Certain aspects and problems of wadi development

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1. Introduction

The primary condition of agricultural production in semi-arid and arid areas all over the world is the provision of irrigation water. Rain-fed territories in such areas rarely produce enough to supply basic foodstuffs and animal fodder. The country's economy must strive to be self-sufficient by producing crops on irrigated areas or alternatively importing food. In developing countries this solution has limited possibilities.

In territories with sufficient water the problem is to utilize surface or groundwater rationally. Surface water may originate from ephemeral water courses, or from perennial ones. The discharge of these wadis varies and the most difficult task is to withdraw the total discharge during a given period and to hinder the partial inflow of water into the sea. The water of wadis rarely reaches the sea, however; it infiltrates to water-bearing layers while traversing the detrital cone of the wadi, so providing groundwater recharge.

Water abstraction from hand-dug wells employing ancestral methods made the over-exploitation of groundwaters almost impossible. Water infiltrating through the wadi-bed and irrigated surfaces assured replenishment of the ground-water removed from the wells. With the introduction of pumped deep wells the danger of water mining is now increasing. Prevention of this problem can be helped by introducing regulating measures, based on thorough analysis of wadi-hydrology. These measures must include water-law, construction of wells, water-rate, improvement in agricultural production, creation of a marketing agency for direction of production and marketing, etc. The modernization of traditional and out-of-date structures and equipment is also necessary.

2. The Wadi Zabid project, Yemen Arab Republic

2.1 Background

The project was established by the Food and Agriculture Organization of the United Nations and financed by the United Nations Development Programme (UNDP) Special Fund. A counterpart contribution was provided by the Kuwait Fund under a special agreement between the Yemeni Government and the Kuwait Fund. The project was completed within a three-year period, by the end of 1972.

Wadi Zabid is one of the seven major wadis draining the mountainous catchment areas down to the Tihama Plainland and flows approximately east-west. The project area lies in the eastern part of the Tihama plain which is located along the coast of the Red Sea. The nominal project area extends to 250 m^2. The irrigable area lies 100 to 250 m above sea level.

Findings of the studies carried out were summarized and evaluated in 12 technical reports for the first phase of the project, attached to a final report supported by an economic feasibility report in 1971, and in six reports for the second phase in 1972.

2.2 Soils

Soil surveys were made over an area of 20 100 hectares. The main findings were that: 44 percent of the area was covered by arid brown soils, 21 percent of the soil was wind-affected, only 50 hectares were salt-affected, and 6 percent was non-arable, wadi bed or inhabited. No class 1 lands were found in the project area; 50 percent belonged to Class 2 and 34 percent to Classes 3 and 4.

2.3 Climate

The project area lying within the Tihama Plainland has a tropical climate with characteristic summer rains and dry winters. Annual rainfall varies from 50 mm near the Red Sea coast to 300 mm on the foothills. The Wadi Zabid catchment area receives annual precipitation ranging from 500 to 1 000 mm.

The annual average temperature recorded near Zabid was 30.5°C, the maximum 43.6, and a minimum value of 15.0°C was measured in the FAO Camp in December 1970.

Annual sunshine duration totalled 2 760 hours in 1970. The unexpectedly low annual total was due to regular sandstorms in June and July in the early afternoon, with strong winds.

Relative air humidity values were an annual average of 65 percent with extremes of 15 and 98 percent. Maximum values occurred between 14 and 16 hours.

2.4 Population

The population of the project area in 1969-72 was about 60 000 of whom 15 000 reside in Zabid, 15 000 in different villages and the remainder, 30 000, in scattered settlements. Ninety percent of the population is engaged in

agriculture and the rest in trade and handicraft.

2.5 Flood irrigation systems and irrigation practice

In 1970 in the Wadi Zabid region an area of 16 900 hectares was installed for irrigation with wadi waters. The traditional system consisted of 16 main supply canals into which water from the wadi was diverted by means of deflectors or sometimes by dams crossing the wadi bed. These structures were made of earth reinforced with boulders and boughs or trunks usually poorly compacted. The construction method led to the structures often being damaged or completely destroyed by bigger floods and it was seldom possible to reconstruct them before the next spate.

In the main canals where the slope made it necessary, and between basins, drops were erected to slow down the flow velocity. Scattered over the irrigated area were a number of ancient structures, built of bricks baked on the spot. Several temporary earth structures were also used for distribution of irrigation water. They would be reconstructed nearly every year. The permanent structures (drops, spillways and certain intake tubes) were equipped with stop-logs to control water levels in the canals or basins. Stop-logs were usually unsatisfactorily used thus the water level could not be properly controlled, resulting in scours and washouts.

Within the Wadi Zabid area basin irrigation had been practised for centuries and water was distributed by a field-to-field method usually making temporary openings in the bunds bordering the irrigated basins. The basins were irregularly shaped and the bunds followed the contour lines. The size of the basins varied significantly.

The canals originate in the wadi bed nearly parallel to the course of the wadi and with a moderate slope until they reach the bank. Then they curve away from the wadi to act as irrigation canals in the fields. There are some secondary and tertiary canals as well. The total length of the main canal network is about 145 kilometres.

Cross sections of the main canals are usually oversized enabling them to receive and convey spate discharges of short duration. The upper canals branching out from the wadi stretch near the Maath Gorge have smaller capacities based on perennial water flow, while the downstream canals are large because they have to accommodate rare but sometimes enormous runoffs. Distribution of water should be effected during very short periods. The total conveyance capacity of the canal network amounts to 720 m^3/sec. Supposing 40 percent loss due to evaporation and seepage in the wadi bed downstream of Maath the constructed canals are able to carry floods of 40 percent probability.

As far as water rights are concerned, the Prophet declared the priority of higher lying areas over lower lying ones in diverting water from the wadi for irrigation. This is in force in all wadis in the Tihama. An exception is the Wadi Zabid region where a special water right was formulated approximately 500 years ago. This right makes maximum use of the base flow and periodic floods by means of a time and space relationship based on the experience of centuries. The areas served by the main canals were divided into three groups. The timing and frequency of water intake were defined for each group.

2.6 Alternatives for development of wadi irrigation

The problems of wadi irrigation were carefully surveyed and analyzed by TESCO-VIZITERV experts. Based on the project's findings and results obtained from several studies six alternatives supported by cost estimations were proposed.

2.6.1 *Alternative 1.* The principles upon which Alternative 1 has been based keep the present order and system of water distribution unchanged, i.e. the evolved main and secondary canals and the basin irrigation method and requires no essential alteration to the well established water rights. The concept was justified primarily by the fact that farmers had considerable experienced in its operation. It was deemed to be more reasonable to strengthen their knowledge and to improve their working conditions rather than to force them to switch over to new cultivation methods which would probably cause at least a temporary decrease in production.

However, in order to increase the income to the farmers and to improve overall living conditions it will be necessary to introduce advanced cultivation methods, improved seeds and other inputs such as fertilizers, pesticides, new plant varieties, and to construct new structures, and increase the present level of mechanization.

Alternative 1 includes the following proposals:

a) construction of ten permanent diversion structures across the wadi bed in sections where canal intake works can be erected possibly on both sides of the wadi;
b) bank protection works built to protect the intake reach of certain canals;
c) existing main canals remodelled by erecting new drops and control structures; and
d) construction of new roads and extension of certain existing ones to improve transport within the area.

The suggestions above are aimed primarily at improving water supply facilities first of all to the traditional temporary diversion structures and at saving high maintenance or reconstruction costs. However, even after the completion of new diversion structures some maintenance costs will still emerge, because the accumulation of silt and boulders in the wadi bed cannot be eliminated entirely due to its unstable character despite the provision of silt releasers on one or both sides of the weirs.

This programme relates to the immediate development of 14 000 hectares of land and was finally recommended as the first phase operation.

2.6.2 *Alternative 4.* An additional 2 000 hectares of land development and flood control up to 20 percent probability could be obtained by the implementation of Alternative 4 in combination with Alternative 1. Alternative 4 entails the construction of a spate-breaker type of dam at Kolah section and of a diversion structure at Maath. Two main canals running parallel to the wadi would be developed by connecting the initial reaches of the existing main canals while keeping further reaches of them as secondary canals

to be provided with distribution structures.

Construction of a spate-breaker at Kolah section would require modification in the water right because its operation would cause a time gap between the arrival of spate and utilization of the water and this would not be in accordance with the spirit of the ancient water right. However, operation of the 16 million m^3 capacity spate-breaker reservoir seems to be a precondition of replacing basin irrigation by furrow irrigation since the reservoir would be able to transform flood discharges into more steady flows.

Alternative 4 raises another question. Retaining floods in the Kolah reservoir would reduce seepage losses in the wadi which form much of the groundwater recharge of the delta area. Obviously this would be advantageous from an irrigation point of view but influence on groundwater development would need thorough investigation. Alternative 4 is therefore more appropriate in a later phase of development.

2.6.3 *Alternatives 2, 3, 5 and 6.* Four other technically feasible solutions were investigated but none of them could economically be justified because they would involve enormous expense.

2.6.4 *Agricultural and economic aspects.* The agricultural survey showed that in years with average floods most of the land was irrigated. In 1968 the aerial photos showed 11 600 hectares of spate irrigation (about 70 percent of the total). In 1970 the detailed survey showed 10 500 hectares of spate irrigation in the main season (more than 60 percent), and a further 650 hectares from the permanent flow beyond the well-irrigation in the lowest part of the system.

It is impossible to analyse the economic aspects of the project since the only available figures were 16 years out of date.

2.7 Conclusion

At the time of the project complete remodelling of the present system and practice was not considered to be financially feasible. However, improving critical points in the irrigation system to ensure better conditionos of water supply and distribution, thereby increasing agricultural production, was obviously necessary. This could be brought about by the implementation of Alternative 1 as a first phase and Alternative 4 at a later stage.

Meanwhile certain reconstruction works within the system were implemented and modifications made to the original recommendations. Details of these modifications are not known, nor whether the increased farm inputs and yields predicted have been obtained, owing to prevailing political and economic conditions at the time of construction. [Our experts could not participate in the work.]

However, we learned that certain difficulties arose in the distribution of wadi waters. We can only speculate on the reasons for this. We suggest that unsatisfactory operation may result from improper handling of structures or from arbitrary changes made to the irrigation schedule contained in the ancient water right. It must be emphasized again that this is only speculation.

3. The Wadi Hajr agricultural rehabilitation project, People's Democratic Republic of Yemen

3.1 Background

The Project Identification Report compiled by FAO appeared in February 1979 in which the objectives, potentialities and conditions of Meifa Hajr Agricultural Rehabilitation Project have been outlined. The Arab Fund for Economic and Social Development financed further planning work which has corroborated the conclusions of the Report.

The Ministry of Agriculture and Agrarian Reform (MAAR) PDRY signed an agreement between MAAR and the Hungarian TESCO-VIZITERV Consulting Engineering in May 1982.

Wadi Hajr is the only water course in the PDRY which in addition to regular but seasonal floods has continuous base flow throughout the year. This was the fact that prompted the decision to develop agriculture in this particular catchment.

The wadi drains a catchment area of about 9 160 square kilometres and flows approximately north to south.

3.2 Soils

About 30 percent of the soils of the Upper Hajr are silty loams. Near the wadi the loam is sometimes more than 2 metres deep while on the third terrace the underlying gravel appears on the surface. The other 70 percent of the soils on the higher terraces are shallow (10-15 centimetres deep) silty loams mixed with gravel and stone. Salinity problems are limited.

In the Lower Hajr subproject near the Bateis weir the cultivable profile consists of rough sand with a high gravel content, while the State Farm area is covered by sand with adequate drainage properties near the wadi bed. Further away the natural drainage is poor and about 80 percent of the land suffers from different degrees of salinity.

Only 4 percent of the soils surveyed belong to Class 2, while 25 percent were classified as Class 3 and 4. Thirty-nine percent of the land was tentatively qualified as non-arable, and 32 percent as unsuitable for cultivation. No Class 1 lands were found in the project area. Encroachment of sand dunes damaged considerable areas.

3.3 Climate

Long-term meteorological data specific to the Wadi Hajr area were not available. The nearest sources of data were Mukalla airport (75 kilometres to the north-east) and the El Kod Research Station (500 kilometres to the south-west). From this station a 13-year comprehensive data set was available and applicable to the project area.

3.4 Population

About 8 500 people live in the project area and neighbouring settlements. In the Upper Hajr district some 14 600 live in 27 settlements. A minority of the population is engaged in agriculture, working with cooperatives or state farms; the majority is employed in other activities outside the area or is considered to be unemployed. At the time of the project 432 people were employed in agriculture in the

Lower Hajr and some 2 000 in the Upper Hajr.

3.5 Irrigation systems and practice

3.5.1 *General.* Results of the hydrological study indicate that waters of the wadi available for irrigation, taking all losses into account, are sufficient for both of the subprojects even when irrigated fields are extended. In addition, in the Upper Hajr springs contribute to the discharge of the wadi downstream of Sidarah. However, a greater amount of base flow would be required for the next development phase. To determine the flow potential of the wadi is therefore essential and uninterrupted observation in the established hydrometeorlogical network should continue.

The quality of irrigation water is good even during periods of base flow.

Hydrological investigations proved that 3 m^3/s base flow for perennial irrigation in any month of the year is available at the present rate of water extraction in the Upper Hajr subproject. This amount of water is sufficient even when maximum utilization is achieved in the Upper Hajr. The perennial base flow of the wadi is sufficient to irrigate most of the potentially cultivable area of the Lower Hajr. The duration and frequency of floods are sufficient to carry out spate irrigation in the Lower Hajr. In order to bring an extended area into production spate discharges must be utilized.

There are two permanent diversion facilities and off-take structures for diverting water from the wadi. The first one at the Bateis canal head in the northern part was built in 1965 and rebuilt in 1978. This canal also carries spate waters occasionally to spate irrigated fields in the south-eastern part of the Lower Hajr. The second diversion structure is located at the Bahafid canal head diverting base flow for perennial irrigation. The Bateis overflow weir has intake structures on both sides and is in acceptable condition; however local erosions in the tailwater apron have to be filled up and repaired. The silt releasers and irrigation canal gates on both sides also need reconstruction.

With the 1982 floods the wadi cut a new course near Bahafid weir destroying one of the canals. In spite of this the Bahafid diversion weir is in acceptable condition but off-take gates have to be renewed and the crest of the dam requires minor repair.

Existing water management procedures have evolved to ensure equity in water distribution according to tradition and local custom. Water is applied according to its availability and experience and to crop and soil conditions either by flooding small basins or by furrows. Individual water applications of around 300 millimetres are delivered to the land before planting and further 100 millimetre applications during the growing season at approximately two week intervals.

Estimates indicate that rehabilitation and modification of the system will allow more efficient water utilization both for perennial and spate irrigation and that the total cultivated area could be increased by about 160 percent.

The method and practice of irrigation are based on farmers' experience and skills and require no essential alteration. A written water right similar to that in force in the Wadi Zabid region does not exist because of the sufficient availability of perennial waters. For distribution of irrigation water a timetable is used.

The drainage network has been only partly developed. Salt accumulation presents problems in the Lower Hajr. The State Farm drainage system does not function. The Cooperative's land irrigated from the Bateis weir has better natural drainage as a result of the wadi depth, and soils generally have better draining properties.

The Cooperative and the State Farm practice shifting cultivation, changing the fields from season to season, using mainly the irrigable fields with lower salinity.

Agricultural inputs (fertilizers) are limited and their application is often omitted to save expenditure. Seeds are obtained partly from local production (millet), and partly imported (eg. melon, egg plant). The level of mechanization needs improvement.

3.5.2 *Upper Hajr irrigation system.* Water from the wadi bed is diverted by 27 temporary diversion structures built in a similar manner to those in the Wadi Zabid. Often all of them are damaged or completely destroyed by floods. The initial sections of the main supply canals near the wadi bed need strengthening to eliminate further erosion.

Irrigation is managed by the Cooperative on 1 600 hectares out of the total 2 000 hectares. The State Farm operates on 10 hectares of land. Water distribution is performed according to the timetable and other rules decided by the Farmer's Board. Irrigation continues day and night and a farmer normally has three or more hours to irrigate his field. If he fails to make use of this opportunity he will lose his chance to water his trees until his next scheduled turn between about 30 to 50 days later.

A detailed investigation and survey of the existing irrigation and drainage networks is the current task of the project phase.

3.5.3 *Access road to the Upper Hajr area.* The road in its present state provides the only access to Jizwill, Al-Goal and Sidarah villages which are situated in confined valleys about 70 kilometres along the wadi course. The road serves a population of about 40 000 and a cultivated net area of 1 610 hectares.

The Ministry of Construction started road repairs but planning of the final improvements remains the task of the next project phase now in progress.

3.6 Development strategies for the Lower Hajr

Development strategies and detailed plans were elaborated for the Lower Hajr area only and they were included in the Tender Document. For the Upper Hajr certain recommendations were made concerning construction of permanent diversion structures and wadi bank protection. The layout of the irrigation scheme is shown in figure 1.

3.6.1 *Irrigation sub-system.* There are three irrigation subsystems to be developed within the Lower Hajr area, namely, the Bateis perennial system on the land of the Cooperative, the Bahafid perennial system and the Bateis spate irrigation system—both on the land of the State Farm.

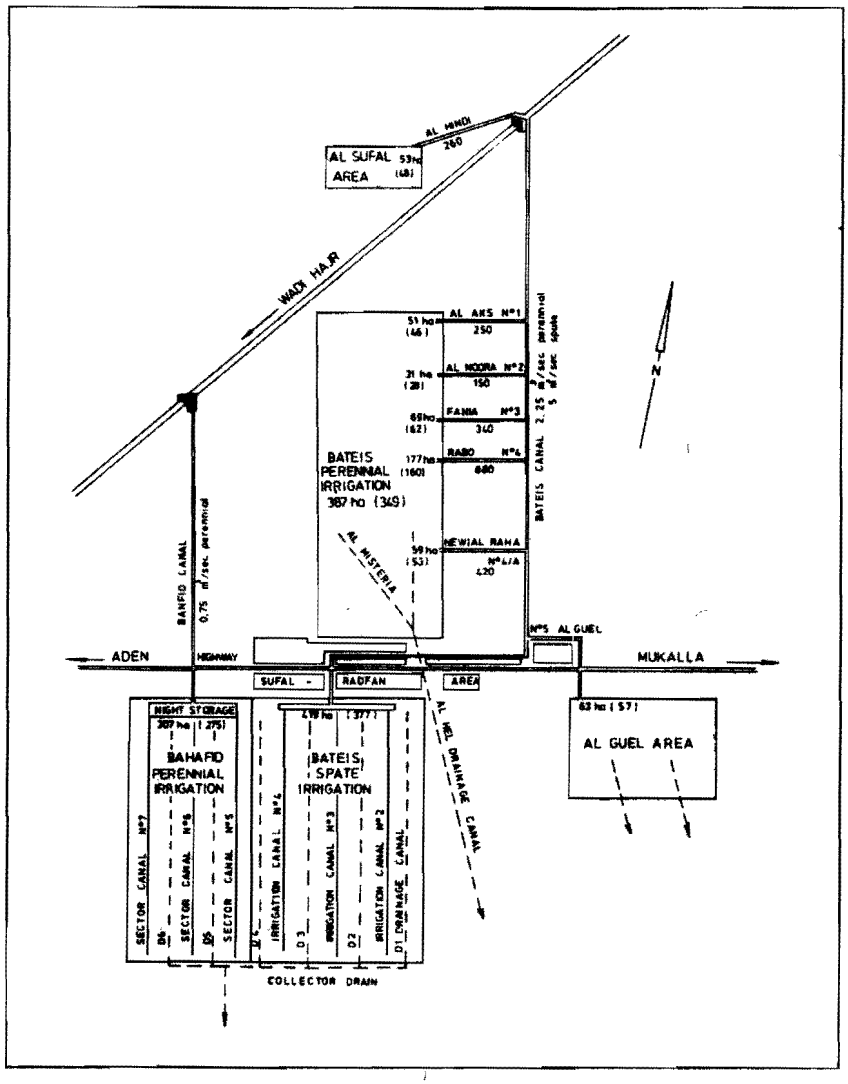

Figure 1 Irrigation scheme for the Lower Hajr

3.6.2 *Bateis perennial irrigation sub-system.* The Bateis main supply canal receives water diverted by an overflow type weir in the wadi bed and must be put in good operating condition to carry 5 m^3/s discharge for the spate system to be established. The same canal should be used for conveying 2.25 m^3/s base flow for the perennial system. Both discharges will be controlled by the Bateis main canal head regulator's gate. Spate discharges must be separated from the perennial system to avoid inundation of the latter through the off-takes to be built in the right hand dyke of the Bateis canal. This can be solved by devising structures provided with closing gates which shut off automatically if the water level exceeds the level pertaining to the discharge of 2.25 m^3/s. After the spate has passed the gates should be manually opened.

The gate of the head regulator of the Bateis canal should be replaced by a new sector gate opening adjusted to the flood water level so that not more than 5 m^3/s may enter the canal. The permanent diversion structure requires minor repairs.

In the spate irrigation system itself, covering 387 hectares, the main field canals need reconstruction in order to give them proper conveyance capacity. None of the irrigation canals requires lining.

New and supplementary drainage canals should be built. No alteration in present water distribution and irrigation methods (small basin) has been foreseen.

3.6.3 *Bahafid perennial irrigation sub-system.* Perennial waters for the Bahafid system are diverted by the permanent weir built across the wadi bed.

The Bahafid main canal will be developed for a continuous design flow of 0.75 m^3/s. This can be released day and night. The night quantity can be stored, thus the rate of irrigation water supplied to the system can be raised to nearly 1.5 m^3/s during day-time operation. Water accumulated during night filling can be released through sector offtake slide gates into the sector canals. Thereafter, opening the sector turn-out structures will guide water to the field canals and out into tertiary canals or directly into irrigation basins.

Neither irrigation canals nor the night storage system will be lined because in present conditions the high expense of lining could not be justified by attractive financial return. Essentially, development of the State Farm perennial irrigation sub-system means completion of the unfinished construction work initiated some years ago.

A drainage network (main collectors) is envisaged to be completed according to the original plans; however, construction of secondary drainage canals and land levelling is not included in the works financed by the project, but will be the responsibility of the Farm.

Upon completion of these works the Bahafid perennial irrigation system will be extended to a total area of 307 hectares.

3.6.4 *Al-Sufal and Al Guel sub-systems.* These sub-systems are not included in the financial plan of the project for economic reasons and are mentioned to indicate further possibilities of extension.

3.6.5 *Bateis spate irrigation sub-system* This sub-system is located in the south-eastern part of the Lower Hajr, in the area of the State Farm.

Construction of the spate system would mean a new development in the area and should be designed so as to cause as few operating problems for the farmers as possible.

We propose the following method of operation. The spate would flow into a distribution canal to be built at the upper end of the spate area. Slide gates in the offtakes of the distribution canal would direct the water to one or all of the three main canals along which basins have to be filled. At the basin the sector canal would be closed in advance by a temporary earth dyke and the basin's bund opened with simple tools.

The downward basin would be separated by a retaining bund from the previous one. As soon as the first basin was filled, flooding of the next would continue either by removal of the earth fill from the sector supply canal and repairing its embankment or through lined spillways in the bunds separating the basins over which the water would flow. In either case water cover of about 600 millimetres would be retained in the basins.

The second method fills the basins almost automatically. If none of the outlets of the distribution canal is opened or if spate arrives in excess, or if the basins are not yet prepared, the emergency weirs, each of 2.5 m^3/s capacity built in the distribution canal, would divert the water into the drainage canals and through them towards the sea.

This system would allow an area of 419 hectares to be irrigated by spates.

3.7 Organization

Formulation of agricultural policy and direction and supervision of agricultural production on a national level is the responsibility of the Ministry of Agriculture and Agrarian Reform (MAAR), Aden.

The Government establishes cooperatives and state farms and fixes the prices of agricultural production and inputs and marketed produce. Since 1970 almost all agricultural production has come from these organizations.

The El Kod Agricultural Research Centre is the national organization for agricultural research. Here the work is carried out in collaboration with FAO and other UN organizations. Extension services are provided by the El Kod Centre and by the directorates of MAAR in the Governorates, but their successful activity is limited by the number of experts available.

The cooperatives are managed locally, and the state farms are directly managed by the Ministry of Agriculture and Agrarian Reform.

Other supporting services and organizations for example, machinery renting stations, corporation for marketing fruits and vegetables, workshops, etc., also exist.

No essential modifications in the present organization were recommended except for the Lower Hajr area where merging of the Cooperative and the State Farm was suggested.

3.8 Agricultural development

Upon agreement between Government Representatives and consultants five development models were elaborated and investigated:

model I:	traditional crops and greater security of food supply with some marketable surplus from crops already familiar to the farmers;
model II:	production of locally well known fruits;
model III:	increased fodder production assuming an expansion of the poultry industry in the market region of Mukalla;
model IV:	cotton as a cash crop; and
model V:	livestock production with traditional crops.

Models IV and V were rejected because a) cotton is not attractive to local farmers because of its high production costs and low returns while labour for harvesting is difficult to find; further, all ginning and manufacturing facilities are located in the vicinity of Aden, thus transportation would be expensive; and b) there is no tradition of livestock production in the project area and high investment in stock and buildings would be required.

The criteria upon which the three remaining models were ranked were: crops proposed should be acceptable to local farmers; surplus crops in excess of subsistence should be readily marketable; potential markets for new crops should be identifiable; alternatives should take full account of the present state of social, institutional and technical development in the area and priority should be given to plants offering the most efficient utilization of natural resources and needing the least adjustment in social, technical and organizational conditions; crops proposed should suit local conditions with particular regard to soil salinity; implementation of proposals should be supported by infrastructural, agricultural and other technical services.

According to these criteria Model I with traditional crops appeared to be the most appropriate for the area.

3.9 Conclusion

This concise description of the rehabilitation project in the Wadi Hajr area was aimed primarily at technical and operational questions. The effectiveness and viability of the solutions applied in the development plan cannot yet be evaluated since the project is presently in its implementation phase.

Obviously the weakest points in the Upper Hajr are the diversion structures upon which the water supply of the date palm groves depends. The situation in the Lower Hajr is more favourable since the two diversion structures of the Bateis and Bahafid canals are of permanent character. They need only minor repair.

Solutions for water distribution in the Bateis and Bahafid perennnial systems seem to be proved in practice,

however, using night storage for the State Farm perennial system in order to increase the discharge available for daytime irrigation.

4. Summary

Comparison of the Wadi Zabid and Upper Hajr irrigation systems indicated certain similarities between the two in respect of both water resource utilization and irrigation methods. Both systems attempt to make full use of perennial flows. This applies particularly to the uppermost part of the Wadi Zabid system. Both systems utilize spate discharge to the fullest possible extent. However, lower parts of the Wadi Zabid area rarely or never receive either perennial waters or flood waters. Both projects struggle for more reliable water supply and the first problem to be solved is the replacement of temporary diversion structures by permanent ones. Improvement of presently used farm inputs and increase of the present mechanization level are required for both development plans.

While lack of irrigation water is a continuous problem in the Wadi Zabid, this problem is not the main restricting factor for the extension of cultivated land in the Upper Hajr. Therefore, planning of rehabilitation of the latter seems to be easier.

The two countries are governed by different political and economic systems. It is worthy of note that despite this fact, the development plans prepared for both countries considered retaining traditional cropping patterns and irrigation methods almost unchanged to be the most applicable. This decision was explained in detail in the relevant reports.

In the Lower Hajr project introduction of spate irrigation in the form of a well established system seems to be a new development, although spate irrigation is not unknown to the farmers in the area.

The intake of the Bateis supply canal conveying spate waters is far from the area to be irrigated and forecast of floods is unreliable. Furthermore, the same canal conveys perennial waters for the Cooperative perennial irrigation system. Thus separation of the two different flows in the Bateis canal was considered unavoidable. This was achieved by designing overflow type weirs for the spate system which increased the capital investment, but decreased the need for labour and diminished the probability of damage. In addition automatic but simple gates which close when the water level in the canal exceeds a certain level, were devised.

To automate the Bateis spate system further, tail-water regulators in all of the intake structures could be installed. This would require extremely careful maintenance which could not be expected in the near future and in addition far more capital investment. This alternative would only be appropriate in a later phase of development.

The components of development discussed in this paper relate primarily to technical aspects. However, it must be underlined that increasing farm inputs, ensuring systematic maintenance, organizing extension training courses for the farmers, making provision for skilled personnel, etc., are vitally important measures, on which the success of the projects depends.

Economic factors of course must be borne in mind, but since the international situation and political considerations affect them in ways beyond the control of those planning the projects, can only be regarded as a guide towards the goals to which investment should be directed.

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