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ECOLOGICAL IMPLICATIONS OF MEKONG RIVER DEVELOPMENT PLANS

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The Mekong, one of the great rivers of the world, rises in the mountains of China and flows through China, Burma, Laos, Thailand, Cambodia, and South Vietnam, entering the South China Sea some 2700 miles from its origin. The Lower Mekong Basin whose planning is considered here includes the river's watershed in the four riparian countries, Laos, Thailand, Cambodia, and Viet-Nam, an area inhabited by twenty million people.

To harness the heretofore undeveloped river, the governments of Cambodia, Thailand, Laos, and the Republic of Viet-Nam established a Committee for Coordination of Investigations of the Lower Mekong Basin, to work under the auspices of the U.N. Economic Commission for Asia and the Far East (ECAFE) "to promote, coordinate, supervise and control the planning and investigation of water resources development projects in the Lower Mekong Basin." This project has now entered the implementation stage. Several tributary projects have been completed and major mainstream projects are well advanced. It will take many decades to fully materialize the development scheme, but considerable support has been forthcoming from outside countries. The "Mekong Committee" has thus far made good progress because of a spirit of cooperation among them; the long-run success of the Mekong scheme will depend on a continuation of this spirit.

The planners and executors of the various phases intend to change a seasonally variable water supply to one controlled by man, to curb destructive floods and to make cheap energy abundant.

In 1959 I flew over many a square mile of the Mekong valley with an FAO team. Our first order of business was to decide what studies were necessary to select dam sites and to devise plans for contingent investigations. At the time of this survey over the mainstream and a number of tributaries I was impressed by how strong and ubiquitous a stamp man has already put on this land, despite the low population density of certain regions. Even in what at first glance appeared to be wilderness were many telltale signs of human occupancy. I have viewed these

signs from close up and marvelled at the way they represent man's adjustment to a complex monsoon-dominated ecosystem.

This mutual adjustment of man and nature took place at a rate far slower than that engendered by Homo faber occidentalis, whose presence heralded by our plane overhead, presaged that man's relationship to the land and its waterways would soon be channeled into new directions at a very rapid pace. This paper will explore some changes that the dams of the Mekong project are likely to cause in the non-human components of the Mekong ecosystem, but I cannot refrain from believing that the repercussions on the human co-actors are equally important. As I firmly believe that it is easier to move earth than to move men and that dams can be built faster than new attitudes toward water and land, I will also speculate on some approaches to improving the newly-to-be-created, dam-dominated ecology.

Effects of the new dams on fisheries

Fish and rice are the staff of life in Southeast Asia, and the Lower Mekong watershed encompasses some of the world's most productive freshwater fisheries. Contributing to this abundance are the yearly inundations of low-lying areas in Cambodia and Vietnam at the onset of the monsoon rains. Two large groups of freshwater fishes, the minnows (Cyprinidae) and the catfishes (Siluriformes), are represented by hundreds of species each, as a result of their evolutionary proliferation in Southeast Asia.

The total freshwater fish harvest in all Mekong-related waters is probably greater than 200,000 metric tons. Important components of this harvest are contributed by the fisheries of the Great Lake of Cambodia, by the fisheries of the Mekong River itself from Luang Prabang to the China Sea, and by a seasonal sea fishery off the Mekong Delta where certain species congregate at the time of the silt-laden, nutrient-rich high water flow.

While the natural histories of most species are but incompletely known, our knowledge is sufficient to predict that the mainstream dams proposed at Pa Mong near Vientiane (for river control), and at Sambor or Stung Treng in northern Cambodia (for power production) would have several undesirable effects on the native fish.

The projected dams would certainly block the spawning migrations of a number of species. For instance, the largest true freshwater fish known, Pangasianodon gigas, which spawns above the Pa Mong dam site, would be kept from its breeding sites and almost certainly become extinct. Studies of its now-unknown migration patterns that might lead to artificial propagation below the dam are not indicated by any economic value of the fish, although its roe, prepared like caviar, is a high-priced delicacy. Such lifting devices as fish ladders cannot be used here because of the unusual size and little-known habits of this species. Preservation for its own sake appears unlikely in the circumstances. The major dams will also bar some fish from access to important tributaries. Among the fish so affected would be the sardine-like Hilsa species caught in great numbers in northern Cambodia and in the Nong Han lake of northeastern Thailand. Another highly prized foodfish, Cirrhinum sp., ascends the Mekong and its larger tributaries above Sambor, the Se Kong, and the Se San, side streams with great seasonal water fluctuations; this system might also be interrupted.

These large dams will alter seasonal flow rates and bring subtle changes in the river bottom and in the interplay between flow and temperature at certain seasons, thereby altering the conditions upon which spawning physiology is based. The projected Pa Mong dam is a large structure and will certainly alter the stream flow below it and thus change the fish fauna. Moreover, this portion of the river supplies protein to a region where it is scarce indeed, thus making it imperative to avoid unfavorable impact on the fish population.

Seasonal inundation in low-lying areas of Cambodia and Vietnam is due in part to local excesses of rainwater and in part to flooding from the main river and its tributaries. Sediments carried onto land in this manner maintain fertility for both agriculture and fish production. Eventually, control of the river implies that only irrigation agriculture will be practiced and that many swamps and lakes will disappear; with them will go the harvest from the untended fish populations that used to inhabit them. Additionally, since the dam-altered Mekong will carry less silt, the sea fish concentration in the river's effluent cone in the sea is bound to decrease, thereby lowering the harvest from another sector of the fishery economy.

All the preceding facts suggest that the dams will reduce the fish harvest from the Mekong ecosystem unless certain management measures not now planned are taken. Studies in various regions of India, China and Soviet Russia have shown that large reservoirs can produce fish yields far greater than those previously harvested from the rivers they have modified. Requirements include the selection of species best suited for each specific reservoir, the establishment of facilities for artificial propagation of certain desired species, and intensive management and regulation of the reservoirs. A team of biologists, technicians, and extension experts is desirable for each reservoir.

One of the planned major dams is to cross the outlet of the Great Lake of Cambodia and may permit application of such measures. In fact, one of the main benefits hoped for from this project is increased fish production. This now-shallow lake would be stabilized by the dam at a low-water depth of 2.5 meters, about one meter deeper than at present. At this water level there would be less stirring of sediments by the wind and more photosynthesis. The area of the new lake will be approximately three times its present extent. It is hoped that the dam will allow fish still to enter the lake with the rising water but will retain them at will when the water falls. Fishing in the lake is now practiced by highly mobile fishermen who shift their abodes with the advancing and receding water. The fish harvest

has declined over the past two decades due to changing land use around the lake, silt interfering with primary fish production, and heavy fishing. It is hoped that the overall effect of the dam will be one of increasing primary production in the aquatic ecosystem, although the species composition of the lake biota may change, with some species declining and some augmenting. Since the present lake is being changed only to a larger but similar version of itself, one may expect the fishermen to adjust also with the fish.

Matters are different for both fish and men when new reservoirs are created. The story of the tributary reservoir built at Nam Pong in northeastern Thailand is a case in point, to be heeded by planners of other and larger dams. When the new lake had been formed in 1966, extending over approximately 410 square kilometers, a fishery had also sprung up, unplanned, in expectation of fish proliferation. Middlemen and organizers for what promised to be a profitable venture were attracted, as were some settlers and outsiders displaced from their former abodes, all of whom had to learn fishing as a new full or part-time trade. No extension services were provided for these new fishermen, and no rearing station for suitable high-yield fish species was established, but instead the new reservoir went the way of untended new waters and became topheavy with predators. Although the predators, the snakeheads (Ophiocephalus sp.), are prized foodfish, harvesting them is like cropping wolves instead of deer or cattle, and consequently the fish yield is considerably less than it might be.

It may however be argued that since fisheries were not included in planning the reservoir, even the limited output of the Nam Pong fishery (a yield of about 30 kg/ha) was a success. In fact, optimal use of the reservoir's fish potential would have involved anticipatory attention to transportation, storage, and distribution facilities for sites a hundred or more kilometers away, in addition to the biological management of the reservoir. Now that a market is created, and growing rapidly, there should be concern for early changeover from the predator-dominated waters to a properly cropped and stocked fishery of herbivores, omnivores,

and a few predators. Although the riparian countries' mutual agency has a fishery expert, his powers are advisory only. However, the proper planning of fisheries during dam and reservoir development, making them locally feasible, spells the difference between ecologically sound and unsound uses of a reservoir.

Only 150 kilometers to the northwest of Nam Pong is the proposed site of one of the world's largest dams, the Pa Mong, to contain a lake surface behind it of 1500 or more square kilometers. Like Nam Pong, it will cover forest land and displace a few thousand people (none of them now fishermen). If no advance planning is done for protein production, its now vaunted fishery potential is not likely to be realized. Under proper management the reservoir could produce between 10,000 and 20,000 metric tons of fish, an estimate based on yields from the Great Lake of Cambodia ecosystem and some well-managed Indian reservoirs. At a yearly per capita consumption rate of 20 kg., as in Cambodia, most of the animal protein needs of between a half-million and a million people could be supplied by this source. This amount far exceeds what is now caught in the river a hundred kilometers above and below the dam site. If the irrigation system to be created with the dam were shaped to include pond culture, this aquatic protein production could be multiplied: Each one-hectare pond in Southeast Asia can yield a fish harvest of a ton per year, under even moderately intensive management.

It must be stressed, however, that realization of such potentials requires advance planning and early execution of adaptive research. These activities should include selection of species, propagation trials, and the devising of fishing methods and management techniques to smaller reservoirs, including such topics as where and how to clear trees and anticipation of distribution and marketing needs.

Furthermore, the problems to be anticipated in turning the present residents into fishermen may be even more difficult. While the prospect of changing the habits of traditional farmers has received attention from rural sociologists, anthropologists, and economists, parallel problems in fisheries have hardly been considered. It would be worthwhile to do so in planning the best fishery uses of

the reservoirs now to be created on the Mekong.

Possible impacts of new dams on Mekong ecology

This section will be an overview and therefore suffers almost by definition from the same disregard of details that besets macro-models such as the Mekong development scheme. Some possible consequences of dams appear clear, however.

In the present hydrological pattern certain low-lying areas near the river and its larger tributaries, especially in Cambodia and Vietnam, are flooded annually. A French colonial administrator wrote of them in the early 1900's: "This rhythmical movement of the waters, regular, like breathing, furnishes much of what is needed to improve the land. High waters deposit on the soil a layer of rich silt and spare the farmer the drudgery of transporting fertilizer to the fields, and when the water recedes he finds the ground all ready to support rich and remunerative crops."

These regions of rich river-valley fields on alluvial soils are the sites of the most diversified agriculture practised in the valley, and would certainly be endangered by a more regulated river flow. Mineralization would be accelerated, the soil temperature would increase, and their fertility would decline. However, these lands could easily be irrigated due to their topography, their cultivators are settled, and it may not take too much change in the farmer's outlook or reorganization of their practices to adapt to a new and also prosperous regime. I would also expect further crop diversification, the introduction of high-yield varieties, and some mechanization soon after irrigation water can be supplied.

In contrast to the fertile river valleys, most of the watershed of the Mekong has poor to medium-grade soils; they are dry, often leached, over-used, and sometimes acid, especially in northeastern Thailand with its low humic gleys, its grey and red-yellow podsols. Cultivation has been attempted where forests should

have remained. In remote areas slash-and-burn agriculture is practised, as well as the burning of forests for driving game. The use of manure, let alone fertilizer, is virtually non-existent. This type of land use is logical and perhaps even economically justifiable in a primitive economy with a vast surplus of land. But given demographic trends, it must sooner or later conflict with other land use patterns and lead to deleterious run-off and erosion. Eventually the shifting cultivators will settle and compete with small villages for suitable soil to grow crops. Without irrigation they would be limited to one crop a year, but their growing season could be a nearly year-round one if water were available. The soils would need to be built up, rotation practised, and fertilizers and probably insecticides employed for the high-yielding crop varieties advisable to plant in proper terracing or strip cropping patterns. We also assume that the new irrigation canals would be built with more regard for natural drainage patterns than were those that now exist.

Theoretically, then, vast areas of soil would be improved by the building of dams and changes in agricultural practices could occur. There are, however, in the human ecology of the region formidable obstacles to attaining this utopian state. Transition to irrigation agriculture of the kind envisaged requires a complex social organization with cooperation between social units such as villages, delegation of authority, and a well-functioning central or provincial government extension service, to name only the most important ingredients. Agriculture in much of the basin, but certainly in northeastern Thailand, is a family affair with each family autonomous in decision-making, and help is traded between families only occasionally. Many villages are not well-functioning social units, and cooperation among villages is virtually unknown. The creation of irrigation districts with common funds to be administered would pose severe cultural obstacles.

There is clearly some one-sided emphasis in Mekong development planning. It is perhaps not germane to this conference to speculate on how to redress this imbalance, but it is important to stress that ecologists and sociologists must be

given a stronger voice both in the planning process and in the execution of the various schemes, because they can be instrumental in bridging at least a few of the gaps that now exist.

There will arise as a result of dams many square kilometers of new water surfaces and many kilometers of new shorelines in the Mekong valley. In addition, many water courses will have new connections such as the new canal from Pa Mong to Nam Pong. Diseases and their aquatic intermediate hosts will have an opportunity to spread. Snails and mosquitoes are probably of greatest concern as vectors. Snails are known to carry a liver fluke (the snail host is Bythnia sp.) and three species of schistosomes (S. Japonicum, S. spindale and Trichobilharzia sp.). Opisthorchiasis (liver fluke) infection is reasonably high in certain portions of northeastern Thailand, while the incidence of schistosomiasis is, at present, low. Snails are also hosts of the worm parasite Angiostrongylus cantonensis, which causes eosinophilic meningitis. Paragonimiasis is also found endemic in northern Thailand; its metacercariae have been located in freshwater crabs. Diseases carried by water-dependent insects include malaria and Bancroftian filariasis, both now having low incidence levels in the area.

There is a reasonably good chance that one or several of the intermediate hosts of these diseases may undergo proliferation when permanent waters are increased as they will be through mainstream or tributary reservoirs. The health authorities of the riparian countries are at present ill-equipped to carry out an evaluation of the results probable from changes in the aquatic ecology. To my knowledge inadequate attention is paid to the problem on the part of international organizations. Strategies for increased mosquito eradication and the use of mollusk poisons are the least measures that should be anticipated.

The new dams will also affect wildlife habitats throughout the region. The largest presently planned dam is Pa Mong. Though no bird and mammal survey has been done in the area to be flooded it appears unlikely that unique habitats or

truly endemic species exist in the 1500 km^2 reservoir site. Nevertheless, such a faunistic survey would be well worth making.

Another potential dam development centers around Khone Falls and Stung Treng in northern Cambodia; while no feasibility studies of this project have been made as yet, preliminary reconnaissance indicates that considerable areas of savannah habitat would be flooded. The water would cover a region known to harbor not only the rare primitive cattle, the kouprey (Bos sauveli), already threatened by uncontrolled hunting, but also a large number of other ungulates. Their density is reported to rival that of ungulates on the African plains, and game farming in northern Cambodia appears as a distinct wildlife management possibility. It is highly recommended that an intensive survey of the larger vertebrates of this region be made and that, should the findings warrant it, such a good conservation land use as game farming be considered in the planning for river modifications in this area.

If irrigation is practised in some portions of the basin as a result of dams and reservoirs, farming will become intensified and with it the use of insecticides. It is hoped that by that time chlorinated hydrocarbons will have been replaced universally by non-persistent varieties. Fishes are very susceptible to certain insecticides. Some adaptive research may be necessary to safeguard fish harvests, and certainly to make possible fish culture either in conjunction with the growing of rice or in ponds close to areas where other crops need insecticide treatment. It should be stressed that insecticide use in the tropics requires emphasis on the insects' year round growing season, their consequent ability to develop resistant strains faster than insects of the temperate zone, and attention to the peculiar nature of tropical soils, both wet and dry.

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Under any political system the population of the Mekong basin is sure to increase, and its aspirations will rise. Increased power and improved agriculture

are therefore desirable, as are the other benefits of dams such as flood control and the improvement of navigation. Disfunctions in even the nonhuman ecology may result from a planning process that relies overmuch on what man can do with bulldozers and cement. Strains in the relation of man to the land on which he has to live are inevitable when such rapid changes are initiated. If those who plan and execute the changes attempt an assessment of optimal social and ecological rates of change, these consequences may be less painful. For this assessment studies now not undertaken are needed, as is the advice at all levels of ecologists and sociologists, representatives of disciplines sometimes but not sufficiently consulted.

I thank my colleagues at the Center for Southeast Asian Studies of Kyoto University where this paper was written and R. V. Pantulu of the Mekong Committee for much counsel and advice.

Appendix

Source: A Compendium of Major International Rivers in the ECAFE Region
Water Resources Series #29
United Nations, New York, 1966.

MEKONG RIVER

Summary of basic data

Total drainage area	795,000 sq km	307,000 sq mi
Drainage area of the lower basin in Laos, Cambodia, Thailand and Viet-Nam	609,000 sq km	236,000 sq mi
Drainage area at Chiang Saen (near Burma border)	189,000 sq km	73,000 sq mi
Drainage area at Vientiane	299,000 sq km	115,500 sq mi
Drainage area at Kratie (547 km from the sea)	646,000 sq km	250,000 sq mi
Length of main river	4,350 km	2,700 mi
from source to Chiang Saen (upper basin)	1,955 km	1,215 mi
from Chiang Saen to the sea (lower basin)	2,395 km	1,485 mi
Slope of river		
from source to China border	1:400	
from China border to Vientiane	1:2,900	
from Vientiane to river mouth	1:16,000	
Average annual precipitation over river basin	1,380 mm	54.5 in
Maximum flood discharge		
at Chiang Saen	11,900 m^3/sec	420,000 cfs
at Vientiane	20,800 m^3/sec	735,000 cfs
at Kratie	67,000 m^3/sec	2,360,000 cfs
Average annual discharge		
at Chiang Saen (1961-63)	2,770 m^3/sec	97,700 cfs
at Vientiane (1923-44 and 1948-63)	4,575 m^3/sec	161,500 cfs
at Kratie (1933-44, 1946-53 and 1960-63)	14,300 m^3/sec	522,000 cfs
Minimum discharge		
at Chiang Saen	570 m^3/sec	20,100 cfs
at Vientiane	701 m^3/sec	24,800 cfs
at Kratie	1,250 m^3/sec	44,100 cfs
Specific flood discharge at Kratie	0.104 m^3/sec/sq km	9.50 cfs/sq mi
Average unit discharge at Kratie	0.0229 m^3/sec/sq km	2.10 cfs/sq mi
Maximum annual runoff at Kratie (1939)	567 billion m^3	460 million acre ft
Average annual runoff		
at Chiang Saen (1961-63)	87.3 billion m^3	70.7 million acre ft
at Vientiane (1923-44 and 1948-63)	150 billion m^3	121.5 million acre ft
at Kratie (1933-44, 1946-53 and 1960-63)	467 billion m^3	378 million acre ft
Mean annual runoff expressed in depth at Kratie	722 mm	28.4 in
Minimum annual runoff at Kratie (1936)	391 billion m^3	317 million acre ft
Maximum silt content at Vientiane	3,076 ppm	or 0.31%
Average silt content at Mukdahan (1963)	597 ppm	or 0.06%
Average annual silt runoff at Mukdahan (1963)	170 million metric tons	
Average annual silt runoff per unit area at Mukdahan (1963)	435 m tons/sq km	1,100 long tons/sq mi

MAIN TRIBUTARIES IN THE LOWER BASIN

	Drainage area sq km	Length km	Discharge in m^3/sec			Gauging station
			Maximum	Minimum	Average	
Nam Ou (Laos)	25,600	380	...	...	700 — 800	...
Nam Ngum (Laos)	16,000	260	3,250	77	567 (1962)	Tha Ngon
Nam Theun (Laos)	14,700	230	...	...	...	
Se Bang Fai (Laos)	9,550	220	3,320	15	685 (1961)	Se Bang Fai
Se Bang Hieng (Laos)	19,800	320	6,360	15.4	773	Ban Ken Done
Se Done (Laos)	7,790	190	2,420	1.6	229	Ban Nanay
Nam Mune & Nam Chee (Thailand)	117,000	550	3,930	13.7	627	Ubon
Se Kong (Cambodia)	29,600	370	9,980	77	1,740 (1961 & 62)	Ban Khmuon
Se San (Cambodia)	18,000	360	12,600	106	1954	Ban Komphan
Srepok (Cambodia)	30,800	390	...	...	...	...
Tonle Sap (Cambodia)	84,400	400	12,500	0	792	Prek Kdam
Stung Sen (Cambodia)	17,800	290	930	4.2	255	Kampong Thom

Note: ... indicates information not available.

Physical features

One of the great rivers of the world, the Mekong, (which is called the Lan Tsang in China and the Mekong in Burma, Laos, Thailand, Cambodia and Viet-Nam) rises on the snow clad slopes of the Dza-Nag-Lung-Mung range in the Tibet-Sikang plateau, about latitude 33°N and longitude 94°E, at an elevation of about 5,000 metres (16,700 ft). It flows in a south-easterly direction through rugged mountain ranges for a distance of about 425 km to Chamdo town, at elevation 3,000 metres (10,000 ft). There it changes its direction to flow south and enters Yunnan province of China near Yentsing town after a distance of 300 km.

In Yunnan, it flows through steep gorges and mountain wastes, which are little known, for about 1,000 km. A few mountain torrents join the river from both sides. The famed Burma Road which links Lashio in Burma with Kunming in China crosses the Mekong at a point approximately 23° 30'N, at an elevation of about 1,450 metres (4,700 ft). From its point of exit from Chinese territory near Keng Hung where the elevation is about 300 metres (1,000 ft), it forms a common border between China and Burma for a short length of about 30 km. Its width along this stretch reaches 300 to 400 metres. Then it forms the border between Burma and Laos for approximately 200 km to near Chiang Saen town.

Between Chiang Saen and Pak Tha, where it leaves the Thailand—Laos border to flow in Laos, it is joined by Nam Mae Ing from Thailand. From Pak Tha to Luang Prabang the river flows east and is obstructed by a series of rapids. Some important tributaries, viz. the Nam Tha, Nam Beng, Nam Hou and Nam Seng join the river in this reach.

At Luang Prabang, where the elevation is about 200 metres above mean sea level the river turns to flow south to Chiang Karn. The distance between Chiang Saen and Chiang Karn is approximately 650 km.

From Chiang Karn the river changes its direction to flow eastward, forming once again a common border between Thailand and Laos; mountain ranges diminishing in size appear on both banks of the river to about 30 km above Vientiane, where the river debouches into the open plain. From this point to Nakorn Phanom, where it again turns to flow southward, and thence to Savannakhet, the river flows through open country over a sandy gravel bed. This reach is open to navigation except at Keng Kabao above Savannakhet, where a series of rapids occur. Many important tributaries join the Mekong within this stretch, the Nam Ngum, Nam Theun or Nam Ca Dinh, Se Noi or Se Bang Fai from Laos and Nam Song Khram from Thailand. From Savannakhet downstream to the confluence with the Mune river, the Mekong cuts into the plateau's sandstone strata and a series of rapids called Khemmarat form serious barriers. In many sections, the river is confined within high gorge walls. The current is torrential and during flood time the velocity may be as high as four to five metres per second. Navigation is possible only by powerful craft. Large tributaries draining into it are the Se Bang Hieng from Laos and the Mune river from Thailand. This stretch, which forms the Thailand-Laos border from Chiang Karn to a short distance downstream from the mouth of the Mune river, is 820 km.

From there to Khone Falls in Laos, a distance of 190 km, the Mekong flows in an open valley and the river is dotted with rocky outcrops separated sometimes by small islands. Khone Falls has a drop of about twenty two metres within a distance of ten kilometres. Here again, the river is divided into many channels separated by rocky islands. Naviga-

tion is impossible here because of the torrential current. Some five kilometres below the falls, the Mekong enters the plain of Cambodia.

Upstream of Stung Treng two large tributaries, the Se Kong and the Se San join the Mekong from the left bank at the same point. At Sambor north of Kratie, rock outcrops protrude to low water-level making navigation during the dry season impossible. Below Kratie, the Mekong assumes the form and characteristics of an alluvial river. The river banks are built up by flood deposits and there are sand bars, sand banks and islands scattered along its course. During the dry season, the tidal effect is felt at Phnom Penh, where the Tonlé Sap or the Great Lake joins the Mekong. The lake acts as a huge detention reservoir moderating the flood flow downstream. Immediately below this confluence, the river bifurcates into the Mekong on the east and the Bassac on the west. These two effluents are connected by the Vam Nao in Viet-Nam, about fifty kilometres below the border between Cambodia and South Viet-Nam. Further downstream, the Mekong is divided into five branches before it enters the South China Sea.

The lengths of the Mekong in Cambodia and South Viet-Nam are 505 and 225 km respectively.

The total length of the Mekong is about 4,350 km (2,700 miles) and the total drainage area 795,000 sq km (307,000 sq miles), of which 77 per cent or 609,000 sq km (236,000 sq miles) is within the lower basin.

The lower Mekong basin, as it is now generally called, refers to the watershed below the Burma-Laos-Thailand border near Chiang Saen. It includes the watershed in the four riparian countries, Laos, Thailand; Cambodia and Viet-Nam, the area of which is larger than the whole of Thailand or France.

Rainfall and runoff

The Mekong is a perennial river; it is snow fed in its upper reaches and receives monsoon rainfall in the lower reaches. The average annual precipitation over the basin is about 1,380 mm. The minimum discharge at Kratie in Cambodia is 1,250 m^3/sec., whereas the average annual discharge at the same station is 14,800 m^3/sec. The peak discharge generally occurs during the September-October months. The average highwater discharge at Kratie is about 33,200 m^3/sec.; and in 1939, the year of highest recorded flood, the peak discharge at this station was estimated to have reached 67,000 m^3/sec. Every year the river discharges about 575 million acre-feet into the South China Sea.

Era of development just begins

Twenty million people live in the lower Mekong basin. They use its waters in their households and in their cultivated fields. They fish in its waters and travel about on the river and its tributaries. In spite of that, the river has hardly been harnessed. Its tremendous volume of water has been utilized in with fatalistic acceptance of the benefits and scourges bestowed by a great river in its natural condition. Its great hydroelectric potential has never been developed and less than 3 per cent of the area under cultivation is irrigated, drained or protected against floods. The most extensive hydraulic work so far undertaken is a network of drainage and navigation canals in the delta west of the river in the Republic of Viet-Nam.

As early as 1951 the Economic Commission for Asia and the Far East (ECAFE) decided at its seventh session at Lahore to include the problems of flood control of international rivers in the work programme of the Bureau of Flood Control. (Later this name was changed to Bureau of Flood Control and Water Resources Development and subsequently to Division of Water Resources Development.) The Bureau suggested the initiation of a study of the Lower Mekong Basin. A team of Bureau experts, jointly with officials from the riparian countries, then reconnoitered the lower basin and prepared a report outlining the possibilities for development of the Mekong (Flood Control Series No. 12, 1957). It pointed out five project sites which deserved high priority for investigations, viz. Pamong; Khemarat, Khone Falls, Sambor and Tonlé Sap. In October 1957, the Governments of Cambodia, Laos, Thailand and the Republic of Viet-Nam established under the auspices of ECAFE, a Committee for Co-ordination of Investigations of the Lower Mekong Basin, composed of representatives from the riparian countries. The agreement provides that the Committee shall consist of a plenipotentiary representative from each of the four riparian countries, and vests in the Committee the authority "to promote, co-ordinate, supervise and control the planning and investigation of water resources development projects in the Lower Mekong Basin," and to "make requests on behalf of the participating governments for special financial and technical assistance and receive and administer separately such financial and technical assistance".

At the request of the Committee, a mission of specialists headed by Lt General Raymond A. Wheeler of the United States was organized in 1957 to undertake an on-the-spot survey of the river, and prepare a detailed programme of investigations leading to the development stage. The report of the mission reaffirmed the potential of the Mekong as outlined in the ECAFE report and specifically

recommended a five-year programme of studies and investigations. This programme was adopted at the second session of the Co-ordination Committee held in February 1958.

A further step in the implementation of the Mekong programme was the appointment of an Executive agent of the Co-ordination Committee within the framework of ECAFE in 1959. The Executive Agent ensures a measure of continuity between Committee sessions and deals with the ever-increasing technical and administrative complexities of the project.

With the help of many countries and agencies, most of the above programme and several other tasks have been completed. More than that, the project has entered into its implementation stage. Two tributary projects have been constructed and three more are under construction.

The Mekong development project has captured the imagination and interest of the World. Financial aid, both granted and loaned, and technical assistance given to the Mekong project up to the end of 1965 amounted to $105 million equivalent. In addition to the four riparian countries, 21 countries[1] from outside the basin, 11 United Nations agencies,[2] 2 foundations and a number of private business organizations have collaborated with the Mekong Committee in making the above sum available either in cash or in kind.

Works on the Mekong development project so far carried out and those which are under way are briefly described below:

1. *Basic data collection*

Hydrologic work in the Mekong Project is carried out by the Hydrology Departments in each of the four riparian countries, which are staffed by some 50 engineers and technicians assisted by a few experts in the Committee's Secretariat. With the co-operation of France, India, New Zealand, the United Kingdom and the United States, a basic network of 44 stream ganging stations has been established in the lower Mekong basin. The collected data are published annually in the Hydrologic Yearbook which was started in 1961.

With assistance from India, the United Kingdom and the United States, a network of 51 meteorological stations has been established throughout the lower basin. In collaboration with national meteorological services in each of the four countries, the data on temperature, wind velocity, humidity, evaporation, solar radiation and precipitation are collected and also published in the Hydrologic Yearbook.

Aerial photographing, levelling and ground control of the Mekong River from the Burma border to the sea was completed with the assistance of Canada in 1961. Mainstream maps on a scale of 1:20,000 from the Burma border to Phnom Penh, aerial mapping of three mainstream dam sites—Pa Mong, Khone and Sambor—and maps and mosaics of several dam sites on the major tributaries on the scale of 1:2,000, also prepared by Canada, were completed.

2. *Basin planning*

In the Mekong Scheme, the Committee's overall plan has so far been following very closely the original scheme as outlined in the report *Development of Water Resources in the Lower Mekong Basin.*[3] In the light of the vast amount of basic data collected under the Committee's auspices from 1959 onwards, the Committee decided in 1962 that an amplified and improved basin plan should in due course be prepared. This work assigned to the ECAFE secretariat, is to be completed towards the end of 1967.

3. *Mainstream projects*

The Committee in 1957 assigned first priority to three mainstream projects—Pa Mong, Sambor and Tonle Sap—and hopes ultimately to develop these into a system of five or more mainstream projects. Progress to date on the three first priority mainstream projects is briefly described below.

Pa Mong. The proposed Pa Mong mainstream project is conceived of as providing one of the principal reservoirs in the system of projects within the Mekong Scheme, making possible a measure of control of the river from above Vientiane in Laos down to the sea. On the basis of present data, it is hoped that this project may be able to irrigate about one million hectares of land in the north-east of Thailand and Laos and that it can have, if desired, an installed capacity of about one million and a half kW of power. Its reservoir would facilitate upstream navigation for a considerable distance.

The geologic investigation of the dam site by means of bore holes was started in 1962 and completed in 1964 by an Australian Snowy Mountains

[1] Australia, Belgium, Canada, China, Denmark, Federal Republic of Germany, Finland, France, India, Iran, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Pakistan, Philippines, Sweden, United Kingdom and United States.

[2] United Nations ECAFE, United Nations Development Programme, United Nations BTAO, ILO, FAO, UNESCO, WHO, WMO, IAEA, IBRD (World Bank) and World Food Programme.

[3] Flood Control Series No.12, United Nations publication, Sales No.:1957.II.F.8.

Mekong Team. The first phase of the feasibility study of the project undertaken by the United States Bureau of Reclamation Team was finished in June 1965 and the second phase, which has already been started by the same organization, is to be completed by 1968.

Sambor. The proposed Sambor mainstream project in Cambodia is conceived of as a run-of-river power plant project, involving a dam to utilize the regular flow of the Mekong with a very limited reservoir storage. The preliminary investigation suggests a dam 36 metres high and about 29 km long. In the initial stage, the installed capacity would be about 650,000 kW with an annual output of 4.6 billion kWh. The electric power could be used for industrial and domestic purposes as well as for extensive irrigation and drainage pumping in Cambodia and the Republic of Viet-Nam.

The geologic investigation of the many alternative dam sites was completed in 1963 by the Australian Team under the Colombo Plan. The dam site and reservoir area maps were also completed through the Canadian and Philippines Mekong support programmes. During 1964, mapping of the irrigable area of some 80,000 to 100,000 ha was commenced by the Service Geographique Khmer and it is anticipated that this work will be completed by the end of 1966. The comprehensive feasibility report is under preparation with the assistance of Japan and it is hoped that the report will be brought to completion by the end of 1967.

Tonle Sap. The conception of the Tonle Sap Project centers upon the installation of a gated barrage across the Tonle Sap (Great Lake). It is proposed to regulate the operation of the gates in the barrage so that the storage capacity of the Great Lake is utilized to reduce the intensity of the flood during the high flood period, to maintain water level in the Great Lake at about one metre above the present lowest water level, and to provide adequate flow in the Mekong River during the dry season to facilitate navigation for oceangoing vessels moving to and from Phnom Penh, the capital of Cambodia. Thus, the implementation of this project will result in such benefits as securing increased fish production, irrigation, navigation, salinity control, reduction of flooding and, probably in conjunction with cheap electric power at Sambor, the reclamation of unproductive areas in the delta.

The fisheries study of the Great Lake was made by France. During 1964, the Philippines completed a contour map of the Great Lake reservoir and the International Atomic Energy Agency submitted to the Committee a detailed report of sedimentation in the Lake. The engineering feasibility of the barrage was completed by India also in 1964.

4. *Tributaries projects*

Since its establishment in 1957, the Committee has adhered to the principle that planning for the development of water resources of the Mekong should cover the entire lower basin, including the mainstream and its tributaries. The Committee holds the view that tributary projects, although smaller than mainstream projects, are of great importance, partly just because they cost much less and require much less time to construct than mainstream projects, and partly because experience gained in and markets developed by the tributary projects, situated throughout the basin, will prepare the ground for the larger mainstream undertakings.

A reconnaissance of the 34 principal lower Mekong tributaries was completed by a Japanese Team in 1961. The report of the team has since then served as a basic study in the Committee's tributary development work. To date, five tributary projects have entered the stage of construction (Prek Thnot in Cambodia, Lower Se Done and Nam Dong in Laos, and Nam Pong and Nam Pung in Thailand). Feasibility investigations have brought six additional tributary projects to the point where they are ready or approaching readiness for negotiations for construction finance (Battambang in Cambodia; Nam Ngum in Laos; Upper Se San, Drayling, Darlac and Krongbuk on the Upper Sre Pok in Viet-Nam). Six tributaries are under varying degrees of investigation (Stung Pursat and Stung Sen in Cambodia; the Upper Se Done and Nam Theun in Laos; and Lam Dom Noi and Huey Bang Sai in Thailand). Thus the Committee is now involved in work on 17 tributaries.

The following paragraphs give a brief description of six tributary projects, of which two have been completed (Nam Pong and Nam Pung in Thailand), three are under construction (Prek Thnot in Cambodia, Lower Se Done and Nam Dong in Laos) and one is anticipated to begin the construction shortly (Nam Ngum in Laos).

Nam Pong tributary project in Thailand

The project comprises a storage dam with a powerhouse at Pong Neeb site situated about 50 km northwest of Khon Kaen town in north-eastern Thailand and a diversion dam at Nong Wai, 35 km downstream from the first dam. The storage dam is an earth-fill dam 30 metres high and 800 metres long. The powerhouse has an initial installed capacity of 16,000 kW (2 units of 8,300 kW) which will be increased to 25,000 kW, capable of generating some 65 million kWh annually in the final stage. The diversion dam will divert water into a system of canals for the irrigation of 22,000 ha in the first

stage and 47,000 ha in the final stage. The project also has flood control and fisheries development benefits.

The construction of the storage dam and powerhouse, the diversion dam, transmission lines and substations was commenced in 1964. The project was financed partly by a loan from the Federal Republic of Germany to Thailand and partly by Thailand itself. The storage dam and powerhouse, transmission lines and substations were brought to completion and the dam and powerhouse were inaugurated in March 1966. The diversion dam is to be completed shortly and the construction of the canal system has been commenced.

Nam Pung tributary project in Thailand

The Nam Pung dam and power plant are about 30 km southwest of Sakol Nakorn town in northeastern Thailand. The dam is of rock-fill type, about 30 metres high and 940 metres long. The power plant generates some 18 million kWh annually from two units of 3,500 kVa each. The project will also give irrigation benefit to some 8,000 ha by pumping water from the Mekong River and gravity irrigation in the dry season to some 16,000 ha.

The construction of this project was financed by the Thai Government. The dam, power plant and transmission lines were completed and put into operation in November 1965.

Nam Dong tributary project in Laos

The project is located about 9 km south of Luang Prabang. The first stage will comprise two units of 345 kW each and an additional unit of 345 kW will be installed in the final stage. The electric power generated here will be supplied to Luang Prabang. The target date of completion is 1969.

Lower Se Done tributary project in Laos

The dam and power plant are situated about 30 km north of Pakse in southern Laos. The power plant will house two units of 720 kW each. The project is to be completed in 1969.

Prek Thnot tributary project in Cambodia

The project, comprising storage dam and power plant and a diversion weir, is about 70 km west of Phnom Penh. The weir will be 12 km downstream of the storage dam. The project when completed will generate some 37 million kWh annually from two units of 9,000 kW each. It will also irrigate some 70,000 ha and give flood control benefit. The construction work is under way.

notyet

Nam Ngum tributary project in Laos

Since 1964, the Committee has attached high priority to this project as the next on the list of those under construction.

The dam site is about 70 km north of Vientiane. The dam will be of concrete gravity type, 66 m above the bed rock with a length of 360 m. The project is designed to generate initially 20,000 or 30,000 kW and finally 120,000 kW and to irrigate initially 5,000 ha and finally 32,000 ha both by gravity and pumping. Based on the feasibility study, the project will cost initially some $27 million.

This project is of capital importance to Laos, not only because of the direct benefits to Vientiane and environs of power and irrigation, but also because the project will at one stroke end the dependence of Vientiane on imported fuel supplies for power generation and replace such dependence with a foreign currency earner in the form of the Nam Ngum power exported to Thailand. This project will be the first within the Mekong complex which will involve the international exchange of electric power. The power from the Nam Pong project in Thailand will be exported to Laos during the period 1966/69 and the power from Nam Ngum dam will be exported to Thailand after its completion.

In May 1965, half of the requisite funds for the project was pledged as a United States grant and, in June the same year, the World Bank agreed to administer the construction of this project.

5. *Navigation improvement*

To ensure well balanced over-all economic development of the four Lower Mekong riparian countries, the development of waterways, including waterways equipment and port installations is being undertaken together with the development of other means of communication in the basin, and as an integral part of the development of the basin's water resources. Without waiting for the great benefits to navigation which will be brought by the completion of the mainstream dams, short-run measures are being taken to assist navigation by improving and marking the channel and by improving ports, shipyards and boat design. Much progress has been achieved in this field; hydrographic survey offices have been established or strengthened in the four riparian countries; a hydrographic survey of navigable stretches of the river from Luang Prabang to the sea has been undertaken and various navigation charts have been produced and surveys undertaken for river training works, bank protection and dredging on many stretches. At the river mouth, three large buoys (8 ft diameter) have been moored on the bar in the China

Sea to guide ocean-going vessels to the entrance of the Mekong River. In the maritime section of the river, buoys (with 5 ft diameter) with electric lights have been installed in the Quatre-Bras navigation channel leading to Phnom-Penh harbour; leading lights and range lights are being installed on beacons on the stretch between the Cambodian/Vietnamese border and Phnom-Penh.

An $18 million programme has been endorsed providing for substantial increase of tugs and barges in the Mekong delta in Viet-Nam.

6. *Ancillary projects*

Economic and social studies A Ford Foundation team visited the basin in 1961 to study the various complex socio-economic problems connected with its comprehensive development. The report of the team was published in 1962. Many of the Committee's ancillary projects have subsequently been based upon or modified by recommendations of this mission, including resources inventories; power market surveys; flood forecasting and agricultural research, demonstration and training.

Natural and social resources inventories Towards the end of 1964, the United States offered to prepare a comprehensive assessment of resources on the Lower Mekong Basin utilizing existing information in line with a recommendation of the Ford Foundation Mission report. The project will be undertaken jointly by the Resources Inventory Center of the Corps of Engineers and the Tennessee Valley Authority, and is expected to be completed in 18 months.

Comprehensive regional agricultural planning in selected areas At the end of 1964, the Government of Israel offered to assist the Committee with comprehensive regional agricultural planning in regions of the basin, covering diverse aspects of development, including transport, public health services, and industrial development. The Committee requested, and Israel agreed, that assistance would be given to undertake as soon as possible the comprehensive regional planning of 5,000 ha to be irrigated by the Nam Ngum tributary project in Laos.

Mineral Surveys It was early recognized by the Mekong Committee that mineral industries within the Lower Mekong Basin would stimulate and enhance its economic development and, besides, provide substantial markets for electric energy. Mineral exploration initiated by the Committee is at present being carried out with aid from the United Nations Special Fund and with bilateral aid from France and the United Kingdom.

Experimental and demonstration farms Recognizing the importance of research and demonstration stations not only to provide comparative basic data for the development of future irrigation projects, but also to assure the speedy and full utilization of water resources in the whole basin, the Committee seeks to establish such stations in all four riparian countries. There are now nine of these stations in operation in the Committee's programme.

Domestic power market France has, with a team of three experts, carried out for the Committee a projection of power markets throughout the basin, which was commenced in March 1963; the field work was concluded in November 1964.

Regional power market The Committee is carrying out by stages a power market analysis concerning potential transport-oriented electric-process industries for the area and the intra-regional market. Studies have been initiated of the possibility of establishing electro-chemical and electro-metalurgical industries in which power figures as a significant cost, such as those producing fertilizers, caustic soda and steel by the use of electric furnace. The possibility of establishing a large-scale pulp and paper industry has been studied by the Committee with the help of the Nordic Group of countries, Denmark, Finland, Norway and Sweden. Within the conception of regional industries which will provide the market for the Mekong power, it is proposed also to study some of the industries of the countries located outside the Mekong Basin but within the region, which operate at present on relatively more expensive power and for which cheaper power in their own countries is not likely to be available. The study will include examination of the extent to which such industries might with advantage locate some of their activities within the Mekong Basin.

Flood warning system In 1962, a survey of the feasibility of a flood warning system was undertaken for the Mekong Committee under French aid. The report of the survey, which was completed in January 1964, indicates that long-term flood forecasting appears impossible because of the present insufficient basic data and knowledge of the Mekong Basin hydrology and meteorology. However, a short term forecasting method is recommended for use in the various stations of the Mekong from Luang Prabang to Kompong Cham in Cambodia so that prediction could be made up to about 9 to 10 days in advance at Phnom Penh. During 1964, the Committee was able to establish such a short-term flood warning system between Stung Treng and Phnom Penh in Cambodia. It is hoped that, with the development of further data, further progress will be possible towards the establishment of a flood warning system.