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INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

INTERNATIONAL DEVELOPMENT ASSOCIATION

PROJECT PERFORMANCE AUDIT

of

SUDAN ROSEIRES IRRIGATION PROJECT
(Loan 284/Credit 2)

July 10, 1974

Operations Evaluation Department

PROJECT PERFORMANCE AUDIT

SUDAN ROSEIRES IRRIGATION PROJECT

PREFACE

Loan 284 and Credit 2 of June 14, 1961, were closed in July 1972 and the following report represents an audit of achievements under the loan/credit against the objectives on the basis of which they were approved. The report is based on a review of the relevant Bank files and documents, on discussions with Bank staff, Sudanese officials, and consultants who were involved in the project implementation and on the findings of a three-week mission to Sudan, which was undertaken to gather the basic information regarding the actual use of the water stored by the Roseires Dam and the related agricultural developments since 1966, the year of the dam's completion.

The valuable assistance provided by the Government of the Sudan in the preparation of this report is gratefully acknowledged.

Currency Equivalents (1961-1973)

1 Sudanese Pound (LSd) = 1,000 Milliemes (mms)
US$ 1.00 = LSd 0.345
LSd 1.00 = US$ 2.872

Weights and Measures

1 meter (m) = 39.37 in
1 cubic meter (m^3) = 35.31 cubic feet
1 metric ton (ton) = 2,204 lb
1 feddan = 0.420 hectares = 1.038 acres

Sudan Fiscal Year ends June 30

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SUMMARY

On June 14, 1961, the Bank made a US$ 19.5 million loan and IDA a US$ 13 million credit (Loan 284/Credit 2) to the Sudan to assist in the financing of the Roseires Irrigation Project. Kreditanstalt fur Wiederaufbau (KfW) of Germany also participated in the financing with a US$ 19 million loan. The project was based on engineering studies made by consultants and Bank technical missions in October 1958 and May 1960. It comprised the following:

Part A) the construction over a six-year period of a dam on the Blue Nile near Roseires at an estimated cost of US$ 87.8 million equivalent (including associated works).

Part B) the development, over the final three-year period of the dam construction, of new pump irrigation schemes and the extension and intensification of the Gezira/Managil gravity irrigation schemes at an estimated cost of US$ 88.7 million equivalent.

The main objective of the dam construction was to provide sufficient water during the annual critical period (December-May) when the Blue Nile flow is at its lowest level. The gross operating storage capacity of the Roseires Dam reservoir was estimated to be 3,024 million m^3, which after an evaporation allowance of 300 million m^3, would provide a net storage of 2,724 million m^3 per year for irrigation uses (less provision for sedimentation of 15 million m^3 per year). The dam was to be constructed so as to permit a further heightening by 10 m.

The construction of the dam commenced in November 1961 and was substantially completed by June 1966, one year ahead of schedule at a cost of about 97% of the appraisal estimate.

The following additions were made to the original project in 1964 and 1965: powerhouse foundation (US$ 3.7 million); powerhouse substructure (US$ 2.6 million); engineering fees for various soil surveys (US$ 2.3 million); preparation for an irrigation canal headworks at the east bank of the dam (US$ 0.4 million). In 1968, the Tambul Pilot Farm (US$ 0.7 million), to conduct applied agricultural research, was added to the project.

The following compares planned (by 1967) and actual (by 1973) developments of Part B of the Roseires Irrigation Project:

	feddans ('000) Est.	Act.
Intensification of cropping, Gezira area	290	95
New pump schemes	670	168
Extension of Gezira/Managil area	200	175
Expansion sugarcane production, Guneid area	3	0
Total	1,163	438

The main reason for delays in developments of new pump schemes was the lack of detailed plans at appraisal time and the nationalization fears in the mid-1960s that discouraged private investments; about half of the new pump schemes were expected to be private.

The major agricultural project to be developed as logically following the Roseires Irrigation Project was the Rahad Irrigation Project. Although the project was appraised by the Bank in 1968 and 1970, it was not until 1973, after a third appraisal, that the Bank agreed to participate in its financing. Main reasons for postponement of participation in this project by the Bank were its estimated low economic return in 1968 (8%), the large size of the investment, the lack of a comprehensive national development plan and, in particular, major uncertainties regarding the capacity of the Government to provide the required local currency funds.

Since the development of new pump schemes is behind schedule and the annual needs for stored water had been overestimated at appraisal time by about 730 million m^3, or about 40% of the expected annual use -- because major benefits of the 1959 Nile Waters Agreement with Egypt were overlooked -- only about 20% of the present net operating storage capacity of the Roseires Reservoir is now being utilized for irrigation purposes. Since the dam completion the use of Roseires stored water for irrigation has fluctuated around 400 million m^3 per year as compared with the appraisal estimate of 1,900 million m^3. Major efforts have however been made in the last years to develop schemes for greater use of the water and the present construction program of irrigation schemes, including the major Rahad Project, is expected to increase the utilization of the Reservoir to about 70% by 1980.

In spite of the fact that only 40% of the estimated area has been developed or intensified, actual net agricultural benefits in 1972/73 amounted to 65% of the estimated benefits due to higher than expected cotton yields and prices. Most of the agricultural benefits to this date resulted from the extension/intensification of the Gezira/Managil Scheme. In addition, the dam has generated substantial hydroelectric benefits following the installation in 1972 of three turbines of 30 Mw each under a Bank-financed project. The dam, together with the related investments in agriculture and power, is now estimated to yield a rate of return of about 9%.

The Roseires Irrigation Project accounted for 22% of the total investments in Sudan in the 1961/62-1966/67 period, and for 43% of those in

agriculture and irrigation. The agricultural developments have generated substantial employment: a total of about 18,000 new tenants have settled on the new schemes and extensions developed since 1966/67, with average tenancies of 17 feddans (7 ha), and they have provided seasonal work for about 100,000 pickers. The agricultural benefits have been distributed equally between the tenants and the Government. However, for the first ten years (1961-1971) the project had a negative impact on the Government's finances, resulting in a total net deficit of about US$ 86 million equivalent.

In conclusion, the study suggests that the decision to build a dam at Roseires was right given the high priority of irrigation for the development of Sudan and particularly the high profitability of cotton production in the Blue Nile area. Although the original justification of the dam was based solely on irrigation benefits, its large hydroelectric potential, now beginning to be exploited, would have contributed significantly to justify the investment. However, in retrospect, construction of the dam seems to have been premature by about five years, mainly because of the delays in the development of new pump schemes, and the overestimation of the needs for stored water at appraisal time. Also, there has been a lack of comprehensive planning of the utilization of the Nile Water resources and developments have followed one another on an ad hoc basis. No detailed studies of the expected irrigation schemes were made at appraisal time and power generation was not stated as one of the project objectives. What was needed then was a package investment program which would have permitted the coordination and optimization of irrigation, agriculture and power developments. Had such planning and package investment program been developed before appraisal, the project, together with the other schemes, would have yielded much higher economic benefits. This detailed planning would also have helped avoid some of the delays in agricultural developments due to the political uncertainty in the country. Finally, the Bank could have played a more useful role, through earlier and more frequent supervision, in the preparation of the agricultural part (Part B) of the project.

PROJECT PERFORMANCE AUDIT: SUDAN ROSEIRES IRRIGATION PROJECT

1. Background

On June 14, 1961, the Bank made a US$ 19.5 million loan and IDA a US$ 13 million credit (Loan 284/Credit 2) to the Democratic Republic of the Sudan to assist in the financing of the Roseires Irrigation Project. Kreditanstalt fur Wiederaufbau (KfW) of Germany also participated in the financing with a loan of US$ 19 million. The objective of the project was to provide, by means of the storage capacity of a dam to be built on the Blue Nile River near Roseires, sufficient water during the restricted season (December through May) to make possible the execution of new agricultural developments.

Sudan is the largest country in Africa with an area of about 2.5 million km^2 and a population of about 17 million. Less than 2% of Sudan's total area is cultivated, i.e. about 11 million feddans, including about 3.3 million feddans under irrigation. Most of the land is **semi-arid** and used for grazing and marginal dry farming except for the far southern area, which lies in a tropical rainfall belt. The mainstay of Sudan's economy is agriculture, which employs 90% of the population and contributes almost 100% of exports (cotton alone accounted for 58% of total exports in 1970/71) as well as 36% of the GDP (1968/69). Irrigation from the Blue Nile has been the key to agricultural development: most of the irrigated land is situated in the delta area formed by the confluence of the Blue Nile and the White Nile Rivers at Khartoum (see attached map). The largest of the irrigated schemes is the Gezira, most of which was developed successfully in the 1920s, with the major Managil extension added in the early 1960s. The total Gezira/Managil Scheme now commands an area of approximately 2 million feddans and its cotton production in 1970/71 accounted for 60% of total cotton production in the country.

The Roseires Dam was conceived in the early 1950s as a way to irrigate by gravity the large adjoining Kenana area on the Left Bank of the Blue Nile, in the way the Sennar Dam had been conceived in the 1920s to irrigate the Gezira area. In October 1958 the Bank sent a mission to Sudan at the request of the Government to examine the technical and economic aspects of the Managil and Roseires irrigation projects. These two projects were at the time the only immediate and major possibilities for expansion of commercial agriculture (mainly cotton) in the country. The mission reported favorably on both schemes but recommended that Managil should be given priority. The Government was informed, however, that before the Bank could consider participation in financing these projects, adequate arrangements had to be made with regard to the riparian interests of other countries on the Nile River.

In December 1959 the Government informed the Bank that agreement had been reached with the United Arab Republic allocating the waters of the Nile between the Sudan and Egypt, including a provision for deducting from this

allocation the future requirements of other countries that had claims for water. Concurrently, the Government renewed its application for assistance to finance the Managil Scheme as the first stage of its irrigation program and the Roseires Project as a subsequent stage. Following a further appraisal of the proposal in March 1960, negotiations were concluded in June 1960 for a Bank loan of US$ 15.5 million equivalent to assist financing the Managil Irrigation Project (Loan 258-SU). Technical missions visited Sudan in March and May 1960 for further examinations of the Roseires Project.

Any further expansion of irrigation after the completion of the Managil Scheme would have been restricted by irrigation water shortage during the December-May season of low river flow. The Roseires Irrigation Project was expected to remove this bottleneck to further irrigation development.

The Roseires Irrigation Project comprised the following:

Part A) the construction over a six-year period of a dam on the Blue Nile near Roseires, 106 km downstream from the Ethiopian border, and of the necessary works to regulate the releases of stored water; and

Part B) the development, over the final three-year period of the dam construction, of new pump irrigation schemes and the extension and intensification of the Gezira/Managil gravity irrigation schemes.

The estimated cost of the dam construction (Part A) including preparatory and associated works was US$ 87.8 million equivalent (including interest charges during construction). External financing for US$ 51.5 million was required to cover foreign exchange expenditures of US$ 43.2 million for construction of the dam -- including the reimbursement to the Sudanese Government of US$ 350,000 used to hire consulting engineers between July 1960 and July 1961 -- and interest charges of US$ 8.3 million during construction.

The Roseires Dam was to have a maximum height of about 60 m and an overall length of 16.1 km, of which 15.0 km was to be earthfilled. The total volume of concrete and earthfill was to be approximately 0.61 million m^3 and 5.2 million m^3, respectively. The gross operating storage capacity of the Roseires Reservoir was estimated to be 3,024 million m^3, which after an evaporation allowance of 300 million m^3, would provide a net storage of 2,724 million m^3 per year for irrigations uses (less provision for sedimentation of 15 million m^3 per year). The reservoir was expected to more than double the amount of available water during the annual shortage season. The dam was designed to follow a further heightening by 10 m (Roseires Stage II), which would increase the reservoir capacity by an additional 4,600 million m^3. The 1958 Bank mission had suggested postponement of the major Kenana irrigation scheme to include it with Roseires Stage II.

No concrete plans for the financing of Part B were agreed upon in 1961. The total cost of the irrigation works and farm developments, to be undertaken between 1964 and 1967, was estimated at US$ 88.7 million equivalent. When fully operational, the annual net agricultural benefits (mainly from cotton) were estimated to be 17% of total investments. The Government expected that about half of the new pump schemes would be private schemes.

The Roseires Irrigation Project was a key component of the Seven-Year Development Plan extending from 1961/62 to 1967/68, the terminal year being based on the expected completion date of the Roseires Dam. However, the Plan never went beyond the draft stage as it was concluded that with the resources available over the period a balanced investment program, including the Roseires Project, could not be reached. In its place, the Ten-Year Plan of Economic and Social Development extending from 1961/62 to 1970/71, with an estimated investment of US$ 1,650 million, was proposed and accepted by the Government. The implementation of Part A and Part B of the Roseires Irrigation Project was to account for 11% (US$ 176.5 million) of the Ten-Year Plan.

II. Project Implementation

1. Part A, the Dam

The construction program of Part A was divided into ten contracts, for which bids had been submitted before loan signing. The first nine covered the associated works while the tenth contract covered the construction of the dam. Contract 10 was estimated to account for about 88% of the entire cost of the program (Table 1) as well as most of the foreign exchange expenditures.

The construction of the dam was begun in November 1961 by the Italian contracting firm, Impregilo. The consulting firms of Sir Alexander Gibb & Partners (of London) and MM. Andre Coyne and Jean Bellier (of Paris), who designed the dam, were placed in charge of supervision. Several changes in design were implemented during the construction period due mostly to the shearing strength of the clay under the 15 km of the embankment. A continuous mass concrete raft design replaced the discontinuous double buttress arrangement initially planned.

Soil surveys in the early 1960s, financed under the project, showed that the Right Bank Rahad area was more suitable for gravity irrigation than the Left Bank, where the Kenana Scheme was originally planned. Consequently, the Roseires Dam today is equipped with two off-take exits for gravity irrigation, one on each side, but none is being utilized at present (even the recent Rahad Project, at least in its first stage, is being constructed as a pump scheme, pumping from the run of the river downstream of the Roseires Dam). In the meantime it had also been decided to add a power

station to the dam, which in practice has now reduced the net operating storage of the dam for irrigation purposes by about 25%, from a level of 2,724 million m^3, as estimated at appraisal time, to about 2,085 million m^3 1/ (after evaporation allowance of 300 million m^3 in both cases); however, it should be noted that due to sedimentation such a reduction was expected to take place but only progressively at a rate of 15 million m^3 per year over a 40-year period.

Thus the following additions were made to the original project in 1964 and 1965: powerhouse foundation (US$ 3.7 million); powerhouse substructure (US$ 2.6 million); engineering fees for various pre-investment surveys (US$ 2.3 million); preparation for an irrigation canal headworks at the east bank of the dam (US$ 0.4 million). In 1968, the Tambul Pilot Farm (US$ 0.7 million) was added to the project.

Impregilo performed an efficient construction job in spite of difficulties in railway transport from Port Sudan to the dam site. Construction of the dam was substantially completed by late June 1966, in accordance with the accelerated construction program proposed by Impregilo in 1962. This was one year ahead of the appraisal's scheduled completion date of July 1, 1967. Impregilo collected a bonus of US$ 730,000 from the Sudanese Government on account of the completion on schedule (as specified in the contract). The actual cost of dam construction was approximately 97% of the total estimated cost (detailed information is presented in Table 1 and Table 2 contains the schedule of loan disbursements).

A good indicator of the progress of dam construction is the volume of concrete placed, which is given below:

Volume of Concrete Placed
(m^3)

	By Year	Cumulative
1961/62	23,400	23,400
1962/63	76,600	100,000
1963/64	372,500	472,500
1964/65	197,980	670,480
1965/66	172,523	843,003
1966/67	6,997	850,000

1/ The power station was designed for a mininum level of 467 m, which is the level of the two off-take exits for gravity irrigation. As long as these exits remain unutilized (probably until the mid-1980s), the power station will be the real cause of the reduction of the net storage of the dam for irrigation purposes by 25%.

2. Part B, the Irrigation Schemes

The implementation of Part B of the Roseires Irrigation Project, the construction of new pump schemes and the extension and intensification of the Gezira/Managil Scheme, did not receive any financial assistance from the Bank except for the pre-investment surveys, including soil surveys, engineering studies and agricultural research, which were added to the project in 1964-65 and had a cost of US$ 3.2 million. These studies led to the preparation of new agricultural investments at Es Suki and Rahad, where the soil surveys had identified sizeable blocks of good land due to low ESP[1/] and salinity levels.

The major agricultural project to be developed as logically following the construction of the Roseires Dam was the Rahad Irrigation Project, for which the Bank showed a strong interest in the past but did not make any formal commitments towards its financing until 1973. Although the project was appraised in 1968 and 1970, it was not until 1973, after a third appraisal, that the Bank agreed to participate in the financing of the first stage of the Rahad Project (Credit 364-SU). The main reasons for postponement of participation in this project by the Bank were its estimated low economic return in 1968 (8%), the large size of the investment, the lack of a comprehensive national development plan and, in particular, major uncertainties regarding the capacity of the Government to provide the required local currency funds. There was also overall economic and political uncertainty during this period and the Bank did not finance any project in Sudan from September 1968 until June 1972.

Aside from Rahad Stage I, the Sudanese had to depend on their own resources to finance the development of the Gezira/Managil extension and intensification, the new pump schemes, and other agricultural developments. All actual investments were public as no new private scheme developed following nationalization fears in the mid-1960s, though actual nationalization did not take place until 1970. As a background, it is worth mentioning that in contrast with the stability of the early 1960s (1960-64), the period during which Part B investments took place (1964-71) was marked by political instability, including two revolutions (October 1964 and May 1969).

The following table compares planned (by 1967) and actual (by 1973) developments of Part B of the Roseires Irrigation Project:

	feddans ('000)	
	Est.	Act.
Cropping intensification, Gezira area	290	95[a/]
New pump schemes	670	168
Extension of Gezira/Managil area	200	175
Expansion of sugarcane production, Guneid area	3	0
Total	1,163	438

a/ Increased to 195,000 feddans in 1974 due to the cultivation of 100,000 additional feddans of wheat.

1/ Exchangeable Sodium Percentage.

More details about the actual agricultural developments since 1966 are given in Table 3.

Before the completion of the Roseires Dam, about 61% of the land commanded for irrigation in the Gezira/Managil Scheme was under crop each year; the rest of the land was kept fallow to make maximum use of flood season water and to minimize problems of crop diseases and weed control. With more water now being available, cropping has been intensified from 61% to 66% of the total land under rotation, meaning that 41,000, 32,000 and 22,000 additional feddans each year (a total of 95,000 feddans) have been cropped with cotton, wheat, and groundnuts, respectively. Also, Gezira/ Managil was extended by 175,000 feddans by new developments in the southwest and southeast.

New pump schemes irrigated only 168,000 feddans out of the estimated 670,000 feddans. Wad El Haddad (32,000 feddans), which is a part of Gezira/ Managil, Guneid Extension (48,000 feddans) and the Es Suki Scheme (88,000 feddans) were developed. Total investments in agricultural developments until 1972/73 were 40% of the appraisal estimate of US$ 88.7 million (Table 1). Presently under construction are the following schemes: Rahad Phase I (300,000 feddans); Northwest Sennar (37,000 feddans); and Abu Naama Kenaf (30,000 feddans). When these new schemes are fully developed, the total number of feddans served with new pump schemes will increase to 535,000.

The Tambul Pilot Farm was the final item financed under the Bank loan/credit (US$ 650,000). The purpose of the Pilot Farm was to conduct applied agricultural research to explore possibilities of introducing new technology for improving yields and reducing costs of agricultural production on irrigation schemes for Sudan, in general, and for the Rahad Irrigation Project in particular. The most important contribution of the Pilot Farm has been the experiments leading to the proof that the application of long furrow irrigation in the Blue Nile area leads to better yields than the basin irrigation which is used in Gezira/Managil. As a result, long furrow irrigation will be used in the Rahad Project and possibly other future irrigation projects as well.

As part of the loan covenants, the Sudanese Government had agreed to carry out Part B fully although its financing was left open at appraisal time. Due to delays in development of new pump schemes this major covenant has not yet been entirely fulfilled. However, there has been no breach of agreement as no specific timetable for implementation of Part B was mentioned in the loan documents (it was only specified that irrigation works would commence during the construction period of the dam). All other loan covenants (referring to both Part A and Part B of the project) were adhered to.

3. The Project in the Ten-Year Development Plan

The physical accomplishments of the Roseires Irrigation Project have been a major portion of the Ten-Year Development Plan. They have been called

the "backbone" of investments in Sudan today. The investments in the project were to account for 11% of the entire investment of the Ten-Year Plan. In practice, the investment totals of both the Ten-Year Plan and the Roseires Irrigation Project were not reached. The Development Plan was almost abandoned after the October 1964 revolution, but its quantitative targets continued to provide guidelines for the annual development budgets from 1965/66 to 1969/70. Actual public sector investments were about US$ 870 million equivalent or about 90% of the Plan target, but this figure is misleading since the Plan assumed a stable price level, which was not the case and hence fewer projects were executed. Investments in the private sector dropped considerably after 1968 owing to unsettled political conditions and frequent changes in policies pertaining to the sector, culminating in the nationalization measures of 1970; they amounted only to about US$ 70 million during the Plan period. The Roseires Irrigation Project accounted for US$ 118 million, or 13% of the US$ 940 million actually invested during the period covered by the Plan.

III. Use of Roseires Stored Water by Irrigation Schemes

At appraisal time, the use of the water stored in the Roseires reservoir was planned as follows:

		(million m^3)
a)	Conversion " restricted" pump schemes to unrestricted pumping	255
b)	Cropping intensification in Gezira area	700
c)	New pump schemes	601
d)	Extension of Gezira/Managil area	162
e)	Increasing supplies for existing schemes	161
f)	Expansion sugarcane production, Guneid area	34
	Total	1,914

The above uses were supposed to take place as soon as the dam would be completed. A balance of about 800 million m^3 had not yet been specifically allocated; it was to be used for further irrigation, after a reasonable provision for sedimentation, then estimated at 15 million m^3 per year.

The use of stored water since 1966 has been much lower than expected. Considering the hypothetical 80% reliability natural flows of the Blue Nile as used at appraisal time and excluding pre-planting water for cotton, a practice introduced on a large scale in the Gezira/Managil Scheme following the completion of the Roseires Dam but now intended to be discontinued in the

future as having practically no noticeable impact on yields,[1/] the use of Roseires stored water for irrigation has been fluctuating around 400 million m^3:

1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73
0	404	245	494	426	682	337

i.e. approximately a 20% utilization of the present net operating capacity of about 2,085 million m^3, as compared with the 70% utilization planned for 1967 at appraisal time (1,914 million m^3 out of a then estimated capacity of 2,724 million m^3).

This major conclusion regarding the utilization of the Roseires Reservoir is based on 80% reliability flows of the Blue Nile (Table 4), actual uses of Blue Nile Waters for irrigation in the Gezira/Managil Scheme and Pump Schemes (Table 5) and on assumptions and methods of calculations detailed in Tables 6, 7 and 8. The basic method of calculation consisted of deducting the monthly natural flows of an 80% year (average monthly flows expected to be exceeded statistically four years out of five), from the actual monthly uses of the Blue Nile Waters: irrigation schemes, evaporation from dams, and minimum release downstream to Khartoum (for local use). This led to the utilization of the water stored at both Sennar and Roseires Dam during December-May; outside this period all irrigation requirements can be met from the natural flows of the Blue Nile, then extremely high as shown in Table 4. Deducting from this balance the operating storage of the Sennar Dam, built on the Blue Nile in 1925 to irrigate by gravity the large Gezira area, it is possible to obtain the volume of Roseires water used for irrigation. This method is certainly an oversimplification of the various uses of the Blue Nile Water, but still is quite reliable as more complex calculations that we tried for sample years gave similar results: in one case we used 10-day periods instead of monthly periods; in another we subdivided water uses into three parts: upstream Roseires, downstream Roseires-upstream Sennar, and downstream Sennar, and cross-checked that the "actual" monthly discharges at Roseires Dam and at Sennar Dam matched the ones "calculated" by subtracting actual monthly irrigation uses from actual monthly flows.

Table 8 summarizes the results of the use of Roseires stored water based on several sensitivity analysis tests. First, the consideration of actual monthly flows of the Blue Nile for each year instead of the statistical average 80% year leads to the conclusion that in the last seven years only in one year, 1972/73, which was exceptionally dry (one of the driest in the last 60 years), has the dam proved to be significantly useful for irrigation purposes; in another year, 1969/70, it was marginally useful (14% of its capacity), and in the remaining five years it has not been utilized at all. On the other hand, the consideration of pre-planting water, which was

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1/ According to the results of research by the Agricultural Research Corporation, Gezira Research station; some published in an article in the Cotton Growing Review, London, October 1971, "Pre-Watering of Cotton in the Sudan."

actually used for the Gezira/Managil Scheme, leads to a slightly better utilization of the Roseires Reservoir, about 250 million m^3 more for each of the last four years.

There are three main reasons explaining this low utilization of the Roseires Reservoir for irrigation. First, the development of new pump schemes in the Blue Nile has been much slower than expected, and has used only about 140 million m^3 of stored water during the critical period instead of the expected 601 million m^3. Second, the appraisal report had overlooked the fact that the 1959 Nile Waters Agreement with Egypt implied that upon completion of the Aswan High Dam in Egypt -- which took place in 1969[1/] -- the Sudan would be free to draw any amount of water from the Blue Nile during the until then "restricted" seasons (January-July) provided the total annual withdrawals (including the flood season) did not exceed 18,500 million m^3 as measured at Aswan (this compared with an annual share of 4,000 million m^3 before 1959); the appraisal estimates were apparently based on total withdrawals from the natural flow during the restricted season of 1,134 million m^3 [2/], whereas in an 80% year the natural flows of the Blue Nile amount to 1,866 million m^3 through the critical period January to May (2,404 million m^3 in a median year), meaning that at least an additional 732 million m^3 (when using the 80% reliability criterion) were made available for irrigation since 1969; one of the reasons why this additional volume from the natural flow was overlooked is the fact that the Roseires Dam Project had been first appraised in 1958, i.e. before the 1959 Nile Waters Agreement with Egypt was signed, and the assumptions of the 1958 Technical Mission in calculating the needs for stored water were used in the 1961 Appraisal Report apparently without any modification. Third, both the conversion of restricted pump schemes to unrestricted pump schemes and the expansion of sugarcane production at Guneid did not take place, resulting in a reduction in water use by about 280 million m^3. The only agricultural development that took place as expected is the extension/intensification of the Gezira/Managil Scheme; however, mainly due to the second factor indicated above (benefits of 1959 Nile Waters Agreement overlooked) it uses only about 200 million m^3 of stored water as compared with an estimated 862 million m^3.

1/ By 1969 the Aswan Reservoir had been filled up to a level of 60,000 million m^3, enough to avoid the need for a Sudanese "restricted period;" the Reservoir full capacity is 157,000 million m^3 comprising 30,000 million for dead storage, 37,000 million for flood protection and 90,000 million for operating storage (about equal to the total natural flow of the Nile at Aswan in a median year).

2/ Historic withdrawals from the Nile flow (284 million m^3) and the equivalent of the release to Egypt of stored water from the Jebel Aulia Dam on the White Nile (850 million m^3).

The comparison of 1972/73 use of Roseires stored water with appraisal estimates (in both cases considering 80% year natural flows) is summarized below:

	Appr. Est.	Actual Use
	(million m^3)	
Extension/Intensification of Gezira/Managil Scheme	862	197
New pump schemes	601	140
Other various planned uses (see page 7)	450	0
	1,913	337

The "Memorandum on Utilization of Water from Roseires Reservoir" of January 1966, written by consultants[1/] at the Government's request and financed under the project, updated the 1961 appraisal report estimates regarding the use of stored water. It forecast that the major use of Roseires Stage I (present stage) would be the development of two major irrigation schemes on the Right Bank, to be supplied by gravity from Roseires: Rahad-Hawata-Guneid Scheme (850,000 feddans) and Roseires Scheme (250,000 feddans), together requiring about 1,400 million m^3 during the critical period, and therefore using about two-thirds of the net operating storage of Roseires. The fact that these two schemes have not yet been developed confirms the present low utilization of the Roseires Reservoir. However, major efforts have been made in the last years to develop schemes for greater use of the Roseires Reservoir; the first stage of the Rahad Project (300,000 feddans), which is now under construction, is expected to use by 1979/80[2/] about 550 million m^3 of stored water whereas two other substantial users will be the major sugar project at N.W. Sennar and the planned intensification of the crop rotation at Gezira/Managil by the cultivation of 225,000 additional feddans of wheat[3/]. Our estimate is that by 1979/80 a total of 1,446 million m^3 of Roseires stored water will be required for irrigation, implying a utilization ratio of 68% (Table 7).

1/ Sir Alexander Gibb & Partners and Sir M. MacDonald & Partners, London.

2/ 1979/80 is expected to be the first year of full production of the first stage of the Rahad Project as the 300,000 feddans are planned to be developed progressively over the period 1976/77-1978/79 (100,000 feddans each year). Rahad Stage II (520,000 feddans) is likely to be developed only in the 1980s, and therefore is not considered in our 1979/80 forecast of water use.

3/ Including 100,000 feddans of wheat newly developed in 1974.

The dam has been constructed so as to permit a further heightening by 10 m (Roseires Stage II), which would increase the reservoir capacity by an additional 4,600 million m^3. The Sudanese Government is now considering to initiate studies for this heightening. Both the 1961 Appraisal Report and the 1966 Memorandum estimated that the major use of Roseires Stage II would be the development of the Kenana gravity irrigation scheme on the Left Bank (1.5 million gross feddans), which was the original thought in the early 1950s but had been eliminated from Stage I in 1958, as suggested by the Bank, because of the large size of the investment. It has not yet been decided whether and when this large irrigation scheme will take place, mainly because it has been shown that rainfed agriculture can be successfully developed in that area; however, the other irrigable areas (all on the Right Bank) identified by the pre-investment surveys financed under the project and also amounting to about 1.5 million gross feddans (including 0.5 million for Rahad Stage II) are likely to be developed in the 1980s.

Another factor to be considered regarding the future heightening of the dam for irrigation purposes is the total annual limit of 18,500 million m^3 (measured at Aswan) that the Sudan can withdraw from the Nile according to the 1959 Nile Waters Agreement with Egypt (today, the actual annual withdrawal amounts to about 13,000 million m^3); according to the 1966 Memorandum, the total water withdrawals from the Nile at the full utilization level of Roseires Stage II would exceed the limit set by the 1959 Nile Waters Agreement by 5,500 million m^3. However, the implementation of conservation schemes in the Sudan, now under study (Jonglei Project), would bring an additional annual share to the Sudan and Egypt of about 3,000 million m^3 each. Under the Rahad Irrigation Project (Credit 364-SU) the future utilization of the Roseires Reservoir is to be studied by consultants.

IV. Agricultural Benefits

This section covers the net benefits of all the agricultural schemes that have developed in the Blue Nile area since 1966 and are directly related to the construction of the Roseires Dam. In Section VI, where we present the calculation of the economic return of the project, we indicate which proportion of these agricultural benefits can be attributed to the dam.

The goals of the Roseires Irrigation Project in terms of number of new feddans developed have not yet been attained. As was noted earlier, the major shortcoming has been in the new pump scheme developments. When the pump schemes presently under construction (Rahad Stage I, Northwest Sennar, Abu Naama) are completed and operational, the total number of feddans of new pump schemes developed will be 535,000, or 135,000 feddans less than the appraisal estimate. Rahad Stage I should be fully developed in 1979/80; N.W. Sennar is waiting for the construction of a sugar factory for which financing has not yet been arranged; and Abu Naama should be fully developed in July 1974 with the kenaf processing factory to be completed at the end of the year.

The net agricultural benefits were calculated in the case of exports as being equal to f.o.b. value minus production, processing and transportation costs and in the case of domestically consumed products as farm-gate value minus production costs. 1972/73 actual net benefits are given by major agricultural scheme and by crop in Table 3. The benefits of Gezira/Managil extensions have been large as a result of substantially higher (15%) cotton yields than expected coupled with high cotton prices (50% higher in 1972/73 than originally expected). Thus, although only 90% of the extension in area projected in the appraisal has been developed, the actual benefits exceeded forecasts by 50% in 1972/73. In the intensification of Gezira/Managil with cotton, wheat and groundnuts, a similar phenomenon can be observed: the area intensified, 95,000 feddans, is only one-third of the appraisal forecast of 290,000 feddans. However, the benefits are 75% of the appraisal forecast due to the high price of cotton in 1972/73. Thus, in spite of the fact that only 40% of the estimated number of feddans have been developed or intensified, actual net benefits in 1972/73 amounted to 65% of those forecast in the appraisal. If the net benefits that will result from the full operation of the pump schemes presently under construction are taken into account, the total net benefits -- assuming cotton prices to return to their level of the 1967/68-1971/72 period, still 25% higher than originally expected[1/] -- will be US$ 40.8 million equivalent in 1980, surpassing the US$ 37.3 million estimate forecast in the appraisal, but 12 years later than expected.

V. Hydroelectric Benefits

In 1968 the Bank made a loan of US$ 24 million equivalent to the Sudan (Loan 522-SU) to help finance the construction of a powerhouse at Roseires with installation of three 30 Mw generating units and the associated transmission line to Khartoum. Total costs were estimated at US$ 33.3 million equivalent. Construction was completed in 1971 at a total cost of US$ 34.7 million equivalent and power generation started at Roseires in August 1971. The Roseires power production reached 237 million kwh in 1972 and about 280 million kwh in 1973[2/] as compared with a potential output of 570 million kwh in a dry year (600 in a median year). This low utilization of the three turbines is due to the fact that the present demand for power in the Blue Nile grid is still relatively low, and also to the continued use of thermal (and diesel) generation at Khartoum to provide dependable power supplies -- partly a result of difficulties with the Roseires generating units, and reliance on a single 220 kv line for transmission of power from Roseires.

The Roseires Power Project was justified on its own, with the dam investments, justified originally on the basis of irrigation benefits only, considered as sunk costs. However, in retrospect these investments may be evaluated together so as to cover comprehensively the benefits of the dam. A power survey in 1963, financed by the U.N. Special Fund and for which the Bank was executing agency, concluded that the Roseires Dam would be the most

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1/ The Appraisal Report's forecast for the price of extra-long staple cotton (c.i.f. Liverpool) was US¢ 34/lb, which compares with an actual average of US¢ 42/lb over the 1967/68-1971/72 period (used as a basis for our own price forecasts) and US¢ 52/lb in 1972/73.

2/ Estimate from actual production of 242 million kwh up to November 5, 1973.

economical means of meeting Sudan's growing power demand. As a consequence, the foundation and substructure for a powerhouse was included in the Roseires Irrigation Project. In 1973 the average operating cost (excluding capital charges) of generating 1 kwh at Roseires was about 3.5 mms[1/] (US¢ 1.0) as compared with an average 6.5 mms (US¢ 1.8) for thermal generation; besides, the present large foreign exchange savings on fuel, about US$ 4.3 million in 1973, will rise rapidly given the expected growth in output and the recent trend in fuel prices. Also, the total investments in the hydroelectric power station and associated transmission line are only about US$ 7.2 million higher than an equivalent thermal alternative at Khartoum would have cost, due to the treatment of the dam investments as sunk costs. Under these circumstances, the hydroelectric power generation is undoubtedly the least-cost method. (The Bank has recently sent a mission to appraise a second Power Project that would increase by 30% the capacity of the Roseires Power Station.)

For the determination of the hydroelectric benefits, it was assumed that the economic value of the electricity supplied is at least equal to the value paid by the ultimate customer, i.e. about 15 mms/kwh in 1973. As the average total cost of supplying 1 kwh from Roseires is equal to 6.5 mms (3.5 mms for generation, and 3 mms for transmission and distribution), the net benefit to the economy of 1 kwh generated at Roseires is estimated at about 6.8 mms (US¢ 1.9), taking account of 20% transmission losses.[2/] This calculation results in an annual net benefit of US$ 5.5 million equivalent in 1973, rising progressively with Roseires output to about US$ 8.6 million equivalent by 1978 (Table 9).

VI. Economic Rates of Return

Given the interrelations of the various investments analyzed, and the fact that some of the investments (Roseires Power Station, Rahad Stage I) were not anticipated at appraisal time, we have utilized several approaches to calculate the corresponding economic rates of return.

The first approach is identical to that of the 1961 Appraisal Report and consists of lumping the dam and agricultural investments together and considering as benefits the net value of the resulting agricultural production. The Appraisal Report estimated that following completion of the dam the annual net benefits, pending use of the unallocated waters (800 million m^3), would be 17% of the investment. No internal rate of return was then calculated. However, from the assumptions of the Appraisal Report, it can be deduced that a 14% economic rate of return was expected. Given the lag of almost ten years between the dam investment and some of the agricultural investments, we have calculated the economic returns for the following two cases:

1/ mms = milliemmes; LSd 1 = 1,000 mms.

2/ 6.8 = 0.80 x (15-6.5).

	Rates of Return (%)	
	Appr. Est.	Actual
1) Dam investments and agricultural investments for extension/intensification of Gezira/Managil and new pump schemes already developed (Guneid Extension, Wad El Haddad, Es Suki)	14	8
2) Same as above (1) plus investments for N.W. Sennar, Rahad Stage I and 225,000-feddan Wheat Project	-	10

The actual rates of return are lower than anticipated mainly due to the lag in development of new pump schemes. When adding the hydroelectric investments and their corresponding benefits (as calculated previously), the above rates of return are slightly pushed upwards to 9% and 11%, respectively. Although the hydroelectric investment on its own yields a higher return, about 13%, its effect on the overall return is minor because it represents only 27% of the total investments considered. Had the dam been built only for power generation, it would have yielded an economic return of only 2%.[1/] A list of the basic assumptions and a breakdown of the annual costs and benefits used in the calculations of the rates of return are given in Table 9.

A second approach is to isolate the effect of the Roseires Dam from that of the other investments. Given the present low utilization of the Roseires storage it could be argued that the agricultural investments over the period 1966-72, extension/intensification of the Gezira/Managil Scheme and the three new pump schemes (Guneid Extension, Wad El Haddad, Es Suki) could have been developed without the construction of the Roseires Dam, and that at the most the additional availability of water from the dam has increased cotton yields, on the average, by 10% because in some years irrigation of cotton in the without situation should have been stopped at the end of February, i.e. one month before harvest. Considering this 10% increase in cotton yields for the above 1966-72 agricultural investments as the only benefits attributable to the Roseires Dam, the rate of return falls to about 2%.

In connection with these first two approaches, it is worth mentioning that at the time of the preparation of the Rahad Project (around 1967-68) it was argued within the Bank that without the Roseires Dam, the 1959 Nile Waters Agreement, providing Sudan with more water, would not have taken place and consequently no new irrigation schemes since 1965 would have been possible; at that time the Sudanese view was that the Rahad Project would be the first benefit of the Roseires Dam. It is true that the Bank insisted on having Sudan sign a new Waters Agreement with Egypt before going ahead with the Roseires Project, but this more favorable agreement was made possible in fact by the Egyptian decision to build the High Dam at Aswan, which was unrelated to the Roseires Dam. In our opinion, none of the benefits of the 1959 Nile Waters Agreement should be attributed to the Roseires Dam.

1/ Considering only the three turbines of 30 Mw already installed.

A third approach (our best estimate) would then be a mixture of the first two, i.e. eliminating from the first approach the investments that according to the second one would most probably have taken place in the without situation, i.e. the extension/intensification of Gezira/Managil, Guneid Extension and Wad El Haddad (all under the single management of the Gezira Board). This approach leads to a new estimated rate of return of 9%. This relatively high return is explained by the large investments and benefits of the Rahad Project alone, which without the Roseires Dam could not have been envisaged.

Finally, we have run some sensitivity analysis tests, including changes in forecast yields/prices, timing of both Roseires Dam investment and Rahad Project, and shadow prices for foreign exchange rate[1/] (1.2 factor, given the present overvaluation of the Sudanese Pound). We have not included the benefits of Rahad Stage II as they are not likely to take place until the mid-1980s. The results are summarized in Table 10. On the whole the returns are rather insensitive to these changes.

In conclusion, the dam, when considered together with the investments in agriculture and power (first approach), is now estimated to yield an economic rate of return of about 10%, which is low in comparison with the high potential of the Blue Nile area. If the dam is considered alone, the rate of return falls to about 2% (second approach). The explanation of this large difference in returns is that most of the agricultural investments expected at the time of appraisal could have taken place without the dam and still yielded adequate returns. A mixture of the two approaches (third approach) leads to a return of 9%, which is our best estimate.

VII. Assessment of Overall Impact of Project on the Economy of Sudan

The Roseires Irrigation Project has been called rightly the "backbone" of investments in Sudan, accounting over the 1961/62-1966/67 period for 22% of the total investments and for 43% of those in agriculture and irrigation. Its impact on the whole economy of Sudan has been substantial. When adding the investments of the Roseires Power Project, it has been seen that an overall economic return of about 9% is expected. The agricultural developments have generated substantial employment; a total of about 18,000 new tenants have settled on the new schemes and extensions developed since 1966/67: 8,000 on the Gezira/Managil Scheme, 7,000 on the Es Suki Scheme and 3,000 on the Guneid Extension, with average tenancies of 22, 12 and 16 feddans respectively, and providing seasonal work for about 100,000 pickers. The agricultural benefits have been divided about equally between the tenants and the Government: in 1972/73, 48% of the benefits went to the tenants (mainly in the Gezira/Managil Scheme), 43% to the Government (mainly the share of cotton revenues from the

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1/ We have not run any sensitivity analysis test using shadow prices for labor costs as there is little unemployment during the peak season when most hired labor is used. Also, no costs are attributed to family labor used on farms.

Gezira/Managil Scheme, taxes and export duties) and 9% to the Sudan Gezira Board from its share of cotton revenues. The exports generated (mainly cotton) accounted for 7% of all exports from Sudan in the years 1968/69 to 1970/71 and are expected to increase to about 10% in the future. Also there appears to have been some significant benefits, which we were unable to quantify due to lack of data, to the approximately 20,000 people (mostly nomads) who were living in the Roseires Reservoir area before the dam's construction; those benefits consist mainly of fishing and cultivation, when the Roseires Reservoir is at a low level, of areas flooded during the annual filling period of the Reservoir (September-November).

However, for the first ten years (1961-1971) the project had a negative impact on the Government's finances, resulting in a total net deficit of about US$ 86 million equivalent (calculated by deducting local investment costs, and repayment of interest and principal on loans by the Bank, IDA and KfW from the net benefits to the Government). Only in 1972/73 was there a surplus, estimated at US$ 5.7 million equivalent. This is explained not only by the usually long construction period of a dam, but also by the fact that the Roseires Dam was built about five years too early as a result of two factors: i) the needs for stored water for irrigation had been overestimated at appraisal time (major benefits from the 1959 Nile Waters Agreement with Egypt were overlooked), and ii) the agricultural developments were delayed due to lack of detailed plans at appraisal time and political instability.

Finally, the Roseires Dam has become today the major source of power generation in the Sudan, producing in 1972/73 about 50% of the country's needs in electricity, and its share is likely to grow in the future.

VIII. Conclusions

The study suggests that the decision to build a dam at Roseires was right given the high priority of irrigation for the development of Sudan and particularly in view of the high profitability of cotton production in the Blue Nile area. Although the original justification of the dam was based solely on irrigation benefits, its large hydroelectric potential, now beginning to be exploited, would have contributed significantly to justify the investment. The present trends in prices (in real terms) for cotton and oil make the dam investment even more attractive.

However, in retrospect, the dam investment seems to have been premature by about five years, mainly because the development of new pump schemes was behind schedule and the needs for stored water for irrigation had been overestimated at appraisal time (major benefits from the 1959 Nile Waters Agreement with Egypt were overlooked). The main reasons for delays in agricultural developments were the lack of detailed plans at the time of appraisal and the nationalization fears in the mid-1960s that discouraged private investments. Only about 20% of the net operating storage capacity of the Roseires Reservoir is now being utilized for irrigation. Given the present construction programs for irrigation works, the utilization of the Reservoir is expected to rise to about 70% by 1980.

The dam, together with the related investments in agriculture and power, yields a relatively low economic rate of return of 9%. Most of the agricultural developments to date could have taken place without the dam, and the only difference would have been at most a 10% reduction in cotton yields.

With hindsight, the Bank could have played a more useful role regarding the development of the agricultural schemes included in the project. As the only purpose of the Roseires Dam in 1961 was irrigation, the Bank should have required detailed plans for the irrigation use of the stored water before going ahead with such a large fixed investment. Early supervision by the Bank of the preparation of the agricultural schemes would have been important. Unfortunately, for various reasons (essentially staff constraints) the first supervision mission had to be delayed and took place only in October 1963, more than two years after the signing of the loan/credit. Also, the agricultural part (Part B) of the project was not systematically supervised: in 1965 there was one supervision visit related to soil surveys but the Bank's annual supervision missions between 1966 and 1970 were not concerned with agriculture but solely with the dam construction (mainly questions of disbursements, since the dam had been nearly completed).

One of the Bank's main contributions was the financing under the project of pre-investment surveys which led to the Es Suki and Rahad Project proposals. However, the Bank appears to have been partly responsible for the postponement of the Rahad Project by about six years as the project was first proposed to the Bank in 1965 but a credit agreement was signed only in 1973, following three Bank appraisal missions. The main reasons for postponement of participation in this project by the Bank were its estimated low economic return in 1968 (8%), the large size of the investment, the lack of a comprehensive national development plan and, in particular, major uncertainties regarding the capacity of the Government to provide the required local currency funds. There was also overall economic and political uncertainty during this period which, given the size and complexity of the Rahad Project, made the decision-making process on the Government's part very difficult. However, it is outside the terms of reference of this audit to assess whether the postponement was justified.

More generally, there has been a lack of comprehensive planning of the utilization of the Nile Water resources, and development schemes have followed one another on an ad hoc basis. At appraisal time, there were no detailed studies of the expected irrigation schemes and power generation was not stated as one of the project objectives. What was needed then was a package investment program which would have permitted the coordination and optimization of irrigation, agriculture and power developments. Had such a planning and package investment program been developed before appraisal of the Roseires Irrigation Project, the project, together with the other schemes, would have yielded much higher economic benefits given the high economic potential of the Blue Nile Basin. Finally, this detailed planning would have helped avoid some of the delays in agricultural developments due to the political uncertainties at the time by providing continuity at least on the technical aspects of the program.

SUDAN

Loan 284/Credit 2

Annual Investments[1] in Dam Construction and Related Agricultural Development: Actuals vs Estimates
(US$ million equivalent)

	Dam Construction and Associated Works			Pump Schemes		
	Dam Const.	Assoc. Work[2]	Gezira/ Managil	Guneid	Es Suki	Total
1961/62	4.1	3.4				7.5
1962/63	11.0	3.4				14.4
1963/64	14.6	.9				15.5
1964/65	16.8					16.8
1965/66	13.0		4.4	4.1		21.5
1966/67	14.8		3.1			17.9
1967/68			3.6			3.6
1968/69			3.7			3.7
1969/70			4.2			4.2
1970/71	___	___	2.1	___	10.5	12.6
Total (Actual)	74.3	7.8	21.0	4.1	10.5	117.7
Appraisal Estimate	76.4	11.4		88.7		176.5
Actual/ Estimate	97%	68%		40%		67%

1/ Including both local and foreign costs.

2/ Associated works are composed of the following contracts:

(1)	Site clearance, roads and surface water drainage:	.1
(2)	Water supply and distribution :	.6
(3)	Electrical supply and distribution :	.5
(4)	Temporary housing :	1.7
(5)	Permanent housing :	1.1
(6)	Hospital and offices :	.5
(7)	Post office and schools :	1.9
(8)	Roseires airfield and roads :	1.2
(9)	Roseires bridge :	1.9

Source: Ministry of Agriculture, Sudan Gezira Board, Project Progress Report, Roseires Irrigation Project Appraisal.

Table 2

SUDAN

Loan 284/Credit 2

Annual Disbursements of Foreign Loans for Dam Construction and Associated Works

(US$ million equivalent)

	IBRD				IDA				KFW				TOTAL				Actual as % of Estimated
	Annual		Cumulative		Annual		Cumulative		Annual		Cumulative		Annual		Cumulative		
	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	
1961/62	3.05	1.14	3.05	1.14	2.47	.92	2.47	.92	2.94	1.09	2.94	1.09	8.46	3.15	8.46	3.15	37
1962/63	2.63	2.33	5.68	3.48	1.98	1.90	4.45	2.82	2.54	2.24	5.48	3.33	7.15	6.47	15.61	9.62	61
1963/64	2.83	3.15	8.51	6.63	2.03	2.33	6.48	5.15	2.73	3.03	8.21	6.36	7.59	8.51	23.20	18.13	78
1964/65	3.29	3.41	11.80	10.04	2.30	2.53	8.78	7.68	3.22	3.28	11.43	9.64	8.81	9.22	32.01	27.35	85
1965/66	3.37	3.06	15.17	13.09	2.23	2.08	11.01	9.76	3.33	2.96	14.76	12.60	8.93	8.10	40.94	35.45	86
1966/67	2.52	2.32	17.69	15.41	1.37	1.31	12.38	11.08	2.49	2.25	17.25	14.85	6.38	5.88	47.32	41.33	87
1967/68	1.81	1.94	19.50	17.35	.62	.90	13.00	11.98	1.74	1.88	18.99	16.75	4.17	4.72	51.49	46.05	89
1968/69		1.30		18.65		.27		12.25		1.25		17.98		2.82		48.87	
1969/70		.08		18.73		.03		12.27		.07		18.05		.18		49.05	
1970/71		.09		18.82		.07		12.35		.08		18.13		.24		49.29	
1971/72		.01		18.83		.02		12.37		.01		18.14		.04		49.33	
1972/73		.01		18.84						.01		18.15		.02		49.35	

Cancellations (July 1972) of IBRD loan: .7
IDA credit: .6
KFW loan: .7

SOURCE: Annual Reports (Bank/IDA) and Statements of Loans and Credits.

Table 3

SUDAN

Loan 284/Crédit 2

Summary of Agricultural Developments Since 1966 Related to the Roseires Dam

	Completed Schemes and Extensions				Pump Schemes[a/] Presently Under Construction	
	Gezira-Managil Extensions	Gezira-Managil Intensification	Guneid Extension	Es Suki	Rahad Stage I	N. W. Sennar
First Year of Investment	1965/66	-	1966/67	1970/71	1973/74	1971/72
Total Cost of Investment (US$ mln. equiv.)	21.0	-	4.1	10.5	96.2	52.6
First Year of Cropping	1966/67	1966/67	1967/68	1971/72	1976/77	1973/74[b/]
Gross Area of Development ('000 feddans)	175	95	50	85	300	37
Cropped Area ('000 feddans)						
Cotton	43	41	15	36	140	-
Wheat	14	32	7	-	-	-
Groundnuts	17	22	9	36	93	-
Dura	22	-	5	-	-	-
Sugar cane	-	-	.3	-	-	31
Total	96	95	36.3	72	233	31
Production ('000 tons)						
Cotton	32	29	9	20	119	-
Wheat	10	21	5	-	-	-
Groundnuts	5	7	3	10	84	-
Dura	8	-	2	-	-	-
Sugar cane	-	-	-	-	-	1,048
Annual Gross Benefits (US$ mln. equiv.)						
Cotton	15.5	13.6	4.6	10.5	33.0	-
Wheat	1.1	2.5	.5	-	-	-
Groundnuts	1.1	1.5	.6	2.3	7.7	-
Dura	1.2	-	.3	-	-	-
Sugar cane	-	-	-	-	-	158.0
Total	18.9	17.6	6.0	12.8	40.7	158.0
Annual Cost of Production (US$ mln. equiv.)						
Cotton	6.7	6.3	2.3	4.1	20.1	-
Wheat	.5	1.1	.3	-	-	-
Groundnuts	.9	1.1	.5	5.7	5.3	-
Dura	.7	-	.2	-	-	-
Sugar cane	-	-	-	-	-	150.5
Total	8.8	8.5	3.3	9.8	25.4	150.5
Annual Net Benefits (US$ mln. equiv.)						
Cotton	8.8	7.3	2.3	6.4	12.9	-
Wheat	.6	1.4	.2	-	-	-
Groundnuts	.2	.4	.1	-3.4	2.4	-
Dura	.5	-	.1	-	-	-
Sugar cane	-	-	-	-	-	7.5
Total	10.1	9.1	2.7	3.0	15.3	7.5
Appraisal Estimate of Net Benefits	6.7	11.7	18.9			
Actual as % of Estimated	150%	76%	30%			

NOTE: All completed scheme and extension figures are 1972/73 figures.

a/ All data at stage of full development.

b/ First year of cropping may be delayed pending construction of sugar factory.

c/ Net benefits for groundnuts are negative because the 1972/73 cropping season in Es Suki resulted in poor groundnut yields.

SOURCE: Directorate-General of Planning, Ministry of Agriculture, Sudan Gezira Board.

Table 4

SUDAN

Actual Monthly Flows of Blue Nile
at El Deim (80 km Upstream of Roseires Dam)
(in million m^3)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Yearly Total	Subtotal Dec. - May
1963/64	6122	18845	11540	4963	2377	1781	932	491	233	337	380	1400	49401	4154
1964/65	10390	18883	14660	10290	3357	2735	1117	666	458	518	268	1280	64622	5762
1965/66	4896	12248	8270	6967	2867	2761	884	541	469	342	629	2031	42906	5626
1966/67	6126	12878	11390	4149	2294	1256	715	431	377	376	525	1398	41915	3680
1967/68	6669	14943	13020	9985	3028	1626	1021	741	441	325	365	1625	53789	4519
1968/69	8938	16184	10496	6834	2315	1398	988	685	1110	596	817	1877	52238	5594
1969/70	7278	19620	10610	4036	1760	971	671	400	443	318	342	1039	47488	3145
1970/71	5660	18495	12119	6845	2456	1130	811	546	335	240	477	1635	50749	3539
1971/72	6633	16862	11597	5536	2726	1400	882	525	362	373	643	1380	48919	4185
1972/73	4956	9858	6990	3224	1530	890	685	210	180	148	534	1710	30915	2647
80% Year[a]	5025	13317	10280	4928	2127	1124	662	380	283	216	325	1115	39771	2990
Median Year[a]	6621	15788	12879	6698	2601	1405	789	462	354	287	512	1543	49940	3809

a/ Reliability based on actual 1912- 1971 series.

SOURCE: Directorate-General of Irrigation, Khartoum.

Table 5

SUDAN

Loan 284/Credit 2

Actual Uses of Blue Nile Water for Irrigation: 1966-1973
(in million m^3)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Yearly Total	Subtotal Dec. - May
1966/67														
Gezira/Managil	646	557	455	848	732	568	437	415	457	209	80	2	5401	2165
Pump Schemes	31	39	114	136	128	92	93	93	48	46	46	46	912	418
1967/68														
Gezira/Managil	503	233	548	760	723	574	531	468	444	347	94	0	5238	2459
Pump Schemes	146	92	211	221	178	166	157	142	118	74	78	38	1621	735
1968/69														
Gezira/Managil	243	639	509	911	846	651	521	440	382	291	31	-	5467	2316
Pump Schemes	74	98	211	221	178	166	157	142	118	74	78	51	1568	735
1969/70														
Gezira/Managil	611	513	1285	873	895	706	609	549	451	142	90	-	6725	2547
Pump Schemes	113	74	211	221	178	166	157	142	118	74	78	42	1574	735
1970/71														
Gezira/Managil	646	537	619	1010	953	665	587	414	401	152	20	53	6059	2239
Pump Schemes	146	89	211	221	178	166	157	142	118	74	78	84	1664	735
1971/72														
Gezira/Managil	506	345	544	970	834	649	492	549	550	250	230	370	6288	2719
Pump Schemes	132	101	248	263	204	195	182	167	122	76	80	112	1882	822
1972/73														
Gezira/Managil	486	662	696	832	835	594	480	473	414	144	80	434	6131	2185
Pump Schemes	107	192	266	286	214	214	185	165	127	80	89	108	2033	860

SOURCE: Directorate-General of Irrigation, Khartoum.

SUDAN

Loan 284/Credit 2

1972/73 Use of Blue Nile Water During Critical Period January - May
(in million m^3)

		(Dec.)	Jan.	Feb.	March	Apr.	May	Total Jan. - May
1.	Gezira/Managil[1/]	(594)	480	473	214	80	80	1,327
2.	Pump Schemes	(214)	185	165	127	80	89	646
3.	Evaporation from Sennar Dam	(34)	40	42	37	25	18	162
4.	Evaporation from Roseires Dam	(55)	52	45	46	32	30	205
5.	Minimum Release to Khartoum	(155)	155	140	155	150	155	755
6.	Total Use (1+2+3+4+5)	(1,052)	912	865	579	367	372	3,095
7.	Minus 80% Year Natural Flow[2/]	(1,101)	649	372	277	212	319	1,829
8.	Balance from Storage[3/] (6-7)	-	263	493	302	155	53	1,266
9.	Minus Sennar Storage							724
10.	Balance from Roseires Storage							542
11.	Evaporation Losses from Roseires During Critical Period							205
12.	Net[4/] Use of Roseires Operating Storage (10-11)							337
13.	Net[4/] Operating Storage of Roseires							2,180
14.	% Utilization of Roseires Storage (12/13)							15%

1/ Excluding pre-planting water for cotton in March (200 million m^3) and April (64 million m^3 as other uses estimated at 80 million m^3); in past years as much as 200 million m^3 for each of these two months were used for pre-watering, but this practice is likely to be discontinued in the future as having practically no impact on yields.

2/ Reduced by 2% to take account of transmission losses between Roseires and Sennar.

3/ Sennar Dam (operating storage of 724 million m^3) and Roseires Dam (operating storage of 2,385 million m^3).

4/ i.e. excluding evaporation losses due to the Roseires Reservoir during the critical period (estimated at 205 million m^3 in 1972/73).

Note: Outside the critical period January - May, all irrigation requirements up to now have been met from the natural flows of the Blue Nile. In future years the critical period will extend from December - May.

Source: Basic data provided by Directorate-General of Irrigation; exclusion of pre-planting water in March and April as estimated by Audit Mission.

Table 7

SUDAN

Loan 284/Credit 2

1979/80 Forecast Use of Blue Nile Water During Critical Period December - May
(in million m^3)

		Dec.	Jan.	Feb.	March	Apr.	May	Total Dec. - May
1.	Existing Gezira/Managil[1/]	594	480	473	214	80	80	1,921
2.	Existing Pump Schemes[2/]	214	185	165	127	80	89	860
3.	N. W. Sennar Project	25	22	23	32	38	43	183
4.	Abu Naama Kenaf Project	-	-	-	-	10	13	23
5.	Rahad Phase I	212	128	107	98	-	6	551
6.	Extra Wheat in Gezira[3/]	175	178	101	-	-	-	454
7.	Evaporation from Sennar Dam	35	38	37	39	31	18	198
8.	Evaporation from Roseires Dam	55	53	45	49	39	29	270
9.	Minimum Release to Khartoum	155	155	140	155	150	155	910
10.	Total Use (sum 1 to 9)	1,465	1,239	1,091	714	428	433	5,370
11.	Minus 80% Year Natural Flow[4/]	1,101	649	372	277	212	319	2,930
12.	Balance from Storage[5/] (10-11)	364	590	719	437	216	114	2,440
13.	Minus Sennar Storage							724
14.	Balance from Roseires Storage (12-13)							1,716
15.	Evaporation Losses from Roseires During Critical Period							270
16.	Net[6/] Use of Roseires Operating Storage (14-15)							1,446
17.	Net[6/] Operating Storage of Roseires							2,115
18.	% Utilization of Roseires Storage (16/17)							68%

1/ 1972/73 actual use excluding pre-planting water for cotton in March (200 million m3) and April (64 million m^3 as other uses estimated at 80 million m^3), which has been shown to have practically no impact on yields and will therefore be discontinued in the future. We have adopted 1972/73 as being the best estimate of existing use for Gezira/Managil Scheme because, when excluding pre-planting water, 1972/73 appears to be representative of the last three years (1970/71-1972/73) during which the largest area to date was cropped and also the highest output obtained.

2/ 1972/73 actual use.

3/ 225,000 additional feddans of wheat.

4/ Reduced by 2% to take account of transmission losses between Roseires and Sennar

5/ Sennar Dam (operating storage of 724 million m^3) and Roseires Dam (operating storage of 2,385 million m3).

6/ i.e. excluding evaporation losses from Roseires Reservoir during critical period (estimated at 270 million m^3 in 1979/80).

Note: Outside the critical period December - May all irrigation requirements can be met from the natural flows of the Blue Nile.

Source: Audit Mission's Estimates; water requirements for Rahad Phase I as estimated in the Bank's 1973 Appraisal Report for Rahad Project.

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Actual (1966/67-1972/73) and Forecast (1979/80) Use of Roseires Stored Water

	Considering Actual Flows of Blue Nile		Considering 80% Year Natural Flows	
	incl. pre-watering	excl. pre-watering	incl. pre-watering	excl. pre-watering
	(in million m^3)			
1966/67	0	0	292	0
1967/68	0	0	804	404
1968/69	0	0	645	245
1969/70	579	317	756	494
1970/71	195	0	698	426
1971/72	316	0	1,052	682
1972/73	1,016	752	601	337
Est. 1979/80			a/	1,446
	(in % Utilization of Roseires Storage)			
1966/67	0	0	13	0
1967/68	0	0	37	19
1968/69	0	0	29	11
1969/70	26	14	33	21
1970/71	9	0	32	19
1971/72	14	0	50	32
1972/73	47	35	28	15
Est. 1979/80			a/	68

a/ Pre-watering to be discontinued in the future.

Note: The above calculations (as detailed in Tables 6 and 7) exclude from both the use and the operating storage of the Roseires Reservoir the evaporation losses due to the Reservoir during the critical period.

Source: Basic data provided by Directorate-General of Irrigation for 1966/67-1972/73; exclusion of pre-planting water and 1979/80 forecasts as estimated by Audit Mission.

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Table 9

Loan 284/Credit 2

Annual Costs and Benefits Used in Calculating Rates of Return
(US$ million equivalent)

Year	Year No.	Investment Costs					Net Benefits			
			Agricultural		Hydro-		Agricultural		Hydro-	
		Dam	Actual 1/	Forecast 2/	electric	Total	Actual 1/	Forecast 2/	electric	Total
1961/62	1	7.5				7.5				
1962/63	2	14.4				14.4				
1963/64	3	15.5				15.5				
1964/65	4	14.6			2.3	16.9				
1965/66	5	10.9	8.3		2.3	21.5				
1966/67	6	12.6	3.2		2.3	18.1	.6			.6
1967/68	7		3.4		2.6	6.0	2.0			2.0
1968/69	8		3.7		3.7	7.4	3.7			3.7
1969/70	9		4.3		7.5	11.8	4.0			4.0
1970/71	10		12.6		15.8	28.4	4.0		.9	4.9
1971/72	11			6.0	4.3	10.3	6.9		4.6	11.5
1972/73	12				.9	.9	14.4		5.5	19.9
1973/74	13			35.0		35.0	11.8	4.9	6.0	22.7
1974/75	14			51.9		51.9	11.8	4.9	6.6	23.3
1975/76	15			24.4		24.4	11.8	11.8	7.2	30.8
1976/77	16			5.7		5.7	11.8	12.1	7.7	31.6
1977/78	17			1.7		1.7	11.8	15.5	8.6	35.9
1978/79	18			4.3		4.3	11.8	20.4	8.6	40.8
1979/80	19			4.3		4.3	11.8	23.0	8.6	43.4
1980/81	20						11.8	29.0	8.6	49.4
1981/82	21						11.8	29.3	8.6	49.7
1982/83	22						11.8	31.0	8.6	51.4
1983/84	23						11.8	31.0	8.6	51.4
1984/85	24						11.8	31.0	8.6	51.4
1985/86	25						11.8	31.0	8.6	51.4
1986/87	26						11.8	31.0	8.6	51.4
1987/88	27						11.8	31.0	8.6	51.4
1988/89	28						11.8	31.0	8.6	51.4
1989/90	29						11.8	31.0	8.6	51.4
	30 - 50						11.8	31.0		42.8

1/ Gezira/Managil Extensions and Intensifications, Guneid Extension and Es Suki

2/ N.W. Sennar, Rahad Stage I, and 225,000 feddans of wheat (in Gezira/Managil)

Note: Basic assumptions used in calculating the above costs and benefits are:
- investment costs are actual costs net of taxes and import duties
- net agricultural benefits are: (i) in case of exports: f.o.b. value minus production processing and transport costs (ii) in case of domestically consumed products: farm-gate value minus production costs. In both cases, production costs included both irrigation and agricultural costs; hired labor costs are included fully whereas no costs are attributed to family labor used on farms. Gross agricultural values were forecasted from recent trends (average of the 1967/68-1971/72 period) and production costs were assumed to remain constant in the future.
- net hydroelectric benefits are the value of electricity paid by the ultimate consumer minus generation, transmission and distribution costs
-- foreign exchange rate used is the actual one
- economic lifetime of dam is 50 years

Source: Ministry of Agriculture, Sudan Gezira Board, Central Electricity and Water Corporation

Table 10

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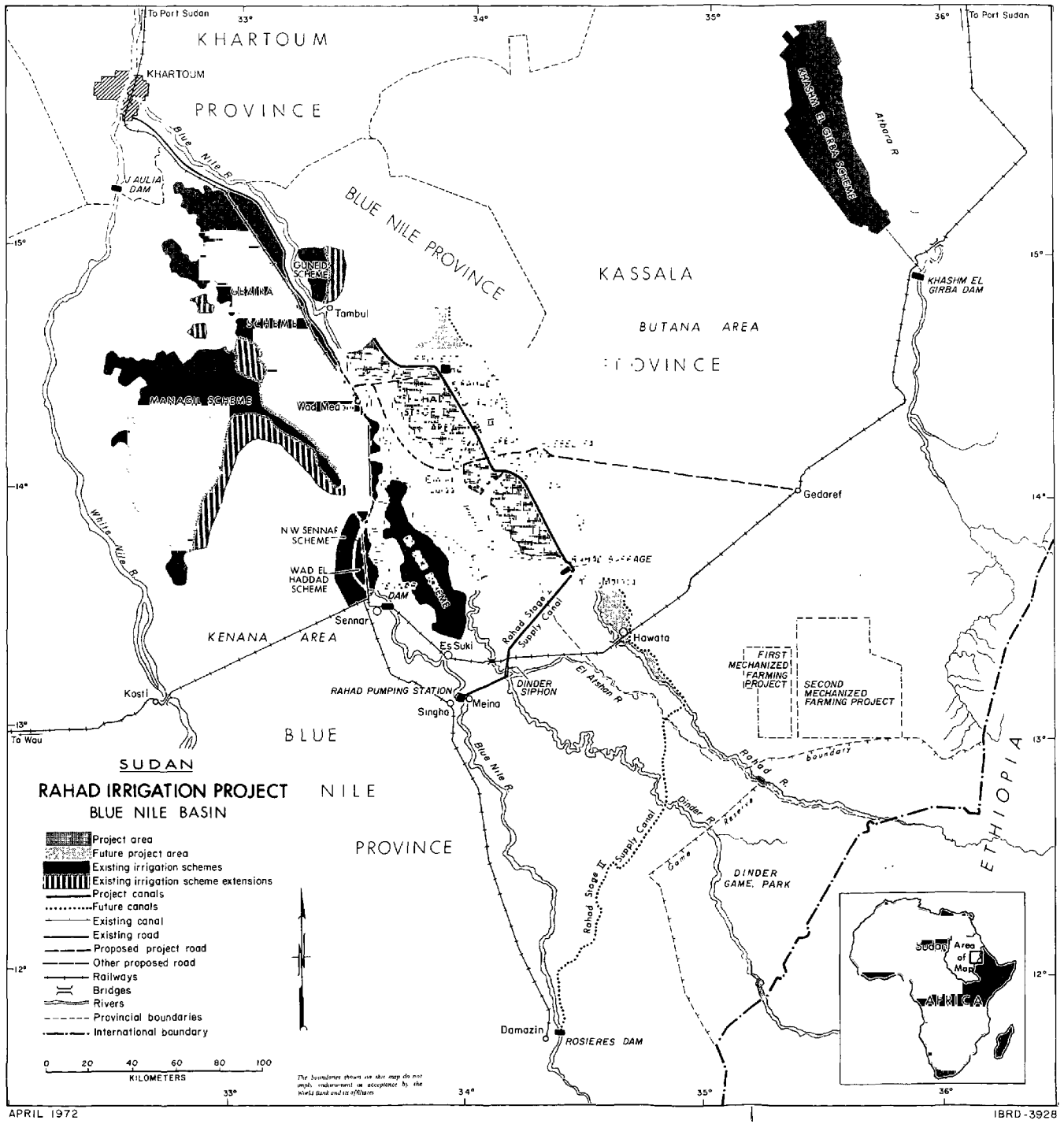
Loan 284/Credit 2

Economic Rates of Return

		(%)
First Approach (Investments lumped together and corresponding benefits)		
(1)	Dam investment and agricultural investments for extension/intensification of Gezira/Managil and new pump schemes already developed (Guneid Extension, Wad El Haddad, Es Suki)	8
(2)	Same as (1) plus agricultural investments for N. W. Sennar, Rahad Stage I and 225,000-feddan Wheat Project	10
(3)	Same as (1) plus Roseires hydro-electric investments	9
(4)	Same as (2) plus Roseires hydro-electric investments	11
Second Approach (Dam investment only)		
(5)	Benefits assumed to be 10% increase of cotton yields of agricultural investments of (1)	2
Third Approach (mixed)		
(6)	Dam investment and agricultural investments for Es Suki, Rahad Stage I and 225,000-feddan Wheat Project and corresponding full net benefits	9
Sensitivity Analysis Tests		
(7)	Dam investment and hydro-electric investments with only hydro-electric benefits	2
(8)	Same as (1) with shadow foreign exchange rate (1.2 multiplying factor)	7
(9)	Same as (1) with decreasing agricultural benefits by 25%	5
(10)	Same as (1) with increasing agricultural benefits by 25%	10
(11)	Same as (5) with increasing agricultural benefits by 25%	2
(12)	Same as (6) with decreasing agricultural benefits by 25%	8
(13)	Same as (6) with Rahad Project starting 5 years earlier	10
(14)	Same as (6) with Roseires dam built 5 years later	12

SOURCE: Calculations based on basic assumptions given in Table 9.

MAP 1



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