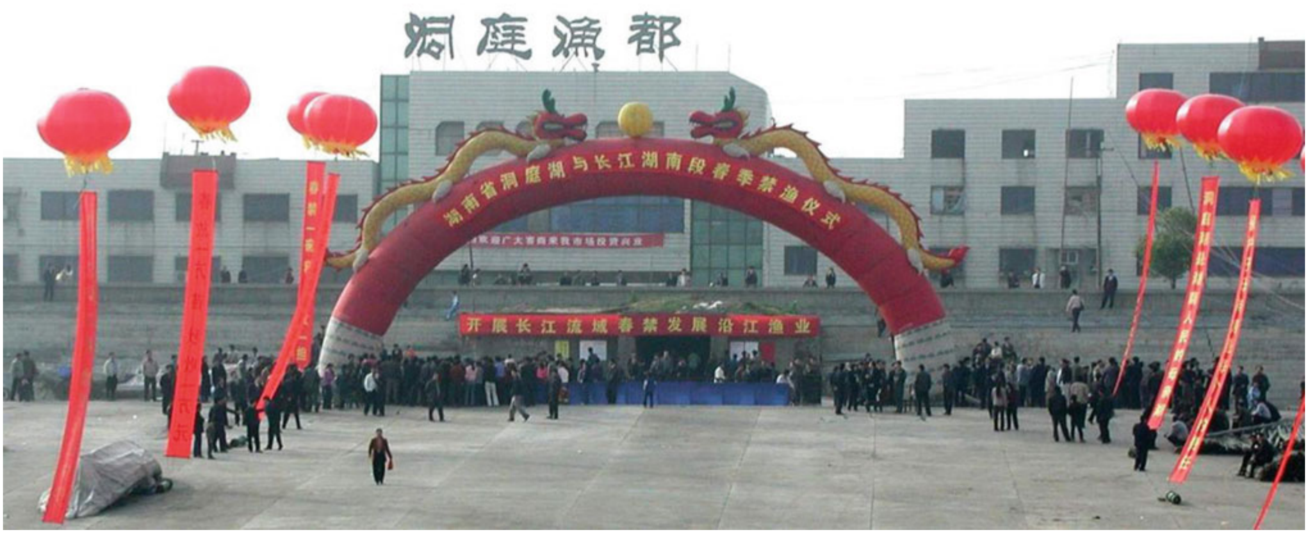
With the improvement of the economic development and the water storage of the reservoir, the number of vessels and volume of shipping have increased sharply. According to statistics from the Gezhouba Dam, the transportation volume of all kinds of vessels passing through the Gezhouba shiplock came to 43 million tons in 2004. The increase in the number of shipping vessels has brought about the increase in pollution, such as sewage, oil-containing water, waste gas and noise, especially the tourist and other passenger vessels, which used to discharge their wastes directly into the reservoir and the Yangtze, causing serious social consequences. So the pollution caused by vessels has always been the focus of attention of all quarters.

The Ministry of Communications (MOC), as the department in charge of inland waterway shipping, has over the years, together with related departments, attached much importance to the control of pollution caused by vessels in the reservoir area. In 2004, together with the National Development and Reform Commission, the MOC issued a circular concerning the Notification on collection of fees for vessels discharging garbage, which resulted in the establishment of the system of transiting vessel garbage and fee collection. It also issued a Notification on placement of oil boom in the reservoir area, requiring the boom arrangement in loading and unloading of all bulk oils or oil-like materials. It drafted the Rules of the Reservoir Area on the Management of Transit and Takeover of Vessel Garbage and Rules on the Management of Pollution of Inland Waterways Caused by Vessels. The Ministry has carried out "Studies on Status Assessment and Counter-measures against Floating Pollution Caused by Vessels in TGP Reservoir Area", the "Study on key technologies to prevent and control pollution caused by vessels" and strengthened the supervision and checks of units receiving pollutants from vessels. The Ministry has also compiled the Emergency response plan against pollution accidents caused by vessels.

Fishing management departments and the fishing ban

The fish resources in the Yangtze have been declining at a fast clip according to the long-term monitoring. The resources of some fish species are already nearing extinction, directly affecting the life of the fishermen and also the sustainable development of the fish ecology and fishing economy. The causes, apart from the water conservancy projects, creating land from lakes and water pollution, indiscriminate and illegal catching is an important reason that allows no time for the resources to survive and recover. So it is the most urgent and the most important task to adopt effective measures to protect and increase the fish resources and make up for the lasting huge "deficit" in the ecosystem so as to make the Yangtze display its due role as a fish gene bank and the multiplication of fish of economic value and renew its past glory. The institution of the fishing ban period is one of the direct and effective means. The Ministry of Agriculture decided to try a three-month spring fishing ban in part of the river sections. The practice spread to all 10 provinces and cities along the Yangtze starting from 2003.

The fishing ban included the fishing ban principle, which requires unified organization and implementation during different periods of time and at different river sections. With the Gezhouba as the boundary, the Yangtze is divided into two sections where fishing ban is introduced during different periods of time. Each fishing ban period lasts three month in each river section. The fishing ban also outlines the scope, specifying that fishing ban is introduced in the mainstream of the Yangtze from Deqin County of Yunnan Province down to the estuary (Nanhuizui to Qidongzui) and the first-level tributaries in Hubei, Sichuan, Chongqing and Guizhou such as Hanjiang, Minjiang, Jialingjiang, Wujiang and Chishui as well as the Poyang Lake area and the Dongting Lake area. The specific time for the fishing ban is: from 12:00 on February 1 to 12:00 on April 30 every year for the river section from Deqin County in Yunnan Province to Gezhouba; from 12:00 on April 1 to 12:00 on June 30 for the river section from Gezhouba downstream to the estuary. All the fishing operations are banned except Tapertail anchovy and *Coilia ectenes*, which are subject to quota control. The state class aquatic products breeding farms and research institutions have to get approval from the Ministry of Agriculture for catching natural fry. During the fishing ban period, the multiplication activities are required. According to incomplete figures, in the three years from 2002 to 2004, the ten provinces and cities released to the river 14 species of fry, including carps, Longsnout catfish (*Leiocassis Longirostris*), Upper mouth culter (*Culter alburnus*), Yellow catfish (*Pelteobagrus fulvidraco*), Far east puffers (*Takifugu* spp.), *Spinibarbus sinensis*, Chinese mitten crab and Chinese sturgeon. Among them, about 150 million fry of the four major endemic species were released.



Ceremony Marking the Fishing Ban in the Dongting Lake area

Check on the implementation and enforcement of fishing ban

Ceremony for releasing fish in Jingzhou

Ceremony for releasing rare aquatic life in 2004

Releasing Chinese sturgeon

Efforts of forestry departments

Since the start of the TGP, the State Forestry Bureau has done a great deal to the protection and restoration of the ecosystem of the reservoir area. It has formulated project plans and made investment in forestry management and protection. In recent years, in particular, it has incorporated the natural forest protection, returning farmland to forests and the Yangtze shelter belt, natural reserve and wild life and plant protection of 20 counties in the reservoir area into the state sponsored projects and provided financial support to accelerate the pace of restoring and improving the forestry ecology.

(1) Protecting natural forests. It has exercised effective management and protection of the existing 34.35 million mu of forests in 20 counties and stopped commercial felling of natural forests and reduced the timber output by 310,000 m^3. It plans to bring the artificial forests to 920,000 mu, aerial seeded forests to 3.01 million mu and sealed-up mountains for tree cultivation to 6.39 million mu by 2010. By the end of 2002, it had completed tree planting on 940,000 mu and aerial seeding on 790,000 mu and the sealed up of 2.3 million mu of mountains for tree cultivation, costing 680 million yuan. It has come down sharply on activities of sabotaging forest resources, poaching and reclamation and occupation of wooded land.
(2) Doing well in returning farmland to forests and promoting the adjustment of the rural industrial structure. According to the preliminary plan for returning farmland to forests, 20 counties in the reservoir area returned 13.30 million mu of farmland reclaimed from forests by the end of 2005. Of this, 6.4 million mu were re-afforested and 6.90 million mu of barren mountains were also afforested. In 2000–2003, 7.605 million mu of farmland reclaimed from forests were scheduled to be returned, accounting for 57% of the total planned. The implementation of the projects of reafforestation and grass planting on farmland reclaimed from forests and grassland has helped improve not only the ecology of the reservoir area but also the agricultural structure, rural economic development and the income of local farmers.
(3) Strengthening the building of shelterbelts in the upper reaches of the Yangtze to create an ecological screen for the reservoir area. In order to reduce sand and mud that enter the reservoir and ensure safe operation of the reservoir, the state started the first phase of the shelterbelt project in the middle and upper reaches of the Yangtze since the very start of the TGP. The project covers 172 counties in 9 provinces which used to suffer from serious water loss and soil erosion. In 1989–2000, the state invested 490 million yuan and localities raised 530 million yuan and put in 1.05 billion workdays, completing the afforestation on 57.76 million mu. This raised the forest cover from 19.9% in 1989 to 25.5% by 2000. The forest cover in the 20 counties in the reservoir area was raised by 10 percentage points. Starting from 2001, the state went on with the second phase of the shelterbelt project and identified key projects for water and soil conservation and reservoir bank protection. According to the plan, the 20 counties in the reservoir area will afforest 4.93 million mu by 2010 and transform 2.81 million mu of low-efficient shelterbelts.

The practice of forest ecology construction over some years has resulted in a set of successful measures for comprehensive control. These include (1) sealing up the mountains for tree cultivation to improve the quality of standing stock and increase the stability of the forest ecosystem; (2) afforesting barren mountains and giving priority to the projects in the reservoir area to increase the forest cover in addition to protecting the natural forests, building shelterbelts and the afforestation projects with aid from Germany and loans from the World Bank. (3) returning land to forests, especially on steep slopes; (4) stopping wanton felling of natural forests and shutting down timber processing enterprises or making them shift to other production; (5) planting firewood forests, transforming firewood burning stoves and using coal, electricity, biogas and solar energy instead in order to reduce the consumption of forest resources; (6) resettling people living on slope land of over 25° in gradient. Sample surveys show that the forest resources in Kaixian County increased rapidly and water loss and soil erosion has been reduced gradually thanks to the project of returning farmland to forests. The farmers' income also increased. Comparing 2002 with 1997, the areas of water loss and soil erosion were reduced by 15,000 hm^2 or by 5.3%. The land used to grow trees increased by 74,000 hm^2 or 50%; the areas covered with forests and grass increased by 12,000 hm^2 or 13%; and forest cover increased by 7.5 percentage points.

In a word, the central authorities and local governments have strengthened supervision and management of the ecological and environmental protection in the reservoir area and committed more investment to the projects. However, the efforts are far from being enough considering the vulnerable ecology, the reservoir demands, the goal of harmony between man and nature, the need for sustainable development and the objective of building an environment-friendly reservoir area. Much remains to be done in reformation and improvement. Only by going on with the efforts in a sustained manner is it possible to bring about a fundamental turn for the better in the ecological environment in the reservoir area and provide the fundamental guarantee for the ecological security and water quality security.

Appendix 1 Organization or Institutions Abbreviation List

Abbreviation	Full Name
AMWG	Adaptive Management Work Group
CAS	Chinese Academy of Sciences
CBWEMC	Changjiang Basin Water Environment Monitoring Center
CCTV	China Central Television
CHIDI	Chengdu Hydroelectric Investigation & Design Institute
CNEMC	China National Environmental Monitoring Center
CTGC	China Three Gorges Corporation
CTGPC	China Three Gorges Project Corporation
CWRC	Changjiang Water Resources Commission
CWRPB	Changjiang Water Resources Protection Bureau
CWRPI	Changjiang Water Resources Protection Institute
CYJV	Canadian Yangtze Joint Venture
EEMS	Ecological and Environmental Monitoring System
EIAD	Environment Impact Assessment Department
IWHR	China Institute of Water Resources and Hydropower Research
MOA	Management Bureau
MOC	Ministry of Communications
MLR	Ministry of Land Resources
MWR	Ministry of Water Resources
NPCSC	Standing Committee of the National People's Congress
NPS	National Park Service
SCST	the State Commission for Science and Technology
SCTGPCC	State Council Three Gorges Project Construction Committee
SEPA	State Environmental Protection Administration
SFA	the State Forestry Administration
SGCC	State Grid Corporation of China
SPCC	State Power Corporation of China
SRIES	Sichuan Research Institute of Environmental Sciences
SSB	State Seismological Bureau
STTGPEC	State Council Three Gorges Project Examination Committee
TGP	ThreeGorges Project
TGPEC	Three Gorges Project Examination Committee
TGPEEMS	Three Gorges Project Ecological and Environmental Monitoring System
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
YFRC	Yangtze Fishery Resources Committee

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2

Appendix 2 Monitoring Indicators' Abbreviation

Abbreviations	Full Name
ArOH	Volatile phenolic compounds
As	Arsenic
BED	Biomass Ecological Density
BOD_5	Five-day Biochemical Oxygen Demand
Cd	Cadmium
COD_{Cr}	Chemical Oxygen Demand (Dichromate Indicator)
COD_{Mn}	Chemical Oxygen Demand (Permanganate Index)
Cr^{6+}	Chromium (VI)-
Cu	Copper
DIN	Dissolved inorganic nitrogen
DO	Dissolved oxygen
Fe	Iron
GNP	Gross National Product
Hg	Mercury
K	Potassium
LAI	Leaf Area Index
LULC	Land Use and Land Cover Change
N	Nitrogen
NDVI	Normalized Difference Vegetation Index
NED	Number Ecological Density
NH_3-N	Ammonium nitrogen
NO_2-N	Nitrite nitrogen
NO_3-N	Nitrate
NO_x (NO_2)	Nitrogen oxides (nitrogen dioxide)
Oil	Oil
P	Phosphorus
Pb	Lead
pH	Acidity
PO_4-P	Phosphate
SiO_3-Si	Silicate
SO_2	Sulfur oxide
SS	Suspended substance
T	Temperature (water, air)
TAs	Total arsenic
TCd	Total Cadmium
TCr	Total chromium
TCu	Total copper

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Abbreviations	Full Name
THg	Total mercury
TK	Total potassium
TMn	Total manganese
TN	Total nitrogen
TON	Total inorganic nitrogen
TP	Total phosphorus
TPb	Total lead
TSP	Total suspended particles (air)
TZn	Total zinc
Zn	Zinc

Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2

Appendix 3 Animal and Plant Names in Latin, English

Wild plants (Check by Prof. Li Zhenyu from The Institute of Botany of CAS)

Latin	English
Abelia biflora	Twinflower abelia
Abies chensiensis	Qinling fir
Acer griseum	Bloodbark maple
Acer tenellum	Thinleaf maple
Adiantum reniforme	Kidney maidenhair
Adiantum reniforme var. *sinense*	Chinese kidney maidenhair
Adina rubella	Thinleaf adina
Aesculus wilsonii	Wilson buckeye
Agonandra brasiliensis	Pau-marfim
Aidia cochinchinensis	Cochinchina randia
Alsophila spinulosa	Spiny alsophila
Amentotaxus argotaenia	Common amentotaxus
Artemisia sp.	Wormwood
Arthraxon hispidus	Ungeargrass
Aster ageratoides	Threevein aster
Bauhinia brachycarpa	Faber bauhinia
Berberis julianae	Chinese barberry
Beta vulgaris	Beetor, Common beet
Betula luminifera	Shiny-bark birch
Bretschneidera sinensis	China bretschneidera
Bryophyta	Moss
Buddleja lindleyana	Lindley's butterflybush
Buxaceae	Box family
Buxus harlandii	Harland's box
Buxus sinica	Chinese box
Camellia oleifera	Oiltea camelia
Camellia tuberculata	Chongqing camellia
Campylotropis macrocarpa	Chinese clovershrub
Caprifoliaceae	Honeysuckle family
Carex brunnea	Chestnut-colored sedge
Carex sp.	Sedge
Carpinus fargesiana	Farges hornloeam
Castanopsis fargesii	Farge's chinkapin
Cathaya argyrophylla	Cathay silver fir
Cedrus deodara	Deodar
Cephalanthera erecta	Silver orchid
Cephalotaxus fortune	Fortune plumyew twig and leaf
Cephalotaxus oliveri	Oliver plumyew
Cephalotaxus sinensis	Chinese plumyew
Cercidiphyllum japonicum	China katsuratree
Changnienia amoena	Uniflowerorchid
Chuanminshen violaceum	Chuanminshen
Cinnamomum camphora	Camphor tree
Citrus reticulata	Orange
Citrus sinensis 'Jin Cheng'	Jin cheng
Citrus sinensis 'Washington Navel'	Washington navel
Compositae	Sunflower family
Coptis chinensis	China goldthread
Coriaria nepalensis	Nepal coriaria
Cornus controversa	Giant dogwood
Corylus chinensis	China filbert
Cotinus coggygria var. *cinerea*	Common smoketree
Cotoneaster sp.	Cotoneaster
Cremastra appendiculata	Common cuckoo-orchis
Cunninghamia lanceolata	Chinese fir
Cupressus funebris	China weeping cypress
Cyclocarya paliurus	Cyclocarya
Cyperaceae	Sedge family
Davidia involucrata	Dove tree
Davidia involucrata var. *vilmoriniana*	Vilmorin dovetree
Deinanthe caerulea	Deinanthe
Dendranthema indicum	Wild chrysanthemum

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Z. Huang and B. Wu, *Three Gorges Dam*, https://doi.org/10.1007/978-3-662-55302-2

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Latin	English
Dicranopteris pedata	Dichotomy forked fern
Dimocarpus longgana	Longan
Dioscorea opposita	Chinese yam
Diphylleia sinensis	China umbrellaleaf
Dipteronia sinensis	China coinmaple
Distylium chinense	Distylium Chinense
Dysosma versipellis	Dysosma
Elaeocarpus sylvestris	Sylvestral elaeocarpus
Emmenopterys henryi	Henry emmenopterys
Erigeron acre	Bitter fleabane
Eucommia ulmoides	Eucommia
Euphorbiaceae	Spurge family
Euptelea pleiospermum	Manyseeded euptelea
Eurya nitida var. *aurescens*	
Eurycorymbus cavaleriei	Cavaler eurycorymbus
Fagus engleriana	Engler beech
Fagus lucida	Shining-leaf beech
Ficus tikoua	Digua fig
Ficus virens	Fig tree
Ginkgo biloba	Ginkgo
Gleditsia sinensis	China honeylocust
Glycine soja	Wild soybean
Gnaphalium affine	Cudweed
Gramineae	Grass family
Gynostemma pentaphyllum	Fiveleaf gynostemma
Hamamelidaceae	Witch hazel family, Liquidambar family
Heteropogoncontortus	Contorted yellowquitch
Hibiscus syriacus	Rose of sharon
Hyacinthus orientalis	Common hyacinth
Imperatacylindrica	White cogongrass, Lalang grass
Keteleeria davidiana	David keteleeria
Lauraceae	Laurel family
Leguminosae	Pea family
Lespedeza cuneata	Cutleaf bushclover
Ligustrum quihoui	Purpus privet
Lindera fragrans	Fragrant spicebush
Lindera megaphylla	Large-leaf spicebush
Liquidambar formosana	Liquidambar
Liriodendron chinense	China tuliptree
Litchi chinensis	Litchi
Litsea cubeba	Mountain spicy tree
Loganiaceae	Strychnine family
Loropetalum chinense	China loropetal
Magnolia officinalis	Officinal magnolia
Malvaceae	Cotton family
Manglietia patungensis	Patung manglietia
Marsdenia sp.	Condorvine
Maytenus variabilis	
Meliosma thomsonii	

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Latin	English
Metasequoia glyptostroboides	Dawn redwood
Miconia jucunda	
Miscanthus floridulus	Japanese silvergrass
Miscanthus sinensis	Awngrass
Myricaria laxiflora	Looseflowered falsetamarisk
Myrsinaceae	Waxmyrtle family, Sweet gale family
Myrsine africana	Africa myrsine
Paederia scandens	China fevervine
Paratecoma perobe	Peroba
Paris polyphylla	Manyleaf paris
Phellodendron chinense var. *glabriusculum*	Glabrousleaf China corktree
Phoebe zhennan	Zhennan, Nanmu
Phragmites australis	Common reed
Pinus massoniana	Masson pine , Chinese red pine
Pinus tabuliformis	Chinese pine
Platycarya strobilacea	Dyetree
Platycladus orientalis	Cypress tree
Potamogeton sp.	Pondweed
Pseudolarix amabilis	China golden larch
Pteridium aquilinum var. *latiusculum*	Western brackenfern
Pteroceltis tatarinowii	Wingceltis
Pterostyrax psilophyllus	Glabrousleaf epaulettetree
Pyracantha fortuneana	Fortune firethorn
Pyrularia inermis	Spineless oilnut
Quercus acutissima	Sawtooth oak
Quercus aliena	Oriental white oak
Quercus fabri	White oak
Quercus glandulifera	
Quercus glandulifera var. *brevipetiolata*	Serrate oak
Quercus phillyraeoides	Wugang oak
Rhododendron bachii	Bach azalea
Rhododendron simsii	Simslejazalea
Rhus chinensis	China sumac
Robinia pseudoacacia	Locust
Rosalaevigata	Cherokee rose
Rosaceae	Rose family
Rubiaceae	Coffice family, Madder family
Rubus sp.	Raspberry
Saccharum arundinaceum	Reedlike sugarcane
Salix exigua	Coyote willow
Sapindaceae	Litchi family, Soapberry family
Sapium sebiferum	China tallowtree
Sassafras tzumu	Chinese sassafras
Schisandra	China magnoliavine
Setaria viridis	Green bristlegrass
Sinojackia xylocarpa	Xylocarpous sinojackia
Sinowilsonia henryi	Henry wilsontree

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Latin	English
Sphenomeris chinensis	Common wedgeler fern
*Spiraea*sp.	Spiraea
Stewartia sinensis	Chinese stewartia
Symplocaceae	Sweetleaf family
Tamarix	Tamarisk, Salt cedar
Tapiscia sinensis	Chinese falsepistache
Taraxacum mongolicum	Dandelion
Taxus wallichiana var. *chinensis*	China yew
Tessaria	Arrowweed

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Latin	English
Tetracentron sinense	Tetracentron
Torreya fargesii	Farges torreya
Trillium tschonoskii	Tschonosk trillium
Verniciafordii	Oiltung
Viburnum utile	Flue arrowwood
Vitex negundo	Yellow bramble
Woodwardia japonica	Japanese chain fern
Zanthoxylum echinocarpum	
Zanthoxylum simulans	Wild prickleyash

Cultivated plants

Abutilontheophrasti	Indian mallow
Agastache rugosa	Agastache
Allium ascalonicum	Shallot
Allium cepa	Onion
Allium chinense	Scallion
Alliumfistulosum	Leek
Alliumsativum	Garlic
Allium schoenoprasum	Chive
Allium tuberosum	Chinese chives
Amaranthus paniculatus	Amaranth
Amaranthustricolor	Copperleaf
Amorphophallus rivieri	Konjac
Apiumgraveliens	Celery
Arachis hypogaea	Peanut
Asparagusofficinalis	Common asparagus
Auriculariaauricula	Edible black fungus
Basellaalba	White vinespinach
Benincasa hispida	Wax gourd
Betavulgaris	Oakleaf goosefoot
Boehmeria nivea	Ramie
Brassica juncea var. *tumida*	Tuber mustard
Brassicajuncea var. *megarrhiza*	Chinese kalem
Brassicajuncea var. *multiceps*	Xuelihong leaf-mustard
Brassicanapus	Rape, Colza
Brassicaoleracea var. *botrytis*	Cauliflower
Brassicaoleracea var. *capitata*	Cabbage
Brassicaoleracea var. *gongylodes*	Kohlrabi
*Brassicarapa*var. *chinensis*	Chinese rapa
*Brassicarapa*var. *glabra*	Chinese cabbage
Brassica rapa var. *narinosa*	Brassica narinosa bailey
Brassicarapa var. *oleifera*	Youbaicai pakchoi
Brassicarapa var. *parachinensis*	False pakchoi
Camelliasinensis	Tea
Canavalia gladiata	Sword bean
Canna edulis	Edible canna

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Capsellabursa-pastoris	Shepherdspurse herb
Capsicumannuum	Hot pepper
Capsicumannuum var. *conoides*	Cherry redpepper
Capsicumannuum var. *grossum*	Ornamental Chinese lantern pepper
Castanea mollissima	Chestnut
Chrysanthemum coronarium	Hawksbeard velvetplant
Citrullus lanatus	Water melon
Citrus ichangensis	Yichang orange
Citruslimon	Lemon
Citrus maxima	Pomelo
Citrus medica	Fingered citron
Citrus medica var. *sarcodactylis*	Bergamot -calabrian
Citrusreticulata	Orange(Tangerine)
Citrus sinensis	Sweet orange
Citrus sinensis'Jin Cheng'	Goose-egg orange
Citrus sineneis'Robertson'	Robertson navel orange
Colocasiaesculenta	Taro
Coriandrum sativum	Coriander
Crataegus pinnatifida	Hornthaw
Cucumismelo	Cucumis melo
Cucumismelo var. *conomon*	Vegetable sponge
Cucumis pepo	Summer squash
Cucumis sativus	Cucumber
Cucurbita moschata	Pumpkin
Daucus carota	Carrot
Dioscoreaesculenta	Sweat potato
Dioscorea panthaica	Yellow yam
Dioscoreazingiberensis	Peltate yam rahizome
Diospyros kaki	Persimmon
Eleocharis dulcis	Waternut spikesedge
Eriobotrya japonica	Loquat
Fagopyrum dibotrys	Buckwheat
Ficus carica	Fig
Foeniculum vulgare	Sweet fennel
Fortunella margarita	Little-fruit citrus

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Fragariaananassa	Strawberry
Glycine max	Soybean
Helianthus tuberosus	Erusalem artichoke
Hemerocallis citrina	Citron daylily
Hordeumvulgare	Barley
Ipomoeaaquatica	Water spinach
Ipomoea batatas	Sweat potato
Juglans regia	Walnut
Lablabpurpureus	Purple haricot
Lactuca sativa	Lettuce
Lactuca sativa var. *angustata*	Asparagus lettuce
Lactucasativa var. *crispa*	Glass lettuce
Lagenariasiceraria	Bottle gourd
Lentinulaedodes	Edible fungus
Lolium perenne	Ryegrass
Luffa cylindrica	Edgeless suakwa vegetable sponge
Lycopersicon esculentum	Tomato
Malvaverticillata var. *crispa*	Axillary southern wildjujube
Momordicacharantia	Balsum
Morus alba	Mulberry
Musa basjoo	Banana
Nelumbo nucifera	Lotus root
Nepetacataria	Fineleaf schizonepeta
Nicotianatabacum	Tobacco
Oryza sativa	Rice
Pachyrhizuserosus	Yam
Panicum miliaceum	Millet
Perilla frutescens	Common garden coleus
Phaseolusvulgaris	Common bean
Phyllostachys edulis	Moso bamboo shoot
Phyllostachys heteroclada	Water bamboo shoot
Pisum sativum	Pea
Poncirus trifoliata	Hardy orange

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Ponnisetum hydridum	Hybrid giant napier
Portulacaoleracea	Purslane
Prunus armeniaca	Common plum
Prunus persica	Peach, Nectarine
Prunus pseudocerasus	Chinese sour cherry
Prunus salicina	Japanese plum or Chinese plum
Punica granatum	Spine wild pomegranate
Pyrus'Atagonashi'	Nachi pear
Pyrus bretschneideri	White pear
Pyrus pyrifolia	Chinese pear
Pyrus serrulata	Ma pear
Pyrus	Pear
Raphanussativus	Radish
Saccharum officinarum	Sugar cane
Sagittariatrifolia ssp. *leucopetala*	Arrow-head
Sechiumedule	Turtle gourd
Sesamum indicum	Sesame
Solanummelongena	Eggplant
Solanumtuberosum	Potato
Sorghum bicolor	Sorghum
Spinaciaoleracea	Spinach
Toonasinensis	China toona
Trichosanthesanguina	Snake gourd
Triticum aestivum	Wheat
Viciafaba	Broad bean
Vigna angularis	Red bean
Vignaradiata	Mung bean
Vitisvinifera	Grape
Zanthoxylum bungeanum	Pricklyash
Zeamays L.	Corn
Zingiber officinale	Ginger
Zizanialatifolia	Coba aspiragus
Ziziphus jujuba	Date

Terrestrial wild animal (Check by Prof. Su Hualong from The Chinese Academy of Forestry)

Mammalia	
Ailuropoda melanoleuca	Giant panda
Anourosorex squamipes	Mole shrew, Sichuan burrowing shrew
Apodemus agrarius	Striped field mouse
Capricornis sumatraensis	Serow
Cervus albirostris	Thorold's deer, White-lipped deer
Cervus nippon	Sika deer
Elaphodus cephalophus	Tufted deer
Felis bengalensis	Leopard cat
Felis temmincki	Asiatic golden cat, Temminck's cat
Lontra provocax	Southwestern river otter
Lutra lutra	Common otter, European otter

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Macaca mulatta	Rhesus macaque
Macaca thibetana	Tibetan macaque
Manis pentadactyla	Chinese pangolin, Common pangolin
Melogale moschata	Chinese ferret-badger
Moschus berezovskii	Chinese forest musk deer, Forest musk deer
Muntiacus reevesi	Chinese muntjac, Reeves' muntjac
Mustela sibirica	Siberian weasel
Naemorhedus goral	Goral, Long-tailed goral, Chinese goral
Neofelis nebulosa	Clouded leopard

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Niviventer edwardsi [Leopoldamys edwardsi]	Edwards's long-tailed great rat, Edwards's rat
Panthera onca	Jaguar, Jagure, El tigre
Panthera pardus	Leopard, Panther
Panthera tigris	Tiger
Panthera tigris amoyensis	South China tiger, Chinese tiger
Presbytis francoisi	Francois'langur, Francois'leaf monkey, Black leaf monkey
Rattus nitidus	Himalayan field rat
Rattus norvegicus	Brown rat
Rhinopithecus roxellanae	Snub-nosed monkey, Golden monkey
Selenarctos thibetanus	Asiatic black bear
Sus scrofa	Wild bora, Wild pig
Viverra zibetha	Large Indian civet
Viverricula indica	Little civet, Lesser civet, Small India civet, Chinese lesser civet
Birds	
Accipiter gentilis	Northern goshawk
Accipiter nisus	Eurasian sparrowhawk
Accipiter virgatus	Besta sparrow hawk
Aegypius monachus	Cinereous vulture
Aix galericulata	Mandarin duck
Anas platyrhynchos	Mallard, Common mallard
Anas poecilorhyncha	Spot-billed duck, Indian spot-billed duck
Aquila chrysaetos	Golden eagle
Aquila heliaca	Imperial eagle
Branta ruficollis	Red-breasted goose
Ceryle alcyon	Belted kingfisher
Chrysolophus amherstiae	Chinese copper pheasant, Lady Amherst's pheasant
Chrysolophus pictus	Golden pheasant
Ciconia boyciana	Oriental white stork
Ciconia ciconia	White Stork
Ciconia nigra	Black stork
Cygnus columbianus	Whistling swan
Cygnus cygnus	Whooper swan
Empidonax traillii	Southwestern willow flycatcher
Falco peregrinus	Peregrine falcon
Falco tinnunculus	Kestrel, Common kestrel
Grus japonensis	Red-crowned crane
Grus leucogeranus	Siberian crane

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Haliaeetus leucocephalus	Bald eagle
Mergus squamatus	Scaly-sided merganser
Milvus migrans	Black kite
Pandion haliaetus	Osprey
Platalea leucorodia	White spoonbill
Platalea minor	Black-faced spoonbill
Pucrasia macrolopha	Koklas pheasant
Streptopelia chinensis	Spotted dove
Syrmaticus reevesii	White-crowned long-tailed pheasant
Tragopan temminckii	Temminck's tragopan, Crimson-bellied tragopan
Reptiles	
Trionyx sinensis	Chinese soft-shelled turtle
Chinemys reevesii	Reeves'turtel,Chinese three-keeled pond turtle
Scincella spp.	Smooth skink
Alligator sinensis	Chinese alligator
Amphibians	
Andrias davidianus	Chinese giant salamander
Oxyloma haydeni kanabensis [Oxyloma kanabense]	Kanab ambersnail
Rana guentheri[Hylarana guentheri]	Guenther's frog
Rana limnocharis [Fejervarya limnocharis]	Terrestrial frog
Rana nigromaculata [Pelophylax nigromaculata]	Black-spotted pond frog
Rana plancyi [Pelophylax hubeiensis]	Hubei gold-striped pond frog
Rana rugulosus [Hoplobatrachus rugulosus]	Chinese tiger frog , Chinese bull-frog
Insect	
Oxyloma haydeni kanabensis [Oxyloma kanabense]	Kanab ambersnail
Rana guentheri[Hylarana guentheri]	Guenther's frog
Rana limnocharis [Fejervarya limnocharis]	Terrestrial frog
Rana nigromaculata [Pelophylax nigromaculata]	Black-spotted pond frog
Rana plancyi [Pelophylax hubeiensis]	Hubei gold-striped pond frog
Rana rugulosus [Hoplobatrachus rugulosus]	Chinese tiger frog , Chinese bull-frog

Aquatic life (Check by Prof. Liu Huanzhang from The Institute of Hydrobiology of CAS)

Zooplankton	
Alona	
Arcella	
Bosminidae	
Brachionus	

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Cladocera	Water fleas
Centropyxis	
Chydoridae	
Copepoda	Copepod

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Cyclopoidea	
Difflugia	Amoebas
Epistylidis	
Keratella	
Phryganella	
Rotifera	Rotifer
Vorticella	Stalked ciliate
Hydrophyte	
Ceratophyllum demersum	Hornwort
Hydrilla verticillata	Hydrilla
Myriophyllum spicatum	Eurasian milfoil
Potamogeton malainus	Pondweeds
Vallisneria natans	Tape grass, Eel grass
Benthic animal	
Mollusca	Mollusk
Amphipoda	Sand fleas
Anodonta woodiana woodiana	Mussel
Arconaia lanceolata	Mussel
Armina (Linguella) babai	Arminid
Arthropoda	
Cephalopoda	
Chironomidae	Midge
Cipangopludina chinensis	Chinese mystery snail
Coelenterata	Cnidarians
Corbicula fluminea	
Cristaria plicata	Mussel
Crustacean	
Decapoda	
Echinodermata	Echinoderm
Eriocheir sinensis	Chinese mitten crab
Gastropoda	Snail
Gemmula deshayesii	
Hemicentrotus pulcherrimus	Green sea urchin
Hirudinea	Leech
Hyriopsis cumingii	Mussel
Insecta	Aquatic insects
Isopoda	Sow bug
Lamellibranchia	Mollusks
Lanceolaria grayana	Mussel
Limnoperna lacustris	Shellfish
Odonata	
Oligochaeta	Oligochaete
Oratosquilla oratoria	Mantis shrimp
Polychaete	Bristle
Scapharca subcrenata	Ark shell
Unio douglasiae	Mussel
Aquatic mammals & Fish	
Acheilognathus	
Acipenser dabryanus	dabrys sturgeon
Acipenser sinensis	Chinese sturgeon
	Pinkgray goby

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Amblychaeturichthys hexanema	
Amblycipitidae	
Anabarilius	
Ancherythroculter	
Ancherythroculter nigrocauda	
Anguilla japonica	Japanese eel
Aristichthys nobilis	Bighead carp
Bangana rendahli	
Carassius auratus	Goldfish
Catostomus discobolus discobolus	Bluehead sucker
Catostomus latipinnis	Flannelmouth sucker
Cetacea	Whales, Dolphins, Porpoises
Cobitidae	Loaches
Coilia ectens	Japanese grenadier anchovy
Coilia mystus	Anchovy
Collichthys lucidus	Bighead croaker
Coreius guichenoti	Largemouth bronze gudgeon
Coreius heterodon	Bronze gudgeon
Ctenopharyngodon idellus	Grass carp
Culter alburnus	Upper mouth culter
Cultrinae	
Cyprinidae	Minnows or carps
Cypriniforme	Cypriniforms
Cyprinus carpio	Common carp
Engraulidae	Anchovy
Engraulis japonicus	Japanese anchovy
Harpadon nehereus	Bombay-duck
Hemimyzon yaotanensis	
Hemisalanx brachyrostralis	Ice fish
Homalopteridae	Hillstream loach
Hypophthalmichthys molitrix	Silver carp
Hypothalmus edentatus	Mapara,Highwaterman catfish
Jinshaia sinensis	
Larimichthys crocea	Large yellow croaker
Larimichthys polyactis	Little yellow croaker
Lateolabrax japonicus	Japanese sea bass
Leiocassis crassilabris	
Leiocassis longirostris	Longsnout catfish
Leptobotia elongata	Elongate loach
Leptobotia rubrilabris	Redlip loach
Liobagrus marginatoides	
Lipotes vexillifer	Chinese river dolphin, Baiji
Liza haematocheilus	Redlip mullet
Megalobrama	
Megalobrama elongata	
Megalobrama pellegrini	
Mylopharyngodon piceus	Black carp
Mystus macropterus	
Myxocyprinus asiaticus	Chinese sucker

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Neophocaena phocaenoides	Finless porpoise
Odontoceti	Toothed whales
Oncorhynchus gorbuscha	Humpback chub
Onychostoma sima	
Pampus argenteus	Silver pomfret
Parabramis pekinensis	Bream
Paracobitis potanini	
Pelteobagrus fulvidraco	Yellow catfish
Pelteobagrus vachelli	Darkbarbel catfish
Phocaenidae	Porpoises
Plagioscion squamosissimus	Curvina, South American silver croaker
Platanistoidea	River dolphin
Platysmacheilus nudiventris	
Prochilodus lineatus	Curimba,Streaked prochilod
Procypris	
Procypris rabaudi	Rock carp
Psephuyrus gladius	Chinese paddlefish
Pseudorasbora parva	Stone moroko
Pterodoras granulosus	Armado,Granulated catfish
Rhinichthys osculus	Speckled dace
Rhinogobio cylindricus	
Rhinogobio typus	
Rhinogobio ventralis	
Salanx cuvieri	Icefish
Salmonidae	Trout
Sardinus pilchardus	Sardine
Schizothorax	Snow barbels
Schizothorax chongi	Finescale schizothoracin
Setipinna	
Setipinna taty	
Silurus meriaionalis	Catfish
Silurus spp.	Oriental sheatfish,Far east asian catfish
Siniperca chuatsi	Mandarin fish
Spinibarbus sinensis	
Stolephorus commersonnii	Commerson's anchovy
Stromateoides argenteus	Pomfret
Takifugu spp.	Far east puffers
Tenualosa reevesii	Reeves shad
Trichiurus haumela	Hairtail, Cutlassfish
Xenocyprinae	
Xenocypris	

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Xenocypris yunnanensis	Kunming nase
Xenophysogobio boulengeri	
Xenophysogobio nudicorpa	
Xyrauchen texanus	Razorback sucker
Other aquatic animals	
Arachnoidea	
Armina (Linguella) babai	Arminid
Charybdis bimaculata	Two-spot swimming crab
Limnodrilus	Tubifex
Loligo japonica	Squid
Oncomelania hupensis	Snails
Palaemon gravieri	Chinese ditch prawn
Portunus trituberculatus	Blue crab, horse crab
Algea	
Bacillariophyta	Diatoms
Chlorophyta	Green algae
Chrysophyta	Golden-brown algae
Closterium	
Cocconeis	
Cryptophyta	Cryptomonads
Cyanophyta	Cyanobacteria
Cyclotella	
Cymbella	
Diatoma	
Euglenophyta	Euglenoids
Fragilaria	
Gomphonema	
Gyrosigma	
Melosira	
Navicula	
Nitzschia	
Oscillatoria	
Pediastrum	
Pinnularia	
Pyrrophyta	Dinoflagellate
Scenedesmus	
Spirogyra	
Staurastrum	
Surirella	
Synedra	
Tabellaria	
Ulothrix	
Xanthophyta	Yellow-green algae

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