Directorate of Intelligence

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Libya's Great Manmade River Project: Plans and Realities

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A Research Paper

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Libya's Great Manmade River Project: Plans and Realities [redacted] 25X1

A Research Paper

This paper was prepared by [redacted] Office of Global Issues; [redacted] Office of Near Eastern and South Asian Analysis; [redacted] 25X1 25X1 25X1

Comments and queries are welcome and may be directed to the Chief, Strategic Resources Division, OGI [redacted] 25X1

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Libya's Great Manmade River Project: Plans and Realities

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Summary

Information available as of 15 September 1987 was used in this report.

Libya is facing serious water supply problems. Many of the overused aquifers along the densely populated Mediterranean coast have been damaged by the infiltration of seawater, a process that cannot be reversed. To help offset this loss and also to meet future water needs, Muammar Qadhafi embarked on an enormous project in 1983 called the Great Manmade River Project (GMRP)—two pipeline systems designed to bring large volumes of subsurface water from deep under the southern desert to water-short regions along the Mediterranean coast. Construction has been under way for about three years, and the project will probably take another decade to complete. Although construction costs will strain the economy, we believe that this project is the only realistic option the Libyans have to ease growing water problems and that any successor to Qadhafi will also regard it as essential. 25X1

Our technical analysis of the Al Kufra and Sirte Basins in southeastern Libya—the water sources for the project—indicates that surprisingly large amounts of high-quality subsurface water are present there. Indeed, we estimate that the volume of water in both basins could approach that of Lake Ontario, about 1.5 trillion cubic meters (m^3), and probably is three times higher, or the equivalent of Lake Michigan. Even at the low end of the range, we believe that, with prudent water resource management, this vast amount of water is more than ample to support planned extraction of 5 million m^3 daily and to allow the Libyans to sustain this rate indefinitely. 25X1

Internally, the Great Manmade River Project has major implications for the Libyan economy. The planned extraction rate nominally represents:

- Almost two-thirds of Libya's present water needs and possibly one-third of the country's requirements by the year 2000.
- Enough water to allow, in principle, a doubling of Libya's present amount of irrigated land. 25X1

The GMRP will continue to absorb a very large share of Libya's investment budget—about $30 billion over the next 10 to 15 years. Nevertheless, we believe the Libyans can cover the cost of this project out of current revenues, not debt. 25X1

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Despite Qadhafi's claim, our analysis indicates that this project will not allow Libya to become self-sufficient in food production even if it is fully completed. The increased supply of water would, however, give the Libyans a chance to limit food import dependency, a major national vulnerability. Without a project of this scale, Libyan food import dependency would inevitably increase in response to a rapidly growing population, an outcome that Qadhafi regards as politically unacceptable. 25X1

On the international front, the Great Manmade River Project could become the source of new friction in Libyan-Egyptian relations. Geologically, the subsurface structures in southeastern Libya extend into western Egypt and provide the only water source for oases in that region. Our analysis indicates that the Libyans can extract planned amounts of water and still not interrupt the natural flow into western Egypt. Only if the Libyans were to dramatically exceed planned volumes would Egypt's water supply in that region be threatened, but such extraction rates would increase the risk of serious long-term damage to the basins supplying Libyan water. Nonetheless, a Cairo perception that the Great Manmade River Project poses a threat to future water supplies in western Egypt could serve to aggravate already strained relations. 25X1

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Contents

Scope Note

This Research Paper reviews the background, specifics, progress, expectations, and implications of Qadhafi's much publicized Great Manmade River Project. Central to this assessment is a comprehensive analysis of the water potential of the Al Kufra and Sirte Basins in southeastern Libya, the water sources for the project. The CIA has developed a new methodology to estimate water volumes that are likely to be present in these basins. Specialists at the US Geological Survey have reviewed the methodology and agree with our evaluations. Although Libya has discussed plans to also exploit the vast water resources of western Libya, we believe that this area will not be developed until well after the turn of the century. [redacted] 25X1

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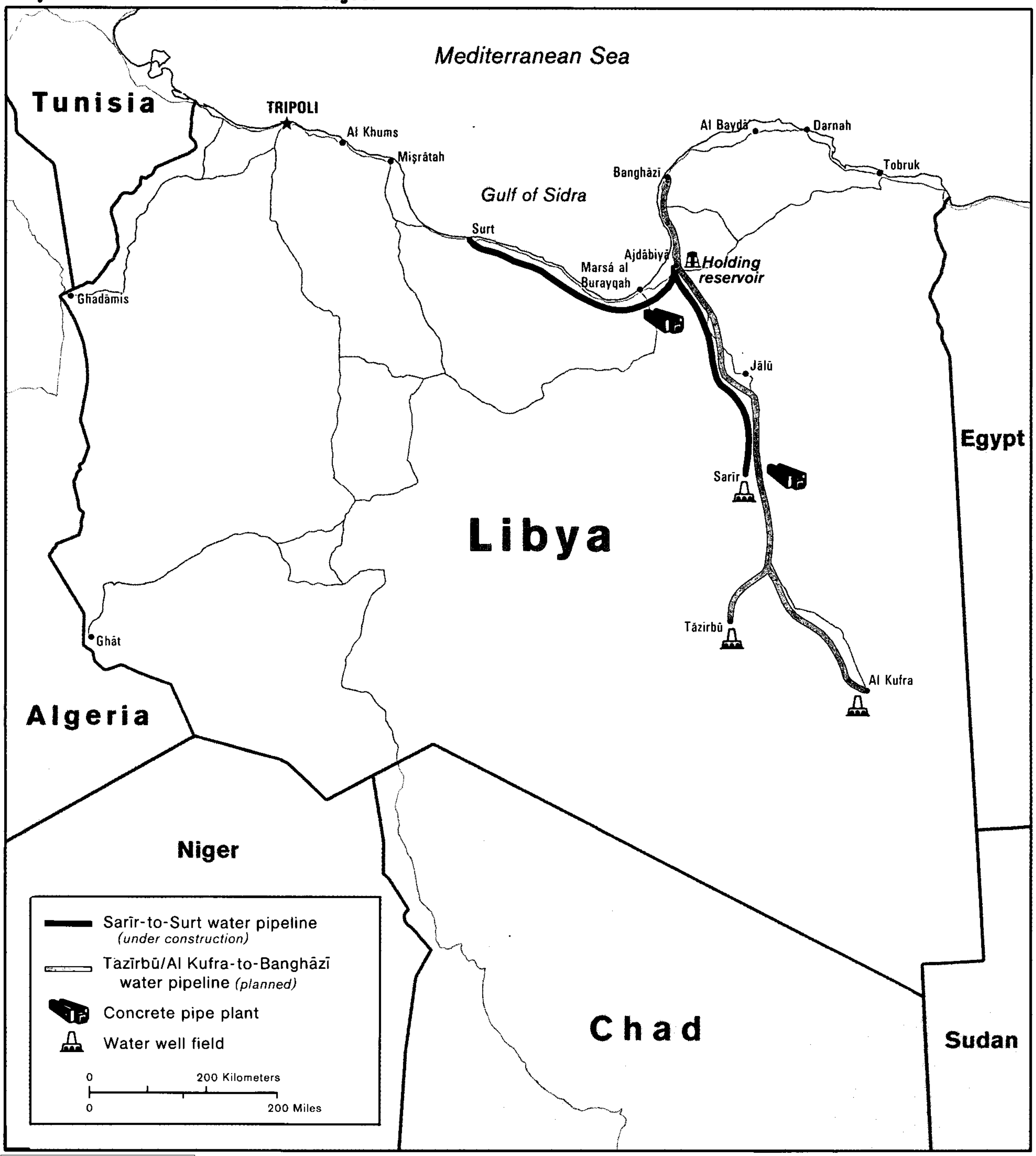
Figure 1
Libya's Great Manmade River Project



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Libya's Great Manmade River Project: Plans and Realities [redacted] 25X1

Background

Lack of adequate supplies of high-quality water is one of the key constraints on Libyan economic development. Tripoli's only reasonable option is to continue to invest huge sums in an enormous, long-term effort—the Great Manmade River Project (GMRP)—whose practical benefits are still many years off. Without adequate water supplies, Libya's food import dependency will continue to grow, undercutting Qadhafi's long-term goal of achieving self-sufficiency in food production (figure 1). [redacted]

Water Supply Issues

Typical of many countries in the Middle East, Libya depends on subsurface water sources to meet virtually all of its requirements. Surface water sources are scanty at best. No perennial lakes or rivers exist in the country, and in vast portions of Libya no measurable rainfall occurs for several years. Even in northern Libya, where the rainfall is greatest, the wadis dry up within a few hours after a heavy rainfall, which usually occurs between November and March.[1] The small amount of surface water available is also highly saline, making it unsuitable for irrigation and barely fit for human consumption. [redacted]

Libya has mounted an impressive effort to build desalinization plants to help meet the country's growing water needs. Using [redacted] open source material, we have identified 14 such plants along the Mediterranean coast that have been built since the mid-1970s (figure 2). Output of desalinized water has increased dramatically, from about 5,800 cubic meters per day (m^3/d) in 1976 to almost 345,000 m^3/d in 1986.[2] Despite this increase, desalinization plants account for only about 5 percent of Libya's current estimated water requirements. Moreover, desalinized water is extremely expensive—at least $2 per cubic meter, according to Libyan claims—almost 10 times the cost of underground water. Desalinized water therefore cannot be used economically for irrigation. Simply put, barring a huge jump in world commodity prices, it is cheaper for the Libyans to import food than to attempt to grow an equivalent amount using this very expensive water. According to Libyan claims, desalinization capacity is scheduled to triple to about 1 million m^3/d by the year 2000. Even if this goal were achieved, however, this amount, in principle, still represents only about 5 percent of the amount of water Libya projects it will need by then. [redacted] 25X1 25X1

Domestic Water Requirements

Although we have no firm information on Libya's water requirements, a reasonable estimate of total usage can be made by looking at probable sectoral consumption levels. On the basis of an analysis of probable per capita needs and possible agricultural needs, we estimate that Libya's current water requirements amount to between 7 and 9 million m^3/d. This estimate suggests that Libya's water needs are roughly four times that of Jordan, and about two times that of Israel. In terms of US comparisons, Libyan water consumption is about triple that of Los Angeles County and about five times the consumption of the Washington metropolitan area (figure 3). [redacted] 25X1 25X1

Looking at water usage from a sectoral perspective, Libyan water needs can be subdivided into consumption for agriculture, personal usage, and industries. Agriculture alone accounts for about 60 percent of Libyan water consumption. Irrigation techniques in Libya are primitive, usually consisting of little more than crude ditches, and much of the water is lost to evaporation or runoff. Although precise comparisons are not possible, on a per hectare basis, Libyan water use for agriculture is probably five times as much as Jordan's and about 10 times as much as Israel's, 25X1

[1] Wadi is an Arabic word denoting a desert streambed that is dry except for brief periods after rainfall. [redacted]

[2] Throughout this paper, we measure water volume in cubic meters. One cubic meter of water is equivalent to 263 gallons. [redacted]

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Figure 2
Distribution of Major Desalinization Plants and Annual Rainfall Patterns

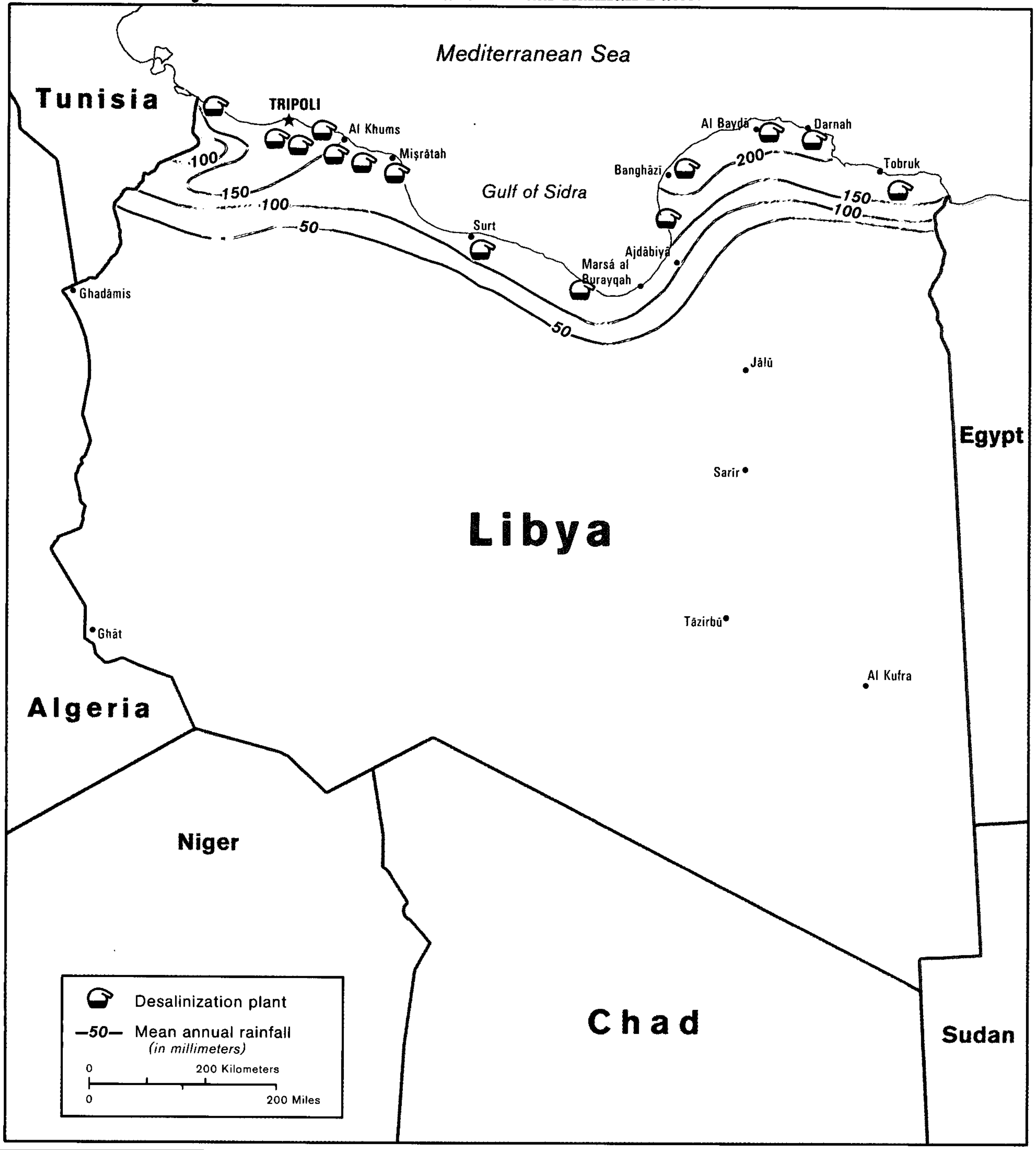

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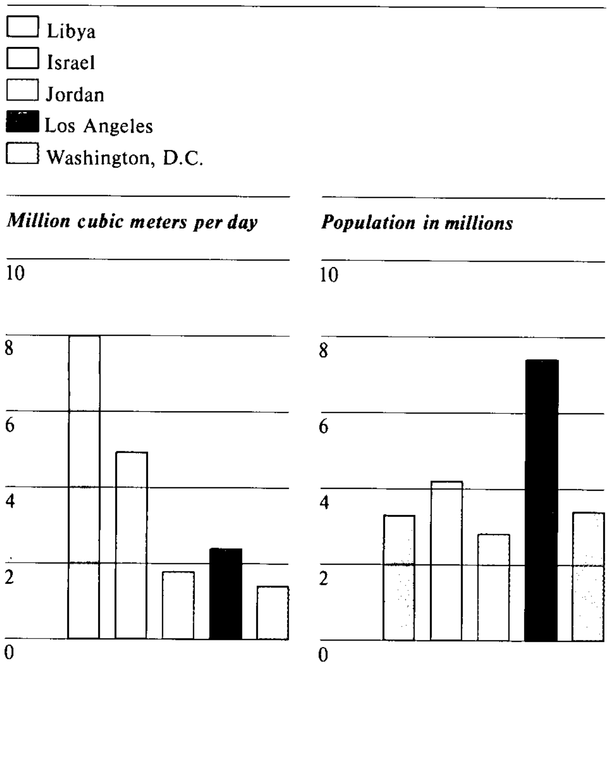
Figure 3
Comparison of Water Requirements and Population



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indicating the large amount of waste and mismanagement of water resources in Libya's agricultural sector. Human consumption—virtually all of which is centered along the Mediterranean coast—accounts for most of Libya's remaining needs. Industrial water requirements are very small, probably no more than 5 percent of total water needs. Libyan specialists estimate that the country's water requirements will increase to about 15 million m³/d by the turn of the century. Although we have no data on which to base an independent projection, the Libyan estimate seems reasonable and is very close to projected growth rates for the population.

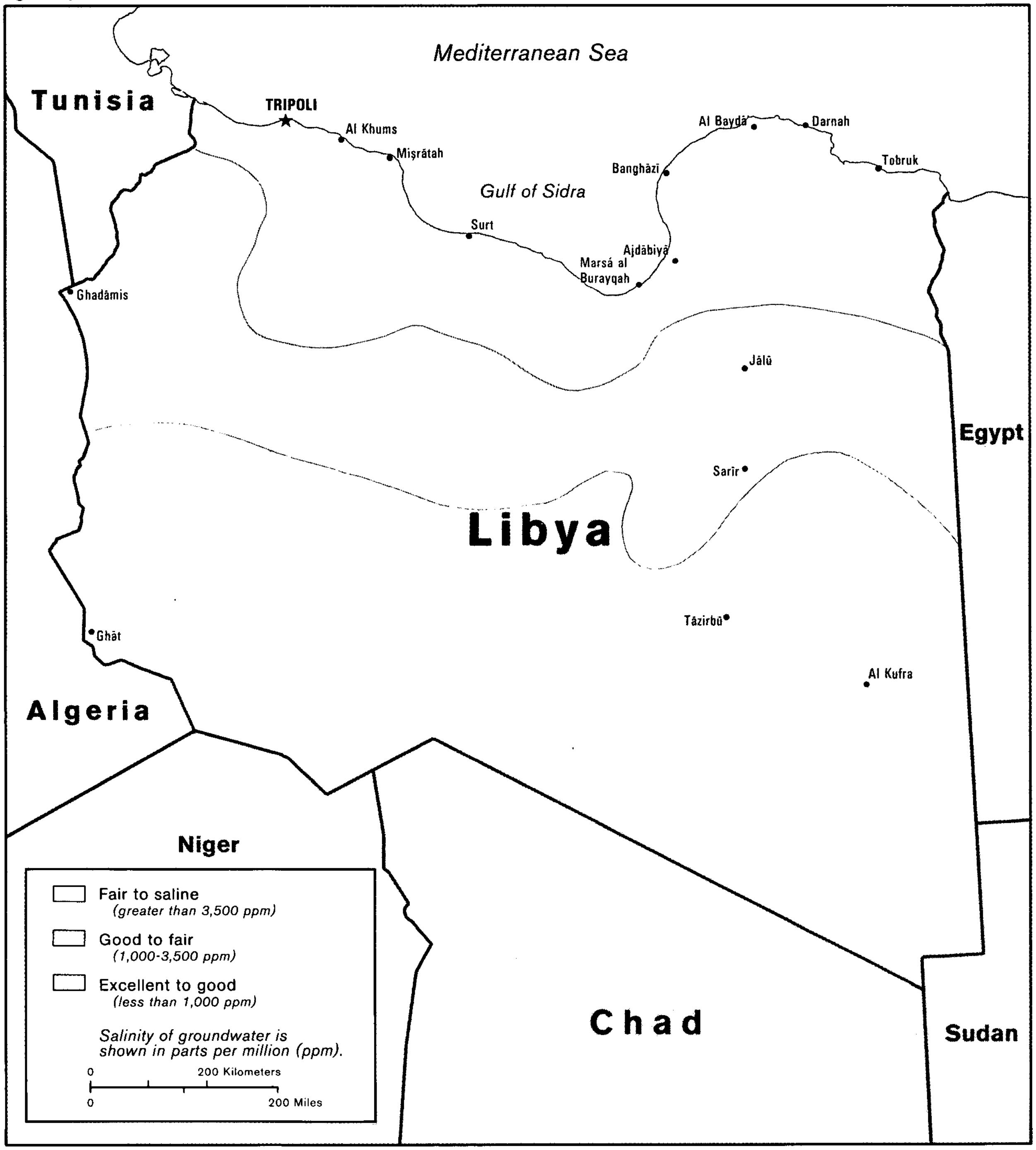
The Agricultural Base and Import Dependency
Although Libya devotes the bulk of its water resources to agriculture, crop yields still fall short of internal food requirements. Over the last 10 years, total agricultural output has increased by about 30 percent, but the gain was wiped out by the 40-percent increase in population. Libya's food import dependency has grown steadily since the early 1970s, and in 1986 imports accounted for about 60 percent of Libya's food supply and about 20 percent of its total import bill. Given steady increases in population, we see little likelihood that Libya will be able to prevent further increases in food dependency, at least for the foreseeable future. In addition to limited amounts of arable land—only about 2 percent of the land is suitable for agriculture because of poor soil composition and lack of moisture—growing shortages of water are increasingly hampering Libyan agricultural development. 25X1

The Great Manmade River Project

Libya has admitted publicly that it is facing serious water supply problems, especially along the Mediterranean coast. In essence, the aquifers—subsurface structures that hold water—now being exploited there have been severely depleted by overpumping. Around some of the densely populated cities, such as Tripoli, Banghazi, and Surt, the aquifers have also been severely damaged by the infiltration of seawater, rendering much of the water unsuitable for irrigation, industrial purposes, or human consumption (figure 4). Once an aquifer has been infiltrated by seawater, few 25X1
practical steps can be taken to correct the problem. As the population increases, the increase in water needs will result in even greater demands on the existing aquifers. Libyan leaders are clearly aware of their growing water shortage vulnerability, and, based on recent commitment of resources, they have made development of new water resources second only to defense as a national priority. 25X1

To deal with the problem of diminishing supplies of high-quality water, Qadhafi embarked on an enormous engineering project designed to exploit the vast underground water potential known to exist in southeastern Libya. Trade and industry journals have dubbed this effort as the Great Manmade River 25X1
Project. According to Libyan Government claims, the project is designed to transport for 50 years about 5

Figure 4
Quality of Groundwater



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Saltwater Intrusion

In nontechnical terms, saltwater intrusion (infiltration) of an aquifer occurs when fresh water is extracted faster than it can be recharged. When saltwater moves into the aquifer to replace the excess fresh water withdrawn, the fresh water nearest the contact boundary quickly becomes useless for human consumption, agriculture, or industrial purposes. Saltwater infiltration can be prevented by reinjecting fresh water—rainfall or treated sewage—from reinjection wells that must be located on the seaward side of the producing wells. But reinjection is extremely expensive. Almost without exception, wells that become infiltrated with saltwater are abandoned.

million m³/d of high-quality water from aquifers in the Al Kufra and Sirte Basins through buried concrete pipelines to water-short regions in the northern part of the country.

To illustrate the volume of water involved, 5.0 million m³/d represents in principle:

- About one-third of the average daily waterflow in the Potomac River at the Great Falls.
- Roughly one-third of Libya's projected water requirements by the year 2000.
- Enough water to irrigate at least 100,000 hectares of land, nominally a 50-percent increase in Libya's present irrigated land.

The pattern of construction activities to date suggests that the magnitude of the GMRP is such that it will have to be carried out in two stages, resulting in two pipeline systems. The first stage—the Sarir-Surt pipeline—will bring water from 126 wells near Sarir (in the Sirte Basin), north to a holding reservoir near Ajdabiya and then west to Surt on the Mediterranean coast. This pipeline system will stretch about 1,000 kilometers (km). The second stage, or the Tazirbu-Banghazi line, will bring water from 108 wells near Tazirbu (in the Al Kufra Basin), north to Ajdabiya and then northeast to Banghazi. This pipeline system will run about 900 km.

A Project Assessment

Many factors come into play in the assessment of any engineering project as massive as the GMRP. There must be a careful assessment of the amount of water that exists in the aquifers and the amount of rainfall that is available to feed them. In addition, the engineering considerations involved in transporting the huge volumes of water must be examined in detail. Finally, basic economic factors related to the investment costs and economic trade-offs need to be analyzed. 25X1

Subsurface Water Resources

The existence of large subsurface water potential in southeastern Libya is well known. Occidental Petroleum made the initial water discoveries in this area in the early 1960s. Subsequent investigations of the Al Kufra and Sirte Basins conducted by US and several West European exploration firms have consistently indicated the presence of large amounts of water. A study conducted by the United Nations Conference on Desertification in 1978 placed the water potential of the Al Kufra Basin at 3.0 trillion m³. On the basis of our geological and hydrological assessment of the conditions likely to exist in both basins, we estimate that: 25X1

- There is only a small chance that the volume of water will be as low as 1.5 trillion m³, roughly the water volume of Lake Ontario. 25X1
- There is an excellent chance that the volume of water will be about 5 trillion m³, slightly more than Lake Michigan.
- There is an outside chance that the volume of water could be as much as 9 trillion m³, about the same as Lake Superior (figure 5).[3] 25X1 25X1

Given the size of the aquifers known to exist in southeastern Libya, we believe that about 75 percent of the water resources—some 3.7 trillion m³ in our middle estimate—are in the Al Kufra Basin (table 1). Although different in size, the Al Kufra and Sirte

[3] See the appendix for a discussion of the methodology used to calculate the amount of water involved. 25X1

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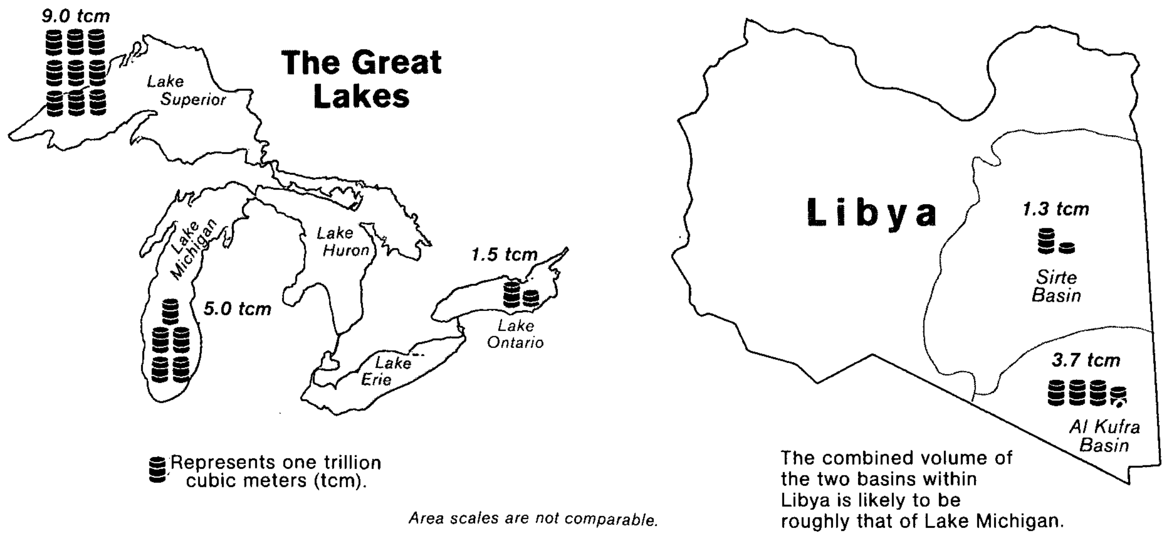
Figure 5
Subsurface Water Potential of Basins in Eastern Libya Compared With the Volume of the Great Lakes



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Basins are hydrologically similar. As detailed in the appendix, both basins have aquifers at shallow depths and should pose no major problem in terms of bringing water to the surface. Geochemical analysis of water taken from these basins indicates that the water is uniformly excellent in quality for irrigation or human consumption. [redacted]

Recharge Capacity

Despite the vast subsurface water potential involved, the Libyans cannot extract water volumes indiscriminately. Indeed, Libyan technicians need to plan carefully so that the amount of water taken from the aquifers roughly balances with the amount of natural recharge (replenishment).[4] If the extraction were to exceed the recharge, the aquifers could be irreversibly damaged by the infiltration of saltwater. Given the enormous volume of water involved, however, the damage to the aquifers probably would not become apparent for five to 10 years after the initial infiltration started. [redacted] 25X1

We examined historical data on precipitation patterns in southern Libya and northern Chad, the sources for the underground water in the Al Kufra and Sirte Basins, to calculate the probable rate of natural recharge. Although considerable variations exist in annual rainfall patterns, we estimate that rainfall averages about 22 billion m^3/yr in this area. Because of the topography, we estimate that between 50 to 75 percent of the annual rainfall would contribute to the groundwater of Libya; the remainder would drain into northern Chad and Sudan. According to studies of other parts of the Middle East where soil and climatological conditions are similar to Libya's, only about 10 percent of the precipitation will percolate down to the water table. Most of the remainder will be lost to

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[4] Recharge only affects so-called unconfined aquifers. Confined aquifers are sealed by impermeable caprock, which rainfall cannot penetrate. [redacted] 25X1

Table 1
Estimates of Libyan Subsurface Water Resources [a]

Trillion cubic meters

Basin	Low	Median	High
Total	**2.7**	**5.0**	**8.4**
Al Kufra	1.9	3.7	6.3
Sirte	0.8	1.3	2.1

[a] Variations in our estimates primarily reflect uncertainties in thickness of aquifers and variation in storage coefficients.

[redacted]

evaporation. Taking all of these factors into account, we estimate that about 1.4 billion m^3/yr of water will be available on average as a recharge for the aquifers in the Al Kufra and Sirte Basins. Because of the many uncertainties that exist in our technical data, we believe that the recharge capacity could be as low as 1.1 billion m^3/yr or as high as 1.7 billion m^3/yr (figure 6). [redacted]

Because of natural recharge rate, we believe Libya's goals for water extraction are realistic. According to official plans, Libya intends to pump 730 million m^3/yr during the first phase of the GMRP and eventually boost this volume to 1.8 billion m^3/yr. With our midrange estimate of the average annual recharge—1.4 billion m^3/yr—the Libyans would not have to exceed the annual recharge rate during the first phase of the project. Moreover, they would have to extract only an additional 400 million m^3/yr during the second phase, and this additional rate of withdrawal would not significantly reduce the water reserves held in the aquifers for 50 years or more.
[redacted]

Engineering and Manufacturing Considerations

Although a huge project, the GMRP is not a technically complicated one. Indeed, the technology needed to produce the large-diameter concrete pipe—which is the heart of the project—dates from the 1950s and is well known. [redacted] prestressed concrete pipe for the project is being produced at two plants in Marsa al Burayqah and Sarir that were built with South Korean assistance expressly for that purpose (figure 7). Both plants are now fully operational. [redacted] 25X1

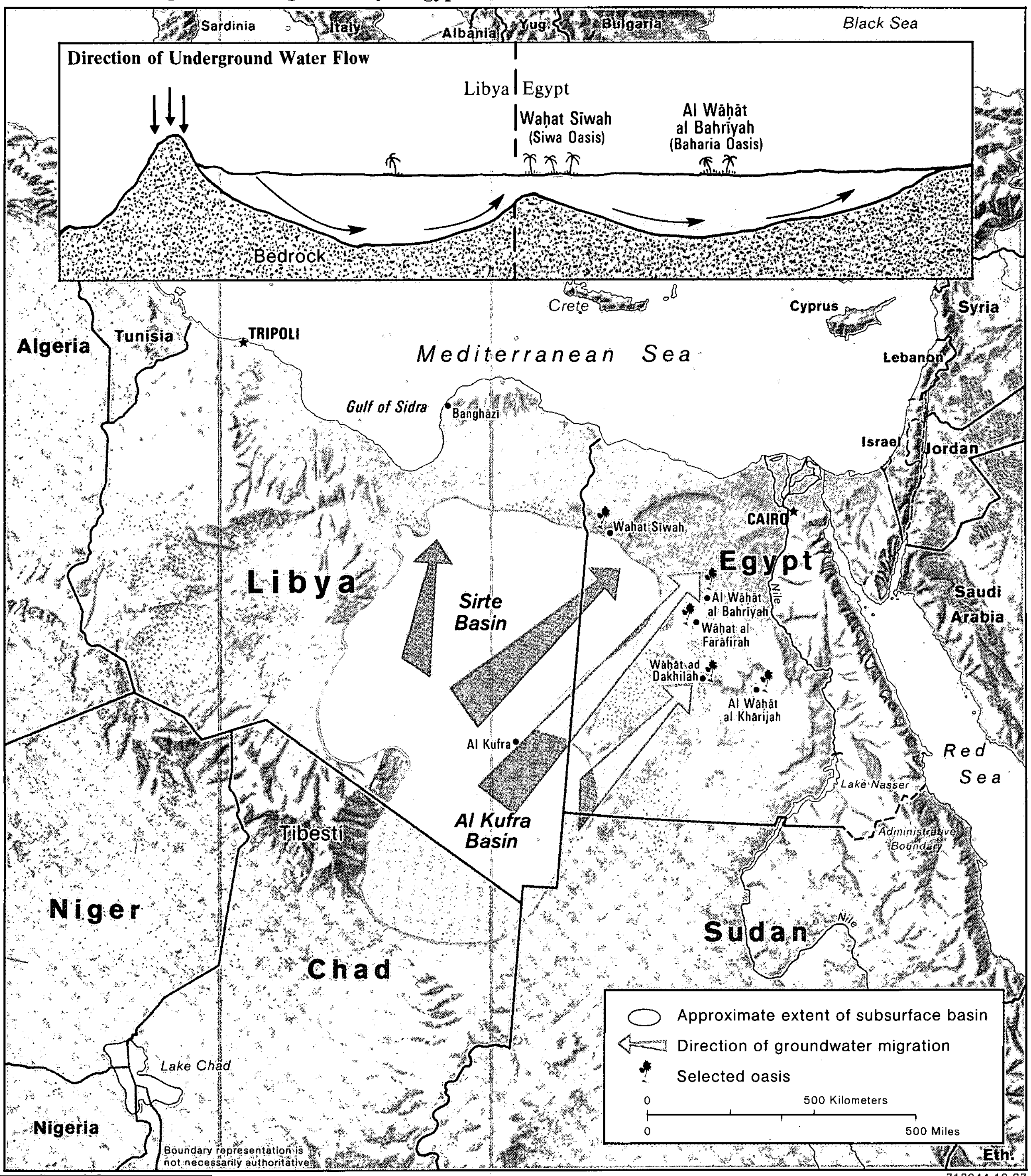
The track of the pipeline also poses no formidable engineering problems. Over the course of the pipeline, the terrain is generally flat with a slight natural gradient that will allow water to flow by gravity from the aquifers in the south to the reservoir at Ajdabiya. Pumping stations may be required for sections of the pipeline that extend from Ajdabiya west to Surt and north to Banghazi. No mountain ranges will need to be transversed, nor will any tunneling be required. 25X1
[redacted] 25X1

Despite the technical simplicity of the GMRP, there will be problems to overcome. The major problems, in our view, will come from the novelty of transporting water via buried concrete pipelines, and the Libyans clearly will be learning by trial and error. According to press reports, problems such as leakage around the pipe joints have already emerged and have been one of the factors causing the project to fall behind schedule. Another possible problem is that the highly saline 25X1 desert soil may have a corrosive effect on the pipe, especially in areas subject to intermittent rainfall. The Libyans may need to apply special paints or corrosive-resistant coatings to protect the pipeline. In time and with continued financing, the Libyans should be able to solve these engineering and physical problems. Finally, although the water is high quality it contains fairly high concentrations of carbon dioxide, a gas that is corrosive to many types of steel. Therefore, the Libyans will have to use stainless steel or other corrosive-resistant materials—products readily available from many suppliers—especially in pumping 25X1 stations along the coastal sections of pipeline. [redacted]

The Economic Dimension 25X1

The GMRP is by far Libya's most important economic development project. Although expensive, the project appears to enjoy Qadhafi's unqualified support. Contrary to almost all of the other development projects, which have been halted or slowed in recent years because of lower oil revenues, work on the GMRP has moved along steadily, experiencing only 25X1 technical delays. [redacted] 25X1

Figure 6
Groundwater Migration Along the Libya-Egypt Border



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Despite the financial burden the GMRP imposes, we believe that Qadhafi will continue this project—even if the costs prove higher—to reduce Libyan vulnerabilities on the food front. Qadhafi has repeatedly stated that Libya must become self-sufficient in food production, arguing that a food importer can never be independent of foreign pressure. Although we believe that there is virtually no possibility that Libya will become self-sufficient in food production, the GMRP at least offers some possibility for reducing food imports or, in view of the growing population, for preventing import increases. As a very rough estimate, the amount of water that will become available in the initial phase of the project—730 million m^3/yr—would be enough to irrigate about 40,000 hectares. Assuming this land were used for wheat and that yields were similar to those in Egypt—about 3.5 metric tons per hectare—production could increase by 140,000 tons per year, roughly 30 percent of Libya's wheat imports in 1985. Obviously, as the GMRP begins to reach capacity and more water becomes available, the nominal amount of additional wheat (or other crops) that could be produced will increase in tandem. [redacted]

Progress to Date

Construction of the GMRP has been under way for about three years. As of August 1987, [redacted] a considerable amount of support and ancillary construction has either been finished or is in a late stage of construction. For example:

- The pipeline service road between Sarir, Ajdabiya, and Surt has been completed.
- The pipe plants at Sarir and Marsa al Burayqah are operational, and at least 4,000 pipe sections have already been produced.
- The huge holding reservoir at Ajdabiya is in the late stage of construction (figure 8).
- Trench digging is in progress between Ajdabiya and Jalu (figure 9).
- Surveys of the Sarir well field have been completed. [redacted]

[redacted]. In any event, given the overall status of construction, we believe that major pipe-laying activity on the Sarir-to-Surt pipeline will probably begin within the next year and that completion of the pipeline will take several more years. [redacted]

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Future Plans and Expectations

The GMRP will continue to absorb a very large share of Libya's investment budget for many years. We do not have enough information to assess how the total costs of the GMRP will be apportioned, however. The bulk of the expenditures clearly will be for construction of pipe and for laying the pipe. Drilling the large number of water wells in the Al Kufra and Sirte Basins will also be costly. The Libyans claim that the cost of the GMRP will be entirely covered by current revenues, not debt. This claim seems reasonable in view of the fact that Libya has a comparatively small foreign debt and current cash reserves are high. Oil exports should continue to generate substantial export earnings well into the next century. [redacted]

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Cost overruns and delays, however, have plagued the GMRP since the initial planning of the project in 1983. According to the original schedule announced by Tripoli, the project would cost about $10 billion and operations would begin in 1989. On the basis of installation needs and engineering expenses, we calculate that the project will cost more than $30 billion spread over 10 to 15 years and will probably take until the turn of the century to complete. Although pricing increases account for most of the higher cost, various other factors have contributed to the delays. [redacted]

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- The prime contractor apparently did not realize that some sections would go through particularly hard ground, and therefore substantial blasting will be required.

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- After the US bombing in 1986, Tripoli decided to lay the pipe deeper than originally planned, further slowing digging operations and requiring the pipe segments to be wrapped in more expensive wire mesh to prevent fatigue and corrosion.

- Most of the sections laid leak and will have to be repaired or replaced. We believe this problem does not stem from basic flaws in the production technology but instead is a result of inexperience and poor workmanship, conditions which should get better with time.

- Maintenance requirements will be more extensive than initially planned because long sections of the pipeline are laid through salty soil, which has caused corrosion to occur faster than anticipated. 25X1

Despite these problems, we expect that the pace of delay will ease over time. Given the relatively simple nature of the technology and, in our view, the basic engineering soundness of the project, the chances appear good that the current problems—frequently encountered in the initial stages of construction—will be overcome, and fewer new ones are apt to appear as the Libyans gain practical experience. 25X1

The ability of the Libyans to maintain production of concrete pipe sections seems to be one of the factors that will determine the overall pace of construction. As noted, the first stage of the project—from Sarir to Surt—will cover more than 1,000 km. Each pipe section is 7.5 meters in length, implying that about 133,000 sections will be needed. The pipe plants at Sarir and Marsa al Burayqah are designed to produce the equivalent of 1,650 meters per day. If the output of both plants is directed toward the Sarir-to-Surt pipeline, this line will require roughly two years' output from both plants. Although crude, the calculation suggests that it will take until at least the early 1990s before any water will be available from the southeastern basins. The capacity of pipe plants also suggests that the Libyans will not be able to construct both pipelines simultaneously, and overall construction time could easily be in the four- to five-year range.

Although subject to considerable uncertainty, our best estimate is that the Sarir-to-Surt pipeline should be complete, or nearly so, by the early 1990s. Plans call for initially transporting 730 million m^3/yr through this line. We believe that the Libyans will start by pumping small volumes to test the line for leaks and gradually gear up to capacity levels—a test period that could take from six months to a year.

We doubt that the Libyans could even begin construction of the Tazirbu-Banghazi line until the line from Sarir-Surt is much further along. As noted, the combined output of both plants would not be sufficient to meet the requirements of both lines if they

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Construction Problems in Perspective

Although the Libyans clearly will encounter many problems building the GMRP, we are convinced that these problems do not stem from basic flaws in the technology but rather from the size of the undertaking and the inexperience of the construction crews. Indeed, somewhat similar problems have occurred in the United States in projects involving the transportation of large water volumes. Perhaps the closest US analogy to the GMRP is the huge Feather River Project in California—a successful engineering effort to transport more than 7 million m³/d from northern California to water-short regions in the southern part of the state. Although different in design, in the early stages of construction of the Feather River Project, numerous problems were encountered with leaks at holding reservoirs, aqueducts, and pumping stations. Similarly, the final cost of the project was three times more than estimated and completion took several years longer than planned.

[redacted]

were built simultaneously [redacted] the Libyans are concentrating on the Sarir-Surt pipeline. If the Libyans were to start building the required infrastructure for the Tazirbu-Banghazi line now, construction would probably take about two to three years. Assuming pipeline construction will start around 1990, this line could become available some time in mid-decade. When both lines are fully operational, plans call for transporting about 1.8 billion m³/yr. With continued investment, we believe the Libyans stand a chance of approaching this goal sometime near the turn of the century. [redacted]

Implications

. . . For Libya

In our view, Libya has little choice but to go forward with the GMRP. The Libyans will be increasingly hard pressed, even with this project, simply to meet the essential water needs of the population. At the same time, the GMRP poses potentially serious risks for Qadhafi. The GMRP will continue to drain resources, probably for at least another decade, and require more austerity measures in the domestic economy. As Qadhafi restrains current consumption and postpones or cancels other development projects, popular discontent could increase, especially if the GMRP experiences long delays. Clearly, the regime's prestige will decline further in the event that Qadhafi's pet project does not deliver the benefits promised. [redacted] 25X1

. . . For Libyan-Egyptian Relations

The GMRP is a potential flashpoint in Libyan-Egyptian relations. From the extensive technical literature available, geologists have known for many years that the groundwater in southeastern Libya migrates slowly to the north and northeast and is discharged in western Egypt at oases in Wahat Siwah, Wahat Al Farafirah, Al Wahat Al Kharijah, and Wahat Al Dakhilah (figure 6). We estimate total water discharge in these oases at about only 1.5 million m³/d, but this is adequate because western Egypt is sparsely populated and regional water needs are extremely 25X1
small. [redacted] 25X1

We see little chance that the GMRP will pose a 25X1
serious threat to the water supply of western Egypt, 25X1
but it could serve to aggravate Libyan-Egyptian relations. Egyptian subsurface water resources would be at risk only if Tripoli extracted water at rates substantially in excess of the natural recharge of the Libyan aquifers. Over time, such an outcome would drastically reduce the natural waterflow into western Egypt. It would also be self-defeating for the Libyans because their own water resources would be seriously damaged. Because these are highly technical issues not generally understood, Cairo could perceive that the mere existence of the GMRP would threaten 25X1
future water supplies in western Egypt. This alone would add to already strained relations with Tripoli. [redacted] 25X1

. . . For Other Water-Short Regions

If the GMRP proves to be technically feasible, as we believe it will, it could well serve as a model for many other water-short countries. A US company has already conducted a prefeasibility study for the Saudis, assessing the possibility of transporting water from two rivers in Turkey through Syria, Iraq, and Kuwait into northern Saudi Arabia. Turkey is reportedly pushing the idea hard because of the revenue it would bring, and the Saudis may be receptive because the costs of the delivered water would be far cheaper than the desalinized water that they currently rely on.

The African Sahel could also be a future candidate for a pipeline approach similar to the GMRP. Various studies have consistently pointed to the possibility of substantial groundwater potential in eastern Sudan, and southern parts of Niger, Kenya, and Ethiopia as well. Given the poverty of the nations in this region, however, any construction project would clearly need to be carried out with Western assistance, and its scale would be likely to be modest.

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Appendix

The Water Potential of the Al Kufra and Sirte Basins: An Estimating Approach

The CIA performed detailed technical assessments of three basic factors to estimate the water potential of the Al Kufra and Sirte Basins. Essentially, we assessed:
- The type of aquifers in these basins.
- The physical volumes of these aquifers.
- The amount of water these aquifers can realistically contain.

We used slightly different approaches to calculate potential water volumes, depending on the type of aquifer involved. Because any estimate of subsurface water resources involves many uncertainties, it is best viewed as a range. In all cases, we estimated what, in our view, represents reasonable minimum and maximum values for the amount of water that may be present. Our "best" estimate is simply our subjective evaluation of the most reasonable figure near the midpoint of the estimated range.

Types of Aquifers

Two types of aquifers exist in the Al Kufra and Sirte Basins. Technically, these aquifers are defined as:

- Confined or artesian aquifers where the water is held in an enclosed geologic structure, somewhat like an oil reservoir.

- Unconfined or water table aquifers where the water is not held in an enclosed geologic structure. Water enters the aquifer at points nearest the surface, seeps through pores in the underground rocks, and is discharged at surface points.

Water can be taken from either type of aquifer, although drilling costs will be higher in the case of confined aquifers because of the greater depths involved. We estimate that about 55 percent of the total water resources in the Al Kufra and Sirte Basins appear in confined aquifers.

Calculation of Potential Water Volumes

For Confined Aquifers

Estimating the water potential of confined aquifers involved a two-step calculation. We measured the physical volume of the aquifer by first determining its surface area (areal extent), and then by multiplying the surface area by the average thickness of the aquifer. Using this technique, we estimate that the volume of the confined aquifers in the Al Kufra and Sirte Basins is about 350 trillion cubic meters (m^3) and 160 trillion m^3, respectively. We excluded parts of the Sirte Basin above 28° north latitude because it is possible that saltwater infiltration may have already occurred in this area. 25X1

When the volume of the confined aquifers had been determined, the potential amount of water was calculated by multiplying that volume by the "storage coefficient" of the aquifer. Simply put, the storage coefficient is the amount of water per unit volume of the aquifer. Libyan data along with technical data on hydrologically similar aquifers in Egypt allowed us to determine probable minimum and maximum values for this coefficient. Taking all of these factors together, we estimate that the amount of water in the Al Kufra and Sirte Basins probably ranges between 1.6 and 4.1 trillion m^3, or an average amount of about 2.8 trillion m^3 (table A-1). 25X1

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For Unconfined Aquifers

We took a slightly modified approach to estimate the water potential of the unconfined aquifers in the Al Kufra and Sirte Basins. In the case of confined aquifers, we have more confidence in our estimate of the volume of the aquifer and somewhat less in the estimate for the storage coefficient. To establish a reasonable range, we held the volume constant and varied the value of the storage coefficient. In the case

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Table A-1
Libya: Water Potential of Confined and Unconfined Aquifers in the Al Kufra and Sirte Basins

Confined Aquifers	Area (*kilometer*)	X	Thickness (*meter*)	=	Volume (*trillion cubic meters*)	X	Storage Coefficient (*trillion cubic meters*)	=	Water [a] Volume (*trillion cubic meters*)
Al Kufra	350,000		1,000		350		0.003		1.0
							0.005		1.9
							0.008		2.8
Sirte	400,000		400		160		0.003		0.6
							0.005		0.9
							0.008		1.3
Unconfined Aquifers									
Al Kufra	350,000		250		87.5		0.01		0.9
			500		175		0.01		1.8
			1,000		350		0.01		3.5
Sirte	400,000		50		20		0.01		0.2
			100		40		0.01		0.4
			200		80		0.01		0.8

[a] Because of rounding, components may not add to the totals shown.

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of unconfined aquifers, we took the opposite approach. We have more confidence in the probable value for the storage coefficient and less confidence in the possible volume of these aquifers. Taking this approach, we held the storage coefficient constant and varied the volume of the aquifer by specifying a possible range of thickness of the aquifer. Based on this approach, we estimate that the amount of water in the unconfined aquifers in the Al Kufra and Sirte Basins ranges between 1.1 and 4.3 trillion m^3, or an average amount of about 2.7 trillion m^3. 25X1