

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

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 TGP 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

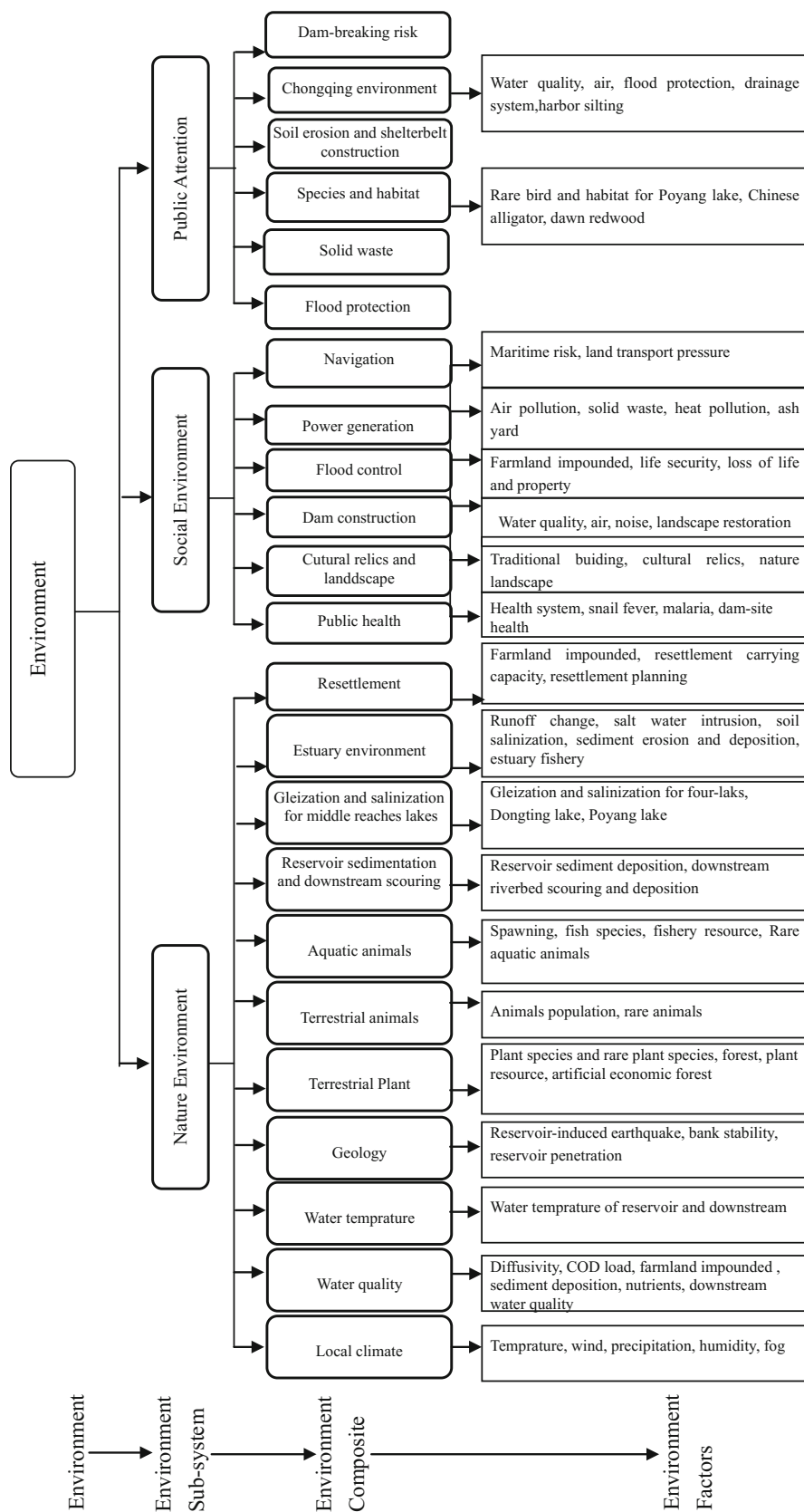


Fig. 2.1 Hierarchic System of EIA for the TGP

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 bank-side 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 BOD₅ 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 BOD₅ 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 densimetric 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 $6000 \text{ m}^3/\text{s}$, $F_d < 0.1$ 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 $1.7\text{--}9.3^\circ\text{C}$.

(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 $11,000 \text{ km}^2$, 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 $0.20\text{--}1.23 \text{ m}$ 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



Dabry's 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 *Polyodontidae*. There are two species of fish in the *Acipenseridae*: Chinese sturgeon (*Acipenser sinensis*) and Dabry's sturgeon (*Acipenser dabryanus*). There is one species in the *Polyodontidae*: Chinese paddlefish (*Psephurus 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

¹Institute 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 F₂ 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 Yangtze 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 Chenglingji 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 Gorges 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 genres 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 falseamarisk (*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.

²This 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.

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-leaved tree as firewood. Some of the primordial vegetation, especially the ever-green broad-leaved 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 skioophyt. 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 falseamarisk 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



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

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



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 (*Neofelis nebulosa*), Leopard (*panthera pardus*), and South China Tiger (*Panthera tigris amoyensis*); 22 species for the second-class protection: rhesus macaque (*Macaca mulatta*), 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 temminckii*), 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 (*Syrnaticus 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 macrocephala*).

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 genera, 242 families and 19 orders in the insecta, including 16 new genera, 289 new species, 16 newly recorded genera and 94 newly recorded species. Besides, there are 67 species in 44 genera, 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*, *Myricaria 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

³Wuhan 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.

⁴Xiong (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 (~100 km) rather than on the local scale (~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

本报记者 江夏 朱勇

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气候影响评估室主任 张强

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、8三个月为全国的汛期。到10月份霜降之后,黄河流域的汛期才会结束。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。渠江一天多时间暴涨30多

米,造成不少堤段溃顶淹没,受灾严重。

洪水经过三峡水库刚峰调度后,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?

按规划设计,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年气候观测数据分析和气候数值模拟结果分析,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,靠近库区地区降水可能减少,远离库区在15公里左右的地区降水可能增加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,可能会出现雾日增加,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观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 m³/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 (*Tenu-*alosa 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 m³ and the average volume flowing into the sea in the 1980s being 6 billion m³.
- 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 (*Echino-dermata*), 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 sub-crenata*), 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

Leptospirosis. The epidemic foci and hosts of *leptospirosis* 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 tritaeniorhynchus*) 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 hm² 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 hm². 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 hm², 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 Qu Yuan 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 m³/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 m³/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 m³/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 m³/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/km². 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 km²) has been kept at a very good standard.

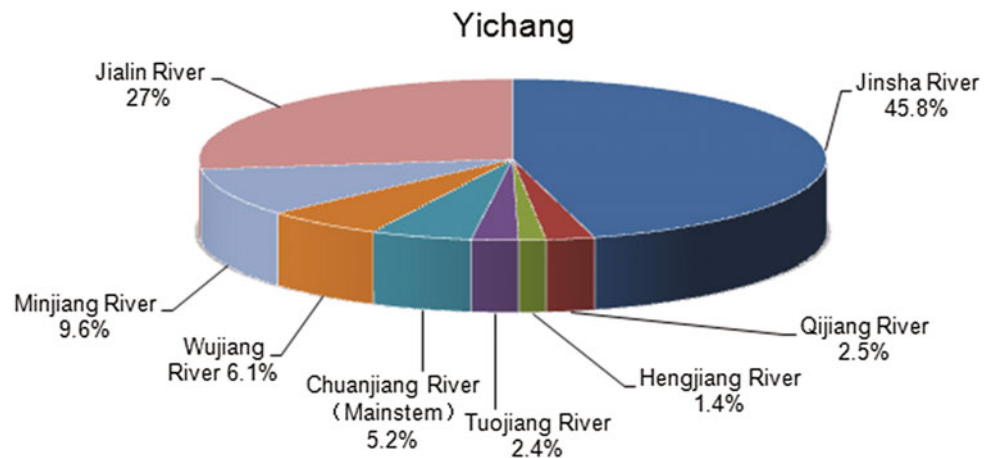
In 1998, the pollution of the Maopingxi stream was thoroughly resolved by shutting down, stopping the operation and merging polluting enterprises, and adopting other measures. The water of the stream has become clear.

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/m³. 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.

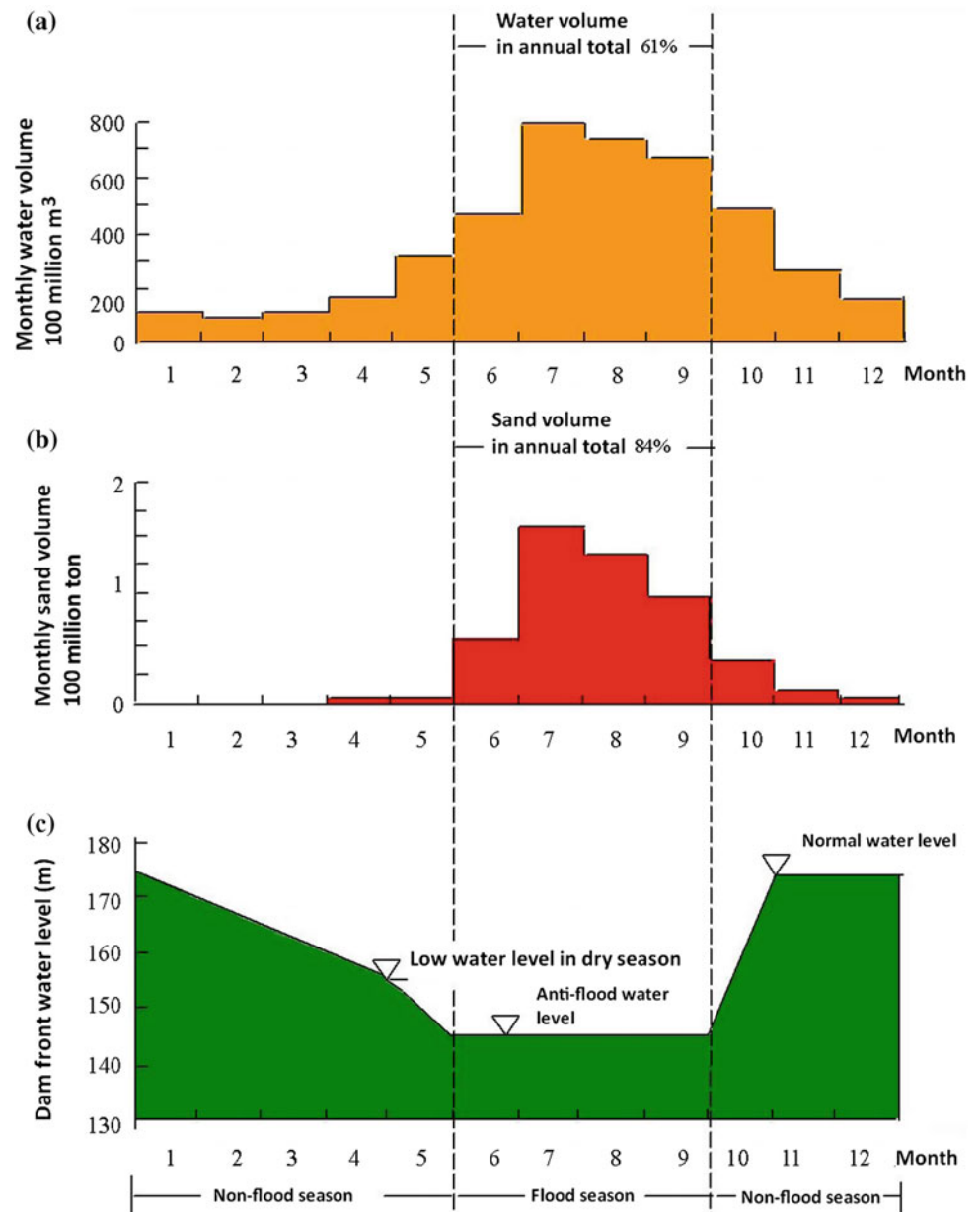
- (2) Problems of navigation and port in the fluctuating backwater area and countermeasures

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 m³ and that downstream will be 20,000–180,000 m³, 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 m³ 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.

Mathematical 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 m 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 m³/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 built. 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-verifying 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 EIA 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.

Three Gorges Dam

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