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# Egypt: Vulnerability of Nile Water Supply

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**A Research Paper**

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*March 1986*
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# Egypt: Vulnerability of Nile Water Supply [redacted] 25X1

**A Research Paper**

This paper was prepared by [redacted] 25X1
[redacted] Office of Global Issues, with 25X1
contributions by [redacted] Office of Near 25X1
Eastern and South Asian Analysis; [redacted] 25X1
Comments
and queries are welcome and may be directed to the
Chief, Geography Division, OGI [redacted] 25X1

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# Egypt: Vulnerability of Nile Water Supply

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## Key Judgments

*Information available as of 28 February 1986 was used in this report.*

Egypt is in transition from water abundance to water shortage. Reductions in the Nile River's flow resulting from the recent Sub-Saharan drought highlighted Egypt's precarious dependence on the river—the country's only significant source of water. For six straight years (1979-85), water flowing into Lake Nasser—Egypt's huge reservoir on the Nile behind the Aswan High Dam—never exceeded 55.5 billion cubic meters (bcm) annually, the amount allotted to Egypt by a 1959 agreement with Sudan. During these six years, Egypt discharged from Lake Nasser not only more water than the amount that flowed in but also more than its 55.5-bcm allotment. As a result, Lake Nasser's level declined, and the High Dam's electricity output diminished. If the drought had continued another two years, the amount of reserve water available for irrigation would have been entirely depleted.

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Normal rainfall occurred in late summer of 1985, but, considering recent climatic trends, drought could recur at any time. If normal rainfall continues, permitting storage in Lake Nasser to be replenished, Egypt has some time to improve water use and allocation. Nevertheless, we believe Egypt must act forcefully and urgently to forestall a possible future water crisis. 25X1

At Egypt's current rate of population growth, the Nile will have to support twice as many people by the year 2010 as it does today. Planned agricultural expansion that will merely slow the widening of Egypt's food deficit will require a 15-percent increase in water use by the year 2000. (The country, which was a net food exporter as late as 1970, now imports 50 percent of its food.) 25X1

Even as Egypt's own water demand is increasing, population, agricultural development, and, consequently, water use in upstream Sudan and Ethiopia are increasing. Until now, Egypt has been getting a portion of Sudan's share of the Nile because Sudan has not used its full share of water allocated by the 1959 agreement. If Sudan had used this water during the past six years, Lake Nasser's usable storage would have been depleted last year. Sudan, in pursuing plans to further develop its irrigated land, eventually will increase its water consumption beyond its allotment, claiming that water to be saved through various conservation projects will offset the increase. However, the chief conservation project—the Jonglei Canal—has been stalled for several years by an insurgency in southern Sudan. Therefore, in the next 15 years or so, Sudan's use could exceed its allotment, leading to confrontation with Egypt. 25X1



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With a large population and few resources, Ethiopia is eager to develop its own Nile waters. Ethiopian plans to build a series of dams on the Blue Nile are of grave concern to Egypt because 85 percent of the Nile's water originates in Ethiopia. Ethiopia has not participated in major meetings of the Nile riparian states, nor has it acknowledged any usage rights of downstream users. Already frosty relations between Addis Ababa and Cairo may deteriorate to the point of conflict should Ethiopia initiate large-scale unilateral development projects on the Nile. [redacted] 25X1

Even discounting the possibility of future drought, Egypt will experience a drawdown on its existing water resources through growth in its own demands and increased use upstream. To meet future needs, Egypt must:

- Continue to improve water use efficiency through conservation measures and education of farmers. (Egyptian farmers resist changing centuries-old water use practices that are both extremely wasteful of water and injurious to soil quality.)
- Support efforts to complete the Jonglei Canal and other upstream conservation projects.
- Seek and develop new sources of water. Ground water is the most likely new water source because desalinization is overly expensive. [redacted] 25X1

Potential water shortages in Egypt have important implications for Egypt's domestic and foreign policies—and for US interests. Failure to provide adequate water supplies for agriculture, industry, and electric power generation would place additional strains on the government and create pressures to take action against upstream water users. Although Cairo would probably be able to procure needed food supplies in the event of irrigation water shortages, additional imports would further aggravate already severe financial problems. Egypt is already the second-largest recipient of US economic aid; a population outstripping its water and food supplies is certain to require more. Actions needed to head off the problem also require foreign assistance. USAID involvement in projects to improve agricultural productivity and irrigation efficiency will require a long-term commitment to realize a significant effect. [redacted] 25X1

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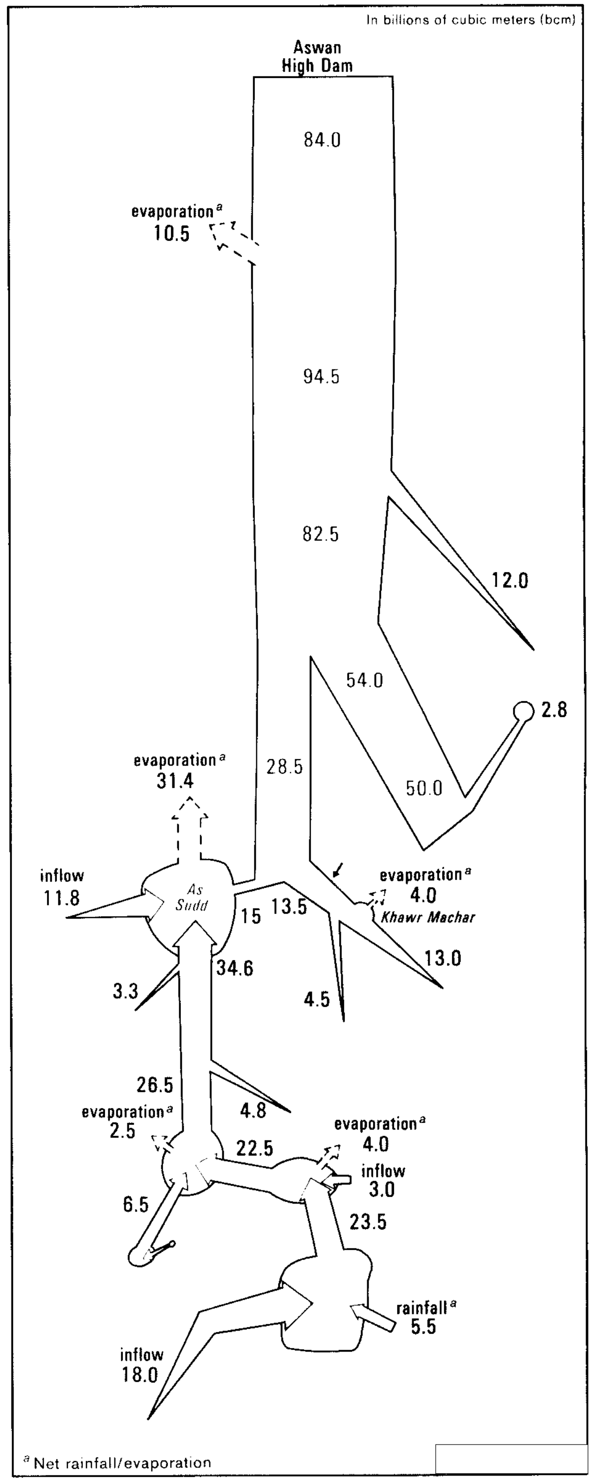
**Figure 1**
**The Nile Basin**


**Figure 2**
**Nile Flow**

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# Egypt: Vulnerablity of Nile Water Supply

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## Introduction

The Nile River, Egypt's only significant water source, is totally dependent on rainfall far to the south—mainly in Ethiopia. Before the completion of the Aswan High Dam in 1970, Egypt suffered whenever the lands at the headwaters of the Nile experienced drought. For more than a decade after the dam's completion, water stored in seasons of above-average rainfall provided Egypt with a sufficient amount of water to cover short periods of drought. During the drought in Sub-Saharan Africa from 1979 to 1985, however, the Egyptians were obliged to draw down reservoir reserves to critically low levels. Only late summer rains in the Ethiopian highlands in 1985 saved them from serious water allocation and conservation decisions. 25X1

Egypt relies on the Nile for irrigation, inland navigation, industrial and domestic consumption, and electricity generation. With an ever-increasing population, the country has no near-term options other than conservation and increasing its use of Nile water. Therefore, should drought resume, Egypt's water situation will be more precarious than it was during 1984-85, especially if Sudan and Ethiopia continue to use an increasing amount of Nile water upstream.

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***Sources***

*The Nile is probably one of the most studied and most measured rivers in the world, as evidenced by the open availability of annual records on Nile River flow, Lake Nasser levels, and electricity generation. Such annual records are necessary to determine trends; monthly records, however, are required to monitor the current situation. During the height of the recent drought crisis, timely reporting by the US Embassy in Cairo was our primary source of information. At other times, reporting on the water situation tends to be fragmentary.* 25X1

*Data on water use are less reliable, mainly because water use is much harder to measure. Academics, the Egyptian Ministry of Irrigation, and USAID disagree on water use figures, particularly those regarding agricultural use and the tremendous amounts of water wastage associated with the irrigation systems. Water use figures in Sudan are probably even more questionable.* 25X1

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## Water Supply

More than 91 percent of Egypt's 60.7 billion cubic meter (bcm) annual average water supply comes directly from the Nile, and another 8 percent comes indirectly from the river through downstream reuse.[1] The 6,671-kilometer Nile River—the longest river in the world—drains an area three times larger than Egypt that includes portions of nine countries: Egypt, Sudan, Ethiopia, Uganda, Zaire, Rwanda, Burundi, Kenya, and Tanzania (figure 1). None of the Nile's water originates in Egypt itself because rainfall there is negligible. To meet its needs, Egypt must rely on Nile water arising in the eight upstream nations.

### Blue Nile

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The Blue Nile is the more important of the Nile's two main tributaries, supplying Egypt with most of its water—some 57 percent (figure 2). Annual discharge from the Blue Nile's source—T'ana Hayk' (Lake Tana), in the Ethiopian highlands—is estimated at 3 bcm. Numerous tributaries along the Blue Nile's course boost its flow to an average of 54 bcm annually at Khartoum. The Blue Nile carries to the main stream the rich volcanic silt of Ethiopia that each year replenished the lower Nile Valley and Delta before the completion of the Aswan High Dam. 25X1

[1] The remainder, about 1 percent, comes from ground water.

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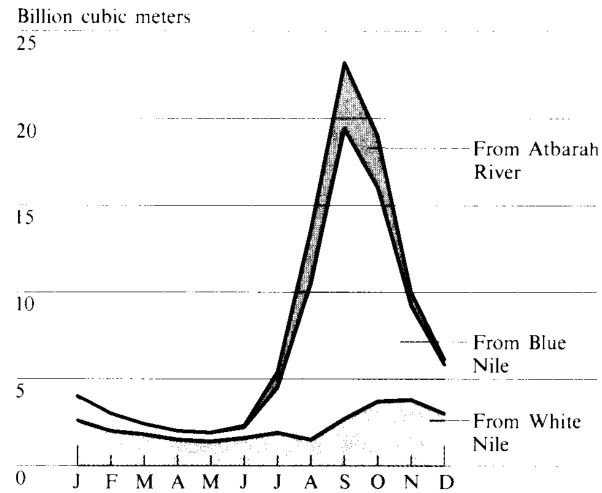
**White Nile**
The White Nile begins as the Kagera River in Burundi. After collecting water from the basins of Lakes Victoria, Kyoga, George, Edward, and Albert, the White Nile leaves Uganda. By the time the river reaches Mongalla in southern Sudan, the flow has increased to about 30 bcm. At this point, however, the river enters As Sudd—80,500 square kilometers of stagnant swampland—where it loses about half of its volume to evaporation as it meanders slowly through the dense vegetation. North of As Sudd, the Nahr Subat (Sobat River) replaces much of the water lost in the swamp, so that the river's annual flow at Khartoum is 28.5 bcm. 25X1

**Main Nile**
The White Nile and the Blue Nile merge to form the main Nile at Khartoum. Downstream from Khartoum, the Nahr 'Atbarah (Atbarah River) is the only major tributary, increasing the Nile's average historic discharge to 84 bcm annually at Aswan. The Atbarah, the Blue Nile, and the Sobat all originate in the Ethiopian highlands; together, they account for about 85 percent of the Nile's annual flow. Although numerous seasonal wadis lead into the Nile north of the mouth of the Atbarah, the amount of water they add to the main stream is negligible. This stretch of the Nile between the Atbarah and the Delta is the world's longest without perennial tributaries.

The flow of the Nile varies seasonally because of varying climatic conditions in Ethiopia. Rainfall around the equatorial lakes of Africa and, consequently, discharge of the White Nile vary little throughout the year. Rainfall in the Ethiopian highlands, on the other hand, is highly seasonal—picking up in April, peaking in August, then dropping off dramatically in October. This rainfall pattern accounts for the seasonal surge in the Blue Nile, and accounted for the flooding of the Nile each September before construction of the Aswan High Dam (figure 3).

Superimposed on the Nile's seasonal pattern is an annual flow that varies considerably from year to year. Since 1871 the annual natural yield [2] at Aswan has ranged from 150 bcm in 1878/79 [3] to 42 bcm in 1913/14 (figure 4). Extreme fluctuation in annual flow prompted 19th century Nile authority Sir William Willcocks to remark, "Mean years are of no value, since the surplus of one year is not available for the next." 25X1

**Figure 3**
**Seasonal Flow of the Nile[a]**




[a] Average natural yield at Aswan.

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[2] Natural yield—a hypothetical estimate of discharge at Aswan assuming no Sudanese withdrawal—is used to compare historic records of Nile flow with today's figures. Until Sudan began extensive irrigation schemes in the 1920s, natural yield and actual flow at Aswan were nearly identical. Because Sudan now uses approximately 16 bcm annually, today's actual flow is well below natural yield; this explains why actual inflows of 40.5 bcm in 1982/83 and 37 bcm in 1984/85 represent higher flows than the 1913/14 figure of 42 bcm. 25X1
[3] The Nile's hydrological year runs from 1 August through 31 July of the following year. 25X1

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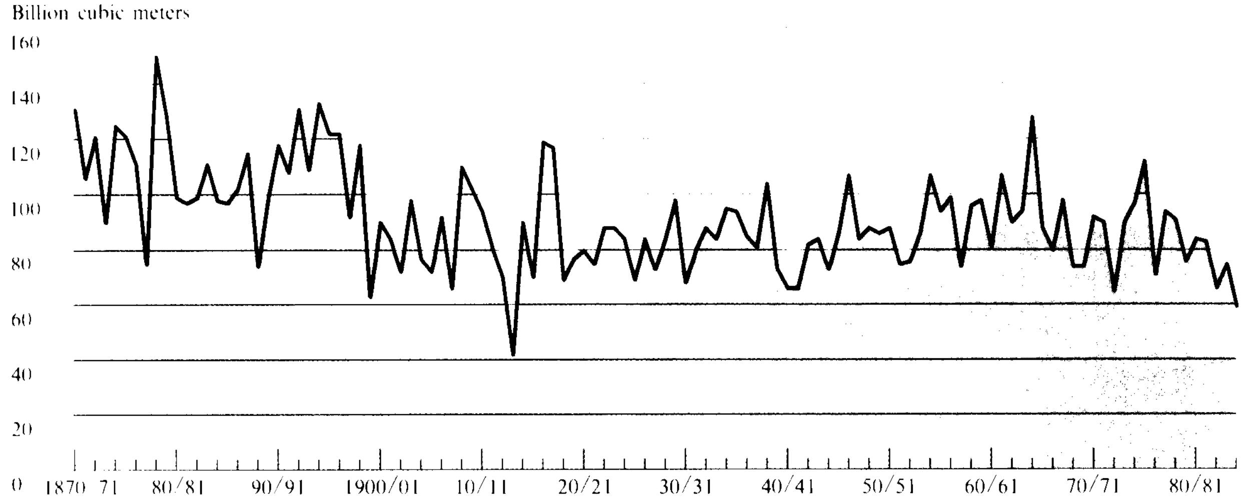
**Figure 4**
**Annual Natural Yield at Aswan[a]**




[a] Water years

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## Water Management

Because of the Nile's seasonality and year-to-year unpredictability, several attempts to regulate the river's flow have been undertaken during this century. Since 1900, five dams—the Er Roseires and Sennar on the Blue Nile, Jabal al Awliya on the White Nile, Khashm al Qirbah on the Atbarah, and Aswan Low Dam on the main Nile—were built to provide seasonal storage of the Nile's waters. These dams trap the final portion of the annual surge, releasing it later in the year when needed. Combined storage of these facilities, however, is 16.4 bcm—only 20 percent of the average annual flood. This was not enough to tide Egypt over a severe drought year.

Recognizing the need for over-year storage, the Egyptian Council of Ministers approved the Century Storage Scheme in 1949. This plan called for the construction of several projects, including a canal bypassing As Sudd, over-year storage in Lake Tana and Lake Albert, and a regulator dam on Lake Victoria.[4] These projects were designed to provide protection against floods and droughts and to regulate the river's flow for agricultural expansion in the delta. 25X1

When Gamal Abdul Nasser came to power after the 1952 Egyptian revolution, he elected to temporarily abandon the Century Storage Scheme and, instead, concentrate on a single project that would meet the same water storage and regulation goals while serving as an immediate showcase of Third World development. Consequently, in 1960 construction began on the Aswan High Dam. Egyptian officials expected the dam to accomplish the following:

- Reduce flood and drought damage. 25X1
- Increase the amount of land under cultivation.

[4] This last project became the Owen Falls Dam and is the only portion of the Century Storage Scheme so far completed. The dam provides power to Uganda, but Egypt receives little benefit from the water stored in Lake Victoria in the absence of another dam at Lake Albert and a canal through As Sudd. 25X1

*Figure 5. The Aswan High Dam, 1971. Lake Nasser is seen in the process of filling.* [redacted]

- Increase the agricultural production on existing land by allowing perennial irrigation, thereby permitting double and triple cropping in parts of Upper Egypt.
- Improve navigation conditions.
- Provide large amounts of cheap electric power.
- Permit the development of a small fishing industry on the dam's reservoir. [redacted]

The river was blocked by a coffer dam in 1964, and the High Dam was completed in 1970 (figure 5). The reservoir—called Lake Nasser in Egypt and Lake Nubia in Sudan—was filled nearly to capacity by 1975. When full (183 meters above sea level, 13 meters below the dam's crest), the reservoir has a surface area of approximately 5,000 square kilometers (roughly the size of Delaware), and extends 500 kilometers upstream. The total capacity of the reservoir is 164 bcm, of which the lowest 30 bcm is dead storage (below the spillway level), 90 bcm is long-term storage, and the upper 44 bcm is for flood protection.
[redacted]

Although some of its expected benefits have yet to be fully realized, the Aswan High Dam nevertheless has been a boon to Egypt. Without its regulatory effects,

***Rainfall Seasonality at the Headwaters of the Nile***

*Seasonal patterns of rainfall around the Equator are a result of movement of the belt of the earth receiving the sun's direct, perpendicular rays. This belt is an area of low pressure characterized by ascending air masses that yield large amounts of rainfall. To fill the hole left by the rising air, air masses from north and south move toward the Equator to form the intertropical convergence zone (ITC). Equatorial regions experience the rainfall effects of the ITC year-round, but most markedly around the spring and fall equinoxes, when the sun is directly overhead. This accounts for the fairly consistent rainfall in the Lake Victoria region, with slight peaks in April-May and September-November. As the Earth revolves and the Sun's direct rays move northward, the ITC follows, so that by July it is centered approximately 18° north latitude over Africa, supplying the Ethiopian highlands with seasonal rain. As the ITC retreats southward again, rainfall drops off.* [redacted]

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*Conditions similar to the current African drought occurred in the 1820s and 1830s, from 1900 to 1915, and in the 1940s. Following a series of wet years in the 1950s, dramatic changes have taken place in the rainfall patterns of the Sub-Saharan region, particularly that of the Sahel. Essentially, the ITC with its associated precipitation-yielding air masses has not moved as far north each year as it had earlier. Precipitation, which had been averaging 15 percent above normal in southern areas and 35 to 40 percent above normal along the Saharan fringe, began a gradual decline.* [redacted]

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Egypt would have suffered from floods in 1964 and 1975 and from droughts in 1972/73 and 1976/77. Most recently, water stored behind the dam during years of abundant rainfall in the 1970s insulated Egypt from the effects of the devastating drought in Ethiopia and Sudan from 1979 to 1985. [redacted]

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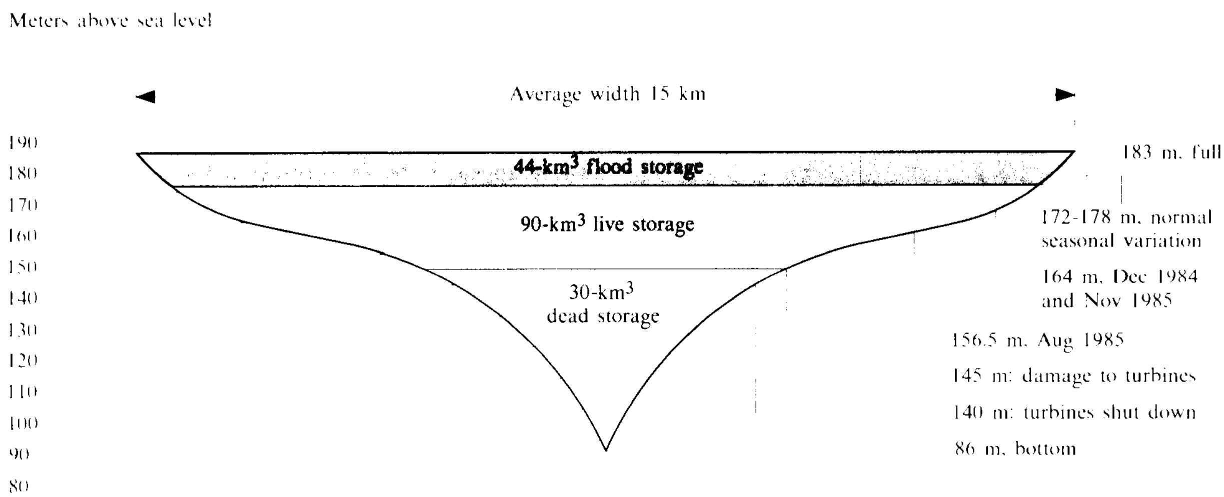
**Figure 6**
**Lake Nasser: Cross Section**

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## The Drought

The drought pattern that affected the Nile River watershed from 1979 until at least mid-1985 began in the late 1960s in the western areas of Sub-Saharan Africa and gradually spread eastward to include the countries in the Nile basin. The western Sub-Saharan region experienced continuous drought from 1968 through 1973, with precipitation deficits ranging from 15 to 40 percent. Rainfall over the region increased considerably during 1974 and 1975, leading to reports that the drought had ended. In 1976, however, it returned.

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From 1968 through 1979, rainfall was above average in much of the Nile watershed, and Lake Nasser experienced only two years of deficit flow—1972/73 and 1976/77. During these two dry years, water previously stored behind the dam allowed Egypt to withdraw approximately 55 bcm—the usual annual discharge. Between 1968 and 1979, the reservoir level rose 22 meters, and its volume increased by 73 bcm (figure 6 and 7).

Beginning in 1979, however, drought conditions extended into the eastern Sub-Saharan region. Western Ethiopia—the source of most of the Nile's water—suffered severely, resulting in six years of below-average Nile flow. Rainfall in the highlands was as low as 25 percent of normal in 1984. Near-normal rainfall fell in the Nile basin in 1985, although it was distributed erratically. To term this the end of the drought now, however, might be just as premature as it was in 1975.

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Despite the Nile's fluctuation from year to year, water records since 1700 suggest a hundred-year flow cycle with periods of high flow in midcentury and periods of low flow at the beginning of each century. On the basis of this perceived cycle and current world weather patterns, some climatologists foresee the possibility of below-average rainfall continuing for the next 15 to 20 years. Most meteorologists agree, however, that they lack the quantitative data and methodology to scientifically predict the onset and duration of drought, particularly in Africa.

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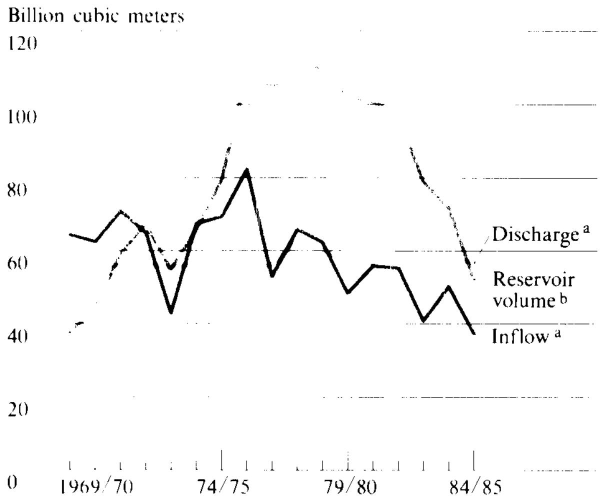
**Figure 7**
**Lake Nasser: Inflow, Discharge, and Reservoir Volume**




[a] Water years.
[b] Volume as of 31 July (lowest level).

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## Water Use

During the six years of drought, discharge from Aswan annually averaged 57.3 bcm—an amount greater than that allotted to Egypt in the 1959 bilateral Agreement for the Full Utilization of the Nile Waters. Discharge, previously averaging 55.2 bcm between 1968 and 1976, was increased in 1977-78 and 1978-79, presumably as a result of increased demand. Even though the Ministry of Irrigation released 62 bcm and 60 bcm during those two years, no water deficit resulted, as inflow remained slightly greater than outflow. During the subsequent drought years, however, discharge remained high, as inflow to Lake Nasser dropped dramatically and Egypt withdrew stored water. If, instead, discharge during the past six years had averaged 55.2 bcm, Egypt would now have an additional 13 bcm behind the dam, and the hydroelectric problems that occurred as a result of lowered reservoir levels would have been far less severe.

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Prudent water management should have called for effective conservation measures during at least the past year or two to cushion the effects if the drought had continued.

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USAID officials estimate that, of the water discharged in a typical year, only about 55 percent is used productively. During 1982, for example, when 58.7 bcm were released, Egypt productively used only 31.8 bcm, allocated as follows:

*Billion cubic meters*

| Use | Amount |
|---|---|
| **Total** | **31.8** [a] |
| Agriculture | 27.1 |
| Municipal | 1.8 |
| Industry | 0.3 |
| Power/navigation [b] | 2.6 |

[a] Despite its seeming precision, this is only a rough estimate. Egyptian water authorities and other experts cite water use figures that vary by as much as 35 percent from the AID estimates.
[b] The 2.6 bcm shown as used for power/navigation represents water releases from Aswan during periods when the water is not required for other uses downstream.

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The remaining 26.9 bcm of lost water, according to AID and Egyptian water experts, is divided almost equally between irrigation conveyance losses and on-farm losses and waste. This lost water eventually enters the sea, seeps into the ground, or evaporates. These losses would be even higher were it not for extensive reuse of irrigation drainage water, which requires costly repumping.

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Of all uses, only power generation was directly affected by the recent drought. Normal release of water stored in the reservoir saved the downstream users from the necessity of adopting any conservation measures. If the drought had continued, however, AID experts estimated that a reduction of irrigation flows would have been unavoidable by mid-1986.

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### Agriculture

The recent drought in the lands of the Nile headwaters had no appreciable effect on Egyptian agriculture. If, however, reduced rainfall upstream had continued and annual inflow and discharge had remained at average 1979-85 levels, Egypt would have depleted Lake Nasser's live storage by 1988. At that point Egyptian water supplies would have consisted of the Nile's annual flow (which in the past six years met only 83 percent of Egyptian use), and, at most, 4 bcm of ground water. The cropped area would have had to be reduced proportionally (or the crop mix changed), and Egyptian food production would have dropped to below today's already poor level of about 50 percent self-sufficiency.

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Egyptian agriculture is almost entirely dependent on irrigation from the Nile River. Except for a narrow strip along the Mediterranean Sea, rainfall in all parts of Egypt is in most years inadequate for nonirrigated agriculture. The present irrigation system has been developed since the early 1800s, following centuries during which Egyptian agriculture was limited to one crop per year following the annual Nile flood in August and September. Perennial irrigation became significant after completion of the first low dam (barrage) to channel water into distribution canals in 1861. By the end of the 19th century some 1.5 million hectares was under perennial irrigation, and by 1980—after completion of the Aswan High Dam—virtually all of Egypt's present cropland was irrigated year-round and was double cropped (figure 8).

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Perennial irrigation, however, brought with it new problems, chief among them waterlogging and increased soil salinity. According to USAID, production on one-third of the cropland has been reduced by these factors alone, and two-thirds of the land suffers from poor drainage, presaging future production problems. The primary cause of the salinity and waterlogging is a rising water table—the result of seepage from the distributing canals, the inadequacy or nonexistence of drainage systems, and the propensity of the Egyptian farmer to overwater. This tendency to overwater is a result of several factors: the farmer's general ignorance of plant needs, unlevel fields, inefficient irrigation pumps, and the Ministry of Irrigation's unpredictable system of water distribution, which prompts the farmer to take as much water as he can when he can get it.[5] 25X1

*Figure 8. Archimedes' screws drawing water from canals. This and other primitive irrigation methods are still widespread along the Nile.* 25X1

Irrigation efficiency—the ratio of the amount of water used by growing plants to the amount of water drawn from the Nile—ranges from about 25 percent to a high of 75 percent, but probably averages no more than 45 percent. Increasing average irrigation efficiencies to about 65 percent, which USAID believes is technically feasible and has been routinely accomplished in Israel and Jordan, would provide a savings of at least 10 bcm annually. In the long run, existing open-ditch irrigation, which is the dominant Egyptian practice, will have to be converted to sprinkler and drip irrigation to minimize water losses. Experience has shown, however, that without continual prodding by outside "experts" the Egyptian farmer will revert to his old ways and engage in irrigation practices that effectively waste a large share of the available water. 25X1

[5] Overwatering is often blamed on the fact that water is available to the Egyptian farmer without charge and therefore is of marginal value to him. Actually, cost is significant, for the water must be lifted onto the fields, and the rental price of a water buffalo to power the pumps should provide incentive against pumping more water than is needed.

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***Egyptian Crops***

*About 2.8 million hectares of Egypt's total territory is under cultivation, most of it double cropped. This is barely 3 percent of the country's area, and almost all of it is in the delta or within a few kilometers of the Nile above Cairo. More than half of this land (allowing for double cropping) is devoted to food production, and about 17 percent is used for growing livestock fodder. Another 10 percent is planted in cotton, which, together with cotton products, makes up one-third of Egypt's exports. Almost two-thirds of the food-producing area is planted in grains—principal among them corn, wheat, and rice. The other three major food categories are vegetables, fruits, and sugar cane. Cotton, rice, and sugar cane require relatively large amounts of water, but also yield a high value per hectare, and may thus represent wise land use.* [redacted] 25X1

Food production in Egypt is currently growing at an annual rate of about 2 percent, while the population of more than 50 million is increasing at 2.8 percent a year and will double in about 25 years if left unchecked. This presents Egypt—a net food exporter only 15 years ago—with a growing food gap that necessitates massive foreign (almost half US) aid inputs each year. To increase agricultural output, Egypt has successfully reclaimed some 375,000 hectares of new land in the past 30 years. Current plans call for development of 0.85-1.25 million hectares of additional new land—more than half of it in the Eastern Delta and Sinai—by the year 2000. All of the estimated 8.8 bcm of water needed to cultivate this land is intended to come from the Nile and is supposed to be made available through improved irrigation and water use efficiency. We believe, however, that, even if only a small portion of these new lands is developed, Egypt will be hard pressed to divert water to them, especially in times of prolonged drought. [redacted] 25X1

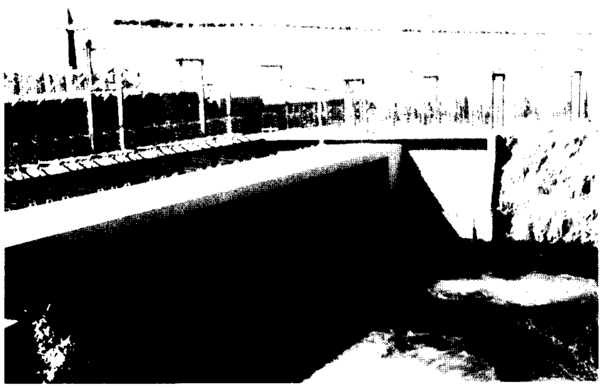
**Electricity**

The principal effect on Egypt of the upstream drought, and the resulting lower water levels of Lake Nasser, was to temporarily reduce hydroelectric output. About one-third of the 29 billion kilowatt hours (bkWh) generated by Egypt in 1984 came from two hydroelectric power stations—the Aswan High Dam (26 percent) and the Aswan Low Dam (7 percent). Output of the two dams that year was about 9.4 bkWh, as compared with 11.8 bkWh in 1983. Electrical output declined further in 1985 as the water level stayed below optimum. [redacted] 25X1

To generate power at 100-percent capacity, the level of Lake Nasser must be at least 165 meters above sea level. The water level fell below this in July 1984 for the first time since 1974, when the reservoir was filling. By April 1985 the water level had reached 159.5 meters, resulting in a reduction of power-generating capacity by 10 percent—some 175 megawatts. During the summer of 1985, generating capacity remained well below the maximum, falling to 79 percent of capacity when the water level dropped to 156.5 meters in August. Numerous brownouts in the Aswan area resulted. Although the level of the lake had risen to 164 meters by November 1985, power capacity remained about 3 percent below optimum. [redacted] 25X1

If the water level were to fall below 145 meters, prudent operation of the turbines would call for them to be shut down to avoid rust damage. Because USAID will be replacing the old, Soviet-built turbines over the next several years, the Egyptian Electricity Authority had decided to operate the units below this critical level if need be. This would still permit power generation at 65-percent capacity. At 140 meters, however, all units would have to be shut down because of air intake. To reach 140 meters, the reservoir would have had to lose some 30.6 bcm of water from the August 1985 level—equivalent to the net deficit between May 1984 and August 1985. [redacted] 25X1

***Generation of Electricity***



*The Aswan High Dam power plant.*

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*Water held in Lake Nasser flows through 12 hydro-turbine generators, each capable of producing 175 megawatts. Since only 10 units operate at one time, maximum generation is 1,750 megawatts. The spillways carry the water not needed for power generation to the downstream canal. Because the dam's discharge is controlled by the Ministry of Irrigation, power production varies seasonally with the needs of irrigation, ranging from a maximum of 1,750 megawatts during August through October, to a minimum of 900 megawatts during December through February. Electricity is conveyed from the transformers by two 500-kilovolt transmission lines nearly 800 kilometers to Cairo, and by eight 132-kilovolt lines to the Aswan area.*

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Egypt's power supply will continue to be affected in 1986, even if this year's rainfall is normal. On the basis of last year's highest level (164 meters in November) and assuming average monthly inflows and discharges, we estimate that the reservoir level will drop to 161 meters by May and may reach last year's low in August 1986 before returning to higher levels. During this time, power generation will remain below 100-percent capacity. For the reservoir to stay above 165 meters year-round, one or more years of above-average rainfall are necessary.

In the long term, however, hydroelectricity will not play as large a role in Egypt as it now does. Because Egypt's hydroelectric potential has nearly been met,[6] hydroelectric production is likely to remain stable over the next several years, given normal upstream rainfall. Demand for electricity, on the other hand, is expected to continue to grow with increases in population and industrial expansion. Although Egypt is currently reviewing bids by foreign contractors to build its first nuclear reactor at Ad Dab'ah, other nuclear power plants are not likely to be built in the near future because of prohibitive construction and operation costs. Egypt will more likely increase the number of oil- and gas-fired generators (the amount of energy generated by these stations has already more than tripled since 1976) or turn to coal as a power source. Should a major drought occur in the future, the relative impact of disrupted hydroelectric sources on the nation's energy supply would be less than it would be now. 25X1

**Political Perspectives**

Egypt's total dependence on the Nile for survival mandates a constant and extraordinary preoccupation with the security of the river that is as old as Egyptian civilization. These concerns, which are amplified during times of drought, underlie Cairo's policy of trying to maintain good working relations with Nile Valley countries, especially Sudan and Ethiopia. Sudan in particular is viewed as a southern extension of Egyptian territory, and close ties to Khartoum are an axiom of policy. Egypt has also participated actively in meetings of the multilateral Undugu group—a broad coalition of most Nile riparians[7] with common interest in maximizing water usage and preventing, through group pressure, independent policies damaging to other members. 25X1

[6] That is, hydroelectric potential has nearly been met unless one counts the ambitious, multibillion-dollar scheme to connect the Mediterranean to the Qattara Depression, which would generate some 10,000 megawatts through the resulting difference in elevation. To date, the project remains on paper. 25X1

[7] As of the group's third meeting in August 1985, the following states are members: Egypt, Sudan, Uganda, Rwanda, Burundi, Zaire, Tanzania, and the Central African Republic (not a Nile riparian). Although invited, Ethiopia and Kenya have yet to join.

25X1

25X1

**Upstream Use**

Until recently, Egyptian fears of upriver tampering were more psychological than real, as long as upstream states were too underdeveloped to affect the water flow. The gradual economic development of these states in the postcolonial period, however, has led to a number of irrigation and other water diversion schemes that threaten to diminish Egypt's water supply. [redacted]

25X1

Concern over water sharing resulted in the Agreement for the Full Utilization of the Nile Waters, signed by Egypt and Sudan in 1959. Based on the then average natural yield at Aswan (84 bcm), and on the then assumed benefits and losses of the future Lake Nasser, the agreement allotted Egypt 55.5 bcm. Sudan's allotment, as measured at Aswan, is 18.5 bcm—equivalent to a flow of 20.5 bcm as measured around Khartoum, upstream of which occurs most of Sudan's consumption.[8] The agreement also considered a 10-bcm annual evaporation loss from the then planned reservoir. The net benefit of any increased yield in wet years was to be divided equally between Egypt and Sudan. However, no provision was made for years of reduced yield. [redacted]

The agreement also considered the great volume of Nile basin water lost in the swamps of southern Sudan and called for development of projects to reduce these losses. The costs and net water yield of these projects were to be evenly divided. To date, only one of the projects has been started. Construction of Phase I of the 360-kilometer Jonglei Canal, which is planned to divert water around As Sudd, at present is halted at 80-percent completion by insurgency in the region. When and if completed, Phase I will increase yield by 4.3 bcm, according to project planners. Together with the Jonglei Canal Phase II and other projects still on paper, the Nile's yield is planned to increase by 18 bcm. Egypt's 9-bcm share of these projects would help serve as insurance against future drought (figure 9). [redacted]

At present, Sudan's annual net water use is estimated to be between 15.5 and 16.5 bcm. Almost 90 percent[9] of this is used to irrigate the 1.7 million hectares that make up the various agricultural schemes along the Nile and its tributaries in the central part of the country. (These irrigated lands produce almost all of the nation's cotton—its principal export crop—as well as large amounts of oilseeds and grains.) Sudan uses irrigated land much less intensively than does Egypt. At any given time, as much as 40 percent of the land lies fallow. This accounts for water needs per hectare in Sudan that are only half those in Egypt. Private households and industry use only 3 percent of Sudan's water. Storage losses make up the remainder of Sudan's annual water needs. [redacted]

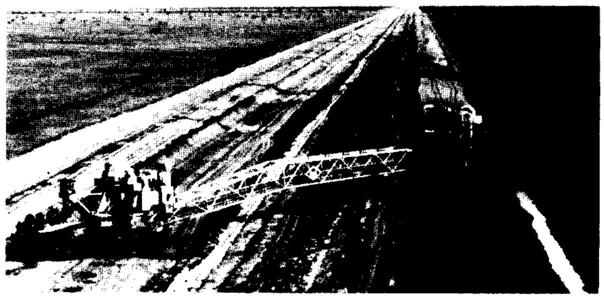

*Figure 9. The Jonglei Canal under construction in 1982.* [redacted]

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One reason Egypt survived the recent drought was because Sudan has yet to use its full share of Nile water allotted under the 1959 Agreement. As measured at Aswan, the amount of water that Sudan uses annually is as much as 3.7 bcm less than its 18.5 entitlement. Therefore, assuming relatively constant Sudanese use, about 22 bcm of extra water—water that Sudan legally had the right to use—flowed into Lake Nasser during the past six years. If Sudan had used its full annual entitlement, reservoir volume last July would have been around 30 bcm; all live storage would have been gone, and generation of hydroelectricity would have been nil. [redacted]

25X1

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If Sudan implements all the water-consuming programs called for in the 1979 Master Water Plan, the US Bureau of Reclamation estimates that by the year 2000 it will be using some 26 bcm annually—5.5 bcm more than its current entitlement, as measured at Khartoum. Sudan's share of water saved by various

[8] About 10 percent of the Nile water at Khartoum evaporates before it reaches Aswan. [redacted]

[9] Includes an estimated 10-percent conveyance loss. [redacted]

25X1

25X1

conservation projects, including the Jonglei Canal and a similar canal/flood embankment system diverting water from the Khawr Machar (Machar Swamp) and its high evaporation rates, would offset the increase in planned use. At present rates of construction, however, we believe that Sudan will be hard pressed to meet its conservation and usage goals in the next 15 years. [redacted]

25X1

The only other riparian state of immediate concern to Egypt is Ethiopia. Here, where 85 percent of the Nile's water originates, plans developed with US assistance before 1964 called for the use of 4 bcm a year to irrigate areas along the Blue Nile and Atbarah Rivers. None of the water-using components of these plans has gone beyond planning stages. [redacted]

25X1

In the Lake Tana region, however, Italy is beginning a series of water regulation projects associated with the Ethiopian Government's policy of population resettlement. By September 1986, the Italian Assistance Fund plans to have completed the first phase of a small dam on the Beles Wenz, creating a 10-million-cubic-meter (mcm) reservoir. Several even smaller downstream dams will follow, eventually providing hydroelectric power for the area. Italy's most ambitious project will be a dam at the outlet of Lake Tana, raising the lake by 2 meters. A canal and tunnel system will then convey Lake Tana water to the Beles Valley for the irrigation of about 200,000 hectares; such an irrigated area would use 1 bcm to 2 bcm annually. Despite Italian assurances that a dam at Lake Tana will not reduce the Nile's flow, but rather will provide regulation beneficial to all parties, Egypt remains concerned. [redacted]

25X1

**Relations With Neighbors**

We believe competition for Nile water will increase in the next 15 years. Some development schemes, such as the Jonglei Canal, ultimately may provide more water, but not in the quantities needed to sustain Egypt's burgeoning population and the development policies of the upstream states. At current rates of population growth, we estimate the river will have to support twice as many people by the year 2010 as it does today. This competition probably will lead to strains between Egypt and upstream states, and may result in open conflict. [redacted]

In the event of prolonged drought, Egypt will probably rely on diplomacy to keep the water flowing, but this option has limits. The US Embassy in Khartoum reports that many Sudanese believe Egypt intends to reap the lion's share of benefits from cooperative water projects, and they resent Cairo's argument that Sudan has other sources of water as well as a much smaller population. Khartoum, meanwhile, is preoccupied with an ongoing insurgency in the south and appears in no hurry to complete the now suspended Jonglei Canal, which lies in a contested area. Furthermore, the greatest of the Nile schemes—the Aswan High Dam and the bulk of Lake Nasser—lies within Egypt itself and enables the country to weather the effects of drought far more easily than its upstream neighbors. [redacted]

25X1

Egypt has virtually no diplomatic leverage over Ethiopia. With a population of more than 40 million, no oil or coal, and a history of recurrent drought, Ethiopia is eager to begin exploiting its own Nile resources. According to the US Embassy in Cairo, recent reports that Addis Ababa plans a series of dams along the Blue Nile have deeply shaken Egypt, yet Cairo's attempts to discuss the issue have been rebuffed and its diplomats have not been allowed to visit the areas in question. In addition, although Ethiopia recently joined the other riparian states at a Nile River resources workshop in Bangkok, Addis Ababa has refrained from participating in the Undugu group. In our view, frosty relations have forced Cairo to behave cautiously and to avoid initiatives Addis Ababa could interpret as provocative. [redacted]

25X1

Egypt maintains sufficient defense forces to guard against any threat to the river within its own territory—such as Libyan leader Qadhafi's reported plans to attack the Aswan High Dam. An Egyptian surgical attack on any future Ethiopian dams would be an act of desperation and is highly unlikely, in our judgment, for political and logistic reasons. However, Egypt probably would consider supporting major dissident forces in northern Ethiopia in hopes that a large active insurgency would occupy Addis Ababa's energies and preclude dam construction, particularly in contested areas. [redacted]

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25X6

## Domestic Concerns

We believe prolonged drought by itself is unlikely to threaten political stability in Egypt unless food stocks were allowed to become perilously low in the wake of decreased agricultural production. Even so, civil unrest would probably ensue only if the government were obviously derelict in procuring needed food supplies from abroad. Such dereliction is highly unlikely. [redacted]

With the bulk of the population clustered on the banks of the Nile, transportation of food to needy areas would not be a problem. Finally, the Egyptians are no strangers to drought, and the buffer provided by Lake Nasser should give Cairo ample leadtime to head off potential famine. The mechanism for food imports is already in place—Egypt has not been self-sufficient in food for at least a decade and currently imports more than half of its food requirements. [redacted]

## Outlook

We estimate that by the year 2000 Egypt's available water supply will increase by 4.8 bcm, from the present 60.7 bcm to 65.5 bcm annually.[10] This projection is based on the assumption that Egypt will increase its use of groundwater and reuse of irrigation water and that Sudan will complete at least Phase I of the Jonglei Canal project. Because these variables can only be roughly approximated and could be affected by political and economic changes within Egypt and in the upstream nations, we have developed a range of best case and worst case water supply scenarios for the year 2000:

*Billion cubic meters*

| Source | Worst Case | Best Case | Probable |
|---|---|---|---|
| **Total** | **54.5** | **75.5** | **65.5** |
| Average inflow at Aswan | 58.0 | 58.0 | 58.0 |
| Increase resulting from upstream conservation projects | 0.0 | 4.5 | 2.5 |
| Decrease resulting from upstream use | 9.0 | 0.0 | −3.7 |
| Ground water | 0.5 | 1.0 | 0.7 |
| Reuse | 5.0 | 12.0 | 8.0 |

[10] These estimates of present and future water use assume average rainfall and natural river flow. [redacted] 25X1

On the basis of several academic and government projections, we believe that Egyptian water demand in the year 2000 will be about 67 bcm, slightly more than our estimate of the probable supply and considerably more than our worst case scenario. [redacted] 25X1

Egypt suffered few ill effects from this past drought only because:

- Above-average rainfall in the mid-1970s had created a reserve from which Egypt could draw.
- Almost 4 bcm annually flowed into Lake Nasser that, by entitlement, could have been used by Sudan.
- The drought did not continue a seventh year.

In the future, Egypt cannot rely on this combination of circumstances. Considering the precarious nature of the future supply-and-demand situation, if rainfall remains normal (allowing little or no reservoir buildup from excess rainfall) and if Sudan develops its agricultural lands to the extent that it uses its full water allotment or more, Egypt will be unable to pass through a similar drought in the future without disastrous consequences for its economy. Such a situation would be likely to lead to confrontation with upstream users over sharing of water resources. [redacted] 25X1

25X1

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