cubic kilometers a year of what hydrologists call "renewable water resources" (from precipitation, run-off from Nile system waters outside the national borders, etc.) available to the country. Because so much of northern Sudan is in the Saharan-Sahelian arid belt, Sudan ranks below, in absolute volumes of annual renewable water resources, geographically smaller countries located in the rainbelts of Western Africa. For example, Sierra Leone has, on average, 160 cubic kilometers a year of renewable water resources; Nigeria, 308; Guinea, 226; Liberia, 232; and Cameroon, 208.

However, the total national volume of water alone is not the story. The question is, how much of the available water is "withdrawn"—diverted for potentially productive uses (agriculture, industry, domestic needs, power production)—and how well is the water utilization organized for these purposes? For example, look at the Imperial Valley of southern California, where limited amounts of Colorado River water were put to efficient use, and a manmade garden oasis was created, yielding up to four crops per year in the desert sun.

In Sudan, the fraction of available water resources "withdrawn" for use is about 14%. This is comparable to other nations located in arid zones—South Africa at 18%, or Mexico at 15%. Of Sudan's 14% annual withdrawals (18.6 cubic kilometers on average), fully 99% of this is applied to agricultural use for irrigation, and the other 1% fraction is for domestic use. Water use for industrial purposes is practically nil, which is an important consideration for development planning.

Moreover, Nile River Basin waters are shared among several nations. Therefore, were Sudan to withdraw significantly more of the Nile flow, Egypt would be shorted. Egypt at present uses 97% of its renewable water resources, which are currently confined to the Nile. Egypt ranks, with Israel, at the top of the list of nations with the highest "withdrawal" fractions of their renewable water supplies.

This is the context in which to understand what otherwise appear to be large per capita annual withdrawals of water in Sudan and Egypt. Sudan uses about 1,089 cubic meters per person per year, and Egypt 1,202 cubic meters. But with 99% of this water withdrawn going for agriculture in Sudan, and 88% of withdrawals going for agriculture in Egypt (7% for domestic use and 5% for industrial use), the seemingly large per capita annual withdrawals do not at all denote a

The Jonglei Canal

In the Sudd, the great swamp in which gather the waters of the upper White Nile, in the state of Jonglei (which borders on the south with the equatorial states of Sudan), there stands a half-finished, 180-kilometer long, manmade channel, the northern portion of the Jonglei Canal. The completed canal is intended to divert a portion of the water from entering the Sudd, and send it directly for a total of 360 km, from south to north, from Bor to Malakal (see **Figure 4**) to provide great ecological and economic benefits to both the immediate region and downriver lands.

In 1994, the President of Sudan, Gen. Omar El Bashir, announced a commitment to completing the project.

The channel digging began in 1978, after a 1976 agreement (and 1980 emendations) between the government of Sudan and the French engineering firm Compagnie des Constructions Internationales (CCI). A famous excavating machine, the "Roue-pelle," or "Bucketwheel," was brought in from Pakistan, where it had dug the 101-km Chasma-Jhelum link canal between the Indus and Jhelum rivers (completed 1970). The Bucketwheel was built for the Pakistan project by the Lübeck-based German firm of Orenstein und Koppel Tagebau und Schiffstechnik, based on an adaptation of a digger in use in the open-pit lignite mines near Cologne.

Thanks to the initiative of Sudanese hydrologist Yahia Abdel Magid, the Bucketwheel, which went into use in Pakistan in 1968, was refurbished and brought to Sudan for use. It is the largest excavator in the world, weighing over 2,100 tons. It consists of 12 giant buckets (3 cubic meters each) hung on a circular wheel (12.5 meters in diameter), which dig earth, then dump it onto a transmission belt, which in turn deposits it on an embankment. It is self-propelled. Operating at full tilt in 1981, the Bucketwheel was excavating 2 km a week, and digging at a rate of 2,500-3,500 cubic meters per hour. There were three eight-hour shifts of 25 operators, including Pakistani, Sudanese, and French nationals. The great machine requires 40,000 liters of gasoline per 24 hours.

Now the Bucketwheel lies disabled in Jonglei. In 1984 all work on the canal was suspended, after counterinsurgency operations were mobilized against it and other infrastructure initiatives, by opponents of development in Africa.

The canal is designed to divert about 25 million cubic meters a day from the southward flow of the upper Nile waters just north of Bor (see Figure 4), and channel it through a cut of 360 km, which would deliver at Malakal about 4.7 billion cubic meters annually.

This would mean adding to the downriver Nile volume about 3.8 billion cubic meters yearly, as measured at Aswan (subtracting for losses in transmission). Under applicable agreements, this increment of water would be shared high-tech, advanced economic profile.

As a comparison, the United States withdrew 2,162 cubic meters per capita in the early 1970s, with 42% in agriculture, 46% in industry, and 12% domestic use.

Both Egypt and Sudan would gain more water from Nile flow from the Jonglei Canal and other upper Nile system improvements, perhaps up to 7% more water downstream, and there are watersharing agreements in place for this incremental increase. But the essential source of additional water to these dry lower Nile lands is to desalinate Mediterranean Sea, Red Sea, and Suez saltwater with cheap nuclear power, at strategic development locations on the coastlines.

Limited transport grid

The limited transport grid in Sudan reflects decades of deliberate non-development under imperial British rule, and its continuation under the postwar regime of the International Monetary Fund and World Bank (see **Figure 4**).

There are only about 5,503 kilometers (3,432 miles) of rail lines in Sudan, and these lines are mostly between major towns. There is no real area density of rail coverage; statistically, rails are 0.0019 km per square kilometer of the country. There are 29 diesel locomotives. The rail links run between Port Sudan and Khartoum in the east; Wadi Halfa' in the north (on the Egyptian border); El Obeid in central Sudan; Nyala in the west; and Wau in the south. The administrative center and manufacturing and repair shops of the Sudan Railways Corp. are in Atbara, north of Khartoum on the Nile River.

As of the mid-1980s, the overall road network, not counting dirt tracks, added up to 6,599 km (4,100 miles), of which 3,160 are main roads, and about 60% is paved. This means the national statistical road density is 0.03 km per square kilometer. Thus, like rail, this limited length of paved roadway does not constitute area coverage, but is a system of selective links. In 1980, a major road between Port Sudan and Khartoum was completed (1,197 km, or 744 miles). Bridge improvements on the White Nile have facilitated traffic circulation between Khartoum, North Khartoum, and Omdurman.

Another way to look at the lack of paved roads is that there are 98 km of paved roads per 1 million persons in Sudan. In contrast, there are 302 km of paved roads in Egypt per million persons. In Nigeria, 376 per million persons. In continental United States, there are 10-15,000 km of paved roads per million people.

50-50 by Sudan and Egypt.

The draw-off of 25 million cubic meters daily from the feed waters of the Sudd would reduce the swamp area by an estimated 36%, from an average total swamp area (1905-80) of 16,900 square kilometers down to 10,800 square kilometers. The designed flow rate is 3.5 km per hour to inhibit weed growth.

The canal is designed to vary in width from 28 to 50 meters, and to vary in depth from 4 to 7 meters, to accommodate boat traffic. Parallel to the canal there is intended to be an all-season roadway, and ancillary projects include slipways, bridges, ferries, civil works for crossings and regulation, and other infrastructure.

Proposals for the Jonglei Canal, and other major Sudd and Nile Basin projects, go back generations. In many cases, engineers under British rule were the most enthusiastic designers and advocates of improvement projects, but imperial "hydropolitics" blocked development initiatives at every turn.

For example, in 1904, Sir William Garstin, inspector general of irrigation at the Egyptian Ministry of Public Works, proposed what became known as the "Garstin Cut" to channel the White Nile; but it and successor designs were blocked, until Sudan became independent and took action on its own. In 1876, a member of the British Royal Engineers, Gen. F.H. Rundall, proposed a high dam at Aswan. But it took the development policy of Egyptian President Gamal Abdul Nasser to make this happen.—*Marcia Merry Baker*

FIGURE 4
Limited transport grid