Contributing Paper

Social Impacts of Large Dams: The China Case

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Social Impacts of Large Dams Equity and Distributional Issues

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Introduction

"No water, no life on earth" was an old Chinese saying. Even today, Chinese people still love to use this proverb to emphasize the importance of water as "the water of the lives *(shengming zhi shui)*"[1]. However, freshwater resources are limited and unevenly distributed by season or location across the whole China. Generally, western and northern parts are lack of water resource, while in southern and coastal areas it often appears in torrents causing floods and loss of life and property, especially in summer.

The availability of adequate quantities of water with the appropriate quality is one of the fundamental requirements for socio-economic development. In the past, the main sources of domestic and industrial water have been aquifers. Today, many of these are now overused and their rate of recharge is far less than what is extracted.

One of the most efficient ways to manage water resources for human needs is to construct dams that create reservoirs for the storage and future distribution. Throughout the history of the Chinese people, dams and reservoirs have been used in collecting, storing and managing water needed to sustain civilization. Up to now, there are approximately 22,104 dams higher than 15 meters concurrently under operation in China, while the eldest is more than 2,200 years old (such as the well-known *Dujiangyan Irrigation Project).* On the other hand, more than 85% have been built in the last 50 years[2].

Their supply must be augmented with additional water from reservoirs. Large urban areas depend heavily on water stored in reservoirs during high flows and used during periods of low rainfall. This is especially critical in arid regions. This need for stored water will continue, since many aquifers are over-used. The primary source of fresh water supply is from precipitation. However, the hydrologic cycle varies and is not predictable. Of the total precipitation, only 1/3 remains for runoff to our rivers, the rest is lost to infiltration and evaporation. To accommodate the variations in the hydrologic cycle, dams and reservoirs are needed to store water and then provide consistent yearly supply.

Most dams are designed and built for multi-functional purposes. This produces a broad range of domestic and economic benefits from a single investment. The primary benefit of dams and reservoirs is water supply. An additional local benefit is the employment opportunities during the multiple year construction of a reservoir project. Other key purposes and benefits include: irrigation for agriculture (food supply), flood control, hydropower, inland navigation, recreation, etc.

Although dams provide significant benefits to the society, their impacts on the surroundings should be considered seriously and thoroughly, which include resettlement and relocation, socioeconomic impacts, environmental concerns,

[1] In agriculture field, China has a famous slogan "Water Resource is vital to agricultural development", which was proposed by Former Chairman *Mao Zedong* in 1952.
[2] Source: *Large Dams in China*, China Water Research Institute, 1998.

sedimentation issues, and safety aspects. Thus, such concerns and impacts should be reduced or eliminated through a set of careful planning and the incorporation of a variety of mitigation measures.

In this paper, the impacts of irrigation dams on agricultural development in Chinese history were firstly analyzed. Good[3] practices in maximizing sustained performance, in minimizing socio-economic costs and in achieving high level of equity in the distribution of costs and benefits of dams, especially irrigation dams, were identified and summarized. Then, suggestions for improved equity in the distribution of costs and benefits of dams between local and national-regional levels were made. Finally, principles, guidelines and approaches for achieving a more equitable sharing of dam project impacts were formulated on the basis of Chinese situations and circumstances.

As the *Dujiang Weir* (Chinese name *Dujiangyan*) Irrigation Project is well-known throughout the world, it was taken as a study case of the paper to illustrate and analyze the benefits, costs, concerns and impacts of dams in China. However, practices and experiences from other dams and reservoirs (such as the *Three Gorges Dam*) were also taken into consideration and integrated.

Large dams and Reservoirs in China: A Historical Review

As of today, dams and reservoirs in China account for about 20% of the total in the world[4]. Generally, approximately 45% were designed and constructed for irrigating agricultural lands[5].

Dam construction in China has a long history. Tracing back to ancient Chinese history, one can find that the most ancient reservoir, *Shaopi*, was built in *Eastern Zhou* Dynasty (598-591BC) in *Anhui* Province. It is an earth dam, 10m high, and has been in regular operation up to now. The later *Zhibo irrigation canal* in *Shanxi* Province (453BC) and *Dujiangyan irrigation project* in *Sichuan Province* (219BC) are very famous engineering works, especially the invented masonry spillway dam, 3.8m high, on the navigation canal in *Guangxi Autonomous Region* which was constructed in 219 BC and is still operating now.

Dam construction using modern technology learnt from abroad started in the first five decades of 20th Century. Concrete dams were built in 1941 in Northeast. Most

[3] It is possible the practices illustrated here are bad in some circumstances, although we are taking as good ones. Or it may be still unknown whether good or bad due to invisibility as of today.

[4] Data sources: a) International Commission on Large Dams (ICOLD), 1999; b) China Water Research Institute, 1999

[5] In Chinese terms, a project with a name of “dams (*da ba*)” is called for those to generate hydropower or flood control as its main purpose, while those with a name of “reservoir (*shuiku*)” designed for irrigation as its main purpose. For example, the first purpose of *Three Gorges Dam* is power generation and flood control, and that of the *Miyun Reservoir* is irrigation and household water supply. However, “dams” is used in this paper to refer to both dams and Reservoirs.

masonry dams were constructed for water supply and a few earth dams for irrigation. In all, there were only 22 large dams before 1949.

Dam construction has developed very fast since 1950. There are now 17,526 dams 15-30m high and 4,578 dams exceeding 30m. Dams higher than 100 m in operation by the end of 1999 number 32. There are about 320 dams under construction in 1999, with 23 being more than 100 m high in recent years. The highest double curvature arch dam is *Ertan*, 240 m high, to be completed in 1999. It is the fourth highest concrete dam in the world.

Regarding dam type, the embankment dam is in the majority. The number of concrete dams is gradually growing as dam heights steadily increase, but the new trend is towards the concrete faced rockfill dam and RCC dam, the number of which is gradually rising.

The *Three Gorges Project*, which attracts worldwide attention, has the largest hydropower station in the world. Its installed capacity of 18,200 MW as well as peak flood discharge of 124,300m3/s (check flood) are both world records. The total amount of engineering to be work is tremendous. The total volume of concrete to be placed is 27.94 million m3 and reservoir capacity is 39.3 billion m3; construction is now in full swing.

In pursuing water resources and hydropower development, many more major projects will start in the 21st Century, including *Xiluodu* arch dam (height 273m) and *Xiangjiaba* gravity dam (161m) on the *Jinshajiang*, *Jinping* 1st cascade (300m) on the *Yalongjiang*, *Hongjiadu* concrete faced rockfill dam (178m) on the *Wujiang* River; *Xiaowan* arch dam (292m) on the *Lancangjiang*, *Longtan* RCC gravity dam (216m) on the *Hongshuihe*, *Laxiwa* arch dam (250m) on the Yellow River, etc.. These projects will symbolize the further greater progress of dam construction in China and promote dam construction technology.

Benefits from Dams for Food Production and Security

1. Dams can provide access to irrigation for agriculture by storing water in times of surplus and dispensing it in times of scarcity

One of the biggest uses of water resource in China is agricultural irrigation. This will account for about 50-60% of total water supply by the year 2000 in China. Since the early 1949, more than 40% of the land suitable for agriculture has been irrigated, and it has contributed to about 1/3 of Chinese food production.

It is estimated that 80% of additional food production by the year 2025 will come from irrigated land. Most of the areas in need of irrigation are in the North and West

China[6]. Even with the widespread measures to conserve water by improvements in irrigation technology, construction of more reservoir projects will be required.

As an example, Dujiangyan Project was designed to provide irrigation as its main purpose for a large area in Sichuan Province. Before 1949, the project benefited a total of 14 counties with more than 200,000 hectares of irrigated lands. As of today, the coverage of the project extend to vast hillside areas with approximately 750,000 hectares[7].

However, before the Dujiangyan Project was built 2200 years ago, those areas where currently benefit much from the irrigation perspective were always flooded and submerged, especially in summer seasons[8], because no dams or even dikes were existed. The downstream of the Minjiang River were ever called "flooded areas (*shui fan qu*)", but now "the irrigated areas".

In poor northwestern part of China, precipitation has been low with about 300-600mm annually. Along the Yellow River Basin, about 4 large dams were or are being constructed to lift water level for power generation and for irrigation pumping for the arid areas. "No water, no crops; with water, a harvest" is true. It was estimated that about 30% of the increase of food production in Ningxia and Shanxi Provinces were contributed to the irrigation provided by the dams in Yellow River[9], such as the Xiaolangdi Project and Shanmenxia Project.

2. Dams can protect arable land from being destroyed by flood and soil erosion, and can adjust water distribution scheme (i.e. runoff) among different seasons and years to meet the pattern of demand for irrigated agriculture.

Dams and reservoirs can be effectively used to regulate river levels and flooding downstream of the dam by temporarily storing the flood volume and releasing it later.

The most effective method of flood control is accomplished by a number of multipurpose dams strategically located in a river basin. The dams are operated by a specific water control plan for routing floods through the basin without damage. This not only eliminates flooding, but also provides other benefits such as water supply, irrigation, hydropower and water quality. The number of dams and their water control management plans are established by comprehensive planning for economic development and with public involvement. Flood control is a significant purpose for many of the existing dams and continues as a main purpose for some of the major dams currently under construction.

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6 Lester Brown, "*Water shortage in China will shake the Global Food Security*", Worldwatch Institute, 1998 July

7 Source: *An Introduction to Dujiangyan Project*, Dujiangyan Administration Bureau of Sichuan Provincial Water and Electricity Department, Water and Electricity Press, 1986

8 There were a lot of popular stories about the struggle by the local residents to fight against the floods in Minjiang River in the history.

9 Source: Yellow River Administration Bureau, 1995

Dams can adjust natural runoff with its seasonal variations and climatic irregularities to meet the pattern of demand for irrigated agriculture, power generation, domestic and industrial supply and navigation.

In North China where generally in April-May and October-November precipitation is very low, and these are the critical seasons for wheat, corn and other main foodgrain crops. Without sufficient irrigation at these periods, food production will decrease greatly, which will lead to a negative impacts on food security, livelihood and income of the self-sufficient and marginal farmers.

3. Dams can adjust local climate and can enhance environmental conditions

All dams and reservoirs as many other human activities, become a part of the local environment which they influence and transform to a degree and within a range that vary from project to project. Frequently seeming to be in opposition, but not necessarily irreconcilable, dams and their environment interrelate with a degree of complexity that makes the task of the dam engineer particularly difficult. The solution must be found to try to strike a balance between divergent, and sometimes-contradictory goals.

In arid regions of China, it was observed that a new dam and or reservoir project once completed could change the local humidity of the surrounding areas, and could generally benefit agricultural conditions. For example, the Miyun Reservoir was observed to adjust the local "mini" climate that results in a increase of precipitation of approximately 10% for downstream river basins in drought seasons (March-May)[10]. The reservoir is located in suburb Beijing, and water has been a shortage. A small increase of rainfall is good for crops in winter seasons.

It is also good for the health of the local residents because of the fresh air.

4. Dams and reservoirs can save labor for the elderly and women families in irrigating the crops.

Under the *Household Responsibility System*s in agricultural field in China, each household must seek ways to irrigate his own farmlands, and each is responsible for his own pieces of land. The village collective community would provide help in building basic infrastructures, such as roads, canals or irrigation facilities, but the labor-consuming and hard work is mostly watering the fields.

[10] Source: *The impacts of Miyun Reservoir on Local Ecological and Environmental Conditions*, Miyun Reservoir Administration Bureau, 1992. However, I as an economist would argue this might not be true. It is hard to identify which lead to the increase of the precipitation in the area, either the reservoir or global warming. Anyway, many hydrogeological engineers in China would rather believe in this phenomena.

After a dam is constructed, the downstream river basins will realize auto-flow irrigation. This is of great importance in social equity aspects. Each farmer household will get queued to irrigate their lands in order assigned by the production team leader or village chief. A kid or elderly farmer is enough to take care of the water flows, and alter the watercourses after one block is irrigated. Without dams and reservoirs, the elderly and women family should hire other farmers to irrigating the crops that will be very costly to them.

5. Dams and reservoirs can promote aquaculture and fisheries development in a river basin

As the farmers' living standards rise, two important scenarios occur in most parts of China:

- Food structure has been changing from traditional vegetarian-oriented to meat-oriented style due to the water availability from the dams and reservoirs in Northern China. Fish culture is influential (especially in South China) in Chinese food culture, which implies people believe in that fish is good to intelligence, memory and longevity. From 1978 to 1998, fish consumption per capita across China increased 218%, while in south China 42% (Jiangsu Province) and north China 434% (Ningxia Province)[11]. However, no reservoirs, no fishing. In North China fish is generally cultivated in fishing farms where water comes from a dam or reservoir.
- Fish farming is a favorite industry for many farmers to make well-off. Appropriate fishing technology in the reservoirs is mature nowadays, and it is easy for the farmers to learn with a small investment. For the farmers living around the Miyun Reservoir, their income increased by more than 200 percent from 1978 to 1997, and more than half came from fishing[12].

6. Dams can promote the development of non-agricultural activities, such as eco-tourism, recreation, inland navigation

Water stored in reservoirs is also used for non-agricultural needs, and at last these activities could benefit food security goals in the way that farmers can buy foods with the money earned from non-agricultural activities. The attractiveness of reservoirs for tourism is often a significant benefit, in addition to the other purposes of a dam. This is very significant in areas where natural surface water is scarce or non-existent.

Recreational benefits associated with lakes, such as boating, swimming, fishing, bird-watching and nature walks, are also taken by the farmers to make well-off. The operation of the dam and reservoir can enhance tourism.

[11] Source: Ningxia Provincial Statistic Yearbook, 1999; Jiangsu Provincial Statistic Yearbook, 1999; China Statistic Yearbook, 1999

[12] Source: Miyun Reservoir Administration Bureau, 1997

Inland navigation is also a goal of comprehensive basin planning and development utilizing dams, locks and reservoirs that are regulated to provide a vital role in realizing regional and national economic benefits.

7. Dams and reservoirs can provide small hydropower for household lighting, food processing, pumping, etc..

The availability of energy is essential for the socio-economic development of a region. It is advantageous to use energy that is clean, efficient, dependable and renewable. Hydropower meets all of these requirements.

The technically most advanced and economical source of renewable energy is hydropower. Hydropower projects produce energy with a high rate of efficiency and without burdening future generations with pollution or waste. Hydropower projects can be developed with very small capacities for local consumption or with very large projects as part of a regional or national system. As part of a multipurpose project, hydropower can also help to finance other functions of a reservoir or river, such as irrigation water for food supply, drinking water, flood protection, household lighting, food processing, improved navigation or recreation.

Concerns, Impacts and Mitigation

Although dams and reservoirs could provide significant benefits for food production and food securities, we should realize the socio-economic concerns and impacts associated with the achievements of these benefits. Special attention should be given to the negative impacts, either ecological, or economic, or social[13]. A clear picture of the impacts must be analyzed prior to the construction or even completed. For instance, given the Three Gorges Dam would have significant environmental impacts on agricultural production both upstream and downstream, some researchers made a quantitative study, and concluded a chart to illustrate the interrelations and the interactions between dam construction and agricultural development, see Figure 1.

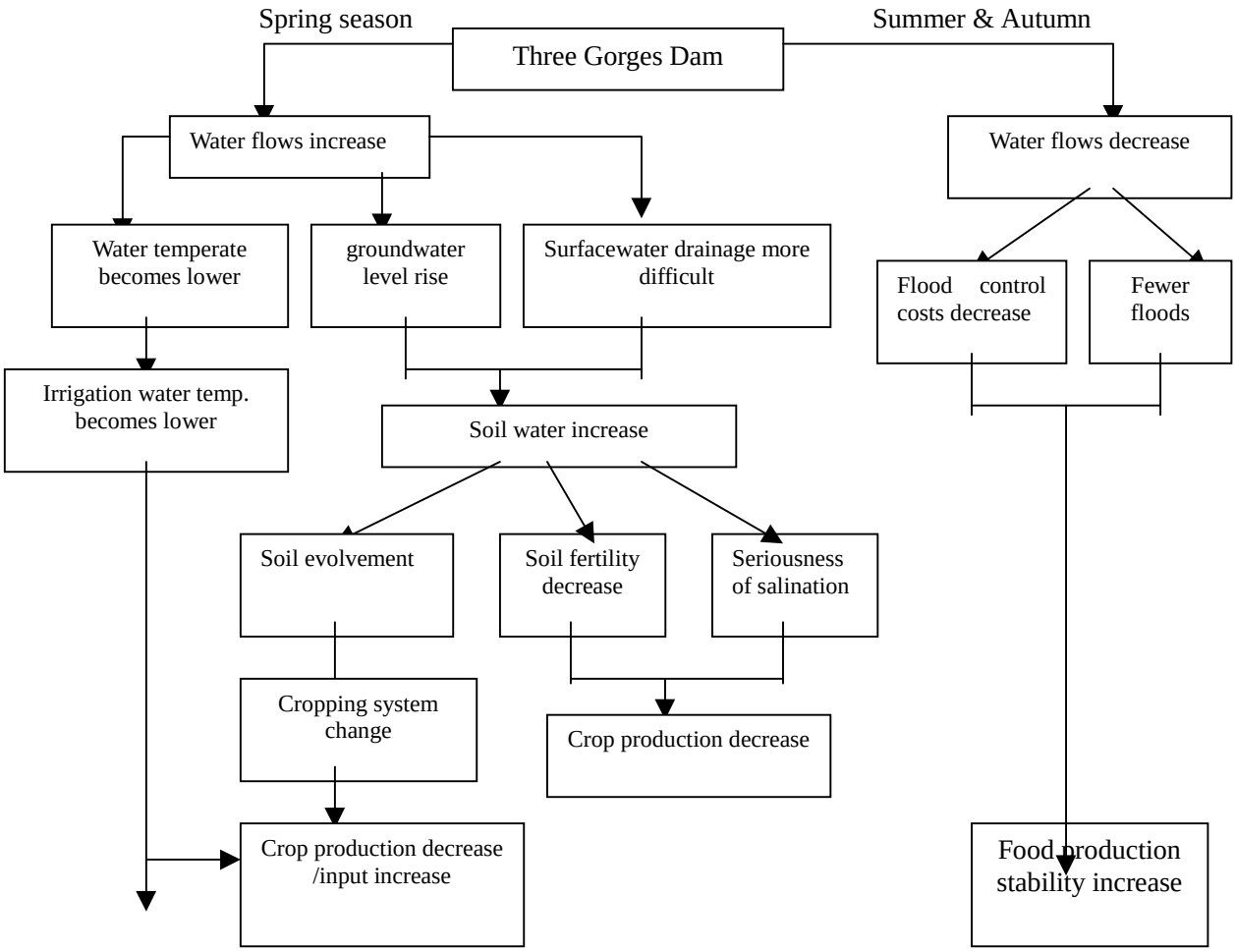
In China, however, socio-economic impacts analysis for any economic activities including dams and reservoirs were involved only after 1981[14]. Prior to that, there were economic benefit assessments for a new engineering project, no environmental and social evaluations were required by the administrative agencies. In addition,

[13] The ecological and environmental tolls brought about by the Three Gorges Dam were estimated as much as 10.2 billion Chinese yuan (approximately 1.25 billion US dollars). See Fu Shouning & Wang Jianguo, *Economic Evaluation of the Ecological and Environmental Impacts of the Three Gorges Dam*, Chengdu Geological Research Institute of the Chinese Academy of Sciences, 1987.

[14] Li Jingwen, *Theory and Methodologies of Feasibility Study*, published in the "Technological and Economic Evaluations of Key Projects in the Trans-centuries" (edited by Li Jingwen, etc.), Social Science and Literature Press, Beijing 1997.

economic assessment emphasized the possibility and feasibility of economic profits for the dam's projects. For example, if a project was estimated with no positive profits, then it was probably aborted and denied by the government.

Figure 1 Illustration of the Impacts of Three Gorges Dam on Downstream Agricultural Development



Source: Geng Guoqiang, etc., *Impacts and Countermeasures of the Three Gorges Dam on Downstream Agricultural Environment*, Najing 1987.

One fundamental reason for this phenomena was at that time China encountered and especially realized neither environmental nor social security problems. Environmental awareness was totally a strange word for the policy-makers and even experts.

Certainly, soil erosion, land degradation and air pollution all existed in many parts of China, the point was almost all the intellectuals including professors, university teachers, technicians, engineers were exiled to remote rural areas to get trained by the farmers in 1960s-70s. Social and political movements were the core of all kinds of works. “Nominal” social equity was emphasized in terms of income and social status, and efficiency was neglected under traditional socialist system. All groups should and must sacrifice themselves to ensure the collective benefits of a dam or reservoir with no complaints or disagreement.

After the opening-up in early 1980s, different classes or beneficiary groups were categorized by the criteria of income level, minority, scale and magnitude for a dam project. The interests of various groups were diversified in terms of different groups with different interests and concerns. On the other, the roles that the government played in project development were changed from direct regulation to market-oriented guidance. Collectivism conciliarism was also challenged by the philosophy of “money omnipotence”. Now, everyone is not willing to sacrifice his own economic returns from a project if it conflicts with the collective benefits. Such changes imply that conflicts between different groups should be taken into consideration to analyze the socio-economic impacts of a dam or reservoir on local and downstream residents.

The social side to the comprehensive conception of environment include the people, their land and settlements, their economy and traditions. On the other hand, the impact of dams and reservoirs on this environment is inevitable and undeniable; land is flooded, people are resettled, the continuity of aquatic life along a river is interrupted, and its runoff modified and often reduced by diversions. Generally for a socio-economic analysis of a dam project, both economic costs and social costs need to be covered which include:

- research costs for dam and reservoir programming,
- construction costs of dams, dikes and canals,
- operation and maintenance (O & M) costs of the dams,
- resettlement costs for the migrants (such as house rebuilding costs, compensation for the migrants),
- gender imbalances,
- the losses of cultural heritages,
- transaction costs (corruption costs) of a project, etc..

From the research point of view, unfortunately, socio-economic impact analysis for a dam project has been “symbolized” and formalistic in China as of today, especially for social impact analysis. This occurred even in the Three Gorges Project. Resettlement and livelihood problems were generally emphasized in terms of rebuilding a house for the migrants or a compensation for them to be able to build a new house elsewhere, while the potential social impacts of the new activities of them on the new habitats were neglected.

Numerous literatures and studies can be found on ecological and environmental

impacts of the Three Gorges Dam on local, upstream and downstream of Yangtze River, unfortunately there are difficulties to find any concrete research on social impacts of the Dam. As a matter of fact, social impact analysis was not even included in the Feasibility Study Stage of the Dam to my knowledge. This may be explained as saying that the priority for the disputous Three Gorges Dam was focused on ecological considerations, and social aspects were not a problem or were "ignored" by the decision-makers and experts with technical engineering background, because the focus of the disputes had been its huge negative ecological and environmental impacts.

However, it is still hard to say that no social considerations are taken for a dam in China. Alternatively, social aspects were judged, estimated and balanced by the policy-makers qualitatively on the basis of *social experiences and knowledge* with consultations from experts and technicians. Local leaders and farmers were also approached, but generally their concerns were not fully taken into account in the decision-making process. Although there were some complaints or even protests against a dam project, the victims could finally give in with a compensation from the government or project investors.

Table 1 is a general framework of socio-economic analysis for a dam project in China. If a dam is seen as a need with consensus from most administrative departments, it will be built no matter whatever social impacts were analyzed, either positive impacts are greater than negative impacts, or vice versa. In other words, social impacts are still not emphasized in the feasibility analysis of a project in China.

One reasonable explanation for this is that the Chinese people are endurable in the history, one individual is not willing and able to fight against the collectives or the powerful national institutions. They would prefer to choose a trade-off in the notion of "a few is better than nothing". However, this is not saying that the government administrations do not consider any concerns from the affected people.

Like an environmental or economic impact analysis, social impact analysis includes both local, upstream and downstream of the river in China. Specific attentions would be given to the resettlement problems of the local and upstream river basin encountered by the dam. They are the ***direct*** affected people, and should be considered at first according to the logistics of policy-makers. And the impacts of a dam on the local and upstream are also direct, open and transparent to outsiders, national and international discourses. However, downstream residents are considered as ***indirect*** stakeholders. So the policy-makers try to make a trade-off between the directly and indirectly affected people.

Table 1 A General Framework of Socio-economic Analysis for a Dam Project

	Positive Impacts	Negative Impacts
local level	• increases in irrigated land • food production • employment opportunities • wage level • improvements in nutritional status of the population • local and regional economic development	• position of small and marginal farmers • land concentration • loss of access to common goods • traditional knowledge • social cohesion • cultural impacts • health impacts
regional & national level	• food production • food security • population's nutritional status change • poverty alleviation	• distribution of costs and benefits across social and economic groups and areas/regions

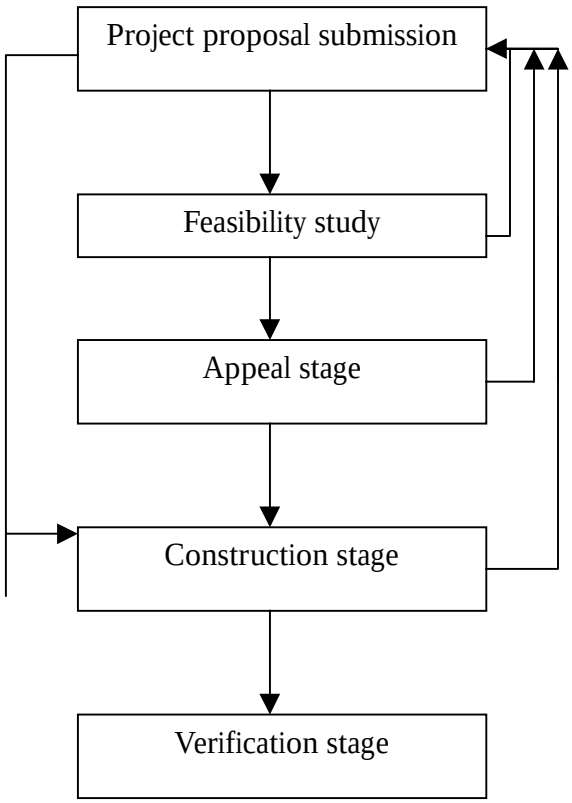
If a project would encounter strong opposition from downstream, and would have severe social impacts in terms of large amounts of migrants moving into a new place downstream, the impacts on downstream river basins would be taken into consideration. Such questions generally need to be answered[15]:

- How to resettle and allocate the migrants amongst the areas downstream?
- How about the population density and economic development status in downstream? Is it feasible to move into so many households in a area?
- Can it be accepted by the local residents?
- Can they be harmonized with each other?
- Are there ethnic and minority problems between local and migrated people?
- How different and similar are the life styles and customs between local and migrated people?
- Who should pay the compensation for the migrants to rebuild a new home?
- What kinds of roles do downstream governments play in resettling, replanning, reallocating the migrants and in resolving conflicts between old residents and newcomers?

Now let us hereby describe the typical process of a dam project in China. Generally, a dam project construction covers feasibility study stage, appeal stage, construction stage, and verification stage (see Figure 2), of which the first two stages are of great significance for the success of a dam.

[15] Excerpted from "A Preliminary Analysis of the Social Impacts of Xiaolangdi Project" by Lailai Li, Institute of Environment and Development, Beijing, 1998

Figure 2 Dam construction procedures



feasibility study stage

After the developers submit a project proposal to respective water administrative bureau, a preliminary feasibility study report is required to indicate and clarify the importance as well as financial and technical feasibility of the project. For large dam projects, economic, social and environmental benefit assessments are the integral parts of the proposal. The trade-offs between positive and negative impacts are estimated and justified in the study report.

The preliminary feasibility study should answer the following questions:

- Is the investment possible to get foreseeable profits?
- Is it necessary to do the final feasibility study?
- What other questions need to be further studied, such as market analysis?

If the preliminary feasibility study is accepted by the policy-makers or bureaus, a final copy of feasibility study will be requested to make an in-depth research on

technological and economic analysis. Then a core group of people will be invited to evaluate the report whether it is economically, environmentally and socially feasible. Various experts, technicians and engineers will participate in the evaluation process. All comments will be feedbacked to the developers to revise their design and the feasibility study report of the dam, until it is finally accepted by the advisors and administrative agencies.

However, for small dams and reservoirs that are invested by local residents with few migrants involved, the decisions are made by the local communities surrounding the areas. Experts are consulted for the design, location, and construction of the projects. Majority rule applies in such occasions. No feasibility study is required.

Today, the planning and operation of dams do not only focus on technical aspects. Full consideration is given to whether or not the project is socially, environmentally and economically justified, and whether the normal functions of the river will continue to be preserved. Only projects with acceptable impacts should be considered for construction.

Some of the main concerns in the feasibility study stage are as follows:

- *Safety aspects* To ensure the continued and dependable delivery of benefits from a dam, the developers and/or the owner must have a comprehensive plan for operation, maintenance and rehabilitation. As dams become older, safe performance becomes a concern. This requires more attention in the form of evaluations of safety considerations to ensure that they must meet current technology and regulations.

  Dam safety activities include monitoring structural performance, developing emergency action plans, training of dam operators, exercises involving the local officials and population and implementing risk reduction actions. As residential and commercial development expands in a river basin, the hydrologic characteristics of the basin also change. This requires a periodic and thorough review of the rainfall and runoff characteristics as well as the identification of other changes in the hydrology of the basin.

- *Socio-economic impacts* Since dams are often seen as essential for national economic development, their macroeconomic benefits tend to be highlighted, while their local economic and social impacts have sometimes not been adequately evaluated. One of the most important objectives of a dam is to ensure that an appropriate share of the benefits go to the population directly affected.

  Resettlement programs must involve the identification of the affected population as well as the affected activities such as agriculture, irrigation, forestry, commercial and industrial. The impacts on various stakeholders must be analyzed. According to a study on the Environmental Impacts of the Three

Gorges Dam, the Dam Project will have to resettle at least 636,564 (static figure with the dam height of 170 meters) or 794,796 (static figure with the dam height of 180 meters) rehabitants covering at least 14-20 counties within Sichuan and Hubei Provinces. At least 10000 hectares of arable lands, 2800 hectares of orange forests, 10.79 million square meters of houses and rooms, 374 factories, 119 township enterprises, 62 docks and 23 important cultural heritage sites will be submerged by the Dam project[16].

In sub-tropical zones of China, sanitation must be addressed. Reservoirs can create an environment, which is favorable for the transmission of water-related diseases. As the primary preventive measures , sanitation and health-care programs for the population around the reservoir should be taken into account in conjunction with designing appropriate operating rules.

- *Environmental concerns* Managing water resources in a river basin has an impact on its natural water cycle. The actual size and natural condition of the area to be developed and the extent of development will determine the scale of the impact, so concerns about environmental issues and implementation of mitigation measures, are essential elements in the planning of a project.

  For instance, such aspects need to be clarified and considered: the extent of the clearing of vegetation in the area to be flooded, the multi-level outlet structures to optimize downstream water temperature and quality, provisions for the migration of fish and other aquatic organisms, and operational rules for regulating downstream flows at critical times to protect habitat for reproduction or migratory routes.

  The enhancement of the biodiversity of a reservoir in moderate climates may be also one component for environmental concerns in tropical zones, where such a diversity would foster harmful disease.

- *Sedimentation problems* Fast-flowing streams have the capacity to erode and transport soil, sand, gravel and stones as bed load and suspended material. When this fast flowing stream enters a calm reservoir, this solid material is deposited. There are two positive impacts of sedimentation: 1) The deposits in the entry zone of the reservoir (inner delta) provide highly diversified habitats for wildlife. 2) Following the removal or settling of suspended solids in the reservoir, the water released from the dam is less turbid and the water quality is improved. Additional downstream benefits are enhanced recreation, improved local living conditions and facilitating riparian and aquatic wildlife.

  The problems are its negative aspects. Reservoir sedimentation could be progressive loss of storage capacity, and increased erosion in downstream river

[16] Gao Fuhui and Chen Guijie, *"Analysis of Migrants Environmental Capacity of the Three Gorges Dam"*, published in the Symposium of Ecological and Environmental Impacts of the Three Gorges Dam and Countermeasures, Science Press, 1987, pp1012-1013.

channels. Without full consideration of reservoir sedimentation, the living period of a reservoir would be shortened. To remove the sedimentation is very costly and impossible to a large extent. In this aspect, the Shanmenxia Project gave a severe lesson for Chinese dam designers and policy-makers. This project was firstly designed by Former Soviet Union experts with few experiences and knowledge in areas with serious soil erosions in Loess Plateau, the ability and availability of power generation and irrigation was only lasted for less than 1/3 of its design period due to the fast growing sedimentation problems.

Various sediment-handling measures are available to mitigate the negative impacts of reservoir sedimentation. The problem is whether such are included in the design of the dam. Successful techniques include erosion control by fostering and safeguarding the natural vegetation cover, bypassing, sluicing, flushing and dredging.

Whether there is a component of appropriate planning and operational regimes for reservoirs that are susceptible to sedimentation is also vital to the feasibility. This will help accentuate the positive aspects of sedimentation and lessen the negative impacts.

Appeal stage

This stage is open to all people involved and affected upstream and downstream the river for comments and revisions of the proposal. Various stakeholders have a chance to speak out their concerns and objections for the dam project.

“Stakeholders” is a new term in China, but the meaning and essence of it are familiar to most policy-makers, which refers to the relevant people, groups and organizations affected by and associated with the dam development.

The identification of the “stakeholders” is decided by the administrative agencies. Governmental intervention is sometimes required to make the administrative agencies ensure the participation of all the stakeholders involved if some of them are ignored. Governmental and non-governmental organizations, individuals, minority groups, upstream and downstream representatives could be considered as the stakeholders. Those with little relevance to the dam are usually excluded from the scope of the stakeholders.

Several categories for the stakeholders are classified by the government based on the extent and degree of their losses in property, land, and wealth. Special concerns and priority are given to those who are fragile, who are sensitive groups (such as minority groups), and who are severely affected by the dam.

An order is shortlisted to help prioritize the relevance of stakeholders to the dam development. Local political /administrative planning units downstream also get

consulted and involved in dam planning and development. If some kinds of people are ignored by the government, they can directly appeal their concerns to the dam administration agency in order to be included into the stakeholder list.

Once the positive impacts are quantitatively and qualitatively greater than the negative impacts, and all of the concerns and conflicts can be solved and balanced appropriately in due course, the project would get a legal construction certificate from administrative agencies to start constructing. Under the monitoring of a monitoring agent, the dam can be constructed and verified when completed.

The government plays different roles in dam development as both the administrators and the investors, which may result in the neglect of some stakeholders participation and of consideration of the negative impacts on affected people. Excitingly, such has been changing in terms of the investors are being diversified.

Good Practices and Experiences: An Example of *Dujiangyan Irrigation Project*

As stated above, up to now in China there are few analytical studies on dam's social and environmental impacts and on actual achievements in terms of economic development as a result of dam construction, especially for small and medium-sized dams. However, we may take *Dujiangyan* Irrigation Project to summarize the Chinese experiences in maximizing sustained performance, in minimizing socio-economic costs and in achieving high level of equity in the distribution of costs and benefits of dams[17].

Three considerations were taken into account to select the successful story:

(1) *Dujiangyan Irrigation Project is well-known for its long history in the world*. It is located in the middle of Sichuan Province 60 Km away from the Capital City Chengdu and 1 km from the town of Guan County. *Dujiangyan* Irrigation project covers plain and hillside irrigation zones, the former at the Chengdu Plain and the latter at the hillside areas east of Longquan Mountain. Main rivers including *Minjiang* River and *Tuojiang* River provide water flows for the Irrigation project. Precipitation is relatively equally distributed within a year from 1100-1232 mm[18].

(2) *Dujiangyan Irrigation Project has successfully lasted for more than 2200 years,*

[17] This is not saying we were confronted within the *Dujiangyan* framework. Experiences and practices from other projects were also taken into account to illustrate how a Chinese dam or reservoir is and can be successful in terms of economic, environmental and social perspectives, and why.

[18] Dujiangyan Administration Bureau of Water Resource and Electric Engineering Department of Sichuan Province, *on Dujiangyan*, Water Resource and Electric Engineering Press, 1985, pp1-20.

and now it irrigates more than 800,000 hectares of arable lands. Prior to the construction of the dam, flooding often occurred in summer seasons every year in downstream Minjiang River basin. The geographic disadvantages accelerated the seriousness of the floods, since water courses became wider and with no dikes or dams became unstable in summer seasons, after the Minjiang River flows across the town of *Guan* County. It was the project that changed water from a disaster into a valuable resource, and altered the life of the people downstream the Minjiang River in the Chengdu Plain.

(3) *The project brought about significant benefits to the regions*. Taking the changes and benefits in the period of 1949-1998 as an example, average food production per mu[19] was increased from about 250kg in 1949 to more than 500kg in 1990; irrigation acreage increased by 3 times; floodwoods were transported from 1000 m^3 to 30,000 m3 a year; an extra of 700 million m3 water supply were provided for urban industry and domestic use; about 500 power generators were installed with a total of 90,000 kilowatt installing capacity of electricity generation, etc..

(4) On the other, *very limited negative social and environmental impacts were emerged by the project*. Almost all the people interviewed including upstream and downstream appreciate and welcome this project, and get consensus that it is a good dam for the people[20].

Based on the knowledge and understanding, four aspects of good practices and experiences can be summarized from the *Dujiangyan* Project and others: site selection, scientific project planning and programming, effective and sustainable management system, and block water charging approach.

(1) *Good location of a dam is vital to the success*

Site selection together with the implementation of some advanced techniques will result in both new and rehabilitated projects that minimize unacceptable social and environmental impacts. One of the important and fundamental reasons why the Dujiangyan Project worked so well for so many years is its excellent site selection[21].

A good site for constructing an irrigation dam should meet the following criteria:

- favorable natural geological conditions/situations
- prone to removal of the sedimentation
- a guarantee of mature techniques for the dam at the site
- minimum of rehabitants affected by the dam.

[19] One mu is equal to 1/15 hectare.
[20] Dujiangyan Administration Bureau of Water Resource and Electric Engineering Department of Sichuan Province, *on Dujiangyan*, Water Resource and Electric Engineering Press, 1985.
[21] *An Introduction to Dujiangyan Project*, The Dujiangyan Administration Bureau of the Sichuan Provincial Water and Electricity Department, 1986.

Dujiangyan Project was designed and constructed with the “fish rostra” at the top of the Minjiang River alluvium plain, and then two sub-rivers were derived from Minjiang River: the inner sub-river and outer sub-river. The inner sub-river was designed to provide water for irrigation, while the outer sub-river for flood discharge. In this way it is easier to adjust water flows and to adjust the water allocations between inner sub-river and outer sub-river in different seasons.

Meanwhile, the wonderful design and the good site location of the Dujiang Weir did not require a large dam but a “dike” with less than 10 meters high, which meant less uncertainty and risks for downstream people and higher technological guarantee at that time 2200 years ago.

In addition, the location of the “fish rostra” is also prone to sedimentation removal in a natural way. 80% of the sedimentation sands could be washed away automatically by water flows in outer sub-river[22].

Site selection had been given high priority recently by the Chinese government in many projects of large dams and reservoirs. The Three Gorges Dam project had invested much in geological and hydrological research in Sichuan and Hubei Province, and had taken much longer time than expected to define an ideal location of the dam in order to ensure the success of a dam at the first step.

(2) Scientific project planning and programming is the key to technological, economic, environmental and social feasibility of a dam.

Cost-saving principle was well utilized in Dujiangyan Project in terms of most of the dam materials were local materials, such as sands, woods, bamboo cage, cobblestone, etc. Using local materials could decrease the costs of dam construction to a large extent without sacrifice of the dam quality. Such technological preferences adapted well to local situations, and it was practiced and proved for so many years that these are “scientific” technologies.

On the other, to identify a good dam construction technique is also an integral component of scientific project planning of a dam. Some approaches for Dujiangyan dam construction were well practiced and extended to many large dam projects for irrigation in China. After 1949, “*Movable Steel Matrix Trestle Approach*” for dam construction was invented firstly to build the *Jiguang* and *Luban* Dams, which are covered by the Dujiangyan Project. It was practiced that this was one of the new good practices to build dams in the new coverage administrative areas of Dujiangyan. The design and construction techniques are still welcomed and utilized by other dam engineers and investors. In this respect, *Shanmenxia* Reservoir was a lesson for Chinese engineers and experts.

[22] Source: *An Introduction to Dujiangyan Project*, Dujiangyan Administration Bureau of Sichuan Provincial Water and Electricity Department, Water and Electricity Press, 1986, Pp4-8.

Environmental concerns have been a new component to dam construction after 1980s. *China sturgeon* is one of the most precious and endangered fish species living in the Yantze River. To protect them from being extinction and to decrease the negative impacts of the Three Gorges Dam construction on the migrating rules of China sturgeon, the Dam structure was revised for a lot of times to try to make sure the fish could swim freely for reproduction in upstream and downstream river basins.

Effective management of water resource is essential to sustaining the existing and future population. Basin-wide planning for water management is the key element to providing optimum water supply and other benefits. For a dam, this also applies as a truth. Not only the impacts of a dam on the upstream but also on the downstream should be taken into full consideration at the planning stage as an holistic system of the whole river basin.

- It was reported that due to lack of consideration of impacts on the downstream water supply and environmental consequences of building a dam in the upreaches of Colorado River in the United States the downstream ever irrigated lands now are becoming dried and desertified[23].
- In China, many experts argue the outflows of the downstream Yellow River which led to no irrigation in Shandong and Henan Provinces were resulted from the too many dams constructed in upstream of the Yellow River, such as Ningxia Yinhuang Irrigation Project, Shanmenxia Project, Xiaolangdi Project and other small and medium-sized ones which are still being constructed. In 1998 it was observed that there had been as many as 240 days with no water flows at all in the lower reaches of the Yellow River.

(3) Effective and sustainable management system is a guarantee for the success of a dam

Under the traditional socialist system, both institutional arrangements and strict and thorough management systems are of great importance to the success of a dam. Institutional arrangement was set to allocate the responsibility of dam management, and management system (or regulations) to provide incentives for managing the dam well and to provide punishment for any mistakes and wrong decision-makings.

Dujiangyan Project set up a perfect management mechanism for many years. Before 1935, a special staff or envoy was always assigned to be responsible for the Dujiangyan Project dam with direct supervision from a “Minister”, even if the governments changed periodically or in war time. At that time, water monitoring, sedimentation removal and canal maintenance had been the main tasks for the envoy.

In as early as 1935, a special Dujiangyan Engineering Division under the Department of Construction of Sichuan Province was set up to manage the project because the

[23] Source: *China Daily*, November 22, 1999

irrigation areas became more diversified and far-reached. In 1949, a formal Dujinagyan Administration was established to be responsible for the dam and canal maintenance and water allocation plans.

Since 1950s, a more specified management institution and management system had been used in Dujiangyan Project. *Participatory Management Approach* were involved to invite various non-governmental organizations and individuals (such as the sub-canal administration committee by the farmers themselves, water management group of a village, water delivering team, water delivering farmer, etc.) to join the management groups, and they were assigned to be responsible for the management of sub-rivers and small canals in the fields.

A detailed framework of the Dam Management System was illustrated in Figure 3. As you can see, there were generally 6 levels of administrative agencies for the dam and irrigation water allocation in Dujiangyan Project, each level was specified with different functions and responsibilities (see Table 2).

Between and among different levels of administration bureaus there might exist some conflicts and overlapped or duty-obscured problems, however, the centralized up-down system dominated the decision-making process which implied the lower levels must follow the upper ones. In this way, if there occurred some problems in flood control, water distribution scheme, or sedimentation removal, it could be finally settled down and agreements could be reached between various stakeholders and various levels of administrators.

Furthermore, NGOs and governmental organizations were all involved in the dam management decision-making process. The participation of various NGOs and individuals into the management and decision-making process would help to provide for them strong incentives to save water resources, to manage and utilize well the canals and water engineering facilities, and to increase the water use efficiency in order to make agricultural production more stable and sustainable.

Figure 3 Dujiangyan Administration Institution after 1979

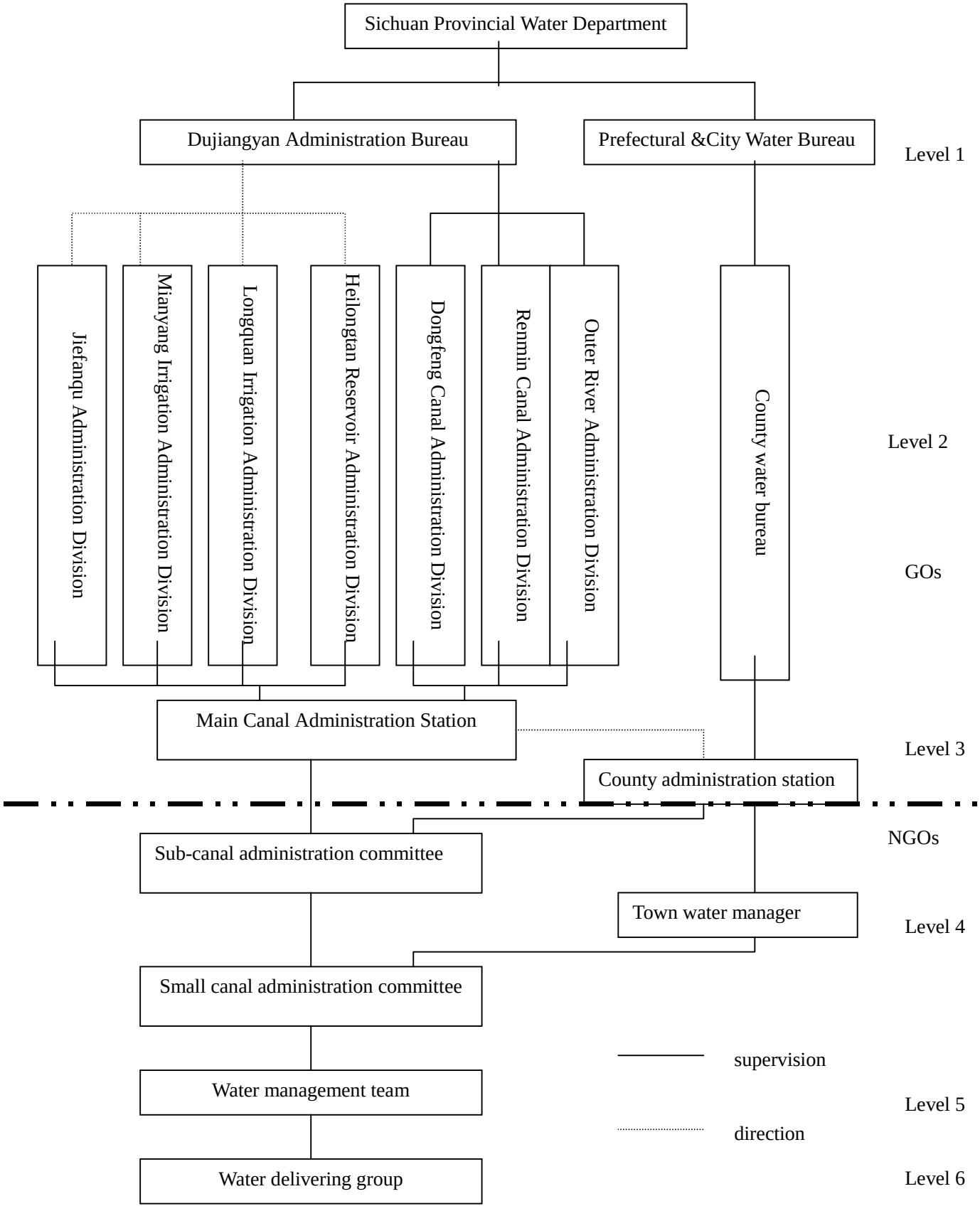


Table 2 An hierarchical structure of water management system in Dujiangyan Project: 1979-1999

Level	Name of institution	Functions and responsibilities
1	Dujiangyan administration bureau	● Top leader ● Water fee collection ● Annual maintenance ● Flood control ● Project renewment ● Water distribution between counties and canals ● Collaboration
2	Irrigation zone administration & county administrative bureau	● Water management of the local irrigation zones ● Supervision of the local canal maintenance ● Water distribution within irrigation zones ● Water fee collection ● Sedimentation removal ● Flood control
3	Main canal administrative station	● Water distribution ● Water fee collection ● Sedimentation removal ● Canal maintenance ● Flood control
4	Sub-canal and small canal management committee	● NGOs ● Water distribution ● Water fee collection ● Sedimentation removal ● Canal maintenance ● Flood control
5	Water management team	● NGOs ● Water distribution within production teams or villages ● Water fee collection ● Canal maintenance ● Sedimentation removal
6	Water delivering group	● NGOs ● Definition of water delivering order between farmers and households

(4) To increase the social equity between poor and rich farmers, and to help achieve gross control of water fee collection, block water charging approach has been one feasible option

Theoretically, up to now there are still disagreements amongst and between environmental and resource economists about whether block water pricing is good or bad to social equity goals[24]. Some economists say yes, while others say no. However, the Dujiangyan Project and other Chinese dam and reservoir experiences in sustainable water management disclosed that block water charging approach is feasible and acceptable to both farmers and policy-makers.

It was proved that Chinese farmers can accept this water kind of water pricing approach all over the country, they are willing to pay the different prices in different regions upstream and downstream the river. Water fee collection is not a problem in these areas where such approach was used in general. For the less developed areas, water fee could be considered as a burden for the farmers, and some poor farmers may feel they can not afford the water fee level as high as other farmers with higher incomes. The experiences disclosed water fee could not be over 1-3% in poor areas of China[25]. Otherwise, either it was denied by them because of inaffordability.

Through block pricing options, poor farmers and downstream farmers with inferior access to irrigation water from the rivers would pay at a lower price, and rich farmers and upstream with easy access to water at a higher price. In addition, water consumption by different industries at different seasons would pay at different prices (see Table 3). In this way, the rich farmers would “compensate” the poor farmers to pay the higher water charges, and the total water fee collection would be able for the water administration to sustain M&O of the dam and rivers.

Some Principles, Guidelines And Approaches

I). Decision-makers should make sure that in order to provide strong incentives for investment on dam construction, benefits from investment must be assured for the investors.

Decision-makers must make sure that the project will have high social, economic and ecological returns and/or benefits, and then the investors could be convinced and assured. In other words, those dams without favorable and foreseeable significant benefits are better to be prohibited by the policy-makers. Otherwise, such dams are

[24] Jeremy Warford, *Marginal Opportunity Cost Pricing in Municipal Water Supply*, EEPSEA working paper, 1994. And Dale Whittington, *Can Marginal Cost Pricing be socially equitable?* EEPSEA working paper, 1998.
[25] Lubiao Zhang, 1995, *Water management system in the North China: Practices and Experiences*, China Water Resource, No. 4.

deemed to be with few or even no positive benefits, and would bear negative social impacts for both the current and the future generations. To assure the future returns, technological guarantee is a prerequisite in terms of mature technology and selection of cost-saving technologies.

Table 3 Water Pricing Options For Different Water Users In Dujiangyan Project in 1979-1983

Water users	Water fee (yuan/m3)	
Agriculture	0.05-0.10 (Spring)	0.02-0.05 (Autumn)
industry	0.02 (recycled)	0.09
household	0.02-0.04	
fishery	0.8% of annual income	

Source: Dujiangyan Administration Bureau, 1992.

In China, investment has been a problem in terms of sources and quantity. The government is lack of sufficient fund to invest a dam, especially a large one. It must seek for other sources to provide investment for it. On the other, even for irrigation dams the farmers are willing to contribute in-kinds and labor rather than money, though the beneficiary groups are mainly rural communities within the downstream of the dams, because the farmers are still not well-off, and they have to make sure whether their investment could be returned with a profit in the short term.

In the past it has been the hallmark of our very best engineers to see the natural environment as one of their responsibilities too, which is why many dams and reservoirs harmonize so well with their environment. Today, however, the enormous increase in human knowledge, including that in the field of environmental science, means that a whole team of specialists is needed to access and utilize that knowledge for a water resources development project.

The decision on what is usually a very considerable investment for a dam project must be based on an unequivocally realistic economic analysis, which would tie down a major share of its financial resources for many years. Any tendency to overstate the benefits and understate the costs must be strictly avoided.

This also requires taking the impacts on the natural and social environment into account. In spite of proposals put forward by international financing institutions and a growing literature on the subject, some such impacts are difficult to quantify or plainly defy expression in monetary terms. In such cases, they must be incorporated in the decision making process at a higher level of judgment than is implied by a merely numerical cost-benefit analysis, and the dam promoter should explain how such non-

quantifiable impacts affect his decision.

An important item on the benefit side is the useful life of the reservoir. Hence, actually available live storage volume must be estimated according to reliable data on the transportation of solids according to realistic assumptions on reservoir sedimentation processes and the effect of mitigating measures. Sedimentation control in the reservoir by sediment flushing, sluicing or dredging must be supported by erosion control in the watershed in order to prolong reservoir life as far into the future as possible.

Multipurpose benefits which do not produce revenues for financing the project must nevertheless be taken into account in assessment of a project or a comparison with alternatives. Such comparison includes the environmental advantages of hydropower over thermal generation.

II). Decision-makers must recognize the notion of sustainability and "inter-generational equity", which implies that their decisions impact on future generations, and that those generations have inherent rights.

The principle of "inter-generational equity" i.e., that decisions to benefit the present should not jeopardize future generations, has gained increasing recognition. The notion of sustainable development has been widely accepted by the commons, and has been designated as one of the two National Policies which would be a guideline for national economic development programming and legislation relevant to environmental issues.

The principles require decision-makers to ensure that the needs of the present do not compromise the basic needs of the future. These basic needs, in a biological context, include the maintenance of life form populations at levels sufficient for their healthy survival, providing special protection for rare and endangered species; utilizing natural resources in a manner which optimizes their use while minimizing damage from that use, and controlling consumption.

The growing number of State Constitutions which refer to a Right to the Environment, encapsulate this theory as well. Nonetheless, while this principle is strongly protective of biodiversity and varied life forms, it is to be read in conjunction with principles that recognize two very human needs - development and eradication of poverty.

III). Decision makers should ensure that before any decisions are taken, those who could be adversely affected have the right to participate in the discussions of dam design and construction, have an opportunity to engage in prior informed consent, and they should also ensure that decisions are enacted consistent with appropriate due process.

The principle of Prior Informed Consent makes it incumbent upon decision makers to ensure that potentially affected parties are aware in advance of the potential threat from elements which are intended to be introduced to their environment.

In addition to being informed with adequate notice, it is incumbent upon decision-makers to be sure that affected parties have an opportunity to voice their concerns and participate in the decision-making process. This includes increasing recognition of non-governmental actors to participate in the consideration of environmental issues, especially the cultural and ethnic considerations in minorities regions, such as the Tibetan Minority.

IV). Policy-makers must promote the process of democracy and decentralization in environmental management. Participatory Management Approach must be applied in dam and reservoir projects. Encouragement and punishment systems are a necessity.

Human rights are the intrinsic rights for all people in the world in any aspects. The resettlement of the migrants would alter their normal living styles, living standards, and custom. Their benefits affected by the dam construction must be protected, and their losses must be compensated. Their comments must be respected. Policy-makers should provide for the migrants and affected groups access to higher administrative and legislative levels.

Participatory Management Approach is essential for a success of dam maintenance and operation. Various stakeholders must be involved in the Dam and Reservoir Management Organization including village chiefs, the elderly people, women, upstream and downstream farmer representatives, expert, policy-makers, etc..

Any action requires continuous, comprehensive and objective information on the project to be given to governmental authorities, the media, local action committees or other non-governmental organizations, and above all to the directly or indirectly affected people and their representatives. In such information transfer from planners to the public, dam engineers must contribute, through their professional expertise, to a clear understanding and dispassionate discussion based on facts and not on irrational ideas of the positive and negative aspects of a project and its possible alternatives. Dam promoters must act as mediators and educators with the aim of becoming good neighbors and not intruders.

V). Decision-makers must utilize block water charging approach for irrigation water from the dams and reservoirs for the beneficiary groups in different location and streams.

The farmers with different locations will get different returns of water and preferences to use the water. Block water pricing Approach should be used in any water project. For example, those farmers with easy access to water from the reservoirs should pay

at a higher water fee level, and for those poor farmers at a low level.

VI). Concerns for the environment, including both natural conditions and social aspects, must be manifested from the first planning steps, throughout all phases of design and implementation, and during the entire operating life of a project.

Dam promoters must be aware of the fact that although dams are the most important means of making surface water available at the place and time of demand, there are also other, non-structural means of increasing water utilization which can be applied in addition to dams or as an alternative, such as the tapping and recharging of groundwater or desalination of seawater.

Furthermore, with resources increasingly limited or difficult of access, more thought must be given to demand-side management, to achieving better results with less water input by increasing the efficiency of water use in irrigated agriculture and industry, by reducing losses in supply systems, by the treatment and recycling of waste water, and by the conservation of water and energy. Hence, during the initial stages of planning a dam project, the question should be studied whether alternative solutions exist that could possibly fulfil the various purposes of the dam project at lower long-term costs to society and the environment.

The larger the project, the greater the effects on the natural and social environment to be expected, and the wider the scope of the multidisciplinary, holistic studies which they require. Large-scale development demands integrated planning for an entire river basin before the implementation of the first individual project(s).

Projects must be judged everywhere and without exception by the state-of-the-art of the technologies involved and by current standards of environmental care. The scope for reducing any detrimental impacts on the environment through alternative solutions, project modifications in response to particular needs, or mitigating measures should be thoroughly investigated, evaluated and implemented.

A complete post-construction audit of an entire project or at least a performance analysis of major impacts should be carried out in order to determine the extent to which the environmental objectives of the project or of certain mitigating measures are being achieved. The results of such analyses should be published as a contribution to our knowledge on such matters, and for application to future projects.

As soon as a project becomes operational, its impact on the environment should be assessed at regular intervals, based on data and sources resulting from adequate pre-construction monitoring. Depending on the individual situation, certain critical parameters should be monitored as a basis for a subsequent performance analysis of the project, resulting in a better understanding of its interactions with the environment.

In this context, there is also a need for more ecological research on dams and reservoirs which have already seen many years of service. Mistakes and shortcomings could be avoided, many of the recurring controversies relating to the ecological impacts of new dam projects could be prevented and the problems involved could be clarified and solved more easily, if our latent store of long-term experience with the operation of so many dams and reservoirs were to be collected, processed, evaluated and published in the framework of research projects based on carefully directed investigations. Such research projects would also provide and enhance the basis for a general policy of intensified collaboration with environmental scientists.

Conclusions and Suggestions

As is the case with any complex infrastructure project, dams have some impacts on their surroundings in the river basin. However, adverse effects can be reduced or eliminated by careful planning, public involvement and by incorporating a variety of mitigation measures.

Throughout the history of the world, dams have played a major role in storing and managing water needed to support civilization. Today, China is undergoing major changes in ethical values, business practices and living conditions as a result of rapid advances in technology and expanded communications associated with the continued unprecedented increase in population. At the same time there has been a careless use of our natural resources and accelerated pollution of the environment.

The concerns and adverse impacts of dams can be minimized or eliminated by careful planning and design that incorporate public involvement and input in the early stages of this process. When the appropriate mitigation measures are identified early in the planning and design process for a dam and reservoir, they can be efficiently and effectively incorporated into the design, construction and operation of the project.

Water remains the vital resource to sustain civilization around the world. Sustainability of life in some regions of the world is threatened by the imbalance between the demands and available supplies of water, food and energy. Dams and reservoirs can and should be compatible with the social and natural environment of the region. The challenge for the future will be the utilization of dams and reservoirs for the wise management of water resources as part of social and economic development goals.

On the basis of lessons learned from good practices and other concrete cases in China, some suggestions are recommended to improve the equity in the distribution of costs and benefits of dams between local and national-regional levels:

1) Investment must be combined with benefit-sharing. This is of great significance to small andmedium sized dams and reservoirs with investment from individuals and enterprises. Only in this way can they be provided the incentives to make

financial contributions to dam development.

2) Participatory management approach should be utilized in water project management. Various stakeholders should be involved not only in dam planning, design, construction, but most importantly in dam management. Encouragement and punishment systems should also be established and executed properly. Cultural and ethnic considerations should be emphasized especially in minorities regions.

3) Technological guarantee is a prerequisite for the success of a dam. Without this no dams could be developed, operated and managed well. Cost-saving principle applies for any irrigation dams to preferably use local construction materials to decrease the costs.

4) Block water charging approach should be used for irrigation dam projects. This would increase the social equity as well as acceptability and feasibility of a project. Gross returns must be assured in the way that net benefits from higher blocks should be higher than or at least equal to net losses from lower blocks of irrigation water charge.

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References

1) *China Statistic Yearbook*, 1999, China Statistical Press, Beijing.

2) China Water Research Institute, *Large Dams in China*, Beijing 1998.

3) Dale Whittignton, 1998, *Can block water tariff approach be socially equitable?* EEPSEA Working Paper, Singapore.

4) Dujiangyan Administration Bureau of Sichuan Provincial Water and Electricity Department, 1986, *An Introduction to Dujiangyan Project*, Water and Electricity Press.

5) Dujiangyan Administration Bureau of Water Resource and Electric Engineering Department of Sichuan Province, 1985, *on Dujiangyan*, Water Resource and Electric Engineering Press.

6) Fu Shouning & Wang Jianguo, 1987, *Economic Evaluation of the Ecological and Environmental Impacts of the Three Gorges Dam*, Chengdu Geological Research Institute of the Chinese Academy of Sciences.

7) Gao Fuhui and Chen Guijie, 1987, *"Analysis of Migrants Environmental Capacity of the Three Gorges Dam"*, published in the Symposium of Ecological and Environmental Impacts of the Three Gorges Dam and Countermeasures, Science Press.

8) International Commission on Large Dams (ICOLD), 1999.

9) Jeremy Warford, 1994, *Marginal Opportunity Cost Pricing for Municipal Water Supply*, EEPSEA Working Paper, Singapore.

10) *Jiangsu Provincial Statistic Yearbook*, 1999, China Statistical Press, Beijing.

11) Lailai Li, 1998, "A Preliminary Analysis of the Social Impacts of Xiaolangdi Project" Institute of Environment and Development, Beijing.

12) Lester Brown, 1998, "*Water shortage in China will shake the Global Food Security*", Worldwatch Institute.

13) Li Jingwen, 1997, *Theory and Methodologies of Feasibility Study*, published in the "Technological and Economic Evaluations of Key Projects in the Trans-centuries" (edited by Li Jingwen, etc.), Social Science and Literature Press, Beijing.

14) Lubiao Zhang, 1997, Water Management System in North China: Practices and Experiences, Research Report, IAE/CAAS, Beijing.

15) Miyun Reservoir Administration Bureau, 1992, *The impacts of Miyun Reservoir on Local Ecological and Environmental Conditions*.

16) Miyun Reservoir Administration Bureau, 1997, *Miyun Reservoir*, Beijing.

17) *Ningxia Provincial Statistic Yearbook*, 1999, China Statistical Press, Beijing.

18) Yellow River Administration Bureau, 1995, Yellow River Water Distribution

Schemes, Zhengzhou