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THE ROLE OF HYDROLOGY IN THE UNITED NATIONS WATER DECADE

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INTRODUCTION

P. SANTEMA

Water is essential for life. It makes up nine-tenths of the human body's volume and two-thirds of its weight. Without water, no one can survive for more than a few days. This vital element covers about three-quarters of the earth's surface. But 97.4 per cent is salt water in oceans; 1.8 per cent is frozen in polar regions. Fresh water, needed by human beings to sustain life, health and productive activities, constitutes only 0.8 per cent of the world's supply. Furthermore, part of this relatively small amount is contaminated.

For half the world's people - and three-fifths of those living in developing countries - reasonable access to a safe and adequate drinking water supply is still more a wish than a reality. As an answer to this problem the UN Drinking Water Supply and Sanitation Decade (1981-1990) was agreed upon during the United Nations Water-conference, held at Mar del Plata, Argentina in 1977. It was officially launched 10 November 1980, during the 3rd session of the UN General Assembly at New York. The decade can be regarded as an initiative of major importance which can mean a crucial change in the lives of many millions of people in the developing world.

The limited availability of fresh water, its uneven distribution over the earth's surface as well as the shortterm and longterm variations of the rainfall put the hydrologists in a special position. It is their task to indicate the possible resources for water supply for each individual case. Especially in developing countries this implies a challenge to develop suitable methods in this field of work.

The workshop on 'the role of hydrology in the U.N. Water Decade' endeavours to give a review of the present knowledge and experience in this field within The Netherlands.

THE REALITY OF THE WATER DECADE*

J. M. G. VAN DAMME

ABSTRACT

The Water Decade is an attempt of governments and United Agencies Organizations to take a major step in the provision of water supply and sanitation facilities to the millions of people who now lack these services. The paper starts off with explaining how the Decade resulted from a gradually growing awareness of the implications there of both in terms of health and other issues; this is being elucidated with tables.

In the attack of this complex problem new thinking on the required actionswas needed; the usefulness of the Decade in this respect is being discussed: such new developments as the required combination of water supply, sanitation and health education; more emphasis on social issues; and a distinction between support programmes and coverage programmes are briefly reviewed.

In spite of recent negative publicity the Decade can be regarded as a successful initiative. Arguments for this opinion are being given, along with some figures regarding the present situation of external financial support.

*) Official name:
International Drinking Water Supply and Sanitation Decade (1981-1990)

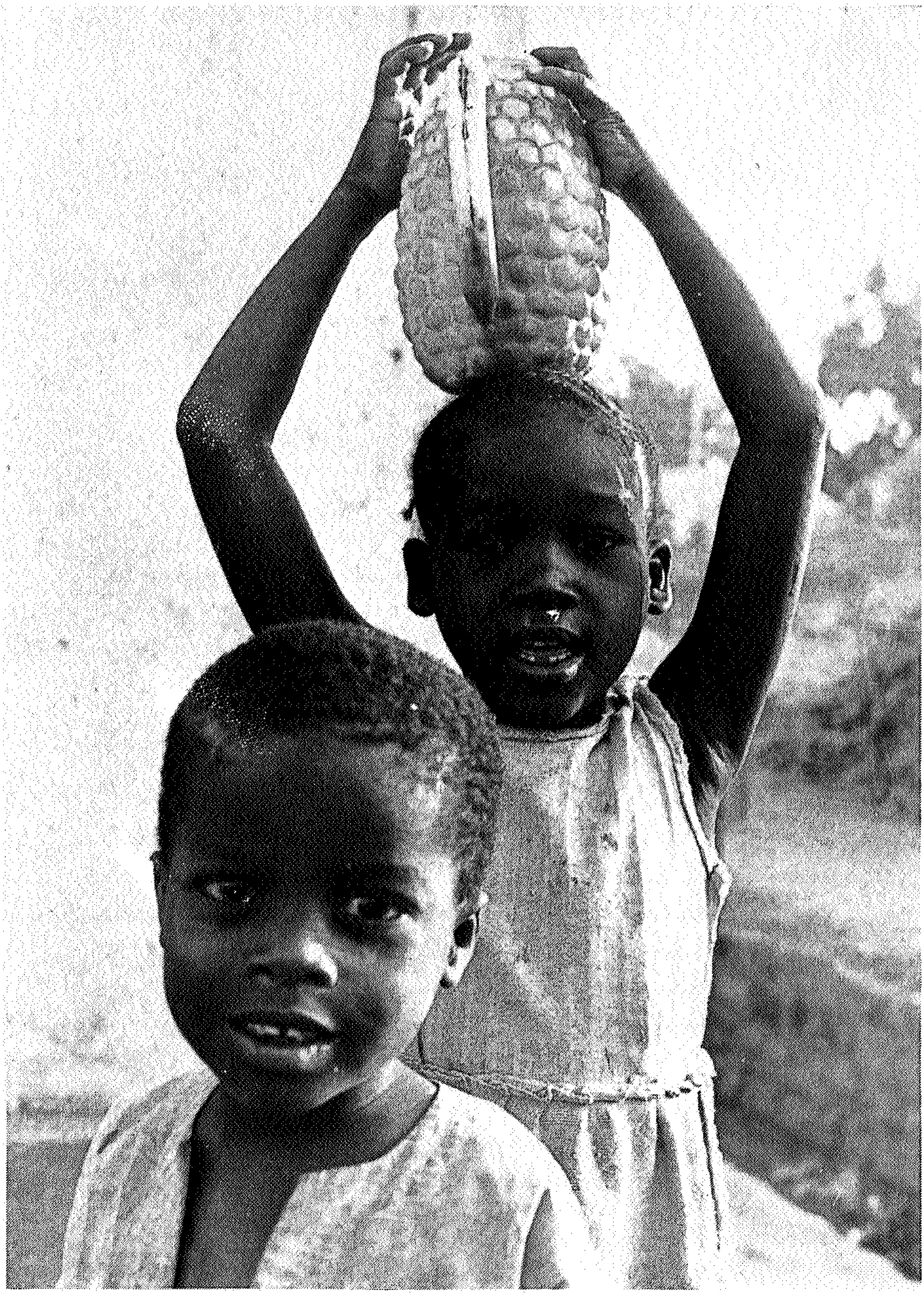

Figure 1 You cannot be young enough to starting to learn how to carry water. Bamako, Mali 1982. Photo: IRC - Toon van Dam

1 INTRODUCTION

The number of people in developing countries that must do without a proper daily supply of safe drinking water counts in the many millions. Basic sanitation is even less frequently available than safe water. The results of all this is that a large part of these millions suffers from water and excreta related diseases. Many people, and especially children, do not survive them.
Special attention for the drinking water supply and sanitation problems in developing countries started in the seventies. The UN Conference on Human Environment at Stockholm (1972) was the first to come forward with a public statement on the need of water and sanitation development: 'It is recommended that development assistance agencies should give higher priority to support Governments in financing and setting up services for water supply, disposal of water from all sources, and liquid waste and solid waste disposal and treatment. Habitat (UN Conference on Human Settlements, Vancouver, 1976) carried the message further by recommendation C 12: 'Safe water supply and hygienic waste disposal should receive priority with a view to achieving measurable qualitative and quantitative targets serving all the population by a certain date'. The year 1990 was specifically mentioned in the implied necessary actions. The UN Water Conference (Mar de Plata, 1977) recommended subsequently 'the Decade 1981-1990 should be designated the International Drinking Water Supply and Sanitation Decade and should be devoted to implementing the national plans for drinking water and sanitation'. A plan-of-action, contained in a specific resolution, worked this recommendation out in further detail. The Decade was proclaimed in November 1980 in a special session of the United Nations General Assembly. The objective is: 'Safe water and adequate sanitation for all by 1990, if possible'.

One might wonder whether the proclamation of an umpteenth decade is meaningful. I think that the answer is 'yes'. It needs to be considered that the Water conference and the Decade have not developed out of nothing. They are in fact carried by numerous officials and technicians in dozens of countries, the governments of which have agreed to prepare for the Decade and to implement it. It already begins to show that these

Table 1 Estimated service coverage for community water supply, 1970 and 1980 +)

Region	Urban population				Rural population				Total population			
	1970		1980		1970		1980		1970		1980	
	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)	%
Africa	24	67	44	72	27	13	61	23	51	21	105	32
Americas	122	76	167	75	29	24	52	37	151	53	219	60
South-East Asia	77	50	145	66	61	9	254	30	138	17	399	37
European	27	68	51	83	28	45	40	56	55	54	91	68
Eastern Mediterranean	52	79	74	79	26	19	54	32	78	38	128	48
Western Pacific	29	76	38	73	22	23	51	42	51	38	89	51
Total	331	67	519	73	193	15	512	32	524	29	1 031	44

+) Figures do not include China

Table 2 Estimated service coverage for sanitation (excreta disposal), 1970 - 1980 +)

Region	Urban population				Rural population				Total population			
	1970		1980		1970		1980		1970		1980	
	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)	%
Africa	17	48	28	46	48	23	37	14	65	27	65	20
Americas	121	75	120	54	28	23	34	24	149	53	154	42
South-East Asia	119	77	112	51	27	4	59	7	146	18	171	16
European	17	43	34	56	3	5	24	34	20	20	58	44
Eastern Mediterranean	41	62	54	57	17	12	22	13	58	28	76	29
Western Pacific	31	81	29	55	10	11	67	55	41	31	96	55
Total	346	70	377	53	133	10	243	15	479	27	620	27

+) Figures do not include China.

agreements are leading to results.

A good example of how meaningful such an endeavour maybe can be found in Latin America. In 1961 Governments of that region agreed in a conference at Punta del Este (Uruguay) to strive for water supply facilities for 70% of the urban and 12% of the rural population. This goal was indeed practically reached and several other initiatives led to additional results, in particular regarding training and education, financial systems and technology development. Essential elements for the success of this initiative, and this unvariably is also valid for the present Decade, were motivation, determination and co-operation.

The goal of the Water Decade is outright ambitious - as a goal should be. The numbers of people who will have to be served over the coming years can be derived from Tables 1 and 2 (taken from World Health Organization, 1983). The overall situation is that in developing countries approximately 70 % of those who live in rural areas, only 32% have access to reasonable safe water and 15% to sanitary excreta disposal facilities. Of the urban population, 73% have access to piped water (54% through house connections and 19% through standpipes) and 53% to sanitary excreta disposal facilities. These facts became even more dramatic when realizing that half the population of the world (excluding China) live in developing countries.

2 HEALTH AND OTHER RELATIONS

Every hour, between 1000 and 2500 Third World children under five die simply because they do not get clean water to drink or enough water to wash themselves properly. Every year, somewhere around 6 million children of the same age group die from diarrhoea. It is also known that as many as half of all the hospital beds in the world are occupied by people with water-borne diseases.

Table 3 (taken from United Nations Development Programme) presents a grouping of diseases related to water and excreta, and Table 4 gives figures for Africa, Asia and parts of Latin America in 1977-1978.

Table 3 Categories of diseases related to water and sanitation.

- *Water-borne diseases*

spread by drinking or washing hands, food or utensils in contaminated water, which acts as a passive vehicle for the infecting agent.

- *Water-washed diseases*

spread by poor personal hygiene and insufficient water for washing. Lack of proper facilities for human waste disposal is another contributing factor.

- *Water-based diseases*

transmitted by a vector which spends a part of its life cycle in water. Contact with water thus infected conveys the disease-causing parasite through the skin or mouth.

- *Diseases with water-related vectors*

contracted through infection-carrying insects which breed in water and bite near it, especially when it is stagnant.

- *Fecal disposal diseases*

caused by organisms that breed in excreta when sanitation is defective.

Table 4 Diseases related to water and sanitation; figures for Africa, Asia and Latin America (1977-1978)

	Infection	Infections thousands /year	Deaths thousands /year	Average no. of days lost per case	Relative disability +)
Water-borne diseases	Amebiasis	400,000	30	7-10	3
	Diarrhoeas	3-5,000,000	5-10,000	3-5	2
	Polio	80,000	10-20	3,000+	2
	Typhoid	1,000	25	14-28	2
Water-washed diseases	Ascariasis (roundworm)	800,000-1,000,000	20	7-10	3
	Leprosy	12,000	Very low	500-3,000	2-3
	Trichuriasis (whipworm)	500,000	Low	7-10	3
Water-based diseases	Schistosomiasis (bilharzia)	200,000	500-1000	600-1000	3-4
Diseases with water-related vectors	African trypanosomiasus (sleeping sickness	1,000	5	150	1
	Malaria	800,000	1,200	3-5	2
	Onchocerciasis (river blindness)	30,000	20-50	3,000	1-2
Fecal disposal diseases	Hookworm	7-9,000,000	50-60	100	4

Source: Julia A. Walsh and Kenneth S. Warren 1979

\+ 1 means the sufferer is bedridden,
2 able to function to some extent,
3 able to work,
4 experiences minor effects

Tables 5 and 6 (taken from Agarwal, 1980), putting these and other figures in perspective, speak for themselves.

Table 5 Estimated numbers of people suffering from water-related diseases

* 500 million people with trachoma (often causing blindness)
* 250 million people with elephantiasis
* 200 million people with bilharzia (snail fever)
* 160 million people with malaria
* 100 million people with diarrhoea (gastro-enteritis)
* 30 million people with onchocerciasis (river blindness)

Table 6 Alternative expression of tabel 5

* The entire population of non-communist Europe partly blind with trachoma
* Every citizen of the Soviet Union with the fat, swollen legs of elephantiasis
* The whole of the United States of America urinating blood from bilharzia
* Everyone in Japan, Malaysia and the Philippines sweating and shivering with malaria
* Almost everyone in Brazil aching and incapacitated with diarrhoea
* The total population of Iran sightless from river blindness

Table 7 puts the water health relation in positive terms. It indicates that water can have significant effects on several of the above-mentioned and other diseases if adequate water supplies for bathing, washing of clothes and cooking utensils, food preparation, and other hygienic purposes are available.

Table 7 Estimated proportion of preventable water-related diseases in East Africa in 1966

Diagnosis	Percent reduction expected if water supply were excellent
Guinea worm	100 %
Thyphoid	80
Urinary schistosomiasis	80
Leptospirosis	80
Trypanosomiasis, gambiense	80
Scabies	80
Yaws	70
Inflammatory eye disease	70
Schistosomiasis, unspecified	60
Trachoma	60
Bacillary dysentery	50
Amebiasis	50
Dysentery, unspecified	50
Tinea	50
Gastroenteritis, 4 wk to 2 yr	50
Gastroenteritis, over 2 yr	50
Skin and subcutaneous infections	50
Diarrhea of the newborn	50
Paratyphoid and other *Salmonella*	40
Louseborne typhus	40
Intestinal schistosomiasis	40
Ascariasis	40
Louseborne relapsing fever	40
Otitis externa	40
Classic skin (leg) ulcer	40
Trypanosomiasis, unspecified	10
Dental caries	10
Overall	52

Source: White et al., 1972

Figure 2 Isn't our pump a beauty? (Philippines)

There are several other implications of inadequate access to regular water supplies. It hardly needs argument that productivity and education are severely hampered if women or children have to fetch water daily over distances of up to 12 km, and if men, women and children are unfit for work or education, because of sickness. In many places lack of regular water supplies leads to a heavy burden on the already scarce financial means: water vendors are known to sell water (often of doubtful quality) for a price which is sometimes up to 100 times the price of water from a normal piped supply. In other places there are environmental implications. Overgrazing of cattle near wells in the sahel-area forms a disastrous contribution to deforestation.

A question often heard is whether better water and sanitation, leading to better health, not automatically also leads to population increase and thus increased hunger and poverty. The contrary is true: studies and experiences of all kinds support the fact that a lower mortality rate leads to a lower birth rate.

3 ACTION REQUIRED

There are as many Decades as there are countries and there are just as many different situations, requiring different approaches. There are no two countries alike, and there are no cut-and-dried approaches which can be universally applied. There are differences in climate, in stage of development, in political structure, in cultural setting, in population per unit area, in urban-rural ratio and in economic strength, to mention only a few. In terms of water supply and sanitationdevelopment these differences must firstly be reflected in the choice of technology - several other papers of this conference deal with this subject. Secondly the conditions in the countries concerned in a structural and institutional sense (e.g. manpower situation, potential involvement of the community, legislative arrangements, availability of data etc.) determine to a high degree the viability of technical projects. In many cases the conditions need to be improved before or at the time of the construction of facilities.

It is for this reason that the World Health Organization (1981) suggests that a distinction be made between coverage programmes and support programmes. Coverage programmes seek directly to extend coverage; for instance, by building rural water supply or water and sanitation facilities. Support programmes reduce constraints; for instance, if a government decides on a plan for the attainment of Decade targets in a large arid area of the country and a total lack of hydrological data makes it impossible to carry it out, a 3-year groundwater study may be required in support of the regional coverage programme.

WHO suggests that support programmes may be needed in the following areas, each country having to define needs and content according to the support required by its coverage programme:
- manpower development;
- communication and health education;
- community participation;
- information and technology;
- health and water-quality surveillance;
- groundwater studies.

The support programmes on groundwater should pay particular attention to: training of personnel; protection of aquifers against pollution; water conservation; and hydrogeological data.

The described development points in the direction of a need for programmatic, next to, or even instead of project wise approaches. Coverage programmes could according to WHO be directed to: rural areas; urban fringe areas (squatter settlements, slums, shanty towns); small and medium-sized towns; regions (large water catchment, river basins, geographical areas); as well as intersectorial action.

In the past, many well-meant initiatives have failed. Part of the reasons must be sought in the fact that projects were executed, for which the supporting conditions were lacking. In many cases too little attention was paid to the dependence of success; of other factors (such as revenue collection acceptability, maintenance opportunity, etc.). For contributions by organizations and people from outside the particular country (including e.g. international consultants), this implies that more than in the past the situation in the country needs to be taken as starting point of activities, which in turn must be characterized by a flexible approach. The success of the process rather than that of the directly visible result is the matter that counts. Especially transfer of knowledge and know-how is thereby of crucial importance.

It is now generally felt that the results of the 150 or so Decades in terms of health impact can only be significant if three elements water supply, sanitations, and environmental education, are dealt with simultaneously and co-ordinated. In terms of lasting effectively on the longer term, human resources development (including community involvement) and maintenance of installations are important. In terms of more value for the (scarce) resources, more emphasis on rehabilitation of decayed facilities is needed. From a water resources point of view the Decades in the countries do not so much have to contend with a quantity problem but partly with a distribution and partly a quality problem. These require effective organization and generous co-operation, two aspects which make the Decade efforts no less challenging than other efforts in our society.

4 STATE-OF-AFFAIRS

Much has been said, is being said, and will yet be said about the degree of success of the Decade and the chances of attainment of its goals. The Decade's success will be determined less by the number of taps and pumps, than by the ability in the countries to self reliantly construct, effectively maintain and adequately use them. From a development point of view it will than be less important whether in a given country the goal will be reached in 1990, 2000 or 2010. Obviously for many if not most countries, the last cited date will be nearer to the goal of 100% coverage than the former one. (Naturally from a human point of view this makes a dramatic difference for the people concerned unfortunately that sad fact cannot make the impossible possible.)

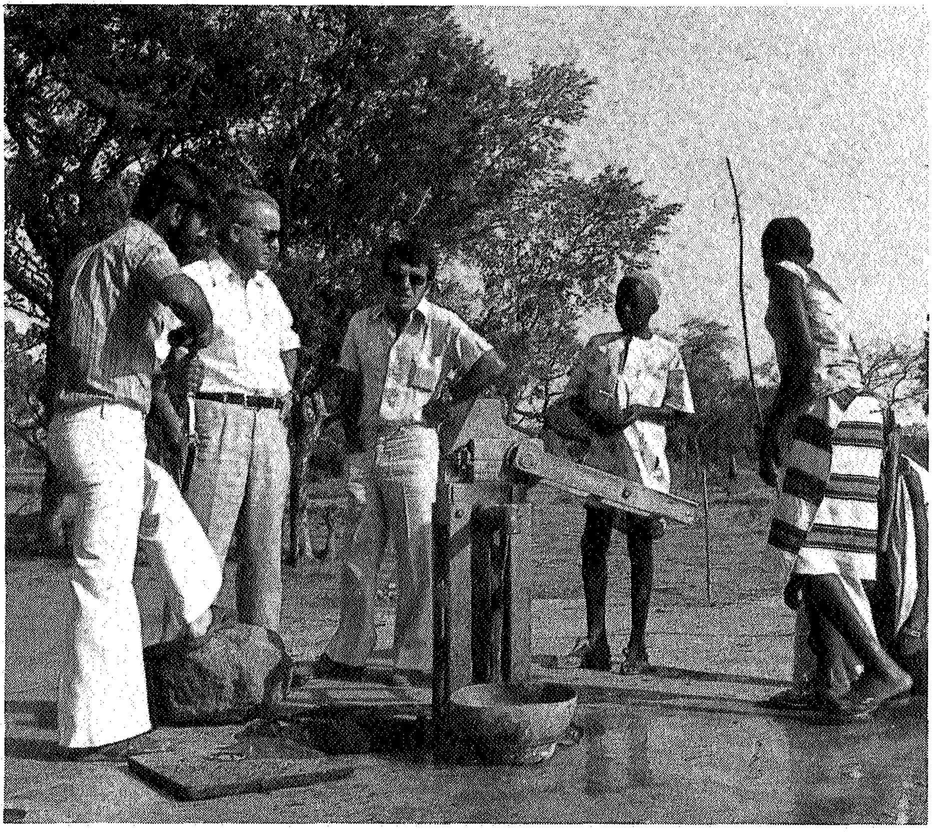

Figure 3 A new asset of the village; the Abidjan pump

Another often mentioned aspect is that less international funding is coming forward than was hoped for or expected a few years ago. This fact means different things to different people. We all know that this fact is heavily influenced by the present economic recession. There is, however, another side to this. All the money in the world could not have given water to all people, if the countries themselves would not take the leading initiative. The happy other fact now is that the majority of the developing countries take the Decade very serious and do take the matching initiatives. That in the long run will prove more important than a temporary increase of external funding. This is more so since first the countries are known to finance 2/3's or more of the needed expenditure from their own resources, and secondly the success of the programmatic approaches as indicated earlier in this paper are more influenced by commitment and initiative in the countries than by the amount of external funding.

It remains true, however, that in order to make significant progress on the short term, more money is needed than now is being allocated. But the actual situation is less discomforting than is often assumed. The facts are that there is a steady increase of internal funding in all developing countries for water supply and sanitation. Even the increase is increasing; the average increase for water supply in the eightees is 1½ times that of the seventies. The average increase for sanitation in the eightees is 9 times that of the seventies.

As far as external financial support is concerned, the World Health Organization (1983) reports that during the 1970s, assistance grew rapidly as a number of bilateral development support agencies and development banks took interest in the sector, e.g. the official development assistance (ODA) of the 17 bilaterals of the Development Assistance Committee (DAC) grew from an average of US $ 3555 million for the years 1971-'73 to 9965 in 1979, 11361 in 1980 and 11663 in 1981. Out of these average figures for sector distributed bilateral aid, the water and sanitation constitued 1-2 % in the beginning of the seventies but grew to an average of 6-7 % for the beginning of the Decade. Table 8 presents an overview of the current situation (World Health Organization, 1983).

Table 8 Distribution of external support in the first year of the Decade

	1970-1979	1980	1981
	(in millions of US Dollars)		
Bilaterals	2 419.0	715.3	803.5
Development Banks and Funds	2 200.0	450.0	500.0
World Bank	2 850.0	631.0	641.5
United Nations	370.0	145.0	150.0
Non-Governmental Organizations	300.0	110.0	130.0
	8 139.0	2 051.3	2 225.0

There are other positive signs. Recent estimates by the World Bank indicate that over 100 million people have benefitted from the provision of water supply and sanitation sources since the Decade started. In over 80 countries national action committees have been formed to specifically concern themselves with the sector and more than 60 countries have set specific targets; 50 of them have prepared concrete plans or are in the process of doing so. The Steering Committee for Co-operative Action for the Decade is developing into an action stimulating body which by some is being seen as a good example of adequate co-ordination among programmes of the United Nations Organizations.

The judgement of the present state-of-affairs depends on which questions are being asked. The most important ones seem to be:

- are better approaches being developed, leading to more lasting and used facilities?
- are the benefits of water and sanitation being more appreciated and are facilities more desired by the people concerned?
- do the countries assume more commitment regarding water and sanitation, including the allocation of internal resources?
- do international agencies and bilateral donors take an increased interest in the sector?

The overall assessment based on the answers will undoubtedly depend on who does the assessment. A point of fact is that the answer to all questions is 'yes', although 'yes' in varying degrees. There perhaps lies the danger. Developments and actions may show a positive trend, but maybe not be enough in the long run. The more reason to forcefully build on them. It is up to all of us whether the final judgement will lead to a selffulfilling prophecy uphill or downhill.

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HYDROLOGICAL PROBLEMS IN THE WATER DECADE-WATERWISE PLANNING

A. R. BERGEN

ABSTRACT

The aspects of the hydrological problems of the Water Decade are being detailed sub-sequently from source to consumer, taking into account the respective policy, priority, quantity and quality.
To arrive to a choice of source, local and regional characteristics such as climatology, ecology, society structure, morphology and geology should be considered thoroughly.
The hydrologist should be able to make an educated guess for the selection of suitable sources, or using appropriate algorithms, rather than absolute hydrological data, which are non-existent or incomplete in all developing countries.
Due to shortage of available funds (economic recession) and the lagging behind of human resources development, a pragmatic approach is being suggested for the first phase of the water supply in the Third World, according to appropriate (local) guidelines and reduced service level(s); thus reducing required investment costs.
At least operation and maintenance of the system should be paid by consumers, to prevent deterioration of the system soon after completion.
The UN Water Decade is doomed to failure, unless a more cost-effective approach will be acceptable. This should fit the local socio-economic and health circumstances, whilst sufficient individual domestic water supply should be preferred rather than drinkable water.

1 INTRODUCTION

The objective of the UN Water Decade 1981-1990 can only be realized if the Water Decade is reflected in the national development plans of the developing countries themselves and in the policies of the International Agencies (IBRD, ADB, UNDP, etc.) and the donor countries.

The hydrological problems of the Water Decade have to be traced back to national or even local circumstances. The national and local situations can be very divergent both from the view of hydrological (infra)structure and hydrological characteristics.

Generally it can be said that hydrology is the basis for every form of development, people settle near water, higher concentrations of people near rivers. Where there are people there is water, where more people settle, more water is required to maintain the livability.

The hydrological characteristics of the individual ecosystems involved, along with other factors, will define solutions within the framework of the aims of the Water Decade.

Where is the requisite water to be found? The availability still plays a central role. According to the discharge frequency curves of the river Rhine at Lobith, the discharge in a 2% dry year (approx. 1000 m^3/sec.) would be a sufficient quantity to cover the first phase of the additional requirements in the whole Third World.

Throughout the world as a whole there is sufficient water to meet human's need but unfortunately not always in the right place, at the right time or in adequate quantities.
How can the local availability of water be controlled so that the needs are fully met in a continuous supply?

In the Western World, the available water is predominantly used for agriculture, industry and production of energy and only a small proportion for domestic purposes. In the developing countries, most of the available water is used for agriculture, but the development of industry is extremely important in the framework of economic self-reliance (see Figure 1). However domestic watersupply, in spite of a small part of the total need, is of equal importance.

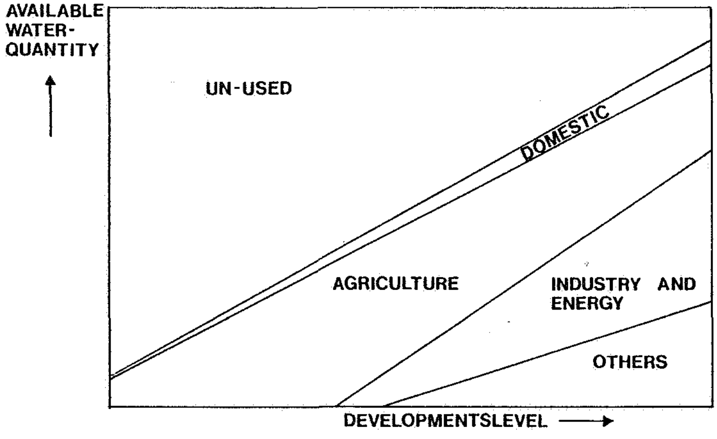

Figure 1 Developmentpattern of water consumption

Even if water is scarce, the domestic need for drinking, cooking and washing will always have to be met.

The redistribution of the available water or "socialization of water" will therefore be the primary consideration.

I have chosen the following scheme for the hydrological problems of the Water Decade (Figure 2).

In this lecture the inter-relationship between source and consumer as well as between consumer and source is illustrated exclusively from the hydrological viewpoint for watersupply and sanitation. For watersupplies we read the table from source to consumer. When considering the sanitation aspect, a source is created around the consumer leading to waste water, drainage and after waste water treatment finally back to a source.

The provision of watersupplies and sanitation is a iterative process for the physical as well as for the non-physical aspects; we will come back to that later.
The aspects of the hydrological problems of the Water Decade will be detailed subsequently, following the points introduced in the scheme.

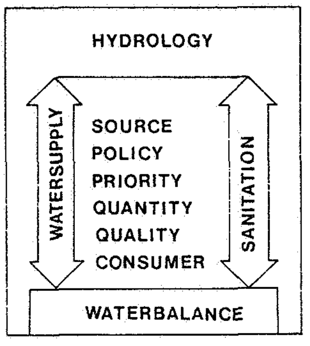

Figure 2 Watercycle

2 SOURCES

Which sources are locally or regionally available?

These sources are given in Table 1.

Table 1 Suitable sources

SOURCE \ SYSTEM	URBAN	SEMI-URBAN	RURAL
RAIN WATER	—	+	+
SURFACE WATER	+	+	+
GROUND WATER	+	+	+
SEA(BRACKISH)WATER	P.M.	P.M.	—

Rain water, in general, is probably not adequate as a source for urban watersupplies, although it can be used together with other sources, or as a real alternative in rural or semi-urban areas, when there is a lack of ground or surface water. Rain water systems are more cost-effective and appropriate to individual family dwellings or small communities.

Surface water systems have some negative points if used in rural situations. These are the need for treatment, operation and maintenance fully by skilled personnel and relatively costlier per cubic metre.

Groundwater is unquestionably preferable as a source for drinkingwater supplies.

Sea or brackish water is included for the record, but should be used only whilst lacking other sources.

In general it can be stated that data concerning rainfall, surface water discharges and groundwater bearing formations are either non-existent or incomplete in all developing countries. At the same time, the effort and money required for intensive studies or data collection are not available. A choice of source must however be made within a reasonable time span, in order to enable the realisation of project implementation for watersupply systems, within reasonable project planning time scales. To this end, the hydrologist, taking into account socio-economical, cultural, institutional, legal, political and environmental factors will have to make systematically a rapid analysis of the water problems identified within a defined area and make recommendations concerning the selections of sources. This should, if possible, be followed by a preliminary hydrological survey.
Information from the local population and their direct involvement in projects from the beginning, i.e. a "bottom-up" approach will simplify the task of the hydrologist. Monitoring and evaluating this information with modification where required will allow the hydrologist to make the right choice of source (educated guess). Depending on the scale of the watersupply system, the investments

involved and having made the choice between surface water or groundwater, the hydrological investigation will vary in depth.
Any treatment and intake works constructed, in most cases, need to be designed to meet the water demands of the population for the next 10-15 years, initial costs being high.
However for a normal groundwater system a more phased approach can be used for investment with phases of 1, 2 or 3 years. Therefore the choice of surface water as a source appears to be open to mistakes, more prone to modifications etc.
Lacking of geohydrological data in general, will favour an easy choice for surface water as a source.

To arrive at a choice of source, the following local and regional characteristics will have to be considered: (see Figure 3)

* climatology
* ecology
* society structure
* morphology
* geology.

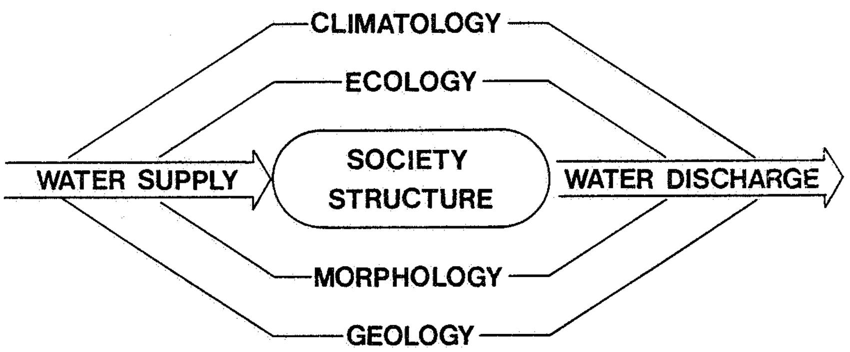

Figure 3 Scheme of the hydrological problems

2.1 Climatology

The basic water resource is rain. In humid areas the variations in quantity and time is small in comparison with that of the arid areas. The variation in mean yearly rainfall makes statistical analysis of rainfall data almost impossible in dry areas.

The mean annual rainfall varies from 500 to 1500 mm. For the Saharal region the rainfall is normally below 500 mm/year: (from 1968-1973 the rainfall varied from 100 to 600 mm per year, which caused excessive drying in the area).

In other areas of the world there may be no rain at all for one or more years. On the other hand, areas, where rainfall is excessive during a few months each year, are flooded e.g. Ganges, Indus and Mekong deltas in Asia.
With these two extremes, the possibility of using the rainwater as a source is limited. In some arid areas with high temperatures and relative low humidity, evaporation occurs at a higher rate than rainfall.
In Lac de Guiers in Senegal, there is a total depth of water of 3 m of which 1½ metres evaporates each year.
As the bottom of the lake is covered with one meter of silt, only 0,5 m of water remains available as a water source for Dakar.

2.2 Geology/morphology

The hydrological problems of an area are closely related to its geological, geohydrological and hydrogeclogical structures, from soft rock, limestone (karst) to hard rock, coastal plains to mountain region.

Although during the training of Dutch hydrologists and hydrogeologists, all these aspects are being studied, in a broad spectrum, there is generally little emphasis on practical experience in the field apart from in soft rock engineering. Even in soft rock areas the geological

situation can be very different from what we are used to in our delta areas, for example due to the presence of a lot of silt and clay, together with salt (brackish)-fresh groundwater.
Likewise in volcanic areas, there are often considerable amounts of heavy metals in the sub-soil, which will be apparent in groundwater analysis.
Also a high fluoride content in groundwater is quite normal.
In The Netherlands, apart from localised soil pollution, only iron, manganese ammonia, chlorides etc. are recognized within the groundwater.

Also because of build-up in surface drains, there are factors to which we are unaccustomed and the hydrologist is failed or unable to find a solution.

The hydrographic pattern of flood streams can comprise peaks and extreme seasonal effects. Consequently the hydrologist is using calculated guess work rather than absolute data.
The hydrologist should be able to make an educated guess or using appropriate algorithms.

2.3 Ecology

The local, regional and international ecology is affected by both natural phenomena and also by human's activities.

Soil erosion has extremely increased in the Sahel due to the drought; this, in turn, leads to the formation of deserts. The process is speeded up by large scale programmes for well boring. The previously nomadic people remain close to the wells for longer periods causing over-population and over-grazing. Exhaustion and erosion of the soil follow rapidly, hastening the deterioration to desert conditions.

Tropical rain forests govern ecological conditions on a world's scale. The ecological balance is therefore threatened by deforestation due to uncontrolled felling of trees, a consequence of the increase in population and the corresponding increase in demand for food, wood for fuel and charcoal (energy supplies).

It is estimated that in the year 2000 half of the world's forests will have disappeared.

In industrialized areas the forests are continuously threatened by acid rain. Deforestation leads to sharply increased run off of rain water, flooding of rivers and reduction of rain water infiltration into under ground-strata.

Materials wich have a detrimental or dangerous effect on the population or the environment, can be freely exported to many developing countries. Due to lack of alternatives, and in the absence of good agricultural techniques, the farmer is forced to use them and is left with the ensuing negative consequences.
It is estimated that each year 900,000 people are poisoned. Furthermore, these substances, depending on their persistance, percolate through the sub-soil to contaminate the groundwater and via drainage, the surface water. The use of fertilizers, for example, in developing countries is alarmingly.(In 1975 14 million tons were used and the estimate for 1990 is 48 million tons.)

2.4 Society structure

The tendency to urbanization of the world's population (now 40%, and estimated at 50% in the year 2000) is particularly noticeable in the developing countries.
In the year 2000 it is predicted that there will be at least 18 cities with populations of over 10 million. (Mexico City with 30 million and Tokyo and Sao Paulo with 26 million appear to be the largest cities by prediction.)
Increasing urbanization poses many problems for the environment as hydrological aspects result in the release of untreated domestic waste water with the consequent pollution of surface water. This will be seriously detrimental to the environment.

More complicated treatment for drinkwater and waste water systems will demand high investment costs. At present approximately 10 million cubic metres of water are supplied daily to urban areas in India. In the year 2000 39 million cubic metres of water will be required each day. A heavy demand on watersources is inevitable. For example in Jakarta, the groundwater table has been lowered by more than 10 metres in the past 10 years.
In developing countries there are usually a great number of agencies involved with hydrological problems without adequate legal or controlling measures. Public Works, Water resources, Agriculture, Irrigation, Health etc.: all with their own political views and conflicting interests. The work of the hydrologist is additionally complicated by the fact that he often has to deal with decentralized government agencies at national, provincial and local levels.

The unstable political situation in some developing countries can have an adverse effect on project planning.
The problems with the availability of measuring data and information has been mentioned previously.

3 POLICY
Which policies are followed in respective countries?

Since the United Nations Conference on Water in 1977 at Mar-del-Plata and the subsequent inauguration of the Water Decade in November 1980, most recipient and donor countries have generally adhered to the objectives of the Water Decade. However what have all the countries involved actually done to realise these objectives?

An important first step must be the establishment of National Action Committees (NAC). By the first of July 1981 there were committees of this kind in 48 developing countries. The remaining 54 countries checked had at that stage no such committee. Another important point is that in the developing countries great attention has to be paid to the organizational and institutional aspects to promote a national policy for drinking water and sanitation.

It appears that the responsibility for water related activities in the many developing countries is shared by divers Ministries.

Authority is also often delegated to lower government agencies and other related institutions.

In order to undertake long term planning and execution of large scale watersupply and sanitation programmes, it would appear that the overall responsibility should be rested in one ministry or institution, which has the authority and national recognition to make decisions which will facilitate the efficient implementation of any programme or project.

Generally speaking at this point the hydrologist is placed in the invidious position of having to change his recommendations due to there being no one overall controlling organization but many, with conflicting interests.

Sector Planning should on the one hand fit the requirements of national and regional government for macro-economical planning, whilst on the other hand fit the sector planning needs.

In practise, sector planning is often a compilation of projects; but should be more a country-wise sector development.

Operation and maintenance procedures on completed projects are some what lacking and very often these non-physical aspects are neglected or introduced too late.

A great deal of attention must be given to manpower training and development in order to avoid the situation where watersupply systems break down faster than new systems are installed, due to poor operation and maintenance.

It would appear that manpower development and training is important in every project in every sector, especially for:

- governmental organizations
- water enterprises

- local consultants
- material suppliers
- manufacturers
- contractors
- non-governmental organizations (NGO).

Regarding the rural water supply areas, it is presently proposed to concentrate as a priority area, on the real water users i.e. the women-folk who are responsible for their family's watersupply.
The women appear to be greatly concerned with the efficiency of rural water installations.
It may be concluded, having reviewed many developing countries, that no consistent policy exists for the implementation of the objectives of the United Nations Water Decade.

4 PRIORITY

Which priorities are being laid down, and which should be laid down?

The main users of water have already been mentioned:
- agriculture
- industry
- energy production
- dinkingwater supplies.

Which sectors should be given priority, i.e. to which sector should the prime sources in the area be allocated, if there is a shortage of water?

In practise, there is no balanced priority formula.
Politicians tend to give priority to the area where most votes can be won. Even areas with desparately urgent health problems (such as epidemics) are not always given high priority.

If funds for development are scarce, attempts for gradual improvement of watersupplies for as many people as possible on a cost-effective basis must be made.

Donor countries and international institutions often give preference to particular sectors and therefore can keep the local contribution to this sector at a reasonable level; due to inflation during the implementation period however, local contribution covers very often the greater part of expenditure on water.

Most resistance to the use of groundwater as a source for domestic watersupplies comes from the agricultural sector.

One must realise that man can survive
- 5 minutes without air
- 5 days without water, and
- 50 days without food

and that therefore perhaps drinking water systems should enjoy priority above agriculture.

For priority ranking in the selection of the source, the following recommendation is given:

- short term: a) groundwater, if data are available;
  b) surface water;
- long term : a) groundwater: investigate groundwater potentials through extended groundwater resources surveys;
  b) surface water; collect measuring data etc.

Resistance to the allocation of high priority to watersupplies and sanitation is a result of:
* development of other sectors, to obtain consistant integrated development of the area;
* rural versus urban development instead of balanced regional development;
* shortage of funds for development;
* socio-economic and cultural factors; can the consumer pay for the service and does he want to give priority to helping the development of the service?
* shortage of technical and hydrological information;

* shortage of (an) institutional organization(s);
* shortage of trained personnel/skilled manpower.

5 QUANTITY

What quantities are we considering and what are the consequences of these decisions?

In industrialized countries the water consumption per capita per day lies between 100 and 500 litres. The consumption per capita per day in the developing countries lies between 5 and 200 litres, depending on the local circumstances and the watersupply system (rural or urban). (For public hydrants, 5-40 litres and yard-and house connections 30-200 litres.) In general, these quantities are not ensured daily, not even after full completion of the watersupply systems. If a shortage of water occurs in the system, one or more supply areas are being cut down for some hours and sometimes for some days.
This designed capacity for consumption is primarily limited by the yield of the water source or sources, as well as by the funds available for the construction of watersupply systems.

The ability and the willingness of the consumers to pay at least for operation and maintenance of the system should also be a limiting factor. Because, if operation and maintenance is not ensured by the contribution of the consumers, the system will deteriorate soon and begin out of order afterwards. The installation of sewage/drainage systems has to be considered parallel with that of watersupply systems. The World Bank has designed algorithms for the choice of sanitation techniques for pit latrines, septic tanks or sewerage systems, depending on the use of more or less than 50 litres per capita per day.

6 QUALITY

What quality of water must be delivered to the consumer?

The WHO quality guidelines were chosen as starting points for the UN Water Decade.

The belief that standards should be lowered according to local circumstances and that twice the number of systems should be constructed for half the cost appears to be steadily gaining support. Why should one adhere to the guidelines of 0,00 ... mg/l or 0. E.-Coli/100 ml, when the local population in developing countries is used to boil their drinking water anyway, or could be taught to do so? Due to dirty buckets to fetch the water from the public hydrants, uncontrolled reservoirs in the houses, and temporarily break down of the supply system causing contamination, one should admit that the bacteriological quality of the water at the consumers, is far lower than that delivered from the pumping station. The Water Decade unfortunately has coincide with a world wide economic recession and if one clings to existing WHO guidelines, is liable to be a failure. It is therefore logical pragmatic to work to lower yet recommended guidelines according to the choice of source and the local socio-economic and health situation. In Indonesia, the distinction between the supply of "Air Bersih" (clean water) and "Air Minum" (drinking-water) is already clearly understood.
The emphasis on maintaining quality should be directed to the water enterprises and to the consumers as well, by health education (i.e. the third point of the golden triangle: watersupply sanitation and health education).
Besides attention for an appropriate waterquality the aim should also be to provide enough water for bathing and personal hygiene, thus reducing the incidence of water washed, such as food-borne, eye and skin diseases and roads for pathogens.

Quality guidelines should be appropriate for local circumstances. For example, from a point of view of operation and maintenance, which is very often neglected in developing countries, it might be considered to supply slightly agressive water, which helps to keep the distribution system clean.

7 CONSUMER

Beginning with the consumer, using the iterative process from source to quality, the necessary limitations can be identified.

In the middle of the 60's with the setting up of Masterplan and feasibility studies it has been attempted with sociological and economic studies to be as accurate as possible with the requirements of the consumer, the development of waterneeds over a period of time and the ability to pay for the water (a tailored approach).
Presently in some developing countries, Indonesia among others, the first phase of watersupply development is based on a standard approach - the Basic Needs Approach.
For Indonesia, the Basic Needs Approach is as follows:

* at maximum 60% of the population in the area will be supplied with water;
* average consumption is 60 l/c.day for household connections and 30 l/c.day for public hydrants;
* the ratio of house connections to public taps is 1:1;
* standard increases, percentage-wise for industries/commercial consumption and losses through leakage.

After having determined the standardized water demand, the choice of source has to be made quickly and the project implemented in a relatively short time period. The standard approach facilitates first phase designs, cost estimates and budgetting, ordening of pipes, accessories and equipment, checking of designs and supervision.
The standard approach greatly speeds up the entire process of planning, design, tendency and implementation. In this way there is an apparent growth in the national watersupply connection percentage.
Combinations of service level against daily water use per capita are outlined in the following representations.
In the West a 100% level of service is expected:

* sufficient water must be available 24 hours per day;
* there must be sufficient pressure;
* the quality of the water must be up to WHO guidelines, i.e. drinkable from the tap.

It should be mentioned that in many Western countries the 100% service level, particularly regarding the quality, is not reached. In countries

such as Spain, Southern France, Italy, Greece etc., the water at the tap is certainly not always reliable drinkingwater. Why should that be the strived for design criterion for installation of watersupply systems in developing countries in the framework of the Water Decade?
According to common practice in developing countries, less water is being supplied of lower quality under lower pressure and districts are being cut down for hours/days if there is not sufficient water available or due to a breakdown at the pumping station; repair of equipment is being taken care of not before the spare equipment is also out of order etc. Operation of a pumped supply less than 24 hours per day is common practice. In my opinion, it is therefore realistic for watersupply systems in rural, semi-urban and urban areas in developing countries, depending of course on local conditions, to accept a level of service lower than in industrialized countries in order to be technically and economically attainable.
This may mean:

- less than 24 hours per day supplied water from the water enterprise;
- lower pressure;
- lower water quality standards.

All must be within easy reach of the hydrological, socio-economic, budgetary and exploitation capacity for that area and its consumers. Through a combination of a standard approach and a flexible service level, many more systems can be installed more rapidly and at much lower costs. In Tables 2a and 2b an example of the quality and quantity guidelines and appropriate service level are given.

Table 2a Recommendations on quantity and quality and service level

TYPE OF SYSTEM		QUANTITY IN L/CD	QUALITY WHO GUIDELINE	SERVICE HRS/DAY	PRESSURE IN MWC
WESTERN STANDARD		100–500	COMPLETE	24	30
DEVELOPING COUNTRIES					
PIPED SYSTEM	HOUSE CONNECTIONS	60–150	REDUCED	10–24	15–25
	YARD CONNECTIONS	40–80	REDUCED	10–24	5–15
	PUBLIC HYDRANTS	10–40	REDUCED	10–24	5–10

Table 2b Recommendations on quantity and quality and service level

TYPE OF SYSTEM	QUANTITY IN L/C.D.	QUALITY	SERVICE HRS/DAY	PRESSURE IN M.W.C.
DEEPWELLS/ HANDPUMPS	10 – 30	NOT CONTROLLED	24	–
RAINWATER COLLECTORS	5 – 10	NOT CONTROLLED	24	–
PRIVATE SYSTEMS	?	?	?	?

Flow restrictions, scattered reservoir capacity in the houses and as the public taps, reduced peak factors and reduced diameters of transport and distribution mains will reduce the capital investment cost per capita.

For comparison of the necessary capital investment involved, Figure 4 shows the investment per head at a reduced service level, indicated

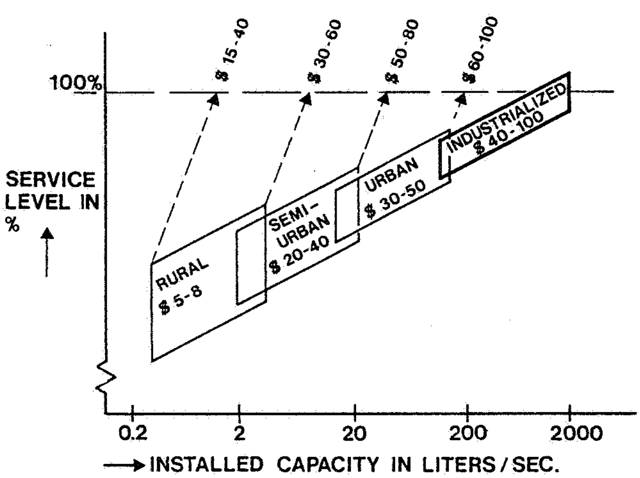

Figure 4 Investment cost for reduced and full service level

against the investment required per head to attain a 100% service level. Depending on the local circumstances, and after the socio-economic needs and ability to pay to make the system self supporting have been determined, the initial system installed by the government should be capable of self development and self financing. It is obvious that good management of the system is imperative. The government must also cater for the non-physical aspects of maintenance and management simultaneously with the physical installation of a system. This and other factors will lead to more even government expenditures in the sectoral planning and implementation of watersupply schemes and sanitation.
By reducing the supply requirements to a limit, the problems of the UN Water Decade will be more readily solved.

Although the relationship with sanitation has already been mentioned, one must now take a more detailed look at this topic. As was stated previously regarding watersupply and sanitation, is the iterative nature of the process. Water intake from a source of a suitable quality and in the right quantities, finally leads to the consumer requiring a drainage sewerage system in order to improve the sanitation. In this case the run off waste water in combination with rainwater and surface water drains will have always to be carefully controlled.
The run-off of water from the consumer, whether or not combined, finally reaches the surface water and/or the groundwater and will there or elsewhere be recycled for watersupplies again.

This iterative development of water cycles I have visualized in a spiral, in Figure 5 a spiraling process, between watersupply and sanitation. In practice the rural systems within the spiral appear to lag the urban systems. However it is most important to see that the spiral is well formed in which case the hydrological questions of the UN Water Decade will be solved in a reasonable way.
The state of affairs at a certain moment is indicated by a point in one of the gradients. Spiraling outside to the right to reach a higher level of watersupply and sanitation development. A small step in the development of watersupply might create an equal or bigger sanitation problem, which has to be solved in due time.
For existing urban systems it is getting time to solve discharge and

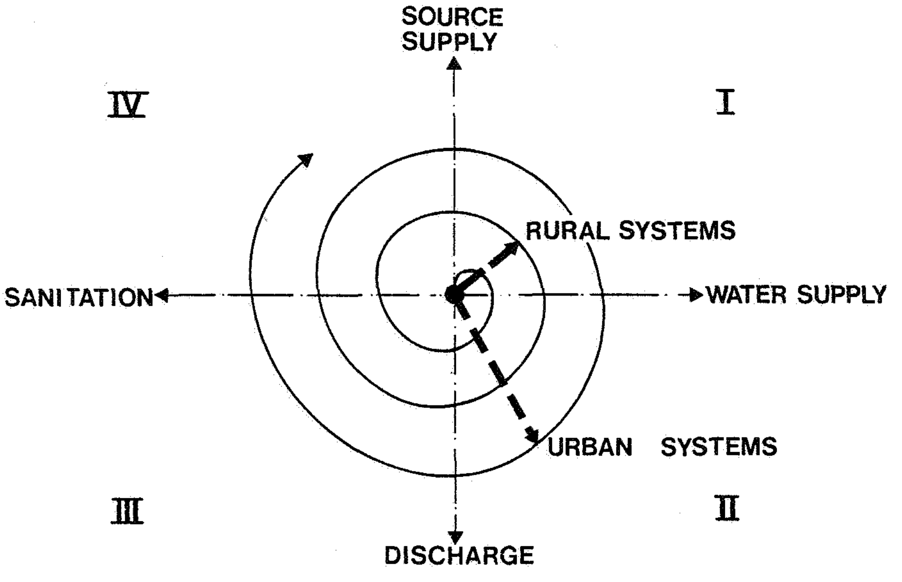

Figure 5 Iterative development water cycle

sanitation problems; although for small systems the available funds, in general, are still being spent for the watersupply development.

8 CONCLUDING REMARKS

Hydrological problems in the Water Decade regime a pragmatic approach to bring the UN Water Decade to reasonable, acceptable results in 1990.

One should accept an as good as possible doing of the job:

* without all required data and measurements;
* with flexible solutions and standard approaches/modules;
* making use of the available resources, data, local and expatriate manpower, local and foreign funds;

* pressed by policy-makers with priorities and goals set for;

* with flexible design criteria for quantity and quality; depending on local circumstances sometimes with emphasis on water quantity rather than water quality;

* with the consumers, concerned and their willingness and ability to pay for the services;

* with appropriate service level, etc.

Waterwise planning is obvious from the hydrological point of view. For this water ballet, the hydrologists need local/regional water balances being improved and safe against the multitude of disturbing factors.

The real water balance in any area will be controlled by many factors, including uncontrolled growth structures, customs and regulations, with insufficient information and technical data, short and long term variations etc.

In order to solve the problems of the Water Decade, one must strive for a systematic improvement of the water balance in the region or country.

New and appropriate methods are also needed and highly desirable, making use of the best techniques, including computers, available and developing sciences, which can produce rapidly efficient and effective results for the vast number of schemes to be implemented in such a short period of time.

This is the only source, giving us certainties from uncertainties.

THE ROLE OF HYDROLOGY IN THE WATER DECADE

G. SANTING

ABSTRACT

Although the general purposes of hydrological investigations for public water supply within the framework of the Water Decade are the same as those of such investigations in The Netherlands, the character of the investigations may be different. This is caused by two circumstances. In the developing countries emphasis will sometimes be laid differently with respect to the general purposes of the investigations; e.g. environmental effects of the exploitation of water resources will often not weigh as heavy as they do in The Netherlands and consequently they will need less investigations. The second factor affecting the character of the hydrological investigations is the difference in social, structural and hydrological conditions under which the investigations have to be carried out. The hydrological character of the area of study, the availability of data, financial resources, manpower, experience, equipment etc. generally differ widely from those in The Netherlands.

Consequently the character of hydrological investigations for water supply in developing countries may also differ in various respects from those in The Netherlands. As a rule the social and structural conditions of the country affect the type of hydrological investigations more profoundly than the hydrological conditions.

A different character of the investigations may, in its turn, make different demands on the capabilities and experiences of the hydrologist,

as compared with his colleagues in the home-country.

1 AIMS OF HYDROLOGICAL INVESTIGATIONS FOR PUBLIC WATER SUPPLY

As the purpose of the present paper is to treat of the typical character of hydrological investigations for water supply within the Water Decade. or more concretely, the differences and agreements in comparison with such investigations in The Netherlands, it is necessary to put down first the aims in general of the investigations. Although the subject of the investigations in question is public and sometimes also industrial water supply, it is clear that quite often multiple-purpose investigation programs, e.g. also for irrigation or water power, are carried out. In this paper, however, only investigations for public water supply, in rural areas sometimes including water supply for cattle, will be dealt with.

The general aims of hydrological investigations for public water supply can be described as follows.

- Finding suitable water sources and evaluating their yields and water quality for drinking water purposes.
- Determining the suitable technical means (wells, intakes etc.) for water recovery.
- Determining the best ways of controlling, managing and exploiting the water sources, both from the point of view of water recovery and with respect to the environment and the interests of other users of the water source.
- Evaluating the effects of other human activities, such as deforestation, land reclamation and the discharge of waste water, on the yield and water quality of the water sources, and determining the measures to be taken to reduce the harmful effects.

These general aims of hydrological investigations for public water supply hold good both for The Netherlands and for the Water Decade. However, the investigations themselves may differ in various respects. This is due to two causes.
In the first place the emphasis with regard to the aims may be put

differently. In developing countries environmental aspects e.g. will often be considered as of minor importance; in other instances the need of water may be so urgent that good management and development of the water source will not immediately get sufficient attention.
In the second place conditions in developing countries will nearly always differ widely from those in The Netherlands. This is not only true for the hydrological conditions but also for the social and structural ones. As differences in the conditions under which the investigations have to be carried out, may greatly influence the character of the latter, this point will be examined more closely. Therefore first the conditions in The Netherlands will be compared with those in developing countries (Chapter 2.); after that the influence of those differences on the hydrological investigations will be discussed (Chapter 3).

2 CONDITIONS WHICH AFFECT THE CHARACTER OF HYDROLOGICAL INVESTIGATIONS

2.1 Conditions in The Netherlands

A distinction should be made between hydrological conditions and those of a social and structural nature. As the latter have a greater influence, they will be dealt with first.

- Basic data over long periods are available and easily accessible.
- A dense network of hydrological observation stations exists.
- As a rule sufficient financial means for the investigations are available.
- Sufficient knowledge, experience, manpower and equipment are present.
- There is generally a good co-operation between the different government offices and other agencies or organizations active in hydrological work. Even with neighbouring countries co-operation and exchange of information are good.
- A great deal of attention has to be paid to the effects of the use of water source on the natural environment and the consequences for other users of the same source. A typical feature in this connection is the partly artificially controlled groundwater level near to groundsurface, as required by the farmers in The Netherlands. Groundwater withdrawals causing a lowering of the groundwater table,

are heavily opposed by the farmers.

As to the general hydrological conditions prevailing in The Netherlands, the following picture, which of course must be very sketchy, can be given.

- The general hydrological conditions in the country are known; the locations for new well fields are already approximately known beforehand. Hydrological investigations, therefore, are often rather local studies, in order to fill up the details in an already known general picture.
- The Netherlands are a delta of powerful rivers which, during most of the Pleistocene era, built up mighty alluvial formations, generally of good permeability. Transmissivity values of more than 10,000 m^2/day are known.
- Rainfall, averaging 750 mm/year, is quite favourably distributed over the year; evapotranspiration leaves a useful yearly rainfall excess of some 200 - 300 mm. Annual variations are small.
- The water sources, both groundwater and surface water, are of a permanent character; storage of water for public water supply is, from a quantitative point of view, not necessary, but is sometimes necessary for reasons of quality because of human-made pollution of the sources.
- In the river watersheds and groundwater basins great changes rarely occur. (The recent Zuyderzee reclamation works and the construction of the long sea-walls in the Meuse and Scheldt river estuary are exceptions.) Discharge and sediment transport of the Rhine and other rivers, seen over longer periods, are fairly constant. It may be stated that a stable hydrological situation exists in The Netherlands; the water regime and the water balance are almost fixed data.

2.2 Conditions in developing countries

When dealing with this question, one should keep in mind that there is not a homogeneous group of developing or Third-World countries. Climatological, geological, hydrological, social, economic conditions show great differences. Differences and agreements with conditions in The Netherlands will vary from country to country. In a short paper like the present one, it is not possible to deal with all those variations; a certain generalization has to be introduced, with the emphasis on those characteristics and features which are of most interest in the scope of this paper. This will mean that, if in a certain instance it is stated that hydrological basic data are scanty in the local archives, there are also developing countries which have good archives and quite well functioning hydrological services. Such cases, however, are of less interest in view of the purpose of this paper.

So, in a very general way, the following conditions in developing countries can be mentioned, first the social and structural ones and after that the hydrological conditions.

- Expedients generally are limited; few basic data, few hydrological observation stations, few maps, insufficient manpower en experience, poor equipment, few roads, inaccessible areas.
- Government offices often work inefficiently and suffer from bureaucracy; government officials from the capital may object to visiting rural areas and doing field work. The competition between different ministries and the reluctance of the employees to take any responsibility hamper the acquisition of information and data by the consultant.
- Co-operation with neighbouring countries is not always possible due to political controversies. In case river or groundwater basins which belong to more than one country, have to be studied, this lack of co-operation may seriously hamper the work.
- Proprietary rights of land and also of water may be quite different from what is customary in The Netherlands.

It would not be fair to just mention these shortcomings without trying to explain how or why some of them have come into existance.
In the last few years before their independence and in the first years after that date conditions in many former colonies were rather disordered. Archives may have got lost, observation stations may have been destroyed or abandoned, people in charge may have moved or have disappeared, funds to repair damage or engage qualified personnel were

lacking.
Another problem is caused by the rapid changes in the natural environment and hydrological conditions by human activities in the last decades in many parts of the world. Because of this fact the hydrological regimes in the affected regions may have changed too. Consequently the long series of hydrological observations of the colonial period have lost part of their usefulness, as they cannot be used straightaway for an analysis of present-day conditions.
Still another problem which arises in very poor regions is the difficulty to maintain the equipment of hydrological observation stations. Particularly the metal parts of the installations are sought after by the local population for making knives and other tools of.
A fourth example to conclude with: many developing countries are overrun with foreign missions, consultants, experts etc. Now, because of lack of co-operation between the different ministries and government agencies of the country in question, there is a fair chance that two missions one after another and each one for a different ministry, visit the same area ask the same questions, try to get the same answers. Moreover, most of these visits do not answer the expectations of the local rural authorities and people, viz. a rapid improvement of their living standard. This situation may easily lead to a refusal of the people to co-operate with the foreign expert.

Now, something has to be said about the hydrological conditions in the countries for which in particular the Decade was started. It is clear that the hydrological conditions may differ in so many ways from those in The Netherlands, that it is hardly possible to give a relatively complete review of these differences and agreements. Moreover, such a review would not essentially contribute to a better understanding of the fact that hydrological conditions have an effect upon the character of hydrological investigations, than a few typical and interesting examples do.

- One of the most conspicuous differences is the size of the hydrological and hydrogeological units, the river and groundwater basins. In The Netherlands they are small and often independent of each other; if in N-Brabant large amounts of groundwater are being withdrawn, effects in the nearby Veluwe are none, and vice versa (provided that the amounts withdrawn in N-Brabant remain below the limit of the safe yield and do not result in a depletion of the groundwater reservoir). Such conditions of course are also known in most other countries. However there are many regions in the world where the units are much larger. This is particularly so in arid and semi-arid regions where rivers and surface water divides, normally constituting boundaries of hydrological units, are absent.

Because of the above-mentioned feature and other ones the areas to be investigated by the hydrologists generally are much larger than those in a small and densely populated country like The Netherlands. Moreover, great differences in topography, geology and climate may exist within a single area, whereas on the other hand relatively little hydrological data of the area is available.

- As to the sub-soil conditions, it should be remarked that in many parts of the world the bedrock is already encountered at a shallow depth below ground surface (e.g. the Precambrian shield in Africa, South America and Asia).

Figure 1 Outcrops of bedrock in savanna, Kano State, Northern Nigeria

Transmissivity of these formations and of the thin covering layers often being small, groundwater resources in such areas are generally quite poor and rivers depend mainly on rainfall; in dry periods they carry little or no water whereas in the wet season they may cause wide-spread and sometimes devestating floods.
Thick unconsolidated sediments, on the other hand, do not always guarantee the presence of good groundwater reservoirs, even in countries with abundant rainfall. E.G. in the Northern coastal plain of the island of Java, Indonesia, Quaternary marine and volcanic sediments of several hundred metres thickness have a transmissivity of only a few hundred m^2 day.

- The physical and chemical properties of groundwater may ask special atttention in connection with water supply projects. In tropical areas a water temperature of 30^o C is still quite favourable, but much higher temperatures, especially of water from deep acquifers also occur frequently.
The groundwater may have certain unexpected chemical properties, which are unknown in The Netherlands. In Upper-Volta, e.g., groundwater with 1600 microgr. of arsenicum per litre was found in newly drilled wells for a rural water supply project. The arsenicum originated from pyrite and arseno-pyrite in the Precambrian bedrock below the aquifer.
Still less known is silenium, which was encountered as a salt in high and dangerous concentrations (> 50 ppm) in groundwater from a depth of 200 m at Balikpapan, Indonesia. Also fluorides and heavy metals should be mentioned.
Another phenomenon which affects the chemical quality of the groundwater, is a consequence of the rise of the sea level by some 100 metres at the beginning of the Holocene period, ten millennia ago. The phenomenon to be described takes place where thick sediments are present below the bottom of a littoral sea. If the top layers of these sediments consist of clay or other almost impermeable materials, the weight of the rising sea water causes a compression of the underlying sediments, thereby expelling part of the (generally salt) water contained therein. This expelled water will be pushed landward through the more permeable strata, may contaminate fresh-water bearing aquifers in the coastal land area and explains the presence

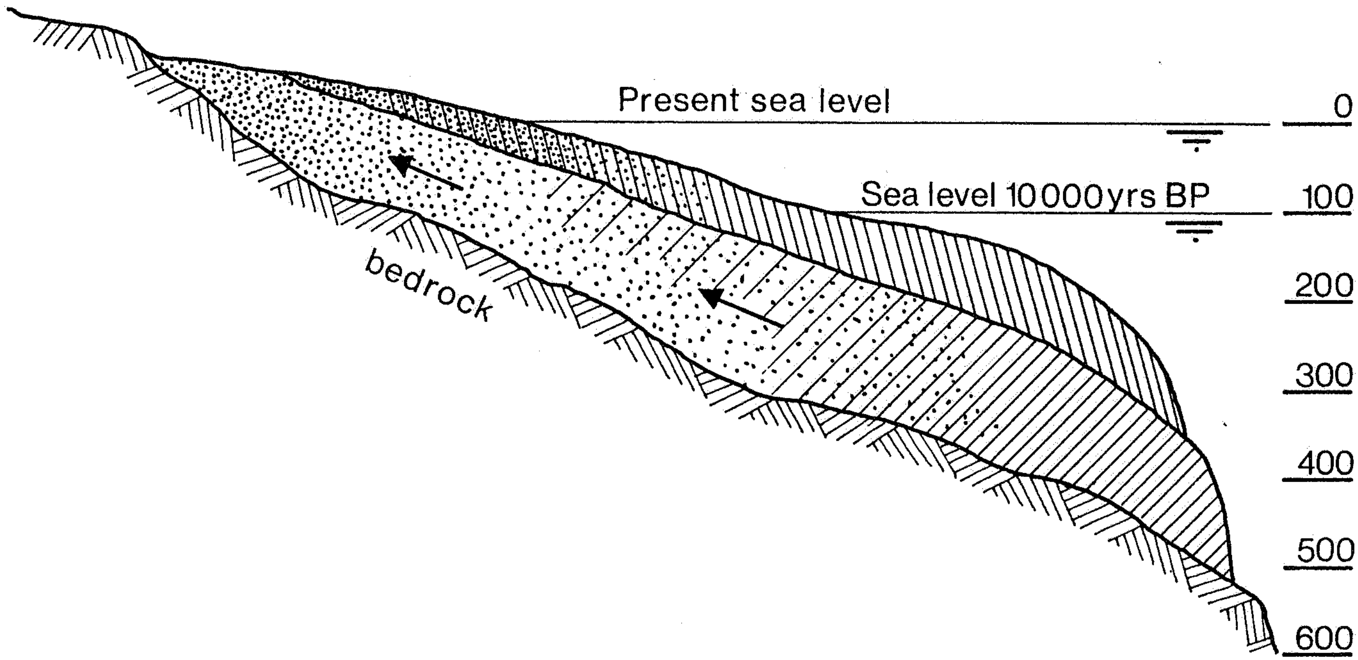

Figure 2 Groundwater expulsion from submarine aquifers by the rise of the ocean level

of brackish water in aquifers far inland where never the sea has been since the end of the Pleistocene.

- Still other influential hydrological conditions have to be mentioned. In developing countries the hydrologist will more often than in The Netherlands be faced with situations in which the water source or the environment has got into a bad or even dangerous condition due to improper management and exploitation of the source. The hydrological world, even in the Western part, is full of examples of bad management or bad designs, as e.g. silted-up reservoirs, aquifers contaminated by saline intrusions, areas suffering from subsidence, and irrigated areas turned into salt deserts.

  Some regions are, contradictory to a first impression, particularly sensitive to human interference. If e.g. in an arid area a town gets a public water supply system, the inevitable leakages and the discharge of waste water may constitute an important new replenishment of the groundwater and this in its turn may result in a quite unexpected rise of the groundwater table of several metres.

  Raising the ground surface in new buildings areas in arid or semi-arid regions, thereby reducing evaporation losses from former marshy areas, may also result in an unforeseen rise of the groundwatertable. To illustrate the importance of this phenomenon it is pointed out that the elimination of an evapotranspiration loss of 10 mm/day over area of e.g. 500 x 500 m^2 already corresponds with an extra replenishment of the groundwater of 100 m^3/hour, which is quite considerable in a region where the natural recharge is very small.

- Finally something should be said about boundary conditions, a very important item. (Boundary conditions are the conditions of inflow, outflow, water levels etc. that are present at the boundaries of the basin or aquifer and that govern the water movement through it.)

  In The Netherlands boundary conditions are rather constant, apart from seasonal and small yearly variations. The effects of human interferences generally are small and of only local importance; their influence on the hydrological regime and the water balance can be fairly well calculates or predicted. Even conditions in the basins of the big European rivers crossing the borders of the country are quite stable. Hydraulic and other water-related engineering works can be designed with a high degree of accuracy without great unexpected risks of failure.

This is not the case in many of the developing countries. There the natural environment is changing rapidly, often at an alarming rate. Consequently also the hydrological conditions are rapidly changing.

The causes are well-known: excessive population growth, decrease of forest areas, giving up of traditional agricultural methods and traditions of conservation of natural resources, large-scale urbanization, wars, the construction of huge dams in the big rivers of the world, etc. To illustrate the magnitude of these causes, a few figures. The rapid population growth in some of the developing countries will result in doubling the number of inhabitants within 20 or 30 years, which will require a duplication of jobs, towns, and all other infra-structural matters.

Yearly population growth	Duplication of population in
2%	35 years
3%	25 years
4%	19 years

The pressure of the growing population and the shortage of arable areas and grazing grounds in many parts of the Third World forces the farmers to cultivate less suitable grounds and to cut down the forests. This in its turn will increase the dangers of erosion and of climatic changes. The use of wood for fuel for cooking also constitutes a threat to the preservation of forests in the drier regions of the world. It is estimated that in a semi-arid and sparsely populated country like Niger the need of fuel for fires and other domestic purposes amounts to 0.6 m^3 per head and per year. In that country the production of wood from natural forests and savannes is about 0.2 m^3/ha per year. The total population of Niger, numbering 5,5 million, therefore, would need 16,5 million ha for their fuel demands, an area equalling more than 4x The Netherlands. As the forest area is smaller than needed, there is over-harvesting of wood and the forest area is decreasing. The areas in the world covered by tropical forests are also rapidly decreasing; every minute some 20 ha of tropical rainforest is burnt or cut down, which makes 10 million ha per year or 3x The Netherlands. It is obvious that such rapid and widespread changes will have an effect upon the hydrological conditions in the affected areas and will create changing boundary conditions.

Many of the items mentioned above make hydrological work in the developing countries more complicated and difficult than that in The Netherlands. There are, however, also conditions which facilitate the work of the hydrologist. For instance separate wet and dry seasons enable the hydrologist to measure accurately the dry-weather discharge of a river and to calculate from that data the groundwater replenishment by rainfall. Sometimes ground survey and geological reconnaissance are made easier because of absence of vegetation; also deeply eroded valleys help in giving information on geological conditions.

3 HYDROLOGICAL INVESTIGATIONS AS AFFECTED BY CONDITIONS IN THE COUNTRIES OF STUDY

At first sight one might think that the prevailing hydrological conditions in the country have a greater influence on the character of hydrological investigations than the social and structural conditions. However, the latter often have an as great or even greater effect than the first. This will become clear in the present chapter.
First the effects of the social and structural conditions will be dealt with.

3.1 Effects by social and structural conditions

3.1.1 Lack of data

One of the most important aspects is the lack of sufficient basic data. In The Netherlands data generally are so plentiful and easily accessible, that many hydrological studies can be carried out at the office desk. In developing countries nearly always additional investigations in the field are indispensable. Even then, the number and quality of the data are limited. Often information will have to be used which in The Netherlands never would be considered as data: remains of floods in the branches of trees, indicating the height of the water; signs of erosion; remains of demarcations of fields, showing that in the past the land was cultivated and that afterwards climatic or other conditions have changed. As good maps may be lacking, it will be necessary to make one's own maps of field data, such as land use, type of vegetation and crops, irrigation, other water use. Therefore, aerial and landsat photographs are so very helpful and almost indispensable in these countries.

Another consequence of the scarcity of data is the necessity to apply as many hydrological methods of analysis and calculation as possible, in order to arrive at the most reliable conclusions. Not only modern advanced methods should be used; because of the scarcity of data just some simple old methods could substantially contribute to getting an insight into the hydrological conditions of the area, such as e.g. analysis of the fluctuations of the groundwater head caused by rainfall, the study of rainfall-runoff relations by means of empirical approximative formulas, water-balance studies etc.

Figure 3 Example of a complicated hydrological situation. Wet rice fields, Bali, Indonesia: springs, rivers, irrigation canals, terraced inundated fields, and groundwater

It should be remarked that due to the scarcity of data and the often complicated hydrological conditions, the risk of failure in these countries is greater than in The Netherlands. If e.g. the nearest rainfall gauge is at a distance of 100 km, the use of the data of that gauge may bring along the possibility of serious mistakes.

3.1.2 Type of water sources needed

A second aspect of the social and structural conditions in the Third-World countries concerns the requirements to be met by the water sources for water supply; these requirements too affect the character of the hydrological investigations.

- The sources should allow for a simple type of exploitation and use; water treatment generally is too expensive and often not feasible because of lack of qualified personnel.
- The sources should preferably be perennial, water storage generally being too expensive.
- The sources should as little as possible be susceptible to pollution, as protective measures will hardly be possible or effective. Particular attention should be given to the practice of excessive use of highly poisonous pesticides and fertilizers in agriculture.
- The autochthonous or traditional ways of fetching and using water also influence the selection of the type of source. In the Third-World countries the majority of the population still lives widely dispersed in the rural areas. The water sources to be used will, therefore, also have to be dispersed over large areas.
- In regions with little water often springs and aquifers will have to be used which in The Netherlands would never deserve consideration, as being too small, but which will do for small rural water supply systems (e.g. shallow wells provided with handpumps for a village of 500 people, needing 500 x 100 litres/day or 50 m^3/day).
  Even desert areas, at first thought considered to be of no value at all with respect to water resources, may offer certain possibilities. Although the average annual precipitation is extremely small, rain generally falls in local heavy showers, of which a fair percentage may reach the groundwater reservoir. An average yearly replenishment

of the groundwater of say 10 mm could easily result from this type of precipitation. Over an area of 1000 km^2 this yields an amount of 10 million m^3/year, which could represent an interesting water source in a sparsely populated area.

- In certain cases a temporary water source might be needed to bridge a period in which a permanent water supply system is built. Under these circumstances groundwater reservoirs might be used wich do not or hardly receive natural recharge and which therefore, by being used, will be mined. In The Netherlands mining of a groundwater reservoir would not be considered as an acceptable procedure. However, if mining of ground-water would not be detrimental to the environment and if otherwise the groundwater resource would remain useless, there is no reason why such a resource should not be used. In several desert areas huge groundwater bodies are known to exist, which up to the present do not serve any purpose or are just at the beginning of being exploited.
- The effects of the use of a water source with respect to the environment have to be kept as small as possible, since compensatory or neutralizing measures as are customary in The Netherlands, will generally be too expensive.

3.1.3 Direct effects

Also directly the character of the hydrological investigations in the developing countries is affected by the social and structural conditions in these countries.

- The investigations have to be carried out in an inexpensive way with limited manpower, experience and equipment, and the water sources have to be located and evaluated within little time. E.g. complete pumping tests with a specially drilled pumped well and a series of observation wells will seldom figure in the working programme; generally the hydrologist will have to manage with tests on single existing wells, both drilled small-diameter wells and wide dug wells. Discharge measurements in small water courses often have to be carried out in a rather primitive way, e.g. with the aid of small portable weirs dug in into the channel bed, or with salt, a pail and a conductivity meter, or simply with a straw thrown into the running water to measure its velocity. Many more similar examples could be mentioned.

- When allocating a water source for a water supply project, the possibilities of rapidly changing boundary conditions and improper exploitation of the source should be taken into account and their consequences studied.

3.2 Effects by the local hydrological conditions

Since hydrological conditions in the developing countries often differ greatly from those in The Netherlands, the question arises in how far these conditions affect the character of the hydrological investigations. As to this question, some important aspects will be dealt with in the papers by Mr. Amesz and Mr. Campen. Moreover, some of the remaining items need hardly be elucidated; it is obvious that in a semi-arid country e.g. much more attention will have to be paid to the evaluation of evapotranspiration than in a country with a wet climate. There remain, however, a few points which have to be mentioned. These points regard the natural environment.

The hydrologist will have to pay attention to the expected effects of the proposed exploitation of the water source and of the proposed water supply system on the environment in that area. The hydrologists is the one who has to inform the authorities and the people about these effects. Generally no other person will think of it; people generally have not the faintest notion about such effects or are not interested at all. What is referred to here are e.g. the spreading of malaria, bilharzia and other water-related diseases as a consequence of human interference in the hydrological conditions. Of course the medical aspects of public health do not belong to the hydrologist's field of work, but he should pay attention to it and notify the health authorities of the country.

Another example is the construction of better watering-places for cattle, which may attract large herds. In areas where the ecological equilibrium is very sensitive to foreign influences, such as in the Sahelian region, the concentration of large amounts of cattle will result in trampled-down and over-grazes vegetation in wide areas around the watering-place, which in its turn may lead to erosion and desertification.

3.3 Final remark

It should be pointed out that on the one hand highly advances equipment and methods are used in hydrological studies in the Water Decade - satellite photographs, geophysical investigation methods, sophisticated hydrochemical analysis, determination of the water age, etc. - and on the other hand rather primitive methods in field work and data analysis. This combination is more characteristic for investigations in the Third-World countries than in The Netherlands.

4 SPECIAL REQUIREMENTS TO BE MET BY THE HYDROLOGIST

When the hydrologist has to work under different conditions and the hydrological work is different from that in the home-country, it is evident that the hydrologist will have to meet different requirements. The lack of sufficient data and experienced assistants will make high demands on his or her insight, knowledge, imagination and inventivity. Often it will not be possible to use standard methods and standard solutions; the hydrologist will have to improvise more than in The Netherlands. Field work will take a much larger portion of his time than at home and it will present more obstacles. A field visit often requires special permits from the national, local or military authorities and will be attended with long courtesy calls to the village chief and palavers with other important people. It is seldom that one can just walk into the fields with his instruments and carry out his work. Therefore the hydrologist should not lack patience and tact. He also should preferably have a good geological background in order to recognize important hydrological and geological characteristics (terraces, faults, grabens, playas, volcanic features, etc.) during his field visits or from air photographs. Some hydro-meteorological and agrohydrological knowledge too is necessary in order to make reliable estimates of evapotranspiration, evaporation losses in reservoirs and lakes, rainfall excess and recharge of the groundwater, storm run-off of rivers etc. Sometimes he must know something about water-conservation methods, in order to be able to give a justified advice.

As generally time, money, equipment and manpower are limited, it is essential with repect to the field work that much attention is paid to the selection of the many items one would like to study in the field and to determine what can be left to be done by the local people or what can be done later. A well defined program is essential, even more so than in The Netherlands, as returning to the field in order to study a forgotten feature will hardly ever be possible.

The large amount of field work will bring the hydrologist frequently in contact with the local population. Through talks with them he will have to get information which in addition to his own measurements and observations can complete the hydrological picture. It is, therefore, useful if he knows something of their language and in particular of their manners and customs; conducts that hurt the local feelings might have unpleasant consequences. Addressing a woman in the village, stroking boy over his hair, passing something to somebody with the left hand, and the like, should be avoided in certain countries. Equally wrong would it be to take a bucket of water from a village well, analyse a sample and, for reasons of economy, throw the remaining water back into the well. People may suspect the hydrologist of poisoning or profaning the well. Many more examples of mistakes in conduct can be given.

Since women are often the ones who take care of water supply, talks with them can be very useful. For this reason it may help to include a female hydrologist or field worker in the team, as in quite a few countries men are not permitted to speak to a woman which is not one of his relatives. Questions to local people have to be worded in such a way that a reliable answer is received. This may not easy at all. Often people give such an answer as they assume the other one will like to hear. Moreover the rural people rarely know the dimensions of a metre or the time of an hour. Quite often they have got bad experiences with authorities or officials from the towns, and consequently are hardly inclined to give information.

Figure 4 Often the hydrologist will find many ready hands to carry his things. Balikpapan, Indonesia

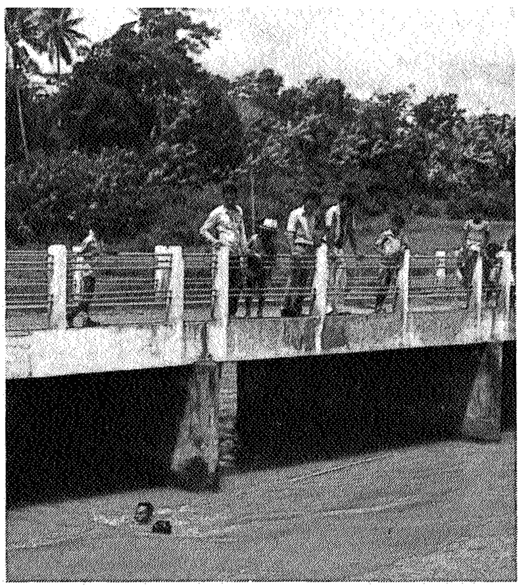

Figure 5 Easiest method of taking a water sample from a river: asking a villager to jump into the water and fill a jerrycan. West-Java, Indonesia

On the other hand the hydrologist sometimes meets with astonishing cases of co-operativeness. He is admitted in the archives to look himself for data; even complete files and unique maps are lent out to him without receipt. I want to stress strongly the necessity that the hydrologist does not abuse such confidence and that he duly returns the documents. By not doing so he not only would destroy the good image of the foreign consultant but he also would make working conditions for his successors much more difficult.

A well-known problem in many developing countries is the lack of a good follow-up after the departure of the consultant and his field team. Therefore the hydrologist has to convince the authorities and the local personnel of the necessity of continuing the series of measurements started by his team and of maintaining the gauges and other hydrological field equipment. The data collected that way may form the beginning of hydrological archives in case they do not yet exist. This implies a certain educational task of the hydrologist. It is clear that for that purpose too some knowledge of the local language and customs is useful or rather indispensable.

A final remark has to be made to correct too romantic ideas that might exist with respect to the hydrologist's work. Generally the hydrologist and his team working in a Third-World country are no longer people left alone in a savage region for many days or weeks like former explorers. Now there are portable radios for communications in the field, radio connections with the field base, the local office or the local representative in the capital. There are telex and telephone connections with the main office in the home country, through which almost immediately the hydrologist can get advice and support from the head office's labs, computer section etc. What remains are some physical hardships, due to climate, topography, the local food, lack of safe water etc.
The greatest risk is caused by tropical or water-related diseases. This risk, however, is sufficiently compensated by the highly interesting work and the stimulus created by taking part in technical assistance, providing water to people suffering from lack of it.

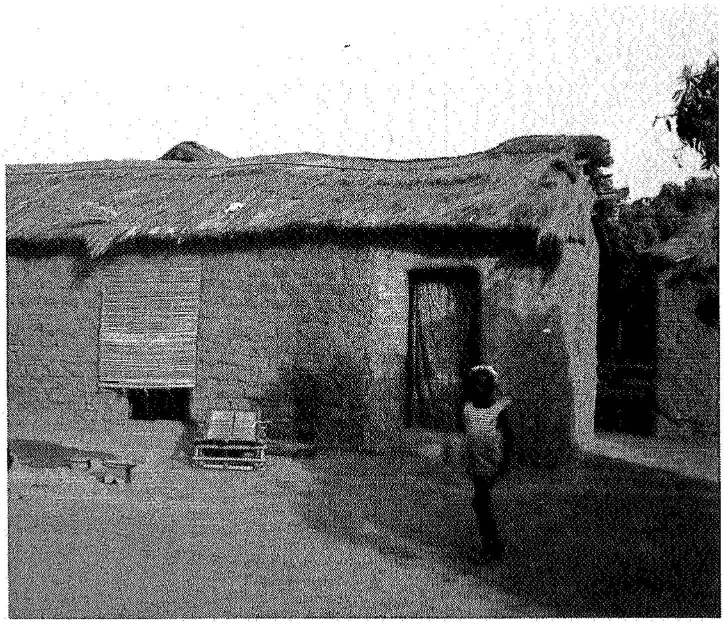

Figure 6 The hydrologist's luxurious lodgings, Kankalaba, Upper-Volta; a hut vacated by the owners by order of the village chief

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HYDROGEOLOGICAL RESEARCH PROJECTS

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ABSTRACT

Hydrogeological investigations are a prerequisite if a nation is to rationally develop and manage its limited groundwater resources, but few Third World countries have optimally functioning research institutes to do these investigations, largely because of the low priority given to hydrogeological research in the past. As part of The Netherlands bilateral aid programme, research projects have been carried out jointly by Groundwater Survey TNO and sister institutes in Latin America, Africa and Asia. The strengthening of research institutes is the main objective of these joint projects. A second objective is the rational development and management of water resources in a specific region. Both objectives are mainly achieved by training personnel and by doing hydrogeological investigations.
During these joint projects it has been observed that there are certain constraints, common to most countries, that hamper the entire water sector. At the national level these constraints are: the lack of a policy for the rational development and management of water, the conflicting tasks of ministries and organizations (whether governmental or private) and the lack of co-ordination between these bodies. At the institutional level the constraints arise because of weak management and the lack of qualified personnel.
The strengthening of research institutes is undoubtedly important. However, if the water sector in the Third World is to be structurally improved, this must be accompanied by a strengthening of water

development organizations and educational institutions.

1 HYDROGEOLOGICAL INVESTIGATION

Hydrogeological investigations can be classified according to scale into nation-wide, regional and local surveys.
Nation-wide surveys focus upon the collection, processing and evaluation of available data and their objectives are:

- to identify the main hydrometeorological and hydrogeological features;
- to define hydrogeological boundaries;
- to identify areas whose water development or water management may cause problems;
- to set priorities;
- to draft a long-term programme for systematic regional hydrogeological investigations.

A nation-wide investigation usually takes a relatively short time (6 months) and is done by an experienced hydrogeologist, assisted by some junior professionals. The accessibility of the data will mainly determine the time required. While the investigation is in progress, work can begin on setting up a data base and an observation network.

Regional or local surveys aim to acquire additional data. Generally, data are scarce and therefore fieldwork is vital: this requires considerable manpower, equipment and funds.
Depending on the stage of water development, regional or local surveys can involve the exploration or assessment of water resources (Annex 1). Initial water development demands exploration, i.e. the identification and location of aquifers. Increasing development requires the assessment of water resources, i.e. the identification of groundwater systems and the description of factors that determine the quantity and quality of water and groundwater resources.

Most of the joint projects done by Groundwater Survey TNO in co-operation with sister institutes in the Third World concern the systematic regional assessment of water resources. These projects require two or three years, to collect, process and evaluate available data, to acquire, process and evaluate additional data and to draft reports.

The joint projects carried out within the framework of the bilateral aid programma of The Netherlands are outlined below.

Furthermore an attempt has been made to highlight the main constraints that hamper the water sector in most countries and that directly or indirectly interfere with the projects.

2 JOINT PROJECTS

2.1 Project objectives

The long-term or development objectives of these can be summarized as follows:

- building up institutions;
- ensuring the effective use, rational development and proper management of water resources.

Therefore the short-term or immediate objectives are:

- manpower training;
- assessment of water resources.

The manpower training includes: on-the-job training, short courses and fellowships for training in The Netherlands. The on-the-job training is considered to be the most important and is done during the hydrogeological investigations. In fact, continuous on-the-job training occurs because of the nature of the organizational set-up: the sister institute is responsible for doing the hydrogeological investigations, whereas Groundwater Survey TNO bears the responsibility for adequate training, instruction and advice. Consequently the on-the-job training covers all aspects of investigation: inventory, acquisition and processing of data, and the reporting of the results.

While the project is in progress, short courses are organized. These are generally not only attended by the project team but also by professionals or technicians from other departments, institutes or

universities in that particular country.
If the technical co-operation is long term these short courses are often formalized and both the organization and the lecturing are gradually taken over by the sister institute.

2.2 Selection of project area

The area of study should be selected using the following criteria:

- its priority for water development or water management;
- its suitability as a case study for training local personnel;
- whether it is a representative basin;
- cost benefit ratio;
- accessibility, safety, availability of maps, etc..

In addition, the policy of the national government and the strategy of The Netherlands bilateral development co-operation will determine the area to be selected.
Project areas are frequently situated in remote and isolated regions. Therefore project planning must be thorough and must anticipate problems of transport, communication, housing, fuel, spare parts, motivation of personnel, etc.

2.3 Main activities

2.3.1 General

The main aspects to be studied and the related investigation techniques are summarized in Annex 2. A schedule of activities is presented in Annex 3. An explanation and some related issues follow.

2.3.2 Data collection

Much time is required to collect the available data, because they are usually not easily accessible.

The following difficulties occur:

- data are found to be widely distributed among various departments, organizations or institutes;
- official letters are required to obtain access to the data, but this authorization is not always given;
- documentation is poor and location maps are lacking;
- there are no facilities for making copies.

It is vital to establish an optimally functioning data base, not only to improve accessibility to data but also to prevent invaluable data being lost.

2.3.3 Well inventory

Although not a spectacular activity, a thorough well inventory may produce a considerable amount of data. Often, this time-consuming activity provides the only reliable data about water abstraction.
An example of a well inventory data sheet is given in Annex 4: it comes from a well inventory carried out in the project area located in the Yemen Arab Republic. During approximately four months 1800 wells were inventorized.

2.3.4 Establishment and operation of networks

Once wells have been selected, a network needs to be established to monitor groundwater levels. An observation network is also often required to monitor rainfall and river discharge. Sometimes a meteorological station has to be set up. Setting up such networks, especially ensuring that they operate smoothly, is a time-consuming task. To secure continuity after the lifespan of the project, the operation of the networks should be taken over by local bodies as soon as possible.
Most countries generally lack a groundwater observation network. Yet water management cannot be reliably planned without long time-series of data as groundwater levels.

2.3.5 Geophysical operations

The reliability of geophysical surveys depends on the method applied, the quality of the instruments and the amount and quality of the additional data. Specialized experts and reliable instruments are required. Geophysical operations are expensive but the savings resulting from them can more than outweigh their cost.

Settingup an instrument workshop and related manpower training is an inevitable concomitant of geophysical surveys. In most Third World countries the maintenance and repair of geophysical and other instruments generally leave much to be desired.

2.3.6 Drilling

Drilling is often the major priority, because available borehole data are scarce and unreliable. The drilling method and the drilling rig will be determined by the depth of drilling the objectives of the drilling programme, what facilities, are available for maintenance, costs, and the availability of fuel. Important issues in drilling operations are: the use of drilling fluid additives, the sampling of rocks, the sample descriptions and, in addition, the design of the wells, the completion of the wells and their subsequent development. Generally, an experienced drilling supervisor is essential.

2.3.7 Geophysical well logging

Geophysical well logs provide continuous and objective records that are consistent in time and place, and do not vary according to the terminology of different drillers and geologists. Proper geophysical well logs enable lithostratigraphic units from different boreholes to be correlated within a region of geological coherence.

Our understanding of the geology and hydrogeology of some countries would be considerably improved if geophysical well logs could be run as a matter of routine in 10% of the boreholes drilled. In some countries over 1000 wells are drilled per year.

2.3.8 *Aquifer tests*

An aquifer test or pumping test is one of the most useful means of determing the hydraulic properties of water-bearing layers and confining beds. However, the depth to the groundwater level is often considerable: this makes it expensive to drill observation boreholes. In most cases well tests (pumping and observation in the same borehole) can be carried out, resulting in reliable transmissivity data. Experience is required to carry out aquifer tests properly and to interpret the results.

2.3.9 *Hydrochemical investigations*

The frequency of sampling and the amount of water samples to be chemically analysed, usually depend on the capacity of the available laboratory and sometimes on the availability of chemical reagents or spare parts for equipment. It is rarely possible to do bacteriological analysis of water samples from remote areas, as these samples cannot be sent to the laboratory in time. Some data on the chemical composition of the water and some qualitative information on bacteriological contamination can be obtained using field kits.

2.4 Requirements

2.4.1 *Manpower requirements*

The achievement of the objectives mentioned above requires considerable manpower of the sister institute: 5 - 10 professionals. 10 - 20 subprofessionals and 20 - 40 assistants, drivers, draughtsmen, auxiliaries, etc. In addition, administrative support is required to solve logistical problems.
The training needs to be implemented by a team of residents consisting

of a hydrogeologist (who is also co-manager of the project) a hydrologist, a geophysicist and a technician.
In addition experts seconded for short periods are required to cover special fields of interest such as: supervising drilling operations, specifying the data base, setting up an instrument workshop, implementing modelling techniques, running special training courses, etc.
Without experienced experts and adequate technical backstopping the projects cannot be properly implemented.

2.4.2 *Equipment*

Much equipment is required for intensive field survey: vehicles, a drilling rig, computer facilities, and hydrogeological, hydro-meteorological and geophysical equipment. The Netherlands contribution to the projects partly covers the equipment requirements.

2.4.3 *Operational costs*

Field surveys in remote areas require funds to cover the operational costs of: transport, operation and maintenance of vehicles and drilling rig; housing and office facilities; field allowances etc. The operational costs are considerable. Generally they are financed entirely by the sister institute.

2.5 Organization and responsibilities

Often a research institute begins systematic, regional hydrogeological investigations as a direct result of the project, yet neither the project nor the project activities fit into the organizational structure of the institute. Generally, the project at least partly overlaps the activities of existing sections or divisions in the local research institute (e.g. drilling, groundwater, surface water). If the main task of the project - the systematic regional hydrogeological

investigation - is to proceed smoothly, then the role the research institute can play must be clearly and formally defined. The project or a series of projects should finally be formalized in a properly functioning organizational unit.
Both TNO and its local partner in the project must be committed to ensuring the continuity of the project. This implies that the sister institute should be responsible for doing the hydrogeological investigation collecting and evaluating data, and drafting reports), whereas Groundwater Survey TNO should be responsible for training local staff and for giving advice and instructions.
The Netherlands team is supervised by the Netherlands co-manager; the counter part team is supervised by the co-manager of the sister institute.

Joint projects cannot succeed unless there is a good relationship between the two teams, especially between the two co-managers.

3 CONSTRAINTS

3.1 Introduction

In the course of joint projects in countries in Latin America, Africa and Asia, certain constraints have been found to severely hamper the executive and administrative performance of the water sector in general and thereby, to interfere with the projects. It goes without saying that the constraints mentioned below do not apply to all countries.

3.2 Constraints at national level

General awareness of the need for water management is a recent phenomenon: in the past research oriented activities received low priority. In most countries emphasis was or is given to water development. Generally, the policy is to provide full rural water coverage by the year 2000.

Goodwill, intentions to improve rural life, voluminous technical reports from the United Nations, and enormous financial and technical support from many donor countries, have all contributed to this commitment. But the resulting task far exceeds the capacity of the responsible departments and agencies. Moreover, the lack of planning, and of control and co-ordination between the various departments and foreign agencies often prevents water supply systems from being established quickly and properly.

In most countries various ministries (Agriculture, Health, Housing, Public Works, Environment, Livestock, Energy, Tourism etc.) and agencies plan, finance, construct or operate facilities for water supply and use. Often responsibilities overlap and there is duplication of effort and conflict of authority. Generally, there is no co-ordination or communication between the various departments and agencies.

Facilities for training and education are limited in most countries. Universities seldom specialize in hydrogeology, hydrology or geophysics. Only a few countries can offer post graduate courses in these subjects, or training facilities at professional and sub-professional levels.

3.3 Constraints at the institutional level

At the institutional level the main constraints relate to weak organization, poor management, and a shortage of qualified manpower, equipment and funds. The organization is often piecemeal: the emphasis is usually on administrative management rather than on building up good relations between the staff of the institute and between the institute and other institutions or government departments. The drawing up of technical plans and their implementation are also often ignored.

The most common deficiencies in management are:

- failure to transform government policy into implementation plans;
- emphasis on short term activities rather than on considering long term needs and potentials;
- lack of interaction and communication between organizational units.

Management posts are often occupied by senior administrators/politicians whose tenure rarely lasts more than one year.

As a result of the shortage of qualified personnel on the labour market and the low government salaries, job mobility is high. In some countries the annual turnover of newly recruited professionals is 25%, which implies a complete replacement of all professionals during a period of 5 years.

Systematic regional hydrogeological investigation rarely forms an integral part of the activities of research institutes, because of the low priority, given to research in the past. Furthermore there is a shortage of qualified manpower, and equipment and of funds to cover the operational costs.

In spite of the high priority given to water development in most countries, the responsible organizations do not function optimally. Great improvements could be made in exploration and exploitation methods.

4 SOME CONCLUSIONS AND RECOMMENDATIONS

- In most countries there is an urgent need to establish a government policy that is oriented to the rational development and management of water resources.
  In general, too many agencies are involved in making decision and in carrying out water supply programmes, and these agencies have conflicting tasks and responsibilities. A rational reorganization and co-ordination of water programmes could considerably improve the water sector.

- Top management posts are often held by senior administrators/ politicians whose average tenure is short. Such management posts should be occupied by senior officers who have proven ability in technical management.

- There is a severe shortage of qualified manpower at all levels. There is an urgent need to strengthen the facilities to train and educate personnel in the water sector. Such training and education could improve the demand and supply relation on the labour market and would reduce excessive job mobility.

- The capabilities of organizations responsible for water supply and use need to be strengthened, especially regarding:
  - drilling techniques;
  - design, completion and development of wells;
  - design, construction, operation and maintenance of water supply systems.

- The capabilities of research institutes need to be strengthened with emphasis on:
  - systematic regional hydrogeological investigations;
  - the establishment of an optimally functioning data base;
  - the establishment and maintenance of observation networks.

ANNEX 1

STAGES OF WATER RESOURCES DEVELOPMENT AND SUPPORTING ACTIVITIES

OPTIMIZATION	SYSTEM ANALYSIS
↑	↑
CONSERVATION	CONTROL
↑	↑
INCREASING DEVELOPMENT	ASSESSMENT
↑	↑
INITIAL DEVELOPMENT	EXPLORATION

ANNEX 2

MAIN ASPECTS AND RELATED TECHNIQUES OF INVESTIGATION

Main aspects	Techniques of investigation
1. *Geometric configuration of aquifers*	drilling, geophysics, hydrological mapping, cross sections
2. *Boundaries of groundwater system* - hydrogeological boundaries - hydraulic groundwater divide	hydrogeological maps, cross sections water level map
3. *Mechanism of replenishment* - from rain - from rivers - subsurface inflow - fossil water - others	geohydrological inferences, water level hydrographs and maps, observation of river flow, geochemical methods, isotope methods
4. *Mechanism of natural outflow* - through springs - into rivers, lakes - evapotranspiration - subsurface outflow	geohydrological inferences, water level maps, salinity maps, geochemical methods, isotope methods air photos
5. *Estimate of average monthly/ annual replenishment*	waterbalance methods, water level map, pumping tests

6. *Pattern of flow*	geohydrological inferences, water level maps, pumping tests, geochemical methods
7. *Water resources*	well inventory
Quantity	projections; additional study
- present water consumption	geohydrological inferences;
- future water demand	modelling for evaluation of
- available water resources	exploitable yield, geochemical methods
Quality	geochemical methods
- groundwater types	
- groundwater salinity	
- groundwater pollution	
- bacteriological contamination	bacteriological analysis

ANNEX 3

SCHEDULE OF ACTIVITIES

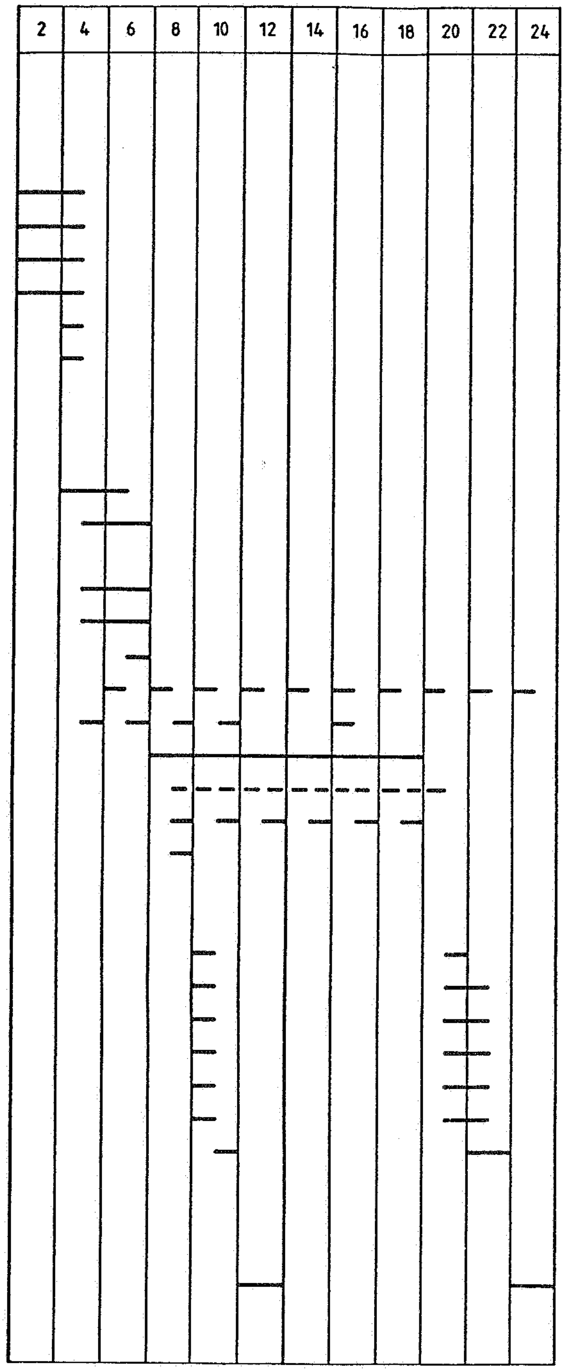
1. Data collection/
   evaluation

   - maps, photos
   - geology, hydrology
   - hydrometeorology
   - water supply and demand
   - aquifer types
   - identification of aquifer
     system

2. Field activities
   - well inventory
   - establishment of network
     . groundwater level
     . river discharge
     . rainfall
     . met. station
   - monitoring of network
   - geophysical operations
   - drilling
   - geophysical well logging
   - aquifer tests
   - hydrochemical investigation

3. Evaluation
   - aquifer geometry
   - boundaries of aquifer
     system
   - replenishment
   - natural outflow
   - flow patterns
   - water resources

4. Reporting
   - Interim report
   - Final report



ANNEX 4

WELL INVENTORY DATA SHEET

A.	Well identif. no:		Owner:
	Location:		(location sketch at sheet 2)
	Coordinates:	° ' "N	° ' "E
	Elevation:	m + msl	(map/altimeter/level)
	Air photo run:		Photo no.:

B.	Type of well:	dug/drilled	When constructed:	
	Number of times deepened:		When and how much:	
	Total depth:	m (measured)	Diameter:	m (at surface)
	Casing depth:		Casing material	
	Screen depth(s) and diameter(s):			
	Type of rock:	from 0	to m:	
		from	to m:	
		from	to :	

C.	Method of water lift:	pump/bucket/		
	Type of pump:		Capacity of pump:	HP
	Type of engine:		Capacity of engine:	HP
	Pump intake at:	m	Pump runs dry:	no/yes
			after	hrs/min.
	Yield (estim/meas.)	l/s	Drawdown (estim/meas.)	m

D. Water use: domestic - approx. no of persons:

irrigation - area + main crops:

other uses.

Average pumpage duration:

hrs/day, days/wk, months/year (months: through

hrs/day, days/wk, months/year (months: through

E. Original depth to (static) water level: m

Actual depth (meas./estim.) to water level: m

Estimated seasonal variation of water level: m

F. Groundwater quality according to users: good/fair/bad (fresh/brackish/saline)

Electrical conductivity µS/cm at 25°C

Temperature °C

G. Suitability of well for investigation purposes:

geophysical logging: yes/no

pump test : yes/no

groundwater level monitoring: yes/no

water quality sampling: yes/no

H. Inventory made by:

Date:

I. Remarks:

J. Location sketch

WATERSUPPLY OF SMALL URBAN CENTRES IN UPPER-VOLTA

N. A. AMESZ AND F. J. H. DIRKS

ABSTRACT

Within the framework of the Dutch-Voltaique bilateral co-operation, International Water Supply Consultants IWACO B.V. (Rotterdam, The Netherlands) was charged to study technical and economic feasibility of installing watersupply systems in ten small urban centres in Upper-Volta.

The studies, carried out by IWACO's permanent regional branch office for Western Africa in Upper-Volta, consisted of four main components:

1) demographic and socio-economic surveys;
2) hydrogeological investigations;
3) technical designs;
4) financial and economic evaluation.

The first part, the demographical and socio-economic surveys, served to determine the total population living in the various centres and their future developments and, secondly, to which extent they would become client of the future public water system, this in relation to their monetary income and the availability of alternative sources of water.

As the hydrogeological situation of Upper-Volta is complex, the second part notably groundwater investigations constituted a basic component.

Water in sufficient quantities is only available in faults and fractures zones in the underlying hardrock and photogeologic studies, field inventories, detailed geophysical prospecting, test drilling and subsequent pumping test were required to confirm the presence of exploitable groundwater resources.

The technical lay-out of the systems should be such that at minimum costs one could obtain a maximum of reliability and an efficient operation and maintenance in combination with as low as possible recurrent costs (fuels, personnel etc.).
The last item, the financial and economic analyses served to investigate how the systems would have to be incorporated within the National Water Office and how their cash flow would be affected in the next coming decades.

The studies were completed by mid 1982. In all centres groundwater reserves were confirmed to be available in quantities sufficiently to cover the demand up to the year 2005. However, from the financial analysis it appeared that costs of water increased rapidly when the size of the scheme becomes smaller. In order not to jeopardize the financial situation of the National Water Office it was recommended to postpone the construction in three of the centres and, secondly, to increase the national waterrates substantially. Both recommendations were accepted by the Voltaique Government and the joint appraisal mission of the BOAD and the Dutch Government early 1983.

1 INTRODUCTION

Within the framework of the bilateral co-operation between Upper-Volta and The Netherlands, International Water Supply Consultants IWACO was charged to execute a preparatory study on the technical and financial feasibility to introduce and exploit public watersupply systems in 10 small urban centres in Upper-Volta. The results of the studies were to be submitted to a consortium of funding agencies, among which The Netherlands, in order to raise the necessary funds for construction. The study was carried out by IWACO's Regional Branch Office for

West Africa in Upper-Volta, and consisted of four main components:

- a socio-economic and demographic study;
- hydrogeological investigations;
- technical design;
- financial and economic analyses.

The surveys started early 1981 and were completed by mid 1982.

2 BOUNDARY CONDITIONS

The physical and socio-economic conditions of Upper-Volta are rather typical for the larger part of Sahelian and sub-Sahelian Western Africa. As these boundary conditions have determined both the selected methodology of the study and the final evaluation of the results, a brief outline of the locally prevailing conditions is given below.

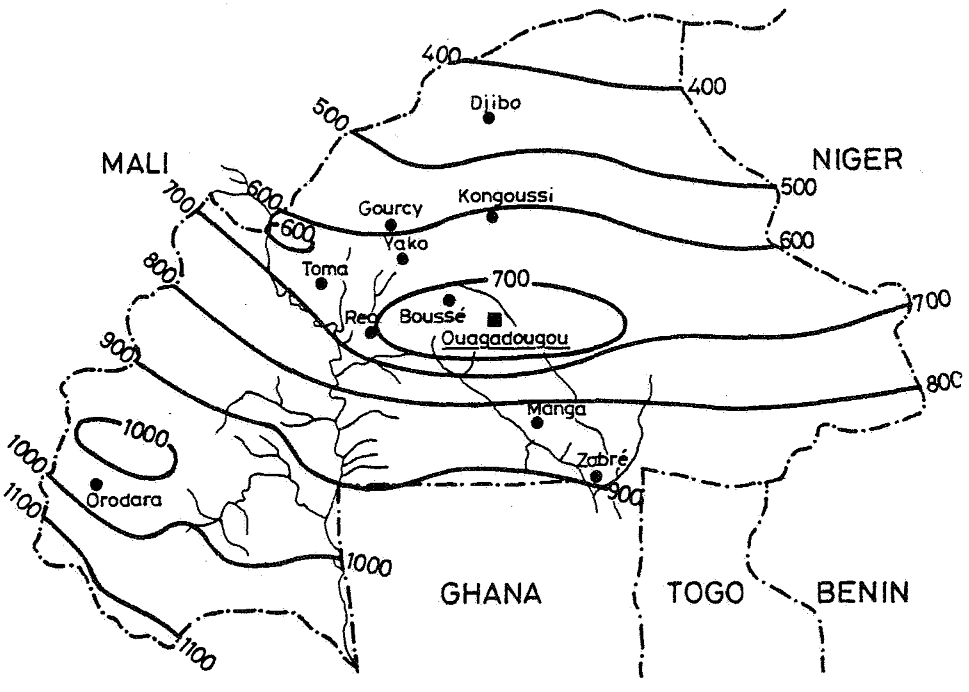


Figure 1 Location map, precipitation lines

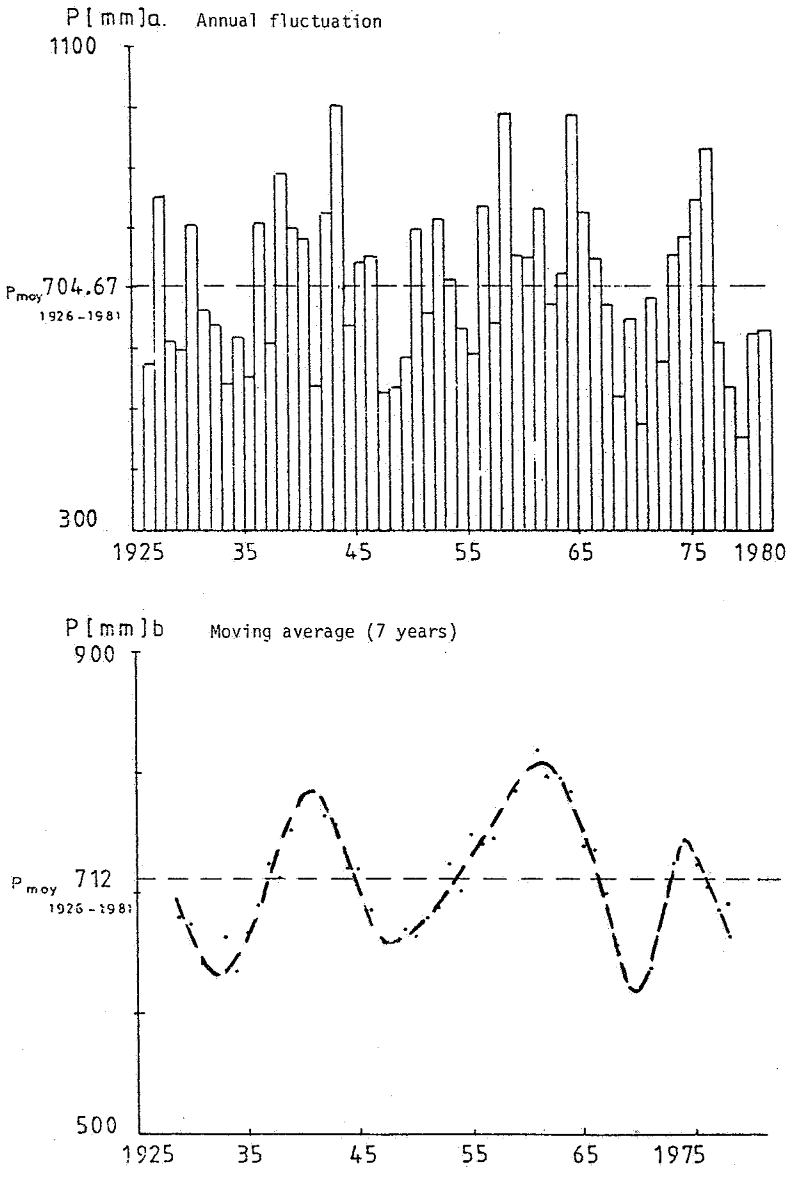


Figure 2 Rainfall pattern at Kaya

2.1 Climate

The average annual rainfall varies from 400 mm in the northern part of the country (Sahelian conditions) to 1100 mm in the southern part. See also Figure 1. Almost all rainfall is concentrated in a 3 to 5 months period (May-September); the remaining 7 to 9 months are almost completely dry.

Apart from this geographical variation there are very distinct yearly fluctuations. An example is shown in Figure 2: the precipitation pattern at Kaya. The upper graph shows the rather irregular annual pattern over the period 1925-1980. The average is 704 mm, while the minimum and maximum values are 450 and 1000 mm respectively. The lower graph represents the moving average (7 years) and indicates clearly the succession of longer dry and wet periods. The severe drought of the early seventies is rather distinct, while the suçceeding wet period is only a moderate one. Some other stations in Upper-Volta show a similarity, while at other stations the oscillation is less important and sometimes dominated by a continuous decline of rainfall. The evaporation is high: around 200 mm per year.

2.2 Hydrogeology

About 85 percent of Upper-Volta is situated on crystalline rocks which are part of the so-called West African precambrian shield (see Figure 3a). The substratum is generally composed of either intrusive or metamorphic rocks. A typical geological profile is shown in Figure 3b. The topmost part of these rocks is weathered to an average depth of 20 to 30 m but sometimes up to a depth of over 50 metres. In general these weathered zones have a poor porosity and permeability. However, in many locations dug wells with a capacity of an average of 5 cubic metres per day can be installed. Higher yielding wells (say: up to 10 m^3/hour) can only be drilled in local vertical or sub-vertical fractured zones around faults in the hard rocks. However, these fractures zones are not immediately visible; location is only possible by means of special investigation methods,

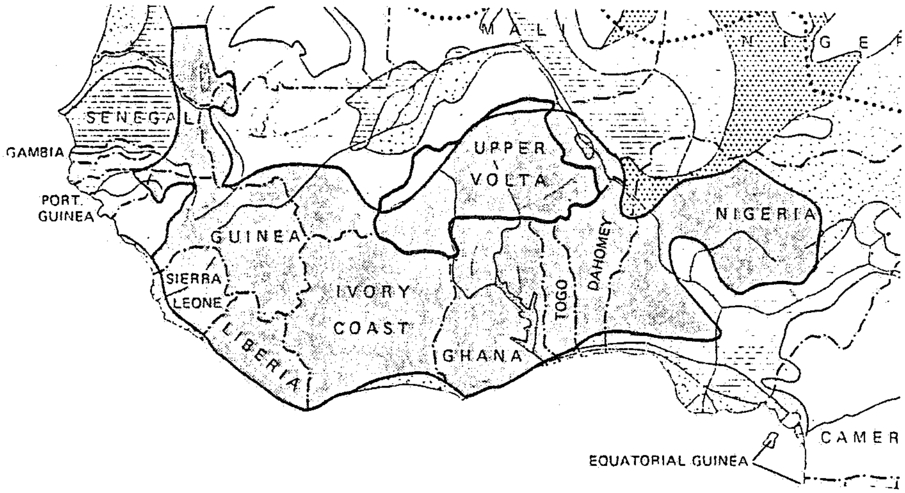


Figure 3a Precambrian shield in Western Africa

which will be discussed later on. Nine out of the ten centres are situated on the cristalline shield. One (Orodara) is located on more recent sediments (sandstone mainly) that cover the remaining 15 percent of Upper-Volta.

It is to be expected that the multi-yearly fluctuations in rainfall will affect the hydrogeological system. For instance, it is known from incidental observations that groundwater levels have lowered locally up to 10 metres during the last decades, with disastrous effects on many traditional dug wells. However, specific data on the magnitude of this lowering of the groundwaterlevels and its regional extent are not readily available. The same goes for the rate of recovery (if any) of the groundwater levels during a wet period.
In order to provide the answer to several of these fundamental questions, a basic study of the national groundwater balance has been started recently, and should eventually provide the scientific basis for a rational planning and development of the country's scarce water resources.
The study is being financed by The Netherlands, while the investigation programme will be carried out by IWACO in close collaboration with the

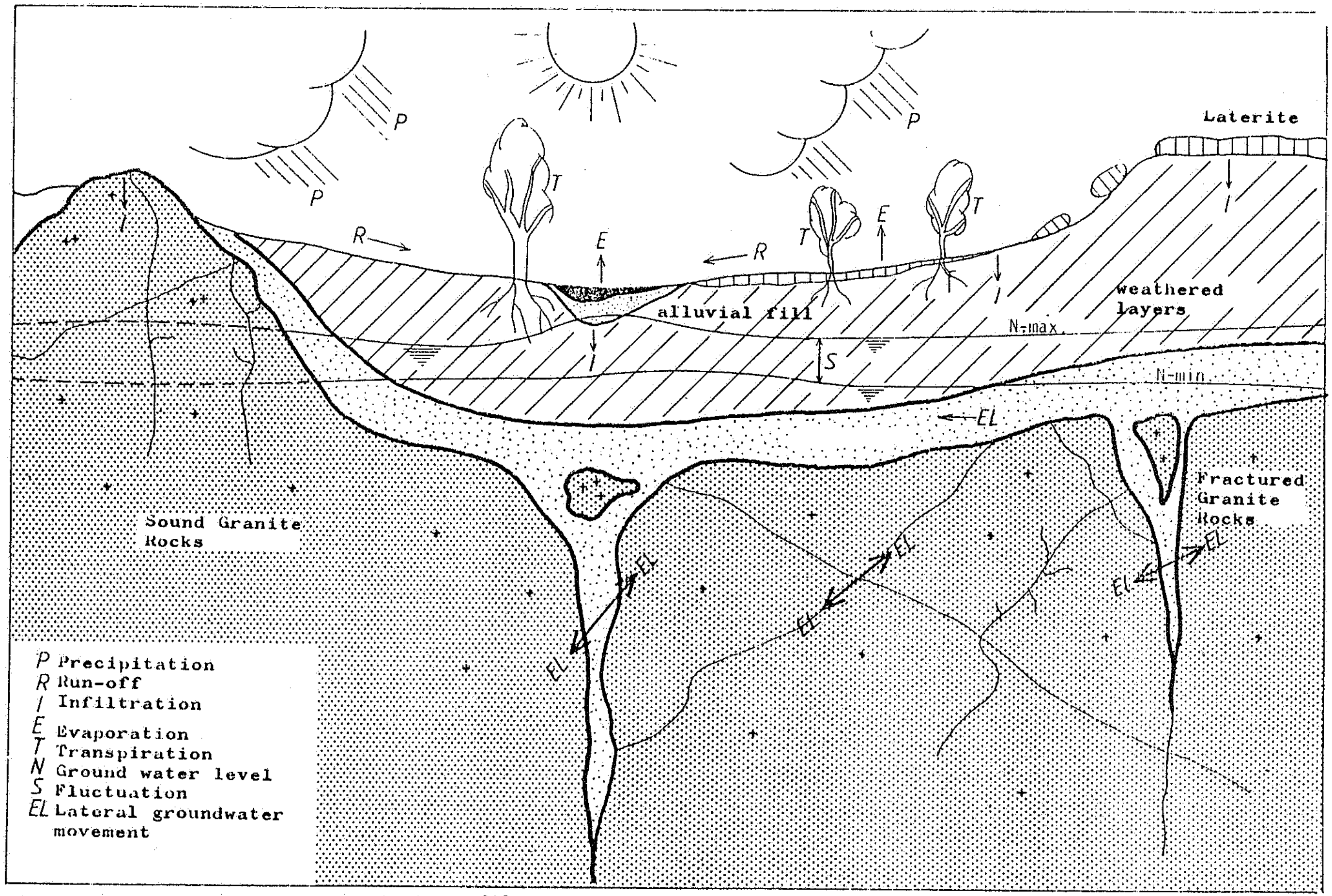


Figure 3b Typical hydrogeological profile

Directorate of Hydraulics and Rural Infrastructures of the Ministry of Rural Development of Upper-Volta.

2.3 Hydrology

Upper-Volta's drainage pattern is relatively dense. The drainage basins are generally flat, the vegetation is rather scarce and the topsoils generally have poor hydraulic properties. As a consequence run-offs are immediate and, due to the fact that storage within the basin is virtually absent, there is no base flow.
The only permanent streams in Upper-Volta are those that drain the sandstone platforms in the south-western part of the country. In the main part of the country permanent surface water is only found there where it has been retained by small dams. However, due to their small capacities and the high evaporation rate these reservoirs do not allow for exploitation on a reasonable scale.

2.4 Socio-economic situation

Upper-Volta is completely land-locked, the nearest seaharbour being at a distance of 100 kms; thus imported goods are expensive. The national economy is almost entirely based on agriculture. Other natural resources are virtually absent. Some 90 percent of the 6 million inhabitants live in small rural villages, subsisting mainly on their own agricultural production while trying to reach the level of self-sufficiency.
A supplementary production of some cash crops sometimes provides a modest monetary income. However, with a total rural income of US $ 200,-- per capita the country belongs to the poorest of the world. The total bilateral and multilateral aid, consisting of grants and soft loans, has an annual volume of US $ 200 million. As a consequence, the nation becomes more and more dependent on the industrialized countries, not only for the initial capital investment for projects, but also - which is more alarming - for the financing of the annual running costs of a project.

Recently an international meeting, concerning these so-called "recurrent costs" was held between the Sahel countries,
One of the most important conclusions was that for any new project, detailed cash flows will have to be predicted for 10 to 20 years ahead while the recurrent costs should be minimized.

It was agreed that as a minimum requirement for the present project the consumers of water would at least have to be able to cover the operating cost of the systems (fuel, personnel, chemicals, maintenance and repair) and also that the installations would be designed such as to minimize these costs.

3 WATER DEMAND PROJECTIONS

Extensive surveys were carried out in order to establish a reliable forecast of the water consumption in each of the ten centres, serving two purposes:

- to avoid capital consuming over-dimensioning and
- to establish a realistic cash flow projection.

Several factors will determine the future water consumption.

First of all the total population of the centres and villages in the immediate surroundings, had to be determined. Official census data were used which were subsequently verified by study or aerial photographs of appropriate scale. In-depth stratified sampling of households has provided data on migration patterns during the past ten years, on household sizes, on priorities and on the actual water consumption.

Secondlv, a survey to determine which percentage of the population would be inclined to use the future public schemes had to be carried out. It was supposed that the behaviour would depend on two main factors:

- the availability of alternative water sources and
- the available monetary income.

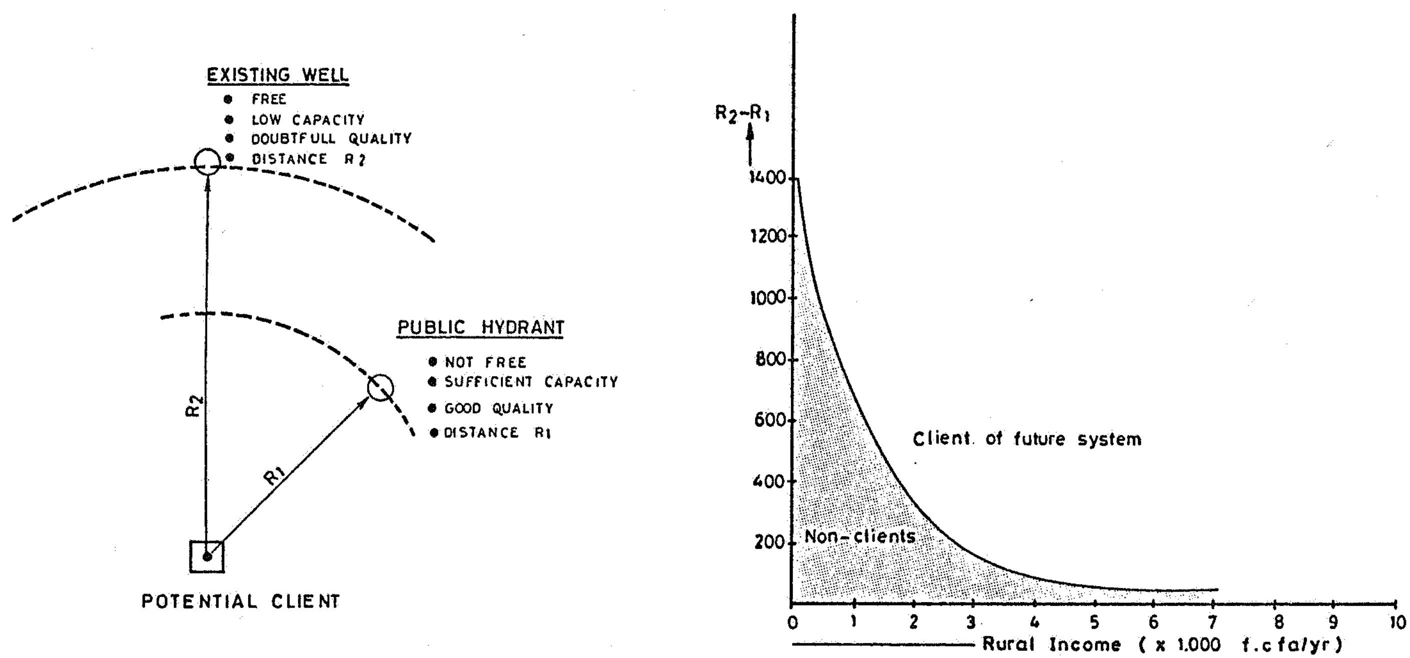


Figure 4 Dicission problem

Public schemes in centres where digging or deepening of wells is relatively easy, probably would not attract many paying clients, while in other centres where people draw their water from shallow mud pools at a respectable distance, because the granite rocks do not allow for digging or because the groundwater table is too far of, such a public system would be wanted and used. This decision problem has been schematically represented in Figure 4.
However, the available income may cause a restriction. In Upper-Volta water is sold at the public hydrant at about FCFA 200 per m^3 (US $ 0.70) which amount includes the fee for the permanent attendant. With an average consumption of e.g. 20 litres per capita per day during the nine dry months of the year, the annual water expenses would amount to US $ 4.00 which represents 10 to 20 percent of the average monetary rural income; however, in poorer regions of the country it would be even more than that, and this would in many cases restrict the potential water consumption.

The following forecasts were eventually used both for the hydro-geological studies and for the technical designs.

Centre	1995			2005		
	Population		Water-demand	Population		Water-demand
	(total)	(clients)	(m^3/day)	(total)	(clients)	(m^3/day)
Djibo	9 100	8800	311	12 350	12000	634
Manga	11 700	4360	169	13 750	6250	272
Zabré	10 650	3915	166	13 350	6545	322
Boussé	6 200	3410	121	7 400	5080	206
Kongoussi	11 000	5950	213	13 500	8600	362
Yako	10 250	4050	168	11 950	6350	319
Gourcy	13 110	4100	179	14 550	5850	285
Toma	5 300	2400	95	5 900	3400	163
Reo	4 700	950	54	5 500	1700	115
Orodara	12 700	3900	230	14 650	6200	476

4 HYDROGEOLOGICAL STUDIES

The purpose of the hydrological surveys is to localize renewable groundwater reservoirs having capacities to meet the water demand of 1995, preferably within a close range of the towns.

As the required capacity of groundwater can be only expected in fractured zones in the hard rocks, the methods of investigation were such that (sub)vertical fractured zones in the substratum, under the cover of weathered horizons, can be located. The hydrogeological characteristics of the aquifers were to be determined in order to be able to predict and to quantify any changes in the hydrogeological system due to the expected exploitation.

In this chapter the subsequent steps of the studies are discussed and some typical examples are shown.

4.1 Preparatory phase

At first, the existing data such as topographical and geological maps, climatological and geological data, reports, etc. were collected and studied.
Secondly, detailed topographical and hydrogeological maps were designed, based upon interpretation of satellite images (Landsat) and aerial photographs. The latter, at a scale of 1 : 30 000, were produced especially for the project.
These new topographical maps contain up-to-date information concerning topography, hydrography, land-use, occupation, etc. The hydrogeological map contains information on geology (outcrops), morphology, hydrography, covering layers (lateritisation) and it shows the lineaments as derived from the interpretation of the satellite-images and from the stereoscopic interpretation of the aerial photographs.
Based on this information, a preliminary selection was finally made of so-called target-areas: zones where, for various reasons, the presence of groundwater is likely and which, as a consequence, justify further prospecting.

4.2 Field surveys

The aim of this phase of the studies was the actual location of the aquifers and the determination of their hydrogeological characteristics, as soon as their existence was confirmed.
This paragraph summarizes the various kinds of fieldinvestigations which were subsequently carried out.

4.2.1 Field reconnaissance and groundwater level observations

A field reconnaissance was executed by the hydrogeologist in order to confirm and to complete the newly designed maps. Geological outcrops were examined in detail. Existing dugwells and boreholes (if any)

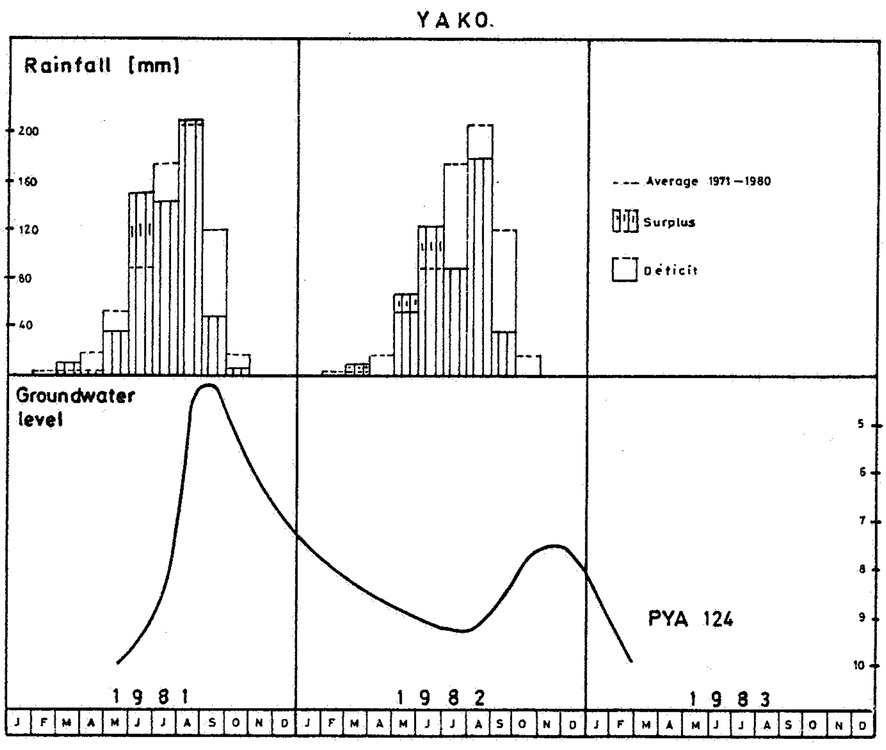


Figure 5 Groundwater level fluctuation

were examined, water levels were measured and water samples were taken for quality control. The data thus collected were added to the hydrogeological map. Based on the fieldfindings, the aerial photographs were re-interpretated when necessary.

In the second phase, a programme of measurements was set up to monitor closely the water-table fluctuations. Water levels were measured in each of the centres in about five representative dugwells and, if available, boreholes. These measurements have been repeated weekly over a period of at least one year.
Some typical seasonal fluctuations are represented in Figure 5.

4.2.2 Geophysical surveys

A geophysical survey was then carried out on a number of pre-selected areas. The aim of the geophysical survey is to discover whether fractured zones are present in the substratum and, if so, to determine their accurate location. Moreover, by means of these geophysical measurements, the thickness and the nature of the overburden as well as the nature of the hard rock itself can be determined.
Two different methods were applied:
- the well-known geo-electrical method, and
- the electromagnetic Slingram method.

The geo-electrical method consists of apparent resistivity profiles measured with the Schlumberger or Wenner array, as well as geo-electrical soundings with the Schlumberger array.

The electro-magnetic Slingram method, known from oreprospecting surveys, has recently successfully been introduced by IWACO in hydrogeological studies in West Africa.

Electro-magnetic measurements were made using different frequencies and along profiles which were sometimes previously measured geo-electrically. The methodology of the measurements was such that first some reconnaissance geo-electrical soundings were made. Based on the interpretation of these soundings, the appropriate depth of investigation of the profiles could be established.

Whenever possible, iso-resistivity maps and vertical sections were drawn up. Examples of a typical geophysical profile and an iso-resistivity map are shown in Figures 6 and 7.

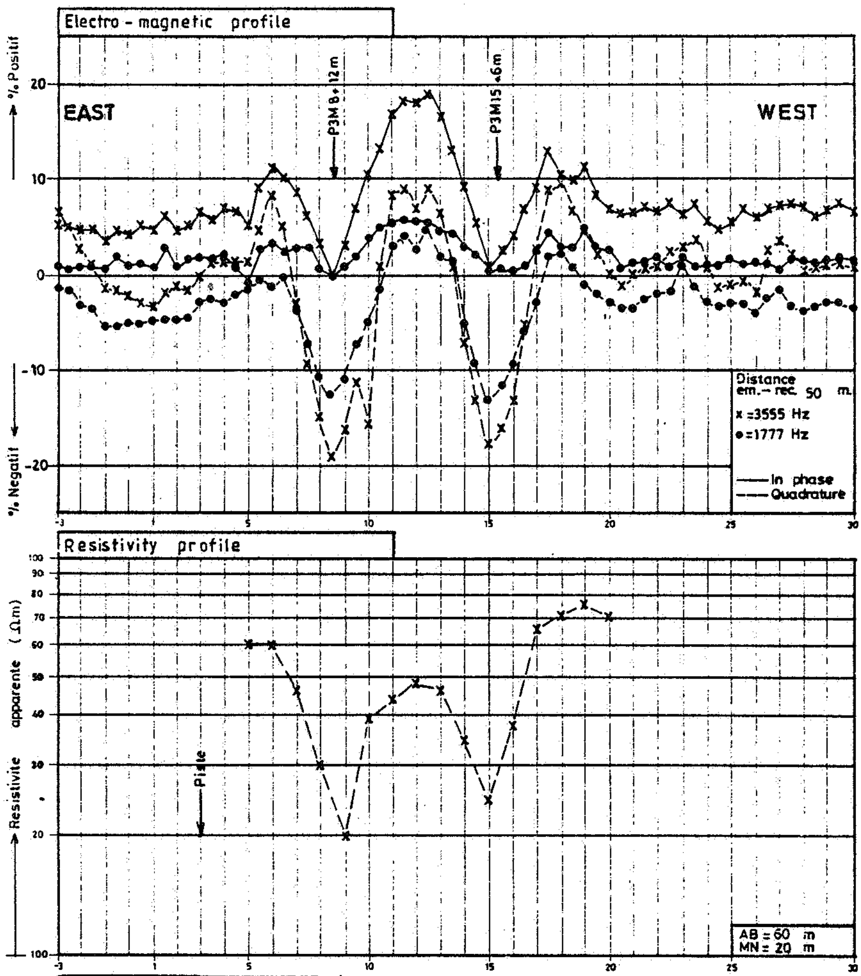
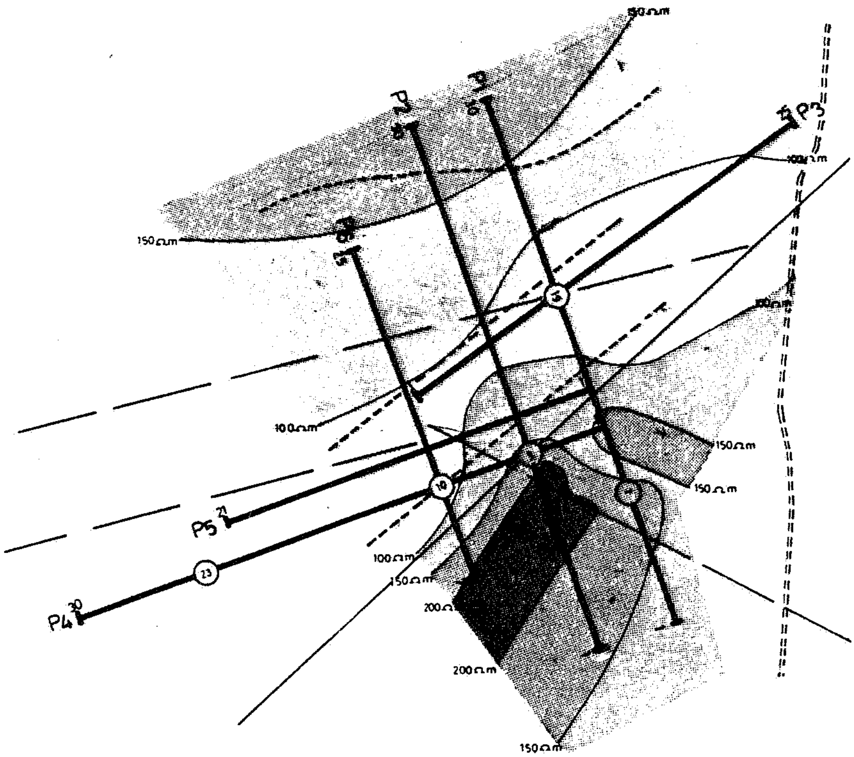


Figure 6 Geophysical profile



Geophysical profil
Electrical sounding
Lineament from aerial photographs
Direction of subsurface conductor
Iso-resistivity line

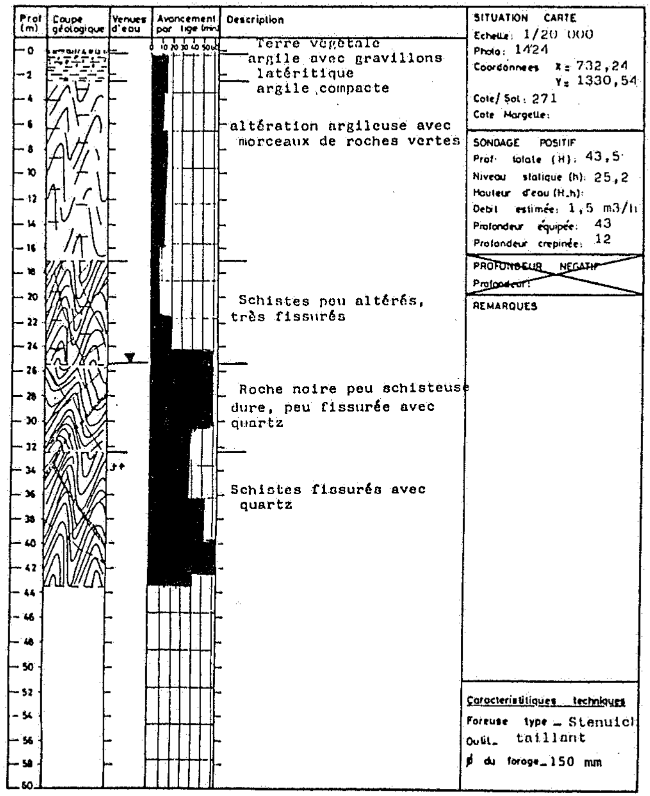
Figure 7 Iso-resistivity map

4.2.3 *Test drilling*

Based on data thus collected a selection was made of promising sites for test drilling.
With the rotary percussion method (hammer-down-the-hole) driven by compressed air, 165 mm diameter holes were drilled into the hard rock up to a depth of 80 m.
The drilling was closely monitored in order to collect as much information as possible about the depth and type of wheathering, the penetrated lithological formations, the presence of fractured zones, the depth of water entrance, etc. A typical borelog is given in Figure 8.

When the borehole was at depth, high strength PVC tubes with an internal diameter of 125 mm were lowered into the borehole. At a certain depth opposite the fractured zones, these tubes are slotted to allow groundwater to enter. The annular space around the PVC was filled with gravel and sealed with a clay pack, Finally, the borehole was cleaned and an estimate of the well-yield was made by continuous blowing at a constant rate.

Within the drilling programme, a limited number of observation wells was made. These wells, situated in the vicinity of a positive reconnaissance borehole, should provide additional information on the configuration and hydraulic behaviour of aquifers in hard rocks areas and was to confirm expected inhomogeneity of the substratum or changes in the lithology. An example is given in Figure 9. Here, the geophysical surveys indicated the probable existence of schist bands within granite rock. Test drilling at sites SB1 and SB3, with observation wells SB4 and SB6 confirmed this hypothesis.



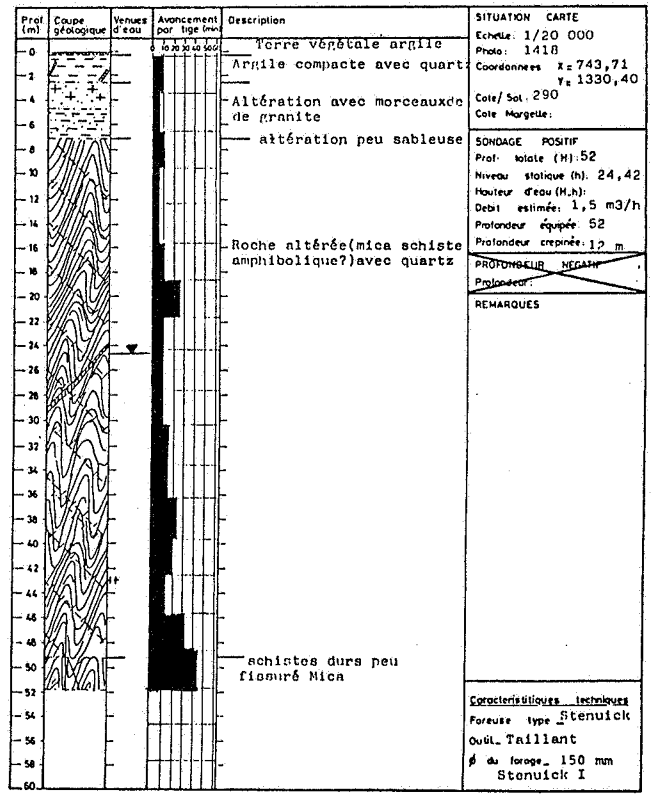


Figure 3 Typical borelog

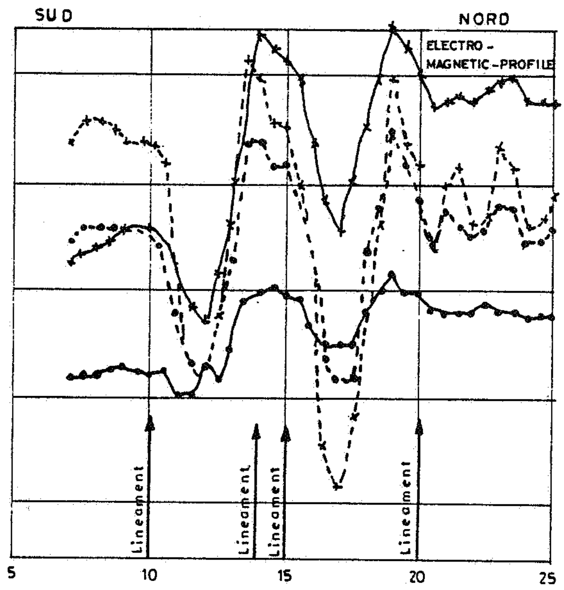


Figure 9a Electro-magnetic profile

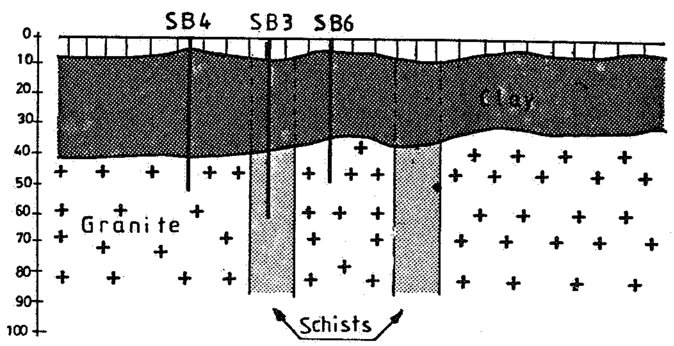


Figure 9b Geological section

The results of the test drilling programme are shown in the following table.

	Yield m^3/hour								
Towns	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	≥ 8
Yako *)									
Gourcy	3			1		1			
Djibo	2			2			1		
Boussé	1	1	1	1				2	
Kongoussi *)									
Manga			1	2					
Zabré			1	2					
Réo		1		1			1		
Toma	1			1				1	
Orodara									2
TOTAL	7	2	3	10		1	2	3	2

*) Not included in drilling programme

4.2.4 Aquifer tests

Step-draw-down tests were carried out to determine the hydraulic properties of the borehole. These were followed by a pumping test which lasted several days up to one week.
At some of the centres several piezometres were installed at different

distances from the production wells. The main objective was to acquire more information about the continuity of the aquifer, its hydraulic properties and its anisotropy. Specific data on aquifer behaviour in Upper-Volta are scarce while aquifer tests of long duration, as performed within the scope of the present project, are rahter unique up till now.

Figures 10 and 11 represent some interesting results of the aquifer test at Boussé. For a period of 6 days SB3 has been pumped with a continuous rate of 7.0 m^3/hour. Four observation wells, in different directions and distances (17.5; 38.5; 49 and 250 m respectively) were monitored closely during this period. The geological situation is heterogeneous: the existence of schist bands within the granite rocks was confirmed by the drilling programme. SB1, SB3 and SB7 are well within the schists while SB4 and SB6 are situated in the fractured granite rocks.

It was expected that the schist aquifer would be highly anisotropic, and would be discontinued perpendicularly to the geological direction. However, the drawdown data seem to indicate an axial symmetric drawdown pattern which seems to correspond with a radial flow of groundwater in a homogeneous aquifer having a uniform transmissivity of 20 m^2/day. The low values found for the elastic storage indicate a semi-confined aquifer; for the schist aquifer a value of 5.7×10^{-5} was found, which is substantially superior to those of the granites.

4.2.5 Waterquality investigations

Physical and chemical analyses were executed on water samples collected from the test-holes during the pumping tests and on samples from existing water points. Analyses were carried out to determine the type of groundwater and its quality in view of human consumption.

Special attention was paid to determine the arsenic contents as very high natural arsenic contents of groundwater in metamorphic rocks have been registered recently in Upper-Volta (AVV-IWACO, Etudes hydrogéologiques, 1979-1980).

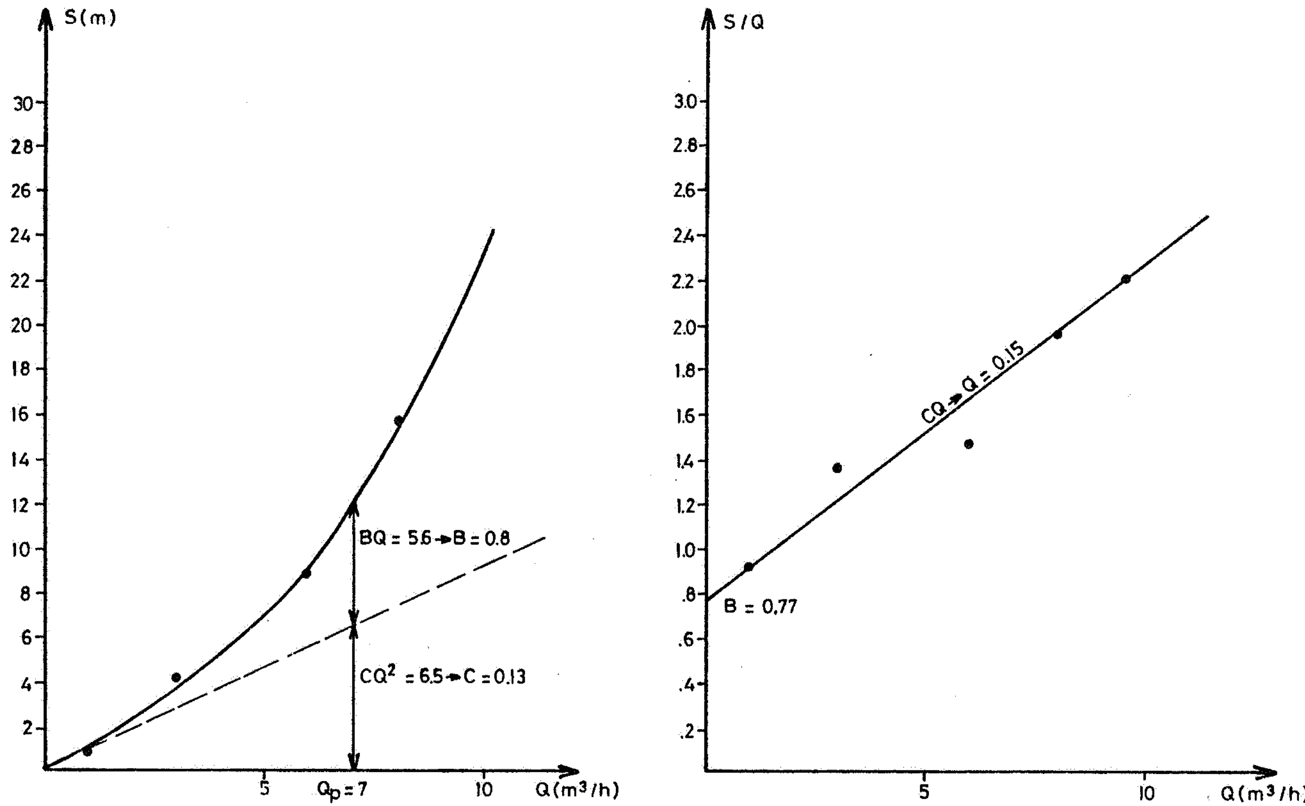


Figure 10 Step drawdown test at Boussé

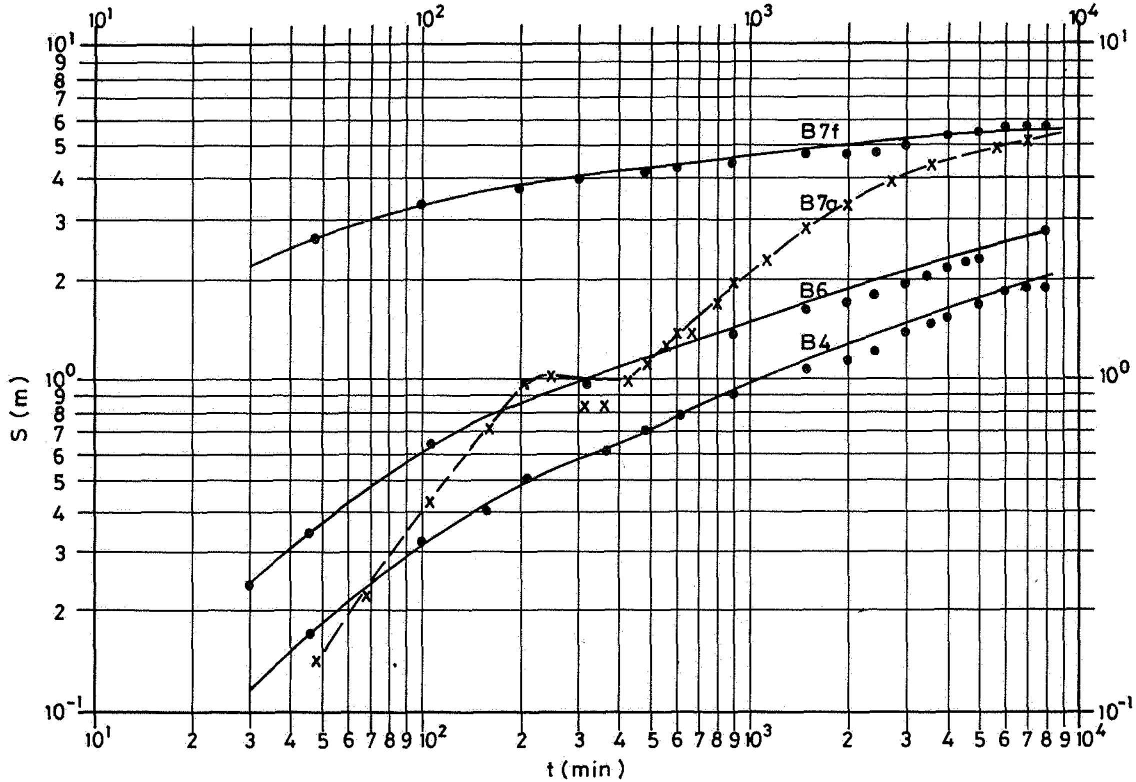
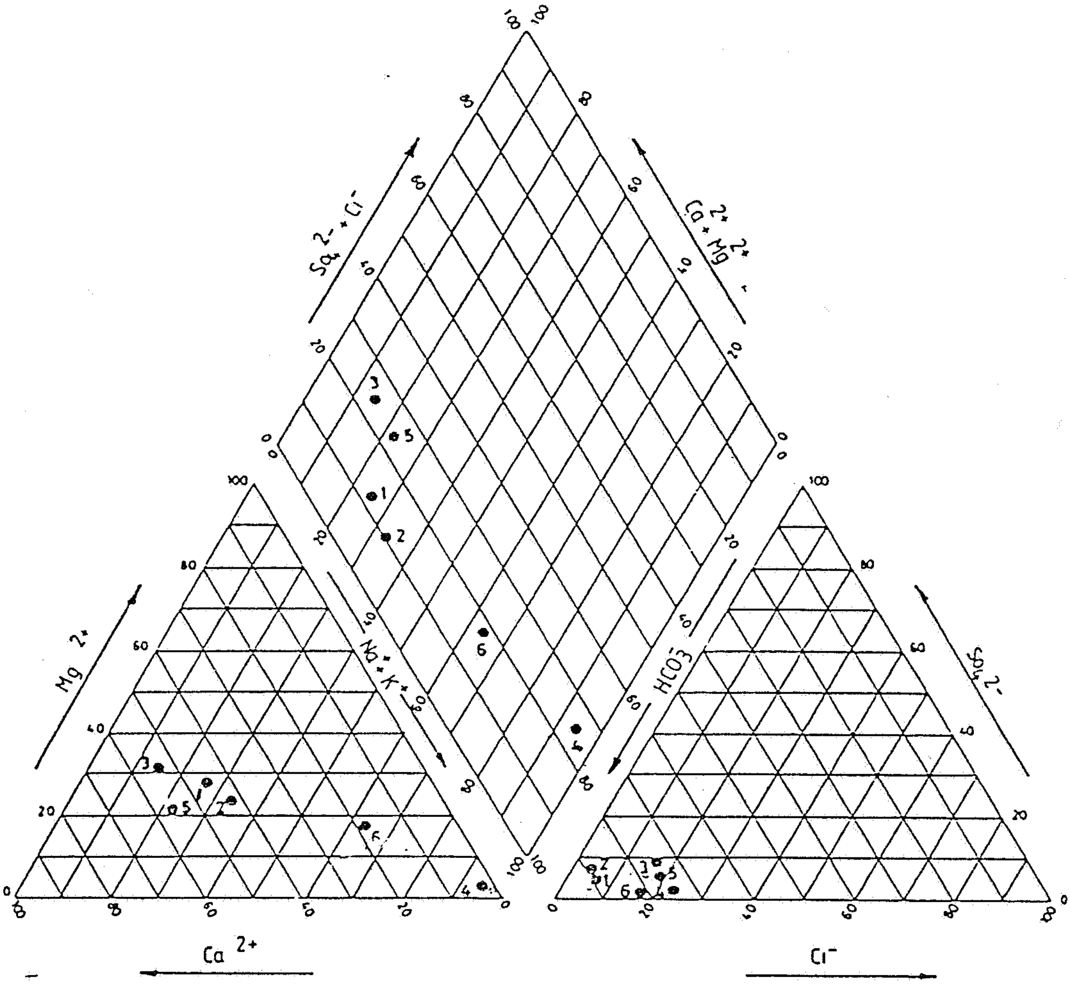


Figure 11 Drawdown graphs of observation wells

A piper diagram is shown in Figure 12. All groundwater encountered in this project is of the sodium or calcium bicarbonate type



N^O IWACO		Description
1	D110	Borehole
2	SD2'	Borehole
3	D100	Borehole
4	D116	Borehole
5	D107	Dug well
6	D113	Lake

Figure 12 Piper diagram

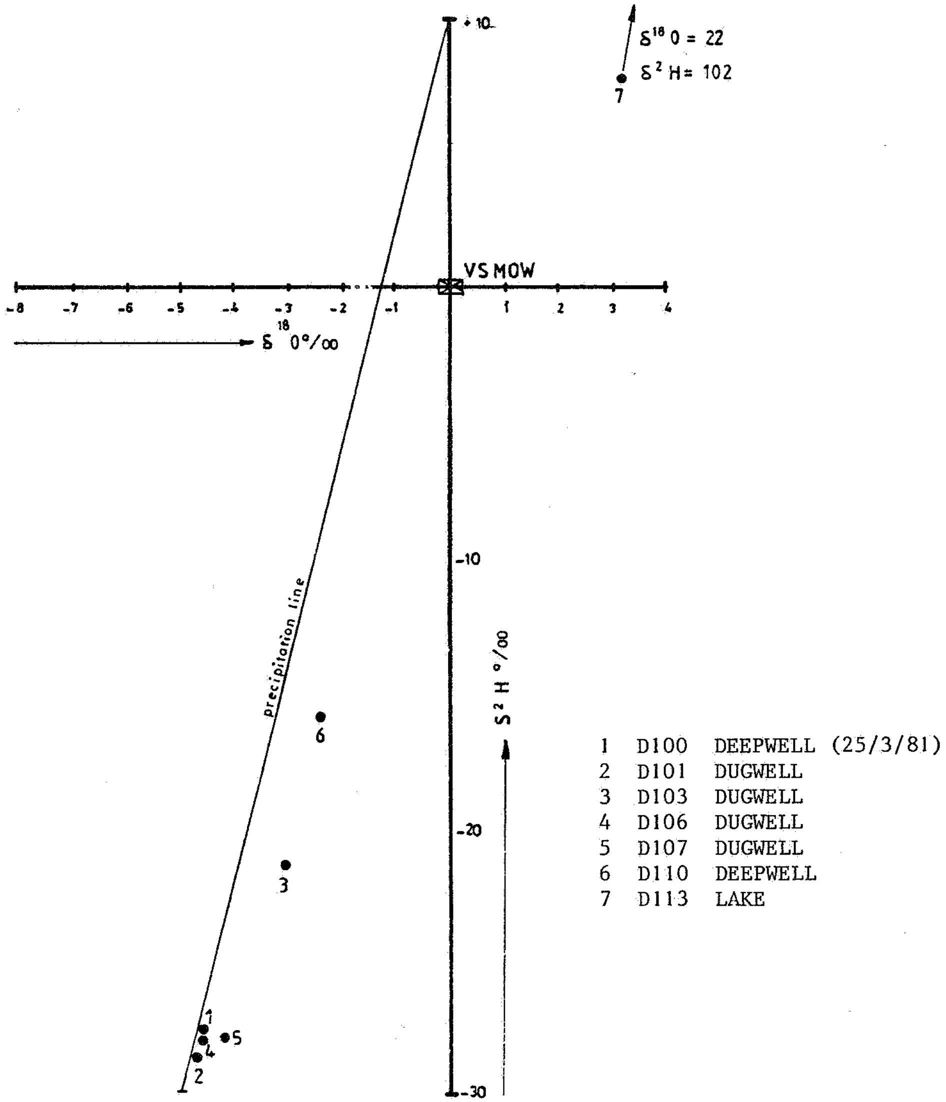


Figure 13 Isotopic investigations at Djibo

4.2.6 Isotopic investigations

Isotope analyses were performed on selected water samples. Stable isotopes 18-0 and 2-H contents have been determined to gain information concerning the origin of the groundwater. Furthermore, the radio-active isotope tritium content was established to gain information about the possible age of the groundwater.

The stable isotopes 18-0 and 2-H occur naturally in water in known ratio's. Based on world-wide measurements, ratio's for precipitations are plotted and an average line is constructed (see Figure 13). Due to evaporation, the 18-0 and 2-H content of surface water increases and their ratio changes. Figure 13 shows three samples with values clearly deviating from the precipitation line.

Sample nr. 7 has been taken at an artificial lake which is exposed to a high rate of evaporation. Results of sample nr. 6, taken from a borehole at a close distance of the lake, clearly indicate that the water, at least partly, has been exposed to evaporation which allows to advance the hypothesis that groundwater infiltrates from the artificial lake. The same applies to water sample nr. 3 taken from a dugwell.

Due to thermo-nuclear explosions between 1958 and 1963, the tritium content of the precipitation has increased about thousand-fold.

Town	Sample nr.	Date	Tritium contents
Orodara	S01	01-04-1982	2
Yako	Y143	-03-1982	1
Gourcy	G102	10-01-1982	8.1
Djibo	SD2	13-12-1981	30.1
Djibo	D 110	21-12-1981	26
Boussé	SB3	22-01-1982	1

The high values for the radio-active isotope tritium indicate that at least part of the water sampled at Djibo and Gourcy is of recent date.

5 TECHNICAL STUDIES

The watersupply systems had to be simple, reliable, easy to operate and to maintain; they should operate at the lowest possible running costs and they should be adapted as much as possible to existing operational skills and national standardization.

A typical system consists of:

- several deepwells equipped with submersible pumps;
- an operation building including generator house, operator's office and stock;
- a chlorination unit;
- distribution network (given the low quantities of water, the maximum pipe diameter turned out to be Ø 150 mm);
- a watertower (steel);
- public hydrants (at least 1 per 500 consumers or within walking distance of 250 metres of the consumer);
- private connections (public institutions, schools, missionaries and private consumers).

To minimize operating costs a separate study has been carried out concerning the application of solar energy. It was proved that, on a commercial basis, such systems would become feasible within the coming years.

Civil works, trunkmains and water towers have been designed in view of the demands up till 2005 while the deepwells, the secondary distribution systems and the electrical power facilities have to meet requirements until 1995.

6 FINANCIAL AND ECONOMIC ANALYSIS

This part of the study served several purposes:

- to present an investment programme;
- to calculate the production costs of the drinking water at the various centres;
- to assess the consequences of integrating these systems within the exploitation budget of the National Water Office;
- to provide detailed cash-flow and fund-flow projections both for internal accounting and for external financing;
- to assess the social benefits of the project.

The average production costs over a 33-year period have been calculated in three different ways. The first method (A) takes into account the recurrent costs only, while the second method (B) had to cover 40% both of the initial and the future investments; the last one (C) was based upon 100% coverage of investments. A discount rate of 4% has been applied.

Centre	Production costs (FCFA/m3)		
	A	B	C
Djibo	68	93	131
Manga	110	147	202
Zabré	98	137	195
Boussé	146	189	252
Kongoussi	79	98	126
Yako	101	132	179
Gourcy	81	110	153
Toma	172	215	279
Réo	205	259	340
Orodara	77	99	132

Several factors contribute to the important differences in production costs (from FCFA 131 to FCFA 340 per m^3). However, it appears that the overruling factor is the size of the system, as shown in Figure 14.

At present the "Office National des Eaux" (ONE: National Water Office) runs watersupply systems in the 7 main centres and in 10 smaller centres. A progressive tariff structure is used nation-wide which ensures a balanced exploitation based on cross-subsidizing between small and important consumers respectively. However, nearly all the clients in the secondary centres belong to the group paying the lowest - social - tariff of FCFA 70 per m^3, which is far below the production costs. The exploitation of the schemes would thus heavily depend on a relatively small group of important consumers in the capital.

Moreover, in the near future considerable investments are necessary to cover the capital's fast growing water demand. For these reasons it has been proposed to increase the lowest tariffs (which have not been altered since 1968) with 35% which would ensure a positive exploitation in three of the centers while in four other centres at least the recurrent costs would be covered.

In seven centres water would then be sold at a tariff below the economic production costs. The main justification for this was found in an improvement of the health conditions. There are indications that water-related diseases, particularly by the end of the dry season when fields have to be prepared, restrict the optimum use of available manpower. Secondly it was concluded that installing public watersupply schemes in small urban centres, together with rural electrification, education and health facilities as well as other rural infrastructures, would contribute to the government's policy of integrated rural development and decentralization, which indirectly would reduce the excessive migration to the few large urban centres of Upper-Volta.

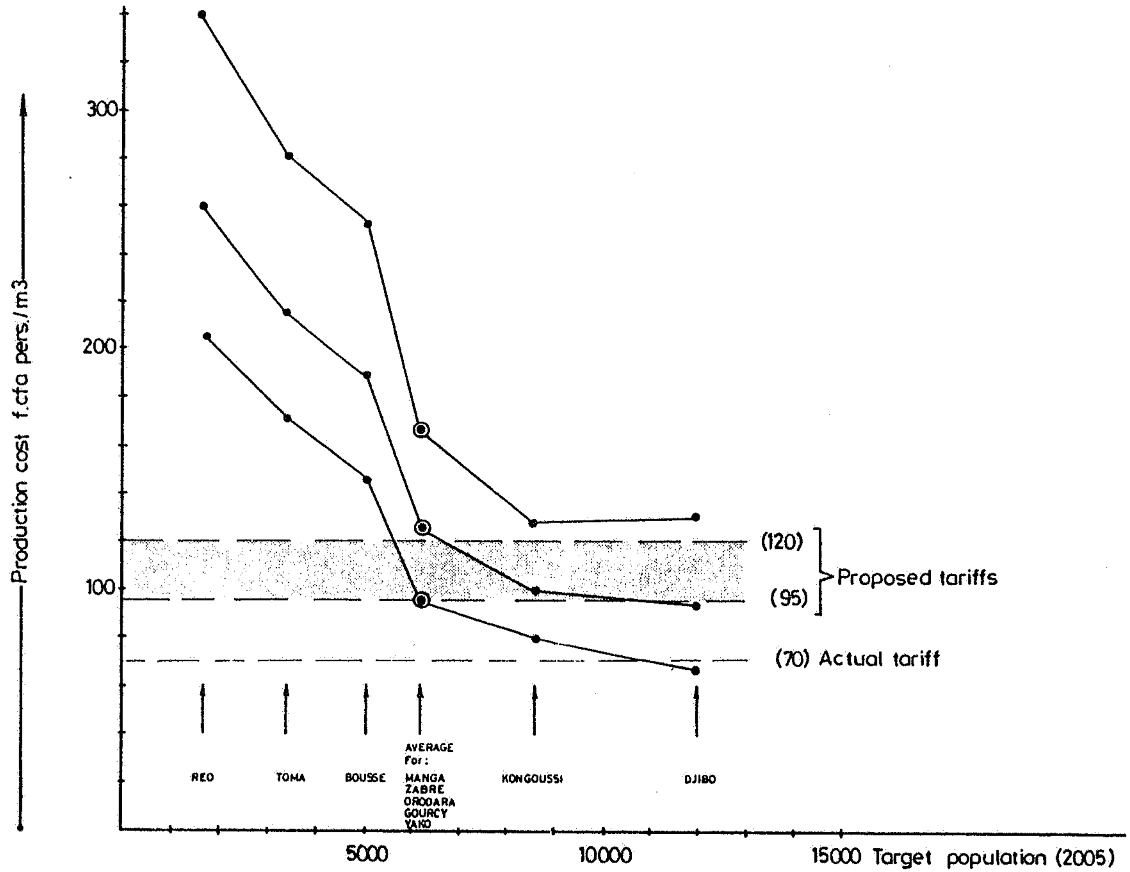


Figure 14 Production costs versus size of town

7 CONCLUSIONS

- Both water resources and capital resources are scarce in Upper-Volta. Any project, which-ever, requires a complete feasibility study to ensure an optimal use of both resources.

- Detailed hydrogeological investigations confirmed the existence of renewable groundwater resources in all centres, meeting the demands of the year 2005, and thus ensuring the technical feasibility of the schemes.

- However, a detailed analysis of the capital costs and operating costs of the systems as well as the financial status of the National Water Office proved that, without tariff modifications, the systems might run into severe financial problems within a period of ten years, which would certainly jeopardize a continuous exploitation of the schemes.

- It was concluded that in seven out of the ten centres the introduction of a public system is economically justified. In the remaining three centres the production costs would be excessively high, due to the small scale of operation. In one of these centres the traditional watersupply appeared to be satisfactory and improvement by means of a piped system was not on the priority list of the villagers; another centre was doubtful in this respect, while in the third centre the situation was indeed very urgent, although it was felt that the simple construction of a few deepwells with handpumps could alleviate the most urgent needs.

- The conclusions of the feasibility study were shared by an appraisal mission of the West-African Development Bank (BOAD) and the Government of The Netherlands and the decision was reached to co-finance the project.

MASTER PLANNING FOR THE DOMESTIC WATERSUPPLY FOR SIX MEDIUM- LARGE CITIES IN INDONESIA: SIX CITIES WATERSUPPLY PROJECT

R. G. CAMPEN AND E. J. WEDMAN

ABSTRACT

Although the Six Cities Water Supply Project has not been planned within the scope of the Water Decade, the construction of the designed water supply systems takes for the larger part place in the period 1980-1990.
In 1974 the Governments of Indonesia and The Netherlands agreed to co-operate in the project.

The cities Solok, Curup, Lubuklinggau, Serang, Tasikmalaya and Ternate were included in this water supply project. The Terms of References required that a masterplan for water supply would be drawn up for the year 2000. DHV Consulting Engineers should prepare a feasibility study and detailed designs in the Six Cities Water Supply Project.

The scope of this article will be limited to a concise discussion of the hydrological and hydrogeological aspects of the domestic water supply of Tasikmalaya and Ternate (two of the six cities), preceded by some remarks concerning the methodology applied in the masterplan and feasibility studies.

1 INTRODUCTION

1.1 The project

In 1974 the Governments of Indonesia and The Netherlands agreed to co-operate in the project.

As executive agency for The Netherlands the Directorate for Technical Assistance (DGIS) of the Ministry of Foreign Affairs was appointed, for Indonesia the Directorate of Sanitary Engineering which operates within the Directorate General Cipta Karya of the Ministry of Public Works and Electric Power. DHV Consulting Engineers executed the masterplan and feasibility studies, made detailed designs and drafted the tender documents for the first phase of the project and is supervising its implementation, except for Solok, which is done by an Indonesian consultant. The masterplan study included the following cities (see map, Figure 1):

Town	Province	Population (1976)
Solok	West Sumatra	28,000
Curup	Bengkulu	85,000
Lubuklinggau	South Sumatra	49,000
Serang	West Java	91,000
Tasikmalaya	West Java	143,000
Ternate	Maluku	42,000

Figure 1 Map of Indonesia

1.2 Assignment and progress

The Terms of Reference required that a masterplan for water supply be drawn up for the year 2000. The masterplan was to be divided into two phases, the first of which ending in 1990. For this first phase the Consultant should prepare a feasibility study and detailed designs.

Target of the study was to supply as large a proportion of the urban population as was technically and economically feasible with water from a public water supply system.
The improvement of the sanitary conditions resulting from providing the population with easy access to safe and sufficient water is expected to yield a positive effect on the level of public health.
The progress of the study was grosso modo in agreement with the proposed timeschedule. The study commenced in March 1976 and was concluded in April 1978. As supplementary designs were required part of the design work continued into 1981, but this did not hamper the implementation, which started in the course of 1978.

The implementation was considerably delayed, mainly by the following factors:

- the enormous amount of regulations to be coped with for the international supply tendering, leading to long delays in arrival of valves, fittings and other specials;
- counterpart allocations have consistently been lower than proposed, leading to delays as already available tender documents had to be adapted, bills of quantities reduced while a number of consecutive contracts became necessary where otherwise a single contract would have been sufficient;
- the size of contracts was purposely limited in order to stimulate tenders being awarded to local, smaller contractors, sometimes impairing the quality of the work.

Although in March 1982 parts of the cities had a continuous water supply, the goals set were not achieved, neither quantitatively (number of connections) nor qualitatively (CO_2-removal, chlorination).

2 METHODOLOGY

2.1 Water supply situation in 1976

The population of Indonesia was estimated at some 133 million in 1976. Approximately 25 million people (19 %) lived in cities of more than 10,000 inhabitants. The rural population lives in some 44,000 villages of less than 10,000 inhabitants.

In 1975 some 8.3 million urban and 4.3 million rural people were being served by public water supply systems. Of the total of 12.6 million people served by these systems some 2.7 million had house connection, while 7.2 million were served from public taps, mostly through water vendors.

The majority of the population thus was (and still is) using shallow wells (sometimes situated inside the house) and other traditional sources like springs, rainwater collectors and rivers. Most of these sources are subject to contamination.

2.2 Water demand till the year 2000

As a first approach, the number of inhabitants was determined who live within the boundaries of the administrative area of a city.
In agreement with the Indonesian Authorities it was decided that areas with a population density under 40 persons per ha would not be served. The present population of the areas to be served in all six cities together is 295,000. The capacity planned to be constructed in the first phase of the project, up to 1990, should be sufficient to provide about 462,500 people with water. In 2000 this number would be 625,000.

An important requirement is further, that the consumers are supposed to pay for the water delivered to them. Starting from the principle, that households cannot spend more than 3% of their income on water, three types of connections are envisaged, viz.:

- house connections, a private connection to the supply system with in-house piping for distribution of the water to several points;
- yard connections, a private connection with a singly point of supply only, situated in the yard and
- public taps.

The water demand (in litres/caput/day) per type of supply is assumed to grow on an average as follows:

- house connection, from 110 l/c/d in 1976 to 135 l/c/d in 2000;
- yard connection, from 75 l/c/d in 1976 to 85 l/d/d in 2000;
- public tap, 20 l/c/d constant over 1976-2000.

Taking into consideration the results of an investigation of a so far highly successful rehabilitation and extension water supply project in Bogor and general income projections, the type of water supply for households per income class was determined on a l/c/d basis.
It was assumed that towards the end of the masterplan period all households would be able to afford a house or a yard connection.
The water demand for non-domestic consumers (schools, hospitals, industry, etc.) was determined separately.

2.3 Water availability

On the basis of available information and field surveys the optimum source for the water supply system for each of the six cities was determined. Preference was given to springs, as in most cases pumping costs will be small or even nil , due to their elevation higher than the place of demand and the water quality is good. Purification can mostly be restricted to aeration, to remove most of the free, aggressive CO_2 and chlorination for safety reasons.

A difficult problem appeared to be the assessment of the minimum available yield of wells and springs. Safe yield estimates of groundwater aquifers are difficult to make because both extent and input and output of the aquifer cannot be determined accurately, due to lack of available pertinent information and the restricted time available for field investigations. Where possible, test pumping has been carried out on the aquifers selected and spot measurements, using flow meters, have been made on selected springs. From the spot measurements minimum flows were estimated and, if possible, checked by follow-up measurements in the period of smaller spring discharges.

2.4 Design criteria

With a view to the conditions and the state of maintenance of the present systems, it was proposed to disregard them and to construct completely new ones.

The main elements of a water supply system are:
- a spring tapping structure or a well field, provided or not with purification facilities;
- a transmission main (in some cases equiped with one or more breakpressure tanks);
- a reservoir and
- the distribution network with private connections.

The size of the various structures is based on design standards which have been discussed with the authorities concerned. The distribution network has been calculated by means of a computer programme made available by Cipta Karya. Calculations have been carried out both for peak flow and for night flow.
The technical design of the water supply network has been completed by the drawing up of engineering estimates of the investment.

2.5 Organization and management

Due to the fact that in some cities no or (in other cities) a rather small water supply network is in existence a formal organization capable of running a complete network should be developed more or less scratch.
A general set-up of the organization will be that there is a team of three persons: a managing director, a head of the financial and

administration group and a head of the technical group. They are responsible for the day to day affairs. A board, consisting of representatives of the government should supervise the water enterprise. The enterprise should, however, have a completely independent status especially in the field of financial matters. Early recruitment of senior staff is essential and should be followed by instruction courses in technical, financial and administrative matters, and practical training in the same fields at some selected well-run public water supply companies.
Continued support to the enterprise's management by assigning Consultant advisor(s) to provide an in-service training programme over the initial years is recommended.

2.6 Economic and financial appraisal

A starting point for the financial and economic appraisal of the projects is the adoption of water rates which enable a large proportion of the population to draw water from the system. The aim of the Government of Indonesia is that ultimately the users should finance all recurrent costs.

For the various types of supply different water rates are proposed (house connection, yard connection, public taps, small commercial users and others).
Principally, three sources of financing are available:

a. loan to the water enterprise from the Indonesian Government at a term of 30 years with 6 years' grace period on redemption and carrying 9% interest per annum;
b. equity capital for the water enterprise from the Indonesian Government, which may be repaid partly only, or in delayed instalments depending on the financial situation of the enterprise. Maximum equity participation is restricted to 50 % of the project cost;
c. grant from the Indonesian Government, which is only applicable if interest-free financing is required in excess of the maximum set for equity, above.

The financial requirements have been calculated for some key years, both at 1976 price level and at price level for the expected year of construction. Furhermore a division in foreign and local components has been made.

2.7 Environmental aspects

The Consultant has studied the environmental impacts, which the implementation of the new water supply system may have. It should be stressed that improving the health of the population cannot be reached by an improved water supply only, very important is also the improvement of the sanitation. Construction of a sewerage system, the ultimate solution to the problem is too costly, however.
The Consultant has indicated some pilot solutions which could be deve.oped and expanded by the local government.

3 HYDROLOGY AND HYDROGEOLOGY

3.1 Tasikmalaya

3.1.1 Introduction

Since 1923 Tasikmalaya has a restricted piped water supply system, fed by the Cibunigeulis spring, located 7 km NW of the city.
Due to the high content of aggressive CO_2 in the spring water (as all springs emanating from volcanic aquifers in Java), an aeration plant was constructed, but is out of order for a long time already. The discharge of the springs as well as the pressure in the distribution network are so low that an entirely new system had to be constructed.

In August 1976 a hydrogeological field survey was carried out in the area around Tasikmalaya, mainly to locate and evaluate larger springs. Minor attention was paid to rivers (heavily polluted water) and groundwater (partly because of pollution, partly because of very small well yields).

3.1.2 Available data

During the first part of the study all available data related to the study was collected from the different government and private agencies in Jakarta, Bandung and Tasikmalaya.
The following data and maps were obtained:

- Geological maps of West Java scale 1 : 250,000, published by the Institute of Geology (Bandung).
- A not published hydro-geological report of the area around Tasikmalaya which includes a spring map by the Institute of Geology, Bandung, 1976.
- Records from four deep well drillings around the town from 1914 and 1915 editions of the "Jaarboek van het mijnwezen".
- Some additional information related to this study was available in the internal report of the Kabupaten of Tasikmalaya (E. Muljadi 1972).
- Topographical maps of the area, scale 1 : 50,000 copied from Dutch maps dated 1936.
- Aerial photographs scale 1 : 20,000 of Tasikmalaya. The coverage of these photographs did, however, not include the area of the Cipondok spring.
- Long term monthly rainfall observations of Tasikmalaya from 1885 to present (1945-1950 missing) and more recent other climatological data were obtained from the Institute of Meteorology and Geophysics (Jakarta).

  The old location of the rainfall station is not known, but present observations are all carried out at the airport.
- Monthly rainfall observations at Singaparna 1934-1975, with many missing years. Manunreja (1891-1932), Singaparna-Galunggung (1916-1942) and Jayawati (1916-1938), obtained from the Institute of Meteorology and Geophysics, Jakarta.
- Recent rainfall data of Singaparna were collected at the Kecematan of Singaparna.
- Present discharges of the Cikunten diversion-canal from the Irrigation Dept. of DPU Tasikmalaya, while 1971-1974 levels and rating curves of the Citanduy at Leuwitonjong have been collected from DPMA (Bandung).

Table 1 Average monthly values of some climatic parameters at Tasikmalaya (airport), station 230, elevation 350 m.

Parameters	Period of observation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total or average
Rainfall (mm)	1971-1974	361	481	317	214	331	103	114	116	286	290	326	457	3,396
Temperature (degree C)	1971-1974	25.3	25.4	25.3	25.1	24.9	24.1	23.6	24.3	24.0	24.7	24.9	24.9	24.7
Humidity (%) 1)	1968-1972	79.4	74.8	78.4	78.6	81.8	79.0	78.8	78.0	76.6	75.6	79.4	80.6	78.4
Windspeed (m/sec) 2)	1971-1974	1.7	1.6	1.6	1.6	1.6	1.7	1.6	1.8	1.9	1.8	1.7	1.7	1.7
Sunshine (%) 3)	1971-1974	46	44	57	64	45	59	60	59	45	37	44	34	49.5
Evaporation (mm) 4)		133	128	247	148	108	107	114	131	121	126	130	122	1,515

1) Data according to E. Mulyadi
2) Measurements at height of 12 m, observations transformed to height of 2 m by multiplication with reduction factor $(2/12)^{0.15} = 0.76$
3) 25% of data missing
4) E_o, calculated according to Penman with average monthly values of 1971-1974
$E_p = 0.8 \quad E_o = 1{,}212$ mm.

3.1.3 Climate

The only variable climatic factor is precipitation, all other climatic parameters being stable (cf. Table 1). The monsoons are mainly the cause of the rainfall variation in time but as is apparent from Table 2 and Figure 2, the volcanos cause a local orographic effect.

Table 2 Rainfall data of Tasikmalaya and Cipondok area

Station	Tasikmalaya	Singaparna**	Jayawati	Singaparna Galunggung
Elevation (m)	350	418	800	830
Period of observation	1865-1941	1890-1941	1906-1939	1905-1941
January	369	330	339	533
February	375	333	316	486
March	448	340	365	567
April	333	343	431	617
May	281	284	379	539
June	207	216	306	422
July	164	154	231	359
August	138	143	214	318
September	163	164	289	430
October	331	324	539	724
November	380	360	495	703
December	392	370	387	611
Total	3,581	3,361	4,291	6,309
Standard deviation	828	787	888	1,670
Coefficient of variation	0.24	0.22	0.22	0.26
Total of rainy days per year	169.9	189.3	148.4	235.2
Average rain per rainy day	21	18	29	27

* From Berlage, verhandelingen no. 37
** Singaparna combined with Mangoenraja
\+ Parameters not in all cases calculated from some data series, from which mean has been calculated

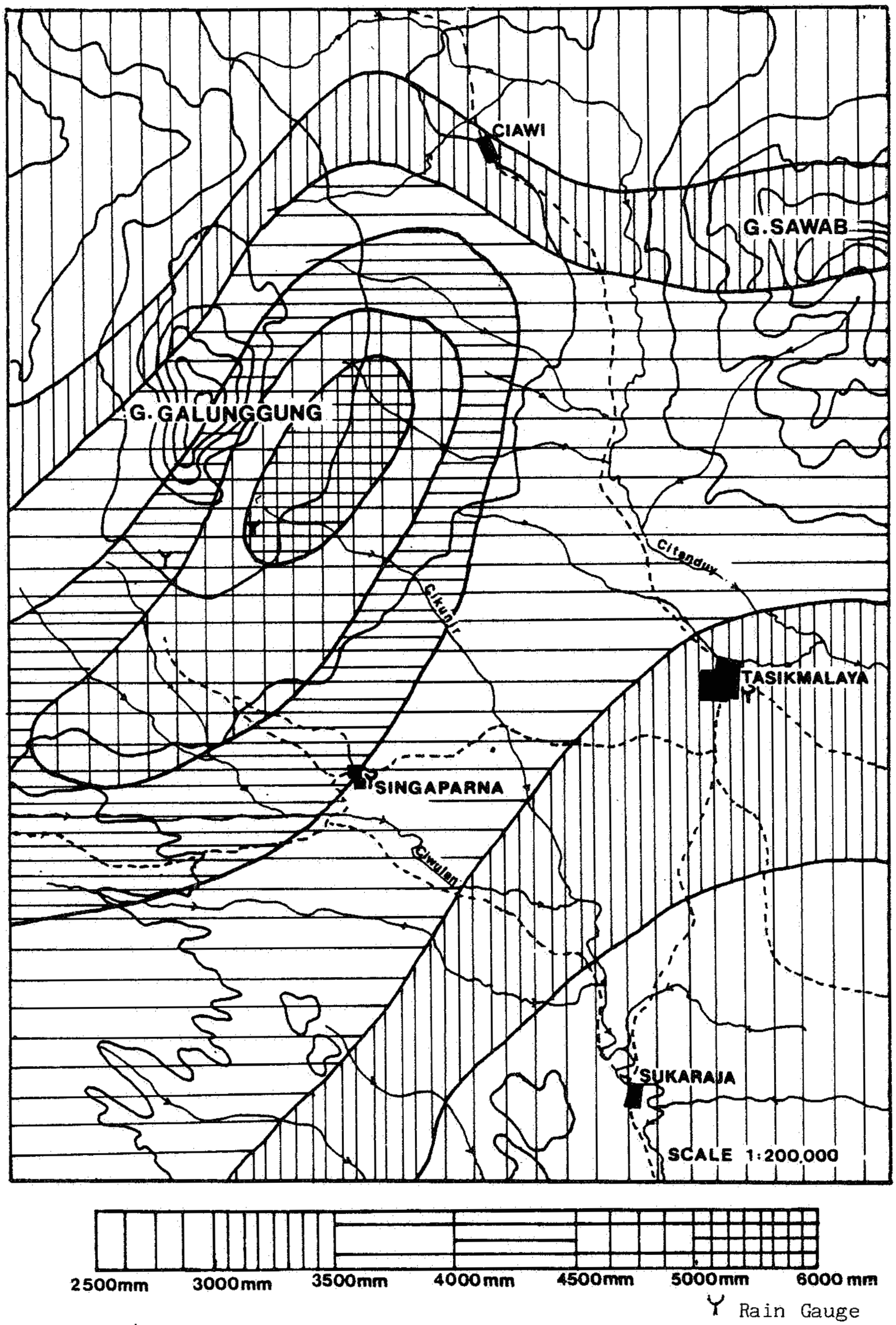


Figure 2 Mean annual rainfall (after LMG Jakarta)

The map, Figure 2, shows further that the amount of rain is not only influenced by elevation; precipitation on the SE slope of Gunung Galunggung is clearly higher than on the slopes of Gunung Sawal, which is only a few hundreds of metres lower.
Although the average monthly precipiation during the dry season is over 100 mm, the probability of a monthly rainfall under 100 mm is high, as the montly statistics of the period 1885-1975 show.
The average monthly evaporation is over 100 mm throughout the year (cf. Table 1).

3.1.4 Morphology, geology and hydrogeology

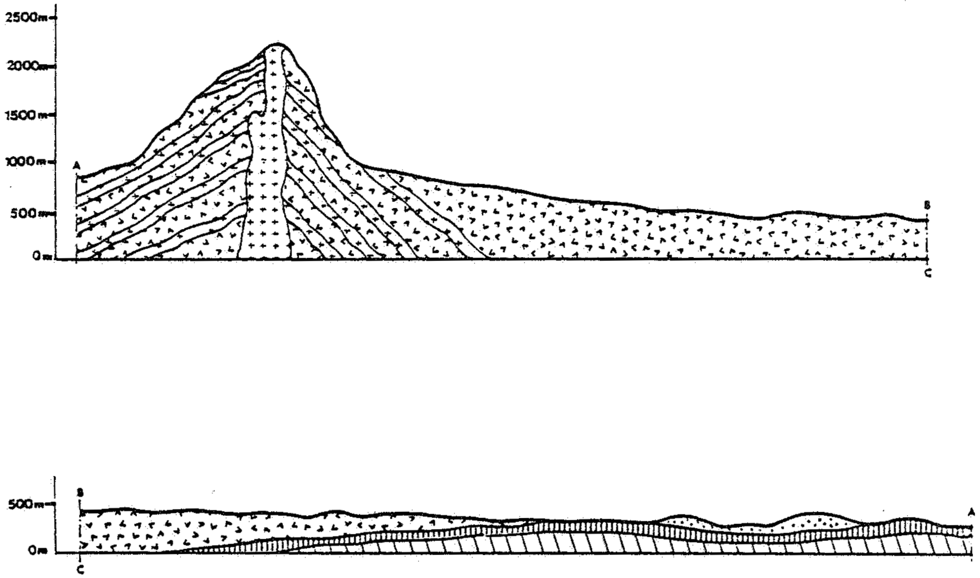
Tasikmalaya is situated in a broad valley, bordered in the north by the volcanos G. Galunggung (2241 m, still active) and G. Sawal (1764 m) and a hill range (elevations up to 600 mm) with steep slopes in the south. The two most important rivers flowing through the valley are the Citanduy, north of Tasikmalaya and the Ciwulan, south of Singaparna.

The northern part of the valley and the footslopes of the volcanos, where many springs originate, are extensively use for wetland rice farming. The hills in the south, where only a few springs occur, are much less in use for irrigated agriculture. Here many quarries occur, exploiting limestone outcrops.

Geologically, two zones can be distinghuished (cf. Figures 3 and 4) viz.:
- the southern hill range, made up of tertiary marine marls, clays, tuff and limestone and
- the northern zone, underlain by quaternary volcanics, covering the tertiary marine deposits.

The core and the summit of the volcanos consist of andesite, their slopes and the valley in between and to the south are made up of sub-horizontally bedded layers of andesite, volcanic breccia, coares and fine-grained ejecta and tuff.

Figure 3 Hydrogeological map of Tasikmalaya



Vert. scale 1 : 5,000

Hor. scale 1 : 100,000

LEGEND

+ + +	Andesite	Quaternary
volcanic pattern	Undifferentiated volcanic material	Quaternary
dotted pattern	Limestone	Quaternary
vertical lines	Tuffaceous clay	Tertiary
diagonal lines	Marl, clay	Tertiary

Figure 4 Diagrammatic geological profile A-A' of Tasikmalaya

The hydrogeology of the tertiary sediments in the south is characterized by low transmissibilities, resulting in only a few springs. In the volcanic zone surface run-off is dominant around the summits of the volcanos, on the middle part of their slopes infiltration prevails whereas on the footslopes groundwater emerges in many springs, the ones at Gunung Galunggung being the largest by far. In the valley groundwater occurs at shallow depth and small springs are abundant.

The shallow phreatic groundwater is being used as the main source of domestic water by more than 70 % of Tasikmalaya's inhabitants. However, wells with a depth of 5 m or less often dry up during the dry season.

Table 3 Water quality near Tasikmalaya

Sample	1	2	3	4	5	6	7
temperature (°C)	32	25.5	60-70	21.5	21.5	20.5	20
pH	*	*	*	*	*	*	*
hardness (°D)	12.3	11.5	23	4.6	4.5	2.8	3.9
specific conductance (micromhos/cm)	635	200	2500	305	280	195	220
colour (units Pt/Co)	55	8	15	50	50	50	18
turbidity (FTU)	12	4	1.5	10	8	7	1
iron (mg/l Fe)	0.03	0.05	0.12	0.075	0.05	0.05	0.055
manganese (mg/l Mn)	0.00	0.20	0.45	0.08	0.00	0.00	0.08
copper (mg/l Cu)	0.07	0.10	0.20	0.09	0.08	0.07	0.08
ammonia (mg/l NH_4)	**	**	**	**	**	**	**
chloride (mg/l Cl)	440	5	25	16.25	10	2.5	3.85
nitrite (mg/l NO_2)	0.00	0.00	0.05	0.01	0.00	0.01	0.02
nitrate (mg/l NO_3)	4.40	5.72	3.52	2.64	1.76	2.20	3.08
sulphate (mg/l SO_4)	43	68	406.25	9.0	2.5	0.99	8.00
fluoride (mg/l F)	-	0.12	0.43	0.30	0.34	0.32	0.48
E-coli in 100 ml sample	12-52	0	-	5-10	1-16	6-11	-
E-coli in 50 ml sample	0	0	-	2	0	5	-

* pH meter out of order
** no ammonia free distilled water available
Sample 1 Singaparna
Sample 2 Cibunigeulis
Sample 3 Cipanas
Sample 4 Cisaladah
Sample 5 Cikabuyala
Sample 6 Manggung
Sample 7 Cipondok

Already in the beginning of this century (1913-1915) attempts have been made to exploit artesian aquifers at great depth. Boreholes of more than 400 m have been drilled and artesian water has been found indeed, but yields are extremely small (a few litres per minute). Elsewhere on Java comparable situations occur in volcanic deposits, due to the extreme thinness of the water-bearing layers. These aquifers are in fact only exploitable where they crop out over considerable distances (springs) or by means of large-diameter wells.

The quality of the groundwater is generally good, except a too high content of aggressive CO_2 and bacteriological contamination in open, shallow wells, especially in the urban areas.

3.1.5 Surface water

Rivers in the Tasikmalaya area are mainly rain-dependent with low to very low discharges towards the end of the dry season and frequent flash floods during the rainy season.

The low flows of the two largest rivers, the Citanduy and the Ciwulan being of the order of some cumecs, they would both be able to supply Tasikmalaya with domestic water. However, the quality of the riverwater, especially during low discharge periods is thus, that elaborate and costly purification measures would be required. Therefore, preference has been given to the much cleaner springwater as a source of the domestic water supply for Tasikmalaya.

3.1.6 Springs

General

The Institute of Geology in Bandung made and exhaustive inventory of the springs around Tasikmalaya. Within the scope of the masterplan study the most promising springs have been located and their discharges have been measured, using Ott flow-meters (cf. Table 4).

Table 4 Characteristics of springs visited

Name of springs	Distance to as the crow flies	Tasikmalaya pipe length (approximate)	Elevation (m)	Discharge August 1976 (1/sec)	Result of the bacteriological analysis	Result of the chemical analysis	Temperature (°C)	Use of the water during dry season
Cipondok	19 km	26 km	590	550	not polluted	good	20	20% irrigation daily use, 80% direct discharge in the river
Cisaladah	18 km	22 km	850	159	reasonable	good	21.5	100% irrigation and daily use
Cikabuyutan	18 km	23 km	750	64	reasonable	good	21.5	100% irrigation and daily use
Cisanghiang	20 km	26 km	610	50-100	not sampled		23	20% rural water supply 80% irrigation, daily use
Manggung	15 km	23 km	570	59	polluted	good	20.5	10% rural water supply 90% irrigation, daily use
Sarongge	15 km	23 km	650	15-20	not sampled			100% irrigation, daily use
Cibunigeulis	6 km	9 km	475	8-12	good	good	25.5	100% water Tasikmalaya

Because as a rule only one discharge measurement per spring could be performed it was of importance to get an insight into the low-flow characteristics of the various suitable springs and notably into the time-lag between precipitation/recharge and spring discharge.

Edelman (1972) developed a method adopting an aquifer bounded by two parallel infinite ditches and an impermeable layer with a cyclical precipitation input.

Introducing (partly estimated) values for effective porosity, transmissibility of the aquifer and periodicity of the rainfall gives a time-lag of the minimum spring discharge behind the minimum rainfall/recharge of 1.5 months. More realistic assumptions, such as a more concentrated spring discharge as compared with a ditch has led to the adoption of a time-lag of 2 to 3 months in the Tasikmalaya area where thin aquifers with limited transmissivities prevail.

Cipondok spring

The Cipondok spring has been selected as the source of the water supply system of Tasikmalaya. It is located halfway up a steep hill along the Cikunten river, near Desa Sukaradja (cf. Figures 3 and 5).

From the top down, the hill is made up of:

- some 5 m of weathered volcanic breccia and tuffs;
- an approximately 20 m thick layer of homogeneous andesite with a pronounced columnar structure;
- a loosely cemented waterbearing volcanic breccia, some 5 m thick and with a good permeability;
- approximately 10 m impervious tuff;
- an indesitic layer, wedging out in downstream direction, and
- some 5 m thick, medium to coarse-grained layer of tuff.

The Cikunten river has incised itself into the hill, thus exposing the waterbearing layer between the upper andesite layer and the impervious tuff. Groundwater is flowing out of this layer, constituting the Cipondok spring.

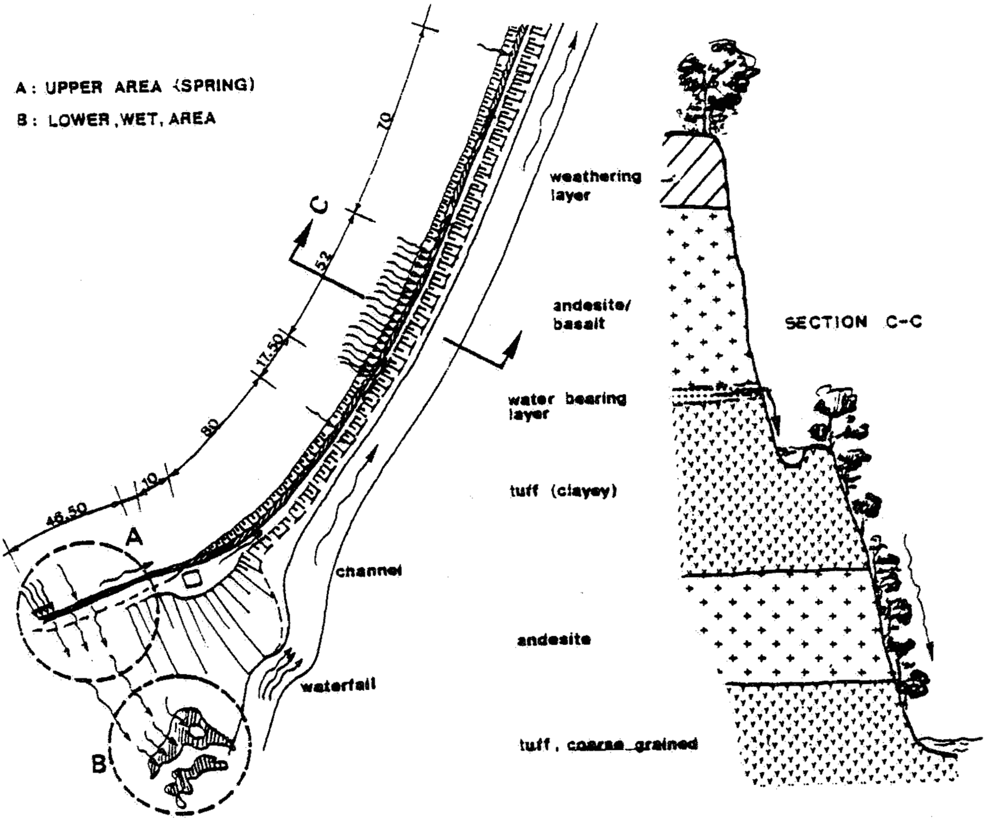


Figure 5 Cipondik spring

The discharge of the spring was 322 l/s on August 20, and 532 l/s on December 22, 1976. As the maximum daily water demand of Tasikmalaya has been assessed to be 275 l/s in the year 2000, the discharge of Cipondok spring was considered sufficient. The quality of the spring water is good, except for its too high content of aggressive CO_2, which can be removed by aeration.

3.1.7 Environmental aspects

The sanitary situation in Tasikmalaya was reasonable during the field work period.

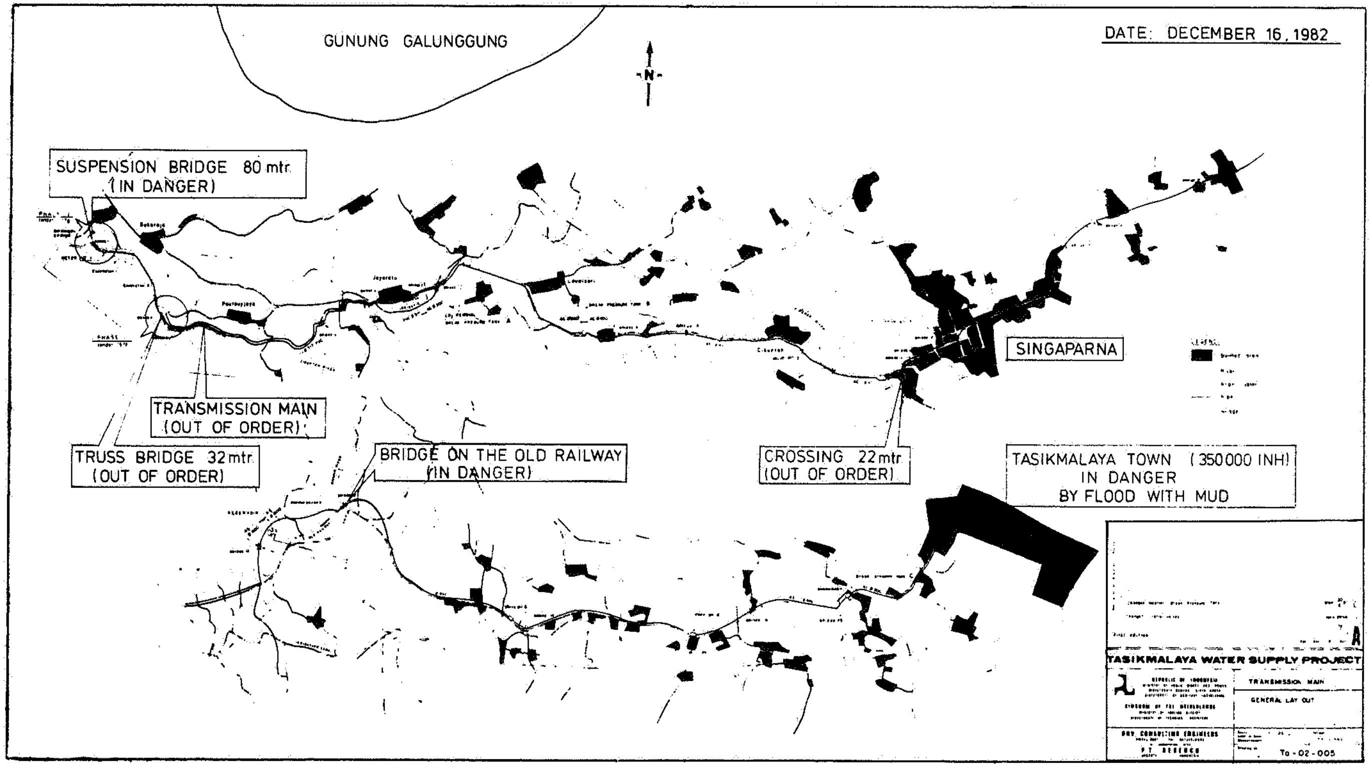


Figure 6 Map of Tasikmalaya

60 to 80 % of the urban population had a private toilet, connected to the sewerage or the drainage system, or they made use of the public toilets in the business area. The remaining 20 to 40 % had a pit latrine or used the river as a toilet.

The town has a fairly well maintained open sewerage system. Solid waste is collected with a frequency of once a day to once a week. It is being dumped at a site northwest of Tasikmalaya, outside the city.

There is some industry, notably a textile mill, draining somewhat polluted waste water (30 m^3 per day) into the river.

Relatively few cases of severe waterborne diseases were reported from Tasikmalaya city. There was (1976) no cholera and typhoid fever was scarce. Diarrhoea and gastro-enteritis do occur, as well as water-washed diseases, viz. scabies and skin and eye diseases.

A particular environmental aspect were the many eruptions of the Gunung Galunggung volcano during 1982, with resulting devastating flash floods towards the end of 1982, damaging various structures in the transmission main (cf. Figure 6). The water supply of Tasikmalaya could no longer be effectuated by gravity, the original system being temporarily replaced by pumping.

3.2 Ternate

3.2.1 Introduction

Initially it was the intention, to use the crater lake Danau Laguna, situated at 6 km south of Ternate-town, as a source for its domestic water supply. In fact, work on a public water supply system drawing water from the lake had started some years before. Available information indicated that the area of Danau Laguna was some 3 km^2 and that amply sufficient water would be available. However, further information and a first field reconnaissance showed, that the lake was much smaller (0.18 km^2 only) and did not contain sufficient water.

In September and October 1976 additional fieldwork was carried out, whereas in February and March 1977 final field test were made, focussing on hand-dug wells as a source for the water supply for Ternate.

3.2.2 Available data

The following data have been made available and/or collected:
- topographical map of the island, scale 1 : 20,000 copied from an old Dutch map dated 1916 with contour lines at 10 m intervals;
- topographical maps scale 1 : 1,000 covering the coastal strip in which the town is located. The maps are made by Biro Tri Tunggal (Bandung) in 1976 and show contourlines at 1.00 m intervals;
- aerial photograph of the town and its direct surroundings. The source of the photograph is unknown;
- long term monthly rainfall observations of Ternate from 1879 to 1941, 1951-1957 and 1971 to present from the Institute of Meteorology and Geophysics (Jakarta);
- daily rainfall data from 1971 to present from the meteorological station at the airport of Ternate and from the agriculture department of Ternate.

No detailed geological or hydrological information was found.

Within the original scope of work a survey of surface water resources and general assessment of groundwater possibilities were carried out in July 1976.
In September and October 1976 an inventory was made of existing springs and wells, among other things by the execution of geo-electrical measurements and pumping tests.

A final detailed survey, concentrating on the feasibility of further groundwater exploitation through pumped wells was formulated in a fieldsurvey of November 1976 and executed in February and March 1977. The programme consisted mainly of long duration (5 x 24 hours) pumping tests with discharges up to 15 l/sec. from deep wells in the city (up to 26 m below groundlevel) and pumping tests of shallow wells on the edge of the Ake Gaale swamp.

3.2.3 Climate

The tropical climate of Ternate is characterized by the equatorial double rain periods, falling each time after the sun has reached its zenithal position. From Figure 7 (see page 151) it can be seen that the maximum rainfall takes place around April and November.
The surrounding sea, which always has a temperature slightly above 26°C has a tempering influence on the Ternate climate. For this reason the ranges of the different climatic variables (except rainfall) will be small throughout the year and over the years.
Table 5 gives some average monthly values taken from the three year period of available data at the airport. Figures will for reasons given above not differ very much from long period averages. Observations are carried out at 32 m above mean sealevel hence observations are only valid for the lower parts of Ternate. The temperature in the Indonesian archipelago usually drops 0.6°C per 100 m rise hence the average temperature, which is 25.9°C at the airport station, will be at the peak in the order of 16°C (increase due to volcanic action not taken into account). In the period of observation average minimum monthly temperatures were never lower than 20°C, while average maximum monthly temperatures were never above 32°C.
The average annual relative humidity at the meteorological station was 85.5 % but will undoubtedly be higher near the peak, which is almost every afternoon surrounded by clouds. The average sunshine percentage is 63 % at the station but it will be less near the peak.
The prevailing wind direction is north, but sometimes, when the east-monsoon reigns in large parts of the archipelago long spells of south-eastern winds can be encountered at Ternate. The average wind speed is, despite Ternate's closeness to the sea, rather low.

Table 5 Monthly average values (1973-1975) of some climatic characteristics at meteorological station of Ternate airport, elevation 32 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yearly Average or Total
Rainfall (mm)	181	216	153	335	253	183	179	109	175	256	319	274	2633
Temperature (degree C.)	26.1	25.6	25.9	26.3	26.3	25.9	25.9	25.5	25.9	25.9	26.0	25.7	25.9
Humidity (%)	83.7	85.3	84.0	86.0	87.0	86.0	86.3	84.3	86.0	85.0	86.0	86.0	85.5
Windspeed* (m/sec)	2.7	2.5	2.7	2.1	2.1	1.8	1.8	2.1	1.7	2.0	2.2	2.3	2.2
Sunshine (%)	62	61	61	65	65	65	49	66	64	72	69	57	63
Evaporation (mm)													
monthly	155	140	161	150	147	135	127	152	150	161	153	149	1780
daily	5.0	5.0	5.2	4.9	4.5	4.5	4.1	4.9	5.0	5.2	5.1	4.8	4.9

* Original observations carried out at 12m above groundsurface, but reduced to 2m above ground surface by multiplying data with 0,76.

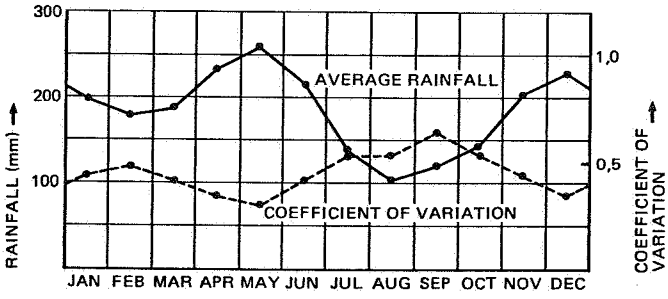


Figure 7 Graph of monthly precipitation and monthly coefficient of variation (time period 1870-1975, period 1942-1950 and 1958-1970 excluded).

There are not sufficient rain gauges on the island to quantify the possible orographic effect of the high, relatively steep volcano on the rainfall. From the recent observations (cf. Table 6) the following tentative conclusions may be drawn.

Precipitation is highly local and randomly scattered and consequently annual totals do not differ much on various locations. To assess whether the elevation of the groundwater table as measured in September-October 1976 could be regarded as a reasonable average for the end of the second dry period, the precipitation during July/September 1976 (218 mm, cf. Table 6 was compared with long-term data for the same months (cf. Table 7).

It appears that 218 mm, although low is not extremely so. Non-exceedance of 200 mm was 22 % for the 73 years of records.

It may therefore be concluded that spring discharges and groundwater levels as measured in September-October 1976 were not exceedingly low.

Table 6 Recent monthly rainfall totals in mm of all stations at the island of Ternate

Year	Station location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Jul-Sep
1971	***	M.V**	148	210	148	165	288	114	178	180	178	308	M.V	-	472
1972	Airport	212	396	122	228	205	51	13	41	0	48	266	19	1601	54
1973	Airport	144	104	75	232	161	173	98	151	289	110	301	231	2069	538
1974	Airport	92	417	163	488	304	148	199	29	107	340	307	268	2862	335
1975	Airport	306	128	220	285	294	230	240	147	128	317	348	323	2966	515
	Kota	255	242	212	275	301	303	283	127	67	314	187	274	2840	477
	Sasa	210	138	198	249	377	334	422	137	123	301	234	405	3128	682
1976	Airport	273	236	131	257	233	177	116	50	52	127	195	164	2011	218
	Kota	219	159	132	291	311	234	113	49	10	85	164	94	1861	172
	Sasa	90	86	64	387	220	320	183	105	20	69	87	177	1808	308

Airport - Station managed by Departemen Perhubungan, elevation 32 m, erected 1971 (station no.496)
Kota - Station managed by Departemen Pertanian, elevation 25 m, erected 1974
Sasa - Station managed by Departemen Pertanian, elevation 5 m, erected 1974.

** MV.- missing value
*** Station probably near harbour

Table 7 Ternate: Rainfall statistics of the 1879-1975 period

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
No.of observations	72	74	74	74	72	73	74	73	74	73	73	71	67
Mean (mm)	198	181	189	236	262	213	139	104	120	142	206	228	2208
Standard deviation (mm)	107	107	96	104	100	108	91	71	100	96	112	100	503
Coeff.of variation	0.54	0.59	0.51	0.44	0.38	0.51	0.65	0.68	0.84	0.68	0.55	0.44	0.23

1. The number of rainy days per year is 134. Berlage computed the average rain on a rainy day as 16.5 mm. He used an annual mean value of 2211 mm, cf Berlage - verhandelingen no.37 Jakarta.
2. Annual mean total does not have to correspond with the sum of the months, because years with missing months have been omitted by calculating annual mean total.

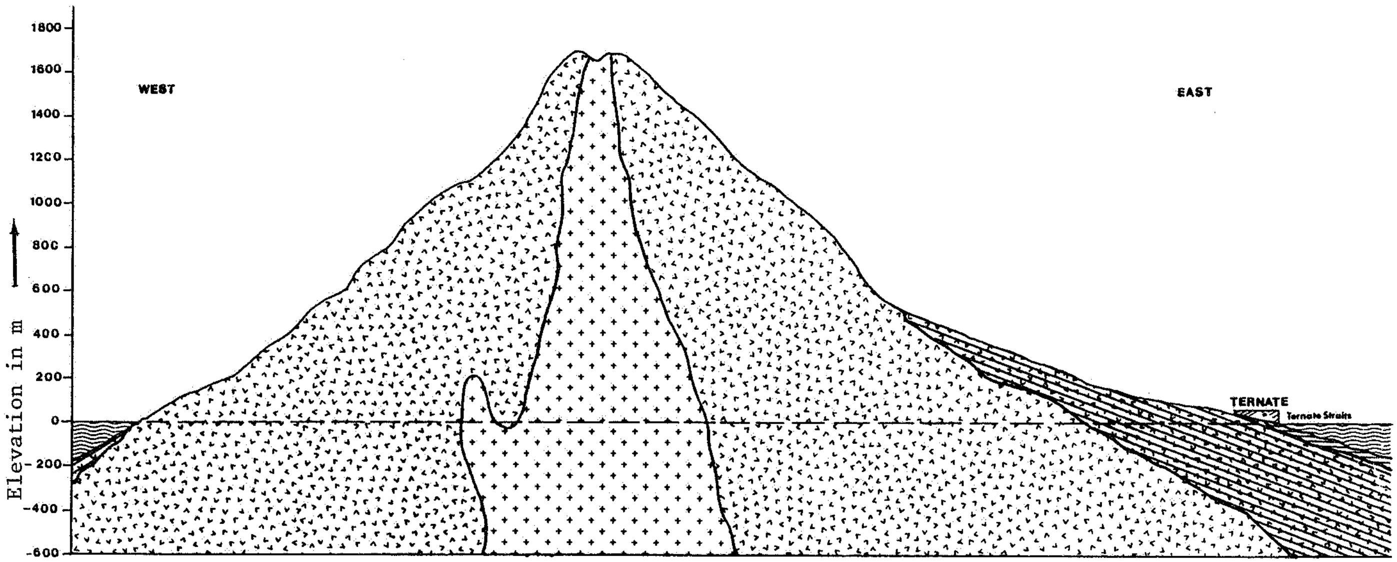
3.2.4 *Morphology, geology and hydrogeology*

Ternate island is the top of a young, fairly symmetrical strato volcano, belonging to the Circum Sunda Oroganic System. This geological system is characterized by vertical differential movements which are still in progress, accompanied by a.o. earthquakes and volcanic activity. In fact, the Ternate volcano is still active, its latest eruption dating from September 4, 1980, when large parts of the island were covered with volcanic ash and the majority of the population, including the DHV project engineer, were evacuated temporarily.

The somewhat pear-shaped island has an east-west width of approximately 10 km and measures some 13 km from north to south. The summit of the volcano is at 1715 m above mean sealevel. It has a massive core of andesite, its slopes being made up of sub-horizontally bedded layers of 'undifferentiated volcanic products' (cf. Figure 8). The island is of quaternary age.

On the western slopes of the volcano a thin top layer consists of pervious material, favouring the infiltration of the major part of the precipitation which subsequently flows subterraneously to the sea, giving only locally rise to some small springs. Only when the top layer is saturated with water or during exceptionally heavy showers, surface run-off occurs through deep narrow channels, the so-called brangkas.

Apart from the western part of the island, the 10 m contourline mostly coincides with the top of an approximately 7 m high cliff, the relic of an old coastline. The largest springs of the island emerge at the foot of this cliff, at a few metres above sealevel only. In the north-eastern part of the island the cliff is made up of sub-recent lava flows with hardly any vegetation yet. They locally give rise to hot springs. Where these hot springs emerge below sea-level, they create an ideal environment for coral growth. Tropical weathering of volcanic deposits has locally resulted in impervious layers, giving rise to small springs higher up the slopes of the



LEGEND

Andesite

Undifferentiated young volcanic material

Undifferentiated volcanic products alluvial deposits

Leguna deposits

Horizontal scale 1 : 40,000

Vertical scale as indicated

Figure 8 Diagrammatic geological profile of Ternate volcano. Some of those springs dry up during the dry season.

The average annual rainfall excess (precipitation minus actual evapotranspiration) is estimated at about 750 mm at sealevel. The excess can be as high as 1300 mm near the peak of the island. However, as the lower parts of the island constitute the larger area the average rainfall excess on the island is taken at some 900 mm.

After subtracting 200 mm for surface run-off, 700 mm is left for groundwater recharge. This is somewhat more than 22 $l/sec/km^2$ which drains into the sea by groundwater flow. Assuming an equal distribution along the entire shore line of Ternate, the groundwater discharge into the sea averages about 60 l/sec per km of coast line. Part of this water can be recovered to serve Ternate with drinking water. However, not all of this water should be recovered because of the danger of saltwater intrusion into the fresh water body below Ternate. As the two crater lakes are completely inadequate as a source of water supply, the overall conclusion from the above is that the fresh water body below the island constitutes the only feasible source for the water supply of Ternate. Perched watertables at higher elevations are too small and too variable to yield sufficient water to make exploitation worthwhile. As an example Air Tege Tege can be taken, which has an estimated discharge larger than 5 l/sec at the end of July 1976, while the discharge on October 2, after two rather dry months, was only 0.15 l/sec. Therefore, groundwater exploitation should be concentrated in the lower parts of the island.

3.2.5 Surface runoff

Rivers are non-existent on Ternate, the only run-off channels being deeply incised brangkas, which are dry most of the year. Surface run-off to the sea is mainly confined to the western part of the island, where alluvial deposits are virtually absent. Elsewhere the greater part of discharge in the upper part of the brangkas infiltrates more downstream, thus recharging the groundwater.

3.2.6 Springs

General

Many springs are scattered all over the island. Some springs are located at higher altitudes. They are used for water supply of the people in the immediate surroundings of the springs, but cannot be considered as sources for the Ternate water supply scheme with the exception of the Ake Gaale and Santosa springs. As the Ake Gaale is the only spring to be used as a source for the water supply of Ternate-town, it will be dealt with separately.

Ake Gaale

Ake Gaale means curling water and is the name of a swampy depression situated along the east coast of the island at the northern outskirts of Ternate-town (cf. Figures 9 and 10). Two small streams flow from the swamp into the sea and as their discharge appeared large enough to use the springs feeding them as a potential source for the water supply of Ternate, the area was surveyed in detail, employing the following methods:

- flow measurements in the small streams;
- the digging of two exploratory trenches at the foot of the cliff, bordering the depression to the north and the west;
- inventory of existing hand-dug wells around the swamp;
- pumptesting two newly dug wells and
- execution of a geo-electrical measuring programma.

From these surveys the following picture arise.

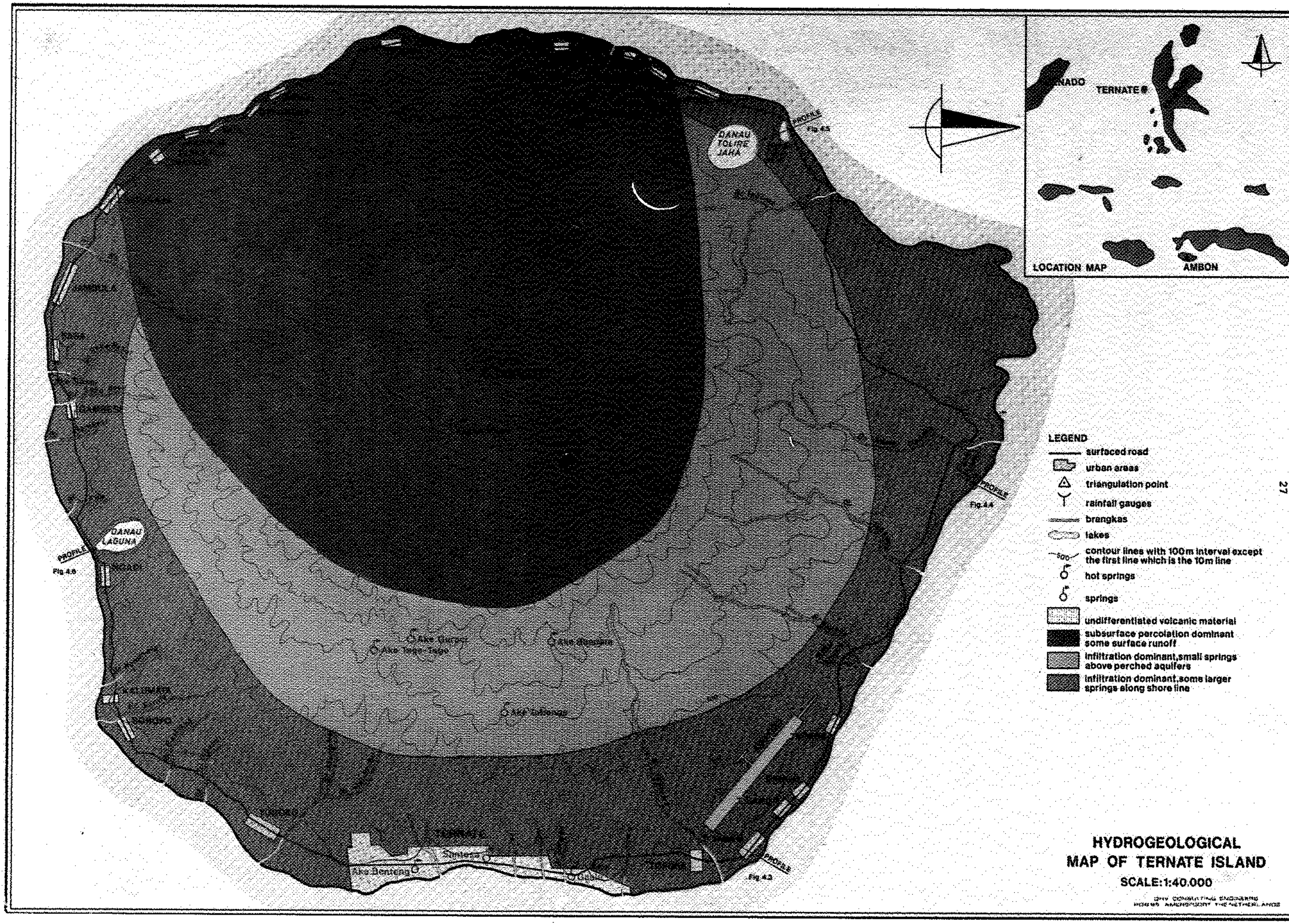


Figure 9 Hydrogeological map of Termate island

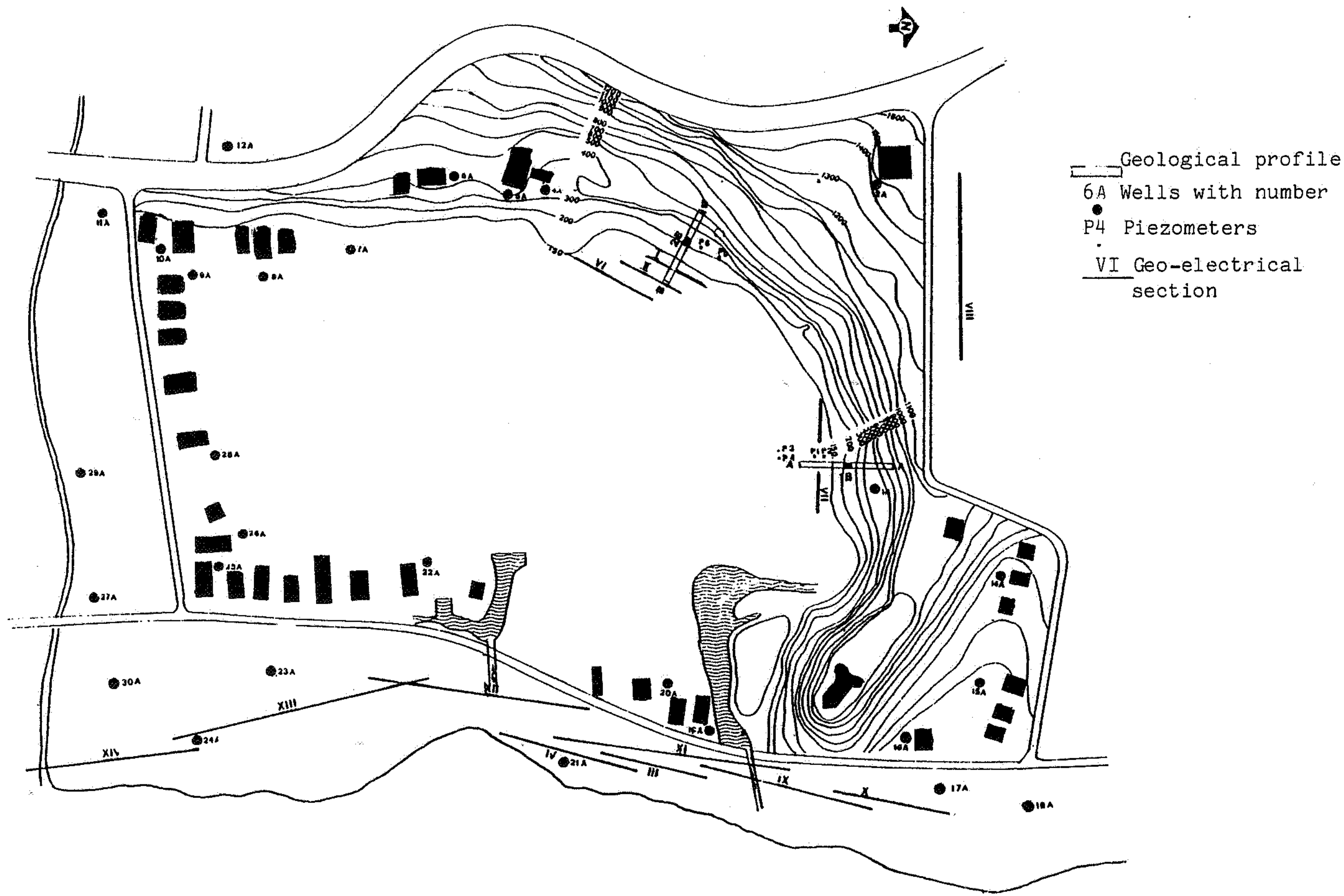


Figure 10 Spring area Ake Gaale with well numbers and geological profiles

The depression is bordered in the north and west by a ridge (average height about 7 m). The northern side of this ridge consists of large boulders of andesitic composition, remains of a lava flow reaching out into the sea. On the western side of the ridge no boulders were observed and in a well here, only a few boulders could be seen at the bottom.

Presumably the depression was in earlier days part of a bay. Gradually the bay has silted up. The high groundwater table has given rise to a swampy sago forest. In two ponds in the swamp fresh water rises through the sandy bottom to the surface from where it is discharged to the sea by means of the two little streams mentioned above.

Geo-electrical resistivity measurements have been executed on the beach in front of the Ake Gaale depression and to the north and the south. These measurements, of which the location is marked on Figure 10, show a fresh/salt water interface at shallow depth on both sides of the depression and no more than 12 m deep near the outflow of the Ake Gaale streams (see Figure 11).

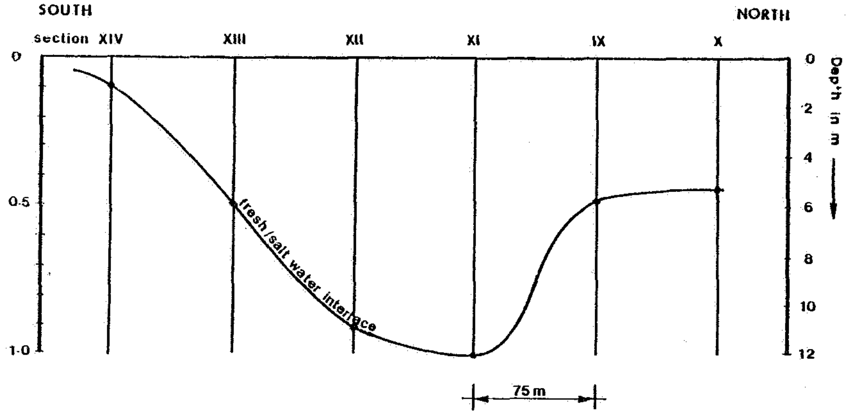


Figure 11 Results of resistivity measurements along the coast in front of Ake Gaale.

Waterlevels in wells at the beach indicate a slightly deeper level. (Ghÿben-Herzberg principle), hence it could be that the geo-electrical measurements indicate a brackish zone. However, the general shape of the interface which is the lowest at the point where the creeks discharge into the sea remains the same.

Discharge of fresh water to the sea is not evenly distributed along the coast, but is concentrated at some places, where more permeable aquifers are present. Ake Gaale is such a place. Most likely the tuffaceous gravel aquifer found somewhere between 1.0 and 2.0 m -M.S.L. plays a role in it. However, the aquifer has a thickness of only 0.60 m. More previous aquifers could perhaps be found at a still lower level. The first mentioned aquifer is overlain by a rather hard semi-pervious layer of loamy sand. This layer tilts downwards towards the coast. In the west and north edge if Ake Gaale the top of this hard layer emerges above groundwater level. Near the coast it perhaps wedges out or has fissures through which water can emerge, and causes springs in the ponds. However, water will also be discharged underground to the sea.

Ake Gaale can be developed for at most 60 l/sec. The safest solution concerning fresh/salt water problems should be a gallery approx. 200 m long extenting from well 1A along the 2 m contour line up to the S.W. corner of Ake Gaale. The invert of the gallery should be at 2 m -M.S.L.
Drawdown of the gallery should be restricted to 0.40 m +M.S.L. (actual waterlevel at the 2 m contour line is about 0.90 m +M.S.L.).

For practical reasons, the gallery could be replaced by a line of wells, spaced at intervals of not more than 15 m; in total 20 wells. The bottom of the wells should be at 2.0 m -M.S.L., while the maximum allowable drawdown should be 0.5 m (in the well itself). Waterlevels in the wells and the swamp should be watched and proper measures should be taken in case of an abnormal decrease of waterlevels in the swamp.

3.2.7 Groundwater investigations

In July and October 1976 well surveys were carried out in and around Ternate-town, to investigate the possibilities of using the fresh groundwater under the island at a source for domestic water supply (see also section 3.2.4)

One of the conclusions of the well surveys was, that longer lasting pumping tests were required. These tests have taken place during February and March, 1977.

The well surveys have taken place
- along three lines of wells perpendicular to the coast located within the city
- at three wells located west of the city of Ternate
- at some wells north of Ternate, near the airport.

The conclusions of the tests can be summarized as follows:
- The layered structure of the aquifer, which was visually observed, together with the facts found during excavation of wells, indicates much larger horizontal than vertical permeabilities, while pervious layers alternate with semi-pervious layers.
- The horizontal permeability of the aquifer at least 500 m from the coast is between 50 and 100 m'/day. Locally much larger or smaller permeabilities can be encountered.

Abstracting large quantities of water from the aquifer above Ternate city is quite feasible. The best solution in the case of an island surrounded by saltwater is a gallery (or drain).

Point abstractions which can create upconing of brackish water are then reduced to a minimum. In the case here the gallery should be at least 500 m from the coast with an invert at or slightly below M.S.L. while the length should be adapted to the quantity of water required. According to the water balance fresh water quantities in the order of 60 l/sec. per km shoreline flow into the sea, hence a safe recovery of 50 l/sec. per km should be possible.

Alternatively a row of dug wells at least 500 m from the coast preferably between the 20 and 25 m contour (waterlevels are between 1.80 and 2.20 m +M.S.L.) could be made. Waterlevels during pumping should stay at least 0.5 m +M.S.L., hence still maintaining a fresh water body with a thickness of about 20 m.
The fresh water lens, together with the rather low vertical permeabilities should prevent any upconing of brackish water in the neighbourhood of the well. From this it can be concluded that a drawdown between 1.3 and 1.7 m may be tolerated. Wells excavated up to 5 m below initial waterlevel could intersect aquifers with a total kD value of 300 m^2/day. This value, together with the drawdowns mentioned above results in yields of about 12.5 l/sec. in dug wells of diameters between 1.5 and 2.0 m. Noting that 50 l/sec. can be extracted per km, spacing of wells should be in the order of 250 m.
Calculation methods based on semi-confined aquifers with parameters as found from the pumping tests did indicate a much smaller radius of influence. However, these formulas are based on constant vertical flow feeding the confined aquifer. The intermittent recharge, during wet and dry seasons makes the assumption of the constant vertical flow not completely acceptable.
The geology of volcanic regions is not very homogeneous. Hence based on the findings above one out of four wells may have to be discarded because of locally very low permeabilities or technical difficulties like encountering very large boulders.

3.2.8 Water quality

Table 8 shows water analyses of the different sources on Ternate. The wells were sampled after they were pumped for at least several hours. Analysis of samples 1, 2, 3, 6 and 7 were carried out by Cipta Karya except for the determination of O_2, CO_2 and the pH which were done directly after sampling by the Consultant. Samples 4, 5 and 8 were analysed by the Consultant using a Hach-fieldkit. The following comments can be made about the samples.

The high turbidity of Danau Laguna must be caused by algae growth.

Table 8 Water quality data of Ternate water sources

Number *	1	2	3	4	5	6	7	8
Temperature (^{o}C)	27	25	26	29	29	27	27	30
pH	7.1	7.6	7.0	7.5	7.8	7.0	7.0	-
Specific conductance ($\mu S/cm$)	430	230	200	(425)+	(480)+	239	227	72
Colour (unit Pt/Co)	-	2	-	25	-	1	1	150
Turbidity (FTU)	-	2.5	-	10	-	2.5	3.5	39
Oxygen (mg/l O_2)	7.0	7.0	7.0	-	-	7.5	7.0	-
Carbondioxyde (mg/l CO_2)	52	36	56	-	-	44	44.0	-
Hardness (mg/l $CaCO_3$)	66.3	88.9	-	72	140	79.8	71.8	-
Iron (mg/l Fe)	0.00	0.00	0.00	0.04	0.31	0.00	0.00	1.75
Manganese (mg/l Mn)	99.1	0.00	44.9	0.00	3.50	0.00	0.00	0.55
Copper (mg/l Cu)	-	-	-	0.05	-	-	-	0.12
Chloride (mg/l Cl)	86.0	10.5	7.0	19.0	45.0	15.5	15.0	5.0
Nitrite (mg/l NO_2)	0.0	0.01	0.0	0.0	-	0.02	0.01	0.02
Nitrate (mg/l NO_3)	0.0	2.64	0.0	-	-	0.88	2.42	3.3
Fluoride (mg/l F)	0.3	-	0.2	-	-	-	-	0.4
Sulfate (mg/l SO_4)	57.0	2.8	11.0	2.0	-	3.8	4.1	4.8
Ammonium (mg/l)	0.0	0.0	0.0	-	-	0.0	0.0	0.5

* 1 - well 1 U, kampung Ubu-Ubu, after 52 hours of pumping (February 4, 1977)
2 - well 4, Islamatic grave yard, after 85 hours of pumping (February 27, 1977)
3 - Santosa, from well, after 78 hours pumping (February 4, 1977)
4 - Ake Gaale - culvert north (July 1976)
5 - Ake Gaale - culvert south (July 1976)
6 - Ake Gaale - well 1 B, after 72 hours of pumping (March 4, 1977)
7 - Ake Gaale - well 2 B, after 24 hours of pumping (March 10, 1977)
8 - Danau Laguna, middle of lake (July 22, 1976)

\+ values would appear to be too high

The very low ammonium concentration in all samples except sample 8 (Danau Laguna) indicates that pollution is nihil. This was affirmed by E-coli determination of the two pumped wells at Ake Gaale. Results were negative.

Noticeable is the high chloride and sulfate content of well 1 U (sample 1) in comparison with the analyses of the other wells. This is also the cause of the higher specific conductance (E.C.) in well 1 U.

Noticeable are also the different compositions of samples taken at the north and the south culvert at Ake Gaale (samples 4 and 5). This means that the water comes from different directions and flows through different materials.

From all sources, except Danau Laguna, can be said that the international water quality standards are met. Only the free carbondioxyde content is rather high.

3.2.9 Environmental aspects

During the various field visits it became apparent that the sanitary situation for Ternate island as a whole was reasonable. No environmental problems are to be expected for the dispersed living rural population. An ample and safe domestic water supply in Ternate-town will eliminate to a large extent the sources of waterborne diseases, provided the necessary supplementary sanitary measures be taken as to solid waste disposal and drainage.

The drainage of non-treated waste water into the sea will undoubtedly lead to pollution. To diminish the chance of contamination of swimmers and bathers it is recommended to construct one main outfall drain away from major population concentration.

4 GENERAL CONCLUSIONS AND RECOMMENDATIONS

- Generally speaking, water is an abundant commodity in Indonesia. Perennial rivers traverse five of the six project cities and springs occur around all of them.

- Making potable water out of mostly heavy polluted river water requires extensive and costly purification measures whereas spring water as a rule only needs aeration and chlorination. A cost analysis has shown that the use of river water taken in near the city is 3.5 times as expensive than tapping a spring at 14 km from the city. Where feasible, spring tapping has been chosen.

- In studies as the one at issue, the period available for field surveys is generally limited to a few months, too restricted to make a reliable assessment of the minimum flows of springs and rivers. A justified estimate of these essential quantities requires the application of, mostly empirical, calculation methods, based on strongly simplified assumptions.

- Hydrological data, notably precipitation figures, are relatively abundant in Indonesia. Generally monthly figures are available, based on observations from the latter part of the nineteenth century until 1941. More recent observations mostly show many gaps. Available data are quite useful to get an impression on a regional level but are often inadequate for detailes local information.

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