A Huge Achievement –

The Many Aspects of the Three Gorges Dam

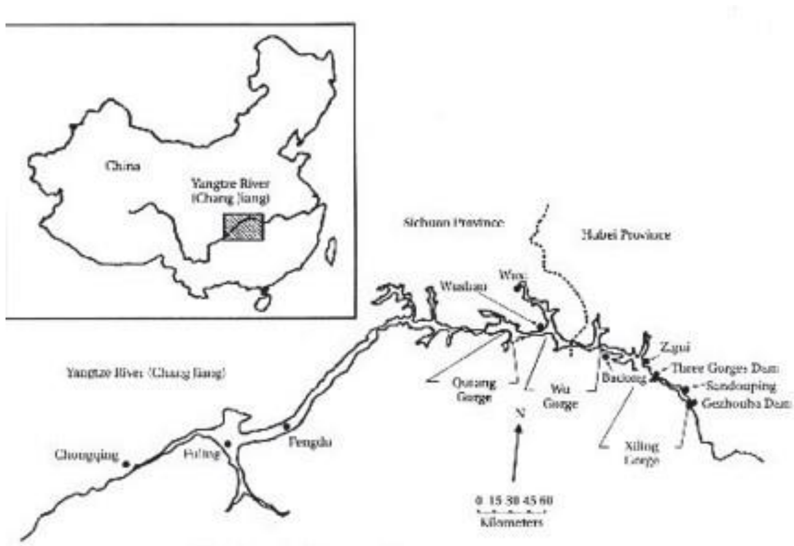
By Jay Hsu

The Three Gorges Dam (TGD) in China is one of the world's most massive structures[1]. It is also the world's largest hydroelectric power stations. In May, 2011, with the completion of six additional generators in an underground power plant, the construction of the Dam – except for a lift capable of hoisting a ship up to 3000 tons – is basically complete. The Dam is capable of peak generating capacity of 22,500 MW. In America, the Grand Coulee dam has a capacity of 6,809 MW, less than 1/3 as much as the TGD, and the Hoover Dam, has a capacity of 2,080 MW, not even 1/11 as much as the TGD!

Washington Post published an editorial, **China comes clean about the Three Gorges Dam**, claiming that China's ruling State Council "…acknowledg[es] serious flaws in the colossal Three Gorges Dam". The following is the first paragraph of the editorial:

> *"NOW THEY TELL US: China's ruling State Council has just issued a statement acknowledging serious flaws in the colossal Three Gorges Dam across the Yangtze River. Though the project has generated much-needed electric power and helped control floods, the statement said, "There are urgent problems that need to be addressed, such as stabilizing and improving living conditions for relocated people, protecting the environment and preventing geological disasters." Even this relatively candid language was a euphemistic summary of*

the chronic deadly landslides, contaminated water and social dislocation brought on by the dam. Indeed, as the State Council spoke, shipping downriver from the dam is all but paralyzed by drought, which might not have happened if the Yangtze had been free to flow as in the past."



MAP 3.2 THE THREE GORGES RESERVOIR

So why does China, on the eve of a huge achievement, deserve diatribes such as this? This writer has devoted the last few weeks trying to get to the bottom of this incongruous act. By going to the official statement of the State Council of China, I feel I have the answer. But before going into details, I like to acquaint the readers with the facts concerning the TGD.

The Three Gorges of China

Before TGD, if you cruised downstream the Yangtze River from the city of Chongqing (which I was privileged to do in 1996); initially the boat would be traveling on a broad river. You would cruise past farms, industrial sites such as ship-repair yards and small towns. While there were interesting historical sites, etc, it could be said that the scenery and landscape were generally bland and unexceptional. This would continue for more than 200 km (125 miles). But suddenly you would see a dramatic change ahead. The River would narrow and flow more rapidly. Its course would become more winding. Mountains with sharp rocky cliffs would rise to towering heights on both sides. They would look majestic and awe-inspiring. You had just entered the Qutang Xia (the Qutang Gorge), the first of the Three Gorges.

Qutang Xia would be followed by Wu Xia and then Xiling Xia, each would possess landscape somewhat different from, but equally as imposing as Qutang Xia. These three Xia's or gorges span a distance of close to 200 miles. Historically, they were celebrated in poems and stories because of their scenic magnificence. At the same time, since the River turned turbulent within these gorges, and was punctuated by fallen rocks and reefs, it became very difficult to navigate. Sailing upstream was further complicated by having to fight against the swift and turbulent current as you pass through the gorges. Through history, many ships had crashed into the reefs and numerous lives had been lost. Just to make these gorges more navigable was a challenge. In the early days under the PRC, engineers used dynamite to blast away some of the reefs and rocks on several occasions. They did succeed in creating an easy passage that does not require a local navigator to come on board to help steer each boat.

TGD History

Sun Yat-sen, the Founder of the Republic of China in 1911, appeared to be the first to envision a way to tame the Three Gorges and turn their liabilities into advantages. In 1919, he proposed the construction of a dam downstream from Xiling Xia, and calculated that such a dam will be able to generate more than 22,000 MW of electricity. The Nationalist government under Chiang Kai-shek wanted to put that proposal into a concrete plan, but war with Japan intervened. After the war, Chiang commissioned an engineer from the U.S. Bureau of Reclamation, John L. Savage to draw up a proposed plan. Preliminary

A statement released by the State Council on May 16th said, "The Three Gorges Dam needs to address some urgent problems, such as stabilizing and improving living standards of the relocated people, protecting the environment and preventing geological disasters in the basin."

from the *China Daily*

work was done in surveying, exploration and design of the dam, including training of a number of Chinese engineers in the U.S., but again, the onset of the Civil War put a halt to these activities.

After winning the Civil War, the PRC, under Mao Zedong, also embraced the vision of Sun, the Father of Modern China. In the 1980's, the proposal to build the Dam was finalized. In 1992 the National People's Congress put the idea to a vote and was passed (for the record, 1767 delegates voted in favor, 177 voted against, 664 abstained and 25 chose not to vote).

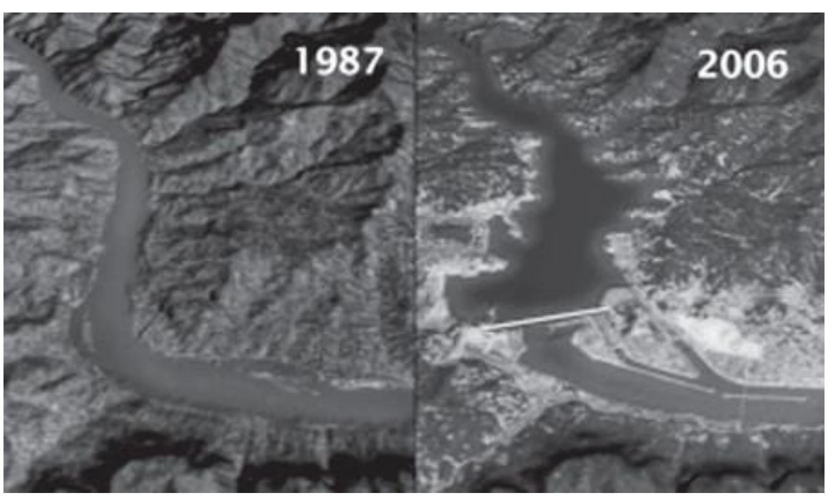
TGD Funding

The Chinese government of PRC estimated that the Dam would cost 180 billion yuan, equaling to $22.5 billion. This would be an enormous sum to be raised for China at that time. China applied to the World Bank for a significant loan. However, the U.S., at that time has stopped dam building because of the protests from environmentalists and others. The U.S. thereby strongly advised the World Bank, which it controlled, not to provide the loan.

China refused to admit defeat and decided to raise most of the needed fund itself. At the end, other than some loans from foreign commercial banks, all the rest of the funds were born by Chinese institutions. At the same time, China also decided to carry out all of the work in the construction of the Dam itself[2].

TGD Design and Construction

The TGD is conceived on an enormous scale. The main part of the dam is nearly one and half mile long (2,309.5 m. or 7,661 ft). The height of the dam is 181 meters (594 ft) above the rock base. Within the dam structure is housed most of the power generating equipment. This consists of 32 generators, each with a capacity of 700MW (currently the largest in the world). 14 are installed in the north side of the dam, 12 in the south side, and 6 others in an underground area in the mountain south of the dam.



Structure-wise, the north side of the dam also features a dual-lane ship by-pass flow-way with five locks on each lane. This flow-way and lock combination is calculated to transport ships up to 10,000 tons through the dam. Since a 10,000 tons ship is rather sizable, the locks have to be massive. The gate of each lock is of the size of a football field (standing on its end)!

In addition, also on the north side, a ship-lift is to be completed by 2014. This is basically an elevator-like device that can lift ships of up to 3000 tons directly over the dam, allowing a faster passage compared to going through the locks. It is estimated that, while going through the 5 locks may take more than five hours, going through the ship-lift will require less than half an hour. The completion of the lift therefore will further increase the level of traffic in the Yangtze.

Official kick-off of the TGD project took place on December 14, 1994[3]. The first task was to build a diversion canal on the south side of the river. Its purpose was to divert the river water around the dam-building area. When the canal was finished, on September 5, 1996, construction of the dam officially began with the building of a cofferdam. This cofferdam covers the entire dam site. It is basically a structure erected within the original riverbed so as to permit water to be pumped out, thus creating a dry area to allow the foundation of the dam to be built. During my trip in late 1996, I had the opportunity to cruise through the diversion canal, and then was given a guided tour of the momentous building project. On Nov. 8, 1997, with the completion of the cofferdam and other steps, the river diversion was officially completed.

On July 1, 2002, the concrete foundation of the entire dam was complete. The cofferdam was then dismantled. On Nov. 6, 2002, the dam was now tall enough to allow water storage level to rise. The diversion channel was now closed. On June 10, 2003: The storage level of the reservoir rose to 135m. On June 16, 2003, the double-lane five-step ship lock became operational. Hereafter, the major remaining work was the installation of the hydroelectric generators. On October 29, 2008, all of the turbine-generator units on the right bank of the TGD were completed and put into operation. Finally, as mentioned earlier, on May 2011, the final six generators also started operation.

To appreciate the massiveness of the project (*Ref. 1*), the total amount of material used in the construction of the dam was staggering: 27,200,000 cubic meters of concrete, 463,000 tons of steel (enough to build 63 Eiffel Towers). The amount of earth moved was 102,600,000 cubic meters.

TGD Benefits

By China's own reckoning, the completion of the TGD has reaped a multitude of benefits; these include:

- **Power Generation – Within the dam structure is housed most of the power generating equipment. This consists of 32 generators, each with a world-leading capacity of 700MW. Of these, 14 are installed in the north side of the dam, 12 in the south side, and 6 others in an underground area in the mountain south of the dam. Together they can generate a total of 22,400 MW, enough to power a mega-city such as New York.**
- **Savings in Greenhouse Gas Emission – It is estimated that (*Ref. 1*) the TGD reduces coal consumption by 31 million tons a year, not to mention the saving of 100 million tons of greenhouse gas emissions, one million tons of sulfur dioxide as well as millions of tons of dust.**
- **Flood Control – The Yangtze River is known for seasonal flooding. With uneven distribution of rainfall, this flooding sometimes takes place upstream of the Three Gorges, and other times downstream. More rare is "historical scale" flooding affecting nearly the whole length of the river.** The TGD now allows, yearly, an amount of water equaling to up to 15 times the upstream reservoir to pass through the dam. By properly regulating this flow through the dam, it can exert significant control over the lesser flooding. By proper timing of the opening and closing of the sluice gates, a fair amount of control of the "historical scale" flooding is also feasible.

- **Greatly Improved Navigation – By allowing 10,000 ton ships to go all the way to Chongqing, whereas only 3000 ton ships can do so before, the volume of goods and passengers traversing the Yangtze is now significantly increased. The Yangtze River region is now a solid contributor to the GDP growth of China. It is expected that, with the completion of the ship lift in 2014, river navigation will improve even more.**
- **Waste Management[4] – The Dam does not by itself improve pollution or waste management. However, in order to keep debris and polluted waters from reaching the Dam, China started a program (under the Ministry of Environmental Protection) to control the amount of waste from entering the waters of the Yangtze and its tributaries. Significant progress in waste management is said to have already occurred.**
- **Technological Innovations and Breakthroughs (** ***Ref. 3*** **) – The building of the TGD posed numerous challenges for China as it chose to shoulder most of the construction tasks. In steadfastly pursuing the tasks, China further showed that it had the ability to innovate and create breakthrough technology where necessary to complete the tasks. The important innovations and breakthroughs include:**

Devising a novel way to pour high quality concrete continuously and at an unprecedented rate;

Became the first nation to devise and build a dual-lane five lock system of unprecedented size in the high sloping terrain of the Xiling Xia;

With the help of a Canadian firm, developed complete information management and synthetic automation systems to control the operation of the entire TGD plus that of the Gezhouba Dam further downstream.

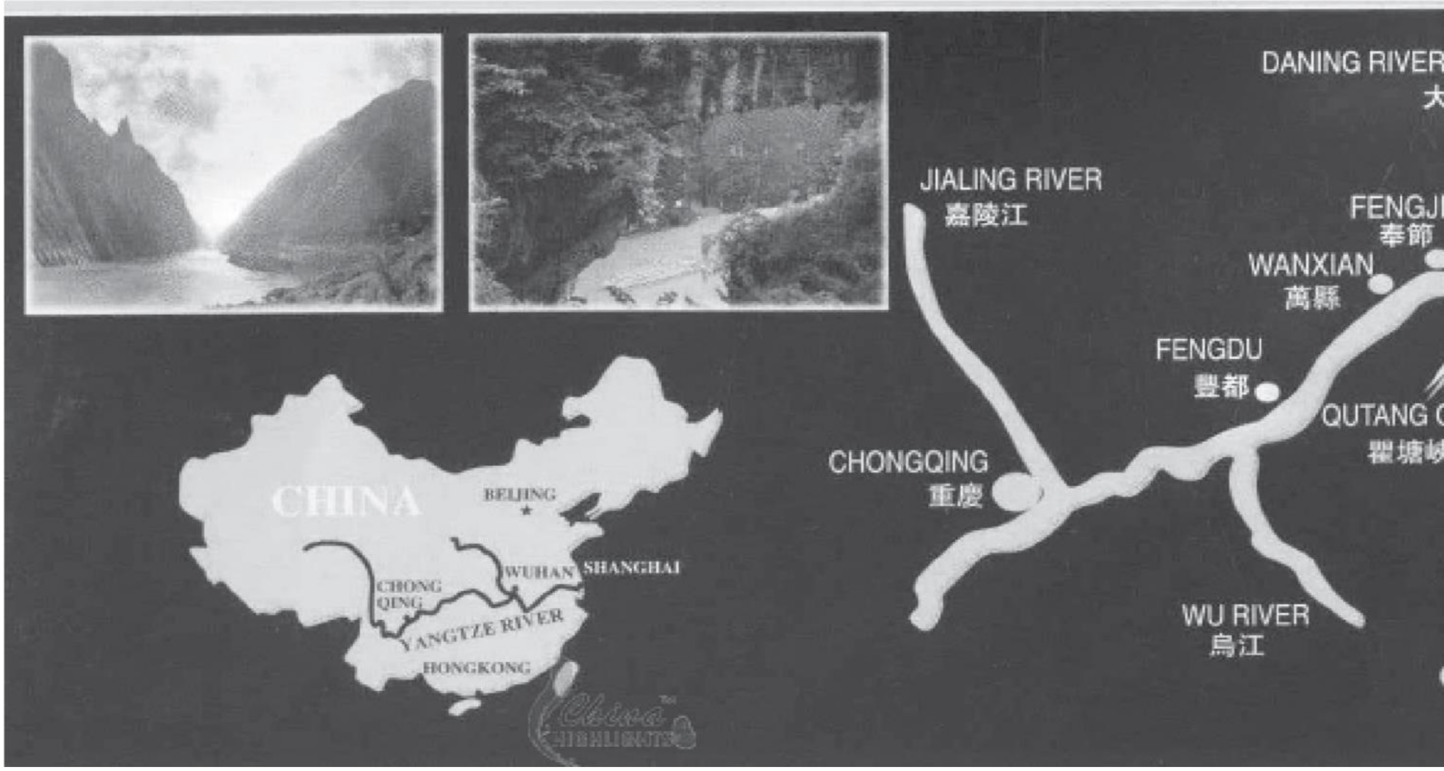
Last, but not least, for the 700MW generators, through a bidding process which required the foreign bidders to form partnership with Chinese firms and transfer key technical information to the Chinese partners[5], the Chinese firms Harbin Electric Machinery Co. and Donfang Electric Machinery Co. were able to produce the last eight of the 700MW generators (four each).

China is in the process of applying these innovations and breakthroughs in building additional hydroelectric dams on the Yangtze and elsewhere (see below).

Further Dam Building by China

China happens to be blessed by being the country with the greatest hydroelectric potential in the world. This is a fact that few Western nations seem to be aware. However, this fact becomes much more understandable if we note that five of the major rivers[6] of Asia all originate in the mountains in Tsinghai or Tibet – a region once referred to as the roof of the world and has an elevation far higher than anywhere else.

Since the hydroelectric potential is directly related to the elevation of the river bed and its rate of drop, the potential of these rivers, especially in their upstream portion (where they descend from the roof of the world) are vast.



Just take the Yangtze River, as an example. It turns out that the TGD, with its elevation drop of 175 meters, uses up only a small portion of the total hydro potential of the Yangtze. Starting from a point in Yunnan Province where the elevation is around 1000 meters (and where the volume of the water in the river becomes sufficiently large for power generating purposes), there are four more major dams now being built or are under the final phase of planning. These are:[7] the Wudongde Dam, with a drop of 950 meter, the Beihetan Dam (820 meters), the Xiluodu Dam (600 meters) and the Xiangjiaba Dam (380 meters). One dam in particular, the Xiangjiaba Dam, is worth mentioning. It has been under construction since 2006 and is slated for completion in 2015. Significantly, the specs call for the installation of eight 800MW generators, larger even than the 700MW ones in the TDG which currently are the world's largest!

Besides the dams being built on the Yangtze, China is also going ahead to build dams on the other four major rivers mentioned above, as well as installing additional dams on some of the tributaries of the Yangtze.

China's Own Qualms about the TGD

A project of such unprecedented magnitude usually comes with some cost. While the TGD was being planned and built, many Chinese expressed qualms on several aspects of the project. Most of the Chinese concerns, however, did not bear on whether this huge project can be carried out, or whether the Dam itself will go wrong in some way. Rather, they tend to be concerns on the people and sites that will be adversely impacted by the dam. Some of the major concerns were:

- **The Welfare of Inhabitants Along the River Who Need to be Moved – Because the rising water level of the reservoir up stream of the Dam will submerge some small cities and**

farmland along the Yangtze, up to 1.24 million inhabitants along the river needs to be moved. In most cases they could simply move to higher grounds where new cities were to be built or new farms started. But in some cases the affected people had to move to a different province, far from their original home.

All those moved were compensated monetarily (though this effort was marred to some extend by corruption of some of the officials involved). This need to migrate a large number of people created much ill will. However, by now all migrants seem to be reasonably well settled. In fact, some of the migrants found better life as they were moved to a rich and fertile area, as in the case of several hundred people who were moved to the fertile and rich Chongming Island near Shanghai.

- **Loss of Historical Sites and Relics – Along the Yangtze River in the Chongqing Municipality, there were a significant amount of historic sites and relics. Many of these can be traced to the Three Kingdom period (circa 230 AD) [familiar to almost every Chinese via the popular novel, Romance of the Three Kingdoms]. Many of them were moved to higher grounds. Still, some of these sites and relics cannot be saved and was much lamented.**
- **The Fear that Debris and Silt will Render the Dam Inoperable – Before the Dam was built, the water way of the Yangtze, due to industrialization along the shores, carried a significant amount of waste material and debris. The river also carried a fair amount of silt (though significantly less than that in the Yellow River). Many in China were concerned that the debris and silt will clog or damage the generating plant, disabling a main function of the dam. This proved to be unfounded. Through its comprehensive Waste Management Plan (see above), the debris and waste material dwindle to negligible proportions. Also, by adopting a silt flushing mechanism first used in the Xiolangdi Dam[8], (the**

largest on the Yellow River), the silt threat was basically removed.

- **The Fear that The Majestic Scenes of the Three Gorges will Lose Luster – There were much fear that the unparalleled scenery of the Three Gorges will be compromised by the raising water level. This turned out to be unfounded. While the water level was to rise a few hundred feet, it proved to be rather insignificant against the several thousand feet height of the imposing mountains and cliffs of the Three Gorges.**
- **The Fear that the Overall Cost will be too much to Bear for China – This of course was also unfounded, as China was able to complete the project on time and within budget, at the same time, it was able to keep up a growth rate in its GDP of close to 10% per year.**

Criticisms from the West

During the same period, there was also a steady drum-beat of criticisms from the Western press, of which the Washington Post, quoted above, is a representative case[9]. There seems to be a group of Western critics who is doubtful of China's ability to build the largest dam in the world by itself. They tend to question the fundamental soundness of the Dam, and the "urgent problems" which arose after the completion of the Dam. Their criticisms tend to be harsh and uncivilized, in a tone of voice reminiscent of the Voice of America during the days when PRC was considered an enemy.

Taken aback from the harshness of the criticism from the Washington Post, I decided to look into the original statement from China's State Council[10]. Immediately, I found that where the Post was quoting "serious flaws," the actual Chinese words should be translated to "adverse effects". Further, the Post mentioned "chronic deadly landslides, contaminated water and social dislocation," presumably as examples of the "serious flaws". However, these accusations were groundless. The statement from the State Council made no mention of them, and I do not know of any such happening being caused by the Dam.

In the other two articles mentioned in *ref. 9*, there were several more legitimate accusations. I will examine these in conjunction with specific points raised by the Chinese State Council (*ref.10*):

- **Small earthquakes – Earlier, some Western critics even claimed that the Dam was located on an earthquake fault line. This was fully refuted by China (*ref. 4*). Now, others, exemplified by Venetia Rainey (*ref. 9*), claim that "the colossal pressure caused by the weight of water (of the reservoir) has caused tremors to occur on a regular basis, forcing the relocation of around 50,000 people. In actuality, this was caused by shifting of the ground at some localities due to the added weight of the water. These occurrences have significantly decreased. By moving people away from these areas (the number of 50,000 was too high) the problem was essentially solved.**
- **Polluted water – Ms. Rainey also reported that, "both upstream and downstream, the flow of water is no longer fast enough to flush rubbish and toxic elements away". This was clearly false from my discussion of the comprehensive waste management plan above.**
- **Localized climate change – There were claims that the reservoir is making the local climate in some areas damper, and allows algae buildup. Of course one would expect some local change. But the changes mentioned by the critics did not appear to be serious. For example, algae buildup can be readily addressed.**
- **Landslides and silt deposits – Landslides occasionally occur in the**

Three Gorges area throughout history. After the dam construction began, some more did occur, partly due to the increase in weight of water of the reservoir. But they are not occurring in a more frequent rate than before. In *ref. 10* , the Chinese leader calls for active planning in the areas of early warning plus fast-reacting steps to address any future land erosion and damage to land and environment. As for silt deposits, as pointed out above, through the positive steps already taken, it was never a real issue.

- **Downstream droughts – This year, during the low water period for the Yangtze, the lower reaches of the river was hit by the worst drought in 60 years. All three articles in *ref. 9* laid the blame on the TGD. Of course the Dam cannot perform miracles, and fundamentally cannot do too much in this situation. But by letting out more water than it normally would, the TGD did help to alleviate the drought. By now the drought is over, and the Dam has resumed its functions.**
- **Welfare of those who were moved – The articles suggest that the 1.24 million inhabitants who were moved are still not being well accommodated. However, as mentioned above, most of these have settled in new locations, including some who were moved to land providing far better living condition than before. In the statement from China's State Council (*ref. 10*), an immediate goal was to "stimulate the development of the dam affected area, bring security and wealth to the migrants and significantly increase employment opportunities". Thus the Chinese government is definitely aiming to continue to improve the welfare of the migrants.**

When examined relative to the positive achievement of the TGD, and the on-going plan by China to comprehensively realize its hydroelectric potential, it seems that the accusations from the West are either unsound or hackneyed. There appears to be more than a slight case of TGD-envy. Whereas the West has not built a dam of any magnitude for decades, and moreover denied loans to China for the TGD, they are shocked to see this world's largest dam being finished on time and within budget. To save face, their only recourse is to criticize every aspect of it.

Report from a Recent Visitor

A good friend, Mr. Chi-sing Chang[11], just returned from a cruise down the Yangtze through the TGD in May, 2011. He was invited to tour the Three Gorges Hydropower Plant. The report from him was that the TGD was working perfectly. He was also pleasantly surprised that the water in the upstream reservoir was very clear, almost pristine. There were no traces of pollution, debris or silt. Indeed, the traffic in the Yangtze River was extremely busy, and along the shores of the Yangtze up to Chongqing, business was blooming. Is TGD a disaster? No way!

Indeed, the Chinese government could do well by inviting the editors of the Post and other carping critics from the West for a cruise down the Yangtze, including a grand tour of the Dam. Only then will they appreciate the groundlessness of their accusations.

###

Jay Hsu was born in Shanghai, China, and came to the United States in 1947. He received his PhD degree in electrical engineering from Cornell University in 1961. He then joined AT&T Bell Laboratories and worked there in various capacities until his retirement in 1996. Jay was the co-author of a book (with Dr. Andrew Meyer), Modern control Principles and Applications, *published by McGraw-Hill in 1968. The book was translated into Russian in 1972. In the last 15 years of his career he was active in management*

science. He and his wife, Irene, frequently travel to China.

References

[1] A comprehensive discussion of the TGD in English can be found under “Three Gorges Dam” in the Wikipedia.
[2] The TGD was by no means the first dam ever built by China. It already had the experience of building the Gezhouba Dam (with the help of the Soviet Union), at the end of the Xiling Xia, downstream from the TGD. Also, on the Yellow River, it had built the Sanmanxia Dam, and the Xiaolandi Dam (see below).
[3] The dates mentioned are documented in,“Persevere in Self-Innovation and Build Up the Three Gorges Project”’ a report (in Chinese and English) published by the Three Gorges Hydropower Plant (TGHP).
[4] From “The Three Gorges Dam from the Mainstream Point of View,” a Report from TGHP.
[5] From “Right-bank Power Station of Three Gorges Project,” a Report from TGHP.
[6] The five rivers are: The Yangtze, the Yellow River, the Lancang River (the upper part of the Mekong River), the Nu River the upper part of the Salween River, a major river in Myanma) and the Yarlung Zangbo River the upper part of the Brahmaputra River).
[7] A report from the “World Journal”, June 20, 2011.
[8] A pictorial report from the Chinese Website, Xinhua.net, on June 21, 2011, shows both the Xiaolandi Dam and the Sanmenxia Dam on the Yellow River carrying out the silt-flushing operation. Interestingly, many Western reporters had alleged that the Sanmenxia, which was built in the ‘50s, was made inoperative by silt. This evidently was not the case!
[9] I also saw critical articles from “The First Post” (by Venetia Rainey), May 20, 2011, and from “The Economist”, June 11, 2011, and a milder one by Edward Wang from “The New York Times” on June 7, 2011.
[10] A version of the original statement from China’s State Council, in Chinese, with the heading, “Chinese Official Acknowledged Adverse Effects of Three Gorges Dam” was printed in the Chinese newspaper, “The World Journal” on May 19, 2011.
[11] I also like to thank Mr. Chang for providing me with three reports from the TGHP (ref. 3-5).