

**TNO Environmental and
Energy Research**

Final review of the WRAY project
phases 2 and 3

1985 - 1990

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**WATER RESOURCES ASSESSMENT YEMEN
(WRAY)**

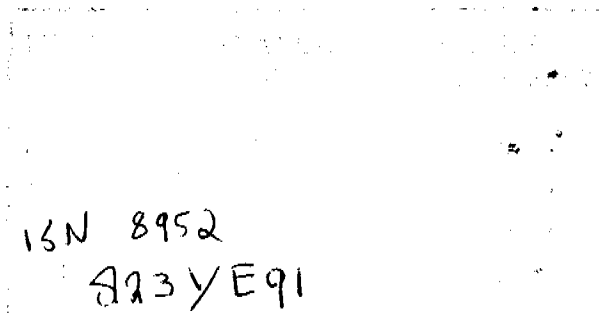
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phases 2 and 3

1985 - 1990

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List of abbreviations

| | |
|---------|--|
| CAMA | Civil Aviation and Meteorological Authority |
| DGIS | Directorate General of International Co-operation |
| DOH | Department of Hydrology |
| ERADA | Eastern Regional Agricultural Development Authority |
| GDWRS | General Department of Water Resources Studies |
| MAF | Ministry of Agriculture and Fisheries |
| MOMR | Ministry of Oil and Mineral Resources |
| NWSA | National Water and Sewerage Authority |
| TDA | Tihama Development Authority |
| TS/HWC | Technical Secretariat of the High Water Council |
| USAID | United States Agency for International Development |
| WRAY | Water Resources Assessment Yemen Arab Republic / Water Resources Assessment Yemen |
| YOMINCO | Yemen Oil and Mineral Corporation |

1. INTRODUCTION

1.1 General

In recent decades the exploitation of water resources in the Northern Provinces of the Republic of Yemen till May 1990, the Yemen Arab Republic has increased rapidly. Funds and technology have become available widely, enabling large numbers of wells to be drilled, powerful pumps to be installed in wells and modern surface water schemes to be established. The adequate selection, siting, design and operation of these is only possible if sufficient knowledge and information is available on the prevailing groundwater and surface water resources and systems. Furthermore, because the country's water resources are scarce, there must be adequate allocation of water, a proper planning of regional water exploitation, and the water resources must be protected against over-exploitation and contamination. These water resources management activities also depend on groundwater and surface water data being available.

Such information, however, was scarce in the Yemen Arab Republic. This was recognized by the YAR government and one of the consequences was the creation in 1978 of the Department of Hydrology (DOH) within the Yemen Oil and Mineral Resources Corporation (YOMINCO). The Department of Hydrology was designated to become a national centre for information on water. For a number of years it received technical assistance from USAID to increase its capability, particularly in the form of training courses. In response to the need to further strengthen DOH, the Yemeni and Dutch governments agreed in 1981 upon a bilateral co-operation programme: "Water Resources Assessment Yemen Arab Republic" (WRAY). The first phase of this programme, the WRAY-1 project, started in 1982.

The WRAY-1 project was carried out by the Department of Hydrology (Geological Survey Board) and the TNO-DGV Institute of Applied Geoscience, on behalf of the Yemen Oil and Mineral Corporation

(YOMINCO) and the Dutch Directorate General of International Co-operation (DGIS), respectively. It began on 1 April 1982 and was followed on 1 September 1985 by the second phase of the co-operation programme: the WRAY-2 project. Finalizing WRAY-1's activities, in particular the production of technical reports, took until almost mid-1986.

The WRAY-2 project was considered as a bridging phase lasting for a period of 12 months only (September 1985 - September 1986).

During this period YOMINCO was transformed into the Ministry of Oil and Mineral Resources (MOMR), DOH was renamed General Department of Water Resources Studies (GDWRS).

During the bilateral consultations of February 1986 a project proposal for a third phase of this co-operation programme, the WRAY-3 project, was approved. This WRAY-3 project was planned to be executed during the period September 1986 - September 1989, but in the course of 1988 all parties involved mutually agreed to extend the project phase till January, 1st 1990. Some finalization activities and the execution of two studies related to the water resources management of the Wadi Surdud area continued during 1990.

This report is a review of the WRAY phases 2 and 3.

1.2 Objectives of the WRAY programme

The long-term objectives of the WRAY co-operation programme can be formulated as follows

- strengthening the General Department of Water Resources Studies of the Ministry of Oil and Mineral Resources;
- carrying out a regional water resources assessment programme in selected areas;
- providing water resources data and advisory services.

The ultimate goal is to contribute to a more adequate development, use and management of the country's water resources.

1.3 Output and benefits of phase 1 (1982-1985) of the WRAY programme

- Improved performance and capability of the General Department of Water Resources Studies. With a significant progress in the capabilities regarding field data collection, installation of hydrometeorological networks and execution of geophysical field investigations.
- A nationwide inventory and compilation of available data. Published as "Hydrology and hydrogeology of the Yemen Arab Republic" in August 1984.
- A water resources assessment study in the Sadah area. Publication of one (compilation) main report and seven technical reports.
- A water resources assessment study in the Wadi Surdud area. Publication of one (compilation) main report and seven technical reports.
- A water resources data base consisting of a collection of:
 - * basic meteorological, hydrological and hydrogeological data
 - * geographical / topographical maps
 - * geological / hydrogeological maps
 - * air photos
 - * reports
 - * literature / textbooks
- Information and data services extended to the water sector in Yemen in support of the national development, use and management of water resources.
- Hydrological monitoring networks in the Sadah and Wadi Surdud areas.

2. OBJECTIVES AND SCOPE OF PHASES 2 AND 3

2.1 Immediate goals

As stipulated in the plans of operation, the immediate goals of the phases 2 and 3 in the period 1985-1990 were the following:

- continued improvement of scientific-technical skills, operational capability and managerial skills of GDWRS personnel.
- continuation of network monitoring in the Sadah and Wadi Surdud areas (fig. 1). Processing and dissemination of data regarding these networks.
- execution of a regional water resources assessment programme in the Wadi Adhanah - Marib area (fig. 1).
- continuation, extension and improvement of water resources information services.
- improvement of local water resources investigations on request of farmers or other "third parties".
- improvement of knowledge of fresh water availability in the Wadi Surdud area (Tihama part).

2.2 Activities

To pursue the long-term objectives and to meet the immediate goals, the following activities were planned:

- training
- continued network operations Sadah and Wadi Surdud

- water resources assessment Marib-Wadi Adhana
- water resources information centre activities
- investigations fresh / saline groundwater in Wadi Surdud
- reconnaissance Upper Wadi Surdud
- pilot study Water Resources Management planning
- local and regional consultancies

3. ACTIVITIES

3.1 General aspects

A substantial part of WRAY activities consisted of fieldwork: in all, project team-members spent more than 300 man-months in the field and the accumulated distance covered by project cars between September 1985 and December 1989 was approximately 650 000 km. Processing, interpretation and presentation of the data obtained was another major category of work; this is evidenced by the fact that 33 technical reports have been issued, under WRAY-2 and 3.

The fieldwork was carried out mainly in the framework of the water resources assessment studies in the Wadi Adhanah - Marib area, the Sadah and the Wadi Surdud area. The processing, interpretation and presentation of data were mainly done in the office; these activities did not only involve the assessment studies, but also the compilation of obtained data (from areas beyond the assessment study areas), database activities and dissemination of data.

A brief summary of the major activities of the WRAY project phases 2 and 3 will follow below.

3.2 Network activities

3.2.1 Sadah area

As a continuation of the extensive Water Resources Assessment Study, executed by the WRAY project during phase 1 (1982-1985), monitoring of the installed network has been the main activity in the area concerned in the period 1985-1990.

Network density was strongly reduced and the remaining monitoring stations were equipped with a new type of recording instruments in 1986. This new type of data collecting instruments (Omnidata, USA) needs less frequent data retrieval than the previously used analogue

type of recorders. This was done to reduce operational cost and optimize time involved in the monitoring and maintenance of the network. One of the remaining groundwater monitoring stations (1643B1-18) fell dry in 1986 and was abandoned consequently.

The network consisted of following units as per 31 December 1986 (fig. 2):

- 1 Meteorological station
- 4 Rainfall stations
- 3 Groundwater stations

At the end of January 1987 all the analogue recorders of (remaining) network stations were replaced by solid state memory recorders (type Omnidata, Tulsa, USA). Collection of data and servicing of the stations has taken place every four months. During 1989 the landowner of well WRAY.2 claimed the well, consequently negotiations started to obtain a new monitoring well, but no new suitable well was found until December 1990.

During the period under review four progress reports concerning the Hydrological network were published. These reports are listed in the complete overview of WRAY reports as presented in Appendix 1.

3.2.2 Wadi Surdud area

As a continuation of the extensive Water Resources Assessment study executed by the WRAY project during phase 1 and 2 (1982-1986) monitoring of the installed network has been an important activity in the area concerned in the period 1986-1990.

The network consisted of following units as per 31 December 1986 (fig. 3).

- 1 Meteorological station
- 10 Rainfall stations
- 1 Stream gauging (run-off) station
- 4 Groundwater stations
- 30 Observation wells (manually observed)

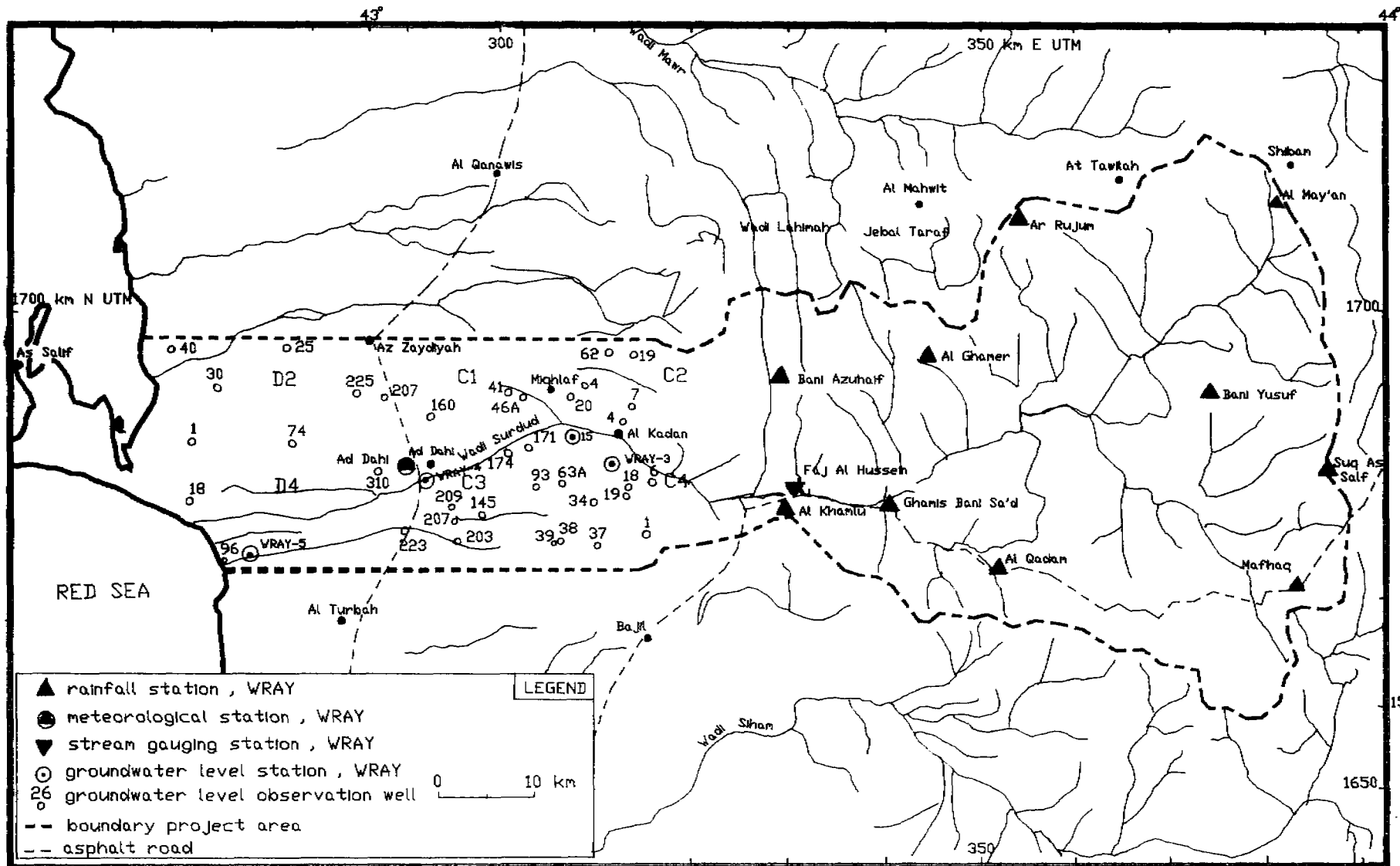


FIGURE 3
WRAY HYDROLOGICAL NETWORK WADI SURDUD AREA

The recorders were replaced by full automatic solid state memory recorders during 1987 (type Omnidata, Tulsa, USA).

The manual recorded groundwater wells are observed every month. The automatised stations every four months. The stream gauging station at Faj Al Hussein is recorded continuously by a nitrogen fed bubble gauge recorder. Data have been collected every month. Current meter measurements of stream flow and topographic levelling of the stream (river) bed have been executed monthly at Faj Al Hussein; current meter measurements only were executed less frequently at Ghamis Bani Sa'd.

Groundwater level monitoring in well 53C4-26 was stopped in August 1986, recording has been continued in the nearby situated well WRAY.3.

Until the automation, most of the rainfall stations in the catchment were served by local observers. The delay in payment of their allowances had a negative effect on their motivation.

Gaps of records have occurred for a variety of reasons. Interruptions in manually observed data series usually were caused by instrumental defects or negligence.

The chronical lack of operational funds made the necessary regular checks by the WRAY team members extremely difficult as well.

During the period under review four progress reports concerning the Hydrological network were published.

These reports are listed in the complete overview of WRAY reports as presented in Appendix 1.

3.3 Follow up to the Water Resources Assessment Study in the Wadi Surdud area

Within the framework of the plan of operations of the phases 2 and 3 of WRAY four activities took place in the area concerned.

1. Exploratory drilling programme in the western part of the Surdud zone of the Tihama coastal plain
2. Simulation of salt water upconing and salt water intrusion in the Surdud zone of the Tihama plain.
3. Reconnaissance survey water resources in the eastern part of the catchment area (upper Wadi Surdud).
4. Pilot study water resources management.

3.3.1 Exploratory drilling programme

The objectives of this programme were to verify the (geo)hydrological interpretations of the geophysical and (geo)hydrological investigations as executed during phase 1 (1984-1985). Besides, the drilling programme had to collect more detailed information regarding lithological stratification, aquifer transmissivity and the depth of the interface between fresh (brackish) / saline groundwater.

Two locations were selected carefully, borehole WRAY.4 south of Ad Dahi, borehole WRAY.5 east of Al Urj, both in the Tihama coastal plain.

Drilling, completion and testing of the boreholes took place in January and February 1986 (Report WRAY-7, 1987).

3.3.2 Simulation of saltwater upconing and salt water intrusion in the western part of the Tihama coastal plain

The results of the investigations as mentioned sub 3.3.1 added to the results of the water resources assessment study as executed during phase 1 (Report WRAY-4, 1986), laid the foundation for the study concerning the saline water upconing and salt water intrusion in response to groundwater abstraction.

Modelling was carried out resulting in a better understanding of the mobility of the saline groundwater under different boundary conditions.

The study was mainly executed by TNO-Institute of Applied Geoscience in Delft. Two visits were paid to Hodeidah to discuss the approach and

study the interim results with TDA's staff hydrologists. The results were presented in draft in November 1990.

3.3.3 Reconnaissance survey of water resources in the upper Wadi Surdud area

Because of the alarming and rapid depletion of groundwater in the exploited aquifers of the Sana'a basin it has become clear that additional sources for the future water supply of the city of Sana'a has to be identified and assessed. In this context WRAY carried out a reconnaissance study of the upper (eastern) part of the Wadi Surdud catchment area at a distance of appr. 30 km of Sana'a.

The study was carried out in several phases from February 1987 till February 1988. To obtain information on the runoff of the upper Wadi Surdud a streamflow measuring section has been selected at the confluence of Wadi Surdud - Wadi Dayan. This station has been visited and monitored at regular intervals.

Based on available information and on the observations made it was concluded that the area is not promising for extensive exploitation and export of water to the town of Sana'a.

The results were presented in January 1989, (Report WRAY-9, 1989).

3.3.4 Pilot study water resources management

The Wadi Surdud area was selected by the WRAY project team for a pilot study on water resources management.

The study was executed by the GDWRS, TNO Institute of Applied Geoscience and Delft Hydraulics; this was done in close co-operation with TDA and TS/HWC, with contributions from two Dutch consultant firms Euroconsult and DHV.

The study was designed at a regional level; spatial variables were aggregated to a certain extent in order to focus on the main features, interactions and impacts. The outcomes of the analysis enable

evaluating strategies in water resources management policy for Wadi Surdud.

A water resources management model was developed to facilitate the analysis. This model allows alternative water resources management strategies to be simulated and presents the predicted impacts in such a way that different strategies can easily be compared using predefined criteria. The outcomes of the study suggest that control of groundwater abstraction is advisable; furthermore that particular scope for more profitable agricultural wateruse is present in the spate command area and in the groundwater irrigated zone.

3.4 Water resources assessment study Wadi Adhanah - Marib

3.4.1 General

During the 1985 bilateral consultations between the governments of the Yemen Arab Republic and the Kingdom of The Netherlands both parties agreed to give high priority to a detailed water resources assessment study in the Marib area. This activity including collection of data as well processing, interpretation and presentation in not less than 7 reports was the backbone of WRAY phase 3.

The main objective of this study was to assess the fresh groundwater and surface water resources in the Marib area taking into account the influences of implementation of the new dam and of the connected irrigation scheme in the Marib area.

The Wadi Adhanah - Marib area consists of three distinct geographical zones. From upstream (south-west) to downstream (northeast) classification is as follows (fig. 4).

- the densely populated area of the highland plains of Ma'abar, Dhamar and Rada at an elevation between 2100 and 2700 m above mean sea level. This area, with a surface of appr. 3300 km² does not

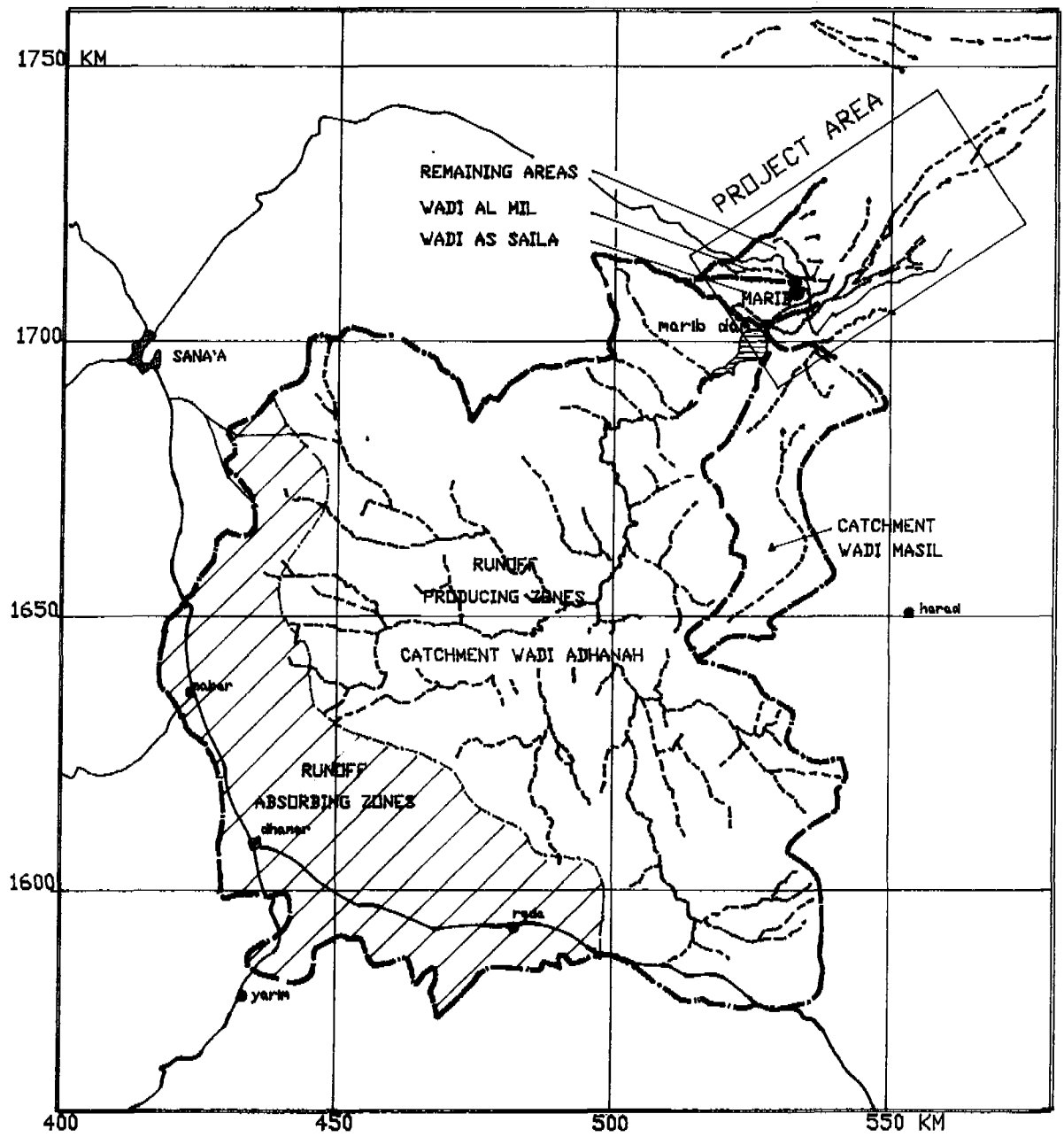


FIGURE 4 : LOCATION OF THE RUNOFF ABSORBING AND RUNOFF PRODUCING ZONE

significantly contribute to the runoff of the Wadi Adhanah (runoff absorbing zone).

- the sparsely inhabited area of the eastern highlands at elevations between 1500 and 2000 m above mean sea level. In this area of appr. 8200 km² excess rainfall concentrates quickly to the Wadi Adhanah system. This runoff is collected behind a recently (1985) completed dam which is situated at the eastern limit of the Wadi Adhanah catchment (runoff producing zone).
- the alluvial plain, downstream of the dam including towns, villages and cultivated land bordering the wadis. This area of appr. 500 km², the Marib plain, at an elevation of about 1100 m above mean sea level has a rapidly increasing agricultural development with a population of about 25000.

This Marib area was the zone of first priority in the assessment study of the WRAY phase 3 (1986-1989).

3.4.2 Technical activities executed in the Wadi Adhanah - Marib investigation

The following major aspects were dealt with:

- exploration and assessment of the groundwater resources in the Marib plain area, where the area's most important groundwater reservoir is situated, and where most of the area's water use is concentrated;
- observation of the surface water resources resulting from rainfall in the Wadi Adhanah catchment and filling the Marib Dam reservoir;
- analysis of the influence of the Marib Scheme (Marib Dam and Irrigation Project) on the available water resources;
- analysis of the sediment transport in the Wadi Adhanah and prediction of sediment accumulation in the Marib reservoir.

3.4.2.1 Operational constraints

Within the investigation period of three years (1986-1989) the project faced a number of problems or conditions that either required modifications of the standard methodological approach or limited the data collection and analysis to some extent. The most important ones are listed below:

- a) The inaccessibility of the catchment area of the Wadi Adhanah. This problem was partly solved by using fully automatic monitoring equipment, but it is one of the reasons why reliable rating curves of the Wadi Adhanah stream gauging stations could not be established.
- b) Limited length of the investigation period: as a result, time series of wadi flow and rainfall are too short to make reliable estimates of the long-term annual means.
- c) Soil conditions in parts of the Marib area unfavourable for the execution of geo-electrical field investigations. This was compensated for by doing additional EM surveys in the drier zones, and in particular by the extensive use and re-interpretation of geophysical data previously collected during oil exploration (especially seismic data).
- d) The lack of detailed and reliable topographical maps and of salient topographical landmarks. This was solved by using sophisticated topographical positioning systems in the Marib area, and SPOT satellite imagery.
- e) Difficult conditions for the execution of the well inventory, drilling and aquifer tests, due to lack of co-operation from the local population. This hampered field observations, particularly after 1987 and during the posterior checks.
- f) The limited time available for modelling groundwater flow. As a consequence, only one of the modelling objectives could be met.

3.4.2.2 Inventory of available information

- Topographical information

Air photos, satellite images and a limited number of topographical maps were available at the start of the investigations.

- Hydrological and hydrogeological information

The reports concerning the Marib Dam and Irrigation project made available to the project by Electrowatt Engineering Services Ltd. and Hunting Technical Services Ltd., 1978, contain a wealth of reliable and relevant information.

Information about the water level of the Marib Reservoir was received from the Marib Branch of Electrowatt Engineering Services Ltd. and from the Eastern Region Agricultural Development Authority (ERADA) of the Ministry of Agriculture and Fisheries (MAF). These data were used to calibrate the data regarding runoff of the Wadi Adhana collected by the WRAY project.

- Meteorological information

Meteorological data from stations belonging to the network of the Civil Aviation and Meteorological Authority (CAMA) and data obtained from MAF were made available to the project. From 1968 onwards useful data were received from the Sana'a station. The station at Marib Airport supplied reliable data from 1985 onwards and intermittent, less reliable data prior to 1985.

- Geological information

Some maps and reports were available at the start of the investigations or became available during the execution period of the project.

- Geophysical information

A wealth of geophysical data was collected from 1982 onwards during the intensive exploration for oil and gas in the area. These data are confidential and the WRAY project had only very restricted access to

the upper (shallow) part of the data. The information received pertained to maximum depths of 1400-1700 m below surface.

3.4.2.3 Geo-electrical survey

In all, 201 geo-electrical sounding were carried out from June 1986 - May 1987 in the Marib region over an area of 1100 km², extending outside the present area of agricultural development.

In view of the extremely high surface resistivities, especially in those areas covered by sand dunes the field measurements were limited to a horizontal spread of 700 m; this limited the depth of the interpretation.

The results are presented in 29 profiles and 4 maps (1:100 000), (Report WRAY 15.1, 1990).

3.4.2.4^a Electro-magnetic survey

Eleven electro-magnetic profiles were executed; 8 were obtained with a coil separation of 200 m and a station interval of 50 m; 3 profiles were obtained with a coil separation of 400 m and a station interval of 100 m. The total length of the EM profiles executed was 98 km.

During the geo-electrical field survey and the EM field survey problems related to positioning were solved by using a Wild T-1000 theodolite with a Distomat 15S positioning system.

The results are presented in 11 profiles and one map (1:100 000), (Report WRAY-15.1, 1990).

3.4.2.4^b Geophysical well logging

To acquire in situ geophysical information on the subsoil in the Marib area, logs were run in 5 boreholes drilled by the WRAY-project at four locations. Besides the logging in these five boreholes, the project ran logs in 60 privately drilled wells prior to the installation of a pump. In all these wells a natural gamma log was run.

The results were published in 5 logs and in a "lithology cross-section". The gamma recordings were published in a gamma correlation diagram (Report WRAY-15.1, 1990).

3.4.2.5 Exploratory drilling

In all, 8 boreholes were drilled in the period February 1988 - May 1989 at 4 locations. At each location a deep production well and a shallow observation well were drilled. The contractor Abdulla Ahmed Alkohali (for general trading & drilling), Zubeiri Street, Sana'a, YAR, executed the drilling, completed the wells and supplied the pump for the aquifer tests as well.

The maximum depth reached was 330 m below surface (WRAY.7B). The total length drilled in the 8 boreholes was 1368 m. The location of the boreholes is indicated on figure 5.

The execution and the results of the WRAY exploratory borehole drilling programme are presented in Report WRAY-15.5, 1990.

3.4.2.6 Hydrological network Wadi Adhanah - Marib

The rainfall recording network consists of:

- 6 automatic stations installed in November 1986
- 4 automatic stations installed in July 1987

The surface water recording network consists of:

- 1 stream gauge station installed in April 1987
- 1 auxiliary stream gauge station installed in December 1987
- 1 lake level station installed in November 1988
- 1 gate-opening station installed in October 1987

The groundwater level recording network consists of:

- 4 groundwater level stations installed in private wells in April - May 1987
- 6 groundwater level stations installed in WRAY exploratory boreholes during the period October 1988 - March 1989

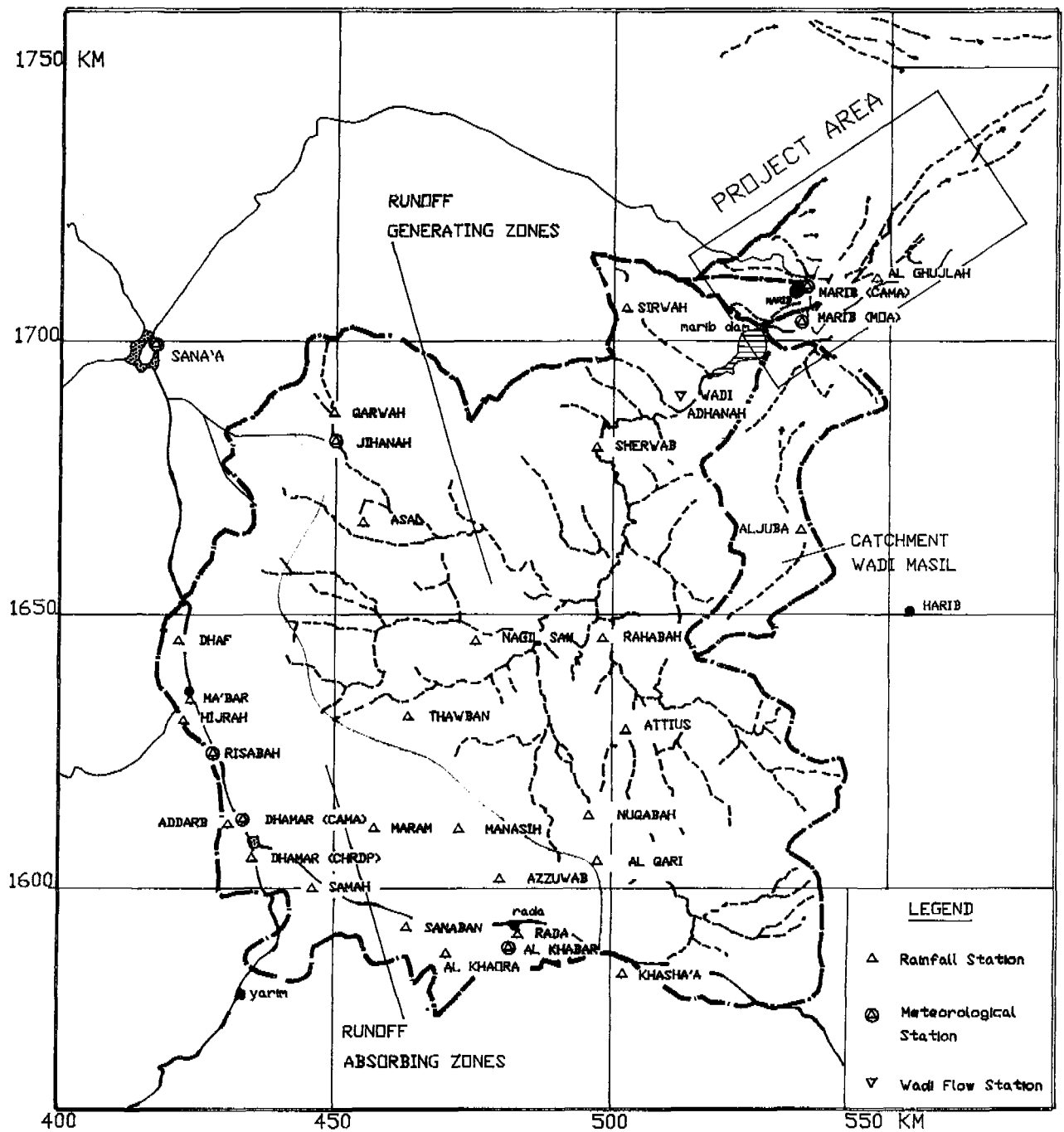


FIGURE 6 : LOCATIONS OF HYDROLOGICAL AND METEOROLOGICAL STATIONS IN WADI ADHANAH BASIN

- 133 observation wells in the Marib area were selected for manually recording of the groundwater level.

All automatic stations are equipped with Omnidata sensors and Omnidata electronic data recording systems manufactured by Omnidata International Inc., Logan, Utah, USA.

The network as installed in the Wadi Adhanah catchment area is presented in figure 6.

The data collected with this hydrological network are presented in Report WRAY-15.3, 1990.

3.4.2.7 Well inventory

The well inventory in the Marib area yielded information on 1513 wells in an area of approximately 500 km². The inventory was executed by a field crew from the department of hydrogeology of GDWRS in the period June 1986 - May 1987.

The information on the execution of the well inventory and the data acquired are presented in Report WRAY-5.12, 1990.

3.4.2.8 Aquifer tests

Single-well tests were executed in 21 private wells. Pumping tests were executed in the WRAY exploratory boreholes at 4 locations in the area. The single-well tests, carried out with the well owner's pump, took place during the period April - June 1988. The pumping tests, performed by using the pump and handling equipment of Alkohali for general trading and drilling, took place during the period October 1988 - March 1989.

The aquifer tests, execution and interpretation are presented in Report WRAY-15.4, 1990.

3.4.2.9 Groundwater modelling

The USGS modular three-dimensional finite-difference groundwater flow model (MODFLOW) developed by M.G. McDonald and A.W. Harbough, Scientific Software Group, Washington D.C., 1988 was used to construct a model that simulates the groundwater flow system in a relative small part of the Marib area.

The modelling process and its results are presented in Report WRAY-15.7, 1990.

3.4.2.10 Sediment transport and accumulation

In response to growing interest and concern regarding the sediment accumulation in the Marib Reservoir it was decided to include a study of the sedimentation pattern within the Wadi Adhanah in WRAY phase 3. The WRAY project invited Professor S.D. Nio of International Geoservices B.V. Leiderdorp, The Netherlands, to execute this study.

A first field survey focusing on the geology, sediment supply and topography of the Wadi Adhanah catchment took place in the period 3-22 July, 1988.

A second field survey focused on a survey of the sediment accumulation in the Marib Reservoir and on a study of the sediment transport in the lower (eastern) part of the catchment. This survey took place in the period 19 February - 10 March 1989.

The execution of the study and the results obtained are presented in Report WRAY-15.6, 1990.

3.4.2.11 Technical reporting

Three interim reports on the investigations in the Wadi Adhanah - Marib area were issued during the period November 1987 - February 1988 (Reports WRAY-8.1 through 8.3).

The final reporting was terminated in May 1990. A total of eight reports concerning the Wadi Adhanah - Marib investigations was published. The reports are listed in Appendix 1.

3.5 Water resources database and information centre

Great emphasis was laid and ample attention was given to a proper functioning of the database of the GDWRS. During the execution of the phases 2 and 3 (1985 - 1990) the emphasis of function was shifted from database to a national water resources information centre.

A great effort was put in collecting documents as reports, airphoto's, geographical maps and satellite images.

The information centre team put effort in developing good relations with other ministries, agencies, projects and organisations dealing with water resources development in the Republic of Yemen. The centre has been equipped with 6 personal computers and peripheral equipment such as plotting and digitizing equipment.

Software has been developed and/or purchased. A special package to obtain insight on what data are available in the centre or known to exist in the country has been developed: the Water Resources Information System (WRIS).

At the end of phase 3 (December 1989) the following data were stored in the information centre:

- climate data in computer files of 59 stations since 1986; and of 110 stations prior to 1986;
- climate data paper files of 21 stations;
- daily groundwater levels of 16 stations since 1986;
- ditto of 8 stations prior to 1986;
- well inventory data of some 11600 locations since 1982;
- some 350 geo-electrical soundings obtained on local investigations since 1982;
- some 1100 geo-electrical soundings obtained within the framework of the WRAY project.

In view of the fact that the external use of the information centre should be as wide as possible a special mission was arranged in the period 18 November - 23 December 1989. It focussed how to improve the exchange of information between the GDWRS and other water related ministries, agencies, organisations and projects.

An inventory of the use of the information centre was made, a plan with tactics and related budget for improving the functioning of the centre was drawn up. The results were laid down in the Mission Report of mr. A.J.H. Negenman.

3.6 Regional and local investigations

The activities related to local investigations, mainly on behalf of private landowners or village communities, have been incorporated in the WRAY project from October 1985 onwards, after the geophysical section of MOMR became a part of GDWRS.

In the period under review appr. 275 geo-electrical soundings were executed to establish the depth of the fresh groundwater table. Appr. 40 well loggings to obtain in situ information prior to the installation of screen and casing were executed.

Besides, several studies with a regional aspect were carried out:

- On request of the Ministry of Economy, Trade and Supply an extensive study in two phases on (ground)water assessment was executed at Al Barh (Wadi Rasyan).
- On request of NWSA investigations were done to assess the water availability for the town of Marib (1987) and for extension of the well field at Al Haimah near Taizz (1987).
- On request of Gitec-Dorsch an investigation with application of several geophysical techniques in Wadi Shiras (Hajja) was executed in the autumn 1988.
- On request of the Ministry of Oil and Mineral Resources the topography of a future site for building a gas bottling plant was

surveyed in detail in 1988 by using the Wild geodetic instruments, which operated previously in the Marib area successfully.

3.7 Presentation of results

Two important public presentations of the project's activities and achievements were organised.

The first symposium was held in the Sana'a Sheraton Hotel on the 26 and 27 January 1986. The symposium focussed on the results of the investigations in the Sadah and Wadi Surdud areas executed within the framework of phase I (1982-1985). This symposium offered the opportunity to inform officials and professionals not only about the technical results obtained but - what is even more important - also about the limited availability of water in the former Yemen Arab Republic. The complete programme is presented in Appendix 8.

The second symposium was held at the Sheraton hotel as well on the 8 and 9 October 1989. During this symposium, in combination with a poster presentation, the results of phase 2 and 3 were presented, with an emphasise on the Wadi Adhanah - Marib investigations and findings.

The first day was attended by 190 persons, the second day by 106. The Middle East Times, Yemen edition, covered the symposium in three successive issues. Six speakers from outside the WRAY project contributed with a presentation in which they gave their vision on the development of the water assessment in the Yemen Arab Republic. The complete programme is presented in Appendix 9.

Besides these two symposia the WRAY project presented their activities and results during a visit of the Minister of International Cooperation of The Netherlands to Marib in January 1989.

To improve the dissemination of data and knowledge available in the National Information Centre for Water Resources at the GDWRS a brochure promoting this information centre was published and distributed in September 1989.

To realise a first step in nationwide understanding and promotion of the capabilities and potential services of the GDWRS the WRAY project contracted mr. S.H. Al Nahti to make a video movie in close cooperation with the staff of GDWRS. This video was shown on the Yemeni Television network in the framework of the festivities of the Revolution Day in September 1988.

3.8 Support to other organisations and/or projects

From the presented activities it becomes clear the WRAY project has been supporting other organisations, - international, governmental as well as regional - by providing them with information and services that may contribute to proper use and management of the water resources.

It concerns the following organisations:

- Tihama Development Authority (TDA) belonging to the Ministry of Agriculture and Fisheries (MAF). Mainly in relation with the studies executed in the Wadi Surdud area. In particular the pilot study on water resources management in the Wadi Surdud area triggered close co-operation.
- Eastern Regional Agriculture Development Authority (ERADA), belonging to MAF, in relation to studies executed in the Wadi Adhanah - Marib area. In co-operation with an irrigation expert of Euroconsult preparation and formulation of future supporting activities took place in March - April 1988. The objectives were to establish an efficient coordination between MAF and the WRAY project and to assist ERADA in the implementation of the new Marib water scheme. The proposal was finally not agreed upon.
- The Information Centre of MAF. Mainly in relation to the exchange of reports.

- The National Water and Sewerage Authority (NWSA). Mainly in relation to the water supply to the towns of Marib and Sadah.
- The United Nations Development Programme. Mainly in relation to a support to the Technical Secretariat of the High Water Council in the field of data dissemination and assistance in selection of equipment. During 1988-1989 this cooperation and support became more and more intensive with the result that was decided to look for a mutual housing. This way the GDWRS developed a close relationship with this UNDP project and obtained the role of the national organisation for groundwater data collection and dissemination in the YAR.
- The Civil Aviation and Meteorological Authority (CAMA). Mainly in relation to the exchange of meteorological data.
- Sana'a University, Faculty of Engineering, Dept. of Civil Engineering. Mainly in contributing to and participating in the training course in Applied Hydrology, organised by the International Institute for Hydraulic and Environmental Engineering during the period September '89 - January '90.
- The World Bank, the United States Agency for International Development and the Bundesanstalt für Rohstoffe und Geowissenschaften. Mainly in supplying data, reports, maps or satellite images as background information for their policy and strategy in defining development projects in the former Yemen Arab Republic.
- The Embassy of the Kingdom of The Netherlands, Dutch consulting firms and evaluation/appraisal missions in the framework of the bilateral Yemen - Netherlands co-operation programme. Mainly in supplying data, reports, maps or satellite images as background information for agricultural projects.
- The Ministry of Economy, Trade and Supply in preparing a project proposal as well a related budget for a water assessment study in

the area surrounding the town of Al Barh in the Wadi Rasyan. The proposed study was related to the water resources planning of a cement factory to be build in future.

The first phase of this study (which was executed by the GDWRS without guidance from Dutch side) took place in the period March - April 1987. The second phase including drilling activities took place in June - July 1989.

3.9 Training

Training was provided for the employees of the GDWRS in four following ways:

1. on the job training through participation in and coaching during the actual execution of the WRAY water assessment studies including field work, processing of data and reporting.
2. participation in "tailor made" short training courses in Yemen.
3. participation in "tailor made" short training courses outside Yemen.
4. participation of selected candidates in fellowship training programmes in The Netherlands.

An extensive overview of the realised training programme is presented in Appendix 4.

Training outside the YAR totaled 455 man weeks of which 420 man weeks training took place in The Netherlands. Formal training inside the YAR, totaled 290 man weeks, not including the English language training at the British Council in Sana'a.

In retrospective it can be remarked that during WRAY-2 and 3 a major effort was invested in the realization of a thorough training programme.

According to their report, the Yemeni/Netherlands evaluation mission (October 1989) came to the following conclusion:

"The time spent on formal training, excluding English (language) courses was 12.2 man-year over the WRAY-2 and WRAY-3 project periods. This is equivalent to some 8% of available professional staff time, a quite remarkable achievement."

Based on the information contained in Appendix 4 and the findings during individual interviews with a random selection of the GDWRS professional staff, the mission concluded the following:

- *the training programme has been executed in an efficient and well-planned way, at least in the field of groundwater resources (which constitute the short-term scope of activities within the GDWRS);*
- *the staff has received adequate training to an extent sufficient for the execution of all the technical aspects of a groundwater resources evaluation study. These required skills include: interpretation of aerial photographs, reconnaissance field work, well inventory and geophysical exploration techniques, aquifer tests, data interpretation, drilling supervision, well logging and completion, and reporting;*
- *training in the field of evaluation of surface water resources has not been executed to the same degree, although some skills have been acquired (streamflow measurements and sediment transport);*
- *there remains some ambiguity with regard to the capability of the Yemeni staff to plan and organise the execution of large long-term studies and the preparation of final reports. Individual staff members expressed doubts as to their performance, especially when utilising the English language. However, a number of small studies (Al-Barh and Al-Haimah), for which the final reports were prepared in Arabic, were executed successfully;*

- training in the area of collection and processing of data from the recently introduced digital monitoring stations has been adequate. There remains to give more training in the hardware maintenance.

**YEMENI TEAM
(GDWRS)**

**DUTCH RESIDENT
TEAM
(TNO / DGIS)**

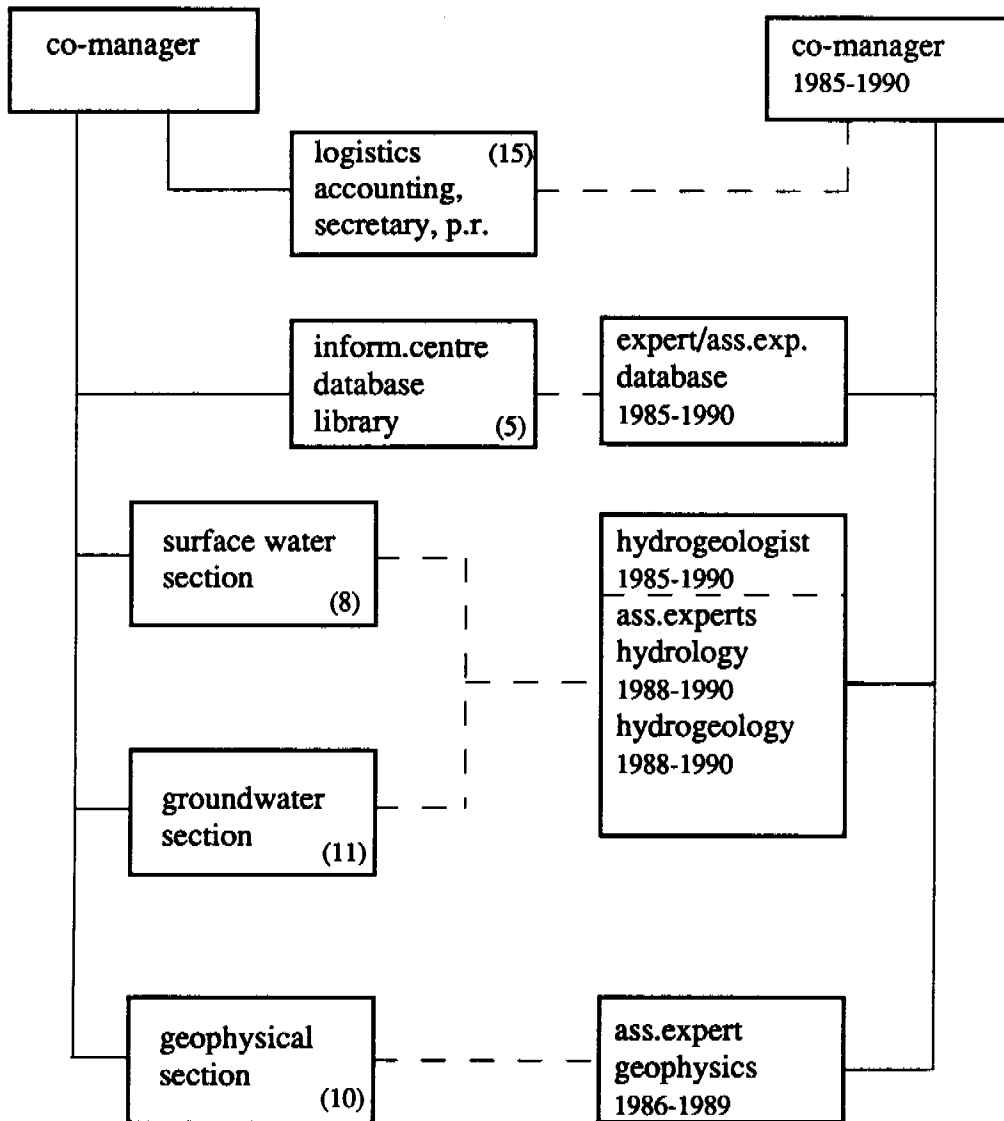


Figure 7 Organisation of the WRAY-2 and 3 project team.
Number of employees in parentheses (situation 1989).

4. MANAGEMENT ASPECTS

4.1 Organisation

During WRAY-2 and 3 all employees of the GDWRS were involved in the execution of the WRAY project.

Figure 7 shows how the teams were organised.

According to the plans of operation the Yemeni team had the responsibility for carrying out the different activities, the Dutch team the responsibility for adequate advise and instruction. In reality, the Dutch team members had still a large share in the organisation and actual execution of the project operations. This was for a large part due to the limited operational strength of the GDWRS as an organisation and to constraints in financial support from the side of the Ministry of Oil and Mineral Resources.

4.2 Personnel

Appendices 2 and 3 list the personnel involved in the WRAY-2 and 3 projects. The size of the Yemeni team fluctuated slightly throughout the project's duration. On average the number of Yemeni team members was 45.

4.3 Equipment

Vehicles, field equipment for data collection and for positioning, computer hardware and software were provided by The Netherlands. Office furniture was partly provided by the Ministry of Oil and Mineral Resources.

4.4 Logistics

The Ministry of Oil and Mineral Resources provided office facilities in Sana'a and a resthouse in Marib. The resthouses at Sadah and Bajil were closed in 1986.

Procedures such as tax exemption, importing of project goods, licensing were undertaken mainly with external support. Yemeni team members have given a considerable and useful contribution to speed up these procedures.

Maintenance of computer hardware, equipment and vehicles required field attention of the project management.

The Yemeni database staff succeeded in maintaining the computer hardware in an excellent way.

The maintenance of equipment such as data loggers, streamflow measuring instruments, geo-electrical resistivity equipment etc. did not receive enough attention. Appointment of a well-motivated and responsible store keeper remains to be fulfilled.

The maintenance of the 11 project vehicles was an almost permanent concern of the project management. Although, according to the plan of operation, the Ministry of Oil and Mineral Resources was responsible for maintenance and repair of those vehicles, this could not be realised because the task apparently was too heavy for only one mechanic engineer and there were almost no funds available for the purchase of oil, plugs, spare parts, etc.

In view of the vital importance of the vehicles for the execution of the fieldwork programme it was decided to cover the costs related to this maintenance from the Dutch budget. The Embassy of the Kingdom of The Netherlands took an initiative by organising a joint-project for maintenance of all vehicles operating in Dutch-assisted projects from March 1987 onwards. From that moment the situation improved but it is obvious that maintenance of vehicles is of such a vital importance for the GDWRS that it should not depend on foreign support.

4.5 Finances

In the plans of operation the Yemeni and Dutch budgets were stipulated to finance the execution of the WRAY projects. Each party bore the costs of its own personnel as well the related field allowances.

Investments and training costs were covered by the Dutch budget. The drilling operations in Wadi Surdud (WRAY-2) and in Marib (WRAY-3) were financed from specially earmarked Dutch financial aid funds. According the plan of operation the operational expenses such as petrols and other consumables should have been covered from Yemeni funds. But in spite of a disproportional effort of the project co-managers MOMR was not able to make those funds available neither in sufficient amount nor in time.

This resulted in an almost continuous borrowing of money from the Dutch budget in order to be able to realise the minimum fieldwork execution. This resulted also in the fact that a considerable amount of operational cost, appr. Dfl 600 000,- was additionally financed from Dutch funds although not budgetted for that purpose.

A general overview of the Dutch budget and expenditures are presented in Appendix 6. Expenditures for operational costs are much higher than budgetted for the reason given above. Training needs were the reason that more funds were spent to training than originally planned. Finally, expenditures on personnel were much higher than originally allocated in the budget mainly because of the extension of WRAY-3 agreed during the mid-term review of 1988. All these overexpenditures could be compensated by savings on other categories of expenditures.

In spite of several serious efforts to obtain a more or less reliable accounting of the contributions from the Yemeni side (MOMR) we did not succeed in receiving an overall picture. We received figures for the period 1.1.1987-1.9.1989 only, which are presented in Appendix 7 as well.

A reliable accurate accounting for operational expenditures only (excluding the expenditures on salaries and per diem) could not be obtained.

5. RESULTS

5.1 General

The results of the WRAY project phases 2 and 3 can be grouped in the following categories:

- improved and enlarged capabilities of the GDWRS;
- technical results obtained in several areas and described in numerous reports (see Appendix 1);
- the extension and further development of the national information centre for water resources;
- contribution to improved understanding of the need for a careful management of water resources.

5.2 Capability of the GDWRS

At the end of phase 1 (1985) the GDWRS professionals and technicians were capable of executing basic fieldwork in hydrology, hydrogeology and geophysics.

During phase 2 and 3 the number of professionals and technicians increased as well the number of different techniques applied in the field.

Much emphasis was put on improvement in skills related to processing, interpretation and filing of the data. All analogously recording monitoring instruments were replaced by solid state memory recording instruments. The co-workers of the GDWRS became acquainted with this equipment as well.

A considerable number of staff members are, as a result of the phases 2 and 3, by now capable in proper handling, understanding and presentation of most type of data collected. Although an enormous

effort was put in the training and guidance in the field of reporting only a few succeeded in (technical) reporting in the English language on their own. The limited capabilities of writing in English remains a handicap for a number of professionals and technicians. Support in understanding hydrogeological processes in detail remains necessary.

5.3 Technical results of the executed studies

The continuation of the **hydrogeological network monitoring** in the Sadah and Wadi Surdud areas has contributed to a better understanding of the (longer term) patterns of rainfall distribution and groundwater level fluctuations in those areas. As well supplying the necessary data for a reliable assessment of available amounts of water.

The **Exploratory drilling of the two boreholes in the Western part of the Wadi Surdud - Tihama area** (report WRAY-7) confirmed the general interpretation on the aquifer and the depth to saline water as made in the water resources study as executed during WRAY-1 in 1985. It furthermore made clear that the higher transmissivity in the western part is related rather to lithology than to a greater thickness of the aquifer.

The more detailed hydrogeological information obtained in the two boreholes has been used in the study on the numerical simulation of salt water upconing and salt water intrusion (report WRAY-21) and in the pilot study water resources management Wadi Surdud (report WRAY-22).

The **Reconnaissance survey of the water resources of the eastern (upper) part of the Wadi Surdud** (report WRAY-9) area brought forward that this area (the Wadi Ahjar part in particular) offers only limited possibilities for additional exploitation of water for Sana'a city.

All springs in the Ahjar area are intensively used for local agricultural purposes. The so-called "Wadi Surdud springs" further to

the West, however, are not exhaustively used. These springs feed the base flow of Wadi Surdud.

The best prospect for groundwater development was found in the Tawilah Sandstone in the area west of the town of At Tawilah, but the distance to Sana'a remains a serious drawback when considering to transport this water economically to the capital.

The study on the **Numerical simulation of salt water upconing and salt water intrusion in the Wadi Surdud** (report WRAY-21) brought following as most important conclusions. The present pumping rate is exceeding maximum sustainable yield independent of the regional distribution (location) of the producing wells. The rate of drawdown of the groundwater table depends on the spatial pattern of the abstraction wells. The average rate is maximum in case the wells are located in the eastern part of the Wadi Surdud Tihama area, it is considerably less if abstraction is concentrated in the western part. The rate of salt water intrusion is maximum in case the abstraction wells are mainly located in the western part of the aquifers, the rate is smaller if the abstractions take place mainly in the eastern part. The study concluded that the drawdown of the groundwater table in the area concerned is a more serious problem than the salt water intrusion.

The **Pilot study water resources management Wadi Surdud** (report WRAY-22) came among others to the following conclusions:

- (1) benefits from irrigated agriculture are particularly low in the spate irrigated and in the groundwater irrigated zones.
- (2) reduction and control of groundwater pumping is unavoidable if sustainable groundwater use in the Tihama zone is aimed for.
- (3) there is particular scope for improvement in two types of irrigated zones:
 - (a) the spate irrigated zone (introduction of conjimetric use and upgrading of the crop pattern)
 - (b) the groundwater irrigated zones (upgrading the crop pattern).

These and other conclusions may contribute to a balanced water resources development use and management in the area.

The most significant findings and conclusions of the **Water resources assessment study of the Wadi Adhanah - Marib areas** (report WRAY-15) are listed below.

- 1) The surface water and groundwater systems in the Marib area are strongly interrelated; any emphasis on surface water use has direct (negative) consequences on the available groundwater resources.
- 2) The potential water demand currently exceeds the permanently available resources, which makes it essential to carefully consider alternative strategies and measures for optimal use of water.
- 3) The impact of the new dam on the water management of the Marib area is considerable; many options for operation of the dam are possible.
- 4) The evaporation losses from the Marib Reservoir are high under those operational strategies that strongly emphasize storage of surface water in the reservoir.
In view of the fact that losses of water due to evaporation have to be minimized high storage volumes in the lake have to be avoided.
- 5) Storage reduction of the reservoir by sediment accumulation resulting from low floods is relatively unimportant.
- 6) In the Marib aquifer groundwater system an "upper" and a "lower" aquifer have been distinguished. The relative shallow zone of the upper aquifer system in the southwestern and central parts of the Marib area is heavily exploited at present.
- 7) The probably impermeable Azal shale layer has been delineated; the presence of this layer in the subsurface has important consequences for the groundwater flow system.
- 8) The lateral extent of fresh groundwater and the occurrence of brackish groundwater has been delineated.
- 9) Evidence has been obtained of current groundwater mining, and it is expected that continuation of these practices will (in the

relatively short term) have negative consequences such as: 1) continuation of the decline of groundwater levels, resulting in increasing costs of groundwater exploitation; 2) exhaustion of certain zones and 3) deterioration of groundwater quality in certain zones.

- 10) Frequent monitoring of groundwater levels in a dense observation network of wells during periods of water release from the dam gave insight into the recharge characteristics of the groundwater reservoir and provided data for calibrating the numerical groundwater flow simulation model.

The information obtained will allow to formulate and test alternative water resources management strategies for the Marib area.

This will be executed under WRAY-4.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 General

It may be stated that the WRAY project fulfilled the tasks and commitments as stated in the plans of operation for the phases 2 and 3. The conclusions of the Yemeni-Dutch evaluation mission (October 1989) were formulated as follows:

The WRAY project has been effective in that it has:

- *strengthened the GDWRS to a good technical level;*
- *carried out regional water resources assessment studies in three representative areas;*
- *provided the infrastructure and collected a considerable amount of information through which water resources data and advisory services can be supplied.*

The WRAY project has been insufficiently effective as regards:

- *the external use of the database; the number of users is still limited and has to increase in future to make the efforts developing the database and keeping it up to date, effective;*
- *the amount of services provided, especially to government organisations;*
- *the administration of equipment for fieldwork.*

Stronger contact with other governmental organisations working in the water resources area could have been achieved.

6.2 Strengthening the GDWRS

The GDWRS has made further progress in developing its capability. Progress was most remarkable in processing and storage of field data in the understanding of the techniques applied and in the ability to communicate in the English language.

Further improvement in the interpretation of data, in reporting and in formulating technical conclusions and recommendations and in proper maintenance of equipment is still necessary.

Proper management of the GDWRS and its departments still needs considerable attention to develop an efficiently and self relyently operational GDWRS.

An efficient and clear logistic support from the side of MOMR is a prerequisite for a proper, task fulfilling, functioning of the GDWRS.

6.3 Hydrological and hydrogeological observations

The WRAY project has clearly shown that data must be collected systematically over longer periods to be able to present a reliable judgement on available water resources.

Interruptions of data collection or neglect of the maintenance of the network (data collecting) instruments is not only entailing a great deal of expenses but is a major threat to the essential value of this major activity of the GDWRS.

6.4 National information centre for water resources

The centre is functioning well as a general access to information regarding hydrology, hydrogeology and, to some extent, geology, geophysics and meteorology.

The efforts to improve and intensify the relation with other agencies active in the water sector in the country should continue.

6.5 Water resources assessment and water resources management

The water resources assessment study executed in the Wadi Adhanah - Marib area offers an excellent basis for a reliable approach to a water resources management study of the area concerned.

It remains essential that the results of the Sadah and Wadi Surdud assessment studies and of the Wadi Surdud water resources management

study are brought forward by the management and staff of the GDWRS to the authorities responsible for the development of those areas. Assistance to those authorities regarding analyses and planning in water resources offers a good opportunity for the GDWRS to contribute to a better use of the scarce water resources of the country.

APPENDIX 1

TECHNICAL REPORTS ISSUED BY THE WRAY-PROGRAMME
DURING PHASES 1, 2 AND 3

APPENDIX 1: Technical reports issued by the WRAY-project during the period 1982-1990 (phases 1, 2 and 3)

- WRAY-1 Hydrology and hydrogeology of the YAR
Van Enk, D.C. and J.A.M. van der Gun, 1984
- WRAY-1 Hydrology and hydrogeology of the YAR
Summary of available information (Arabic)
Van Enk, D.C. and J.A.M. van der Gun, 1984
- WRAY-2 Interim Report on Water Resources of the Sadah Area;
Main Report
Van der Gun, J.A.M., 1983
- WRAY-3 Water Resources of the Sadah Area
Main Report
Van der Gun, J.A.M., 1985
- WRAY-3 Water Resources of the Sadah Area
Main Report (Arabic)
Van der Gun, J.A.M., 1985
- WRAY-3.1 Water Resources of the Sadah Area
Technical Annex 1: Well Inventory Results
Noori Gamal, J.A.M. van der Gun and Nabil Abdul Qadir,
1985
- WRAY-3.2 Water Resources of the Sadah Area
Technical Annex 2: Geo-Electrical Investigations
Van Overmeeren, R.A., 1985
- WRAY-3.3 Water Resources of the Sadah Area
Technical Annex 3: Hydrological Network
Mohamed Danikh and J.A.M. van der Gun, 1985
- WRAY-3.4 Water Resources of the Sadah Area
Technical Annex 4: Exploratory Borehole Programme
Van Overmeeren, R.A., 1986
- WRAY-3.5 Water Resources of the Sadah Area
Technical Annex 5: Geophysical Well Logging
Elewaut, E., 1985
- WRAY-3.6 Water Resources of the Sadah Area
Technical Annex 6: Aquifer Tests
Noori Gamal, J.A.M. van der Gun and Nabil Abdul Qadir,
1985

- WRAY-3.7 Water Resources of the Sadah Area
Technical Annex 7: Groundwater Availability
Elderhorst, W. and J.A.M. van der Gun, 1985
- WRAY-4 Water Resources of the Wadi Surdud Area
Main Report
Van der Gun, J.A.M., 1986
- WRAY-4 Water Resources of the Wadi Surdud Area
Main Report (Arabic)
Van der Gun, J.A.M., 1986
- WRAY-4.1 Water Resources of the Wadi Surdud Area
Technical Annex 1: Geo-Electrical Investigations
Van Overmeeren, R.A., 1985
- WRAY-4.2 Water Resources of the Wadi Surdud Area
Technical Annex 2: Gravity Investigations
Van Overmeeren, R.A., 1986
- WRAY-4.3 Water Resources of the Wadi Surdud Area
Technical Annex 3: Seismic Refraction Investigations
Van Overmeeren, R.A., 1985
- WRAY-4.4 Water Resources of the Wadi Surdud Area
Technical Annex 4: Well Inventory Results
Noori Gamal, J.A.M. van der Gun, 1985
- WRAY-4.5 Water Resources of the Wadi Surdud Area
Technical Annex 5: Exploratory Borehole Programme
Van der Gun, J.A.M., 1985
- WRAY-4.6 Water Resources of the Wadi Surdud Area
Technical Annex 6: Aquifer Tests
Noori Gamal, J.A.M. van der Gun, 1986
- WRAY-4.7 Water Resources of the Wadi Surdud Area
Annex 7: Hydrological Network; Report WRAY-4.7
Mohamed Danikh and J.A.M. van der Gun, 1986
- WRAY-5 Water Resources of the Sadah Area
Hydrological Network, Progress Report 1985
Uil, H., 1987
- WRAY-6 Water Resources of the Wadi Surdud Area
Hydrological Network, Progress Report 1985
Uil, H., 1987

- WRAY-7 Water Resources of the Wadi Surdud Area
Exploratory Drilling Programme WRAY-4, 5
Uil, H., 1987
- WRAY-8.1 Water Resources of the Wadi Adhanah and Marib Area
Well Inventory Results, Interim Report
Abdul Aziz Ahmed, H. Uil, S. Vasak, 1988
- WRAY-8.2 Water Resources of the Wadi Adhanah and Marib Area
Hydrological Network, Interim Report
Mohamed Danikh, Noori Gamal, H. Uil, 1988
- WRAY-8.3 Water Resources of the Wadi Adhanah and Marib Area
Geophysical Investigations, Interim Report
Kool, J.P., 1987
- WRAY-9 Water Resources Upper Wadi Surdud Area
Reconnaissance Survey
Dufour, F.C., 1989
- WRAY-10 Water Resources of the Sadah Area
Hydrological Network, Progress Report 1986
Mohamed Danikh and H. Uil, 1988
- WRAY-11 Water Resources of the Wadi Surdud Area
Hydrological Network, Progress Report 1986
Mohamed Danikh and H. Uil, 1988
- WRAY-12 Water Resources of the Sadah Area
Hydrological Network, Progress Report 1987
Mohamed Danikh and H. Uil, 1988
- WRAY-13 Water Resources of the Wadi Surdud Area
Hydrological Network, Progress Report 1987
Mohamed Danikh and H. Uil, 1988
- WRAY-14.1 Overview of the Hydrological Networks
Negenman, T. and G. Verbeek, 1990
- WRAY-14.2 Hydrological Networks; Automatic Rainfall Monitoring
Stations:
Manual
Heynert, K.V., 1989
- WRAY-14.3 Hydrological Networks; Automatic Groundwater Monitoring
Stations:
Manual
Heynert, K.V., 1989

- WRAY-14.4 Hydrological Networks; Automatic Meteorological Stations;
Manual
Heynert, K.V., 1989
- WRAY-14.5 Hydrological Networks; Automatic Wadi Stations (Surdud & Adhanah); Manual
Abdullah Saleh, Mohamed Danikh and G. Verbeek, 1990
- WRAY-14.6 Hydrological Networks; Automatic Marib Dam Station;
Manual
Abdullah Saleh, Mohamed Danikh and G. Verbeek, 1990
- WRAY-15 Water Resources Wadi Adhanah and Marib Area
Main Report
Uil, H. and Dufour, F.C., 1990
- WRAY-15.1 Water Resources Wadi Adhanah and Marib Area
Geophysical Investigation; Technical Report
Kool, J.P., Ali Ahmed Athari, Abdullatief Hassan Saeed, Khaled Mohammed Alshehari, 1989
- WRAY-15.2 Water Resources Wadi Adhanah and Marib Area
Well Inventory Results; Technical Report
Uil, H. and S. Vasak, 1989
- WRAY-15.3 Water Resources Wadi Adhanah and Marib Area
Hydrological Networks; Technical Report
Heynert, K.V. and H. Uil, 1989
- WRAY-15.4 Water Resources Wadi Adhanah and Marib Area
Aquifer Tests; Technical Report
Verbeek, G., 1990
- WRAY-15.5 Water Resources Wadi Adhanah and Marib Area
Exploratory Drilling Program; Technical Report
Noori Gamal and Ali Saad Atrous, 1989
- WRAY-15.6 Water Resources Wadi Adhanah and Marib Area
Sediment Transport and Accumulation; Technical Report
Nio, S.D., 1989
- WRAY-15.6a Depositional System of the Wadi Adhanah Catchment Area;
A Preliminary Report
Nio, S.D., 1988

- WRAY-15.7 Water Resources Wadi Adhanah and Marib Area
Numerical Modelling of the Groundwater-Flow System in
the Marib Basin; Technical Report
Verbeek, G. and C. te Stroet, 1990
- WRAY-16 Water Resources of the Sadah Area
Hydrological Network, Progress Report 1988
Mohamed Danikh and G. Verbeek, 1991, (in preparation)
- WRAY-17 Water Resources of the Wadi Surdud Area
Hydrological Network, Progress Report 1988
Abdullah Saleh and G. Verbeek, 1991, (in preparation)
- WRAY-18 Water Resources of the Wadi Surdud Area
Hydrological Network, Progress Report 1989
Abdullah Saleh, Ahmed Asshami and G. Verbeek, 1991, (in
preparation)
- WRAY-19 Water Resources of the Sadah Area
Hydrological Network, Progress Report 1989
Mohamed Danikh and G. Verbeek, 1991, (in preparation)
- WRAY-20 Water Resources Wadi Adhanah and Marib Area
Hydrological Network, Progress Report 1989
Abdullah Saleh and G. Verbeek, 1991, (in preparation)
- WRAY-21 Numerical simulation of salt water upconing and salt
water intrusion in the Wadi Surdud Area
Elderhorst, W.J.M., 1991, (final version in preparation)
- WRAY-22 Pilot study water resources management Wadi Surdud
Van der Gun, J.A.M. and H. Wesseling, 1991

APPENDIX 2

GDWRS-TEAM OF WRAY-2 (1985-1986)

APPENDIX 2: GDWRS-team of WRAY-2 (1985-1986)

| | | |
|-----|------------------------|-----------------------------------|
| 1. | Ahmed Wahib | Co-manager |
| 2. | Mohamed Danikh | Chief hydrologist (on fellowship) |
| 3. | Gazi Thabet | Hydrogeologist |
| 4. | Ali Atroos | Hydrogeologist |
| 5. | Noori Gamal | Hydrogeologist |
| 6. | Abdul Latif Hassan | Geophysicist (on fellowship) |
| 7. | Mohamed Assabahi | Geophysicist |
| 8. | Mohamed Abdul Hamid | Geophysicist |
| 9. | Khaled Ashahari | Geophysicist |
| 10. | Addel Derhem | Geophysicist |
| 11. | Abdul Aziz Ahmed | Hydrologist |
| 12. | Ali Al Hamadi | Hydrologist |
| 13. | Abdul Rahman Abdulah | Driller |
| 14. | Saad Saleh | Hydrological Technician |
| 15. | Mohamed Nassiri | Hydrological Technician |
| 16. | Fuad Al Kabir | Hydrological Technician |
| 17. | Abdul Ela Al-Arasi | Hydrological Technician |
| 18. | Nabiel Abdul Kadir | Hydrological Technician |
| 19. | Abdul Aziz Hussein | Hydrological Technician |
| 20. | Ali Shamsan | Hydrological Technician |
| 21. | Ahmed Abdu Saef | Hydrological Technician |
| 22. | Mohamed Al-Fakeh | Geophysical Technician |
| 23. | Kennedy Kassim | Geophysical Technician |
| 24. | Aidroos Ahmed | Geophysical Technician |
| 25. | Jamal Zaifalla | Geophysical Technician |
| 26. | Wadea Abdu | Geophysical Technician |
| 27. | Abraham Ali Saef | Helper |
| 28. | Ahmed Addahbaly | Helper |
| 29. | Sulaiman | Accounter |
| 30. | Isam Al-Kabeer | Administrator |
| 31. | Tahir Ali Musleh | Mechanic |
| 32. | Abdul Hakim | Driver |
| 33. | Saleh Al-Koal | Driver |
| 34. | Ahmed Al-Hoashaby | Driver |
| 35. | Nabil Saef | Driver |
| 36. | Saeed Abdul-Waly | Driver |
| 37. | Yahya Al Kibsi | Processing Technician |
| 38. | Hail Abdullah | Cook |
| 39. | Abdu Abbas | Cleaner |
| 40. | Ahmed Al-Arramy | Watchman |
| 41. | Hamida | Draughtswoman |
| 42. | Fatima Ahmed Al-Seyary | Typist |

APPENDIX 3: GDWRS-team of WRAY-3 (1986-1989)

| | |
|-------------------------|--|
| Ahmed Wahib | Co-manager/General Director till February '89 |
| Mahmood Al Udaini | Co-manager/General Director from Febr. '89 onwards |
| Mohamed Danikh | Hydrologist/Director surface water department |
| Ali Saad Atrous | Hydrogeologist/Director groundwater department |
| Ali Al-Thary | Geophysicist/Director geophysics department |
| Gazi Thabet | Hydrologist |
| Abdul Aziz Ahmed | Hydrologist |
| Abdulla Saeff | Hydrologist |
| Noori Gamal | Hydrogeologist |
| Abdul Khalek Albarakani | Hydrogeologist |
| Amin Mahjub | Hydrogeologist |
| Ali Kassim | Hydrogeologist |
| Ahmed Ali Ashami | Hydrogeologist |
| Abdullatif Hassan | Geophysicist |
| Mohamed Asbahi | Geophysicist |
| Khalid Al Shehari | Geophysicist |
| Abdul Haveth | Geophysicist |
| Yahya Al Kibsi | Geophysicist |
| Abdul Rahman Abdulah | Drilling supervisor |
| Nabil Abdul Kader | Database |
| Abdul Kader Ali | Database (employed by WRAY) |
| Faysal Hazza | Database |
| Basma Al Qubati | Database |
| Mohamed Ali Abdu | Database (employed by WRAY) |
| Ahmed Fara | Geologist |
| Saad Saleh | Hydrological Technician/accountant |
| Mohamed Nassiri | Hydrological Technician |
| Fuad Al Kabir | Hydrological Technician |
| Abdul Aziz Hussein | Hydrological Technician |
| Ahmed Abdu Saef | Hydrogeological Technician |
| Abdul Karim Al Natari | Hydrogeological Technician |
| Wadea Rashid | Hydrogeological Technician |
| Mohamed Al-Fakeh | Geophysical Technician |
| Kennedy Kassim | Geophysical Technician |
| Aidrous Ahmed | Geophysical Technician |
| Abraham Ali Saef | Technician |
| Abdu Al-Arramy | Technician |
| Taher Ali Musleh | Mechanic |
| Ahmed Addahbaly | Assistant Technician |
| Fatima Ahmed Al-Seyary | Typist |
| Ahmed Al-Hoashaby | Driver/Technician |
| Abdul Hakim | Driver |
| Saleh Al-Koal | Driver/Technician |
| Saeed Abdul-Waly | Driver |
| Ali Ushaish | Driver |

| | |
|-----------------|------------------------|
| Abdul Bari | Driver |
| Hail Abdullah | Cook |
| Abdu Ali | Cook |
| Abdu Abbas | Cleaner |
| Ahmed Al-Arramy | Watchman |
| Mohamed Sharaf | Administrator |
| Mukbil Ali Abdu | Accountant (1986-1987) |

Dutch team of WRAY-2 and 3 (1985-1990)

Residents:

| | |
|------------------|-----------------------|
| F.C. Dufour | co-manager |
| K.V. Heynert | hydrologist |
| J.P. Kool | geophysicist |
| W.M.J. Luxemburg | database |
| P.S. Nota | database |
| H. Uil | senior hydrogeologist |
| G. Verbeek | geohydrologist |

Non-resident:

| | |
|--------------------|--------------------|
| J.A.M. van der Gun | project supervisor |
|--------------------|--------------------|

APPENDIX 4: Realized training program WRAY-2 & 3 (1985-1990)

| Subject | Organisation/ Country | Number | | Year |
|-------------------------------------|--------------------------|---------|-------|-------|
| | | Persons | Weeks | |
| Hydrology | IHE/Netherl. | 1 | 48 | 85/86 |
| Geophysics | ITC/Netherl. | 1 | 48 | 85/86 |
| Geophysics | ITC/Netherl. | 1 | 48 | 86/87 |
| Hydrogeology | ITC/Netherl. | 1 | 48 | 86/87 |
| Hydrogeology | ITC/Netherl. | 1 | 48 | 87/88 |
| Hydrogeology | ITC/Netherl. | 1 | 48 | 88/89 |
| Hydrogeology | ITC/Netherl. | 1 | 48 | 89/90 |
| PC Application | MDF/Netherl. | 1 | 3 | 87 |
| Proj. Management | MDF/Netherl. | 1 | 8 | 88 |
| Reporting | MDF/Netherl. | 9 | 4 | 88 |
| Instrumentation 1 | TNO/Netherl. | 7 | 2 | 88 |
| Instrumentation 2 | TNO/Netherl. | 7 | 2 | 89 |
| Autocad Softw. | Comp.Cent./Neth. | 3 | 3 | 89 |
| Syst. Analyses | Bournemouth/UK | 1 | 8 | 89 |
| Satel. Image Int. | TNO/Kenya | (3+1) | 3 | 86 |
| Data coll. pres. interpr. | TNO/Sudan | 5 | 3 | 86 |
| Reporting | Brit.Counc./YAR | 10 | 4 | 85 |
| Instr.Maint. | TNO/YAR | 4 | 3 | 85 |
| Instr.Maint. | TNO/YAR | 3 | 3 | 86 |
| Instr.Maint. | TNO/YAR | 3 | 2 | 87 |
| Instr.Maint. | TNO/YAR | 3 | 3 | 88 |
| Instr.Maint. | TNO/YAR | 6 | 4 | 89 |
| Airphoto/Satel. Interpret. (1) | ITC/YAR | 10 | 2 | 88 |
| Interpret. (2) | ITC/YAR | 10 | 3 | 89 |
| Pumping Tests | TNO/YAR | 2 | 6 | 88 |
| Aquifer Model. | TNO/YAR | 4 | 4 | 88 |
| Database Managem. | TNO/YAR | 2 | 2 | 88 |
| Drilling, Compl. Well test | TNO/YAR | 2 | 2 | 89 |
| Invent. & store keeping | TNO/YAR | 1 | 3 | 89 |
| Model. for water res. management | TNO/YAR | 10 | 2 | 90 |

Besides the above listed fellowships, training programs and short courses special attention has been given to improve the active knowledge of the **English language**. An average of three employees of the GDWRS has been permanently present at English language training programs of the British Council at Sana'a from January 1986 onwards.

Besides the standard 'on the job' training, special attention has been given to make the staff and technicians of the GDWRS familiar with:

- * Digital automatic data recording systems (Omnidata)
- * Data storage and retrieval on computers
- * Filing of data (emphasis on data related to local investigations)
- * Software packages (wordstar, word perfect, autocad, lotus)
- * WILD positioning system (incl. Distomat system)
- * Electro Magnetic field techniques and interpretation.

APPENDIX 5 Visiting supporting experts WRAY-2 and 3

| Project | Supervision and Management support |
|----------------|---|
| 1985 | 14/09 - 07/10 26/10 - 15/11 |
| 1986 | 24/01 - 31/01 24/05 - 06/06 15/11 - 03/12 |
| 1987 | 21/02 - 16/03 25/10 - 09/11 |
| 1988 | 21/03 - 16/04 08/09 - 01/10 |
| 1989 | 26/01 - 12/02 03/02 - 08/02 07/03 - 23/03 23/05 - 02/06 06/10 - 21/10 |
| 1990 | 17/01 - 12/02 |

Technical support

| | | |
|---------------|---------------|---|
| 1985 | 16/11 - 07/12 | equipment maintenance |
| 1986 | 15/06 - 12/07 | geoph. invest. Marib |
| 1987 | 17/01 - 03/02 | eval.autom. data recorder systems |
| | 21/02 - 16/03 | field survey Upper Wadi Surdud |
| | 30/09 - 14/10 | equipment mainten./training/well log |
| | 06/10 - 06/11 | interim reporting geophysical invest. |
| | 11/10 - 20/11 | interim reporting well inventory |
| | 01/12 - 22/12 | instal.autom. streamflow recorders |
| 1988 | 30/01 - 12/02 | drilling supervision |
| | 09/02 - 22/02 | equipment maintenance |
| | 13/03 - 25/03 | equipment maintenance |
| | 24/03 - 26/04 | formulation proj. proposal WRAY-4 and support to ERADA/MAF |
| | 02/07 - 22/07 | database |
| | 03/07 - 22/07 | sediment transport and accumulation-1 |
| | 20.08 - 02/09 | database managm. (combin. with YEPIC) |
| | 03/09 - 25/09 | air photo/satel.image interpretation-1 |
| | 04/10 - 20/11 | pumping tests (field oper.& interpr.) |
| | 1989 | 17/01 - 07/02 |
| 28/01 - 21/02 | | drawing geoph. report |
| 14/02 - 04/03 | | drilling, completion, well testing |
| 18/02 - 11/03 | | sediment transport and accumulation-2 |
| 21/02 - 18/03 | | modelling Marib aquifer |
| 13/06 - 10/07 | | equipment mainten./training mainten. Omnidata instruments |
| 04/11 - 02/12 | | inventory and store keeping of equipm |
| 18/11 - 23/12 | | development of a plan for improvement of Information Management System |
| 26/11 - 16/12 | | air photo/satel.image interpretation-2 |

| | | |
|------|---------------|---|
| 1990 | 02/05 - 24/05 | pilot study water resources management Wadi Surdud |
| | 09/05 - 19/05 | modelling for water resources management |
| | 13/05 - 21/05 | support WRAY-4 project manager |
| | 2/10 - 26/10 | pilot study water resources management Wadi Surdud |

APPENDIX 6 Summary of the Dutch budget and expenditures for the combined WRAY-project phases 2 and 3 (1985-1990)

| | Budget (x 1000 Dfl) | Expenditures (x 1000 Dfl) |
|-------------------------|------------------------|------------------------------|
| Personnel costs | 3318 | 4043 |
| Special costs residents | 350 | 317 |
| Transfers & transport | 455 | 368 |
| Housing & living costs | 1330 | 801 |
| Reproduction | 100 | 115 |
| Subcontracting 1) | 1416 | 1219 |
| Miscellaneous | 175 | 137 |
| Equipment | 1263 | 1153 |
| Operational costs | 230 | 893 |
| Training | 250 | 454 |
| Contingencies | 613 | - |
| Total amount | <u>9500</u> | <u>9500</u> |

- 1) Excluding an amount of YR 1,106,000 transferred from the drilling budget of WRAY-1. This amount was entirely spent to the boreholes WRAY-4 and WRAY-5 in the Tihama (Wadi Surdud).

APPENDIX 7 Summary of a part of the Yemeni budget and expenditures for the WRAY-project phases 2 and 3 (1985-1990)

WRAY-3, period 1.1'87-1.9.'89 only

| | Budget (x 1000 YR) | Actual expenditures (x 1000 YR) |
|--|-----------------------|------------------------------------|
| Total (including operational cost and contingencies) | 16271 | 8126 |
| Operational cost (appr.) | 4117 | 1173 |

APPENDIX 8 Program of the symposium on "Water Resources Assessment Yemen Arab Republic", 26-27 January 1986, Sheraton Hotel, Sana'a

S Y M P O S I U M
WATER RESOURCES ASSESSMENT YEMEN ARAB REPUBLIC

Presentation of results of the first phase (1982-1985) of a technical co-operation program between the Yemen Arab Republic and the Kingdom of the Netherlands

Organised by: the General Department of Water Resources Studies

P R O G R A M

Sunday 26 January 1986

09.00 Coffee/tea

09.30 Opening

-welcome by the Director General of the Geological Survey Authority

-speech by the Minister of Petroleum and Mineral Resources

-speech by the Chargé d'Affaires of the Embassy of the Kingdom of the Netherlands

-speech by the Prime Minister

10.20 Summary of activities and results of WRAY-1
(Ahmed Wahib, General Director GDWRS)

10.30 Break

10.45 Water resources investigations, development and management in the YAR
(Gerard F.J. Jeurissen, supervisor WRAY)

11.15 Water resources assessment studies Sadah and Surdud
(Ronnie van Overmeeren)

12.00 A national information centre for water resources
(Jac van der Gun)

12.30 General discussion

Monday 27 January 1986

- 09.00 Hydrogeological investigations in the Sadah Basin
(Noori Gamal)
- 09.30 Geophysical exploration of the Sadah Sandstone Aquifer
(Ronnie van Overmeeren)
- 10.00 Analysis of groundwater management strategies by modelling the
Sadah Sandstone Aquifer
(Jac van der Gun)
- 10.30 Break
- 11.00 Development of the GDWRS database
(Philip Nota)
- 11.30 Hydrological observations in the Wadi Surdud area
(Jac van der Gun)
- 12.00 Integrated geophysical surveys in Wadi Surdud, Tihama
(Ronnie van Overmeeren and Khaled Ashahari)
- 12.30 Groundwater development potential and constraints in the Wadi
Surdud area
(Charles Dufour and Jac van der Gun)
- 13.00 Final discussion

Appendix 9 Program of the symposium on "Water Resources Assessment Yemen Arab Republic", 8-9 October 1989, Sheraton Hotel, Sana'a

S Y M P O S I U M

Water Resources Assessment Yemen Arab Republic

8 - 9 October 1989

Organised by the General Department of Water Resources Studies

Ministry of Oil and Mineral Resources

Sheraton Hotel

Sunday 8th October 1989

- 08.30 Coffee - Tea
- 09.00 Reception of guests of honour
- 09.10 Welcome
- 09.20 Role of water resources studies in the development of the YAR
... Ali Jabr Alawi (MOMR)
- 09.30 Role of WRAY project in the technical cooperation program of
the YAR and the Netherlands
A.A. Bartelink (Netherlands Embassy)
- 09.40 Role of the Technical Secretariat of the High Water Council in
the future water resources management of the YAR ... Abd. Karim
Al Fusail (T.S. High Water Council)
- 09.50 Developments and achievements of GDWRS through the WRAY-project
... Mahmood Al Udaini (GDWRS)
- 10.10 Coffee - tea
- 10.40 Groundwater management in Al Bayda Province, present situation
and future development.
R.J.J. Teunissen (RIRD)
- 11.10 Groundwater development in the Tihama Basin, the need for an
integrated approach
Yousuf Ali Al Mooji (TDA)
- 11.40 Geohydrological investigations in relation to long term
groundwater resources management aspects in the YAR
J.A.M. van der Gun (TNO/DGV)
- 12.10 Lunch

- 13.10 Hydrological observations in the Sadah and Wadi Surdud areas
(1982-1989)
Noori Gamal (GDWRS)
- 13.40 The Water Resources Information Centre at the GDWRS, achieved
results and future developments
W. Luxemburg/Abdul Latif Hassan
WRAY/GDWRS
- 14.10 Demonstration of software applications within the Information
Centre of GDWRS
Nabil Abdul Kader/Abdul Kader Ali (GDWRS)

Monday 9th October 1989

- 08.30 Coffee - Tea
- 09.00 The early assessment of the water resources for Marib Irrigation Project
R. Bonhage (Electro Watt Engineering)
- 09.30 Irrigation development in the Marib area within the framework of the Eastern Region Agricultural Development Project
P. Joardar/A. Girgirah (ERADA)
- 10.00 The Wadi Adhanah - Marib investigations of the WRAY-Project, planning, execution and results
F.C. Dufour (WRAY)
- 10.30 Coffee - Tea
- 11.00 Hydrological observations in the Wadi Adhanah catchment during the period 1986 - 1989
K.V. Heynert/Abdullah Saif
(WRAY/GDWRS)
- 11.30 The aquifer system of the Marib area, geophysical investigations and findings
Ali Al Thary (GDWRS)
- 12.00 The aquifer investigations of the Marib area, field tests and modelling
G. Verbeek/Ali Sadd Altroos
(WRAY/GDWRS)
- 12.30 Lunch
- 13.30 The water resources availability in the Marib area
H. Uil (WRAY)
- 14.00 The role of the High Water Council Project for Water Management Planning in the YAR
B.S. Hirzalla (UNDP)
- 14.30 Closing of the Symposium
Mahmood Al Udaini (GDWRS)