Three Fragile Gorges

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China's Three Gorges Dam will finally be completed in 2008. The greater challenge lies in how China will establish a long-lasting, comprehensive geological disaster control system that can realistically protect 20 million people living in the fragile Three Gorges area.

By staff reporters Chang Hongxiao and Ouyang Hongliang

China's Three Gorges Dam, which captured the world's attention during nearly 14 years of seemingly endless construction, will finally be completed in 2008. After this summer's flood season, the Three Gorges reservoir is expected to reach its designated level of 175 meters.

The world has never before seen a hydraulic engineering project as long and tortuous as the Three Gorges Dam.

As the world's largest hydropower project, the enormous benefits of Three Gorges are theoretically obvious. The hydro plant has an installed capacity of up to 18.2 million kilowatts and a yearly energy production capacity of 84.7 billion [Kwh], the equivalent generating capacity of 50 million tons of coal. At the same time, the dam plays a significant role in flood control and shipping. Downstream in the Jingjiang region of Hubei Province, flooding is now expected to occur once every 100 years, down from once every 10 years, and fleets of 10,000 ton ships will be able to navigate the vast waters of the Yangtze River all the way to Chongqing.

The National People's Congress approved the project on April 3, 1992, and the project began on December 14, 1994. With completion of the project, a romantic poem by Mao Zedong that foretold "a calm lake from soaring gorges" is becoming a reality. After 640 square kilometers are flooded to the maximum height of 175 meters, the reservoir will cover more than 1,000 square kilometers. Its area will exceed China's fifth largest freshwater lake, Chaohu, which covers 753 square kilometers.

However, along with this impressive and somewhat magical transformation, negative impacts of the project have emerged. Besides the large-scale displacements of millions of people, the Three Gorges area is affected by what has always been a fragile environment, one prone to frequent geological mishaps. Whether the various risks brought by such a massive, manmade process can be controlled has been a consistent point of focus for many people.

The Chinese government has been well aware of these challenges during the research of Three Gorges project and the construction period, and is seeking solutions actively. During a Three Gorges Project Ecological Environment Construction and Protection Conference in September 2007, the newly appointed office director of the State Council Three Gorges Project Construction Committee, Wang Xiaofong, openly stated, "We cannot be complacent regarding the ecological (and) environmental safety issues triggered by the Three Gorges Project, and we must not pay the price of a lost ecology in exchange for a period of economic prosperity."

Wang revealed that Chinese Premier Wen Jiaobao, while researching the Three Gorges Project in 2007, also saw the environment as the most important issue.

The project's so-called eco-issues include geological disasters in the Three Gorges reservoir area, water pollution in main stream and tributaries of the Yangtze River, and protection of rare animal species. Among them the geological disaster poses the highest threat.

The Three Gorges Dam spans the river in Yicheng City's Sandouping in Hubei, 38 kilometers from the Gezhouba Water Conservancy Project. After filling to its normal level, the reservoir will influence the main stream of the Yangtze for 574 kilometers. Adding the Xiang Brook, Little River and Wu River, and 50-odd other primary Yangtze tributaries, the banks of the reservoir will stretch for a total 5,300 kilometers.

The vast land of China has plateaus, plains and basins, forming a three-step ladder that higher in the West and lower in the East. The reservoir is on the eastern edge of China's second ladder. It is wedged between precipitous, geologically active mountains. Historically, this is an area of frequent and major geological disasters, such as rock slides. It's often been called a "geological museum." Earth scientists point out that, aside from powerful earthquakes and volcanic eruptions, nearly all the world's geological calamities occur in this area.

To limit the impact of these disasters to the reservoir area and ensure the safety of inhabitants on either shore, the Chinese government has invested more than 10 billion yuan to gradually strengthen measures aimed at preventing geological mishaps. Nevertheless, experts think the real test for the area's geological disaster prevention efforts will come when the water reaches 175 meters.

At 175 meters, the water surface will be 100 meters higher than the pre-dam river level. Moreover, the reservoir each year will have to endure a "water release and restoration" cycle that lowers the surface to 145 meters and raises it again to 175 meters. This significant fluctuation may trigger landslides in areas where they occurred in the past, or spread calamity to new areas.

According to 2001 statistics from the Ministry of Land and Resources (MLR), the reservoir will submerge 1,600 landslide, or nearly two-thirds of the total in the area's 20 counties, cities and districts. And nearly 40,000 people's lives would be affected in Chongqing Municipality's Wushan County alone.

The potential geological disaster has caught attention from the top. The 17th National Congress of the Communist Party in October 2007 inscribed "Scientific Outlook on Development" as a strategic thought to develop socialism with Chinese characteristics. The concept of "Scientific Outlook on Development" has many layers—development as its essence, putting people first as its core, comprehensive, balanced and sustainable development as its basic requirement, and overall consideration as its fundamental approach.

From this perspective, when we highlight the massive economic advantage of the project, alarm should also be raised over the ecological problems, so the future generations can fully enjoy the fruit of the dam.

Thus, weeks after the 17th National Party's Congress, Caijing reporters spent three months in Chongqing's Fengjie County, as well as in Hubei's Badong and Zigui counties, to get a deeper understanding of geologic disaster control efforts and related challenges in the Three Gorges area.

Caijing found that despite exhaustive work by the central government and MLR, as well as local governments and land agencies, severe tests are still ahead as the water rises and we are getting close to the 175 meter high water mark.

So far, a geological disaster management system has not been fully completed. A number of key projects are under way, but preliminary results are not entirely satisfactory. Of course, the greater challenge lies in how China will establish a long-lasting, comprehensive geological disaster control system that can realistically protect 20 million people living in the fragile Three Gorges area.

The challenges provide a reality check for China.

——Editors

In early winter, the Yangtze is locked in a shroud of fog.

In the village of Huanglashi on the north bank of the Yangtze in Hubei, 50-year-old Wang Liancai sits in her doorway and chatters with neighbors. A basket of ripe tangerines sits on her doorstep, slightly more than 200 meters from the edge of the world's third largest river.

Wang was born and raised in this riverside village. But she doesn't know how much longer this tranquil life will continue. In 2003, cracks began to appear in the walls of Wang's home. The roof began to leak. June of that year marked the beginning of the second phase of the Three Gorges project, which would raise the local water level to 135 meters from 90 meters.

In 2007, after the summer rains had come and gone, more cracks began to appear. "The town government told me my house was in a landslide zone and that I would have to move out. But I haven't moved," Wang told Caijing.

West of her home, the East Rangkou town government erected a notice board on May 30, 2006. It says that, according to special monitoring by the Hubei Provincial Geological Environment Monitoring agency, landslides in Huanglashi had intensified. The notice says that entering or stopping in the area, or the

planting of crops, have been prohibited. It also says vessels are not allowed to navigate within 150 meters of the shore.

A road opened near Huanglashi in 1996. Caijing reporters noticed that a retaining wall between the road and mountainside had begun to warp. Homes in higher landslip areas also began to show signs of slipping. Roofs were off-kilter and walls were cracked.

The reservoir's level rose to 156 meters in September 2006, one year ahead of schedule. Water was released during flood season 2007 but is now rising again. It's supposed to reach 175 meters in 2009, but could rise to that level this year.

When the water level finally reaches 175 meters, the project's can realize its flood-control function as well as massive electricity generation capacity even during the dry season.

However, the dangers in Huanglashi are just the tip of the iceberg. Direct and indirect threats from the project have prompted the Chinese government to adopt a number of measures in recent years to deal with a variety of potential disasters. Thus far, these efforts have achieved some level of success by preventing major calamities. However, a number of variables will decide whether the efforts survive the test of time and the maximum water height.

Geological Threat

Historically, the entire reservoir area has been disaster-prone. Now these extremely weak geological formations are a test for the Three Gorges project.

Three Gorges is 200 kilometers long and combines Qutang Gorge, Wu Gorge and Xiling Gorge. The reservoir area covers 56,700 square kilometers, stretching across 20 county and city districts. Sixteen counties and cities, including Wanzhou District, Fengjie County, Wushan County and Yunyang County, fall under the jurisdiction of Chongqing, while four -- Xingshan County, Zigui County, Badong County and Yiling District's Yichang City – are part of Hubei.

Separated by Fengjie, the east and west sections of Three Gorges have completely different geographic features.

West of Fengjie is the eastern edge of the Sichuan basin, an area of rolling hills and wide valleys. Made of Jurassic Period shallow rock, the river valley is wide and mild. To the east is a mountainous region converging Sichuan and Hubei Provinces. Consisting of mainly Triassic Period to Sinian Period carbonate rock, the area is geologically striking. Situated among towering mountain peaks, the valley is narrow and the river current fast. It is the embodiment of "The Three Gorges of the Yangtze River."

Today, lying in a transition zone between China's second and third topographic ladders, the Three Gorges area is still undergoing tectonic change. The western side is rising and the eastern side settling. These changes have created natural beauty on the surface, but enormous geologic threats underground. Adding to the danger are climate conditions that bring heavy rains and seasonal floods.

According to the textbook Water Affairs Volume of China Science and Technology History, rockslides incidents in Three Gorges were first recorded during the Eastern Han Dynasty in 100 A.D. The town of Xintan, 15 kilometers downstream from Zigui County in Hubei, has historically been the hardest hit.

In 1026, a rockslide occurred at Zanhuang Mountain near Xintan, forming the now-famous Xintan rapids. The collapse blocked the Yangtze and capsized countless boats. For the next 20 years, the government forbid boats from traveling the area during the dry season. In 1542, another landslide occurred at Xintan, blocking boat traffic for eight years. The following 80 years saw numerous rock and landslides.

After 1625, Xintan experienced 300 years of peace and calm. But another era of geological activity began in 1920.

The latest big landslide occurred on June 12, 1985, when the upper region of Xintan, from Guangjiaya to Jiangjiapo, experienced a landslide with an estimated 13 million cubic meters of earth and rock, destroying the entire town of Xintan. Two million cubic meters of debris slid into the Yangtze, forming giant waves as high as 36 meters and reversing the river flow for more than 3 kilometers. Between Xiangxi and Xintan, 10 boatmen died and nearly 70 boats destroyed. A 90-meter-long slope section sank into the river, blocking

about one-third of the Yangtze's surface and worsening the already dangerous rapids of the Xintan section of the river.

Caijing reporters visited the area in December 2007, more than two decades after the tragedy. With the exception of a sign marking the Xintan Landslide, there was hardly a trace of the event. However, a crack halfway up a mountain that stretches several kilometers makes it easy to imagine the fateful scene.

Cui Xudong, Xintan village's deputy director and geological disaster inspector, told Caijing that residents and the local government had moved to other areas. Even though the Xintan landslide zone is still relatively stable and has seen little change since 1985, new construction is still prohibited. Current efforts to build terraces in the slope are aimed at stabilizing the geography.

While dining at a small eatery in Zigui, Caijing reporters learned that the restaurant's owner had personally experienced the Xintan landslide. Details were fresh in her mind. She recalled that the landslide started in the dead of night and lasted several hours. The sounds of sliding rocks and debris filled her ears. The next morning, villagers were horrified to find their ancestral home had collapsed into the Yangtze.

Yet geological events have always been a part of life in the Three Gorges area. Statistics published in the Geological Disaster Control Plan in the Three Gorges Reservoir Area in 2001 said rockslides, collapsing earth and mudslides have occurred more than 70 times in the area since 1982. Forty of the largest incidents killed about 400 people and resulted in severe economic losses.

Exacerbating the Problem

Perhaps aware of the vulnerability of the geological environment in the last half century, thousands of experts from the State Science and Technology Commission, Yangtze River Water Conservancy Committee, Ministry of Geology, Chinese Academy of Science, Ministry of Water Resources, State Seismological Bureau, former Soviet Union, United States, Sweden, Canada, Italy, France, Austria and Japan, as well as organizations such as the World Bank, have been involved in seismic and geological surveys and researches of the Three Gorges.

According to the Yangtze River Water Conservancy Committee, the geological surveys have been unique in depth and breadth.

After the Three Gorges Project received official approval from the National People's Congress, the Water Conservancy Committee sent a team of more than 2,000 to conduct a large-scale survey of the geological conditions. The survey, completed in 1999, found that 1,302 collapses and landslides had located below the 175 meter elevation level alone. The data was included in the committee's Planning Report for the Yangtze River Three Gorges Project Reservoir Area Flooding Process and the Safe Resettlement from Landslide Zones.

The report showed 1,302 collapses and landslides under 175 meters alone.

From 2000 to '01, an MLR survey of 20 counties in the reservoir area found 5,384 potential geological disasters, mainly collapses, landslides and mudslides. About half located on each side of the Yangtze.

MLR said 2,548 geological unstable sites were reported in local newspapers by October, 2001, in reservoir area counties. These includes 2,490 collapses or landslides involving 4.5 billion cubic meters of earth, as well as 47 mudslides, six sink holes and five fissures.

These landslides and collapses masses can be divided into those 1,627 below the 175 meter line, moving 3.9 billion cubic meters of earth, and 863 at higher elevations, mainly in resettlement areas, involving 599 million cubic meters.

Exacerbating problems in the disaster-prone Three Gorges are rainfall and human activities.

The Yangtze was dammed in 1997 during the project's first phase. Floods during the second phase increased the reservoir level to 135 meters in June 2003. And the third phase ended in September, 2006, when water levels reached 156 meters. The fourth phase is scheduled for completion in September, 2009, when the reservoir surface reaches 175 meters. But the day might come earlier given the smooth construction progress.

After the reservoir has filled, wet and dry periods will create seasonal fluctuations of tens of meters. A rapid rise or fall in water levels could cause old landslides to recur or trigger new ones. Landslide risks rise as water seeps into the mountain slopes, often weakening the rock, lifting slope bottom and increasing payload.

This effect was apparent after the second phase of flooding was completed in June 2003.

Xu Kaixiang, chief engineer of the Three Gorges Reservoir Area Disaster Control Headquarters, told Caijing that Hubei and Chongqing newspapers recorded 4,688 landslides or collapses in the reservoir area between January and November 2003, compared to 2,490 recorded in 2001.

According to an official report on preventing geological disasters in the Three Gorges area obtained by Caijing, 98 landslide zones had experienced relatively severe deformations since the second-phase, 135 meter water level was reached in June 2003. Among these, monitors discovered severe deformations in 34 landslide zones after the waterline reached 135 meters. Another 33 were found in 2004 and 23 in 2005. Only two new occurring deformations were reported in 2006, but the number increased to 6 in 2007.

Beyond the direct impact of water storage, activities tied to population relocation efforts have also become a major instigator of geological calamity. Man's activities have always affected the Yangtze valley. But the project's submerging of low-lying farmland reduced the amount of land available for human living, and many of the area's original residents moved away. Yet the land still available for farming and people in the rugged Three Gorges area has come under serious pressure.

In an article, Ouyang Zuxi of the China Seismological Bureau's Crustal Dynamics Institute mentioned monitoring in Fengjie showed that deformations occurring from 1999 to 2002 can be partially traced to strong rains. But the major cause, he said, was human engineering activity.

Professor Ioannis Fourniadis of London's Imperial College wrote in 2007, in the journal Topography, that the relocation of reservoir-area residents from low-lying areas to higher ground could lead to new landslides in old disaster zones. He warned of an increase in landslide frequency and intensity.

The Qianjiangping Tragedy

Six weeks separated a landslide in Qianjingping, in Hubei's Zigui county, and the completion of the second phase of water storage. The July 13, 2003, tragedy caught the attention of geologists at home and abroad.

Today the landslide's aftermath can be seen 1 kilometer west of Zigui's Shayi village, and 300 meters past an arched bridge over the Qinggan River, a Yangtze tributary. Yet an inscription on a plaque by the bridge commemorates the waterline's rise to 135 meters – not the disaster.

Before dawn on that fateful day, 20 million cubic meters of mud and rock slid down the mountain at Qianjiangping, killing 24.

More than 500 villagers and 1,000 silicon and brick factory workers lived in the zone. One resident was Xie Kexing, now 72, who told Caijing that after the second phase of water storage, the Qinggan River swelled to twice its previous width. Soon afterward, villagers began to see cracks form in the mountain and in their houses.

A Shaxi town staff member confirmed that the fissures only began to form after the second phase of water storage. After receiving a report from the village government, Hubei officials organized a group of experts to conduct an on-site inspection, which concluded that a landslide was not imminent. No relocation was ordered.

Fortunately, peasants and local government officials, aware that the area was historically disaster-prone, were relatively vigilant. A few short hours before the disaster, the peasants organized their own evacuation, avoiding a much greater misfortune.

Ground conditions grew increasingly dangerous on the black night before the landslide. A terrified Zhou Zugui, who lived on the south side of Qianjiangping, fled north with his wife, leaving behind a box he had packed and several thousand yuan. As he crossed the arched bridge, Zhou recalled hearing the muffled thunder of falling rock and the screams of other villagers fleeing for their lives.

Within minutes, half the mountain collapsed into the Qinggan River, damming the hundreds-meter-wide river

and crashing onto the opposite bank. It created a wave up to 50 meters high that capsized all boats in the immediate area, as well as fishing boats 2 kilometers away at the river's mouth.

The speed and scale of the rockslide far exceeded anything anyone had expected. Village workers told Caijing that, at the time of the landslide, four villagers in a Jeep forced their way into a restricted area to retrieve their belongings, but the mountainous wave swept the car away.

Wang Enrui, an engineer at the Zigui geological monitoring station, told Caijing that the landslide resulted in direct economic losses of 80 million yuan and forced the relocation of more than 1,300 people. The fact that the landslide occurred little more than a month after the second phase of flooding caught the attention of central leaders. Vice Premier Zeng Peiyan made a personal visit to inspect the site.

The central government's initial assessment, four days after the tragedy, said heavy rainfall was the main contributor to the landslide. According to an official Xinhua news agency report at the time, MLR geologists believed that, "The landslide at Qianjiangping was a result of unstable geological conditions at the site, induced by 10 days of sustained heavy rain.

However, nearly two years later in March 2005, Professor Wang Zhihua and Dr. Yang Rihong of the MLR's China Center for Aerial Prospecting and Remote Sensing published a paper in China Geological Disaster and Control Journal which concluded, based on on-site research and a comprehensive analysis of real data, that the rising water level in the second phase of water storage was the main factor behind the Qianjiangping landslide. Heavy rain was a secondary factor, they wrote.

Wang Zhihua is a well-known scholar in China in the field of remote geological disaster sensing. In 1980, during the Ertan Hydropower Development preliminary feasibility study, Wang used satellite and aerial remote sensing technology to conduct a large-scale regional landslide investigation. It was a first for China. Afterward, project teams led by Wang completed remote regional geological environment sensing surveys for six, giant hydroelectric dams and reservoir areas on the Tongjiezi section of the Dadu River, the No. 2 beach on the Yaqing River, the Three Gorges area of the Yangtze, Xiluo Ferry on the Jinsha River, Baihe Beach, and Wudongde on the Jinsha River. They also looked at the upper Yangtze in Qinghai and Gansu provinces, the route connecting Tibet Autonomous Region and Yunnan Province, and other large-scale survey and monitoring projects.

Prescription for Control

Government efforts over the last half-century have achieved significant results. For example, any possibility that the project will spark a major, destructive earthquake in the area has basically been eliminated. The government also has rudimentary answers to questions about whether geologic mishaps will affect the dam's operational safety.

Chen Deji, former director for the Yangtze River Water Conservancy Committee's Comprehensive Survey Department, in 1999 wrote in the international journal Engineering Geology that the reservoir area's largest landslide-prone area, Baotaping, would be unlikely to block the Yangtze even if one-third of the area slipped into the river. At the 135-meter level, Chen said, the rocks and mud would span only one-third of the river. When the waterline reaches 175 meters, a landslide would block only 17 percent. Similarly, since major landslide zones are far from the dam itself, and the combined volume of potential landslide debris is only 2 percent of the reservoir's designed storage capacity, the danger to the dam was limited.

Even so, unknowns abound. Factoring into the process are complex geological conditions, damage caused by thousand of years of human activity, and the fact that most preliminary research strictly focused on the area surrounding the dam itself. Other questions revolve around how a geological disaster in the reservoir area would affect residents and the local environment. Avoiding another Qianjiangping disaster is a significant challenge.

In fact, the complicated geology created uncertainty over the relocations of whole communities. Thus, the process of selecting locations for New Fengjie, New Badong and other relocated cities has been subject to change. In particular, finding a site for New Badong has been the subject of a great deal of disagreement in academic circles.

Currently, there are no perfect answers to questions over whether or when new calamities may erupt, or how to control water levels and slope stability in the face of heavy rains and other extreme conditions. This reality guarantees plenty of work for geological disaster control experts in the Three Gorges area, as well as

plenty of challenges and debates.

In April 1989, before the start of the project, then-premier Li Peng decided to launch a study of two of the largest landslide zones near the dam -- Huanglashi and Lianziya. The former is located 64 kilometers from the dam, the latter 25 kilometers distant. However, of the 40 billion yuan allocated for relocating residents, only 600 million yuan was set aside for geological disaster management.

Sun Guangzhong, a member of the study team and research fellow at the Chinese Academy of Science, told Caijing that the “feasibility was conducted out of the reach of reality. The expert group had a basic estimate as to the seriousness of the geological disasters, but because of the limited nature of China’s financial resources at the time, there was no estimate of the funds needed for disaster control and management, or the total investment.”

As the Three Gorges construction project progressed, the serious potential for disaster gradually became clear. On July 17, 2001, then-premier Zhu Rongji decided that MLR would lead the creation of a Three Gorges reservoir geological disaster management leader group, which would be responsible for disaster management in the area. The whole project was kicked off with directions for “quick surveying, quick planning, quick formation, quick approval, quick implementation.”

Three months later, MLR prepared and announced the Three Gorges Reservoir Geological Disaster Management Plan. The plan called for the “effective management” of previously identified landslide, sinkhole and fissure zones before 2009, and established a geological disaster monitoring and early warning system.

According to Zhu Rongji’s instructions, to ensure the second phase of water storage in June, 2003, the Ministry of Finance took another 4 billion yuan from the Three Gorges fund and earmarked it for “second-phase geological disaster control” with a two-year time limit. The focal point was disaster control in cities, towns and villages with highly concentrated populations, as well as important transportation routes, bridges and ports that would be affected by the 135 meter waterline. The first 600 million yuan in control funds were to be dispersed through original channels for expediting disaster control methods.

After completion of the project’s second phase, and to prepare for third-phase water storage, MLR presented another Three Gorges Reservoir Area Phase-Three Geological Disaster Control Plan in December 2003. Newspapers in Chongqing and Hubei reported disaster control funding would be as high as 15.7 billion yuan. After the examination and approval of the MLR and the National Development and Reform Commission, the central government decided to allocate 7.3 billion yuan for the program.

Undoubtedly, government spending for disaster control – currently at 12 billion yuan – will continue to inch higher as the water level approaches 175 meters.

Warning at Monkey Rock

After the reservoir fills, new management will be needed for the Monkey Rock landslide zone -- a clear testimony to the difficult struggle with the area’s geology.

Monkey Rock is among the most famous landslide zones on the Yangtze. Located in the central section of Chongqing’s Fengjie New Town, it is the largest single recipient of funds for landslide management in the Three Gorges reservoir. The investment is already near 180 million yuan.

Monkey Rock landslide zone covers 120,000 square meters and contains 4.5 million cubic meters of earth and rock. Looking up at Monkey Rock from the Yangtze surface, one can only see that the whole slope spreads out in a fan-shaped expanse, huge and precipitous. Right on top is Fengjie’s Yangtze port. Only after climbing several hundred stairs from the port does one arrive, huffing and puffing, at a riverside road.

Above the riverside road is Fengjie New Town’s central district. A dramatic series of new buildings, including various government offices, rise above the riverside. Cheng Siqian, chief engineer of the county’s geological disaster control center, told Caijing that buildings contain 200,000 square meters space have been built on Monkey Rock landslide zone. They include homes for more than 5,000 people. The migrant population is as high as 30,000. If the area were one day to slip into the Yangtze, Si said, “the consequences would be unthinkable.”

Because so much property and the lives of tens of thousands of people are involved, the central government has poured money into preventative measures to avert the unthinkable at Monkey Rock.

The landslide zone was the target of a round of landslide management in June 2003, before second-phase water storage. The main measures included adding slope protection, riprap and pressure pins to the front edge of the hillside. After depositing 730,000 cubic meters of 20- to 200-kilo stones at the base of Monkey Rock, the first stage of reinforcement under 150 meters was complete -- enough to ensure stability after the reservoir reaches the 135 meter waterline.

However, because the landslide zone's back side is higher, water will gradually flood the high area. The stability coefficient will fall as the water line reaches 156 meters and, eventually, 175 meters.

The stability coefficient is the ratio of a landslide zone's slide resistance and slip tendency. If the coefficient is greater than one, the landslide zone is relatively stable. If it is less than one, earth and rock will slide. If the coefficient is equal to one, experts say the landslide zone is in a state of "maximum equilibrium."

At the moment, this limestone rubble landslide zone is relatively stable. Professional calculations indicate that when the reservoir waterline reaches 175 meters, Monkey Rock's stability coefficient will be 1.2. But during seasonal fluctuations, from 175 to 145 meters, or from 156 to 135 meters, the coefficient will drop to between 0.94 and 0.99. In other words, this almost certainly means Monkey Rock will slip; rapid increases or declines in water levels often trigger landslides.

This means that the landslide area need new treatment through an extensive construction project included in the reservoir's Phase Three Geological Disaster Control Plan. Thus, in May 2006, the 159 million yuan project got under way.

The main control method involves planting rows of "slide-obstructing bolts" at the 156, 166, and 175 meter waterlines that will link the landslide body and the underneath rock to prevent landslides. At the same time, surface and underground drainage systems will be built to reduce erosion in the landslide zone. A support wall of riprap and reinforced concrete will be put into place to ensure the area's stability.

When visiting the construction site, Caijing reporters could see three main construction tunnels on the river-facing side of the Monkey Rock zone at the 156, 166, and 176 meter marks. The work tunnels were slightly higher than a man, stretching 400 meters east to west. In each tunnel, workers dug 38 perpendicular horizontal tunnels running north to south, and dug 10- to 20-meter-high vertical shafts under the horizontal tunnels. They then filled the shafts with reinforced concrete to form the 38 rows of "slip-prevention bolts."

Currently, slip prevention bolts have been completed at the 156 and 166 meter water levels, and the tunnels sealed off. The end of bolt at the 156 meter level corresponds to the starting bolt of the 166meter bolts, and the 176 meter bolts correspond with the 166 meter bolts. This forms an interwoven system that nails the landslide zone to the slip surface. The 176 meter bolts, which are currently under construction, are expected to be completed in September.

In fact, the Monkey Rock reinforcement has become a key project for the reservoir's project to prepare for 175 meter flooding. Industry insiders told Caijing that the Yangtze River Three Gorges Project Corp. had hoped to bring the water level to 166 meters after the 2007 floods, but had to abandon the plan because the Monkey Rock project had not been completed.

Complications at Shijiapo

The Monkey Rock experience has provided a clear example of the difficulties involved in landslide control, but the troubles in the Shijiapo zone have been even more worrisome.

Located in the village of West Rangkou, Guandukou town, and across river from Badong New Town, Shijiapo is part of the much larger Yingpanbao landslide zone, positioned at the mouth of the Shennongxi River, a Yangtze tributary, which is 1 kilometer wide and 650 meters long. The zone area of 465,000 square meters contains 9,787,000 cubic meters of earth and rock.

Deng Mingzao, who oversees geological affairs for the Badong County Administration of National Land and Resources, told Caijing that in early May 2007, the water level of the Yangtze began to drop. As the water level in the main channel fell to 145 meters, a serious slide occurred in the Shijiapo zone. The zone originally had been designated as a resettlement area. A prevention project was launched a year ago. But before its completion, the landslide started already.

The control project, labeled as a most urgent Grade I project, has already cost more than 40 million yuan. After the landslide severely distorted the land, the Badong government had to spend another 7.1 million yuan to relocate 349 people in the landslide zone.

According to the Badong government, the zone would be shored up with “anti-slip stakes, anchor slope protection, a graded retaining wall, water drainage system, and monitoring facilities. Before the landslide altered the land, 105 of Shijiapo’s 127 anti-slip stakes had been put in place and the front-slope protection, retaining wall, and water drainage system had been completed.”

Recalling the landslide a half-year later, nearby farmers expressed lingering fears. Farmer Shi Jin An told Caijing that when the landslide occurred, a four-story residential building close to the Yangtze began to tilt as much as 48 degrees. The entire building collapsed and sank into the Yangtze river, leaving only the roof exposed.

In early December, Caijing reporters inspected a row of anti-slip stakes on the banks of the Yangtze. They were slanting and seriously deformed. On the road behind the landslide zone, peasants were clearing a recently demolished home, putting bricks, stones and lumber on a tractor.

After the landslide, a Badong government report to Hubei’s Three Gorges Geological Disaster Control Headquarters Office said the main reason for the landslide had been the hydrodynamic pressure tows created by the fall in the reservoir’s water level, which caused partial instability. Heavy rains May 11 also contributed to the landslide. Rainfall seeped into the landslide zone and was not discharged timely. Accumulated water severely undermined the stability of the slope, the report said.

The report also said the estimated design and treatment expenses, which were reported to higher level authorities, totaled 86.8 million yuan. However, the preliminary appraisal passed by NDRC and Chinese International Engineering Consulting Co. (CIECC) cut investment to 69.8million yuan.

Last November, the appraisal by CIECC’s core team of experts indicated the investment was still too high, and called for the treatment plan to be optimized for a 50 million yuan investment, including reducing the number of anti-slip stakes from 156 to 134, and canceling slope protection for Yingpanbao. Finally, the budget was reduced to 48.94 million yuan.

On November 9, 2005, NDRC officially approved the CIECC evaluation. NDRC’s final landslide control plan kept the number of anti-slip stakes at 156, but further cut the program’s total investment to 46.4 million yuan.

Caijing has learned that the Hubei provincial government submitted four reports asking for a review of the project investment, but CIECC insisted the Badong disaster control department’s estimate was too high.

Unforeseeable Costs

While Caijing reporters conducted interviews in the Shijiapo zone, many people expressed a belief that geological condition here is too complicated to handle easily.

There are two types of countermeasures against geological disasters: non-engineering measures, which include early warning systems and population relocation; and engineering projects such as the Monkey Rock slope support.

The effects of engineering projects are more obvious but also more expensive. That’s why engineering is usually used to prevent landslides when rising water levels affect local residents’ safety and property. If engineering costs are too high, the next option is relocation. For potentially unstable landslide zones, monitoring and early warning systems are the cheapest and most viable options.

Currently, engineering is the main method for dealing with major disaster areas in the Three Gorges area. For the Phase Two Geological Disaster Control, landslide engineering projects swallowed 1.9 billion yuan of the estimated total cost of 3.9 billion yuan. Reinforcing reservoir shores cost 800 million yuan, while high slope and foundation treatment contributed 700 million yuan, and resident relocation cost 216 million yuan.

Additionally, investigations and assessment cost about 205 million yuan. Monitoring, early-warning, planning, and scientific research altogether received only 87 million yuan.

Control is costly. But how much money should be invested to guarantee disaster control while saving as

much money as possible? When addressing this issue, the intrinsically complicated geologic nature of the reservoir area makes implementing any investment mechanism difficult, and puts obstacles in the way of disaster control for Three Gorges. Indeed, the investment mechanism for disaster prevention has been evolving for a long time.

The earliest effort in landslide treatment at Lianzi Cliff and Huangxi Slope were made before the Three Gorges plan took shape, and were implemented by the Ministry of Geology and Mineral Resources. Funding mainly came from two sources: A total 60 million yuan was allocated by the Ministry of Finance, and 30 million yuan was provided by the former State Development Planning Commission.

After Three Gorges Dam launched, investment for geological disaster control was not classified as a single project investment, but rather placed into a basket of funds for relocating people from the area. Of the 40 billion yuan set aside for relocation development, 600 million yuan was allocated as special control funding. The spending plan was approved by the State Council Three Gorges Project Construction Committee's Department of Relocation. The Surveying and Planning Organ of the Yangtze River Water Conservancy Committee was charged with surveying and planning in geological disaster zones. The entirety of the Three Gorges geological disaster control work was basically decoupled from what was the geological administrative management department at that time.

After July 2001, as the disaster prevention picture became increasingly grim, then-premier Zhu Rongji put responsibility for geological disaster prevention in the hands of the MLR. The specific administrative management system also was transformed so that MLR would draft plans, the planning commission would enact plans, and both Chongqing and Hubei officials would organize implementation.

Later, the State Council Three Gorges Geological Disaster Control Leading Group was formed and its offices established at the MLR's Geological Environment Division. To unify leadership for disaster control, Hubei and Chongqing respectively set up Three Gorges Geological Disaster Control Offices. Each of the 20 counties in the reservoir area also established disaster control centers and monitoring stations in accord with specific guidelines.

NDRC was responsible for project approval and disbursing the first phase investment of 4 billion yuan from the Three Gorges Construction Fund. Since then, the specific workflow reports for phase two and three geological disaster projects have been submitted for approval by each county and city along the river. These plans are collected by officials in Chongqing and Hubei, and sent to the Three Gorges Geological Disaster Control Headquarters. Headquarters forms an initial control plan and sends the report to the Geological Disaster Control Leadership Group Office of MLR. After consultations between MLNR and NDRC, a control plan and investment scope is decided for each of the 20 counties, and funding is divided and allotted to financial authorities in Chongqing and Hubei.

In Hubei, for example, 56 landslide zone projects and 22 stages of river bank protection were included in phase two disaster control. Badong New City alone had 34 deep foundations and high slopes, and farmers were relocated to 55 sites. The central Ministry of Finance allocated 1.1 billion yuan in parts to the Hubei government, and specific projects were organized and implemented by the Hubei Geological Disaster Prevention Office.

Even so, it is difficult for this set of management and investment mechanisms to adjust to a variable and complicated reality.

Although prevention in each area of the reservoir is nominally planned by the MLR, the actual problem of dividing duties among departments has not been thoroughly resolved. For example, as part of phase two geological disaster prevention, 700 million yuan of the 4 billion yuan in total investment was held by the Three Gorges Construction Committee's Relocation Planning Division and earmarked for high shear slope and deep foundation treatment. During the phase three geological disaster prevention project, 2.3 billion yuan of the total investment of 7.3 billion yuan was obtained by the same division and earmarked for high shear slope treatment.

During interviews with Caijing, experts generally said that because geological events are hard to predict, it is extremely difficult to accurately estimate the investment needs for disaster control in the entire reservoir area.

Geological calamity control involves a much higher degree of unpredictability than common engineering projects. When excavation begins, for example, engineers often find that a landslide zone is deeper or much

larger than predicted, forcing them to modify the project plan. But because investment planning is fixed in advance by the central government, there is often little flexibility, jeopardizing the success of control efforts.

A Complicated Chess Game

In some instances, counties and cities exaggerated the seriousness of geological mishaps in their areas to get more funds from the central government. This complicated the project. Many Three Gorges communities are relatively poor, backward agriculture and mountain regions with weak transportation systems and scant financial resources. As a result, Caijing learned through interviews, some local officials hype the scale of their geological disaster control projects.

According to an engineer close to the Three Gorges Geological Disaster Control Headquarters, 1,252 projects were reported during the process of organizing the Third Phase Control Plan. Funding requests totaled as much as 15.7 billion yuan.

Since that figure far surpassed authorities' estimates, the Three Gorges disaster control office quickly dispatched 17 expert groups to study the actual situation and ensure efficient use of funds. These groups hurried to the reservoir area to perform on-site investigations of projects in each area. After combining results of these investigations, the total funding allotted for the Third Phase Prevention Plan was reduced by more than half to 7.5 billion yuan.

Perhaps because of inflated funding requests, comprehensive administrative funding was no longer dispersed to each county and city during the rest of the third phase. Instead, local officials were told to report their needs before an inspection committee approved or rejected projects on a case-by-case basis. Thus, a feasibility report and CIECC comments were needed before a project could be approved. Undoubtedly, for each county and region in the reservoir area, this raised the threshold for engineering projects and made acquiring funds much more difficult.

But this chess game is just like a double-edged sword. Inefficiency and policy errors can creep into such a multi-level approval process. It seems the most common reactions among local officials in the Three Gorges region have been that central authority responses were too slow and the approval process too long, perhaps leading to missed opportunities.

The section chief for discipline inspection at Badong's Administration of National Land Resources, Xiang Shiwei, said his county started forecasting and planning for their third phase geological disaster control program several years earlier. But they had to wait more than a year for approval from authorities. They could not officially start work until May 2006, just four months before water levels were to reach 156 meters.

While this bureaucratic approval process clearly helps prevent local governments from exaggerating funding needs, a capital reduction can pinch projects that actually need money. This puts some disaster control projects in danger of resorting to inferior engineering techniques and possibly hiding serious geological problems. A typical example of this challenge is the landslide management effort at the Zhang Fei Temple in Chongqing's Yunyang County.

The reconstructed Zhang Fei Temple is now located on the south shore of the Yangtze, on the western slope of the town of Panshi. From across the river, it faces Yunyang's new city. The temple is a nationally protected cultural landmark that was moved October 8, 2002, to avoid the rising water around Three Gorges. It was the largest cultural relocation project in the reservoir area. Unfortunately, the temple was moved to a landslide-prone site. After the reservoir began filling with water, the ground shifted several times on the east side of the new temple site.

Funding had a lot to do with the rapid geologic changes that undermined the temple, according to Caijing sources. At first, the temple's disaster control budget was more than 50 million yuan. But CIECC experts, after an investigation, concluded the land was stable and reduced the budget to just over 10 million yuan. After a landslide in summer 2007 in the temple area, the city of Chongqing applied for more than 80 million yuan in additional funds from central authorities. At the moment, a third phase project is still in progress.

Hope for Long-term Mechanisms

Based on Caijing research, it seems insufficient funding for geological disaster management projects is already a pervasive problem. Take Hubei as an example. Second-phase projects for preventing landslides and river bank collapses in four counties of Hubei's Three Gorges area were completed in August 2004. But

the original plan called for relocations from 55 disaster areas to be finished by June 2003. And even though the second phase has ended, only 19 relocations have been completed due to a money shortage.

Wushan and Fengjie counties are the closest of Chongqing's counties to the dam and are prone to major geological disasters. The assistant director of Fengjie's Administration of National Land Resources, Chen Jianhua, told Caijing that their second-phase disaster control program cost more than 300 million yuan. And 366 million yuan has been invested in the county's third-phase emergency project. But according to Chen, " funds are still tight."

According to Chen, the biggest obstacle to proper funding is that appropriations for geological disaster management are currently based on projects which, after construction and inspections are officially completed, can receive no additional funds. But an engineering project can often span 50 years or more, given that maintenance, management and early-warning systems are equally important to geological disaster control.

Ma Xiaohan, a researcher at Hubei's geological disaster control leadership group, told Caijing that as the reservoir water level rises to 175 meters, some landslide-prone areas under special monitoring could very possibly worsen to the point that new relocations are necessary. Where would the money come from? This question has not been answered.

Many counties and cities in the reservoir region – not only riverside communities – must urgently address this problem. For Xu Kaixiang, chief engineer at the Three Gorges Geological Disaster Prevention Headquarters, this issue requires immediate attention. Funding for existing geological monitoring systems is also based on individual projects, and a budget for these systems has been approved only through 2009, when the Three Gorges project is completed. What will happen later?

After the water reaches 175 meters, no one can say for sure what geologic events will occur in the future. What is known is that a lot of time will be needed to develop the ability to thoroughly forecast what are now uncertainties.

At the end of 2006, the China Meteorological Administration and other departments released an International Global Warming Assessment Report. It said that, since the 1950s, disaster cycles in mountainous regions southwest of the Three Gorges Reservoir have shortened, while disaster frequency and losses increased. The report also predicted that the number of days with heavy rain in the south would increase notably. Days of torrential rain also could multiply. Therefore, from now until 2050, disasters in these mountainous regions are expected to grow in intensity, scope, range and frequency. And losses are expected to be increasingly serious.

These are significant factors that policymakers must consider while planning the reservoir area's long-term geological disaster control and management mechanisms. Three Gorges project managers will almost certainly have to deal with the above issues beyond 2050. And, according to many scientists, the trend toward more extreme weather events linked to global warming will not change for the next 100 years.

If policymakers do not develop a comprehensive strategy soon, China will find it enormously difficult to calmly prepare for potential geological disasters in the Three Gorges region and build trustworthy long-term mechanisms to protect future generations. After all, a shadow of geological disaster looms over this fragile land.

Caijing reporter Yang Binbin also contributed to this article.

1 yuan = 14 U.S. cents