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CHINA'S THREE GORGES DAM: "FATAL" PROJECT OR STEP TOWARD MODERNIZATION?

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CHINA'S THREE GORGES DAM: "FATAL" PROJECT OR STEP TOWARD MODERNIZATION?

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Summary. -- China's plans for the Three Gorges Dam on the Yangzi River are a focus of controversy both inside and outside of China. The dam is one of the "Fatal Five" World Bank projects criticized by environmental groups in the United States. The dam entails strategic, social and cultural costs that go far beyond its substantial monetary price. Strategic vulnerability is a major concern. The consequences would be catastrophic should the dam fail as a result of warfare, earthquakes, or other causes. Resettlement of population displaced by the reservoir, especially farmers, presents a formidable obstacle in the mountainous and already-crowded land around the reservoir site. Resettlement could affect minority groups if population is moved to border areas. The reservoir would sacrifice cultural landmarks holding great significance for many Chinese. Erosion and reservoir siltation may impede navigation within a few years, and in the longer term will reduce storage volume, thereby reducing power generation and flood control effectiveness. Filling the reservoir will sacrifice archaeological sites and some natural habitats, although the terrestrial ecosystems present are already heavily disturbed. Effects on aquatic fauna are reduced by the presence of another dam already blocking the Yangzi 40 km downstream of the Three Gorges site. Greater streamflow during the dry season may affect some animals downstream of the dam, including dolphins and cranes. The dikes preventing flooding along the Yangzi will require increased maintenance because of erosion by relatively silt-free water. The dam will reduce nutrient supply to downstream river, lake and estuary ecosystems and to agricultural areas irrigated with Yangzi water, although some of the expected impacts appear to be overstated. The potentials for coastal erosion and for public health problems are not severe when compared to some other major dams, but merit close attention because of the large number of people affected by even slight changes in these densely-settled areas. The uncertainty must be reduced in quantifying the increased hazard of earthquakes provoked by the reservoir. Plans to use water from Three Gorges in a cross-China water transfer project to irrigate the Yellow River valley mean that the severe potential impacts of this massive scheme must also be assessed in evaluating the dam. The Three Gorges Dam is also likely to severely strain China's budget for other needed developments, especially if cost overruns follow the example of other Chinese dams. A number of less expensive and less risky alternatives could achieve the goals set for Three Gorges.

The major justification for building the dam is flood control, an urgent priority because a major flood could take millions of lives and cause property damage exceeding the construction cost of Three Gorges. Alternatives for reducing flood danger include reforestation in the watershed, smaller dams on upper tributaries, and reversing the movement of population to dangerously exposed areas along the middle and lower Yangzi. Electricity is much needed, but could be produced more cheaply and quickly from smaller dams. Energy conservation and population control are more cost effective ways of increasing per-capita power supply. Lesser justifications for the dam include irrigation (including the controversial cross-china water transfer plan), improvement of

navigation to allow larger ships to reach Chongqing (a benefit that would soon be cancelled by siltation), and fish production in the reservoir.

Installation of infrastructure for construction at the damsite before impact assessment is complete raises doubts about the place of environmental evaluation in China's decision process. As is true in all countries, China would best be served by carefully weighing environmental studies before approving major projects. The World Bank, in addition to increasing its own scrutiny of environmental impacts of the projects it funds, could improve decision-making procedures by supporting environmental institutions in the countries receiving assistance.

1. INTRODUCTION

China's plans for the Three Gorges Dam, a massive hydroelectric project on the Yangzi (Yangtse or Changjiang) River, have generated much controversy and misunderstanding. The International Bank for Reconstruction and Development, or World Bank, has provided funding for evaluating environmental aspects of a feasibility study, but has not yet decided whether to contribute funds to the dam's construction. Environmental groups in the United States have attacked the project as one of the World Bank's "Fatal Five"--five large development schemes that have been criticized as indicative of low priority for environmental concerns in the Bank's lending decisions. (The other four are the POLONOROESTE project in Brazil, the Narmada Valley dams in India, transmigration in Indonesia, and a large cattle ranching project in Botswana.)

In February and March 1987 I spent eight days speaking with farmers and other residents in the area that would be flooded by ythe Three Gorges Dam. In the major cities nearest the site (Chongqing, Yichang and Wuhan: Fig. 1) I spent an additional 12 days speaking informally with researchers and officials at universities and government agencies concerned with the project.

While the "Fatal Five" include several major assaults on natural habitats, some of the charges leveled at the Three Gorges project overstate its probable impact. Nevertheless, the dam would have environmental effects and both its financial and human costs will be high. Prior to any decision (either official or unofficial) regarding the dam's construction, China would be well advised to await the results of the impact assessment now underway. This logical sequence of steps may not be being followed in practice.

2. ENVIRONMENTAL CONCERNS

Fourteen environmental organizations, known as the "Tropical Forest Action Group, a Coalition" (TFAGC), published a pamphlet entitled "Tropical Forests and the World Bank" (TFAGC, 1986). The Three Gorges Dam is described as an "ill-conceived megaproject" expected to cause dislocation of as many as three million people, threaten the Yangzi's unique species of sturgeon and dolphin, desiccate downstream lakes thereby threatening the Siberian crane, deprive downstream agriculture and fisheries of silt and nutrients, threaten salinization of the estuary at Shanghai, undercut the dikes along the middle and lower reaches D(2)U of the river, and erode 640 km of coastline.

3. PLANS FOR THE THREE GORGES DAM

The Three Gorges Dam has been under consideration since the mid 1940s when the US Bureau of Reclamation cooperated with the Chinese nationalist government in assessing potential hydroelectric sites on the Yangzi (LaBounty, 1984). The Yangzi Valley Planning Office proposed building the dam in the early 1950s (LaBounty, 1984) and the plan was approved at higher levels in 1958 (Gaines, 1987). The tremendous cost of the dam has helped prevent it from being included in the Five Year Plans and from actually being constructed. The Beijing leadership reportedly decided as early as 1983 to launch the project in 1986 despite major unresolved details (Lampton, 1983, p. 12). A "feasibility" study was initiated in 1986, with financing from the Canadian International

Development Agency (CIDA). Fourteen Chinese agencies are also studying specific aspects of the scheme. These studies are to produce suggestions on how to improve the project's design and to reduce its impacts--not to serve as inputs to the decision on whether to build the dam.

Information on the Three Gorges project is conflicting, partly because the plans have evolved over time. Two sites have received serious consideration. One (indicated by Fang Ziyun, 1986) is approximately 80 km above the already-existing Gezhouba Dam, the other (Fig. 2), is 40 km above Gezhouba. The second site has been selected; known as San Dou Ping, it is downstream from the towns of Zigui and Xiang Xi. Although a higher, longer dam would be required and Zigui and Xiang Xi would be sacrificed, advantages of the downstream site include the greater width of the river--making it easier to accommodate both more generators and sufficent locks for the Yangzi's heavy shipping traffic. The location closer to the Gezhouba Dam will make the Three Gorges and Gezhouba reservoirs contiguous, thus avoiding the problem of occasional periods of insufficient water for shipping in the river stretch immediately below the Three Gorges Dam.

The most likely height for the dam is 180 meters (m), which would create a reservoir 600 km long covering approximately 1,100-1,500 km2. About 300 km2 of this represents the permanently flooded riverbed area. A 150 m high dam has also been considered that would produce a reservoir 500 km long covering about 570 km2. A 200 m high dam, which would flood part of the city of Chongqing (Chungking), appears to be out of the question. A 180 m high dam would generate 13,000 megawatts (MW) of electricity, making it larger than any dam presently existing. The power generating efficiency of Three Gorges, about 10 MW/km2 of reservoir area, is higher than at other major hydroelectric projects around the world. The 200 m high dam under consideration in the early 1980s would have had 25,000 MW of installed capacity (LaBounty, 1984). Plans for a 220 m high dam to produce 30,000 MW (Hachette, 1983, pp. 785-786) are similarly obsolete. However, the Three Gorges Dam could be raised to a higher level at a future date. Plans for raising the existing Danjiangkou Dam on the Han River, for example, are currently under discussion (Lampton, 1983; Liu and Ma, 1983). A higher dam at Three Gorges would provoke significantly greater impacts.

The Three Gorges site is in the western portion of Hubei (Hupeh) Province; most of the reservoir would be in neighboring Sichuan (Szechwan) Province. The difficulty of coordinating a project in two provinces, with the benefits largely in one and the impacts in another, led to a plan to create a new province of San Xia ("Three Gorges") with its capital at Yichang (Ichang). However, press reports indicated that this plan was abandoned in 1986 when China's State Council disbanded its Three Gorges Provinces Group.

4. CONFLICTING OBJECTIVES FOR DAM CONSTRUCTION

Planning of the dam has been underway for a number of years with disagreement among government agencies as to whether to build the Three Gorges Dam now or to postpone its construction until after a series of smaller dams on Yangzi tributaries is built. Dams would be built on at least four rivers: the Min, Daling, Jin Sa and Wu. Cheng (1984, p. 162) cites World Bank sources as ascribing the disagreement to the differing mandates of the agencies: agencies responsible for meeting electric demand on the short term want smaller dams that would come on line sooner, while those whose responsibilities include flood control and communications want the larger dam.

Those responsible for power generation are concerned about the long lead time to begin power generation and the potential power fluctuations if water flow is regulated primarily for flood control objectives (Gaines, 1987). The rival Ministry of Water Resources (which favored the Three Gorges Dam) and Ministry of Electric Power (which opposed it) were merged in 1982, and officials who favored the dam were elevated to the top ranks of the new Ministry of Water Resources and Electric Power (Weil, 1982, p. 13). One of the reasons often mentioned in China for building the smaller dams first is the experience that would be gained in dealing with environmental and social impacts and in solving engineering problems.

Deudney (1981, p. 30, citing *Engineering News Report*, 1980) emphasizes another consideration:

American technical advisers working with the Chinese on the Three Gorges project have advised the construction of three smaller dams rather than one huge one for "national security reasons" -- presumably a reference to China's continued fear of Soviet attack.

Major cities downstream from the dam site include Wuhan (Hankow), Nanjing (Nanking) and Shanghai. Given wartime events in those cities earlier in this century, residents are undoubtedly well aware of the extremes to which warfare can lead. Destruction of dams remains a common military strategy despite Geneva protocols prohibiting such acts (Westing, 1984). The long history of battles in this strategic area, ranging from the defeat of Liu Bei, King of Shu, at Zigui in AD 223 to the Battle of Yichang in 1940, makes it unlikely that Chinese planners would opt lightly for a scheme posited on eternal peace. In addition to the potential horror should the dam break due to hostile attack or other causes, the dam could weaken China's bargaining position in future disputes, either domestic or international. For example, analysts believe that Israel's ability to destroy the Aswan High Dam, which is perched above Egypt's major population centers, was a critical factor in the latter country's willingness to accept a peace settlement in 1978 (Deudney, 1981, p. 30). One can imagine the psychological effect on western countries of a 180 m high dam on, say, the Rhine River in Europe or the Hudson River in North America. China might one day regret having such a Sword of Damocles dangling over some of its principal cities. For whatever reason, the questions of construction priority remain unresolved.

5. POTENTIAL IMPACTS OF THREE GORGES

(a) Population resettlement

The major concern associated with the Three Gorges Dam is the resettlement of the people living in the area to be flooded. The "up to three million" people mentioned by environmental groups (TFAGC, 1986) appears to be an overestimate. The World Bank is cited as giving a figure of 1.4 million (Cheng, 1984, p. 97; see also Weil, 1982, p. 13), which agrees with government agencies concerned with the project. The agencies estimate that approximately 330,000 of the people are farmers, and the rest urban dwellers. Urban populations are much more easily moved than are farmers since cities can be rebuilt on higher ground but all comparable farmland is already occupied.

Moving the urban population is complicated by the fact that many of these people, possibly up to 30% of them, are illegal residents who have come to the cities from the countryside in defiance

of government regulations restricting such moves. The government does not want to provide any housing or other assistance in relocating these clandestine residents lest this be interpreted as a reward for illegal acts (R.J.A. Goodland, pers. comm., 1987).

The issue of what to do with the farmers remains unresolved. Authorities expect some to become urban factory workers while most would "move uphill." The question of whether the mountainous terrain near the reservoir could support the added population is unstudied, although officials recognize its importance.

Vaguely-defined plans for intensive dairy farming and for production of orange juice concentrate are unlikely to make these areas sufficiently productive to support a denser population. In addition to the limited agricultural potential of the land, the people are unaccustomed to milk and cheese (R.J.A. Goodland, pers. comm. 1987).

Not to be taken lightly is the possibility that the farmers, who share the Han race and culture with the majority of China's population, might be deported to distant settlement areas where minority groups now dominate, either in the semi-arid western regions near China's border with the Soviet Union or in the tropical areas near the Burmese and Thai borders. Settlement projects have been underway in these border areas, in part in an effort of the central government to populate them with Hans (Gore and Dale, 1980, p. 321; Samagalski and Buckley, 1984, p. 57).

The farmland to be flooded is not the rich irrigated rice land often associated with the Yangzi. Some of the land is irrigated terraces, but the majority is steep hillsides with rainfed agriculture. By any sort of textbook criterion most of this land should not be farmed anyway--but farmed it is and it constitutes the basis for subsistence of a dense population. The approximately 1,300 km2 reservoir area includes about 300 km2 of river channel that is underwater year round, leaving about 1,000 km2 of uplands and seasonally-flooded lands (which are also farmed). Figures vary wildly for the amount of agricultural land at stake. Cheng (1984, p. 97) gives a value of only 440 km2 of "farmland." Brown and Wolf (1987, p. 208) give a value of 130 km2 of "cropland." Using 1000 km2 for the land area, the rural population density is about 300 persons/km2. The average for China's rural population is about 78 persons/km2, and excluding areas with altitude over 2000 m is about 120 persons/km2.

(b) Natural habitats

Natural habitats in the land area to be flooded are principally rocky cliffs that are too precipitous to farm. Some trees are present, but despite classical paintings and literary descriptions of the area they are, as one person put it, "bald as a monk." Centuries of human use explain the difference. Many of the rocky areas have scrubby growths of bamboo that are currently exploited to feed small paper mills. Somewhat less precipitous hills have planted trees, especially pines and Casuarina. The natural vegetation of the uncultivated portion of the area is classified as two types of "mixed broadleaf evergreen and deciduous thorny scrub" (Hou et al., 1979). None of the vegetation resembles that popularly associated with the term "tropical forest." The area is not tropical at 32o 9' N. Latitude--about the same as Beaufort, South Carolina, USA or Tel Aviv, Israel. While the presence of unique species cannot be ruled out without detailed studies, their occurrence seems

unlikely since vegetation maps indicate the same vegetation types extending well beyond the area that would be flooded (Hou et al., 1979). However, one area with many endemic plant species is located in the upper reaches of the Daling River just outside of the area to be flooded (R.J.A. Goodland, pers. comm., 1987).

(c) Cultural Landmarks

Two of the three gorges would be flooded by the dam: the Qutang Gorge and Wu Xia (Witches' Gorge). The water level in the third gorge (the Xiling) has already been raised by the Gezhouba Dam. While the cliffs remaining above the water level in the flooded gorges will still be spectacular, the narrow canyons and rapids for which the area is famous will be gone. The area holds special scenic and cultural value for many Chinese. The Three Gorges are more than a tourist attraction; along with the Panda and the Great Wall, they are known to Chinese schoolchildren and general public as a symbol of China. They figure prominently in classical Chinese poetry and painting. The Gorges provided inspiration for much of the work of the Tang Dynasty poet Li Bai (AD 701-762), who virtually any Chinese would immediately identify as the world's greatest. Du Fu (AD 712-770) wrote over 400 poems at Fengjie and many more at Yunyang (Bonavia, 1985, pp. 49-5l); both sites would be flooded by the dam. Poetry is far more important to the average Chinese than to the average person in the West. China's long linguistic and cultural continuity make highly relevant today persons and events of over a thousand years ago.

(d) Archaeological sites

The area to be flooded is believed to contain thousands of archaeological sites of interest to scholars. Losses would be reduced by intensifying the search for these remains.

(e) Fauna

The effect of the Three Gorges Dam on fish migration would be minimal because of the existence of the Gezhouba Dam already blocking the river 40 km downstream. Although still "under construction," the Gezhouba Dam closed off the upper Yangzi in 1981. Present construction (to be completed in 1988) is limited to increasing the number of generators and decorating the buildings--the reservoir and environmental impacts are already in place.

Blocking fish migration was a major point of concern in China prior to the construction of the Gezhouba Dam. Calls for building a passageway for fish were ignored in order to reduce costs. The focus of attention was the Yangzi sturgeon (Acipencil sinensis), a relatively uncommon fish that is found only in China. This fish, which can grow to over 5 m in length, spends most of its life in the ocean and ascends the Yangzi to breed. In the years since the Gezhouba Dam blocked access to the sturgeon's traditional upstream spawning grounds, sturgeon eggs have been found in the stomachs of an egg-eating fish species in the middle reaches of the river--indicating sturgeon breeding downstream of the dam (see Zhou Zheng, 1985).

An artificial stocking program has been initiated since the 1981 closure of Gezhouba, with 10,000 sturgeon fingerlings released into the river annually from a hatchery at Yichang. Since it

takes 10 years for the small fish to grow to maturity and return to the breeding grounds, it is not yet known whether the population will be maintained.

Significant effects are not expected for other fish species. No significant effects were found in a study of fish at the Danjiangkou Dam, completed in 1967 on the Han River, a major tributary to the middle Yangzi (Yu et al., 1981).

The Yangzi freshwater dolphin (Lipotes vexillifer) has been a focus of concern. The dolphin population has undergone a precipitous decline since the 1950s as pollution and overfishing have reduced the fish stocks on which the dolphins feed. Blockage of dolphin migration is not a factor since the dolphins did not enter the upper Yangzi even before the advent of the Gezhouba Dam, but the dolphins, now believed to number less than 300, would suffer a further setback should blockage of fish migration by the Gezhouba Dam cause any further reduction in the stocks of fish they eat. The presence of Gezhouba, however, makes concerns voiced in this regard irrelevant with respect to the Three Gorges Dam.

The freshwater dolphins may also suffer from the Three Gorges Dam's effect on water levels in the middle and lower Yangzi. Because the reservoir volume of Gezhouba is small (1.58 X 109 m3), this already existing dam is not capable of maintaining river flow levels significantly above their "natural" (unmodified) levels during the Yangzi's low-water period. The Three Gorges Dam, with over 12 times as much water storage capacity (19.2 X 109 m3), would prevent the middle and lower Yangzi from ever reaching the low natural levels. The 20 m water level fluctuation expected in the Three Gorges Reservoir would release approximately 2 X 109 m3 of water in the low-water period; maintaining a higher water flow in this period will be an important contribution to increasing the power output of Gezhouba, as well as to making best use of the generators at the Three Gorges site. A consequence may be the disappearance of the sandbars that create the eddies dolphins favor as resting sites when tending their young. Wuhan's Institute of Hydrobiology has proposed two semi-natural reserves for the dolphins. One would be at Tongling, about 300 km downstream of Wuhan, while the other would be in a bypassed oxbow at Shishou, about midway between Yichang and Wuhan. The Shishou reserve could be threatened by riverbed scouring caused by clearwater releases from the Three Gorges Dam, leaving the oxbow perched above the river and cut off from its supply of water and fish (Perrin and Brownell, 1987, p. 19).

The Siberian crane (Grus leucogeranus) has also been mentioned as threatened by the project due to hypothesized effect on lake habitats in the plains of the middle and lower Yangzi. Wuhan's Yellow Crane Temple attests to the special place of cranes in Chinese culture. Once widely distributed throughout Siberia, the population is now divided into two parts and is believed to total less than 2000 birds (Meade, 1983, p. 62). One part of the population spends summers in western Siberia and migrates around the western end of the Himalayas to overwinter at sites from Iran to northern India; the other migrates between eastern Siberia and the Yangzi plain (Meade, 1983, p. 62; Thomson, 1964, p. 162). Winter (when the eastern population is in China) is the Yangzi's low-water period. All or most of the cranes overwinter in Poyang (Boyang) Lake where they feed on a floating aquatic weed that is rooted to the bottom; the effect of the Three Gorges Dam would be to raise water levels during this season, possibly eliminating the food source for the cranes (R.J.A. Goodland, pers. comm., 1987). The dam's effect of increasing flow in the low-water period means

that the lake desiccation (TFAGC, 1986) is not a threat. Information is unavailable, however, on how much lake levels might rise and whether sufficient weeds would remain to support the cranes.

(f) Yangzi lake hydrology

Small dams plus the dikes along the river built to prevent flooding of agricultural land isolate many of the Yangzi lakes from the Yangzi River and therefore would lessen the dam's effect on the lakes. These lakes already get most of their water from tributaries rather than from the main river. Yangzi water enters the lakes only during the flood season (May-September), when the dam would least alter stream flow.

The hydrology of the Yangzi lakes has already been greatly altered by flood control measures. Extensive flooding was the rule before the dikes were built in the Ming (1368-1644) and Qing (1644-1911) dynasties. Both Marco Polo in the 13th century and Abb' Huc in the 18th century reported the Yangzi to be over 15 km wide (Bonavia, 1985, p. 81). Since the dikes were repaired and improved in the 1950s massive flooding of agricultural land has been avoided. LANDSAT satellite images indicate that the water from the Yangzi still enters many lakes, however (Chen, 1984, p. 28ff). Some major lakes (e.g., Poyang) only have one-way flow into the Yangzi, while others (e.g., Dongting) have two-way flows (Ren et al., 1985, pp. 230-231). The lakes reduce the flood levels in the middle and lower reaches of the Yangzi by storing runoff from tributaries and absorbing some of the flow from the Yangzi itself. Up to 40% of the peak floodwaters are absorbed by the lakes (Chen, 1984, p. 23).

The potential impact of the dam on sediment inputs to the Yangzi lakes has been raised as a concern (TFAGC, 1986). Large quantities of sediment are deposited when Yangzi floodwaters enter the lakes. In Dongting Lake, Yangzi water annually deposits 141 X 106 m3 of sediment, which, combined with 27 X 106 m3 from tributaries minus outflow of 40 X 106 m3, raises the lake bottom by 4.6 mm/year (Ren et al., 1985, p. 231). These inputs are not entirely a blessing: in the case of Dongting Lake sedimentation has resulted in the lake fragmenting into a series of smaller lakes with reduced storage capacity to buffer the Yangzi from damaging floods. The regulation of the Yangzi flood levels by the lakes is essential to protect large areas of farmland and the valley's dense human population.

Due to the dikes along the river margin and the dams built over the past 40 years to regulate water flow at the mouth of each lake these water bodies apparently do not receive as much silt from the Yangzi as in the past. In the case of one major lake, Honghu, LANDSAT imagery shows much lower silt content in the lake waters than in the nearby Yangzi (Yang et al., 1983).

(g) Erosion and reservoir siltation

Sedimentation is usually a major concern in planning hydroelectric projects since this factor determines a project's useful life. The silt-scouring gates that are planned to counter sedimentation (similar to the ones now functioning at Gezhouba) have apparently never been tried with the lower water velocities that will characterize the Three Gorges Dam. The point at which an increased rate of silt input would overwhelm the effectiveness of the gates is evidently not known. Erosion in the

dam's catchment area could speed sedimentation of the reservoir. In the Yellow River (Huang He) basin, where erosion is much more severe than in the Yangzi basin, silt discharge gates are not expected to be a viable countermeasure for sedimentation of hydroelectric dams. The Sanmen Gorge Dam on the Yellow River has reportedly lost 75% of its 1,000 MW generating capacity due to sedimentation (Deudney, 1981, p. 61). The suspended sediment load per volume of water is about 20 times higher at the mouth of the Yellow River than the Yangzi's 0.54 kg/m^3 (Ren et al., 1985, p. 107), although the Yellow River's flow is much less than that of the Yangzi. Some Chinese environmentalists have expressed fear that increasing erosion could turn the Yangzi into "a second Yellow River" (cited by Smil, 1983, p. 228), although the Yangzi's silt discharge would have to triple before this prophecy comes true.

The Yangzi catchment upstream from Yichang covers 1 X 10^6 km^2 (Yangzi Water Resources Protection Bureau, (ca. 1982), most of which is classified as losing soil at an annual rate over 200 metric tons/km2, with some parts of the catchment producing over 1000 metric tons/km2 annually (Ren et al., 1985, p. 108). The catchment for the Three Gorges Dam would be only marginally smaller, since only one small tributary (the Huang Be He) joins the Yangzi between the damsite and Yichang. Runoff in the Yangzi basin as a whole is 17 liters/sec/m2, with runoff up to 40 liters/sec/m2 in hilly areas in the southern part of the catchment (Ren et al., 1985, p. 229). The current Chinese leadership has recognized the need for reforestation as an urgent priority.

Soil erosion is a major concern in its own right, apart from effect on hydroelectric dams. Erosion in China annually forces abandonment of much badly-needed cropland and reduces yields over even wider areas. The Yangzi basin has been identified as the site of particularly rapid deforestation and increase in erosion in recent years (Smil, 1983, p. 228). Of course, increased erosion in the catchment area would tend to lessen the Three Gorges Dam's impact on downstream nutrient supply, as sedimentation in the reservoir is partially compensated for by greater silt inputs.

Much of the silt that now flows past the dam site would settle at the bottom of the reservoir for the 80-100 years estimated to be needed to fill the reservoir's dead storage volume with silt. Some of the silt would continue to be released downstream. The pH of the water (around 6.5) is in a range where fine silt particles do not rapidly clump together to settle out of the water. The average turnover time for water in the reservoir would be 21 days, but the time would be much faster in the flood season when most of the yearly silt load descends the Yangzi. Water flow at the dam in flood season is expected to be 0.5 m/sec--enough to carry a substantial amount of silt but not nearly as high as the over 3 m/sec flood season flow at the Gezhouba Dam. A fast rate is critical for the functioning of silt discharge gates in the dam.

Silt discharge gates were built into the Gezhouba Dam with great success. These gates, of Chinese design, open doors horizontally at a level below that of the intake for power generation. The gates are opened only at flood season, when the Yangzi's water flow exceeds by many times the maximum amount that could be channeled through the generators. Discharge in the unusually high flood of 1981 exceeded 72,000 m^3/sec. The historical high of 110,000 m^3/sec was reached in the flood of 1870, which swept away the Zhang Fei Temple (opposite Yunyang) that had been standing since the Three Kingdoms Period (AD 220-265). The water surges through the gates with tremendous force, carrying with it silt, sand and gravel scoured from the year's accumulation behind

the dam. At the Three Gorges Dam the lower water flow rate would carry less silt but is expected to be sufficient to maintain the dam in permanent operation after the equilibrium is reached between deposition and scouring. The silt-scouring gates remove deposits only within a few hundred meters of the dam--they are able to prevent blocking of the generator intakes but are incapable of averting much of the loss of reservoir storage capacity caused by siltation. Loss of storage volume reduces flood control effectiveness during the high-water period and power output during the low-water period. Siltation problems for navigation are expected to begin at the upstream end of the reservoir near Chongqing. An American proposal for consulting services has reportedly identified siltation's potential for blocking navigation (plus the threat of landslides) as a key question needing immediate attention (Eckholm, 1986). Siltation could negate one of the dam's hoped-for benefits: the opening of the industrial city of Chongqing to larger ships.

(h) Yangzi Dikes

Chinese authorities believe that any undercutting of the Yangzi dikes by the scouring effect of clear water released from the dam could be countered by the present program of constant rebuilding and continued upgrading of the dikes with additions of rock facing. The burden of any increased dike maintenance would fall on riverside peasants. This burden could be considerable, given the difficulties experienced elsewhere (for example by the US Corps of Engineers) in protecting river embankments with rip-rap. Once floodwaters begin to eat under and behind the facing, erosion proceeds quite quickly. The deepening of the river channel through scouring would provide constant opportunities for the river currents to defeat the facing. Were the dikes allowed to erode, the danger of flooding densely-populated agricultural areas along the middle and lower Yangzi would increase. Neglect of the dikes was a major contributor to the catastrophic flood of 1931. However, the overall effect of the Three Gorges Dam would be to lessen flood danger by storing some of the peak flow.

(i) Agriculture and fisheries production

Production losses in downstream agriculture caused by deprivation of silt and nutrients supplied in irrigation water would probably not be great. The irrigation season for rice is from April to October, which is at the high water period when the reduction in the river's silt content will be least. In addition, the agricultural land in the area receives most of its irrigation water from tributaries--not from the Yangzi itself.

Another factor reducing silt deprivation to downstream agriculture and fisheries is the addition of silt to the middle and lower Yangzi through the entrance of major tributaries. The upper reaches of the Yangzi account for only 46.4% of the annual water flow entering the ocean (Ren et al., 1985, p. 109), meaning that additions from tributaries more than double the Yangzi's flow between the Three Gorges site and the East China Sea. This is quite different than, for example, the Nile River below the Aswan High Dam, where tributaries make no significant additions. However, contributions to the Yangzi's silt from tributaries downstream of the Three Gorges Dam may be less than their large water volumes would suggest: the major tributaries either flow through lakes like Dongting and Poyang (where much silt is trapped prior to entering the Yangzi) or have already been dammed (the case of the Han River, site of the Danjiankou Dam).

Scouring of the river bottom would be an additional source of silt. In the case of the Nile, the clear water released by the dam picks up enough particulate matter from the river bed to recover 80% of its original silt load by the time the water enters the estuary 600 km downstream. Based on this, Chinese authorities expect that the Yangzi would recover its full silt load over a distance of 800 km below the dam. Below the Three Gorges site the Yangzi flows approximately 1900 km before entering the East China Sea, or over three times the distance over which the Nile flows between Aswan and the Mediterranean. Changes in the silt discharge of the Nile following the construction of the Aswan Dam caused serious disturbances to fisheries near the river's mouth (George, 1972; Kassas, 1972). Counting suspended sediment alone, the Yangzi discharges annually 502 million metric tons of silt into the East China Sea, causing the coast to extend seaward at an average rate of 25 m per year (Ren et al., 1984, pp. 107-108). The high rate of silt deposition in the Yangzi delta is not considered a blessing by many since frequent changes in the river's course as it enters the estuary cause problems for agriculture and settlements.

One concern debated within China is that cold water (about 4o C) drawn from low in the water column to run the generators at the Three Gorges Dam would reduce crop yields in land irrigated with it. Rice is adapted to warmer water (usually at least 21o C). Studies are reportedly to be initiated at Wuhan to quantify the effect of irrigation water temperature on Yangzi rice yields. In California and in northern Italy, where irrigation water from mountain sources is too cold for rice, 2 to 4% of the paddy area is devoted to special holding ponds to warm the water prior to use (Grist, 1975, p. 46).

(j) Coastal erosion

Several of the world's major dams have provoked coastal erosion where the silt-free water released from the river mouth is carried by ocean currents along the adjacent coast. Best known are Egypt's Aswan Dam, where east-flowing currents in the Mediterranean have eaten away at the land well beyond the mouth of the Nile River, and the Akosumbo (Volta) Dam in Ghana, which has caused coastal erosion displacing thousands of people both in Ghana and in neighboring Togo. The threat of coastal erosion near the mouth of the Yangzi would be less severe, assuming that the water discharged to the East China Sea will have the high silt content that Chinese officials expect to result from the additions of tributaries and river scouring. An important factor limiting coastal erosion hazard is the location of the Yangzi's mouth at a point where a south-flowing cold current meets a north-flowing warm current, turning the direction of flow out to sea (Espenshade and Morrison, 1974, p. 198). A LANDSAT image of the Yangzi entering the East China Sea (Bonavia, 1985, pp. 137-138) shows that some silt is carried along the coast to the south, but most of it goes out to sea. The hydrology of the estuary is apparently poorly known, however, indicating the wisdom of obtaining better information on any modifications that could threaten either densely-populated coastal areas or the rich offshore fishery.

(k) Estuary Salinization

Salinization in the estuary at Shanghai could be aggravated when the reservoir is filling. Salinization is an existing problem during the December-April portion of the dry season; in 1978 (an

unusually dry year) chloride levels in the source of Shanghai's water supply were well above international standards for drinking water and caused industrial losses totalling US $740,000 (Liu and Ma, 1983, pp. 263-264). Since the initial closing of the Yangzi during dam construction is feasible only during the low-water season, discharge would be interrupted for the time needed to fill the reservoir to the first spillway. Manipulation of the releases from the Yangzi Lakes could buffer the lower Yangzi from most of this impact. Closing the gates on the completed dam to fill the reservoir from the first spillway level to full capacity could be timed to fall in a period of greater river flow for the Yangzi and its lower tributaries.

(l) Earthquake hazard

Earthquakes are another concern in China, a country renowned for its advances in earthquake prediction. At present the Three Gorges area is characterized by many small earthquakes (1-2 on the Richter scale). The weight of the water in the reservoir is expected to raise the magnitude of these to Richter scale values of 5-6. Earthquakes of this magnitude are within the tolerance of the dam (estimated at approximately 7-8) and are not expected to cause significant problems for other structures. The consequences of any mistake in estimating earthquake magnitudes for Three Gorges would obviously be catastrophic. Mark and Stuart-Alexander (1977) have reviewed methods of altering cost-benefit analyses to incorporate the risks of dam failures, although such analyses are normally limited to monetary considerations rather than loss of life.

(m) Public health

The possiblility that the Three Gorges scheme could result in spread of parasitic diseases, especially malaria and shistosomiasis, has been raised by LaBounty (1984, p. 588). Quiet bays in the reservoir would serve as breeding grounds for the mosquitoes and snails that serve as vectors for these two diseases. Although the reservoir would have fewer such shallow bays than do many of the world's reservoirs, Chinese public health authorities would nevertheless have to increase their monitoring and control programs in the newly created habitats.

(n) Climate

The possibility of the reservoir provoking climatic change in the area is a popular concern in China. However, the reservoir's small size and extremely long thin shape (Fig. 2) would make climatic impact insignificant. Any change that did occur would be in the direction of cooler temperatures in summer and warmer temperatures in winter. Both of these would be beneficial changes--the reservoir lies in an area known as the "Three Furnaces of China" (Chongqing, Wuhan and Nanjing) where summer temperatures in excess of 40o C are normal. In winter temperatures reach values low enough to threaten one of the region's best-known products: oranges.

(o) Cross-China water transfer

Some of the plans for massive water transfer from the Yangzi valley to the much drier Yellow River valley include tapping the Three Gorges reservoir (Liu and Ma, 1983, p. 260). Three principal routes have been proposed, each with variations. The "eastern route" would follow the

ancient Grand Canal from Jiangdu to Tianjin; the "western route" would take water from several rivers in western China to the upper reaches of the Yellow River; and the "middle route" would lead from the Three Gorges reservoir to the Danjiangkou Reservoir and continue north to Beijing (Peking). The water transfer schemes have many potential impacts, including soil salinization in the areas to be irrigated in northern China (Liu and Ma, 1983). In the case of the middle route, the inclusion of the Three Gorges-Danjiangkou link would mitigate reduced river flow of the Han River on the 330,000 ha of irrigated farmland downstream of Danjiangkou. A combination of the "middle" and "eastern" routes is believed to be the most likely option for work in the coming decades. In 1982 the State Council of China approved the engineering plan for the first stage of constructing part of the eastern route, well in advance of environmental impact studies or any systematic comparison of the costs and benefits of different options (Liu and Ma, 1983).

(p) China's Development Budget

The cost of the Three Gorges project is a major concern, as massive outlays for the dam could absorb funds that might better be devoted to other projects, in the energy sector and in others. Chinese authorities cite a figure of 20 billion Chinese yuan (US $5.4 billion) for a 180 m high dam. Other cost estimates for the dam include US$ 5.3 billion for a 183 m dam (Weil, 1982), US $12-18 billion for 168 m high dam (Eckholm, 1986), and cost ranges depending on dam height of US $10-20 billion (TFAGC, 1986), US $12-20 billion (Gaines, 1987) and approximately US $7-30 billion (Lampton, 1983, p. 10). Better information would be needed to evaluate these disparate estimates, including confirmation that all of the dam's costs are counted, especially an adequate allocation for the resettlement of the displaced population.

Tremendous cost overruns are endemic to major construction projects in China: both Danjiangkou and Gezhouba cost much more than inital estimates. Part of this is because of the massively inefficient practice of san bian (three sides), or the simultaneous surveying, designing, and building of the dams (Lampton, 1983, p. 16). In addition to frequent changes in design while building Danjiangkou and Gezhouba, both dams had to be halted for two years during construction due to inadequate planning. The Three Gorges Dam would clearly be expensive, and the final price could easily far exceed initial estimates.

6. TRADEOFFS AND PRIORITIES

(a) Electric power

China's living standards are significantly constrained by low per-capita energy availability (World Bank, 1985). Three factors could be changed to raise living standards: (1) increase power generation, (2) decrease the number of people, and (3) increase the efficiency of energy use. A contribution to raising living standards equal to that from power generation at Three Gorges could be achieved by very small changes in the other two factors. Despite China's tremendous achievement in lowering its birth rate from 34 to 18 per thousand, the 1.05 billion 1986 population continues to grow by 11 million per year (Brown and Jacobson, 1986, p. 10). Several alternatives could reduce fertility more effectively with less cultural strain than the present policy (Greenhalgh and Bongaarts, 1987). At the 1982 per-capita electricity consumption level of 325 kWh (Flavin,

1987, p. 83), population growth would absorb the entire output of Three Gorges in 16 years--only one year longer than the projected 15 year construction period for the dam. This assumes the current low living standards; the time needed for the power consumption rate from new additions to China's population to absorb the 57.2 X 109 kWh annual output expected from the 13,000 MW installed capacity generating plant would be even less if living standards were to improve. Merely as an illustration, were the Chinese to use electricity at the 9,600 kWh per-capita rate prevailing in the United States, population growth would absorb the output in only 198 days!

Energy efficiency is another area where small improvements could easily eclipse the gains from Three Gorges. China is one of the least energy-efficient countries on earth: in 1983 each dollar of gross national product in China took over twice as much energy to produce as in the United States and over four times as much as in Japan (Chandler, 1987, p. 182). For example, China's steel industry (which relies heavily on inefficient open-hearth furnaces) uses 38.1 gigajoules of energy per ton of steel produced--more than double the 18.8 gigajoules per ton used in Japan (Chandler, 1985, pp 151-52). Investment in increasing the efficiency of energy use is generally several times more cost-effective than investment in increased generating capacity, especially for capital-poor developing nations (Goldemberg et al., 1985).

China may well want to boost electricity production capacity by 13,000 MW instead of or in addition to saving this much by reducing population and/or increasing efficiency. The gulf between energy supply and demand is obvious in China, where electricity is often rationed. In 1978 about 30% of the country's industrial capacity could not be utilized because of shortage of energy, a situation which remains serious (Gong, 1986, p. 30). Coal, the most likely alternative to hydropower, carries heavy environmental costs. Burning coal causes severe air pollution in most Chinese cities, giving the country some of the world's most acid rain. Very little pollution-control technology is used, however. Coal burning also releases carbon dioxide, which contributes to increasing global temperatures through the greenhouse effect. Generating an equivalent amount of electricity from coal would consume approximately 28 million metric tons of the fuel annually (calculated from World Bank, 1985, pp. 138, 211), releasing about 20 million metric tons of carbon as atmospheric carbon dioxide (calculated from Steinberg and Albanese, 1980, p. 527). Fossil fuel emissions in China in 1983 released 440 million metric tons of carbon, or 9% of the global total from fossil fuels (Brown and Wolf, 1987, p. 211). China is one of the countries that would suffer most severely should sea levels rise--one of the consequences predicted if global carbon releases continue to increase. China's most densely-populated areas, including the fertile plains of the lower Yangzi, are at low elevations that would be flooded at the higher sea levels expected in a world warmed by the greenhouse effect (Brown and Wolf, 1987, p. 208).

(b) Flood control

Flood control is one of the principal justifications for the Three Gorges project (LaBounty, 1984; Zhou, 1985). The potential losses from major floods are enormous--property damage alone from a flood like that of 1954 could easily exceed the financial outlay for building the Three Gorges Dam (see Lampton, 1983, p. 10). The various plans discussed for dams of different heights reflect, in part, the interests of flood control versus power generation. Power output was the principal justification for the higher designs (Eckholm, 1986). Evaluation of the scheme would require a

careful analysis of flood probabilities and potential losses of life and property under scenarios with no dam and with dams of different heights (LaBounty, 1984). One complicating problem already in evidence is the movement of population onto more exposed areas as flood control measures make the river "safer," thereby greatly increasing the potential losses should a flood escape control (Lampton, 1983, p. 10). Alternatives to dams should also be included in analysis of flood probabilities and scenarios: the Ministry of Water Conservancy and Electric Power blamed the 1981 Yangzi floods on lack of storage capacity in dams but the Ministry of Forestry attributed the damage to deforestation (Lampton, 1983, p. 13). Measures that would reduce flood danger include watershed reforestation, smaller dams in upper tributaries, and reversal of the present movement of population to dangerously exposed sites along the middle and lower Yangzi. By itself, a dam building program on the tributaries would be less effective in controlling floods than would the Three Gorges Dam, but information is lacking on the flood probabilities under different combinations of risk-reducing measures.

7. ENVIRONMENTAL IMPACT ASSESSMENT

The procedure to be followed in preparing the Environmental Impact Assessment (EIA) now required of all major development projects in China is described by Fang Ziyun (1986). The Three Gorges project is still under discussion, and apparently no public position has yet been taken by the higher levels of the Chinese government.

Major international funding will be necessary before a full-scale construction effort can begin. The World Bank plus private banks in the United States, France and Japan are considering the plan; it should be emphasized that none of the banks is yet committed to funding it. Nevertheless, activity is already apparent at the site. Three new high-rise apartment buildings have been erected to house workers on the south bank of the river. A new road has been completed on the south side, linking the site with the Gezhouba Dam. On the north side of the river, blasting for a second access road is underway in the "Yellow Cat" and "Lantern Shadow" sections of the Xiling Gorge below the site. These developments are presumably being undertaken on the assumption of a positive result from the environmental impact assessment, which has not yet been completed.

The Yangzi Water Resources Protection Bureau (the agency responsible for the environmental impact assessment) emphasizes that energy from the dam would be a key factor in modernization and that the agency's analysis includes both the impacts and the benefits of the dam. As a general rule, risks and impacts should be evaluated independent of promotion of the benefits. Misadventures are frequent when the distinction is blurred under a single agency--the simultaneous supervision and promotion of nuclear power in the United States by the now disbanded Atomic Energy Commission is the best known example.

8. CONCLUSION

In summary, the Three Gorges project would have a variety of impacts that must be weighed against expected benefits. Strategic vulnerability is a major concern since this 180 m-high dam would be perched above some of China's major cities. Resettlement of rural population from the

reservoir area is likely to be the most difficult short-term problem because of the limited capacity of nearby agricultural land to support more people. If the Han farmers from the flooded area are moved to settlement projects near China's borders the project would contribute to obliterating the minority cultures that predominate there. Movement of urban population is relatively easy, assuming that adequate funds are available; however, the presence of many unauthorized residents in the cities complicates their relocation.

Flooding the gorges would remove a cultural landmark with great symbolic value to many Chinese. Natural habitats in the area to be flooded have already been heavily disturbed and are a relatively minor consideration. The dam may negatively affect dolphins and cranes by flooding shallow water habitats downstream of the dam; fish migrations are already blocked by an existing dam 40 km below the Three Gorges site. Reservoir siltation will impede navigation after only a few years and will eventually reduce storage volume. Silt-free water released from the dam will erode dikes along the middle and lower Yangzi increasing maintenance requirements. Deprivation of nutrients to downstream agriculture and fisheries will be partly compensated by inputs from other sources, but potential impacts need study. The same factors help reduce the potential for coastal erosion, but better information is needed. Officials expect that the weight of the impoundment will provoke earthquakes of magnitudes within the dam's limits of tolerance; high reliability is essential in assessment of seismic effects given the magnitude of the catastrophy that would result should the dam ever rupture. Filling the reservoir would obliterate archaeological sites of interest to scholars, a loss that could be reduced by accelerating the location and recovery of artifacts. The public health impact of the reservoir would probably not be as severe as that experienced in many shallower reservoirs, but the area's high human population density will make monitoring and control measures necessary. If plans are implemented to transfer water from Three Gorges to the Yellow River basin the dam will contribute to the many severe impacts expected from that scheme. The great expense of building Three Gorges would cost China the opportunity to implement many needed development programs, especially if cost overruns follow the example of the country's other dams.

The major justification for the Three Gorges project is reducing the risk of floods in the Yangzi plains. In addition to killing thousands of people, a major flood might cause monetary losses exceeding the cost of dam construction. Alternatives for reducing flood hazard include reforestation in the watershed, building smaller dams on tributaries, and reversing the flow of migrants and industries to high-risk sites. Detailed flood probability calculations and potential damage estimates under various scenarios with and without the dam constitute fundamental information that either does not exist or remains protected from scrutiny. Electricity generation from Three Gorges would be a welcome addition to China's meagre power supply, but the power could be produced more cheaply and quickly from smaller dams elsewhere, or could be saved through energy conservation and population control measures. Over the period needed for dam construction, population growth alone would (at present rates) absorb almost the entire output of Three Gorges.

Completing the environmental impact assessment will be essential in evaluating the range and severity of potential changes. While China may well decide that it is willing to pay the dam's high costs (including strategic vulnerability and loss of intangible cultural and symbolic values), the initiation of preparatory constructions at the dam site before the environmental assessment is complete indicates that the results of the assessment may be moot. Both for the Three Gorges

project and for other development initatives in China it is important that the environmental impact assessment process not become a mere formality whose maximum effect is the implementation of minor modifications in schemes whose existence and overall outline cannot be challenged.

Although China and this project have unique characteristics, the project's evolution has parallels in other parts of the world. Making decisions to implant major projects before environmental factors have been analyzed is common. The POLONOROESTE Project in Brazil (Fearnside, 1985, 1986) is a clear example. Multilateral development banks, especially the World Bank, have been important in speeding the implantation of such projects. Controversy surrounds the question of whether the project review processes within the Banks are adequate to avoid environmentally unwise decisions (Schwartzman, 1986; Walsh, 1986). An obvious first step would be increasing the staff responsible for environmental analysis within the Banks. The World Bank, which funds about 300 projects annually and must review substantially more proposals, had (until recently) assigned to environmental affairs only three of its 3,000 professional employees (Holden, 1986). An internal reorganization in 1987 has raised this figure to 28 (the total may eventually reach 60). It should be noted, however, that few of the new environmental staff are ecologists by training (see Golley, 1987). The World Bank's increase in environmental staff is encouraging; one may hope that these concerns will achieve the prominence in decision-making that they require and that other international lending agencies will create similar environmental departments.

The ultimate responsibility for preserving the environment rests with each individual country. Outside agencies such as the World Bank can have their greatest effect by helping to bolster the institutions responsible for the environment within each country. China would be wise to give high priority to insuring that environmental impacts are evaluated and considered by high level authorities before making decisions on development projects such as the Three Gorges Dam.

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FIGURE LEGENDS

Fig. 1 -- The Yangzi River and proposed cross-China water transfer routes.

Fig. 2 -- Sketch map of the reservoir for the planned Three Gorges Dam (180 m high dam). The map is only approximate, based on publicly-available topographic information (Hubei Planning Committee, 1983; Bartholomew & Son Ltd., 1980). The narrow riverine nature of the reservoir is apparent.

TABLE l: POTENTIAL IMPACTS AND BENEFITS OF THREE GORGES

ITEM	COMMENT
IMPACTS	
Strategic vulnerability	Major concern
. Population resettlement	Major concern.
Cultural landmarks	Significant intangible value to many Chinese.
Archaeological sites	Of value to scholars; needs study
. Natural habitats	Already heavily disturbed; relatively small area to be flooded.
Fauna	Some threats to species requiring shallow water downstream of dam; fish migrations are already blocked by an existing dam 40 km downstream of Three Gorges site.
Yangzi lake hydrology	Higher water level in low water period; no threat of dessiccation.
Erosion and reservoir siltation	Will impede navigation on short term and reduce storage volume on longer term.
Yangzi dikes	Will increase maintenance required.
Agriculture and fisheries production	Some potential impacts need study; some concerns have been overstated.
Coastal erosion	Several factors reduce risk, but needs study.
Earthquake hazard	Needs study; consequences of exceeding the dam's tolerance would be disastrous.
Public health	Probably not severe, but needs study.
Climate change	Not a real problem.
Cross-China Tater Transfer	Many impacts if this scheme is implemented.
China's development budget	Severe drain, especially if cost overruns follow the example of other dams.
BENEFITS	
Flood control	Major justification; alternatives include reforestation.
Electricity	Much needed, but could be produced more cheaply and quickly from smaller dams. Energy conservation

	and population control more cost effective ways of increasing per-capita power supply
Irrigation	A relatively minor justification for the dam for Yangzi valley. Cross-China Water Transfer plan to use Three Gorges water in Yellow River Valley has severe potential impacts.
Navigation	Larger ships could reach Chongqing, but siltation may soon impede navigation.
Reservoir fisheries	Increase in fish production upstream of dam.

NOTES

(1) J.G. Gunn, J.M. Rankin and J.M. Robinson and an anonymous reviewer made valuable comments on the manuscript.

(2) The "upper reaches" of the Yangzi refer to the 4,400 km above Yichang; the "middle reaches" to the 1,000 km from Yichang to the mouth of the Poyang (Boyang) Lake near Jiujiang, and the "lower reaches" to the 900 km through the flat delta plain to the estuary at Shanghai.


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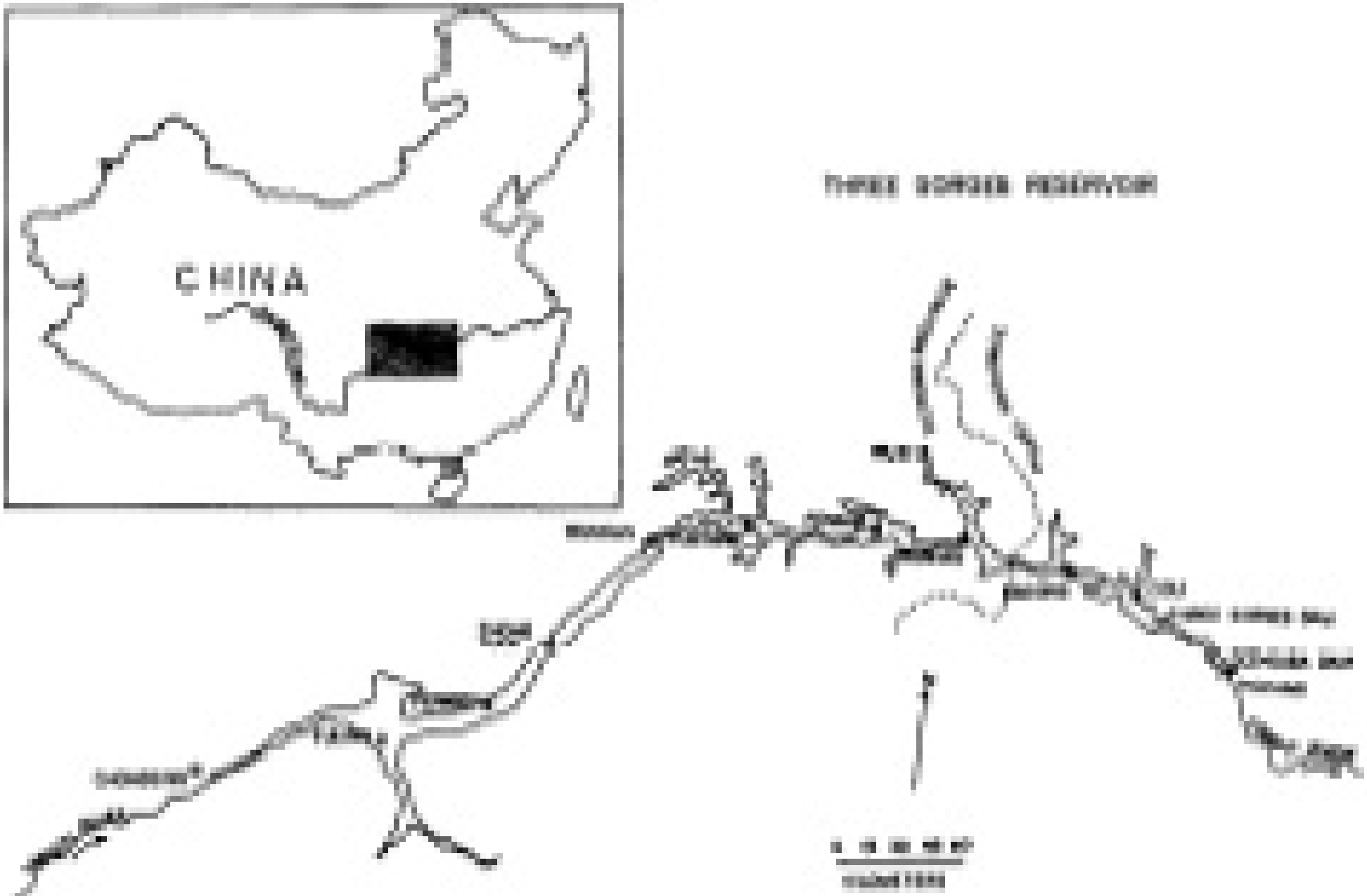
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