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REPORT ON PROGRESS AND PLANNING OF

SINAI WATER RESOURCES STUDY, EGYPT

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British Geological Survey
Maclean Building
Crowmarsh Gifford
Wallingford
Oxon OX10 8BB

Wallingford (0491) 38800
Telex 849365 HYDROL G

Natural Environment Research Council

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REPORT ON PROGRESS AND PLANNING OF SINAI WATER RESOURCES STUDY, EGYPT

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British Geological Survey/Institute of Hydrology
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SINAI WATER RESOURCES STUDY
EGYPT

List of Contents

LIST OF FIGURES

Number

LIST OF TABLES

Number

---

1. Base map and Fgiures 3 and 4 based on Dames and Moore, May 1985 (11)

7 Reallocation of EEC funds

8 Equipment Cost Estimates

9 Cost Estimates for Local Staff Allowances

10 Drilling Programme Cost Estimates

11 Provisional Funding Allocation

SUMMARY

1. Objectives

(a) To review and evaluate the progress of Phase 1 of the Sinai Water Resources Study (SWRS) being undertaken by the Research Institute for Water Resources (RIWR) under a joint co-operation agreement between Government of Egypt (GoE) and European Economic Community (EEC).

(b) To assist RIWR in formulating to technical and financial proposal for a Phase 2 continuation.

2. Background

(i) The SWRS commenced in November 1980 and is ongoing. This began as a three-year water resources study of the Western Sinai but was extended in 1982 to include the whole of the Sinai Peninsula, and area of some 6000 km^2. The main technical activities proposed in the project document were as follows:

* Climate Network. Upgrading of network by installing two new stations and additional instrumentation of four existing stations linked to a regional raingauge network.

* Hydrogeological Monitoring. Establish a monitoring network to provide time-varying data for longer term planning.

* Detailed Resource Studies. Identify the availability of water resources in areas where there was a risk of over-abstraction (El Arish, El Tor) and in areas of high agricultural development potential (El Qa'a, one basin in Middle Wadi El Arish).

* Catchment Studies. Hydrological studies would be carried out in three selected representative catchments to establish the broad relationships between rainfall, runoff and recharge for extrapolation to other similar catchments.

* Deep Drilling Programme. Information on the deep Nubian aquifer resources was very limited yet they constitute a potential major source of

supply. A drilling programme was to be undertaken to make a preliminary evaluation of these resources.

Technical assistance would be provided to the RIWR by external and internal consultants and staff training was also included. Overall direction was to be supplied by a Steering Group.

(ii) The SWRS programmme was established concurrently with the commencement of a major study being undertaken by the Ministry of Reconstruction to select an appropriate strategy for the development of Sinai (Sinai Development Study - SDS1), which included a preliminary assessment of the water resources. The SWRS programme prepared in 1980 was discussed with and accepted by the SDS.

The SDS Final Report was submitted in May 1985. Examination of this report has confirmed that the activities and priorities of the SWRS programme were, and still remain, consistent with the recommendations of the SDS.

3. Review of SWRS Phase 1

Limited progress has been achieved in meeting the original objectives of the SWRS, despite a 75% spend of the Phase 1 EEC funding allocation. Major modifications but of limited value were made to the original programme, notably in regard to the climate network and 'shallow drilling'. Project documentation, the quality of data collected, data storage and data analysis were all found to be poor. Staffing levels in Sinai are only about 50% of those required originally and the Steering Group Committee was never established.

Experienced hydrogeological and other senior staff were not recruited for what is basically a groundwater-orientated study. As a result there has been limited supervision of the project which lead to an undue reliance on subcontractors, poor planning and a failure to integrate results with the main programme. The lack of detailed planning and adequate technical direction are considered to be the main contributing factors to the lack of progress.

A summary of the main conclusions regarding the progress on each of the main activities is given below:

(a) Climate Network

1. Early in the project RIWR instigated a major change in the intended programme for the meteorological network by planning an extensive and costly network of stations inappropriate to the duration or needs of the project.

2. There has been an unnecessary duplication of GMA sites and there appears to have been a lack of cooperation with GMA until recently. The long term logistics of operating the network have not been resolved.

3. An assessment of existing meteorological data has not been made by RIWR. The equipment installed has given a poor data return. The data being obtained from both the first and second order stations are similar due to problems with the evaporation pan recorders.

4. The scale of the network requires excessive efforts in installation, maintenance, data collection and data transfer. None of the information has been transferred to a data base and was only recently tabulated. No analysis has yet been undertaken.

5. The raingauge network has not been installed in the representative catchments.

(b) Hydrological Monitoring

1.Time-varying hydrological information is essential to a water resources evaluation, particularly to establish trends in water levels, quality and abstraction in areas at risk from overdevelopment. The high priority need for such information had clearly been identified.

2. However, despite an attempt to monitor the situation at El Arish there are no monitoring records for El Qa'a - El Tor. Over the period since equipment was obtained a detailed and extremely useful monitoring record could have been obtained, which could have been used to plan and control abstraction. Such a record would also be useful for calibrating future numerical models.

3. The instruments obtained for the network have not proved very satisfactory. Even so, we feel that these problems should have been overcome.

(c) Representative Catchments

1. So far little progress has been achieved in meeting the original programme for representative catchment studies. The raingauge network has not been installed; complementary studies have not been undertaken; and no instruments have been installed in the W. Feiran. We would have expected more detailed advice and guidance from the external consultant in regard to these studies.

2. Run-off stations have been installed in six catchments. However, two of these catchments relate to dam-site investigations not included in the original project proposal by SDS, who give the least priority to such studies.

3. Overall, RIWR are not yet in a position to attempt rainfall-runoff relationships, variations in rainfall with relief or recharge estimates.

(d) Detailed Resource Studies

1. There have been major changes to the planned programme of detailed resource assessment studies. An extensive drilling programme has been undertaken by subcontractors by reallocating funds intended originally for the purchase of a drilling rig and ancillary equipment, although it would appear that the costs of this drilling programme have been met from the GoE allocation. A total of 122 boreholes (17000m drilling) have been drilled. Areas of particularly high priority (El Arish and El Tor) have not been given the necessary attention to define the resource availability. This equally applies to El Qa'a. Instead investigations have concentrated on other areas, particularly at Romana on the north coast and at Maghara.

2. There appears to have been limited pre-site selection study and the number of 'dry' boreholes seems high. The information obtained from the drilling programme is not of high quality and its value for resource

assessments may be restricted. Data on aquifer characteristics is still lacking, only 4 of the 15 planned tests have so far been undertaken.

(e) Deep Drilling

The EEC funding for the deep drilling programme was reallocated to meet the initial costs of incorporating Eastern Sinai into the study area and, consequently, this activity was postponed to Phase 2.

4. RIWR Proposals for SWRS Phase 2 Programme

A technical proposal was submitted by RIWR in August 1985 for a Phase 2 study of three-years duration to undertake the following:

- completion of the studies underway in Western Sinai and extend the basic programme to cover Eastern Sinai

- carry out those activities postponed from the original Phase 1 programme, principally deep drilling, numerical modelling and pilot form development.

The detailed objectives identified by RIWR were as follows:

(a) Groundwater Resources:

(i) A general appraisal of the groundwater situation, including:

- study of shallow Quaternary - Pleistocene aquifers
- study of carbonate aquifers (mainly Cretaceous - Tertiary)
- study of Nubian aquifer
- hydraulic interconnection between the different aquifer systems

(ii) Determine interference between main extraction zones, potential effects of new development areas, and evaluate the environmental effects of intensive abstraction in such areas.

(b) Surface Water Resources:

(i) establish comprehensive water balances of wadi systems in Eastern Sinai.

(ii) quantify recharge from surface water

(iii) Identify surface water schemes to utilize surplus run-off.

(c) Water Development Planning:

Establish a water development plan, including the application of mathematical models, which takes into account the following:

- needs of existing and planned agricultural projects
- potable water demands
- water requirements for private farming and animal watering
- industrial water demand

(d) Pilot Farms:

Implement pilot farm projects in selected areas based on Phase 1 and Phase 2 results. This will include 4 pilot farms, each of 50 to 60 feddans.

(e) Training:

Provide practical training to local personnel.

The project would be carried out over a three year period.

5. Comments on RIWR Phase 2 Proposals

The programme formulated for Phase 1 still remains compatible with the recommendations made by SDS-1 in May 1985. Consequently, a major change in emphasis is not required. However, many aspects of the Phase 1 study have not been completed. Realistic targets that can be achieved in Phase 2 need to be established given various constraints, such as staffing levels.

We recommended that priorities need to be clearly identified so that each particular activity has an order of priority within the overall strategy of the programme and, wherever possible, phased in a way that allows flexibility in their implementation. This should ensure that emphasis is maintained on completing the higher priority activities, any subsequent adjustments being related to those priorities of less importance.

We recommend that the Phase 2 activities should be arranged in the following order of priority which should be linked to project resources and achievements:

High Priority:

- rationalisation of climate network

- detailed groundwater resource studies, principally El Arish and El Tor/Qa'a Plain

- hydrological monitoring network in areas of existing groundwater abstraction

Intermediate Priority:

- establish regional raingauge network
- selection and instrumentation of representative catchments

Low Priority:

- development projects that require detailed resource evaluation and cost benefit analysis

Special Priority:

- deep drilling programme

This programme, which is also presented as a bar chart [Figure 8], differs significantly from the RIWR request in its emphasis on the need to complete the studies included in the Phase 1 programme and in taking account of accepted priorities within the overall development strategy for the Sinai.

Essential aspects of the recommended Phase 2 programme are as follows:

(i) The need to recruit suitable staff, particularly in hydrogeology. The RIWR staff structure should reflect the relative importance of the main water resource being studied, which, in this instance, is groundwater. Specialised studies have to be planned and interpreted in the context of groundwater occurrence. The numbers and experience of the project staff has to be consistent with the scope and scale of the work programme.

(ii) The recommendations include an emphasis on priorities in project implementation and a setting of targets with a view to completing at least the high priority studies within the next three years. Intermediate and low priority studies should be deferred to later in the project, at least insofar as the main implementation is concerned, and could even be postponed beyond the three year period if it appears likely that work on them could jeopardise the completion of the high priority studies. Intermediate and low priority projects should be phased so that the required flexibility for the entire programme can be maintained.

(iii) Shallow drilling in relation to the high priority studies has equivalent importance. Although the basic drilling will be subcontracted, it is essential that the RIWR staff are fully involved in its planning and implementation (site supervision, specialised sampling, logging, testing and analysis). There will be significant demands on project staff in this phase of the work if these recommendations are accepted, much more so than there has been in the past.

(iv) Deep drilling is given a special priority which does not, however, supercede the high priority ongoing studies. Various operational options are discussed. Detailed tender documents have not been prepared since it would be inappropriate to do so until decisions are reached on the precise sites and the drilling option determined. As in the case of shallow drilling, a strong emphasis is placed on the need for full technical involvement of RIWR staff in this work.

(v) Full and detailed reporting is essential as well as close co-ordination with other organisations engaged on selected work. The Steering Group will have a key role and should be fully involved in any important decisions that affect the work programme.

6. Provisional Funding Allocation Phase 2 SWRS

A provisional allocation of 3.37 M ECU (including contengency) from EEC funds will be required to implement the recommended Phase 2 proposals, comprising 1.11 M ECU for non-drilling activities and 2.06 M ECU for shallow and deep drilling. Cost estimates are included for:

- certain items of additional equipment and vehicle spares
- 60 man-months of external consultants and training seminar
- 48 man-months of internal consultants
- local allowances
- shallow drilling to support high and intermediate priorities
- eight deep boreholes and associated tests.

SINAI WATER RESOURCES STUDY

EGYPT

1. INTRODUCTION

The social and economic development of Sinai (Figure 1) has been given a high priority by the Government of Egypt (GoE). The availability of suitable water supplies and their proper management are crucial to this development.

Preliminary assessments of the potential of Sinai together with an overall strategy for planning and development have been prepared by the Ministry of Development, New Communities and Reclamation[1] through the Sinai Development Study Phase 1 (SDS-1). This study was commissioned in November 1980 with the final report presented in March 1985. Particular emphasis was given to the water resources aspects, which included an initial estimate of these resources based mainly on available data. A preliminary water plan was developed identifying water use and demands, primary water sources and costs, an appropriate organisational framework for monitoring and managing the water resources, and an outline programme for further research and investigation.

The recommended strategy (a synthesis of three intitial alternative development strategies) proposed by the SDS-1 estimated that the total water demand by the year 2000 would be 1708 million m^3/year, of which 94% would be met from imported Nile water and 6% from local groundwater sources. Irrigation supplies would account for 93% of the total demand. By comparison, water use in 1981 was estimated to be 42 million m^3/year, comprising 18 million m^3/year from groundwater sources and 24 million m^3/year from imported water supplies (mainly Nile water). Of the groundwater sources used locally, about 4 million m^3/year was utilised for public water supplies and about 12 million m^3/year for irrigation. These figures clearly demonstrate the scale of development possible and the

$\frac{6}{100} \cdot 1708\ M = 102\ Mm^3/y$

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[1] Formerly Ministry of Development and Reconstruction

large investment that will be required to achieve this.

However, water supplies from the Nile are considerably more expensive than local sources, particularly groundwater. Consequently, the policy of the Ministry of Irrigation requires that the groundwater potential of Sinai should be investigated thoroughly before committing large quantities of Nile water, especially in view of the increasing demand for Nile water in other areas of Egypt.

A clear need has been identified to initiate a programme of systematic data collection with complementary localised studies to define the local water resources potential more fully. Such information could then be used to refine the overall development strategy.

In November 1981, the Water Research Centre of the Ministry of Irrigation initiated the Sinai Water Resources Study (SWRS) to evaluate the water resources potential of Western Sinai, an area of some 40000 km^2. This study is being financed under the European Economic Community (EEC) - Egypt Cooperation Agreement and was formulated using an external consultant. It was to be undertaken by the Research Institute for Water Resources (RIWR) supported by the Research Institute for Groundwater (RIGW), both being component organisations of the Water Resource Centre, and would be co-ordinated with the then ongoing Sinai Development Study.

The project was to have been of three years duration, for which an appropriate programme of work [1] was prepared that had been discussed with and accepted by SDS. Technical assistance would be given by external and local consultants, but it was the intention that the project would be carried out largely by suitably qualified and experienced staff (mainly from RIWR and RIGW) with only a limited element of training being provided.

It was fully recognised that the work would extend beyond the three year period. However, the programme and its priorities were constructed in accordance with a three-year time schedule. In the event, work has continued by RIWR to the present time and, indeed, is still ongoing but with a general reduction in EEC funding from 1984.

In April 1982 the eastern part of Sinai, an area of some 20000 km^2, was returned to Egypt. The study area was extended subsequently to include Eastern Sinai. The initial additional costs of doing so were met by a reallocation of funds set aside originally for drilling investigations of the deep aquifers.

RIWR recently submitted a proposal and request for EEC funding of a Phase 2 of the SWRS, envisaged by RIWR in the context of the deep drilling programme omitted from the original schedule.

The original programme of work forming the basis of the Financing Agreement (First Financial Protocol 043/EG) was prepared before the start of the SDS-1 project. However, this had been disucssed with the SDS-1 team, who agreed that it represented an acceptable programme that could be coordinated easily with the SDS-1 project. Hence the SWRS programme appeared fully compatible with the strategy and priorities envisaged in the initial stages of the SDS-1. The conclusions set out in the final SDS report of March 1985 give no reason to alter this opinion. Nonetheless, in view of the extended period of time that has elapsed beyond the three-year planned schedule for the project, it is appropriate to consider the projects achievements both in relation to the original programme and the overall water resource plan of the final SDS report in order to plan Phase 2 of SWRS.

In February 1987, the Natural Environment Research Council (NERC) was commissioned by EEC to review and assess the activities of the SWRS to date (now referred to as Phase 1) and to assist RIWR in planning Phase 2. This evaluation has been carried out by British Geological Survey (who were involved in the preparation of the original terms of reference for the project) conjunction with the Institute of Hydrology. Both are component organisations of NERC.

A two-man mission to Egypt began 11 March 1987, involving 14 days for the Senior Consultant and 21 days for the Consultant. During this visit discussions were held with RIWR and other organisations concerned with Sinai, including

- General Meteorological Authority (GMA)

- UNICEF
- General Company for Research and Groundwater (REGWA)
- Ministry of Development, New Communities and Housing

Individuals contacted are listed in Annexe 2.

A tour of Sinai was undertaken during the visit. This took place from 14 to 21 March 1987 to inspect RIWR field installations and regional offices. Visits were made to El Arish (N. Sinai Regional Office), Maghara, Nekhl, Ras Sudr, El Tor (S. Sinai Regional Office), Sharm el Sheikh and Wadi Feiran. During this tour the consultant team were accompanied throughout by the Senior Geologist RIWR and, for part of the time, by the Deputy Director RIWR and Deputy Head of EEC Cairo Delegation, as well as by RIWR field staff from the regional offices.

The information obtained from the mission to Egypt has been used to describe and assess the achievements made by the SWRS during the past six years, identifying particular problems that have been encountered and establishing whether the direction and progress of the study has been compatible with the objectives of both the original programme and the SDS water plan. The latter is summarized in Section 1.2

The activities and progress of the project are described in Part 2 of this report. These are discussed using the main elements of the original programme undertaken so far, namely:

- climate network
- hydrogeological monitoring
- priority resource study areas
- catchment studies

Also discussed are the supporting aspects of the programme: organisation and staffing; transport and equipment; technical assistance; training; data base and modelling; pilot farm development; project co-ordination and reallocation of funds.

In each section we describe briefly the original programme, cost allocation and modifications, activities and achievements and the problems and difficulties encountered.

The third part of this report examines the requirements of Phase 2, including an outline programme of work, activities to be undertaken and details of the requirements for equipment, vehicles, local staff, technical assistance. Factors that should be taken into account in the formulating of the deep drilling programme, together with a summary of possible options for undertaking this programme are also discussed in Part 3.

1.2 Investigation Programme

The water plan developed by SDS-1 was based on an initial description and evaluation of the water resources potential and land capability, mainly using existing data. One of the key elements of this plan is a programme for further research and investigations that would provide a more detailed basis for the water resources development in Sinai. The immediate and short-term water supply investigation projects for further study recommended by SDS in March 1985 [11] are listed below in decreasing order of importance, those in accord generally with the SWRS original programme are identified by an asterisk:

(i) Groundwater

(a) Exploratory well-drilling and testing programme.*

(b) Geophysical surveys in the El Arish-Rafah area.*

(ii) Nile water

(a) Prefeasibility studies comparing the use of large pipelines and canals for land reclaimation in Sinai.

(b) Prefeasibility studies comparing various take-off points for Nile and drainage water for selected land reclaimation candidate areas.

(iii) Rainfall and dew

(a) Improvement of Sinai meteorological network*

(b) Prefeasibility study of cloud-seeding in Sinai

(c) Prefeasibility study of dew harvesting in the mountain area of South Sinai.

(iv) Surface water

(a) Runoff gauging stations.*

(b) Hydrologic studies on small basins*

(c) Evaluation of potential large and small dam sites.(*)[1]

Although these studies were considered relatively urgent by the SDS, the highest priority was given to establishing a groundwater monitoring and abstraction control programme: firstly, in the El Arish-Rafah area, where overdevelopment was already occurring, and, secondly, in the El Qa'a Plain where this could occur in the near future.

A summary of the other SDS recommendations for further study relating to the SWRS project is given below.

(i) Exploratory drilling/testing programme. An exploratory drilling programme was considered as an essential first step in identifying and developing new groundwater supplies required by the Sinai development strategy, particularly in the Uplands and Southwest subregions (Figure 1). Proposals for such a programme were submitted in February 1981 [2] followed by cost estimates in May 1981 [3]. Despite various modifications, this programme was not implemented.

(ii) Geophysical Surveys in El Arish-Rafah area. It was recommended that geophysical surveys (vertical soundings and constant separation traverses) should be undertaken to:

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[1] RIWR are investigating sites for several dams, although these were only included in a general way in the original SWRS programme.

- ascertain the extent of saline instrusion in (a) the El Arish Quaternary aquifer and (b) the coastal sand aquifer between Sheik Zuwayid-Rafah.

- investigate the origin of relatively poor quality water (a) southeast of El Arish and (b) in the area underlain by the Rafah Pleistocene aquifer.

(iii) Improvements to Meteorological Network. The pre-1982 network of meteorological stations was considered insufficient for a reliable assessment of the Sinai water resources. It was recommended, therefore, that this should be upgraded and expanded.

(iv) Run-off Gauging Stations. Gauges should be installed to measure run-off on the lower W. El Arish, W. Sudr, W. Sidri, W. Feiran, W. El Gerafi and near Tarba and Sharm el Sheikh. Careful selection of equipment appropriate to the conditions in the area would be needed.

(v) Hydrological Studies of Small Basins. Rainfall-runoff relationships and evapotranspiration should be studied on three or four small representative basins varying in size from 5 to 25 km^2. Equipment would include rain gauges, run-off measuring weirs, recorders and evaporation pans with records maintained for at least five years. The information would be extrapolated to larger basins to estimate run-off as well as to provide data for estimates of groundwater recharge and for cost-benefit studies for dams.

(vi) Potential Dam Sites. Eight possible dam sites were suggested by SDS. It was recommended initially that five of these sites warranted further investigation, but this was reduced subsequently to only three (Sudr, El Hadira, Gerafi). The study of each potential dam site would consist of a field appraisal and preliminary cost-benefit analysis (including associated works and delivery system). In view of the constraints on developing surface-storage schemes under the conditions in Sinai, the potential yield of such sites would be very uncertain until at least 5 to 10 years of data were available on rainfall-runoff relationships from complementary studies. A final cost-benefit analysis would not be possible until such information was available.

The programme of investigation recommended by SDS in May 1985 resembles closely the original work programme for the SWRS project, even though the latter was formulated much earlier in October 1980 (see Annexe 1).

Groundwater studies are given the highest priority, foremost in those areas of actual or potential overdevelopment, and surface storage schemes the lowest priority.

The main differences between the SDS recommendations and the original SWRS programme are that more emphasis is given by SDS to expanding the climate network and that RIWR have included certain other areas with in the SWRS project, notably El Maghara, Rabaa and Gifgafa with studies for dams at Maghara and El Quseima.

In the next chapter we describe the progress made by SWRS in regard to the similar programmes of work originally identified for the project and recommended by SDS.

2. REVIEW OF SWRS ACTIVITIES AND PROGRESS

2.1 Project Documentation

We would have expected a considerable amount of documentation to be available for a project of this scale and duration on which we could base our evaluation. Such reports would include those relating to planning, implementation or progress as well as the analysis of results. However, the only reports relating to progress of the project are the progress reports produced by RIWR, evaluation reports by EEC and those prepared by the external consultant (Aquater) during their involvement.

Progress reports were required at six-monthly intervals during the project. However, RIWR have only produced three such reports: November 1983 [4], October 1984 [5], and May 1985 [6]. The latter two reports contain identical wording and none contain much in the way of detailed, factual information. There have been no progress reports for the past two years, although a separate request for EEC funding to analyse and report on the work undertaken so far by the project was submitted by RIWR in December 1986 but not yet approved.

Project evaluation reports were prepared by EEC in January 1984 [7] and January 1985 [8]. These are not technical assessments but refer to various delays in implementing parts of the project and changes made in the project funding. They do not entirely confirm the claims made by RIWR in their progress reports.

The external consultant submitted a series of interim and progress reports [9] and a final report [10] on the project activities up to June 1983. These reports identify some of the problems encountered during the first 18 months of the project but only give a limited account of major changes made to the project work programme analysis of available information or of the project organisation, staffing or training. They prepared a detailed schedule for the three-year duration of the project against which progress was assessed. A series of reports have also been prepared by the local consultants on their particular activities.

Under the terms of the Financing Agreement a Steering Committee was to have been established within six weeks of signature. For reasons that we could not ascertain this committee was not established. The minutes of such meetings would have provided an important source of information from which progress could be charted.

Overall, there is a general lack of a written record of the project documenting changes in direction, progress and achievements. Hence, our appraisal of the situation at present has had to rely very much on dicsussions with RIWR staff (some of whom are new to the project) and on access to their basic records.

2.2 Climate Network

2.2.1 Modifications

In 1980 the General Meteorological Authority (GMA) operated five climate stations in Western Sinai: El Arish, El Mileis (Maghara), Ras Sudr, Abu Rudeis and St. Catherine. Of these, only El Arish was a first order station. Since 1982, the GMA have extended their network to include Rafah, Ras Nasrani and Ras Taba in Eastern Sinai and El Tor on the Gulf of Suez (Figure 2).

The SWRS project proposals recommended that four of the GMA second order stations in Western Sinai should be upgraded and that two new first class stations should be installed at Nekhl and El Tor. This would be undertaken in co-operation with the GMA so that the instruments installed would be compatible with those used by the GMA, who have considerable experience in arid area instrumentation. The GMA sites are located at airports throughout Sinai and are manned allowing easier maintenance and providing better data return. Hence the upgraded GMA stations could have been operated by experienced GMA staff and on completion of the SWRS the new stations could have been taken over by GMA for long term data collection.

X It was intended that the SWRS project would concentrate on increasing the overall coverage of rainfall stations, particularly in the uplands, as rainfall is highly variable under the conditions occurring in Sinai. The rainfall network would assist the extrapolation of the results from representative catchment studies, which themselves would have a denser raingauge network. The other climatological variables are 'conservative' and therefore there would be little to gain from a major extension of the GMA network, particularly in view of the relatively short duration of the project. Funding for the meteorological network for Western Sinai reflected this proposal:

	ECU
- installation of two first order stations	50000
- upgrading of four GMA existing stations	50000
- rain gauge network (mainly in representative catchments)	43000
	143000

SDS considered that the pre-1982 meteorological network was inadequate for a reliable assessment of Sinai water resources. However, this mainly concerns the variability of rainfall in relation to a water balance approach for estimating the resources, although groundwater recharge will generally only occur from concentrated, infrequent surface run-off in Sinai. Evaporation data will be more important to crop water demands and surface storage schemes.

We do not accept the view of the SDS regarding the meteorological station density and certainly the installation of an extensive network by SWRS would be inappropriate: the long-term network is more properly the responsibility of the GMA.

Despite discussions with GMA at the start of the SWRS project concerning co-ordination with GMA in the way intended for the project, these were inconclusive. As a result RIWR decided to proceed independently to establish a separate climate network that would consist of six first-order and 18 second-order stations. The justification for such an extensive network is not detailed in the progress reports. Hence, early in the project there was a significant change in emphasis, which has had important implications on other RIWR activities. Furthermore, the planned raingauge network has not been established in the representative catchments as was intended originally.

Tender documents for the instrumentation were prepared by Aquater but it was not until mid-1982 that contracts were signed. All of the equipment had been received and checked by November 1982 and installation began in December 1982.

By June 1983, first order stations had been installed at five sites: El Arish, Nekhl, Sudr, Abu Rudeis and Qantara. However, none of the second order stations had been installed, due to delays in obtaining meteoscreens from GMA, but by mid-January 1984 nine of these were completed. It was planned to install the sixth first order station at Kuntella in Eastern Sinai and to also transfer six of the planned second order stations to Eastern Sinai.

In mid-December 1983, RIWR requested a reallocation of EEC funds from the deep drilling programme in order to purchase further meteorological instruments to complete the network throughout Sinai. A transfer of 105000 ECU was approved to provide four more first order stations and 12 further second class stations. The instruments were received in January 1985 and January 1986. Hence, the total new allocation for meteorological equipment was 248000 ECU, approximately twice that originally allocated and yet without installing the planned raingauge network.

The RIWR and GMA meteorological network in Sinai is shown in Figure 2. Besides the nine stations operated by GMA, the RIWR installed and planned stations are as follows:

	Planned		Installed (March 1987)	
	1st order	2nd order	1st order	2nd order
West Sinai	6	18	5	11
East Sinai	4	12	1	4
	10	30	6	15

Three of the RIWR first order stations (El Arish, Ras Sudr and Abu Rudeis) are situated within a short distance of GMA stations and two others are relatively close (Ras Mohamed, Gifgafa). There is little or no justification for duplicating GMA sites, unless there was reason to doubt the GMA data. The existing GMA stations should have been assessed and used as an integral part of the project information network.

Three of the four second order stations installed in East Sinai are located close together at Quseima for RIWR studies relating to a new dam.

2.2.2 Instrumentation

The meteorological parameters measured at each type of station are as follows:

First order: Rainfall
Temperature, Humidity, Barometric Pressure
Wind speed and direction
Solar radiation
Pan Evaporation

Second order: As first order, except for solar radiation and evaporation.

However, the evaporation equipment has not operated successfully. Consequently, the only real difference between each type of station is the record of solar radiation.

The following comments were made by Aquater in their final report (10) concerning the suitability of the meteorological equipment.

- Aquater's recommendation to install complete second order stations with integrated instruments was not accepted

- the Hellman-type rainfall gauges were being seriously affected by sand

- abnormal power loss was affecting the evaporation pan recorders such that no evaporation data was being collected

- the barothermograph traces were very faint such that temperature co-efficients could not be applied to the solar radiation data

- only the anemograph was operating successfully as this was designed for desert conditions.

Although Aquater were involved with the preparation of the tender documents, there is no record of them having recommended alternative, more suitable instruments. They concluded in mid-1983 that the network was only partially operating due to equipment and installation problems and required rehabilitation. Data recovery was also poor for a new network. Despite these adverse comments, RIWR continued to purchase the same type of instruments for the Eastern Sinai stations. Our field visit indicated that no significant action has yet been taken to overcome the problems described by Aquater. Some of the instruments are not consistent with those operated by GMA and are not particularly well suited to the conditions in Sinai.

Approximate expenditure on the meteorological network equipment has been as follows:

Supplier		ECU
SIAP	(1982)	100490
	(1985)	41700
MULLER	(1982)	15000 (approximate)
THEIS	(1982)	68220
	(1986)	76000
		301410

This is over twice that allocated, which suggests that the original allocation was more than adequate for the purchase of high quality, desert proof equipment for the original programme proposal. We understand that the equipment made by Theis, which is proving the most reliable, is also used by GMA.

2.2.3 Data return

The greatly extended meteorological network generates a considerable amount of information. (This is in addition to previously existing meteorological data and that from the GMA stations). Consequently, more staff have to be diverted from other activities to collect data, maintain the network and transfer data to data sheets. A proper filing system still does not exist nor has any data been entered into a data base. No analysis has yet been undertaken.

Data files have been assembled for the six first order stations and 14 of the second order stations. Few of the data sheets had basic site information, such as elevation, start of readings or grid reference. We were informed that all rainfall data has been transferred to data sheets. However, the transfer of other data is still incomplete - there are nearly 300 charts still untabulated (solar radiation 172; wind (11 stations) 61; and temperature 51). It was not apparently until late-1986 that a determined attempt was made to clear the accumulating backlog of charts to data sheets.

In mid-1983, Aquater commented that there was a surprisingly low rate of data return for a new network. As yet there are no evaporation data due to instrument problems, which have not yet been overcome (SIAP did not respond to a request from RIWR for advice on this problem). RIWR have not attempted to assess the rate of return and it is difficult to establish whether the situation has really improved since 1983 in order to assess the efficiency of the network. However, on the assumption that the data files and the listing of charts still remaining to be transferred represent the data collected from the network, we prepared simple bar charts of the data available from the first order stations together with listings from the second order stations. This indicated large gaps in the records of each parameter. If these are representative then we can only conclude that the data return is still inadequate and of limited value for analysis.

2.3 Hydrogeological Monitoring

It was intended that monitoring networks would be established in areas where groundwater development was already taking place in order to provide essential time-varying data for longer term planning. Particular emphasis was to be placed on El Arish and El Tor - El Qa'a, although other local areas at risk would be included if required. Thus, to some extent, this activity complements the detailed resource studies. SDS also identified this work as of the highest priority.

The selection of the monitoring sites would be related to the hydrogeological conditions and be preceded by a water point inventory. Where necessary new observation wells would be drilled to provide suitable monitoring points. Key hydrological parameters, such as water levels and water quality, were to be measured on a routine basis. The external consultant was expected to prepare the detailed requirements of the monitoring network and frequency of observations.

RIWR have undertaken an inventory of wells at El Arish together with a water quality survey and some limited water quality monitoring. This work has not been fully analysed nor has any comparison been made with the water quality surveys carried out by SDS. No similar work has been undertaken at El Tor - El Qa'a, despite the continued increase in abstraction in this area.

Both the Arish and El Tor - Qa'a areas should have been priority areas for drilling. However, there is only a test well with three adjacent observation wells at El Arish; a test well with two observation wells at El Tor; and two piezometers in the El Qa'a plain (one of which is located almost adjacent to an irrigation abstraction well and thus of limited use for regional monitoring). None of these wells are being monitored regularly. Aquater do not appear to have assisted in formulating a monitoring network in these areas despite the high priority within the SWRS work programme.

The hydrological monitoring equipment was not available until November 1982. This included automatic recorders, well dippers, EC/pH/temperature meters and flow meters.

Attempts were made to install two water level recorders at Maghara (an RIWR special study area) but neither produced any records due to damage (protective shelters were not installed) or installation problems. The recorders do not appear to be desert proofed. It would also appear that floats were provided only for 6 inch diameter holes and therefore unsuitable for RIWR piezometers. The inertial-type (Seba) water level dippers have not proved very satisfactory. Although all of the 50m dippers are understood to be working, only two of the original five 200m dippers are still operational. Even so, no water levels are measured manually on a routine and regular basis and generally a measurement is only made on each project well on its completion. It would appear that the caps on some project wells are actually welded on after completion to prevent interference: suitable, lockable caps or other protective arrangements have not been used.

Equipment was purchased to monitor water quality, comprising 10 each of conductivity (EC), pH and temperature meters, 6 samplers and 36 sampling bottles. However, the two field geochemistry sets were not obtained and the funding for the mobile laboratory transferred to the contract drilling programme. Occasional water chemistry measurements are made but relatively few chemical analyses have been undertaken. Depth samples have been taken on an irregular basis. (During our visit we noted that these were being taken with an improvised sampler from within the cased portion of wells, and are thus of dubious value).

It was proposed originally that four pipe flow meters would be purchased, mainly for pumping tests. This was increased on Aquater's advice to 100 such meters of various diameters. We understand that 12 of these have been fitted to wells at El Arish to monitor abstraction. However, there are still 67 meters in the El Arish store according to a recent equipment inventory.

In December 1983 RIWR requested a reallocation of funds from the deep drilling to purchase further water level dippers, recorders and samplers for the Eastern Sinai extension. Two water samplers were delivered in mid-1986, although neither appear to have been used. We could find no record of the recorders and dippers having been purchased.

2.4 Priority Resource Studies

Detailed assessments of available water resources were required in the following areas:

(i) Areas at risk from overabstraction[1] -

(a) El Arish[2], the highest priority area where overdevelopment for irrigation supplies was already causing a deterioration in water quality

(b) El Tor[2], where there was an increasing demand for urban water supplies (locally and for supplies piped to Sharm-el-Sheikh area) with a risk of saline intrusion.

(ii) Areas of high agricultural development potential -

(a) El Qa'a plain, which extends north from El Tor. Agricultural development would also pose a risk of intercepting groundwater flow to El Tor.

(b) Middle Wadi El Arish. One basin would be selected: W. El Hamma, W. El Hasana or W. El Bruk.

The El Arish and El Tor - El Qa'a areas were given a high priority by SDS for resource evaluation. The SDS has also identified potential irrigable areas and a plan for their phased development (11). These are shown in Figure 3 and can be subdivided into the following:

- areas where groundwater was the sole source and where the availability needs to be defined. (SW1, 2, 3, 6; UP 9, 10).

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[1] Other local areas also at risk might have been identified subsequently by both the SDS and SWRS.

[2] Whilst included in the list of basic requirements in the 1980 planning document, both areas were omitted in error from the Fiancial Agreement

- areas where the area of irrigation depended on identifying suitable groundwater supplies, where Nile water supplies are only optional. (UP 5, 6, 7, 8; SW 2, 5).

- areas where supplementary groundwater to Nile water supplies require verification. (NW 1, 2, 4; NE 1, 2, 3, 4; UP 1, 2, 3, 4; SW 1, 3, 4).

- groundwater only. (SE 1, 2, 3).

This provided a guide to where investigations of the groundwater resource potential were required, although this might include both shallow and deep aquifers.

Each of the target areas for detailed investigation by SWRS would include well inventories, monitoring, geophysical surveys, drilling and testing. The geophysical surveys would be funded by GoE and it was expected that these would be undertaken by local experts. EEC funds would provide a drilling rig (for shallow holes up to 150m depth), ancillary logging and testing equipment and support vehicles. The drilling programme would begin in year 2 of the project.

Early in the programme Aquater considered that it would take one year to obtain a drilling rig and staffing the drilling operations could be difficult. Consequently, following discussions with RIWR, it was proposed that the drilling, logging and testing would be subcontracted. The funds for the rig and equipment of 164000 ECU and for the mobile laboratory of 36000 ECU were combined to provide 200000 ECU for the drilling contract. They considered that this would provide 15 shallow wells, but combined with an equal allocation from GoE funds a total meterage of 3000m would be possible. This was thought sufficient to investigate the upper aquifer system in central north Sinai.

Hence there were two major changes in the planned drilling/testing programme:

- funds were reallocated to employ subcontractors for drilling, logging and testing operations

NB

- the planned drilling programme targeted at priority areas was altered initially into a more general investigation of the Tertiary-Quaternary aquifers in central north Sinai. Preliminary investigations to assist the selection of drilling sites were largely omitted. It was also assumed by RIWR that drilling should begin immediately, although the original programme intended this to start in year 2.

Drilling began in July 1982. By the end of Aquater's involvement in April 1983, 19 boreholes had been drilled, all in the Maghara - Hasana - Arish area. Logging operations were stopped after the first 10 wells due to a dispute with the subcontractor. By November 1984 a new contract was being prepared by RIWR for further drilling in four other districts of Sinai. This would allow 8000m of drilling at an estimated cost of 2.4M ECU. Drilling progress is summarized in Table 1, which also shows when the drilling in the various areas of Sinai was undertaken. Drilling in south-east Sinai and on the north coast did not commence until 1986.

Three subcontractors were used for the drilling programme providing a total meterage of approximately 17000m. Summaries of the RIWR borehole programme and distributions are given in Tables 2 to 4, based on a recent inventory of RIWR sites, and borehole locations are shown in Figure 4. There are 122 boreholes at 101 locations, which includes 17 test wells but forty boreholes were unproductive (33% of those drilled). Only 13 boreholes are located in E. Sinai, all around Quseima, of which 8 were dry. A further 8 wells are planned around Rafah and 2 in the north-western coastal area near Bir El Abd.

A summary of the information available from the drilling is as follows:

	No. of boreholes with information	
Elevation	37	(NW coast only)
Lithological description	101	
Geophysical logs	54	(none on NW coast wells)
Cores	46	(taken at 30m intervals)
Water Quality	60	(37 in NW area plus 23 others)
Water levels	82	

So far only 4 of the 15 planned tests by RIWR have been undertaken (Table 5). A local expert from EGSMA was employed to produce stratigraphic logs from micropalaeontological analysis of the cores. A laboratory has been established for this purpose.

Overall the information obtained from the drilling is not of a high quality, particularly considering the large investment in this programme. Some borehole information is now being entered onto a data base, but relatively little interpretation has been undertaken.

The distribution of RIWR boreholes, shown in Figure 4, can be grouped into eight main areas, which are listed in Table 3. Only 16 of the 122 boreholes drilled are located in south Sinai. About 60% (or 72 wells) of the total is concentrated in the NW coast near Romana and in the Maghara - Middle W. El Arish area. The distribution in relation to the intended programme of detailed resource studies is discussed further below.

2.4.1 Existing development areas

Besides El Arish and El Tor, RIWR have included the area around Romana on the north-west coast and the Rafah area in the north-east as development areas for detailed study.

The only investigations at El Arish and El Tor for resources evaluation studies include a single test well (with associated observations wells) at both towns. Only that site at El Arish has been tested, and there have also been complementary inventory and limited monitoring studies around El Arish. Geophysical surveys have not been undertaken. Consequently, RIWR are not yet in a position to evaluate the resources available in either of the main priority areas at El Arish and El Tor.

Instead, RIWR have undertaken an extensive drilling programme at Romana, which is also an area also at risk from overabstraction. Seven test wells have been constructed but these have not yet been tested due to contractual difficulties. The wells are located mainly parallel to the coast and are therefore of less value for defining the extent of any saline intrusion. A geophysical survey has not been undertaken nor has routine monitoring been carried out. No real interpretation of the information obtained from the drilling has been carried out.

In addition another area at Rafah has been identified by RIWR where overdevelopment may be occurring. Only limited drilling has so far been undertaken, but eight new wells are planned. A pumping test has been completed in this area.

2.4.2. Agricultural development areas

The El Qa'a and one area in the middle W. El Arish were selected originally for resource assessments, concentrating on the shallow aquifers in these areas.

Two piezometers have been drilled at El Qa'a. One of these is situated very close to an existing irrigation well. The planned geophysical surveys and complementary studies have not been undertaken. Hence, despite the increasing abstraction in this area RIWR cannot yet assess the availability of resources for agricultural development, nor the potential consequences of present abstraction on the water supplies of El Tor.

Three investigation wells were drilled along the coastal plain south of El Tor, one of which was dry. These sites were not supported by surface geophysical surveys. In our view, these boreholes should have been located much closer to the escarpment, where there is greater potential for recharge and a thicker sequence of deposits. But in any case, saline groundwater is more likely to be present in the coastal plain south of El Tor.

A total of 27 boreholes have been drilled in the lower-middle W. El Arish, of which 18 were dry. Exploration in this area was intended to concentrate on the wadi deposits supported by shallow surface geophysics, photointerpretation and field visits to select suitable sites. RIWR commissioned a resistivity survey by EGSMA of the lower-middle W. El Arish, which concentrated on deeper structures with relatively little borehole control.

Photogeological interpretation of structures was made prior to drilling in some areas but final site selection and drilled depths do not always appear to have been co-ordinated with this work. Three boreholes in the middle W. El Bruk are an example of the apparent lack of coordination between the initial studies and subsequent drilling. All three boreholes were dry, none were drilled in the more active wadi channels and the drilling depths were 300m. The locations had been recommended from the photogeological survey as a possible site to intersect the Nubian at a relatively shallow level (about 700m) due to east-west faulting. The holes to 300m therefore seem to have served no useful purpose, neither to tap the shallow wadi deposits or the deeper Nubian.

The lack of pre-site planning and limited use of the geophysical surveys may account for the high proportion of dry boreholes (33%). There seems to have been limited effort to assess the aquifer potential of the wadi deposits in the W. El Arish and its tributaries in particular. Drilling seems to have instead rather concentrated on the Tertiary and Cretaceous sequences in this particular area.

2.4.3 Other areas

Two other areas for exploratory drilling have been selected by RIWR: Maghara and Gifgafa.

The Maghara area has been investigated in some detail by the project for irrigation supplies and by others [12] to locate water supplies for the coal mine. There appears to have been limited co-ordination between these projects, both having carried out extensive drilling in an area of limited resources. RIWR have drilled 18 wells (4 dry), including 5 test wells, and this area was one of the first areas to be drilled. They have also installed two second order climate stations, a wadi gauging station (as part of a study for new irrigation dams) and have begun pilot farm surveys. A soil survey has also been carried out of some 5000 fedans at Maghara by a local consultant. An attempt to install water level recorders was unsuccessful. Despite the extensive work in the Maghara area no resource evaluation has been undertaken and consequently it is surprising that soil surveys and pilot farm locations are already being studied. The concentration of project effort in this area from an early stage in the project may have reduced effort on other aspects and areas of the project programme.

Six piezometers have been drilled in the Gifgafa area. These were all unproductive. Site selection does not appear to have been based on geophysical surveys and no attempt has been made to interpret the information.

2.5 Catchment Studies

Hydrological studies were to be carried out in selected catchments to establish general relationships between rainfall, run-off and recharge. The results would be extrapolated to other catchments to estimate surplus run-off for development schemes, such as enhanced recharge.

Three catchments were proposed: W. Sudr, W. Gharandel and W. Feiran (see Figure 5): these are all in the south-~~eastern~~ western area. The water balance approach could be less applicable to the upland areas in northern Sinai but three catchments would also be selected in this area once experience was gained from the primary selection of catchments.

It was intended that there would be a survey of the south-west catchments, particularly of those provisionally selected, to define their broad characteristics as well as their suitability for the proposed catchment studies and the instrumentation required. This would be undertaken by the external consultant. A network of raingauges, gauging stations and observation boreholes would then be installed in the selected catchments. Where appropriate there would also be supplementary surveys, including geophysical and water consumption.

The hydrometeorological equipment for the catchment studies was received in late 1982. Eight gauging stations have been installed (one of these replaced a site destroyed by flooding on the W. Ruaq) in six catchments:

	Gauging Station	Climate Station	Piezometers
Representative catchments:			
W. Sudr	1	1 first order	2 (1 dry)
W. Gharandel	1	1 second order	-
W. Feiran	-	-	8 (6 dry)
Other catchments:			
W. El Ruaq (upper W. El Arish)	3	7 second order 1 first order	-
W. Quseima (Gudeirat)	2	3 second order	4 (1 dry)
El Maghara	1	2 second order	18 (4 dry 5 test)

These sites are shown in Figure 6. GMA meteorological sites are situated close to the RIWR station at Ras Sudr and near the eastern boundary of the W. Feiran.

2.5.1 Representative catchments

Although the external consultants selected each gauging site, detailed field reconnaissance of each catchment was not undertaken. Expensive masonary structures have been built at the wadi exit at W. Sudr and W. Gharandel, although there is some doubt as to whether these will withstand large floods. So far no run-off events have been recorded at these sites (indeed only one event has been recorded - at the southern station on W. Quseima). The catchment areas of the Wadis Sudr and Gharandel are large (895 and 829 km^2 respectively) and, consequently, only exceptional run-off events are likely to be observed at low points in each catchment. It would therefore have been preferable to have selected smaller sub-catchments (although the SDS recommendation for catchments of 5 to 25 km^2 would seem to us to be too small).

The intended raingauge networks have not been installed in each representative catchment nor have any supplementary surveys been undertaken. Reliable rainfall-runoff relationships are unlikely to be obtained from the present density and distribution of equipment in the representative catchments.

No instruments have been installed in the W. Feiran. This is an important area heavily reliant on groundwater where run-off recharge relationships (and their frequency) need to be established to manage abstraction. The RIWR boreholes were not drilled in this wadi until Jan-Feb 1987 and appear to be related to water supply rather than monitoring purposes. They are poorly sited and several are close to existing boreholes. All but two were dry, they were not preceded by geophysical surveys, and most penetrated some depth into bedrock. The geophysical logs of these sites may require reinterpretation.

The W. Ruaq has been selected by RIWR as a special catchment study in the upper W. El Arish. The area of this catchment is 6481 km^2. The wadi channels in this area are more diffuse and this presents some difficulty with obtaining reliable run-off records. The gauging stations are located near Nekhl at the lower end of this catchment. In general, we feel that experience should have been gained from the southwestern catchments before installing equipment in the Arish basin.

RIWR propose to include the W. Watir on the Gulf of Aqaba as a new representative catchment in southeast Sinai.

2.5.2 Other catchment studies.

RIWR are also undertaking studies at El Maghara and W. Quseima (Eastern Sinai) associated with the design of dams for irrigation supplies. Three of the gauging stations and five second order meteorological stations have been installed in these two areas.

SDS gave the lowest priority to dam site investigations in their recommendations for further studies and their recommended list includes neither of the above two areas. Similarly, the original proposals for the SWRS project do not include provision for the study of dams, except in a very general sense.

However, design studies for irrigation dams are now well advanced, although cost-benefit analyses have not been made nor have rainfall-runoff relationships been estimated with any reliability. In our view it would have been more preferable to have given a higher priority to the representative catchment studies before undertaking dam site investigation studies. The latter may have diverted project efforts away from the original work programme.

RIWR have prepared maps of drainage patterns, topography and geological structures for a total of nine catchments. Besides the six already discussed above, this includes the W. El Bruk/Hasana in the Arish basin and W. Gerafi in Eastern Sinai (Figure 6). These maps have been prepared in the RIWR photointerpretation laboratory by a local expert from EGSMA: most are at a fairly advanced stage.

The maps prepared for the El Bruk/Hasana catchments in part relate to borehole site selection and for a proposed dam site investigation at W. Gerafi. The latter was recommended by SDS as an example of a site for a small reservoir. Both areas have soils suitable for irrigation.

2.6 Supporting Activities

In this section of the report we describe some of the more general aspects of the SWRS project.

2.6.1 Project organisation and staffing

There was provision for 85 full-time staff for the three-year duration of the project, comprising 35 professional/technical staff and 50 administration/support staff. These staff, to be provided mainly from RIWR and RIGW, would be assigned to the following seven organisational units led by a project manager and assistant project manager:

	Staff
Technical Office	7
Hydrogeological Division) Hydrometeorological Division)	9
Data Centre	6
Administration	13
North Sinai Office	25
South Sinai Office	25

The regional offices would each have 8 professional/technical staff. The EEC funds would 107000 ECU for local allowances.

A current staff list was obtained relating to the whole of RIWR. The present complement is 75, of which 54 are presently assigned to the SWRS project. Of these, 28 are based in El Arish and 6 in El Tor. The regional office at El Tor has only recently begun to be staffed (which may in part account for the concentration of project activities so far in the northern part of Sinai), and both regional offices are being supervised by relatively inexperienced staff. However, there have been difficulties in recruiting staff to work in Sinai due to the local allowances.

Verbal reports from the assistant project manager indicate that staff are assigned to the section as follows:

Meteorology	- 4	Administration	- 11
Hydrology	- 4	Computing	- 5
Geology	- 8	Surveying	- 4
Photogeology	- 2	Drivers/Labourers	- 9
Micropalaeontology	- 2		
Drilling	- 5		

These sections are under the assistant project manager's direct control.

There were to be eight senior staff (excluding the project manager and assistant) attached to the project, of whom six were believed to be available in 1980 [1]. However, it would appear that the project still lacks the following senior staff: 1 hydrometeorologist, 3 hydrogeologists and 1 hydrologist. The three present senior staff were not appointed until late 1986 - early 1987 and include a geologist, hydrologist and systems analyst. The project manager (Director RIWR) is a hydrologist who has been with the project since its inception. The assistant project manager, who joined the project in August 1986, is a civil engineer with experience (but no formal qualifications) in hydrogeology: his predecessor was a hydrologist. The senior geologist has limited hydrogeological experience. Consequently, there has been very limited hydrogeological expertise on the project team, which is rather surprising in view of the importance of the groundwater aspects of the project and the availability of qualified staff in RIGW. The lack of senior staff may have caused greater reliance to have been placed on subcontractors, local consultants and on relatively inexperienced junior staff.

The present junior staff are principally geologists or engineers. The geological staff were recruited generally between 1982 and 1984 (most graduated 1978-1980), whereas the civil engineering staff joined the project in 1985 and 1986 (most graduating in 1984-85). An analytical chemist, two geophysicists and an electronic engineer have not yet been recruited.

2.6.2 Transport

An EEC allocation of 200000 ECU was made to provide the following vehicles for Western Sinai:

10 four wheel drive (pick-ups/station wagons)
2 minibuses
2 light trucks

This was subsequently modified by ordering only one minibus and including three additional cars. Contracts were signed and the vehicles delivered as follows:

	Number	Contract date	Delivery
Land Rovers	10	5.5.82	mid-December 1982
Fiat minibus	1	20.8.82	December 1982
Peugeot cars	3	3.82	August 1982
Leyland Trucks	2	10.10.82	mid-1983 (?)

The Leyland trucks were intended to support the RIWR drilling rig but were ordered after the decision to subcontract the drilling (Feb 1982). Consequently, there was less need for these trucks. No spares were delivered for the trucks and the minibus and a local administrative consultant was employed to negotiate a reduction in cost.

The delay in signing contracts and subsequent delivery could have restricted fieldwork activities during at least the first year of the project.

In December 1983 RIWR requested a reallocation of 150000 ECU from the deep drilling programme to obtain additional vehicles for the Eastern Sinai extension. Eight Land Rovers were delivered in August 1985, but without spares, and two minibuses arrived October 1986. The other vehicles (one truck and two cars) were not apparently ordered.

The project transport now comprises:

18 Land Rovers (9 station wagons, 9 pick-ups) 10/12
2 Light trucks
3 Minibuses
3 Cars

A shipment of Land Rover spare parts is still held in Customs, where the tax now due is reported to exceed their value. The pick-ups are deployed as follows: 7 at El Arish, 2 at El Tor. However, one of these is damaged and they are only on a temporary 3-monthly renewable customs release (final clearance is expected soon). The Land Rover station wagons are in store at El Arish. These have not yet been released from Customs.

It was originally intended to purchase tents and camping equipment for use mainly with the drilling activities and for work in more inaccessible areas. An allocation of 50000 ECU was made for this purpose from the EEC funding. In the event these were not purchased for reasons unknown. The lack of field accommodation may have restricted the effective time spent in the field.

Subsequently, the sum of 65000 was transferred from the deep drilling allocation to purchase six caravans. These were purchased from Ireland

and delivered mid-1986 for a cost of about 90000 ECU. However, these caravans are not suited to off-road travel and their axles are now being modified to use them for supporting the field activities.

2.6.3 Technical Assistance

EEC funding provided for the following technical assistance to the project:

213000 ECU	External EEC technical experts	: 36 man-months
71000 ECU	Egyptian specialists	: 65 man-months

(a) External consultants

Aquater of Italy were appointed as the external consultants for the project. Their involvement would include periodic visits by an external co-ordinator and specialist inputs for data storage and mathematical modelling, borehole geophysics, catchment analysis and hydrogeochemistry. Inputs of Aquater staff (10) can be summarised as follows:

	Man-days	Visits
External co-ordinator	375 (Egypt)	9
(hydrogeologist)	60 (Italy)	
Data storage expert	80	3
Mathematical modeller	95	3
Borehole geophysicist	75	2
Hydrometeorologist	170	5
Hydrogeochemist	45	1

The total input was 30 man-months, comprising 14.5 for the external co-ordinator and 15.5 for the other specialists. A total of five trips were made to Sinai (Feb 1985, November and December 1982, two in February 1983), totalling 23 days (2.7% of the time spent in Egypt by all Aquater staff). The total cost of these services was 345440 ECU, an increase of 131400 ECU or 61.4% on that budgeted.

The external co-ordinator arrived in Egypt on 21 November 1981, which was then deemed to be the start of the project. A final report was presented in June 1983 (month 19 of the project). Specialists in computing and hydrometeorology visited in early 1982 to assist in setting up computer systems and equipment tenders. The main involvement extended from September 1982 (after the equipment and vehicles had arrived and when drilling had begun) to April 1983.

There is insufficient detail given in the Aquater reports to gauge their real contribution to the project. In our view the external co-ordinator spent a disproportionate amount of time on the project between the early detailed planning and the subsequent arrival of equipment or transport. Similarly, due to the alteration to the programme regarding the climate network, the hydrometeorological input accounted for 36% (170 days) of the total input from visiting specialists when this aspect was only intended originally to be a small part of the project. The mathematical modelling was considered as a later stage of the work and consequently the involvement of this specialist seems rather high (95 man-days).

In general, we feel that the external consultants did not provide the detailed planning necessary to fully implement the project and utilized a disproportionate amount of their input prior to full mobilisation (late 1982). They were also involved in major alterations to the original programme. However, it would also appear that some of their detailed recommendations were not accepted by RIWR.

More recently, an expatriate hydraulic engineer has been assigned to RIWR on a temporary part-time basis from the Water Research Centre under a USAID funded scheme (Egypt Irrigation Improvement Project). At present he is preparing rainfall-runoff programs as well as a program for entering rainfall data from charts and an element of training for RIWR staff.

(b) Local consultants

It was intended that local experts with experience of Sinai would provide upto 65 man-months technical assistance, mainly in geology, meteorology, surface geophysics, agricultural land use survey and drilling. Table 6 summaries the studies made by local consultants based on verbal reports by the project manager.

Local consultants have provided an important contribution to the project, including an element of training for RIWR staff. However, only about 15% of the funds allocated for local consultants has been utilized and a large part of this has been directed at the Maghara area. Furthermore, some of this assistance has been inapprorpiate in terms of its timing to the progress or priorities of the overall programme. An example of this is the hydrological model which, as yet, cannot be calibrated due to the lack of data from the representative catchment studies. This would also apply to the studies for new dams.

(c) Other technical assistance

Contractors were employed by RIWR to undertake the drilling, logging and testing programme. EGSMA also carried out geophysical surveys in six areas of north and central Sinai.

The drilling programme is discussed in Section 2.4. Well reports, geophysical log interpretations and pumping test data analyses were undertaken by these drilling contractors.

The geophysical survey undertaken by EGSMA involved vertical electrical soundings (VES) in the following areas:

	km^2	No of VES
Lehfin-Arish	160	33
Maghara	100	67
Hemma basin	400	52
W. El Bruk	400	154
Southern W. El Arish	230	50
Gifgafa (W. El Mileis)	180	48
	1470	404

Electrode spacings ranged from 500 t0 4000 m and CGG curves were used to interpret the data. The average coverage was 1 VES/3.6 km^2.

This survey does not appear to have been fully utilized in selecting borehole sites and the amount of borehole and water quality control available for the interpretation was very limited. Computing techniques are now available for interpreting resistivity surveys and we would suggest that, if the basic data are still available, these should be applied to reinterpret the information using the new RIWR borehole data for calibration. The survey was also directed at deeper structures and other surveys of the unconsolidated aquifers have not been carried out.

2.6.4 Training

There was an EEC allocation of 65000 ECU for fellowships. This had not been utilized by January 1984 [7], except for the project manager to visit Europe for discussions. By January 1985 [8] agreement had been reached with the British Council in Cairo for six staff to attend a seven-month course in UK followed by practical training in Egypt using three or four visits by supervisory staff. It was estimated that this would cost 90000 ECU, the excess being drawn from the contingency allocation. This was not apparently organised until the second half of 1985.

The project manager reported that five staff were eventually sent on overseas training: 3 to UK and 2 to Italy. One of these has now returned and the remaining 4 staff are to return in July 1987. His impression was that this training has not been as successful or as appropriate as was hoped, although the success as yet cannot be measured.

2.6.5 Data Base and Mathematical Modelling

A large amount of information is available for the Sinai to which new information would be added from the project activities. It was therefore essential to establish a data base early in the project to store, retrieve and analyse all of this information. Similarly, the collection of hydrogeological data would be directed towards numerical model studies of the shallow and deep aquifers. Specialist advice on these aspects would be needed from the external consultant.

(a) Computing facilities

A data centre team has been established, although a senior systems analyst was not recruited until late 1986. The team consists of two staff for data entry and two programmers. The main computing facilities in Cairo consist of:

- Texas Instruments 73-990 mini (50 megabyte, triple disc drive)
- Printer/plotter
- Fortran compiler
- Digitizer

together with a TI-PC and several Macintosh Apple microcomputers. There are 19 software packages available for the micros, including word processing, spreadsheet and data base packages. It is planned to purchase an IBM-AT micro (although Harza Engineering (under USAID funds) have been requested to examine computing facilities and applications throughout the Ministry of Irrigation, in particular in the institutes of the Water Research Centre).

(b) Data base

Early in the project Aquater prepared an outline design for a data base. This consisted of 17 data sets arranged in a 3-level hierachy (climate, hydrology, hydrogeology). In September 1982 meetings were held to start implementing this system. However, for reasons not explained (possibly inadequate computer storage), a data base was not established. Advice was sought later (date unknown) from Cairo University but RIWR have been uncertain as to which computer to use or software packages available.

In late 1986 RIWR began using the Macintosh microcomputer data base software package. As yet, information entered onto this data base is very limited. In May 1983 the Research Institute for Groundwater (RIGW), also a component organisation of the Water Research Centre, began to examine the use of data base systems and appropriate hardware to store groundwater and other data from throughout Egypt. By May 1984 they had selected an IBM-XT with 256 kilobytes of core memory with a mass storage of 10 megabytes and a commercially available data base software package (Dataflex). Data entry began in October 1984 and is now well advanced [13]. A training programme was also established for its operation. Although this system is related to the storage of a large amount of information, rather than being project orientated, RIWR do not appear to have considered whether this might be suitable for their own needs. RIWR are still attempting to develop a data base system, although a number of suitable software packages are commercially available.

Overall, there has not been sufficient progress with setting up a data base system and this, to a large extent, has restricted data collation and analysis.

(c) Modelling

Aquater proposed that the numerical model developed by Cairo University for the Nile Basin would be appropriate to the Nubian aquifer study. This consisted of a finite element single layer model with upward leakage. They suggested separate models should be designed for the groundwater management of W. Feiran and El Qa'a. The saline intrusion problems along the northern coast of Sinai would require more complex models. In September 1982 RIWR proposed a 3-layer finite difference model instead of using the Cairo University model, since no progress had been made with access to this model. However, this was not recommended by Aquater due to problems of slow convergence. At that stage it was decided to postpone the modelling to the Phase 2 study.

2.6.6 Pilot farm development

The detailed water resources investigations in areas of high agricultural potential would lead to the development of pilot farms. These would be planned in cooperation with other organisations.

RIWR have concentrated on the Maghara area. A land survey has been undertaken by a local consultant and the farm areas are being surveyed by RIWR staff.

However, the evaluation of local water resources by RIWR has not reached a stage where the design of pilot farms can be properly justified.

2.6.7 Project coordination

Under the terms of the Financing Agreement there was a requirement to establish a Steering Committee within six weeks of contract signature. For reasons which we have not been able to fully establish this Committee, which was to meet periodically, was never formed.

It was also anticipated that there would be close cooperation with other organisations with interests in Sinai, in particular the USAID-TAMS Sinai Development Study, GMA, RIGW and Desert Institute. However, such cooperation would appear to have been rather limited; for example RIWR were unaware of the Working Papers produced by SDS-1 or the data base being implemented by RIGW.

Nonetheless, steps are now being taken to rectify this situation with more regular meetings and contact with other organisations. Even so, the formation of a Steering Committee for Phase 2 of the SWRS is essential and must be given a high priority.

2.6.8 Reallocation of EEC funds (First Financial Protocol)

The total EEC funding contribution for the original proposal, as set out in the Financing Agreement, First Financial Protocol 043/EG, was 2M ECU. There were two approved reallocations at RIWR's request (Table 7):

(i) First reallocation (1982). The combined costs of the drilling rig (and ancilliary equipment) and mobile laboratory were transferred to undertake the shallow drilling using by subcontractors. In addition, the costs of the field accommodation and a sum from the contingency were used to meet the higher than anticipated costs of the external consultant.

(ii) Second reallocation (1985). The deep drilling work was postponed to enable the sum set aside for this work, together with part of the contingency, to be used for additional shallow drilling, purchase of caravans, increased field allowances, and for equipment and transport for the initial work in Eastern Sinai.

Actual expenditure, which has been spread over twice the original duration of the project, is shown in Table 7 from information supplied by EEC. Total spend, as of March 1987 is 1534000 ECU (76.7% spend level) leaving an unutilized allocation of 466000 ECU. The main changes in actual spend compared to the original allocation are as follows ('000 ECU):

	Original allocation	Expenditure	Change	
Equipment	293	450	+ 157	(+ 53.6%)
External consultants	214	345	+ 131	(+ 61.2%)
Transport	200	316	+ 116	(+ 58%)
Field Accommodation	50	90	+ 40	(+ 80%)
Fellowships	65	81	+ 16	(+ 24.6%)
Local consultants	71	10	- 61	(- 86%)

Within the expenditure on equipment, the funding of the meteorological equipment for the climate network has increased by 110% compared to the original allocation.

The second reallocation of funds brought the total allocated for shallow drilling to 445000 ECU, an increase of 271% over the original allocation intended for the purchase of a drilling rig and ancillary equipment.

2.7 Summary of Phase 1 Progress

The progress and achievements of SWRS over the past six years have been less than anticipated and the quality of the data collected is often poor. There is doubt as to the wisdom of some of the major modifications to the original programme, most notably in respect to the climate network and 'shallow' drilling. A summary of the conclusions on each separate section of the main programme of study is given below. There are many reasons for the lack of progress in the original work programme but if the main reasons are to be identified, these would be a lack of detailed planning and inadequacy of technical direction.

(a) Climate Network

1. Early in the project RIWR instigated a major change in the intended programme for the meteorological network by planning an extensive and costly network of stations inappropriate to the duration or needs of the project.

2. There has been an unnecessary duplication of GMA sites and there appears to have been a lack of cooperation with GMA until recently. The long term logistics of operating the network have not been resolved.

3. An assessment of existing meteorological data has not been made by RIWR. The equipment installed has given a poor data return. The data being obtained from both the first and second order stations are similar due to problems with the evaporation pan recorders.

4. The scale of the network requires excessive efforts in installation, maintenance, data collection and data transfer. None of the information has been transferred to a data base and was only recently tabulated. No analysis has yet been undertaken.

5. The raingauge network has not been installed in the representative catchments.

(b) Hydrological Monitoring

1.Time-varying hydrological information is essential to a water resources evaluation, particularly to establish trends in water levels, quality and abstraction in areas at risk from overdevelopment. The high priority need for such information had clearly been identified.

2. However, despite an attempt to monitor the situation at El Arish there are no monitoring records for El Qa'a - El Tor. Over the period since equipment was obtained a detailed and extremely useful monitoring record could have been obtained, which could have been used to plan and control abstraction. Such a record would also be useful for calibrating future numerical models.

3. The instruments obtained for the network have not proved very satisfactory. Even so, we feel that these problems should have been overcome.

(c) Representative Catchments

1. So far little progress has been achieved in meeting the original programme for representative catchment studies. The raingauge network has

not been installed; complementary studies have not been undertaken; and no instruments have been installed in the W. Feiran. We would have expected more detailed advice and guidance from the external consultant in regard to these studies.

2. Run-off stations have been installed in six catchments. However, two of these catchments relate to dam-site investigations not included in the original project proposal by SDS, who give the least priority to such studies.

3. Overall, RIWR are not yet in a position to attempt rainfall-runoff relationships, variations in rainfall with relief or recharge estimates.

(d) Detailed Resource Studies

1. There have been major changes to the planned programme of detailed resource assessment studies. An extensive drilling programme has been undertaken by subcontractors by reallocating funds intended originally for the purchase of a drilling rig and ancillary equipment, although it would appear that the costs of this drilling programme have been met from the GoE allocation. A total of 122 boreholes (17000m drilling) have been drilled. Areas of particularly high priority (El Arish and El Tor) have not been given the necessary attention to define the resource availability. This equally applies to El Qa'a. Instead investigations have concentrated on other areas, particularly at Romana on the north coast and at Maghara.

2. There appears to have been limited pre-site selection study and the number of 'dry' boreholes seems high. The information obtained from the drilling programme is not of high quality and its value for resource assessments may be restricted. Data on aquifer characteristics is still lacking, only 4 of the 15 planned tests have so far been undertaken.

3 SWRS PHASE 2 PROGRAMME

3.1 Introduction

3.1.1 RIWR proposals for Phase 2

In August 1985 RIWR submitted a proposal for Phase 2 of the Sinai Water Resources Study. A financing proposal (Second Financial Protocol) was prepared in October 1986 (Annexe 3).

RIWR propose that Phase 2 should complete the studies underway in Western Sinai and extend the basic programme to cover Eastern Sinai. It should also incorporate any aspect of work omitted from the original programme, which involves principally the deep drilling but also to some extent numerical models. The detailed objectives were identified by RIWR as follows:

(a) Groundwater Resources:

(i) A general appraisal of the groundwater situation, including:

- study of shallow Quaternary - Pleistocene aquifers
- study of carbonate aquifers (mainly Cretaceous - Tertiary)
- study of Nubian aquifer
- hydraulic interconnection between the different aquifer systems

(ii) Determine interference between main extraction zones, potential effects of new development areas, and evaluate the environmental effects of intensive abstraction in such areas.

(b) Surface Water Resources:

(i) establish comprehensive water balances of wadi systems in Eastern Sinai.

(ii) quantify recharge from surface water

(iii) Identify surface water schemes to utilize surplus run-off.

(c) Water Development Planning:

Establish a water development plan, including the application of mathematical models, which takes into account the following:

- needs of existing and planned agricultural projects
- potable water demands
- water requirements for private farming and animal watering
- industrial water demand

(d) Pilot Farms:

Implement pilot farm projects in selected areas based on Phase 1 and Phase 2 results. This will include 4 pilot farms, each of 50 to 60 feddans.

(e) Training:

Provide practical training to local personnel.

The project would be carried out over a three year period.

3.1.2 General comments on RIWR proposals

The RIWR programme, as proposed, is rather generalized and takes no proper account of the progress of the work to date, nor of essential priorities. In an extension of limited duration and in view of the lack of progress in many aspects of the Phase 1 studies, it is essential that the Phase 2 programme should identify priorities and constraints (staffing, logistics etc) so as to set realistic targets which have a chance of being achieved in the three year project extension.

As noted in Chapter 1 of this report, the original programme was fully compatible with the strategies and priorities envisaged in the initial stages of SDS-1. The recommendations in the Final Report on SDS-1 give no reason to alter this opinion.

During phase 2 it will be essential to continuously reassess targets in relation to achievements, priorities and time constraints. Particular studies should be allocated in order of priority within the overall programme strategy and, where feasible, phased to allow maximum flexibility in their implementation.

A suggested order of priorities is given below. This takes into account the views of SDS-1, but is modified to also take account of factors relating more to the actual SWRS work programme. It may well be that RIWR will wish to modify this ranking, but should give reasons for doing so. The final agreed ranking of priorities could be incorporated into the financing agreement. This arrangement will ensure that emphasis will always be maintained on the higher priority programmes with any modifications or adjustments relating largely to lower ranking phases of work.

A. High Priority:

- Rationalisation of the climate network with a recommendation that the agreed long term network, or at least the main component, be transferred to the GMA for operation. The transfer would release staff for work on other aspects of the project.

- Hyrological monitoring in areas of major current development with a view to establishing the available groundwater resources and formulating a management programme. The two main areas of current development are El Arish and El Tor - Qa'a Plain.

- Detailed groundwater resource studies in areas of agricultural potential (good soils, likelihood of available water supplies, either from shallow aquifers or possibly deep aquifers). ?

B. Intermediate Priority:

- Regional raingauge network. A low density, low cost network using storage or recording raingauges, perhaps established near settlements to provide some security and a low cost of operation.

- Catchment Studies. The work on this would be phased with preliminary appraisal studies being extended over several catchments, but with decisions on more costly implementation and more detailed studies being deferred until realistic programmes can be formulated for such catchments (preferably fewer in number) that can be conveniently incorporated into the time schedule. The initial appraisals could include the installation of some rain and flow gauges where this can be done easily and cheaply.

C. Low Priority

in Northern El Kurdufan

- Development projects which require detailed resource appraisal and cost benefit analyses. Clearly these priorities could change following positive results from the resource evaluation analyses. In the context of the project time schedule, it is unlikely that this change of priorities would occur and the best that might be achieved could be pilot projects in the later stages of project studies.

D. Special Priority

- Deep drilling. This category is complex and it is more important to identify the issues that would confer priority. Highest priority would be given to deep drilling to supply existing settlements. The work by UNICEF falls into this category. It would be useful to assess the costs of production per capita, both capital and operating. Drilling for new settlements or for irrigation would clearly have lower priority but this would need to be assessed in terms of cost benefit analyses using probable figures of drilling costs and expectations of success. Lowest priority would be for sites located to provide information for aquifer geometry and resource evaluation.

The phasing of these priorities is shown in Figure 8 and discussed further in Section 3.7.

3.2 Climate Network

The GMA operate nine climate stations for the civil airports in Sinai. RIWR are close to completing an additional denser network with the following objectives:

(i) estimate recharge of the Nubian aquifer from direct infiltration (this is of relatively minor importance since recharge is likely to occur infrequently from run-off and there is considerable uncertainty in the distribution of rainfall which will limit the accuracy of rainfall recharge estimates)

(ii) agricultural requirements (irrigation use)

Rapid changes in meteorological conditions are likely to be limited to within 50 km of the coast. Further inland changes in meteorological conditions will be less significant, other than rainfall, which will depend mainly on altitude. Changes in altitude are more rapid in the southern part of Sinai. Thus between 2 and 4 stations in the inland region should be sufficient if integrated with the GMA network, with upgrading of any GMA stations if required. Such a coverage, of up to 13 stations, would provide a much denser network than is available for most other countries with similar arid climates and would be more than adequate to monitor the meteorological conditions.

This proposed arrangement is in keeping with the original proposals and would release RIWR staff now engaged on installation, maintenance and data transfer of the widely dispersed but extensive RIWR meteorological network. These staff would be available for other work more directly related to the water resource investigations.

If possible, the RIWR supplementary stations should also be operated by GMA, otherwise they should be equipped for automatic operation appropriate to arid conditions. The GMA should, in any case, be responsible for the long term operation of the network. Consequently, there should be full discussion between RIWR and GMA regarding the network density, site locations, instrumentation, maintenance and operation, and data analysis with particular emphasis on the longer term requirements.

The network of second-order climate stations serves little purpose since it is probably too dispersed to provide areal rainfall estimates and, due to the number of stations, is unlikely to be incorporated into the GMA long-term network.

More emphasis is required on rainfall variations. However, work in similar arid areas elsewhere suggests that a dense network of rain gauges (possibly 1 per 100 km^2) would be required to establish areal variations due to the often localized and infrequent rainfall events. A regionally dispersed network of storage/recording raingauges that can be installed and monitored conveniently and at low cost may be justified, providing it is accepted that this will only provide an indication of areal rainfall and that such measurements are unlikely to continue beyond the project duration. It may be feasible to involve local people in collecting such information to reduce costs and staff involvement.

More intensive raingauge networks could be considered for the representative catchment studies. The requirements of operating a dense network even within a small area may be impractical but a more modest network would be justifiable, even allowing for the uncertain value of the data. This could concentrate on establishing rainfall variations with altitude along catchments in the southeast and southwest in particular.

A possible supplementary approach to conventional ground-based raingauge networks is the application of remote sensing techniques to measure rainfall. Most rainfall in areas such as Sinai comes from local storms, which can be detected by satellite imagery. Meteosat information would be applicable, which can be analysed by an IBM microcomputer, but would require ground control perhaps provided from the representative catchment networks.

A detailed review of the present meteorological network is required. This must include co-ordination with GMA; an evaluation of existing available data and records, the efficiency of data return from the network; equipment, staffing operation and maintenance arrangements and future requirements. The duration of the project and longer term operations need also to be taken into account in such a review. The available information must be tabulated in an appropriate manner and transferred to a data base system.

We appreciate that the above recommendations for a reduced network would, if implemented, constitute a major departure for the existing RIWR programme and abandonment of work already carried out or commenced. It is partly for these reasons that we have suggested an immediate review of the network and its requirements and objectives with the GMA.

3.3 Representative Catchments

The representative catchment studies have an intermediate priority and are essentially longer term. In view of this we suggest that the work programme should concentrate on only a few selected wadis for which a carefully formulated plan of action should be made taking into account existing information. It would be appropriate to examine wadi systems from which groundwater abstraction is already taking place in order to also combine such studies with resource availability and potential. The catchments should be selected from those bordering the Gulfs of Suez and Aqaba. We would recommend the following:

W. Gharandel or W. Sudr ✓
W. Feiran ✓
W. Dahab

The difficulties of obtaining reliable and representative data and accurate resource evaluations should not be underestimated. Careful consideration of the most appropriate methodology and instrumentation should be made, including alternative approaches, such as groundwater flow studies (using flow net analysis and isotope data for example), to obtain estimates of the following:

- rainfall variations
- rainfall frequency
- rainfall - runoff relationships
- surplus runoff and sediment load
- water balance
- recharge from direct rainfall and runoff

Preparatory work should include (i) detailed field studies for catchment (or sub-catchment) selection, size of catchment to be studied, accessibility and instrument type/density/site locations; (ii) photointerpretation and remote sensing techniques to define the geology, structures, soils, vegetation and catchment characteristics; (iii) a water point inventory (wells, boreholes, springs), baseflow (and seepage loss), abstraction and consumptive use, channel definition and configuration, local information on flow frequency and water chemistry.

In addition, surface geophysical survey traverses should be made with a view to determining the thickness of wadi deposits. Some drilling will be required to provide sites for water level monitoring and to study hydraulic interconnection with deeper aquifers; for aquifer characteristics of the wadi deposits; and to prepare, if possible, water level contour maps. Water chemistry and abstraction/consumptive use will also need to be monitored.

The density of the gauging stations will need to be increased to at least three per catchment, depending on area and sub-catchment extent, since run-off events will be infrequent. The present structures are costly and their design should be changed, since there is some doubt as to their ability to withstand floods. Simple maximum stage level instruments should be installed.

The role of catchment modelling should be considered and may assist the requirements of the hydrological measurements. Theoretical models could be developed after the preparatory work programme but will require several years of measurement for calibration.

Until experience has been gained on the instrumentation and study of the catchments listed above, we would not recommend applying the same approach to the catchments in the upland region.

3.4 Detailed Studies

Hydrological monitoring should be included with the detailed studies and is required as a matter of some urgency. The detailed study areas should be considered as two groups: (i) areas undergoing development (El Arish, El Tor) and (ii) areas of agricultural potential. The former have the highest priority.

3.4.1 Development areas

Immediate action required includes:

- review of the current situation at El Arish and El Tor, including proposed further development, present water levels, quality, abstraction and updated water point inventory.

- geophysical survey to indicate saline water encroachment

- completion of pumping tests at El Tor and RIWR test wells along the north coast.

This information would be used to plan more detailed studies and the monitoring network requirements although monitoring should commence immediately. Earlier studies should be incorporated to assist this planning and a review should be undertaken of any other possible areas at risk from overdevelopment (such as north coast in general or W. Feiran). Information obtained from the RIWR drilling in these areas should be analysed and correlated, and this could include re-logging of boreholes or logging of selected existing boreholes (where accessible). A depth sampling survey should be made and shallow/deeper abstraction levels identified. There should be emphasis on the shallower aquifers but consideration must be given to upward leakage from deeper aquifers in the Arish area in particular.

As far as possible data collection should be orientated towards management models, which will have to take into account water quality. The availability of appropriate models should be investigated as early as possible.

3.4.2 Agricultural potential areas

The El Qa'a plain north of El Tor should be given a high priority since abstraction is increasing in this area without a proper assessment of the resources availability and the risk of intercepting groundwater flow to El Tor. Investigation requirements for this area are similar to those for El Arish and El Tor.

The agricultural areas are more widespread and involve alternative sources of supply as well as cost-benefit evaluations. Pilot farm selections should be postponed until resource studies are well advanced.

We would suggest that less emphasis is now placed on the Maghara area, although we accept that there may be other reasons for the studies being undertaken by RIWR in this area. Even so, these should not divert project resources from other aspects of the work programme. Similarly, surface water storage schemes have the lowest priority in the SDS programme and there should be a reduction or delay in project effort on the design of such schemes. A feasibility study and cost benefit analysis of surface spreading schemes (20 locations were suggested by SDS) could be undertaken but with a low priority. This could include the viability of alternative irrigation methods (such as drip irrigation) and different crop types (to be undertaken in co-operation with other departments within the Ministry of Irrigation), the results from which would assist the pilot farm designs.

Groundwater resources evaluation should be given a high priority. SDS have indicated potential irrigable areas (see Figure 3) and the demand for groundwater supplies in these areas. Areas should be selected (a) where groundwater will be the only available source and needs quantifying; (b) where the availability of groundwater will determine the area that can be irrigated; and (c) where initial estimates of potential groundwater supplies need to be confirmed. RIWR have already undertaken some drilling in some of these areas and the results need to be evaluated in terms of aquifer source, thickness and characteristics, water levels, quality, lithology and stratigraphy.

Cost-benefit factors of utilising different aquifers must be evaluated to extend the initial work undertaken by SDS. The groundwater potential quality and abstraction costs for each aquifer in each of the areas selected for detailed groundwater resource evaluation should be investigated in turn with increasing depth. The wadi deposits in selected areas of the middle W. Arish should be studied using remote sensing, geophysical surveys, photointerpretation and a drilling and testing programme. This would also include an assessment of the impact of any abstraction on downstream users and the frequency and recharge potential from run-off events.

3.5 Deep Drilling Programme

3.5.1 Summary of present situation

The original SWRS programme included a provision for deep drilling to depths of about 1000 m to investigate the potential of the Nubian aquifer in Central Sinai. This was subsequently postponed to Phase 2 when the EEC funding component (600000 ECU) was reallocated to meet the initial costs of incorporating Eastern Sinai into the area of study. Information on the Nubian aquifer in Sinai is very limited and the need to explore the potential of this aquifer still remains.

In 1981 SDS-1 prepared a proposal for a drilling programme in western Sinai [2,3]. This included three deep wells into the Nubian at Nekhl, Mitmeni and Gifgafa, each of which would be paired with a shallower well penetrating the overlying aquifers to study upward leakage and interconnection. Five other sites were suggested in the southwest region (Abura, Alaqa, Nakhul, Safariat and Feiran) where the Nubian is present at shallow depths (150-250m). However, despite various modifications to the extent of this proposed drilling programme it was not implemented.

In February 1981, a pilot scheme proposal was prepared for a joint UNICEF - GoE water supply project in the North Sinai Governate (north of Nakb-Suez). This had to be postponed whilst funding arrangements were confirmed and was subsequently revised [14]. It was implemented finally in 1985 and is still ongoing. The project includes a deep drilling programme (600 ~ 1000m) to provide drinking water supplies for 12 settlements in central Sinai (Figure 8). Two drilling rigs are in operation and are supported by well-equipped workshops and other facilities in El Arish. Deep wells have been drilled so far at El Hassana (1020m), Nekhl (1000m) and W. Amra (900m). The design of each production well is preceded by detailed logging, sampling and testing of an exploratory pilot hole. There have been various delays in the original two-year project (for example, due to faulty drill pipes), but we understand from UNICEF that their programme will be completed in mid-1988 and that detailed tests and sampling will be undertaken at each site. A report is due shortly on the progress of the project and future action. The drill site at W. Amra and the UNICEF facilities at El Arish were visited during the mission to Egypt.

RIWR have provisionally selected sites for the Phase 2 SWRS deep drilling. These are shown in Figure 8. Whilst this has taken into account the UNICEF locations the sites would appear to be selected on geological rather than hydrogeological criteria. Cooperation between RIWR and UNICEF in site selection and training has already begun. RIWR have also obtained cost estimates from a local drilling company for the deep wells.

3.5.2 Objectives and Considerations

It was anticipated originally that the costs of the SWRS deep drilling programme would be more easily justified if such wells could provide water supplies at local settlements in addition to providing information for resource estimates. Without such a benefit deep drilling solely for exploration purposes would be difficult to justify, unless there was an urgent and clearly defined need for detailed information arising from wider strategic planning considerations. Well construction and pumping costs are high for the Nubian aquifer and the exploration phase, as well as the development phase, must take account of cost-benefit and socio-economic considerations, particularly for irrigation supplies.

The UNICEF programme is now constructing wells at locations that would have been given high priority as SWRS deep drilling sites. Consequently, the UNICEF project must be taken into account in defining the objectives, number and distribution of the SWRS deep drilling sites. Furthermore, the UNICEF drilling was intended to provide emergency water supplies. As such, normal cost benefit considerations would not necessarily apply. However, this type of programme would not be expected usually to provide the type of information required for resources studies, either because of constraints of the well distribution or in the type of tests that would be undertaken.

The SWRS deep drilling programme to be carried out in Phase 2 needs to be directed towards either:

(i) providing information in areas of Central Sinai not covered by the UNICEF programme where additional information would be desirable; or

(ii) the much wider regional resource aspects of the Nubian aquifer as a whole.

In either case, the drill sites would be widely dispersed and therefore only enable very broad estimates of the Nubian aquifer resources to be made. Priorities clearly need to be established, with the objectives of each deep well clearly defined and also taking into account cost-benefit and socio-economic criteria. This will require expertise that is at present unavailable in RIWR, such as agro-economics. For example, drilling locations chosen in north central Sinai at, say, the site of a proposed new settlement and for irrigation development would require cost-benefit analysis and comparison with alternative sources of supply. Whereas in south central Sinai, where the agricultural potential is more limited, socio-economic benefit criteria would also need to be examined to justify even an exploration borehole.

At least the following points should be taken into consideration in formulating an appropriate strategy for the SWRS deep drilling programme:

- scale of the investigated area, to determine the number of sites required or the benefit from a limited number of sites

- type of information needed and the urgency of such information in relation to the wider development strategy for Sinai

- RWIR project capabilities and level of involvement, such as the number of staff required for an extensive programme or the need to complete other priority aspects of the project

- technical difficulties of the deep borehole drilling, testing and completion

- cost benefit and other factors.

An initial assessment of the regional potential of the Nubian aquifer has already been undertaken and reported by SDS-1 [11]. This was based on limited information but needs to be studied carefully so that the Phase 2 SWRS drilling and that of UNICEF can be used to refine this earlier assessment. Cost analysis and land survey information given in the SDS-1 report should also be examined in relation to the local or regional aspects of the deep drilling programme, including:

(a) potential and existing irrigable areas

(i) where deep groundwater is likely to be the only source of supply

(ii) where the irrigation potential is such that deep groundwater, in combination with shallower aquifer development, still provides a cost-effective source of supply.

(b) proposed new settlements having domestic/industrial/irrigation water requirements where deep groundwater is likely to be the only source of supply.

(c) long-term water supply requirements on a more regional scale compared to the resources of the shallower aquifers.

The principal irrigable areas identified by SDS-1 occur in the Gifgafa - Queseima area, where, however, deep groundwater supplies are likely to be more saline. For this and other reasons of cost, the potential of the shallower aquifers should be thoroughly investigated prior to any consideration of the deep aquifer. The Phase 1 SWRS shallow drilling has already concentrated on these areas and the results need to be fully evaluated. Four of the RIWR proposed deep drilling sites are located in this area, two of which are relatively close to the UNICEF wells at Hasana (which may not have penetrated the Nubian) and W.Amra, and thus the objectives of these sites should be re-examined. The UNICEF deep wells at Nakhl, Themed and Kuntilla are probably adequate coverage for the central area of the Nubian. The sites provisionally selected by RIWR in the Giddi area and midway between Oueseima and Kuntilla would provide important information for the wider resource evaluation aspects in central Sinai.

The UNICEF programme is orientated towards providing potable water supplies at selected settlements. The forward programme is still under review, but verbal reports from the UNICEF project co-ordinator suggest the following:

- the programme should be completed by mid 1988

- both rigs are likely to remain in Egypt, possibly for work in south Sinai after the project is completed

- detailed tests of the sort required by RIWR will continue to be undertaken at the remaining sites to be drilled

- UNICEF would welcome the opportunity of co-operation with the SWRS project.

The information obtained from the UNICEF programme, including difficulties encountered during drilling and in regard to design or testing considerations, should greatly assist the RIWR deep drilling programme. It would therefore be desirable to delay the RIWR drilling until the UNICEF sites are completed. As the UNICEF locations are known, RIWR could in the meantime prepare appraisal reports for the Phase 2 site selections. We understand from RIWR that the SWRS deep wells do not need to be located at existing settlements, but any boreholes drilled that encounter suitable water supplies should be capable of being converted to production wells.

The RIWR drilling programme should provide at least the following information:

- aquifer characteristics (transmissivity, storage co-efficient, specific yield, permeability, thickness)

- type of flow (fissure or intergranular and relative importance of each)

- upward leakage and interconnection

- water level depths and elevations (for quantifying groundwater flow, influence of barriers, flow directions and hydraulic gradients)

- influence of major structural controls and broad lithological variations

- age determinations and water chemistry/quality

- yield drawdown data, abstraction costs and production well construction/design considerations.

It may not prove possible to obtain all of this information due to the high cost of constructing each borehole. The following considerations should also be taken into account:

(i) Individual aquifers encountered, including the Nubian and overlying aquifers, will need to be tested and screened but saline water will need to be cased-off.

(ii) The drilling programme must consider the various factors affecting the cost of a completed borehole. A dry hole would not be completed and minimal costs would be incurred in the drilling programmme. UNICEF have completed to full depth with open hole thereby saving the cost of upper casing had the hole been abandoned, although this procedure incurs certain risks.

(iii) The upper aquifers may be difficult to test during the drilling programme, particularly as heavy drilling mud will be required.

(iv) Testing the intermediate aquifers may require packer systems which are expensive and difficult to install and operate.

(v) Lost circulation problems are common. These will occur at potentially productive horizons and it is therefore essential to minimize excessive mud invasion of such zones.

(iv) Geophysical logging should be detailed and undertaken by contract.

RIWR will require very experienced site hydrogeologists and drilling engineers for at least the following operations so as to maximize the information obtained from the drilling programmme:

- verticality/alignment, mud control, drilling rates (a penetration rate recorder is recommended)

- supervise the intermediate and final pumping tests and ensure that equipment is available and correctly placed

- ensure satisfactory development of the well (including demudding, jetting, acidification)

- collect and store cores, described lithological samples and collect water samples for various analyses
- analyse the information obtained

The funding will need to support subsequent laboratory work on the fluid and sediment samples including micropalaeontological evaluation, grain size analyses, isotope analyses (including age dating), porosity and specific yield tests on core samples, and chemical analyses. If drilling is undertaken in the outcrop area the unsaturated zone should be sampled (coring should be attempted over the first 20 m and thereafter for 3 m in 10 m to the water table) for hydrochemical/isotope studies of the pore water to provide further information on recharge rates and frequency. In such areas air-drilling techniques for small-diameter holes to the water table are recommended.

The cost and complexity of the deep drilling programmme requires a very careful evaluation of existing information before selecting drill sites and preparing detailed tender documents as well as close, detailed supervision of the work and analysis of the results. A fully documented proposal should be submitted for each proposed drill site containing at least the following information.

- regional and local geological section

- any prior information for the area

- objectives and consideration of use

- test well preliminary design

The preparation of a drilling tender document is not appropriate at the present time until such proposals have been prepared.

The RIWR project staff will need to supervise the work of the contractor throughout the drilling programme. This will ensure that the design specifications are carried out correctly and that information to be collected by the contractor is obtained properly. In addition they should carry out, in association with the contractor, such work and measurements as are necessary and required by the contract document, including lithological and fluid sampling and aquifer testing. (Geophysical logging will need to be undertaken under contract, since it is assumed that the logging equipment purchased by RIWR will be suitable for shallow drilling only).

In addition, numerical model studies (including inferred recharge, regional evaluation and wellfield models) would provide a means of integrating the information obtained. The collection of data should be orientated towards such models and the type of model to be applied needs to be selected at an early stage.

3.5.3 Options for implementation

There are several options available to implement the deep drilling programme of Phase 2 SWRS. These can only be evaluated after full discussions between the organisations concerned. Other Phase 2 priorities will need to be taken into account as well as the considerations outlined above. Should the primary activities of the Phase 2 work programmme not be accomplished then it may be necessary to further postpone the deep drilling until these are complete or use others to supervise the deep drilling programme. The UNICEF drilling programme, which is already ongoing, should be taken into account in deciding the deep drilling requirements.

A more regionally extensive drilling programme such as that proposed by RIWR, would require a separate drilling contract implemented early in Phase 2 and supervised by experienced hydrogeologists and drilling engineers. The sites identified by RIWR include locations that would supplement the UNICEF drilling and also include the Nubian outcrop area (Figure 8). However, they are concentrated in the main irrigable area identified by SDS-1 north of Hasana where water quality may be poor.

Besides UNICEF, the only local drilling contractor currently operating in Egypt with the experience and capability of drilling and constructing deep boreholes of about 1000 m depth is the General Company for Research and Groundwater (REGWA). This company has been operating since 1961, has an annual turnover of about 13 ~ 15 M LE and extensive experience (mainly in Egypt and Libya), including wells of 1200 m in the New Valley and of up to 300 m in Sinai at Arish and El Qa'a. They employ local drillers with considerable experience; provide certain geophysical logs; and perform most of the tests and sampling required, with perhaps the exception of packer tests, which would be performed by subcontractors. REGWA would need to establish support facilities in Sinai for the deep drilling.

We are not aware of any financial limitations of the company that might delay or prevent completion of the drilling programme or the purchase of materials. EEC may need to fund a supply contract, since materials could take one year to obtain without a foreign exchange component.

A reduced SWRS Phase 2 drilling programme, concentrating on central Sinai, could be undertaken by UNICEF. This would be subject to GoE, North Sinai and UNICEF approval. UNICEF have already established an efficient, well-organised and supported drilling operation in North Sinai; have experience with the difficult drilling conditions associated with 1000 m deep wells penetrating the Nubian aquifer; and are set-up to undertake the type of tests required on each borehole. They have two rigs capable of the depths required, which are supervised by expatriate staff. RIWR are becoming involved in the selection of final sites for the UNICEF wells and a drilling engineer from RIWR is working with the UNICEF drilling team to gain experience.

However, the UNICEF programme may have certain constraints in relation to the needs of the SWRS deep drilling:

- site locations may have to be limited to settlements

- the depth of completion might be determined by the occurrence of potable groundwater at shallower depth than the Nubian

- the detailed testing and sampling incur extra costs

- the UNICEF forward plans are not yet available, which could affect timing, rig availability and the detailed tests.

We were informed by UNICEF that their programme could be completed by mid-1988, after which time their facilities may be available for the SWRS project.

There are a number of different combinations for collaborative work with UNICEF, which could also overcome some of the above limitations:

(i) EEC provide funds for UNICEF to drill at strategic locations, not necessarily at existing settlements, selected by RIWR in areas not covered by the UNICEF programme. If this is undertaken after completion of the UNICEF project, RIWR would be able to concentrate on other priority aspects of SWRS and prepare detailed site selection reports and specifications.

(ii) EEC funds are used to support UNICEF by meeting the costs of one or more of the following:

- additional equipment and expatriate personnel

- exploration to greater depths at the UNICEF sites than would otherwise be required by UNICEF

- detailed tests and sampling (including coring and packer tests).

(iii) Combinations of (i) and (ii)

There are several advantages in a co-ordinated SWRS - UNICEF drilling programme, although at present there are various possible options for such an arrangement. We would recommend more detailed discussions with the UNICEF project in the immediate future to explore the possibilities further in more detail. Should the UNICEF rigs not be available then EEC could still fund (ii) above and resource evaluations would be based soley on the UNICEF programme without further deep drilling sites.

Alternatively, REGWA would be employed to drill the additional sites in central Sinai area supervised by RIWR staff.

There is still a further option: a combined programme involving both UNICEF and REGWA, which would be directed more at a regional exploration of the Nubian aquifer. This would probably be beyond the project resources. In our view, it would be preferable to investigate the north central Sinai area before embarking on the wider regional resource evaluation.

Where possible deep wells should be paired with shallower wells and tested to quantify upward leakage and interconnection, as also included by SDS-1 for their proposed drilling programme. This arrangement would add considerably to the drilling costs depending on the number of sites and the depth of the shallow well. Before this is given greater consideration it should be possible to obtain a preliminary indication of the degree of interconnection from water level data from the UNICEF drilling and from age determinations and hydrogeochemistry of water samples collected at different depths during drilling. Interconnection may also be restricted to specific fracture zones. If this aspect is to be investigated, and this would be important to the design of a numerical model, paired wells could be arranged within the following alternatives:

- EEC provide funds for the deep well and the GoE allocation provides the shallower well

- a shallower well is drilled next to a UNICEF deep well where interconnection is indicated by the UNICEF borehole information

- a deep well is drilled next to an existing shallower RIWR piezometer.

3.6 Staffing and Organisation

3.6.1 RIWR staff

The present staffing levels of the SWRS project are less than those required under the Financing Agreement and may be insufficient to undertake the priority activities effectively. We therefore recommend the following:

(i) The required senior staff, notably hydrogeologists, must be recruited in order to provide the necessary level of technical supervision and to supervise the work of the regional offices.

(ii) The complement of the South Sinai Regional Office at El Tor should be increased, as there will be a greater level of activity in Southern Sinai. This should preferably be attained by recruiting new staff rather than transferring staff from the existing complement of the North Sinai Regional office at Arish.

(iii) Local allowances must be sufficient to attract staff of the right calibre for the fieldwork activities.

(iv) A field operations manager should be appointed at a senior level to co-ordinate activities in Sinai.

(v) The project team should be re-organised into the divisions given in the Finance Agreement as soon as possible.

3.6.2 External Consultants

External consultants will be required to provide technical assistance to the project:

(i) Project Co-ordinator. This would be a full-time post and should be a hydrogeologist with extensive water resources experience.

(ii) Senior consultant. Part-time position requiring periodic visits to overview and guide project activities and priorities.

(iii) Specialist consultants to undertake specific studies and training. Their inputs would be distributed throughout the project and their timing and duration agreed between RIWR, Project Co-ordinator and EEC. The main aspects requiring expert assistance include:

* surface and borehole geophysics
* remote sensing applications

* application of computing techniques, including modelling
* catchment analysis
* isotope studies

3.6.3 Local Consultants

Well qualified and experienced staff are available from various organisations in Egypt. Their inputs should be co-ordinated with those of the external consultants and there would be benefit from employing local experts to work with the external specialists so that their combined experience can be used for maximum gain.

The main areas requiring local experts should include:

* assistance with preparing deep drilling tenders and selecting drill sites
* geophysical logging of shallow boreholes
* drilling and testing shallow and deep boreholes
* assistance with the planning and interpretation of surface geophysical surveys
* hydrogeochemistry
* agro-economics

The timing and duration of the inputs from local experts should be flexible in order to match changing priorities. The selection of local experts together with the timing and duration of their contribution should be agreed in advance by RIWR, Project Co-ordinator and EEC.

3.6.4 Training

There is an immediate need for an external geophysical consultant to provide training in the use of the RIWR geophysical equipment and interpretation of results, and an external hydrogeological consultant to provide training in the planning and interpretation of hydrogeological surveys. These inputs should be carried out together for maximum benefit. We would suggest that this is undertaken as a field training exercise in priority areas on the north coast and the El Qa'a area. The external and internal experts will provide an element of training throughout the project.

The training at more junior levels will be largely practical and related to the installation, operation and maintenance of equipment and compilation of field data. This could be provided in co-operation with other GoE organisations, including GMA, Desert Institute and RIGW. One possibility which is already being examined by RIWR, is for the Institute for Training of the Water Research Centre to provide condensed courses. Similarly, there would be merit in computing staff attending the course organised by RIWR for their data base operations. Promotion is linked to qualifications and this must be taken into account in selecting the staff to attend training courses overseas and the type of training courses provided.

Training at senior staff level would be provided largely by the external consultants, and would be orientated to the theory, planning and analysis of water resource evaluation projects. The training requirements will relate to the experience and qualifications of the more senior staff and agreed between RIWR, the Project co-ordinator and EEC.

Consideration should be given to an intensive seminar given by a small team of experts. This could be of two-weeks duration : the first week attended by more junior staff and the second by the senior staff. It would include lectures and practical workshops orientated to the Sinai project.

The success of the overseas fellowships during Phase 1 cannot yet be evaluated. However, the Project Manager has expressed some reservations as to their value. The general view held by RIWR would seem to be that training should be given where possible in Egypt so that it can be orientated to the needs of the project.

3.6.5 Transport

Eight Land Rovers were delivered in August 1985 for Phase 2. These are in store at El Arish but still require customs release. A shipment of spares is also held in customs. However, it is anticipated that clearance will be obtained in the near future.

Providing spare parts are obtained for the project trucks, minibuses and Land Rovers no further transport should be required.

3.6.6 Data base and Modelling

Data collection should be orientated towards a data base and model applications. We would recommend that the SDS-1 system of numbering for hydrographic areas and groundwater areas should be adopted for the data base. Similarly, the RIWR borehole numbering system must comply with the national system used throughout Egypt.

There is an urgent need to establish an effective data base. The RIGW system should be examined. There is little point in specifically designing a data base system, since appropriate software can now be purchased. We have reservations about the applicability of the Mackintosh Apple data base, particularly for integrating rather than merely storing data. Micro-computers should be made available in the regional offices.

The TI mini-computer is likely to restrict the choice of software for both the data base and modelling. We would favour the use of computers, such as IBM, although the hardware requirements of the WRC Institutes are currently under review.

Several groundwater models have been developed in Egypt, including two for the Western Desert (1978) and the New Valley (1984). Whilst a review of these models and their applicability should be undertaken, there is a wide range of groundwater models now available commercially at low cost, which should be equally as applicable. The type of models should include the following:

- steady-state, inferred recharge models (for recharge estimates based on transmissivity and head distribution data).

- regional models:

  (a) north coast
  (b) El Qa'a
  (c) Nubian
- area management models:

(a) El Arish
(b) El Tor

(these must include saline intrusion models)

- wellfield models.

3.6.7 Reporting

Proper documentation of the activities and results of the Phase 2 work is essential to plan and co-ordinate the work programme and monitor priorities. We therefore envisage a series of reports, such as the following:

(i) Interim reports - principally for short term planning and data interpretation (mainly technical)

- detailed implementation reports for each major activity

- activity planning

- consultants reports

- results of feasibility studies (review reports)

- working maps, diagrams etc

- data analysis reports

(ii) Progress reports - to assess priorities and review project achievements:

- frequent summary reports
- quarterly
- six monthly review
- periodic assessment reports (by Senior consultant)

(iv) Final report

These reports will assist in identifying any difficulties encountered so that priorities can be adjusted accordingly, activities co-ordinated, and, where necessary, project resources re-allocated.

3.6.8 Project co-ordination

Co-ordination of the project activities is essential and will improve the liaison with other related projects and organisations. This co-ordination should occur at two levels:

(i) Steering Committee. This would next periodically (say, 3 times per year) and consist of members from at least the following organisations:

Chairman of Water Research Centre

Directors of RIWR, RIGW and Desert Institute

Representatives from: EEC Delegation
Ministry of Irrigation
Ministry of Reconstruction
Governates of North and South Sinai
General Meteorological Authority

Other members could be co-opted during the course of the project, such as from UNICEF and EGSMA.

(ii) Project Group. This would meet each month to discuss the more day-to-day technical activities of the project. It could comprise the following members:

Director RIWR

Senior project staff

External Co-ordinator

Senior local consultant(s)

Deputies should be nominated where senior staff are unable to attend and local consultants may be required to attend as appropriate. The senior local consultant would have an advisory capacity only and would be nominated and approved by RIWR, the Project co-ordinator and EEC.

3.7 Work Schedule and Cost Estimates

3.7.1 Work Schedule

We recommend that the activities to be undertaken during Phase 2 of Sinai Water Resources Study should be arranged in order of priorities, as outlined in Section 3.1.2. This will require a phased and flexible programme of work linked to project resources and achievements.

Figure 8 presents in bar chart form a broad outline of the work schedule for Phase 2 based initially on carrying out high priority activities during Year 1, intermediate priorities during 2 and low priorities in Year 3. The shallow drilling should precede the deep drilling and we have assigned the latter to start in mid-Year 2 for about 12 months. It should be noted that each deep drilling site is likely to take three months to complete, which may in part determine the start and duration of the deep drilling programme in order to provide the necessary data by mid-Year 3 at latest.

Certain planning activities will have to take place at an early stage in order to arrange equipment or other supporting activities and finalize priorities. These should be undertaken as appropriate and when feasible in relation to other activities.

3.7.2 Transport and Equipment Costs

To a large extent the transport and equipment requirements have been met from funds within the First Financial Protocol.

Customs clearance is still required for spares and for the eight landrovers purchase for Phase 2. In addition, some spares were not delivered with certain vehicles. We have included an allocation of 50000 ECU to cover these costs.

There is still a need to purchase certain items of equipment. The rain gauges have not yet been obtained, various spares and replacement parts are needed for the climate stations and simple stage recorders are needed for the representative catchments. However, most of the additional equipment is needed for the hydrogeological activities, including geophysical logging of shallow wells, site location in the more remote areas, for work associated with water point inventories and monitoring, and to provide more suitable instruments. Since most of this will be needed for the high priority activities their purchase should be arranged without delay.

Table 8 lists equipment requirements and estimated costs. This takes into account certain verbal requests by RIWR.

3.7.3 Technical Assistance and Training costs

(i) External consultants.

Provision has been made for a full-time project co-ordinator for three years together with specialist inputs for particular activities and specifically for training, although there would also be a training element attached to the specialist inputs. The allocation specifically for training could be transferred alternatively to fellowships for training overseas.

At least 25 return air-fares should be allowed for. A provisional item for accommodation costs for the external co-ordinator and the visiting specialists is also included in the table below:

	Man-months	'000 ECU
Project co-ordinator	36	360+
Specialists	18	180+
Training	6	60+
Air fares	-	25
Accommodation	-	75
	60	700

(ii) Local consultants

The following allocation has been made for local consultants:

	Man months	'000 ECU
Local consultants	48	60+

3.7.4 Field Allowances

RIWR have experienced some difficulty in recruiting well-qualified staff, especially at senior level, to work under the arduous conditions in Sinai. The funding component for field allowances should provide sufficient incentive to overcome this, particularly since much of the work will take place in Sinai.

We propose a two-tier allowance system designed to attract staff to undertake fieldwork. This is based on a site allowance whilst in El Arish or El Tor and a supplementary allowance given in addition to the site allowance for days spent in the field away from the regional offices. The rates also reflect staff grading.

+ Estimates based on 1986 exchange rates and charges could now be lower.

The daily rates proposed are as follows:

Grade	Site allowance for El Arish and El Tor (EL/d)	Fieldwork supplement (EL/d)
Senior	15	7.5
Junior	7.5	4
Other	4	2
Labourer	2	1

Budget estimates for local staff allowances are given in Table 9. These are based on the anticipated time to be spent in Sinai for each grade of staff as given in the Phase 1 proposal (see Annexe 1).

3.7.5 Drilling costs

We have made a budget allocation of 500000 ECU for the shallow drilling programme. The high priority activities will require the major share of this allocation. Cost allocations are given in Table 10.

There are various options available for the deep drilling programme (see Section 3.5.3) and, consequently, in Table 10 we have indicated unit costs for the main components of the various options (drilling and construction, additional tests and sampling and expatriate staff).

3.7.6 Cost Summary

Table 11 gives a summary of the provisional funding allocation. An earlier financing proposal, based on a funding request submitted by RIWR from their own proposals, was prepared in September 1986. This is shown in Annexe 3 for comparison with our own cost estimates, although the exchange rate has changed since the earlier proposal was submitted and therefore the costs are not strictly comparable. We have included eight boreholes as a provisional allocation for the deep drilling programme.

CONCLUDING REMARKS

1. Careful examination of the Final Report of the Sinai Development Study [11] has confirmed that the original programme was consistent in objectives and priorities with the defined strategy.

2. Progress on the programme has not been satisfactory, mainly we believe as a consequence of inadequate planning and technical direction. The practice of subcontracting out most of the more specialised work - drilling, photogeology, geophysical surveys, pump testing, borehole logging - has not been wholly effective due to the lack of project supervision and a failure to integrate the results with the main programme. This is a general reflection of the inexperience of the staff, particularly in hydrogeology.

3. The recommended programme for Phase 2 differs significantly from that in the RIWR request in its emphasis on the need to complete the studies already commenced and in taking account of accepted priorities. It includes consideration of the deep drilling programme.

4. Essential aspects of the recommended Phase 2 programme are as follows:

(i) The need to recruit suitable staff, particularly in hydrogeology. The RIWR staff structure should reflect the relative importance of the main water resource being studied, which, in this instance, is groundwater. Specialised studies have to be planned and interpreted in the context of groundwater occurrence. The numbers and experience of the project staff has to be consistent with the scope and scale of the work programme.

(ii) The recommendations include an emphasis on priorities in project implementation and a setting of targets with a view to completing at least the high priority studies within the next three years. Intermediate and low priority studies should be deferred to later in the project, at least insofar as the main implementation is concerned, and could even be postponed beyond the three year period if it appears likely that work on them could jeopardise the completion of the high priority studies. Intermediate and low priority projects should be phased so that the required flexibility for the entire programme can be maintained.

(iii) Shallow drilling in relation to the high priority studies has equivalent importance. Although the basic drilling will be subcontracted, it is essential that the RIWR staff are fully involved in its planning and implementation (site supervision, specialised sampling, logging, testing and analysis). There will be significant demands on project staff in this phase of the work if these recommendations are accepted, much more so than there has been in the past.

(iv) Deep drilling is given a special priority which does not, however, supercede the high priority ongoing studies. Various operational options are discussed. Detailed tender documents have not been prepared since it would be inappropriate to do so until decisions are reached on the precise sites and the drilling option determined. As in the case of shallow drilling, a strong emphasis is placed on the need for full technical involvement of RIWR staff in this work.

The need to have consistency of project staff within the scope and scale of the work programme is particularly obvious in the case of deep drilling. With full RIWR staff involvement, there will be constraints on the numbers of deep drill holes that can be adequately supervised, without taking account of the number of sites which can be justified. Within the time duration, staff constraints and the requirements of the high priority ongoing studies, it seems unlikely that this number would exceed eight. The financial allocation included in the RIWR proposal (Annex 3) from both EEC and Government of Eypt sources correlates with a much larger number of deep holes. The consequence of carrying out a drilling programme on this scale would mean either a diversion of staff from other parts of the project, including high priority studies, or alternatively inadequate supervision and testing of the deep holes. Neither alternative would be satisfactory.

(v) Full and detailed reporting is essential as well as close co-ordination with other organisations engaged on selected work. The Steering Group will have a key role and should be fully involved in any important decisions that affect the work programme as indicated on the Bar Chart (Figure 8).

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Sinai Penninsula

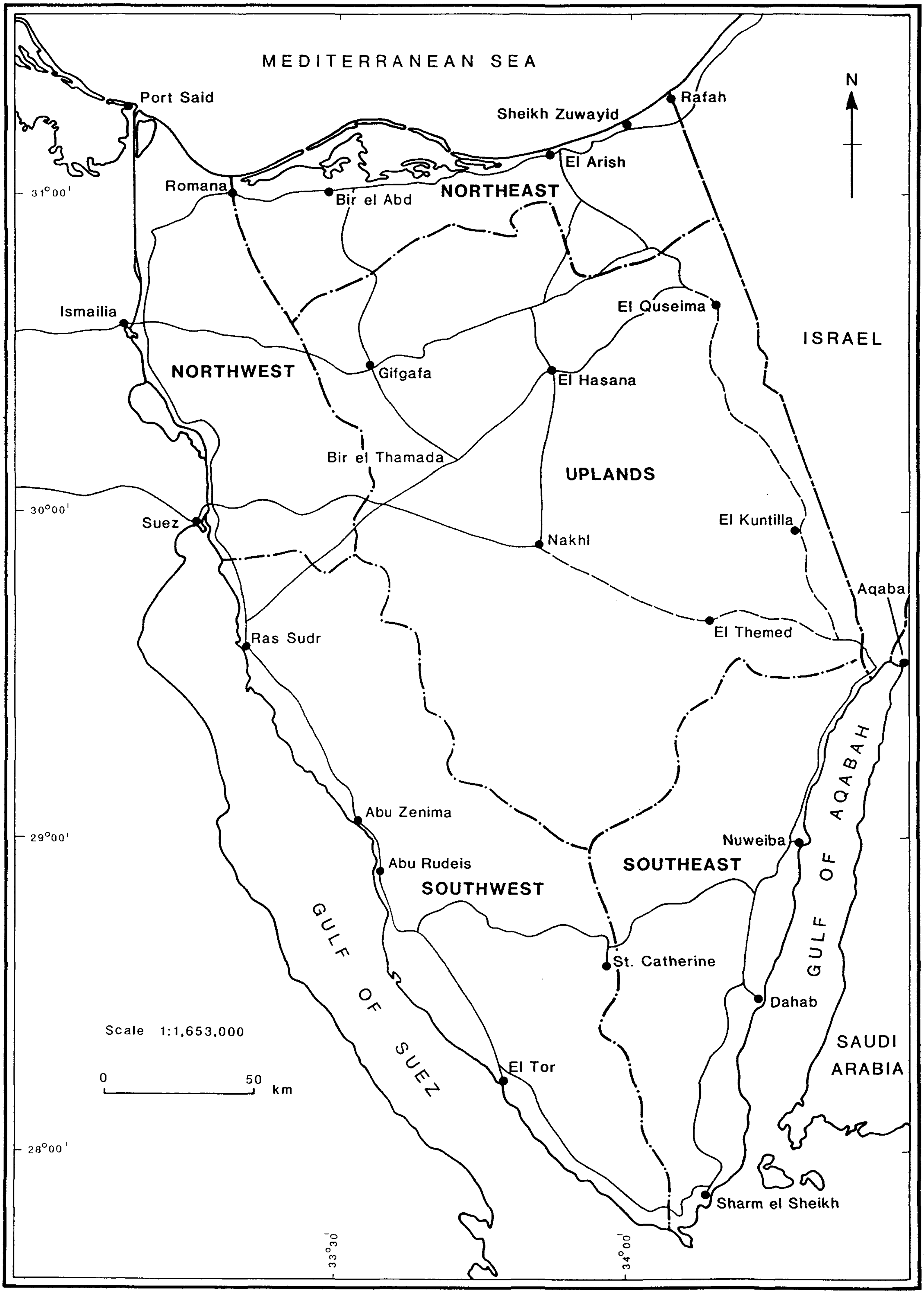


Figure 1

Climate network

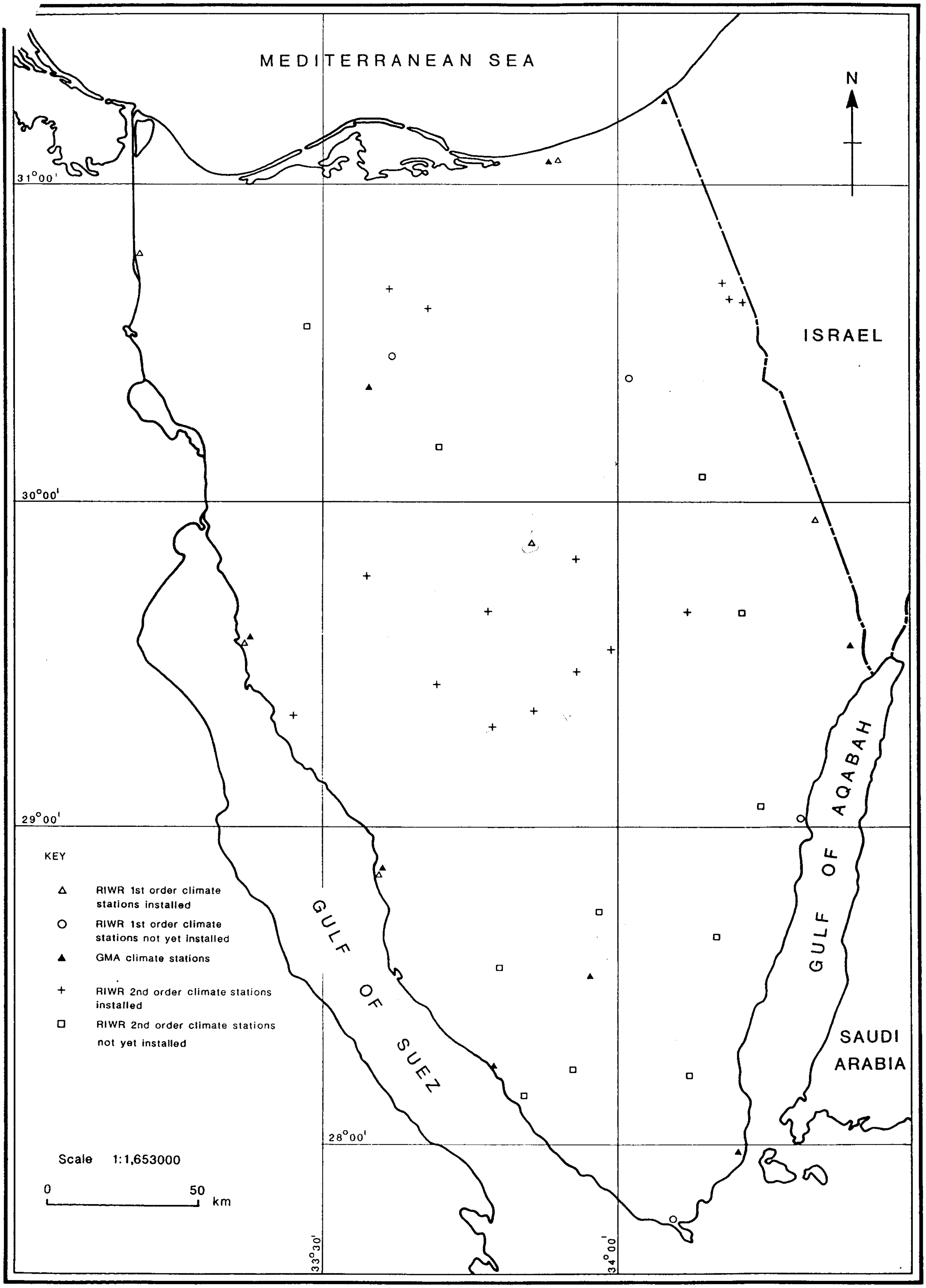


Figure 2

Potential irrigable areas

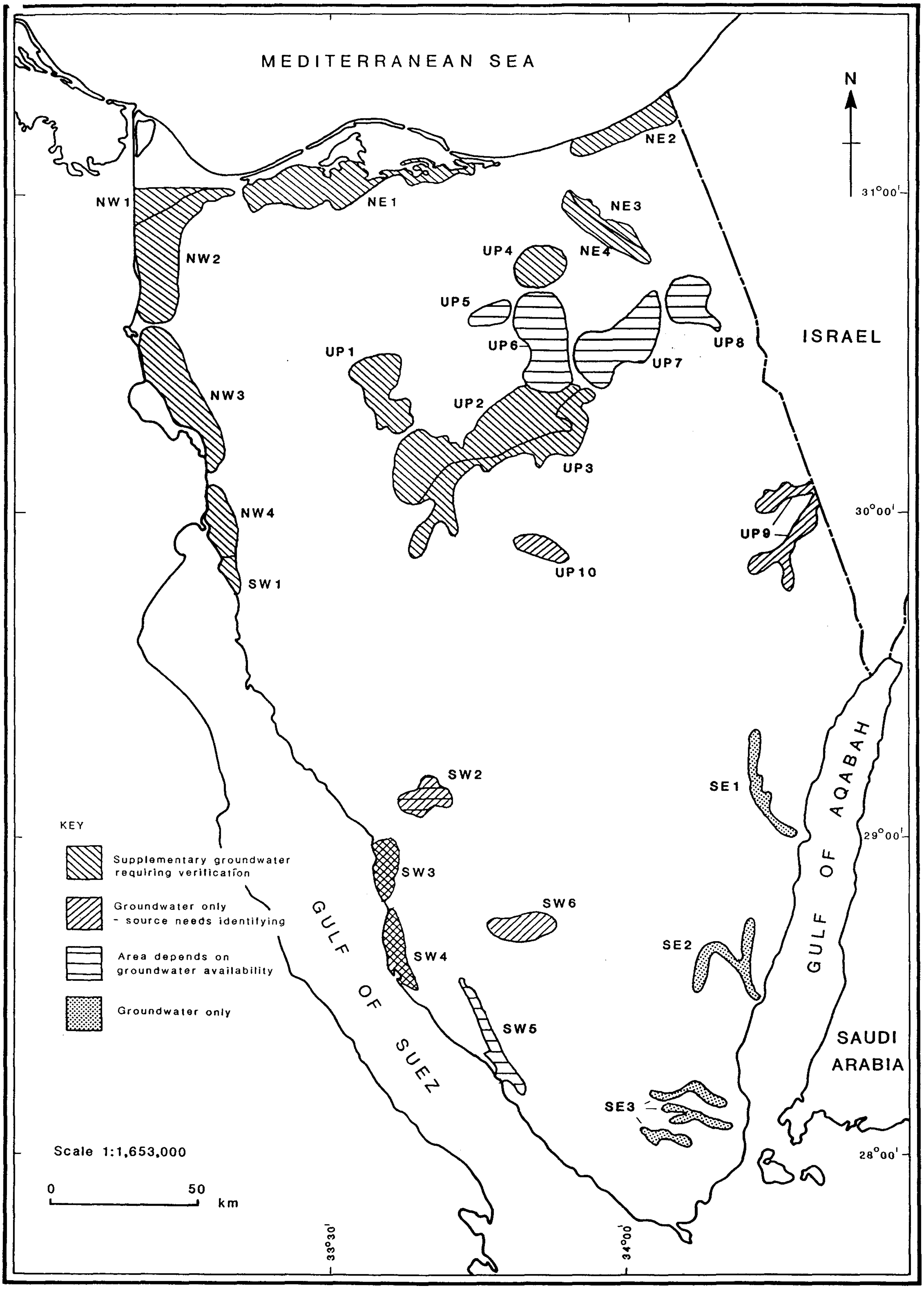


Figure 3

RIWR borehole locations

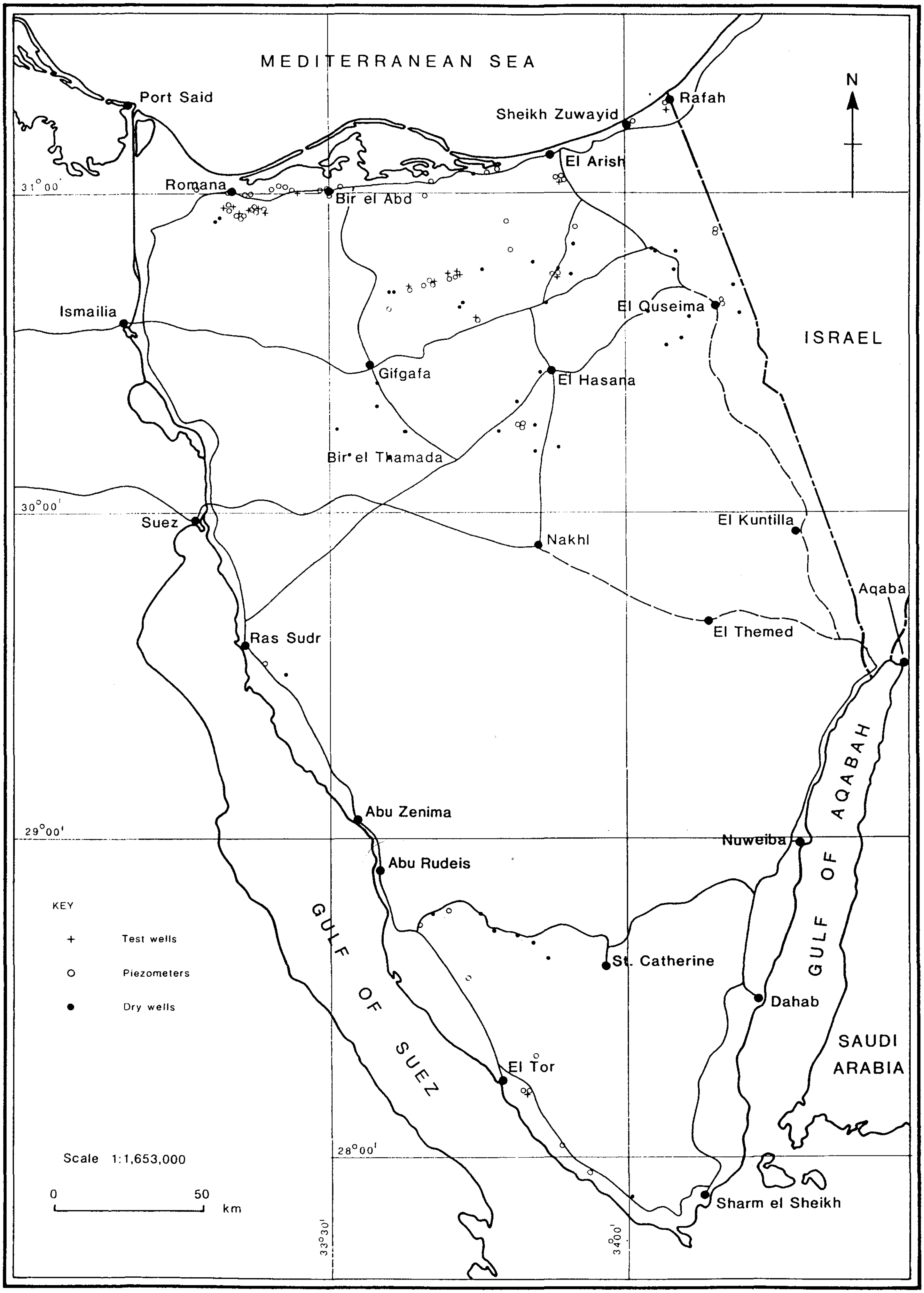


Figure 4

Main catchments

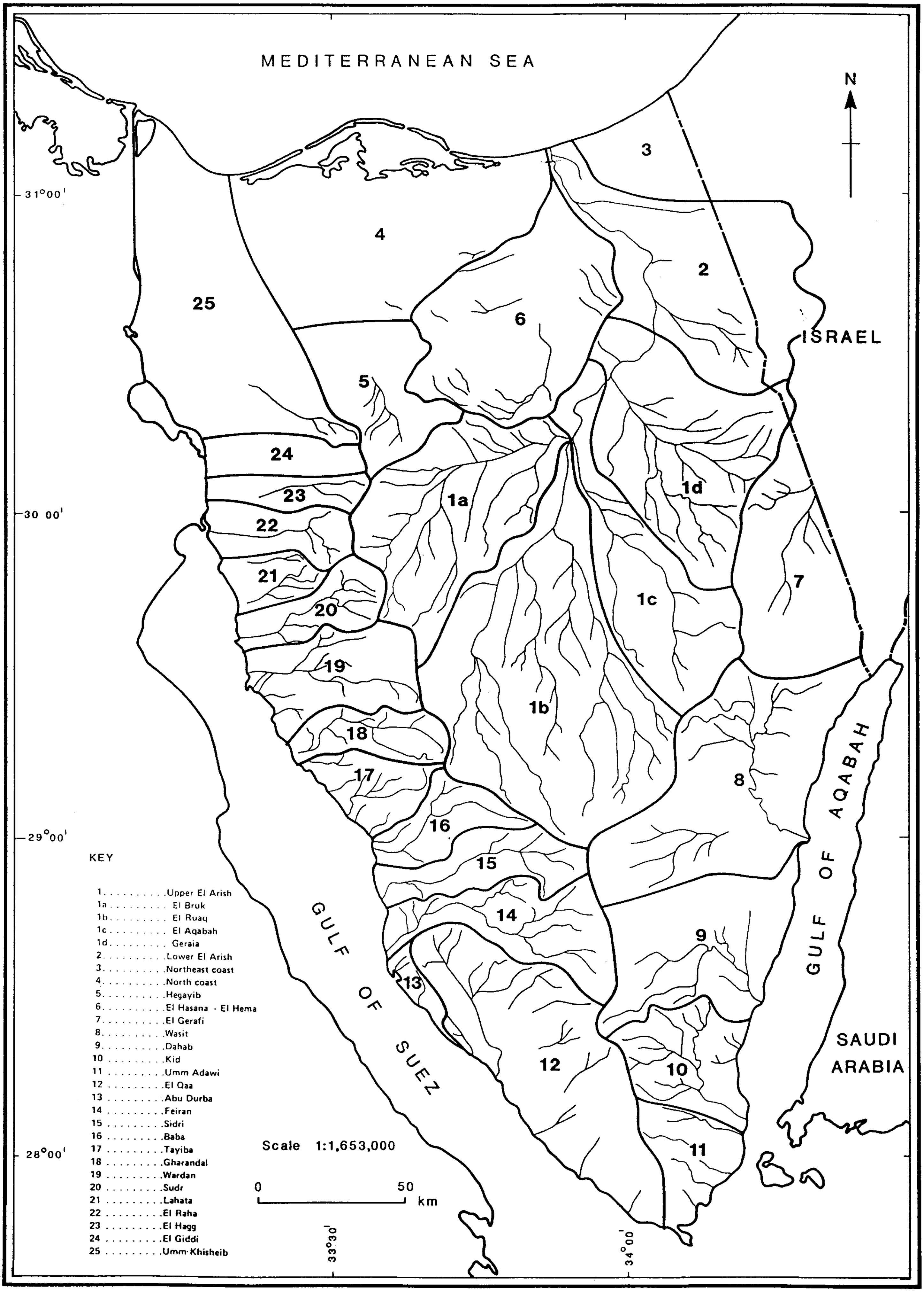


Figure 5

RIWR catchment study areas and gauging stations

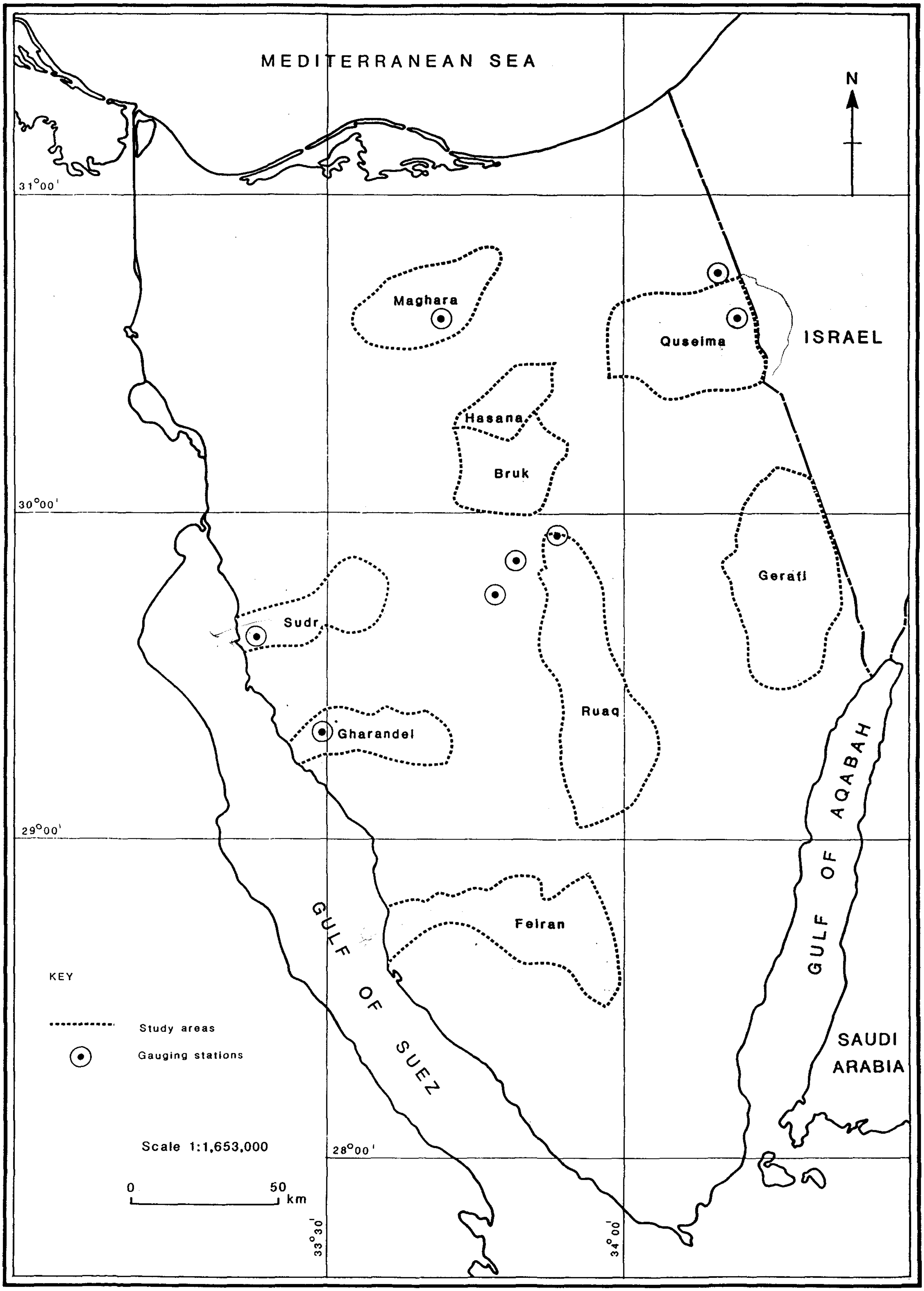


Figure 6

Proposed sites for deep boreholes (RIWR and UNICEF)

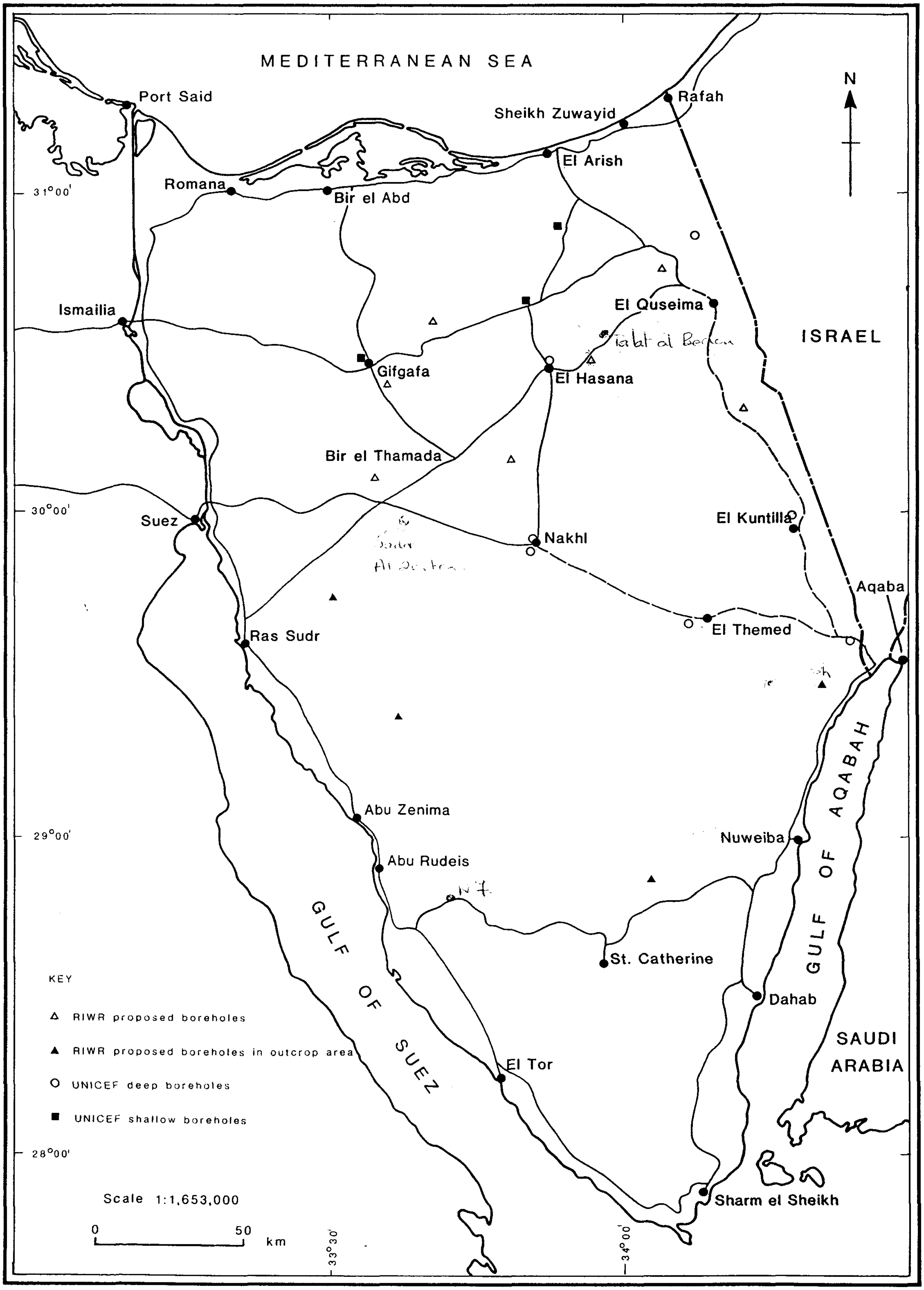


Figure 7

ACTIVITY	YEAR 1 1 2 3 4 5 6 7 8 9 10 11 12	YEAR 2 1 2 3 4 5 6 7 8 9 10 11 12	YEAR 3 1 2 3 4 5 6 7 8 9 10 11 12
A. HIGH PRIORITY			
1. Rationalisation of climate network	· · · · · · D ————	- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -
2. Hydrological monitoring in areas of development (El Arish, El Tor - Qa'a)	· · · · · · D ————	- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -
3. Detailed resource studies in areas of high agricultural potential	· · · · · · D ————	- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -
4. Shallow drilling in areas of high priority	· · · · · · D ————		
B. INTERMEDIATE PRIORITY			
1. Raingauge network	· D	————————	- - - - - - - - - - - - - - -
2. Catchment studies	· D	————————	- - - - - - - - - - - - - - -
3. Shallow drilling in areas of intermediate priority	· D	————————	
C. LOW PRIORITY			
1. Development projects, including pilot farms and surface storage evaluation	· D	- - - - - - - - - - - - - - - -	— ————————
D. SPECIAL PRIORITY			
1. Deep drilling	· D	————————————	————
E. REPORTING: Inception, Progress, Interim, Final	*[1] · · · · · · · · · · * *	*[2] · · · · · · · *	*[3] · · · · * * ——— *

Notes on Activity Schedule

———— Periods of maximum effort

- - - - - Continued activities (including operations, data, transfer, analysis)

· · · · · · · Preliminary planning mainly on medium-low priority activities as feasible and appropriate

D, Decision points

FIGURE 8

ACTIVITY SCHEDULE

RIWR Borehole Completion   Table 1

Year	Number of boreholes
1982[1]	12
1983	10
1984	12
1985	18
1986	59
(1987)	(11)

Area

North coast	April	–	June 1986
North central Sinai	July 1982	–	November 1986
Gifgafa	March	–	June 1985
North east Sinai	October 1984	–	February 1985
Southeast Sinai	October 1986	–	February 1987

[1] Drilling programme started July 1982

Total Drilled Metrage   Table 2

Contractor		Metrage	No.of boreholes	
(1)	Shakar-el-Shereif	615	37	North coast. 3 dry 7 test wells
(2)	ARABCO			
	N. Sinai	4027	25	6 dry, 4 test wells, 2 no record, 2 not completed
	Mid-Sinai	903	3	
(3)	DASCO			
	N. Sinai	1161	6	1 dry, 3 test wells, 1 no record
	Mid-Sinai	2896	12	9 dry, 1 test well (not completed)
	E of Arish	2700	15	7 dry, 1 test
	Gifgafa	1239	6	6 dry
	S Sinai	3426	18[1]	8 dry, 1 test
		16967	122	40 dry 17 test 3 no record

[1] 8 in El Qaa region (1 dry)
2 in W Sidr Upper Cretaceous (1 dry)
8 in W Feiran (6 dry)

RIWR Borehole Distribution by Areas[1] Table 3

	Area		Number of boreholes	
(1)	North Coast	Bir El Abd	34	7 test wells
		E of El Arish	5	1 dry
		Arish	4	1 test well with 3 observation wells
		Rafah	3	1 test well with 1 observation well
(2)	Maghara		18	4 dry, 5 test
(3)	L.W. El Arish		10	5 dry, 1 test
(4)	Queseima	Queseima	4	1 dry
		W. Arish channel	7	7 dry
(5)	Hasana-Bruk		10	6 dry
(6)	Gifgafa		6	6 dry
(7)	Feiran		8	6 dry
(8)	El Qa'a	N. of El Tor	2	
		El Tor	3	1 test well with 1 observation well
		S. of El Tor	3	1 dry

[1] Based on borehole location map provided by RIWR. There are some inconsistencies with the borehole inventory.

RIWR Borehole Distribution by Aquifer **Table 4**

Aquifer	Number of boreholes
Pleistocene - Quaternary	55 (including 15 in S.Sinai)
Tertiary	17
Cretaceous	30
Jurassic	12
Basement Complex	1
Unidentified	7
	122

(a) Test wells

Aquifer		Number of test wells	
Quaternary	North Sinai	8	(NW (7) and Rafah (1))
	South Sinai	1	(El Qa'a)
Tertiary		2	(El Hema : Miocene, 1 piezometer) (El Arish : Eocene, 3 piezometers)
Cretaceous		0	
Jurassic		4	(El Khariq, 1 piezometer) (N. Masgarid, 1 piezometer) (W. El Fath[2], 2 piezometers) (El Fath, 1 piezometer)
		15[1]	

[1] Two sites not completed

[2] Duplicate site by ARABCO replacing DASCO site

(b) Tests completed

	RIWR Well number	Location	Aquifer	Date of test
ARABCO	38D	Arish	Eocene	Oct 1983
	47B	El Khariq	U Jurassic	March 1984
	53B	W. El Fatah	U Jurassic	Sep 1983
DASCO	74A	Rafah	Pleistocene	Oct 1984

Studies by Local Consultants **Table 6**

Subject area	Outline
Soil studies	Study of 5500 fedans, Maghara
Geology	Summary of geological studies in Sinai. Advice on selection of shallow well sites and planning of drilling programme
Hydrology	Hydroloigcal model and report, Maghara
Computing	Advice on mathematical groundwater models and data base
Dam design	Redesign of Rawafah Dam and new Gudeirat Dam
Photointerpretation	Catchment studies, morphological analysis (with training of 3 RIWR staff)
Micropalaeontology	Interpretation of drill cores for stratigraphy (with training of RIWR staff)
Administration	Customs clearance and contract preparation

Reallocation of EEC Funds during Phase 1. ('000 ECU)

Table 7

	Original Alocation	Reallocation 1st	Reallocation 2nd	Expenditure (as of March 1987)
Meteorological equipment	143	143 (-)	248 (+105)	301
Hydrological equipment	71	71 (-)	96 (+25)	*(a)
Hydrogeological equipment	79	79 (-)	79 (-)	149
Drilling rig/shallow drilling(d)	164	200 (+36)	445 (+245)	0
Deep drilling	600	600	0 (-600)	0
Field accommodation	50	0 (-50)	65 (+65)	90
Mobile laboratory	36	0 (-36)	0 (-)	0
Field Allowances	107	107 (-)	167 (+60)	242(c)
Vehicles and spares	200	210 (+10)	360 (+150)	316
External consultants	214	350 (+136)	350 (-)	345
Local consultants	71	71	71 (-)	10
Fellowships (training)	65	65	65 (-)	81
Contingencies	200	104 (-96)	54 (-50)	
	2000	2000	2000	1534 (e)

Allocation remaining 466

NOTES:

(a) Small spend on stage recorders and current meters included within meteorological and hydrogeological equipment

(b) No exact figures available

(c) RIWR contracts. Mainly field allowances and local consultants but also includes 10000 ECU for customes clearance costs and air ticket

(d) Rig and ancillary equipment not purchased. Funding used for shallow drilling contract.

(e) Includes advance spending for Eastern Sinai of 217000 ECU (Transport 99000 ECU; Equipment 118000 ECU)

Equipment Cost Estimates[1] **Table 8**

			£	ECU
A.	Meteorological and Hydrological			
	Raingauges		8000	11360
	Replacement items and spares		3000	4260
	Maximum stage indicators		3000	4260
		Sub total	14000	19880
B.	Hydrogeological			
	1	Borehole logger (300 m, digital) (SP,ER, Caliper, Gamma, Flow)	30000	42600
	3	Temperature-conductivity logger (300 m)	6000	8520
	1	EM geophysical equipment	11000	15620
	3	Satellite Navigation systems	5000	7100
	4	Altimeter	2000	2840
	10	Water level chart recorders	10000	14200
	10	Water level dippers (5x50m; 5x200m)	1500	2130
	10	Pipe flow meters	2000	2840
	20	Pump operation meters	2000	2840
	3	Field geochemistry sets	3000	4260
	4	Digital EC/Temperature meters	1000	1420
	4	Digital pH/Eh meters	1000	1420
	3	Stereoscopes	1500	2130
		Field geological equipment	5000	7100
		Spares and replacement items	5000	7100
		Sub total	86000	122120
		Total	100000	142000

[1] Shown for April 6 1987
Exchange rate £1 = 1.42 ECU

Cost Estimates for Local Staff Allowances[1] Table 9

Grade	Total man-days Sinai	Anticipated proportion on field work (%)	Costs El Arish El Tor offices		Costs Field work	
			LE	ECU	LE	ECU
Senior	4425	25	49800	32270	24900	16135
Junior	10775	50	40400	26180	62000	40175
Other	9000	75	9000	5830	40500	26245
Labourer	9000	100	-	-	27000	17500
			99200	64280	154400	100055

Total 253600 LE (164335 ECU)

Shown for April 6 1987

Exchange rate 1LE = 0.648 ECU

Table 10

Drilling Programme Cost Estimates[3]

		LE	ECU
A.	Shallow drilling		
	(i) For high priority activities - provisional allocation :	-	350000
	(ii) For intermediate priority activities - provisional allocation :	-	150000
	Sub total		500000
A.	Deep drilling[1]		
	Unit cost per borehole (1000m)[4]	275500	178500
	Additional tests and samples per borehole - provisional allocation:	25000	16200
	Expatriate staff[2], per month person in ECU	-	5000

[1] There are various options available for carrying out the deep drilling programme (ref. Section 3.5.3). This could also include provision for EEC funding to support contracts involving foreign exchange.

[2] Verbal request by UNICEF Project Manager for the following expatriate staff:

2 mechanical engineers

1 driller

1 electrician

[3] Shown for April 6, 1987
Exchange rate 1 LE = 0.648 ECU

[4] Deep drilling costs based on REGWA quote dated 18 Jan 1987

Table 11

Provisional Funding Allocation[1]

('000 ECU)

		ECU
1.	Meteorological and Hydrological equipment)	142
2.	Hydrogeological equipment)	
3.	External consultants and Training	(700)
4.	Local consultants	(60)
5.	Field allowances	164
6.	Transport related costs	(50)
	Non-drilling allocation, sub-total	1116
7.	Drilling	
	(a) Shallow drilling : provisional allocation	(500)
	(b) Deep drilling (8 boreholes)	1558
	Drilling allocation, sub-total	2058
8.	Contingency : provisional allocation	200
	Total	3374

[1] Prepared for exchange rates April 1987

ANNEXE 1

ORIGINAL PROPOSALS FOR PHASE 1 SWRS

1. INTRODUCTION

1.1 The present Five Year Plan for Egypt contains two particular policies which are continually emphasised by the government, and are of special relevance to Sinai. These are:

(a) a wish to reduce the concentration of people and economic activity in the Nile Valley and Delta; and

(b) to reduce imports of agriculture (and mineral) products.

In helping to fulfill both these aims the Sinai peninsula has a part to play, but one in which its role has not yet been fixed. Plans for its development by Egypt, interrupted in 1967, are only now becoming relevant again as an increasing proportion of land is returned.

1.2 While the development of Sinai has at present a heightened significance to Egypt because of the recent wars and peace treaty, it is based on sound geographic principles. The peninsula is an area not too far from Egypt's main concentration of population, on a major line of world shipping (Suez Canal) and potentially well placed for direct trading with Israel, Jordan and Saudi Arabia. It also contains a major proportion of Egypt's known oil reserves and has a recognised potential for the exploitation of a variety of minerals. It is therefore a cross-roads, but one with resources of its own to offer, and one which Egypt is keen to develop.

1.3 While the plans for Sinai will be made by a variety of government and private interests, with projects based on different local resources, all will have a common need for a reliable water supply.

This demand can be met in three ways:

(a) Provision of local surface and groundwater;

(b) Desalination of sea and brackish water;

(c) Import of water from the Nile system.

The selection of any one source will depend upon the relative costs of each, and these will be influenced by the amounts of water required.

1.4 Plans are under way to bring water via the Ismailia and Salaam canals to areas east of the Suez Canal which generally lie less than 10-15 metres above mean sea level, for a major expansion of agriculture. Apart from this scheme, for which Nile water has been allocated, there is little future scope for the diversion of Nile water to new projects in Sinai. This is partly because of the water shortage with which Egypt is faced at the beginning of the new millenium, and partly because of the high lifting and conveyance costs of distributing Nile water to other parts of Sinai. Thus Sinai must generally look to groundwater and desalination for its development except in the north-west corner.

1.5 Detailed investigations are needed to evaluate the available groundwater resources. Within the areas of major groundwater reserves, irrigated agriculture may be feasible subject to land capability. Elsewhere groundwater will be required for supplies to centres of population, tourist development, for industrial use (e.g. in connection with mineral abstraction) and for animal watering. Although the locations of requirement are widespread in Sinai, from the viewpoint of early development, it will be important to investigate areas of highest potential and of highest projected demand as soon as possible.

1.6 The Egyptian Government is keen to promote early development in Sinai but concerned that it should occur in co-ordinated and efficient fashion. For this reason, a project has been commenced to plan the overall strategy for the development of Sinai. The project is under the Ministry of Reconstruction and funded by USAID. It will be carried out by Dames and Moore Consulting Engineers, in association with various Egyptian organisation, both Government and private. The terms of reference are comprehensive in concept but defined only in very general terms

1.7 Phase I of the Project is planned to have a duration of 18 months and will be mainly concerned with the identification of project with a high development impact and which are technically and financially feasible. It will therefore include pre-feasibility analysis. Project identification will be restricted to that part of Sinai accessible after interim withdrawal but development strategy will take account of the whole region. (Fig. 1)

1.8 Phase II will be of three years duration and will extend the Phase I programme and provide an overall economic and physical plan for development in Sinai to the year 2010. Terms of reference for full feasibility studies will be prepared on request for those projects judged desirable following consideration of pre-feasibility analysis.

1.9 Individual sector studies include the following:-

Water Resources
Exploitable natural resources
Agriculture and fishing
Population
Infra structure and land use
Tourism

In the case of water resources, the main objective of the strategy will be to identify an adequate quantity and quality to allow rapid and intensive implementation of dependent projects with high development impact.

1.10 The eventual aim of the present proposals of the Research Institutes of the Ministry of Irrigation is to provide a strategy for the evaluation of the total water resources of Sinai leading to effective and planned development. The project therefore combines local specific studies with the establishment of a hydrometric network throughout Sinai to provide the basis for a study of long term trends. The more specific studies will be concentrated in areas of high potential with early development prospects. It is hoped to include limited pilot development within the duration of the project and although this aspect has not been costed, the intention is inherent in the selection of areas for detailed study. Finally, it should be noted that the proposed project should lead to the development of appropriate expertise in the two Institutes mainly involved and with particular relevance to Sinai.

1.11 The project is planned to be of three years duration and external funds requested total US$ 2,800,000. Local funds contribution over this period will be £E 1,750,000.

2. BACKGROUND INFORMATION

2.1 Geology.

Sinai is a triangular shaped land mass extending over 61,000 km^2. Three main geological regions are recognised (Fig. 2) and a fourth subsiduary one may be added.

I Pre-Cambrian crystalline basement area in the south forming high dissected mountains. Maximum elevation is Mt Sinai at 9776 feet above sea level.

II A central plateau of Palaeozoic, Mesozoic and Tertiary sedimentary rocks dipping gently northwards (Fig. 3).

III A folded 'shelf' area of formations in region II which are overlain by Quaternary deposits except on major anticlinal structures (e.g. Jebel Helal in Fig. 3).

IV A fourth region might be added to differentiate the down-faulted sedimentary sequence adjacent to the Gulf of Suez.

2.2 Climate.

The climate of Sinai is arid to locally semi-arid with rainfall at a maximum in a thin north coast strip (Rafah c. 220/mm/a decreasing westwards to El Arish, c. 92 mm/a, and El Qantara, c. 60 mm/a) and decreasing rapidly southward (Nekhl, c. 26 mm/a; Santa Caterina, c. 60 mm/a; El Tor c. 11 mm/a). Higher rainfall occurs in the interior highlands than in the coastal lowlands (cf. Santa Caterina and El Tor). Tables 2.1 and 2.2 summarise available historical records.

2.3 Drainage.

There are no perennial water courses in Sinai but the wadis may experience flash floods of short duration. The drainage network is Pleistocene in origin relating in the main to pluvials in the period 10,000 to 40,000 years ago. There is also a close correlation with the geology (lithology and structure). Wadi El Arish extends over approximately one third of Sinai and has formed on the low angle dip slope of the main sedimentary sequence. Gradients in consequence tend to be low. The wadis directed into the Gulfs of Akaba and Suez have steeper gradients. In consequence of the succeeding (current) arid climatic phase, the wadis show sediment infilling to varying degrees and extensive areas, notably on the northern coastal plains, are covered by dune sands.

2.4 Groundwater Occurrence.

Aquiferous formations occur within rocks of all ages from the Pre-Cambrian to recent. The most important are the Nubian Sandstone aquifer and various formations within recent alluvial sequences. In considering a groundwater resource, the critical parameters to be identified are recharge, available storage, permeability/transmissibility, water quality and development aspects (drilling depths, pumping levels, potential use, etc.).

Recharge: The arid climate of Sinai largely precludes current groundwater recharge except following runoff. Runoff is promoted in the valleys with steep gradients which occur mainly in south Sinai. It is reduced in the Wadi El Arish and the northern coastal plains by reason of the lower relief and wadi gradients and the 'damping'effect of the extensive aeolian sand cover which has obliterated wadis and induces local surface retention.

Porosity and Permeability: Significant porosity and permeability is present mainly within sands and gravels of the Pleistocene to Recent alluvial sequences, in some fissured and karstic carbonate rocks and in the Nubian Sandstone aquifer. Although current recharge is small, some aquifers notably the Nubian, contain significant volumes of old (fossil) water in storage. It has been estimated by Issar (3) that the Nubian stores several thousand million cubic metres.

Water Quality: Water quality in Sinai's aquifers varies considerably. Some of the groundwater in the Nubian aquifer is very fresh with a chloride content of less than 600 mg/l. Similar good quality water occurs in a recent calcareous sandstone aquifer in the coastal strip near El Arish and in alluvial formations (?) east of Al Tor. The groundwater in the crystalline basement area is also fresh but represents a very small resource. Elsewhere, groundwater tends to be mostly brackish to saline, the former having potential for agriculture or for livestock, the latter for industrial use.

2.5 Aquifers in Sinai.

Crystalline Basement: Groundwater occurs at shallow levels in weathered rock or in local fracture zones in fresh rock. Discharge via springs occurs locally. Although water quality is good, the resource is obviously small.

Nubian Sandstone: This is the most important of the hard rock aquifers in Sinai. It averages some 200 m in thickness and is regionally extensive. It outcrops along the edge of the Egma Plateau in south central Sinai (Fig. 4) and dips below younger rocks to the north except where exposed again in a number of anticlinal structures (Jebels Helal, Maghara and Yelleq). In central Sinai, the Nubian occurs at 700-900 metres below ground level and on the north coast at 2500 metres. The water quality is good in central Sinai (300/500 mg/l of chloride) deteriorating northward although information is very sparse. The piezometric head in central Sinai is some 200 metres above sea level and dips gently to north, northwest and northeast to discharge areas. The Nubian aquifer is known to discharge by upward leakage in the lower Wadi El Arish and in the Suez Rift area (Ayn Musa). There is a large volume of water in storage but current recharge is small. Development would have significant economic constraints mainly due to drilling depths and pumping costs but there is a possible potential of some magnitude which clearly merits investigation.

Eocene and Miocene: Mostly carbonate rocks but the later Miocene in the Suez coastal area includes clastics and some evaporites. Permeability of the limestones is not generally high. Water quality is variable from saline to moderately fresh. Saline waters commonly associated with evaporites in the sequence. Fresher waters are derived from current recharge or older Pleistocene waters. Known occurrences are on the Gulf of Suez coast. At Ayn Musa, (1000-1500 mg/l of chloride) the water is probably derived by upward leakage from underlying Nubian and produces an artesian (flowing) head. Other known occurrences are in the Lower Wadi Feiran, the Sahil El Qa'a and in the vicinity of El Tor (water fresh to brackish, recent and fossil).

Wadi Alluvium: Alluvial sequences occur in wadis and coalescing fans. Groundwater quality variable from fresh to brackish, the latter occurring in particular where the parent rock has included evaporites. Groundwater is derived by current recharge following runoff or by leakage from deeper aquifers as in the case of the calcareous sandstones (fagra) of the lower Wadi El Arish.

Dune Sands: These occur extensively in northern Sinai but recharge is only significant in wetter north coast areas. Fresh water overlies saline water at relatively shallow depths and controlled abstraction is necessary for successful development.

2.6 Water Resources : Current Exploitation.

Information on this section is derived largely from the Binnie-Taylor Report (2). The various figures must be regarded with some caution as they do not always correspond with information obtained verbally from other sources.

The population of Sinai numbers around 200,000 the greater part of which probably centres around locations on the north and west coasts. El Arish is the largest town with a population of the town and adjacent agricultural settlements said to exceed 60,000. The population of the interior is largely nomadic.

Potable water resources are mainly derived from the Nile and from groundwater in well fields at El Arish and El Tor. Distribution is by pipeline (more than 500 km) and by tanker.

Industrial demands are mainly related to oil field operations on the Gulf of Suez coast and a number of brackish well fields have been drilled for this purpose.

Irrigated agriculture is most extensive in the vicinity of El Arish using groundwater from a Pleistocene alluvial aquifer (calcareous sandstone) which extends along the northern coastlands from El Arish to Rafah (in occupied Sinai). Recharge to this aquifer is thought to be derived in part from current precipitation and in part from upward leakage from a deeper aquifer (Nubian?). An area of 2000 feddans (c. 1000 hectares) has been quoted but the figure does not correspond with a stated abstraction for agricultural purposes of c. 7000 m^3/d (2). Elsewhere in Sinai, irrigated agriculture is on a much smaller scale but some development does occur in south Sinai, notably at Abu Suweira, Wadi Feiran, Wadi Sidri and El Tor. These developments are mostly in the vicinity of wadis in order to exploit the supply recharged by occasional runoff.

Statistics on water use are summarised as follows:-

- Groundwater provides 90% of water used in Sinai. Of an annual total of 15,000 million m^3, 50% is used for agriculture and 50% for industry and domestic supply

	m^3/day
- El Arish Town Supplies (potable water for local use and piped supply)	8000
- El Arish Agricultural Settlements	7000
- Wadi Sidri (Abu Rhudeis oil field use, brackish)	800
- Wadi Feiran (oil field use, brackish)	1500
- El Tor (potable; some pipe to Sharm El Sheikh)	2000

2.7 Water Resources : Current Planning.

Longer term planning must await the comprehensive strategy to be formulated by the USAID Sinai Development Study. Although no investigations are in progress to assess water resources, some immediate developments have been initiated, mostly on a fairly small scale.

Surface Water: Three major canals are planned to bring water from the Nile to lands at low elevation and suitable for agricultural development in north-west Sinai. Irrigation of 100,000 feddans is envisaged. Construction may already have commenced and the scheme will be implemented over several years.

Groundwater in north Sinai: Significant development for agriculture is proceeding in the El Arish area. The 30 original (pre-1967) wells have been redeveloped and 7 additional wells drilled to provide irrigation water for 1200 feddans (drip type). A programme of drilling has commenced which will provide additional wells at various local centres in the interior (Nakhl, Bir Hassana, Wadi Lefin, Gifgafa, Wadi El Hamma). The wells are mainly planned to supply domestic and livestock needs but some agricultural development may be included.

South Sinai: A similar programme of well drilling is in progress to increase supplies to various existing settlements along the Gulf of Suez coast. In addition 3 deep (250 m) wells are planned at spaced locations in the Sahil El Qa'a. If successful the wells will provide water for agricultural development.

The Governate offices have the responsibility of providing domestic water supply and agricultural development is often associated with the office of the Green Revolution. There is at present no authority in Sinai co-ordinating the various interests nor charged with the responsibility of monitoring the response of the various aquifers to abstraction or estimating resources.

3. BASIC REQUIREMENTS OF WATER RESOURCE INVESTIGATIONS IN SINAI

Although the formal strategy for water resource investigations will be eventually defined in terms of the overall strategy for development in Sinai, the programme can be reasonably anticipated in its broad concepts and additionally so in certain detailed aspects. In other cases, preliminary investigations either in the context of land capability aspects or other ancillary factors relating to development will be needed to assist selection of areas for detailed study and the appropriate methodology.

The following list is intended to define a basic programme of work, suitable for present needs:

(i) Extension and improvement of existing climatological network.

(ii) Hydrological monitoring with particular emphasis on areas of existing development.

(iii) Detailed water resource investigations in:-

1. Areas of significant abstraction (El Arish and El Tor)
2. Areas of high potential (e.g. Sahil El Qa'a, middle Wadi El Arish Valley).

(iv) Investigations to provide immediate supplies to areas of significant need.

(v) Representative catchment studies.

(vi) Study of the Nubian Aquifer.

Regional climatological monitoring

Climatological stations exist at the following sites:-

El Arish (see Fig. 4)
Abu Rhudeis
El Mileis
Ras Sudr
Santa Caterina
El Themed (occupied Sinai)
El Kuntilla (occupied Sinai)

Only El Arish is a first order station and the remainder could be upgraded at comparatively small cost. The distribution of sites provides a fairly good coverage of Sinai and there would seem little point in a major extension of this network. One of two more sites might usefully be added, notably one at Nakhl for central Sinai, and El Tor.

Comprehensive climatological data in this instance is mainly of concern in an agricultural context, However the conditions in Sinai with high aridity and small dispersed areas of agriculture are such that a poor correlation will inevitably exist between calculated evapotranspiration and actual crop water use.

A significant increase in the numbers of rainfall stations is to be recommended, particularly in the highland regions. The sites should be designed to give a good general coverage and the data will assist extrapolation of the results of the rainfall-runoff studies planned for representative basins. A denser network of rainfall stations will be required locally for the basins studies but the observations will of course continue for a limited period of time.

Hydrological monitoring

Routine monitoring of critical parameters such as spring discharges, well water levels and water quality is to be recommended in areas of significant abstraction as a general check on trends. Along with the main climatological and rainfall stations, such measurements would constitute a regional hydrometric network for long term operation.

Detailed water resource investigations

Investigations in depth are urgently required in two areas, El Arish and El Tor. Well fields in these two areas provide the main potable supplies of groundwater in Sinai and significant increases in abstraction are planned in the near future. Little knowledge is available on the extent of the available resources or indeed of the source of recharge, if any. In the El Arish well fields, the water quality is approaching the limits of potability. Further investigations will certainly require additional drilling and geophysical work.

A number of areas have been identified with extensive occurrence of good soil suitable for agricultural development, given adequate water (Ref. 3 and 4). They include the Sahil El Qa'a in south Sinai and various sub-basins in the middle and lower Wadi El Arish in North Sinai. Test drilling is planned in the Sahil El Qa'a. Fossil water supplies are thought to occur in underlying Miocene rocks and some current recharge may also occur from runoff although it is not considered that this would be a large supply since the wadis leading into the Qa'a have small drainage basins. The sub-basins in the Wadi El Arish are commonly of very large extent. Current recharge is not likely to be large but greater potential for development exists if the underlying Nubian aquifer can be economically exploited. In all cases, investigations will require test drilling and geophysical work.

Representative catchment studies

These should be designed as comprehensive water balance analysis of rainfall-runoff-recharge-evapotranspiration. The studies should attempt to evaluate recharge to associated aquifers and to measure any surplus runoff which could be utilised by surface storage schemes, or diversion.

There are significant technical problems in catchment studies in arid areas. Flood runoff commonly occurs over very short periods, perhaps a matter of hours, and measurements can rarely if ever be made by standard techniques (current meter, etc). The usual procedure is to survey a suitable cross-section, observe the height of any floods by a water level recorder installation and to estimate discharge using an empirical formula (Manning's formula) for channel roughness. If a flood can be actually observed general surface velocity observations could provide additional correlation. The accuracy of the method is not high, particularly so when the wadi channel exceeds 100 metres or so and where the channel gradient is low.

Runoff in the broad sediment infilled tributary wadis to the Wadi El Arish is not thought to be very significant and catchment studies may be too inaccurate to be justified. In such cases recharge is probably best evaluated within the underlying aquifers using transmissibility and gradient data. Runoff is known to occur annually in the smaller and steeper wadis which lead into the Gulfs of Suez and Akaba. Catchment studies would be more justified in these areas. The general difficulties of the method are such that a detailed study of one or possibly two basins is to be recommended with limited measurements on a number of other basins to assist extrapolation. One suitable basin might be Wadi Feiran in which significant abstraction of groundwater already occurs.

In assessing the cost and justification for catchment investigations, it is important to have some indication of the order of the resource which may be available. Calculations in the Wadi Sidri have indicated an underflow of 600,000 m^3/a for a drainage area of 600 km^2. The volume is not large and is equivalent to an annual irrigation requirement for some 30 hectares/60 feddans. It is not known whether any surplus runoff occurs which is lost to sea.

Measurement of precipitation will also present some difficulties, particularly in the highland areas. The data would be much improved if recording rain gauges are used. If a helicopter can be made available for routine work, more sites in the less accessible highland areas could be included for the network.

The Nubian aquifer

Figure 5 is from Issar (3) and shows the main outcrops of the Nubian aquifer and some hydrogeological data from a few locations at which wells have penetrated to the Nubian. The author notes the probability of small rates of recharge at the outcrop areas (3×10^6 m^3/annum) and the large volumes of water held in storage. He concludes that the aquifer is essentially continuous between these various locations. Water quality in central Sinai is good (Nakhl, 355 mg/l of chloride; Jebel Helal, 300 mg/l of chloride) and with a comparatively small deterioration towards the eastern and western borders of Sinai (Yotvata and Ayun Musa). Drilling depths, pumping levels and adequate water quality seems likely to be optimum in central Sinai and development for agricultural use may be feasible. The presence of cheap power for submersible pumps would increase the economic feasibility and such power could be available if oil or natural gas is discovered in north Sinai.

The very large volumes of water in the Nubian cannot be fully exploited. Issar calculates very roughly that a quantity of the order of magnitude of 20 million cubic metres of water per year could be utilised for about 30 years. This is a comparatively small amount, if realistic. These calculations of exploitable resources will need to be improved following a phased initial development. They do, nevertheless, indicate the possibility of a fairly limited resource availability.

3.1 The basic programme of investigations outlined above were discussed with the USAID Project Team (including Dr Shatta of the Desert Institute) and the TAMS Advisors to the Ministry of Reconstruction who agreed that, in general it represented a satisfactory programme which could be readily co-ordinated with the USAID Project due to start immediately. Items (iii-1) and (iv) would be given early consideration in the USAID project although this did not rule out subsequent involvement of the Institutes of the Ministry of Irrigation. Regular meetings at short intervals (monthly) have been proposed by the TAMS Advisors to ensure continuous exchange of information. It would clearly be advantageous if the final selection of sites for detailed study should be made in consultation with the USAID Team. Early development schemes based on the Institutes' findings might then be incorporated into the USAID Phase II programme.

The general plan of the programme work is set out below. (See also Table 3.1). Two regional teams are to be established each with basic responsibility for one of the two regions in Sinai. Certain work will be carried out by staff not attached to a regional team (e.g. geophysical survey and drilling). Some of this work is planned to be carried out under contract but it is also intended to develop expertise in these techniques within the Institutes.

References

1. Shazly E M, M A Abdel Hady et al. 1973. Geological Map of Sinai Peninsula from ERTS - 1 Satellite Images.

2. Binnie Taylor Egypt, 1980. Review of Groundwater Resources in Sinai.

3. Issar A, A Bien, A Michaeli, 1972. On the ancient waters of the upper Nubian sandstone aquifer in central Sinai and southern Israel. J. Hydrol. vol. 17, no. 4, pp 353-374.

4. Geofisika Enterprise for Applied Geophysics 1963. Report on the investigations of water and soil resources in north and central parts of Sinai Peninsula. Zagreb, 186 p.

4. SCOPE, PLAN AND TIMING

4.1 General.

The scope of the proposed project is far reaching and long term in its implications for water resource evaluation and development in Sinai with additional emphasis on institutional building of the organisations which will be mainly responsible for the work (the Institutes of the Ministry of Irrigation). In plan the project combines the initiation of a programme of systematic hydrometric data collection with detailed localised resource studies. The latter are hoped to lead to early development within the immediate areas studied and to be suitable for extrapolation elsewhere in Sinai.

A considerable amount of data will be collected during the project of both regional and local significance. A computerised data base is to be established with a view to archival storage as well as for flexible retrieval and analysis. The detailed procedures for data storage have yet to be established but provisional funding for staff and equipment is included.

Much of the first year of the planned three year project will be devoted to detailed planning, procurement of equipment and the siting of meteorological, hydrological and hydrogeological stations. Preliminary visits by consultant experts are proposed at an early stage to assist in the initial important planning decisions on all major aspects.

It is also recommended that a steering committee be set up at the beginning of the project to review and consider all interim proposals and reporting.

4.2 Itemised Programme.

(i) Basic climatological network

The proposed network is planned to provide long term data on Sinai. It will necessitate upgrading of some or all of the existing stations and the addition of one or two more. All first order stations will be fully equipped with instrumentation for the direct and calculated measurement of evaporation and evapotranspiration which is mainly of importance in an agricultural context but will also provide information on the overall climatological patterns in Sinai. Additionally, a number of permanent sites for rainfall measurement will be selected for long term recording. The information from this overall network will allow extrapolation of the more detailed analytical studies planned to be carried out in selected catchments.

Decisions on the upgrading of existing climatological stations, selection of rainfall measuring sites and all instrumentation will be based on joint consultation with the Meteorological Authority in the Egyptian Government. It is possible that full control of this basic network will be vested within the Authority who have offered to provide any required data, either raw or analysed, to the Institutes on demand. The procedure on this matter has yet to be finalised and quoted costings in the budget relate to instrumentation only.

(ii) Hydrological monitoring

This aspect of the programme is also planned as a long term procedure. It will include initially well water levels, spring discharges and water quality but may eventually incorporate some of the run-off stations established in the catchment studies. Observation wells for water levels will probably be drilled for the specific purpose but quality data will be obtained from the pumped discharge of production wells or from spring flows. Spring discharge rates may be recorded continuously with appropriate structures, or periodically.

(iii-2) Detailed water resource investigations in areas of high potential

Two areas have been provisionally selected:-

1. The Sahil El Qa'a basin in South Sinai

2. One of the major basins of the Middle Wadi El Arish in North Sinai (W. El Hamma; W. El Hassana; W. El Bruk).

The final selection will be made after further field survey and in consultation with land use experts, the Government offices and the USAID Project Team.

Summary of Programme of Work:-

Description	Time
Study of existing data in reports and files; also maps, air photographs, satellite imagery.	3 months
Preliminary field reconnaissance of geology, hydrogeology and hydrology. This phase would include selection of an associated representative catchment; also consideration of any requirements for geophysical survey.	3 months
Geophysical survey (objectives: determination of alluvial thicknesses and possible aquifer occurrences in alluvial sequence; indications of water quality in alluvial or bedrock aquifers). Geological survey would also continue as necessary.	6 months
Test drilling (medium depths down to approx. 150 metres) and aquifer testing. Some additional geophysical survey might follow depending on drilling results.	12 months
Final reporting to include any recommendations for pilot development.	3 months
Pilot development (depending on results and planned in co-ordination with other organisations).	

(v) Representative catchment studies

The preferential requirements for a representative catchment in this context are as follows:-

(a) Defined valley suitable for accurate discharge measurement during flash flows and with some periodic surface run-off assured annually.

(b) Some existing development within valley and potential for additional development.

(c) Reasonable access.

(d) Additional value if associated with either of areas for detailed resource studies.

Three catchments have been provisionally selected in South Sinai on the Gulf of Suez and one at least is closely associated with the Sahil El Qa'a Basin. Three catchments may be selected in North Sinai if suitable occurrences exist although as noted above, conditions appear less favourable to this method of study.

Instrumentation will be mainly concentrated within the selected catchments boundaries but general observations will be made in adjacent areas which could include the installation of rain gauges to assist extrapolation and to confirm general rainfall distribution patterns and run-off characteristics.

Summary of Work Programme in item (v)

Description	Time
Preliminary field visits and discussion with other agencies to finalise selection of catchments and details of work programme. Study of existing data, maps, air photographs, satellite imagery.	3 months
Field reconnaissance survey of geology, hydrogeology and hydrology. Site selection for instrumentation (discharge and rain gauges) which could include observation wells. Some geophysical survey, mainly to determine alluvial thicknesses and indications of lithology, water quality.	3-6 months
Instrumentation, observation and analysis. Observations of rainfall and run-off by direct measurement; subsurface flows and recharge by gradient-transmissivity and water level changes, Discharge from system from well abstraction data etc., ans from evapotranspiration calculations of agricultural lands/vegetated areas.	24 months
Reporting which will include recommendations for development such as additional wells, surface storage or diversion schemes, induced recharge etc.; consideration of feasibility extrapolation to catchments elsewhere.	

(vi) The Nubian aquifer study

Comparatively little information exists on the Nubian Aquifer System in Sinai and is derived largely from the few oil exploration wells which penetrate this formation and on deductions from shallower occurrences of groundwater which are thought may be derived from the Nubian Aquifer by leakage.

Drilling depths and water quality will exercise constraints on direct development of the Nubian Aquifer and the main potential may be limited to central Sinai. Locally the Nubian is exposed but elsewhere in this region, it may occur at depths of the order of 800 metres. Drilling costs will be more justified if the test holes can be designed as production wells in the event of their being successful. Site selection in relation to possible usage and the predicted economics of development will need to be given detailed consideration prior to formulating a drilling programme. For the deeper holes, contract drilling will be necessary.

An ancillary but important aspect of the study concerns the resources of these aquifers which may be being supplied by leakage from the Nubian and it will be necessary to attempt to confirm these suppositions. Hydraulic analysis and geochemical characterisation of the various waters will constitute important techniques of study.

Summary of Work Programme for item (vi)

Description	Time
Study of existing data in records and files. Most of the data will be in oil company files, either in Egypt or Israel. Geophysical logs should be re-analysed in detail to confirm stratigraphic successions and to obtain data on water quality, porosity etc. Core and sludge samples should be examined and some may be suitable for laboratory study of permeability and porosity which could then be related to geophysical log data.	6 months
Field survey which will be mainly concerned with measurements in existing wells and observations in the anticlinal outcrop areas in North Sinai and in areas of probable leakage. Geophysical and fluid logging should be carried out wherever possible using the Institutes own equipment and aquifer testing should be carried out on any existing wells. Tests which could be made on the deep disused wells at Nekhl could be obviously of considerable importance. Indeed these wells might possibly be brought back into production. Detailed fluid sampling for geochemical analysis (including oxygen, carbon and hydrogen isotopes could provide important information on interaquifer leakage, discharge rates and locations, groundwater flow directions and aquifer transmissibility. It is not thought likely that geophysical techniques will be applicable but their use is not discounted.	6 months

Description	Time
Test drilling and aquifer testing. Shallow holes, to 150 metres could be drilled by the Institutes own rig. Deeper holes would be drilled under external contract. The contract would need to be drawn up with considerable care and forethought to ensure maximum information and minimum costs. Open hole completion in the Nubian might be possible if the formation is sufficiently consolidated and this would allow narrow diameter holes. Air hammer drilling could then be considered which would be cheap and fast, and would also have the advantage of providing information on piezometric levels, water quality, and general aquifer productivity during drilling. Probable water pressures would need to be predicted in order to select the right size compressor. The technique would encounter greatest difficulty if the Nubian proved highly permeable although foam drilling can extend the range of the technique. A combination hammer-rotary rig would provide for all eventualities. Drilling should be followed by comprehensive geophysical and fluid logging, aquifer sampling and aquifer testing. Emphasis would be needed on single hole techniques of analysis where satellite observation holes would be too expensive.	12/15 months
Reporting and recommendations for development which would need to include well and well field design. Aquifer modelling would help preliminary predictive work.	3 months

5. EQUIPMENT

It is proposed that external funds should supply all field scientific equipment and transport costs. Details with estimated costs are listed below:-

	Items	US$ x 1000	Sub-totals x 1000
5.1	Meteorological Equipment.		
	Instrumentations for two first order stations	70	
	Instrumentation to up grade four existing stations	70	
	Rain gauge network for representative catchments studies	60	
		200	200

Items	US$ x 1000	Sub-totals x 1000
5.2 Hydrological Equipment.		
15 water level recorders	20	
10 current meter sets	40	
4 theodolites	28	
10 engineering levels	12	
	100	100
5.3 Hydrogeological Equipment.		
20 water level recorders	26	
2 deep electric sounders	2	
10 shallow sounders	5	
4 field conductivity meters	2	
1 drilling rig (six inch hole to 150 mts)	160	
1 borehole logger (1000 m)	60	
4 temperature conductivity loggers (300 m)	10	
4 shallow test submersible pumps	20	
2 compressors	20	
2 generators	10	
4 fluid depth samplers	10	
1 shallow seismic equipment	10	
4 pipe flow meters	2	
2 sets field geochemistry	3	
	340	340
5.4 1 Mobile laboratory	50	50
5.5 Land transportation and spares (10 - 4 wheel drive Land Rover Station Waggons or equivalent, 2 - trucks for drilling rig)	280	280

6. PROJECT PERSONNEL

It is proposed that the project will be mainly operated by personnel from the Research Institute of Water Resources Development and the Research Institute of Groundwater.

6.1 Additional Egyptian Specialists will be recruited on a short term consultant basis, mainly in the field of geology, meteorology, surface geophysics, agriculture land use survey, and drilling where their local knowledge and experience of local conditions will be of significant value. A total period of 65 man months is anticipated.

6.2 Technical assistance is expected from EEC experts on a short term basis with a total duration of 36 man months. These experts may include an external co-ordinator who would assist the Project Manager during periodic visits and also specialists in the following aspects:-

(i) Computerised data storage and retrieval, mathematical modelling; system analysis.

(ii) Borehole geophysics

(iii) Catchment analysis

(iv) Hydrogeochemistry

At least 15 visits to Egypt should be allowed for.

6.3 The proposed organisational framework and the personnel requirements of Institute staff are shown in Table (6-1) and summarised below. Designated staff will be assigned locations, either Cairo or Sinai, and the period of time in man months it is estimated that they will be assigned to the project. The status will also be indicated by the following code:-

XX staff currently available in the Indstitutes and budgeted for.

YY additional requirement for which funding will be requested.

Title	Man Months Year 1 Cairo	Year 1 Sinai	Year 2 Cairo	Year 2 Sinai	Year 3 Cairo	Year 3 Sinai	Status
1. Project Manager	12		12		12		YY
2. Technical Office							
Project Manager Assistant	9	3	9	3	9	3	YY
Secretary	12	-	12	-	12	-	YY
Typists (2)	24	-	24	-	24	-	YY
Draftsman (2)	24	-	24	-	24	-	YY
3. Hydrometeorological Division HQ							
Sen. hydrometeorologist	8	4	8	4	8	4	XX
Jnr. "	8	4	8	4	8	4	XX
4. Hydrogeological Division HQ							
Sen. hydrogeologist	8	4	8	4	8	4	XX
Jnr. geologist	4	8	8	4	10	2	XX
Jnr. geophysicist (2)	12	12	12	12	12	12	YY
Drilling engineer	3	9	3	9	3	9	YY
Analytical chemist	12	-	12	-	12	-	XX
Electronic engineer	6	6	6	6	6	6	YY

5. Data Centre

This would have the purpose of establishing a data bank for the different project activities, providing computer facilities for the different divisions and for publishing the collected data and analysis results periodically. Its required personnel are as follows:-

Man Months

Title	Year 1	Year 2	Year 3	Status
	Cairo	Cairo	Cairo	
Sen. Systems analyst	12	12	12	XX
Jnr. Systems analyst	12	12	12	XX
Programmers (2)	24	24	24	YY
Ass. Programmers (2)	24	24	24	YY

6. Administrative Office

The Administrative office would be responsible for all administrative functions such as personnel matters, accounting, transport organisation, typing, filing.

Man Months

Title	Year 1		Year 2		Year 3		Status
	Cairo	Sinai	Cairo	Sinai	Cairo	Sinai	
Sen. Administrator	12	-	12	-	12	-	XX
Jnr. Administrator	12	-	12	-	12	-	XX
Accountant (2)	24	-	24	-	24	-	XX
Typists (3)	36	-	36	-	36	-	YY
Drivers (6)	36	36	36	36	36	36	YY

7. Regional Offices

These are to be set up in North and South Sinai and the following personnel are to be allocated to each office:-

Man Months

Title	Year 1	Year 2	Year 3	Status
	Sinai	Sinai	Sinai	
Sen. Hydrologist	12	12	12	XX
Jnr. Hydrologist	12	12	12	XX
Sen. Hydrogeologist	12	12	12	YY
Jnr. Hydrogeologist	12	12	12	YY

Title	Man Months Year 1	Year 2	Year 3	Status
	Sinai	Sinai	Sinai	
Surveyor/Hydrol. Asst. (2)	24	24	24	XX
Hydrogeological Asst. (2)	24	24	24	XX
Labourers (10)	120	120	120	YY
Driver/Mechanics (4)	48	48	48	YY
Storekeeper	12	12	12	YY
Messenger (2)	24	24	24	YY

7. PROJECT BUDGET

7.1 Summary details of the estimated budget requirements are listed below. Local personnel allowances are field allowances which it is proposed to pay to staff working in Sinai.

The proposed daily rates are as follows:

Sen. Grade staff (10/15 years experience)	£E 10
Jnr. Grade staff (5/10 years experience)	£E 5
Technician	£E 3
Labourer	£E 1

On the assumption of a 25 day month, the periods of time to be spent in Sinai are multiplied by the appropriate rates to obtain the budget requirement.

7.2 External Funds Contribution.

	US$ x 1000	EUA x 1000
Meteorological equipment	200	143
Hydrological equipment	100	71
Hydrogeological equipment	340	243
Field accom. (tents)	70	50
Mobile laboratory	50	36
Vehicles* (and spares)	280	200

* 10 Land Rovers	140,000
2 Mini Bus	40,000
2 Trucks	60,000
Spare	40,000
	280,000

	US$ x 1000	EUA x 1000
Fees external experts	300	214
Fees local experts	100	71
Allowances local pers.	150	107
Fellowships	90	65
Deep Drilling	840	600
Contingencies (11%)	280	200
Total EEC Contribution	2,800	2,000

7.3 Local Funds Contributions.

	£E x 1000
Local personnel fees	150
Office costs	100
Transport costs (fuel & repairs)	100
Deep Drilling (to include casing/screen)	900
Geophysical Survey	250
Isotope/Trace Element analysis	50
Computer time	50
Contingencies (10%)	150
	1,750

8. STEERING COMMITTEE

It is recommended that a Steering Committee be formed which will meet periodically to review the progress of the work and to advise on aspects of future work. Suggested members of the Steering Committee are as follows:-

- Chairman of the Water Research Centre
- Director of the Groundwater Institute
- Director of the Water Resources Institute
- Director of the Desert Institute
- Delegate of the EEC in Egypt
- Representative of the Ministry of Reconstruction
- USAID Project in Sinai representative
- Representatives of the Governorates of North and South Sinai.

TABLE (2.1) LIST OF STATIONS AND THEIR POSITIONS

Stations	Years of Observations	Latitude		Longitude		Altitude in metres	Yearly Normal up to 1967
El Arish	1907-1914 1919-1956 1959-1967	31	07	33	45	15	104
El Quseima	1938-1947 1953-1964	30	40	34	22	330	46
El Hassana	1938-1947 1953-1961 1965-1967	30	28	33	48	250	24
Kuntella	1932-1938 1944-1947 1953-1967	30	00	34	41	540	20
El Kekhl	1907-1914 1919-1921 1940-1947 1953-1967	29	55	33	45	406	19
El Themed	1921-1947 1953-1067	29	36	34	52	760	22
El Tor	1921-1967	28	14	22	37	3	11

TABLE (2.2) DETAILS OF RAINFALL UP TO 1967

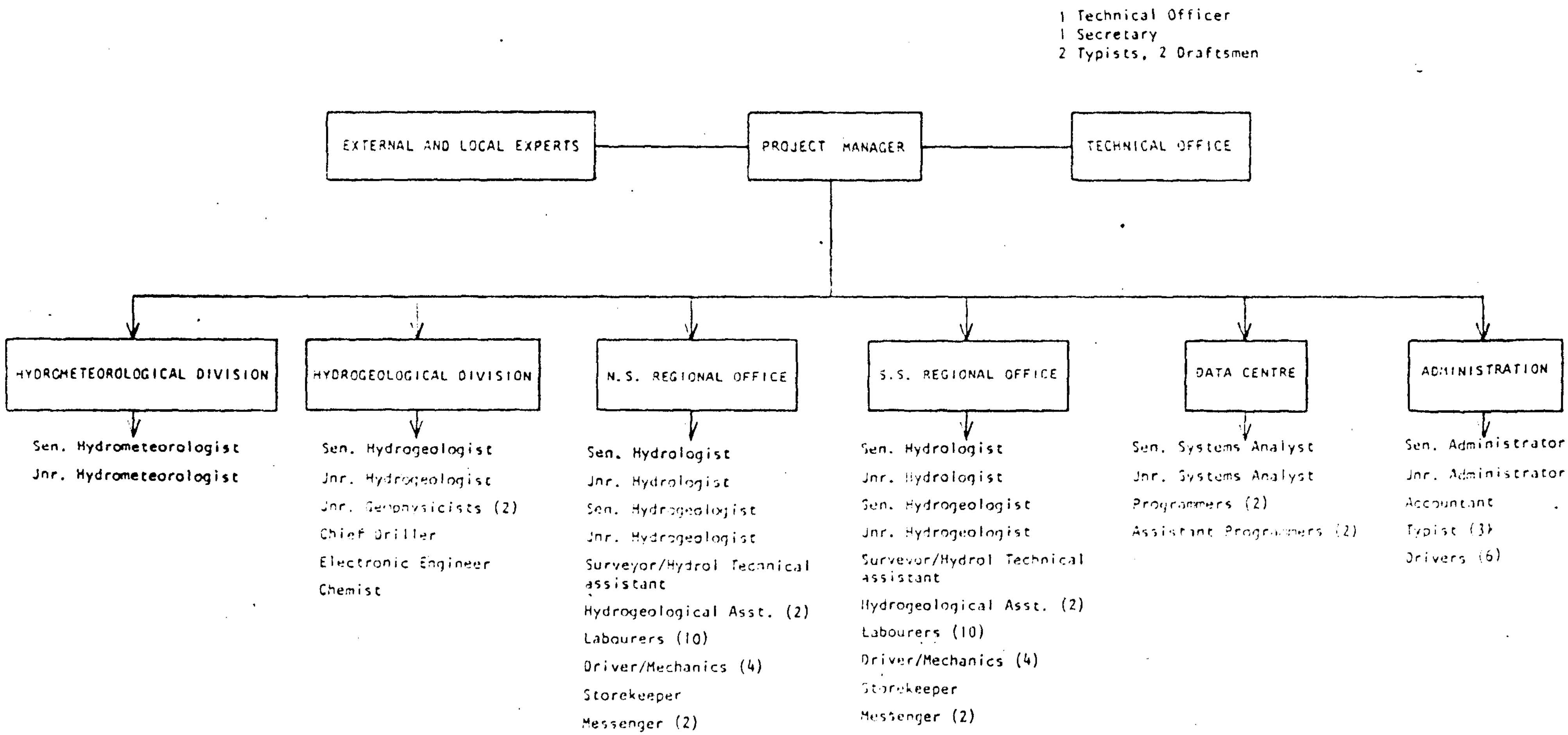
Stations	Maximum Rainfall in one season*		Minimum Rainfall in one season*		Maximum Rainfall in one day	
	mms	year	mms	year	mms	Date
El Arish	214	1963/1964	Tr.	1950/1951	59.0	12.5.1950
El Quseima	(105)	1944/1945	Nil	1948/1949 1950/1951	72.0	19.3.1947
El Hassana	77	1944/1945	Nil	1948/1949 1950/1951	32.0	1.1.1945
Kuntella	76	1964/1965	0	1948/1949	32.0	1.1.1945
El Nekhl	68	1944/1945	0	1959/1960	32.0	1.1.1945
El Themed	313	1925/1926	Nil	S.D.Y.(+)	142.0	18.11.1925
Ras El Negb	89	1965/1966	Nil	1948/1949	20.0	2.4.1953 10.2.1954
El Tor	52	1925/1926	Nil	1952/1954 1956/1957	37.4	8.11.1955

TABLE 3.1

SCHEDULE OF WORK	Year 1 1 2 3 4 5 6 7 8 9 10 11 12	Year 2 1 2 3 4 5 6 7 8 9 10 11 12	Year 3 1 2 3 4 5 6 7 8 9 10 11 12
Item (i)			
Climatological network: siting and instrumentation . .			
Item (ii)			
Hydrological network: siting and instrumentation . . .			
Networks operation			
Item (iii) - <u>Area Resources Study</u>			
Existing data analysis			
Preliminary Field reconnaissance			
Geophysical/Geological surveys			
Test Drilling/Aquifer testing			
Reporting			
Pilot Development			
Item (iv) - <u>Representative Catchment Studies</u>			
Final selection catchment - existing data analysis . .			
Instrumentation, hydrological/hydrogeological survey; observation well drilling			
Observation and analysis			
Reporting			
Pilot Development			
Item (v) - <u>Nubian Aquifer Study</u>			
Existing data study			
Field Survey: logging, testing, sampling existing wells.			
Drilling exploration/production wells, aquifer testing..			
Reporting			

Notes: 1. Project items (iii) and (iv) would be mainly carried out by regional teams other than the specialist functions of geophysics and drilling.
2. Project items (i), (ii) and (v) would be mainly carried out by HQ staff
3. General co-ordination and exchange of ideas is anticipated by periodic staff meetings, seminars, etc.

Table 6-1. ORGANISATIONAL FRAMEWORK



ANNEXE 2

INDIVIDUALS CONSULTED DURING MISSION TO EGYPT

ANNEXE 2

INDIVIDUALS CONSULTED DURING MISSION TO EGYPT

Mr A W Kirk - Deputy to Head of Delegation. Commission of the European Communities Delegation in Egypt.

Dr Hassan Ibrahim - Director, Research Institute for Water Resources.

Mr Ahmad Awwad - Deputy Director, Research Institute for Water Resources.

Mr Tag El-Deen - Senior Geologist, Research Institute for Water Resources.

Mr Usama Nasef - Senior Hydrologist, Research Institute for Water Resources.

Miss Gihan Ali - Head of Computing, Research Institute for Water Resources.

Mr H Biaumi - Engineer El Arish, Research Institute for Water Resources.

Mr V Panic - Senior Officer, Drinking Water Project, United Nations Childrens Fund (UNICEF).

Mr M Shazly - Hydrogeologist, Drinking Water Project, United Nations Childrens Fund (UNICEF).

Mr M El Gazzar - President, Tri-Con International.

Mr S Shatai - Chairman, General Co. for Research and Groundwater (REGWA).

Mr A El-Foukhy - Executive Director, General Co. for Research and Groundwater (REGWA).

Mr M Badawi - Managing Director, DASCO.

Mr A El-Sabban - Chairman, Meteorological Authority.

Dr A Abou-Zeid - Chairman, Central Development Authority, Ministry of Development, New Communities and Reclamation.

Dr S Nour - Director, Water Resources Dept, General Authority for Rehabilitation Projects and Agricultural Development.

Mr A Ashur - Chief Engineer, Ministry of Housing El Tor.

Dr W R Gwinn - Hydrologist Consortium for International Development, Colorado State University.

Mr A Tuinhof - Project Manager, IWACO/RIGW.

Dr A Shata - Consultant Hydrogeologist.

Dr E Shazly - Desert Institute, Geology Division.

Mr M Mousa - Head of Photogeological Section EGSMA } local consultants
Mr R Eissa - Chief Micropalaentologist EGSMA } to RIWR

ANNEXE 3

COST ESTIMATES FOR PHASE 2 SWRS

PREPARED FROM RIWR PROPOSALS (SEPT 1986)