Hydrological Modeling of the Mekong River Basin

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The Mekong river, with a basin of almost 800,000 square kilometers and a length of nearly 4,200 kilometers ranks amongst the world's great rivers. It rises in Tibet and flows through China's Yunnan Province, Burma, Thailand, Laos, and Cambodia before reaching the South China Sea in Vietnam. The riparian people, plants, and animals depend on its annual cycle of flood and drought. Wetlands along the river, including the Tonle Sap and the Mekong delta, supply 50–80 percent of the total protein intake for basin residents in the form of fish.

The Mekong river usually begins rising in May and peaks in September or October, with the average peak flow at Phnom Penh faster than 45,000 cubic meters per second. Flows taper off after November and reach their lowest levels of roughly 1,500 m^3/s in March and April. The average annual total discharge is roughly 450 billion cubic meters.

sustainable water development

Cambodia's Tonle Sap, or "Grand Lac" plays a vital role in the Mekong river system and in the Cambodian economy. In the dry season, the Great Lake's shallow waters cover roughly 3,000 square kilometers, and the lake drains slowly into the Mekong river. As the rainy season progresses, the river rises above the Tonle Sap level, and the flow reverses, filling the lake. The lake typically expands to more than 10,000 km^2. As floodwaters reach the surrounding forest and agricultural areas, the lake receives a massive influx of nutrients that trigger a surge in productivity. The Tonle Sap is renowned to be one of the most productive freshwater ecosystems in the world, supporting 60–75 percent of the inland fisheries in Cambodia, with harvests whose levels have historically reached 100,000 tons per year. After rice, fish is the most important component of the Cambodian diet, accounting for as much as 80 percent of the animal protein consumed.

Figure 1. Existing dams (yellow) and planned dams (red) on the Mekong river and its tributaries.

The Mekong river fisheries are a tremendously valuable resource to the 50 million residents of the basin. Fishers harvest more than 700,000 metric tons of over 300 commercially important species each year. The Mekong discharge into the South China Sea also supports a productive coastal fishery. Estimates of annual per capita consumption of fish are 30 kg in Vietnam, 15.3 kg in Thailand, 13.3 kg in Cambodia, and 6.5 kg in Laos. Fish supply 50–80 percent of the total protein intake of the basin residents.

Fishers and scientists have documented a critical link between the Mekong main channel, its floodplain wetlands and agricultural land. During periods of high water, flooded areas serve as primary breeding and nursing grounds for 90 percent of the Mekong fish species. Nutrients stored in floodplain vegetation are made available to the river food chain when inundated, causing a surge in productivity. Floodplain areas produce three times as much fish per area as the main channel, and of the estimated 700,000 metric tons caught annually, roughly 236,000 tons are attributed to floodplain areas.

Approximately 5 percent of the annual flow of the Mekong is regulated by dams. However, the pace of hydro-development on the Mekong is accelerating. It is estimated that only 20.5 terawatthours per year are developed out of a potential development of 1,090 terawatthours per year in the Mekong countries. While these values are for the countries of the basin in their entireties (except for China, which is for Yunnan Province alone) they do give an indication of the possible scale of development. China alone intends to complete eight large main-stem dams and Laos has started constructing several of the 23 dams planned for completion before 2010. In 1990, the Mekong Secretariat released a study proposing nine main-stem run-of-river dams. Since the first comprehensive survey of the Mekong in the 1950s, more than 180 dams and diversion projects have been proposed for the basin. Earlier plans envisioned a cascade of main-stem dams with more than 6,000 square kilometers of reservoir area. For political, social, economic and environmental reasons, dam proponents have scaled down the main-stem project proposals to pursue sites on the Mekong tributaries in Laos, Thailand, and Vietnam (fig. 1).

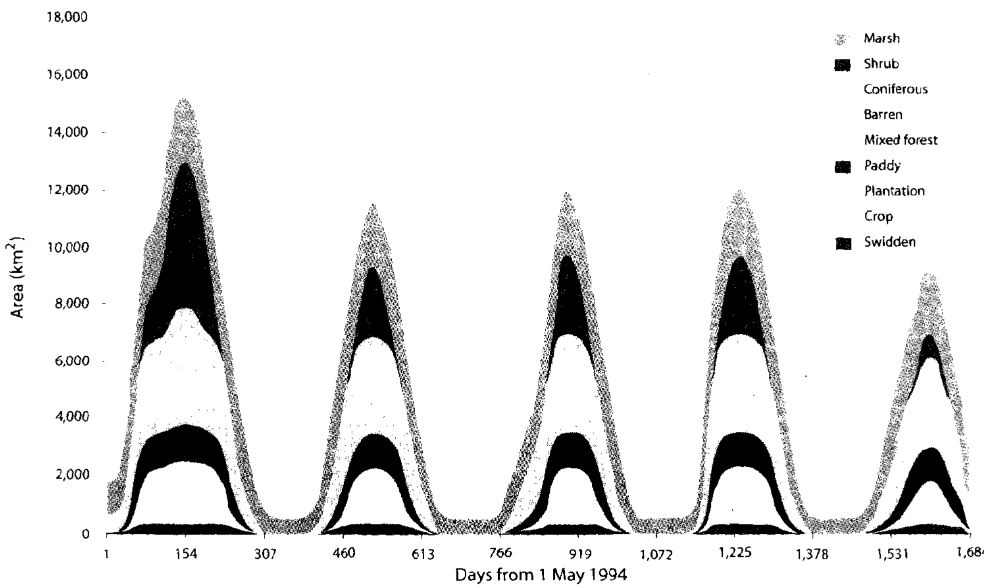
The development of the Mekong basin and, in particular, the construction of dams on the main stem will affect the water levels and flows downstream that, in turn, impact on the fisheries and environment. The implications of basin developments on these interests can be studied using distributed hydrological models. Such hydrological models generally require large numbers of data which, in many countries, are not always available. However, global datasets are becoming increasingly available and data from the Internet can often be used to substitute for ground-based data. The Semi-Distributed Land-Use Runoff Process (SLURP) hydrological model has been used to take advantage of such data sources.

Figure 2. The digital elevation model and the derived river network and subbasins.

As part of a joint project with the International Centre for Living Aquatic Resources Management (ICLARM, Penang, Malaysia) and the Mekong River Commission (MRC, Phnom Penh, Cambodia), IWMI has developed a hydrological model of the Mekong basin that can be used to model the management of water flows and the aquatic resource production in this basin.

The SLURP hydrological model divides a basin into subbasins using topography from a digital elevation map. These

Figure 3. Flooded areas for different land covers, Tonle Sap, Cambodia, May 1994–December 1998.



subbasins are further divided into areas of different land covers using data from a digital land cover classification. Each land cover class has a distinct set of parameters. The hydrological model simulates the vertical water balance, transforming the daily precipitation into evapotranspiration and runoff separately for each land cover within each subbasin.

While the distributions of distances and changes in elevation for each point in the basin were obtained from the United States Geological Survey (USGS) GTOPO30 public-domain DEM off the Internet, the distribution of land covers within the basin was obtained from the USGS 1-km digital land cover map of the world. Figure 2 shows the digital elevation model and the derived river network and subbasins.

Daily climate data (precipitation, temperature, dew point, and wind) were obtained from the US National Climate Data Center's Global Surface Summary of the Day (GSOD) Internet database. Radiation data were estimated from daily precipitation data.

Using these data, the SLURP model simulates the full hydrological cycle for each element of the subbasin/land-cover matrix and routes the runoff to the nearest stream and downstream through the basin. Dams on the Nam Ngum, Chi, and Mun rivers were included in the simulation. In the absence of information, operational rules were assumed. Flows in the Tonle Sap river were simulated from computed flows in the Mekong at Kratie and the volume of the Tonle Sap lake. Relationships were developed between Tonle Sap level and the flooded areas of each type of land cover using 30 m resolution data from Landsat TM.

The SLURP hydrological model was applied at a daily time interval for the period 1.01.1994 to 31.12.1998, with no calibration of parameters. Verification was made by comparing the simulated streamflow with recorded data. The simulated levels in the Tonle Sap were then converted to time series of flooded area with time for the land cover types around the Tonle Sap lake (fig.3). These results may be used to evaluate fish productivity and irrigation productivity as well as water allocation issues and climate change impacts.

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