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# WATER RESOURCES DEVELOPMENT PROJECTS IN AFRICA

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## SUMMARY

A review of the various water resources development projects in Africa is presented in this paper. A consideration of the water resources potential clearly shows that, although technically feasible, much of it remains still untapped. Apart from lack of funds, exacerbated by current recessionary forces, political disputes are to blame for this. Nevertheless, with the background of the recent devastation in the Sahelian belt, some of the development projects discussed are worthy of serious consideration.

## 1. INTRODUCTION

The African water problem has already been discussed and highlighted by the Author in an earlier paper.[1] Unfortunately, the problem has since become more acute, at least in some areas, and the only hope of alleviating the tragic effects of the prevailing natural conditions would now appear to lie in the implementation of projects aimed at developing the water resources of that continent. Water resources development projects in Africa, as elsewhere, fall into two main groups: surface water development projects, and those for developing groundwater resources. The potentials and difficulties (other than financial) of a number of projects belonging to each of these groups are reviewed in this paper.

## 2. SURFACE WATER RESOURCES DEVELOPMENT PROJECTS

Surface water development projects, whether single- or multi-purpose, can be sub-divided according to their functions and objectives in terms of: water conservation; in-basin management; water transfer; use of sea water, etc.

### 2.1 *Water conservation projects*

The overall objectives of the water conservation projects in the Nile Basin is to conserve an amount not less than 30 billion m$^3$/year which is now lost in the swampy areas of the sub-basins of Bahr el-Jebel and Bahr el-Zeraf (14 billion m$^3$/year), Bahr el-Ghazal (12 billion m$^3$/year), and in the Baro (main tributary of river Sobat) and Mashar swamps (5 billion m$^3$/year). One of these projects, which is also one of the World's largest schemes for water conservation, is the *Jonglei* project in The Sudan. Dating

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back to 1938 when it was conceived, the scheme has since undergone several modifications. The first phase of the project includes the diversion of some of the overflow of the Bahr el-Jebel into a canal 280 km long, starting at Bor/Jonglei and discharging into the White Nile near the mouth of the Sobat (Project No. 1, Figure 1). The purpose of the canal, with a planned capacity of 20 million $m^3$/day, is to increase the yield of the Nile by 4·7 billion $m^3$/year at Malakal, or by 3·8 billion $m^3$/year at Aswan, to be divided equally between Egypt and The Sudan.[2] Egypt's share alone is considered to be sufficient for the irrigation of about 75,000 ha. The agricultural development implications for the Sudan, including the utilization of the swamps, have been reviewed by Ibrahim.[3] Subsequent phases of the scheme include the reclamation of the swamps at Bahr el-Ghazal and Mashar, and the possible embankment or diversion of the Baro river (Project Nos. 2 and 3, Figure 1). A detailed description of these projects will be found in Reference 4.

When the execution of Phase 1 of the project had been underway for some time, controversial claims about its potentially harmful consequences were publicized every now and then. Salih,[5] for example, considered that it would be a mistake if the experiences of the Jonglei scheme were not coupled to an in-depth study of all the environmental consequences. Such a study could then be linked to a

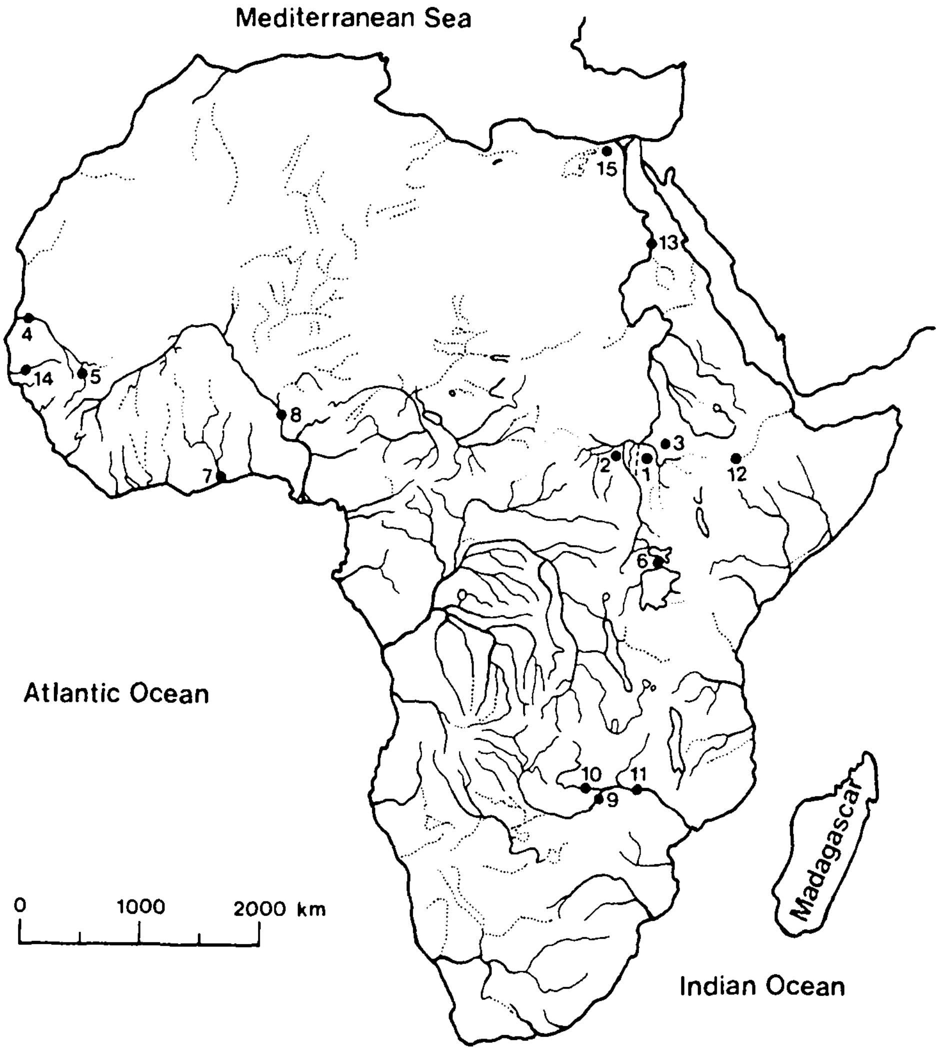

Figure 1. Map of Africa showing the major water resources development projects, both completed and planned (description of projects given in Table 1)

[redacted]

Table 1. Description of water resources development projects shown in Figure 1

| Project No. (Figure 1) | Description |
|---|---|
| 1 | The Jonglei diversion canal |
| 2 | Reclamation of Bahr el-Ghazal swamps |
| 3 | Reclamation of Mashar swamps and Baro |
| 4 | The Diama Dam project on river Senegal |
| 5 | The Manantali Dam project on river Senegal |
| 6 | The Owen Falls Dam on the White Nile (Victoria) |
| 7 | The Akasombo Dam project on river Volta |
| 8 | The Kainji Dam project on river Niger |
| 9 | The Kariba Dam project on river Zambezi |
| 10 | The Kafue Dam project on river Zambezi |
| 11 | The Caborra Bassa Dam project on river Zambezi |
| 12 | The Coka Dam project on the Awash |
| 13 | The Aswan High Dam on the Main Nile |
| 14 | The Gambia estuary barrage on river Gambia |
| 15 | The Quattara depression project |

monitoring programme to serve as a basis for future reclamation activities. Unfortunately, the attitude of the southern part of The Sudan towards the Government in Khartoum compelled the contractor to suspend work on Phase 1 before completion and after a considerable amount of time and energy had been put into it. The current situation is that, if political attitudes do not change, then the chances of resuming work in this reclamation project are remote.

More complicated still is the situation in the Mashar and the Sobat basins. There the execution of the plan and the maintenance of work cannot be carried out without the support and cooperation of Ethiopia—a situation which is difficult to envisage in the foreseeable future.

### 2.2 *Water storage works*

Accruing from one purpose or another, in the African river basins there is now considerable experience of flow regulation using on-stream storage. This experience dates back, at least in contemporary history, to the early Nineteenth Century when the Main Nile at Aswan was dammed. Since then a large number of dams and regulatory works of various types and sizes, and for different purposes, have been built on the Nile and its tributaries such as the Zambezi, the Niger and the Volta. These works have generally fulfilled their objectives with a high degree of efficiency. In particular, the Kariba and the High Dam at Aswan have contributed significantly, and continue to do so, to the alleviation of the drought which has swept certain parts of Africa for a number of years now.

The *Diama* project in The Senegal basin is approaching completion. This project involves the construction of two dams; the Diama in The Senegal and the Manantali in Mali (Project Nos. 4 and 5, Figure 1). In addition, the construction and/or improvements to roads and railways in the area are planned, as is the development of hydro-electric power. However, for Mali, The Senegal and Mauritania, three of the Sahel countries suffering from the ravages of drought, the most important aspect of the project is irrigation. The dams are expected to help increase irrigated land from 75,000 ha to 450,000 ha. Most of this increase will be near the river, particularly in Mauritania and The Senegal, leading to increased production of rice, maize, wheat and vegetables, from about 107,000 tonnes in 1980 to 580,000 tonnes by 1990. In addition, the Manantali dam will provide over 200 MW of electricity for industrial and mining developments, mainly in Southeastern Mali and also possibly in Eastern Senegal. The project is expected, furthermore, to improve the navigability of the stretch of the river from St. Louis to Kayes, a distance of about 100 km, thus providing land-locked Mali with much needed access to the sea. The river traffic is expected to increase from a meagre 10,000 tonnes/year in the pre-project period, to about one million tonnes *per annum* by the year 2000.[6] Unlike the projects described in Section 2.1, this particular project, being implemented under the auspices of the *Organization pour la Mise en Valeur du Fleuve Senegal* (OMVS), so far provides a good example of what can be achieved in Africa through regional cooperation.

Although the Diama project represents a considerable achievement in global financing, it was nonetheless held up for several years because aid commitments lagged behind estimated construction costs. The situation has now become much worse generally, and the financing of similar projects in other areas is becoming exceedingly difficult. Under the present unfavourable economic climate of the Sahel region, there is now doubt on whether the three countries sharing the Diama project will be able to service the loans, at least in the near future.[6]

In addition to financial and economic constraints, there is at present a strong wave of criticism of, and opposition to, the construction of storage and regulation works from environmentalists and other pressure groups. Such interference with natural resources, they contend, would lead to the destruction of the landscape and wildlife, including birds and many species of fish.

In many parts of Africa, another physical constraint to the construction of surface storage works is *aridity*, defined as the precipitation/evaporation ratio. Typically, evaporation losses from the existing reservoirs in the Nile basin amount to about 14 billion $m^3$/year,[7] and that from Sennar, Volta and the Kariba reservoirs is estimated at 30 percent or more of the storage volume. Examples of climatic constraints to water resources development in the Sudan-Sahelian region of Nigeria have recently been presented and discussed.[8]

Aridity increases with increasing severity of the climate. Furthermore, under a given set of climatic parameters, the volume that can evaporate depends upon the size of the surface area of the storage reservoir, the latter rapidly increasing with the level of the reservoir. The Author estimates the annual loss by evaporation from the reservoir impounded by the Aswan High Dam at 1·1, 1·8, 3·0, 4·7, 7·1, 10·3 and 14·7 billion $m^3$/year, respectively, for water levels of 120, 130, 140, 150, 160, 170, 180 and 185 m above the mean sea level. However, it is not always advisable to maintain the reservoir at a low level with the sole object of minimizing evaporation losses because, such a strategy may be in conflict with, among others, navigational and agricultural needs, or with the need to generate a certain amount of hydro-electricity. An optimized policy for reservoir planning and operation then becomes unavoidable.

Of course major storage and regulation works may not by themselves be sufficient for the development of river basin recources. A major conclusion, to emerge from a study of the different types of water resources development projects in the Nile Basin,[9] is that the water resources potential of that basin appears to be great when a relatively small number of major projects are supplemented by a large number of minor projects. The Author considers that this conclusion is also valid for the development of water resources of other river basins, especially those of the Niger and the Zambezi.

The development of hydro-electric power is one of the major purposes of the existing large dams in Africa, as will be seen from Table 2. It is interesting to note, however, that the combined generating

Table 2. Major hydro-electric dam projects in Africa

| Project No. (Figure 1) | Dam | Country | Output (MW) |
|---|---|---|---|
| 6 | Owen Falls | Uganda | 105 |
| 7 | Akasombo/Volta | Ghana | 760 |
| 8 | Kainji (First Phase) | Nigeria | 320 |
| 9 | Kariba | Zambia-Zimbabwe | 600 |
| 10 | Kafue | Zambia | 900 |
| 11 | Caborra Bassa (final stage) | Mozambique | 1200 |
| 12 | Coka | Ethiopia | 45 |
| 13 | The Aswan High Dam | Egypt | 2100 |

[redacted]

capacity of the dams listed in this Table is just over 6,000 MW, which represents a mere 15 percent of the total potential of the Zaire Basin. It is the firm conviction of the Author that the key to a major component of African development lies in the harnessing of this enormous and hitherto untapped potential.

### 2.3 *Sea water control and diversion works*

The Gambia estuary barrage is a multi-purpose project which is expected to bring considerable practical benefits to both The Gambia and Senegal. To be located across river Gambia, at a distance of about 140 km from its mouth (Project No. 14, Figure 1), the planned objectives of the project are: to control salt penetration into river Gambia; to store fresh water during the wet season, to be used for irrigating agricultural crops in the dry season; and to provide a fixed link for vehicular traffic across the river. So far plans have undergone several revisions aimed at selecting the most appropriate site for the barrage in terms of its foundation, and the design of its navigation lock, drainage sluice and enclosure dam. Apart from the technical problems, which are substantial, there are also several environmental, political and social issues hindering project implementation.

The idea of exploiting the difference in head between the Mediterranean Sea and the vast sub-sea-level Quattara Depression in the Western Desert was launched for the first time in 1916 by Professor Penck from the University of Berlin. Subsequently detailed studies were made by Ball[9] during 1927–1933. The intake of the water was planned at Al-Alemein on the Northwestern coast of Egypt (Project No. 15, Figure 1). Sea water, flowing through tunnels and open channels, would be conveyed to a depression whose lowest point is about 150 m below the mean sea level. For example, 3 tunnels, each 10 m in diameter, followed by a semi-circular channel with a radius of about 18·5 m, can convey 540 $m^3$/s of sea water. The 'equilibrium water level' is defined as that level at which the volume of surface evaporation is equal to the volume of sea water diverted. At a level of 60 m below the mean sea level, the surface area is approximately 12,100 $km^2$. Then, the two volumes (i.e. volume of diversion and that of surface evaporation) would be equal, each equal to about 18 billion $m^3$/year, when the annual depth of evaporation from the surface is 1·35 m. These calculations lead to an energy output of about 190 MW and, furthermore, this output could be increased either by increasing the amount of water diverted from the sea, or by reducing the daily hours of turbine operation.

Although over the years this project, known as the Quattara project, has been revised and improved, no decision has yet been taken on whether to implement or abandon it. The difficulties inherent to the project are both substantial and numerous. The major technical difficulties are: the location of the intake structure, with reference to the fact that the proposed sites for the tunnels and channels are surrounded by mine-fields left over from World War II; the alignment of tunnels and their excavation in rocky terrains; dimensions of tunnels, channels and other appurtenances; and the probable contamination of fresh groundwater in the vicinity of the depression.

Twenty-five years ago the annual evaporation, which is a key factor in the design of this project, was estimated at 1·4 m. From the average of the Dalton, Budget, Penman and McIlory methods, five years ago Flohn and Wittenberg[10] revised that figure to 1·75 km. On this basis, the discharge to be conveyed from the sea must now be increased to 675 $m^3$/s, thus necessitating larger tunnels, channels and other structures.

## 3. GROUNDWATER MANAGEMENT PROJECTS

Arid zones to the North and Northwest of Africa are underlain by extensive and deep aquifers, as will be seen from Figure 2 which shows the boundaries of the principal groundwater basins.[11] Clearly, the continuation of sedentary life in and around the desert oases in these basins depends upon the exploitation of groundwater. In the following we will refer to some of the projects aimed at the exploitation and management of a number of these basins.

Starting with groundwater basins in the north of the Sahara, it will be observed that in 1970 the irrigated land almost exclusively given over to the production of palm-date totalled 29,000 ha in Algeria

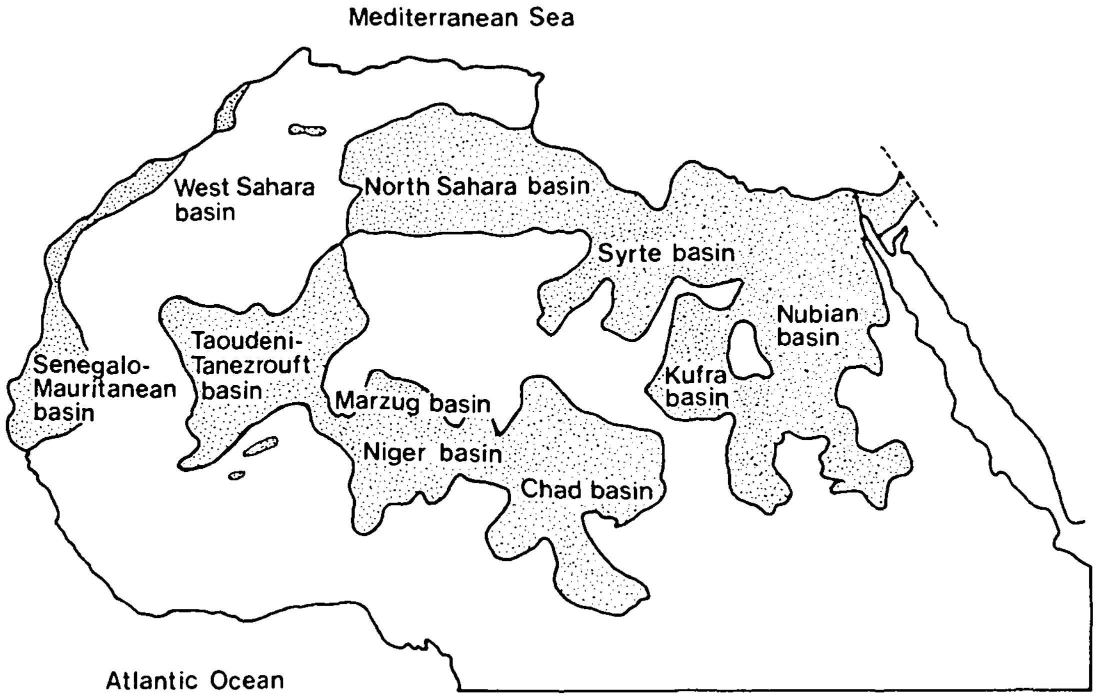

Figure 2. Map showing the major groundwater basins in the Northern half of Africa

and 15,000 ha in Tunisia, representing water demands of approximately 15 and 9 $m^3/s$, respectively. In order to cope with increasing population,[12] it is planned to increase this acreage of irrigated land from about 45,000 ha in 1970 to 95,000 ha by the year 2000.

The artesian basin of the northern Sahara has two principal confined aquifers: the *Continental Stratum* (deep reservoir) and the *Terminal Complex* (shallower reservoir). Previous investigations led to the conclusion that recharge to the basin, from rainfall on its periphery, is approximately equal to the volume of water exploited; and that more intensive exploitation would only diminish the groundwater reserves accumulated during rainy periods of the quaternary era. Further investigations and model studies estimated that an overall drying-up of the springs and foggaras* would occur in around 1980, by which time they will have been replaced by boreholes according to the following schemes:

Algeria: Maximum flow = 58·2 $m^3/s$ from 1500 boreholes for 75,000 ha.
Minimum flow = 41·4 $m^3/s$ from 1000 boreholes for 57,000 ha.

Tunisia: Maximum flow = 22·4 $m^3/s$ from 400 boreholes for 27,500 ha.
Minimum flow = 17·0 $m^3/s$ from 250 boreholes for 20,500 ha.

The implementation of the above scheme would lead to maximum and minimum withdrawals of approximately 2·6 and 1·8 billion $m^3$/year, respectively; it is interesting to note that these rates compare with an average of just 0·75 billion $m^3$/year in 1970.

This scheme is, however, subject to a number of difficulties: wells to be dug to great depths; the possibility of saline water from the secondary aquifers intruding into those being exploited; high water-hammer pressures at the surface caused by the sudden closure of the well; high water velocities, produced by the artesian effect, may cause mechanical vibration which may damage or even destroy the concrete supporting structures; and possible corrosion due to the high level of $CO_2$ in the pumped

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* Local name for galleries collecting groundwater.

water.[13] Clearly, these factors are likely to affect adversely the working life-spans of wells and boreholes (economic analyses show that the optimum life-span of a borehole is 20 years, which compares with 30 years for a well whose depth is less than 1000 m). Furthermore, the economic viability of the scheme presumes that an effective agricultural policy would be pursued to guarantee adequate returns on investment.

Characterized by its aridity, the Nubian basin (Figure 2) is very extensive with a total surface area of about 1·8 million $km^2$, and its store of groundwater is apparently non-renewable. The aquifer has its intake beds in the high plateaux of Erdi and Ennedi, about 1300 m above the mean sea level at Alexandria, which belong to the Chad group. The Quattara depression at the northern extremity of the basin serves as a discharge point. Since 1959, over 350 of what were originally free-flowing wells have been dug in Egypt, ranging in depth from 400 to 1200 m. Due to the intensive exploitation of groundwater in the oases, however, the hydrostatic head in the Kharga oasis, for example, has fallen by more than 35 m in the period from 1956 up to and including 1975. A project is now being implemented in Egypt for increasing the volume of water, extracted annually from the deep Nubian sandstones, from 360 million $m^3$ in 1975 to a massive 2400 million $m^3$ by the year 2025.[13]

The Kufrah irrigation development project in the important oasis of Kufrah, Libya, is aimed at irrigating 10,000 ha to help cultivate alfalfa for the grazing of sheep, and this on-going project is expected to increase water extraction to 220 million $m^3$ annually. Here, as in the Kharga oasis in Egypt, the maximum observed fall in level due to groundwater extraction reached 15–20 m during the four-year period of 1971–1975. Reportedly, the extraction of groundwater at Kufrah does not affect that in the New Valley, Egypt. It is considered that a buffer zone of at least 50 km should separate the spheres of influence of such large groundwater extraction projects.

The major difficulties inherent to groundwater projects are, firstly, the strategy to be adopted for exploiting the aquifer and, secondly, the implementation of an effective scheme whereby the extracted water is used efficiently to generate a reasonable return on investment. To this end, a novel multi-national proposal has recently been made for the exploitation of the Nubian aquifer to benefit Egypt, Libya and The Sudan. Unfortunately, the plan is now under threat from political disputes involving these countries.

A number of studies have so far been made on the water resources of the Chad basin by various non-African as well as international agencies. This basin, covering in excess of 1·4 million $km^2$, extends over vast tracts in Chad, Niger, Nigeria and Cameroon. Other than data collection and processing, there is at present practically no project in this basin for the development of its enormous groundwater resources. As usual, lack of capital is the main reason for this.

## 4. CONCLUDING REMARKS

An overview of African water resources, both manifest and potential, clearly shows that a very great deal can be done to alleviate the chronic shortage of water endemic in several parts of that continent. At present two major problems constrain and thwart such developments: lack of funds and, perhaps more importantly, lack of cooperation at the governmental level due to the various inter-national political disputes. It is very much to be hoped that in not too distant a future the alleviation of human suffering, caused by the shortage of water, would transcend more mundane geo-political considerations, thus making it possible for nature's bounty to nourish those who now suffer.

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