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MANUAL FOR RURAL WATER SUPPLY

WITH MANY DETAILED CONSTRUCTIONAL SCALE - DRAWINGS

Publication No. 8
St.Gall 1980



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Preface by the Editor

Helvetas (SATA) and the Community Development Department of the United Republic of Cameroon (CD) have been closely working together since 1964. The purpose of this cooperation is to support the effort of the rural population to build up a local infrastructure by giving technical assistance. All these community development activities are self-help projects, initiated by the local people. Priority is given to the most deprived areas.

Water evidently plays a very important role in the development of rural areas. A supply of clean drinking water not only reduces the numerous diseases caused and transmitted by polluted water, but is very often the first step towards other development scopes like health, nutrition, sanitary programmes, etc.

When a water supply is being planned, all technical and socio-economical aspects have to be considered carefully. As one of the consequences simple techniques, simple designs, and a simple system are used. In this context greatest attention has to be paid to the fundamental problem of maintenance, that is even before starting with the construction of a project.

Assisting the rural areas and their population in improving the quality and accessibility of drinking water is one of the major concerns of the Community Development Department in Cameroon. During all these years of collaboration the technical staff of CD/Helvetas has gained valuable experience in the planning and execution of rural water supply and water point projects. Intending to provide Community Development officials, engineers and field staff who are planning and implementing water schemes in rural areas with useful information, a Manual for Rural Water Supply was first issued in 1975 (SATA-Helvetas Buea, Cameroon). Since then, improved and more adapted techniques and material have been developed which lead to this revised second edition of the Manual for Rural Water Supply. The technical data and drawings needed for the Manual have been compiled by the CD/Helvetas field engineers in Cameroon and partly completed by referring to various international publications.

We hope that this Manual will serve its purpose by contributing to a general improvement of the water conditions in developing countries.

Our sincere thanks go to all persons who have been involved in the preparation of this Manual.

May 1980

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Foreword by the Publisher

It is very fitting at the beginning of the UN decade dedicated to water that an organization that has got a vast experience in rural water supply construction in developing countries should decide to make a special effort and compile and edit material of field engineers to make the publication of a comprehensive practical manual on this subject possible.

The result of this effort is the manual presented here. It is based on actual field activities during the last fifteen years in the United Republic of Cameroon (West Africa). Despite its being based on experience in one specific country the material is certainly very useful in the context of other countries also and provides a guide line on how to identify, plan, organize and execute drinking water projects.

Manyfold aspects such as hydrology, safety standards for drinking water, design of water schemes, construction and maintenance, spring catchments, barrage and river intake systems, distribution systems and water lifting are treated. The material is suitable specially for engineers and construction supervisors but serves also to give a comprehensive overview of all aspects of rural water supply to non-technical people.

The technology that has evolved and that is documented in this manual is first class craftsmanship using traditional western techniques and materials. Emphasis is on solid, longlasting structures of simple design and on the use of labour intensive methods and local materials wherever possible. The goal is to achieve systems of trouble free operation, stable quality of drinking water and minimal, simple maintenance and management requirements.

The field of well digging is covered very briefly only, and the exploitation of alternative energies for water lifting is referred to only in connection with the use of hydraulic rams. Specific alternative technologies such as alternative cements, the use of bamboo and other local material for reinforcement and traditional, local construction skills are not included since the manual is based on action oriented projects rather than research.

Although the publication is based on actual field experience and presents practical examples, it is not presumed to be either exhaustive or final. It is certain that local adaption and modifications will always be necessary. With this publication, SKAT intends to create an opportunity for field testing and feedback of information. The reader therefore is requested to give his comments and suggestions for changes, corrections and additions which he considers necessary or useful. Such contributions will be gratefully accepted by SKAT and will be used in the future revision of the manual.

It would not have been possible for SKAT to publish the manual without the help of Helvetas who not only compiled and edited all the material but also sponsored the publication. It is therefore only appropriate that we express our thanks to Helvetas and to all the people who contributed to this work.

St. Gall, May 1980

SKAT, Swiss Center for
Appropriate Technology

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Chapter 1: HYDROLOGY

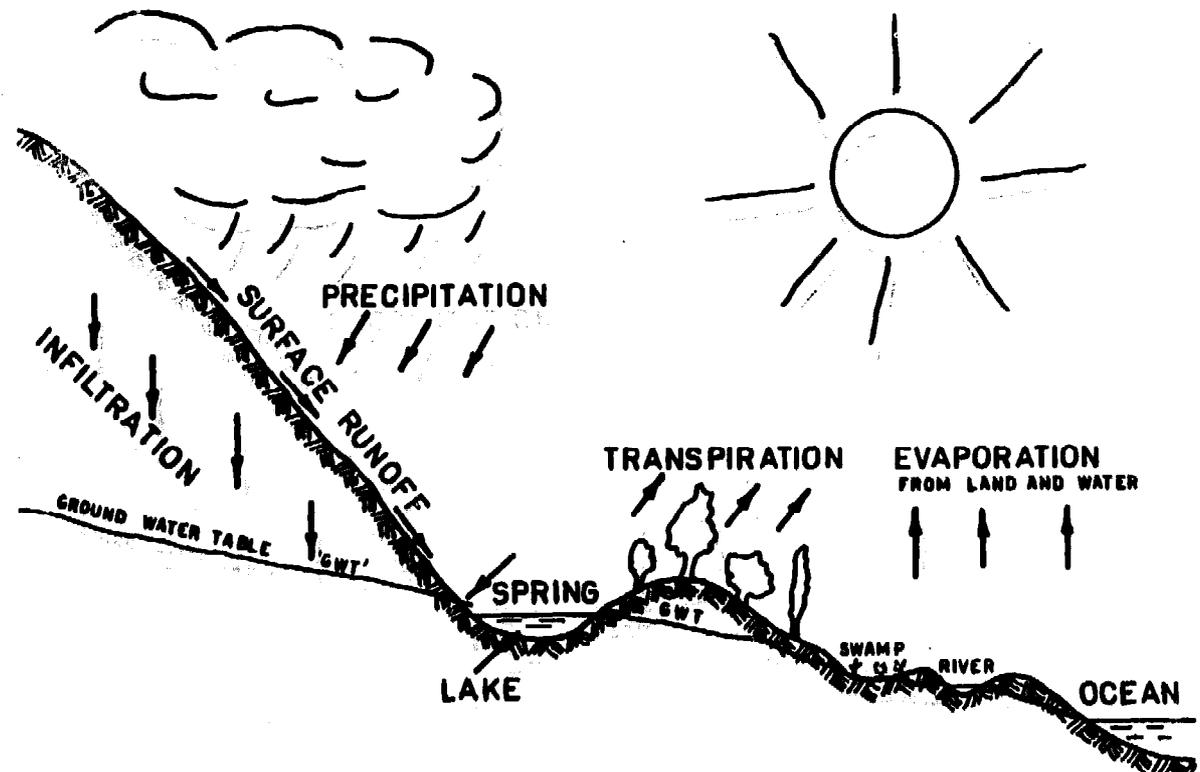
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1-1 DEFINITION AND HYDROLOGIC CYCLE

Hydrology is the science of distribution and behaviour of water in nature. Hydrology is a part of climatology. The cycle of water or Hydrologic Cycle is without beginning or end and consists of the following:

- Precipitation: All water from the atmosphere deposited on the surface of the earth as either rain, snow, hail or dew.
- Surface run off: The water which is derived directly from precipitation and passes over-ground into water-courses is known as surface run off. The surface run off then consists of the precipitation less the losses from infiltration and evaporation.
- Evaporation, transpiration: Combined loss of water from land and water-surfaces by evaporation and plant transpiration.
- Percolation: The term percolation describes the passage of water into, through and out of the ground. The term infiltration is frequently used to describe the entrance of water into the ground and its vertical movement down to the ground-water table, while percolation or ground-water flow is applied to the movement of water after it has reached the water-table.

Fig. 1 Hydrologic Cycle



1-2 CLIMATIC PATTERN AND RAINFALL

The main features of the climate in Cameroon are the 4 - 5 months-long dry season from November to March and the corresponding rainy season of 7 - 8 months.

Notes on the climatic characteristics of the various areas are based on inadequate records in terms of duration and number of stations. Nevertheless, an idea of the main climatic zones can be found when considering some basic factors:

- Throughout most of West Africa, the rainfall and the humidity decrease with increasing distance from the coast, but in South-West and North-West Province of Cameroon this pattern is sharply modified by the topography.
- The main rain-bearing winds come from the south-west. Wherever these are interrupted by high land, heavy precipitations result over all south-west facing slopes with complementary rain shadows in the N.E. For example, Dibundcha on the south-west side of Mount Cameroon averages 10.4 m of rain per annum, whereas Mpundu at the northern side receives only 1.5 m per annum. Similarly Fontem, at the south-west of the high plateau averages 4.3 m compared to Ndop with 1.6 m per annum.

1-2.1 QUANTITY OF RAINFALL

Rainfall quantities can be mapped with isohyets, i.e. all points with the same annual rainfall are linked and the resulting lines give us an idea of the distribution of the rainfall in a region. (see Fig. 2 and 3)

1-2.2 VARIATION OF RAINFALL

The rainfall varies greatly throughout the year and from one year to the other as well as from one station to another (see annual rainfall map). The monthly variations have been analysed by Brown and Clarkson for the Bamenda Station records 1923 - 1953 and the results are shown in Fig. 6. In the diagram, the upper and the lower ends of the monthly pillar show the greatest and least rainfall recorded during this period. In four out of five years the monthly rainfall may be expected within the dotted lines. The black line across indicates the arithmetic means of 30 years of records.

Fig. 2 Isohyetes West-Coast (1967)

KEY:
▽ ANNUAL RAINFALL IN m 1967
— ISOHYETES m

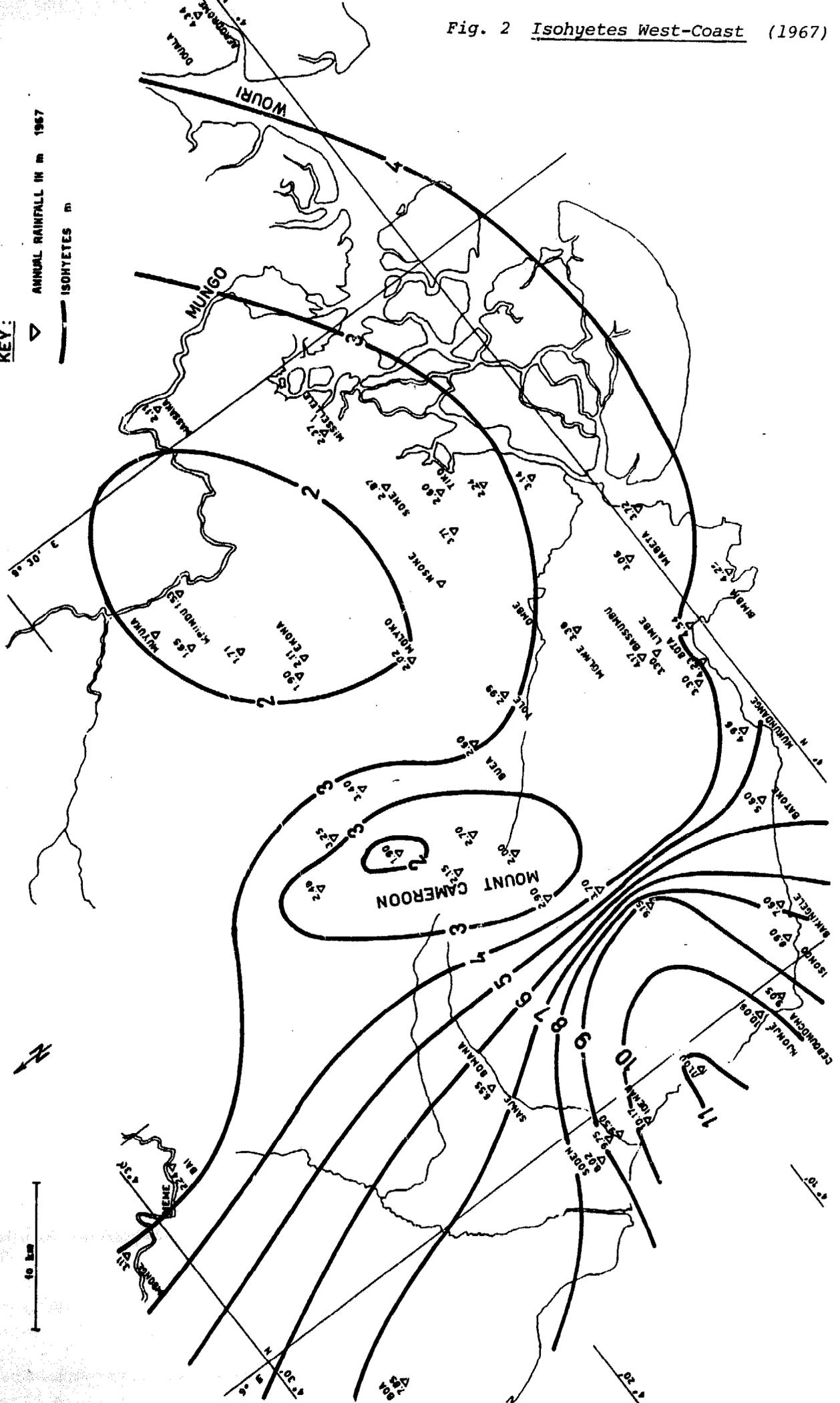


Fig. 3 Distribution of annual rainfall

- 1 OVER 375 cm
- 2 200 - 375 cm
- 3 150 - 200 cm
- 4 100 - 150 cm
- 5 70 - 100 cm
- 6 BELOW 70 cm

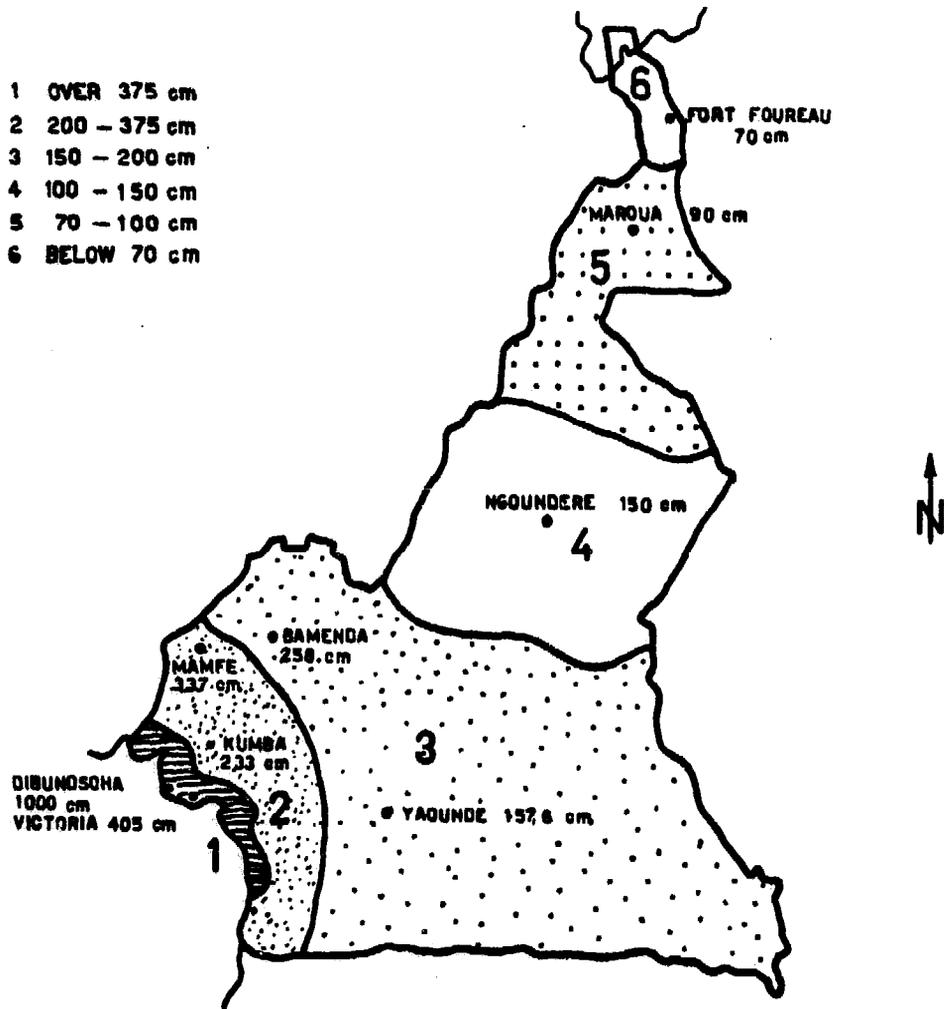


Fig. 4 and 5 Monthly rainfall

Fig. 5 Year 1968

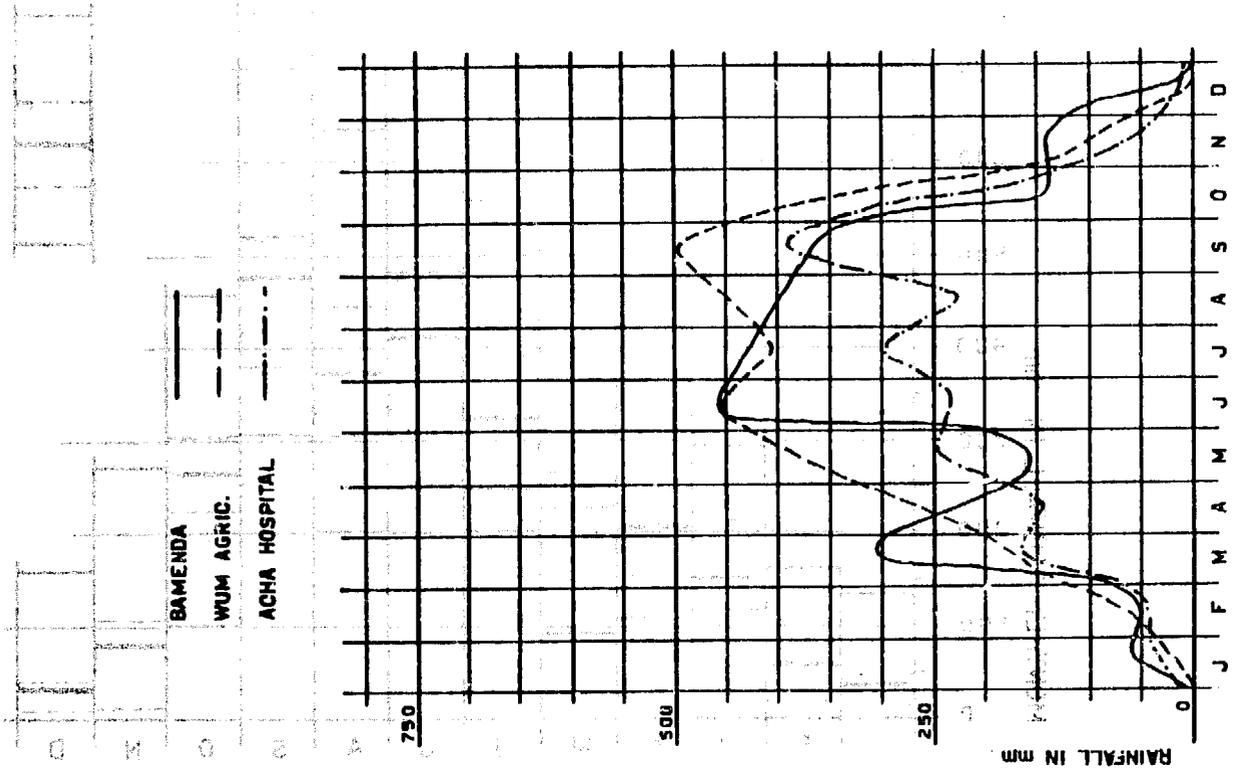


Fig. 4 Year 1967

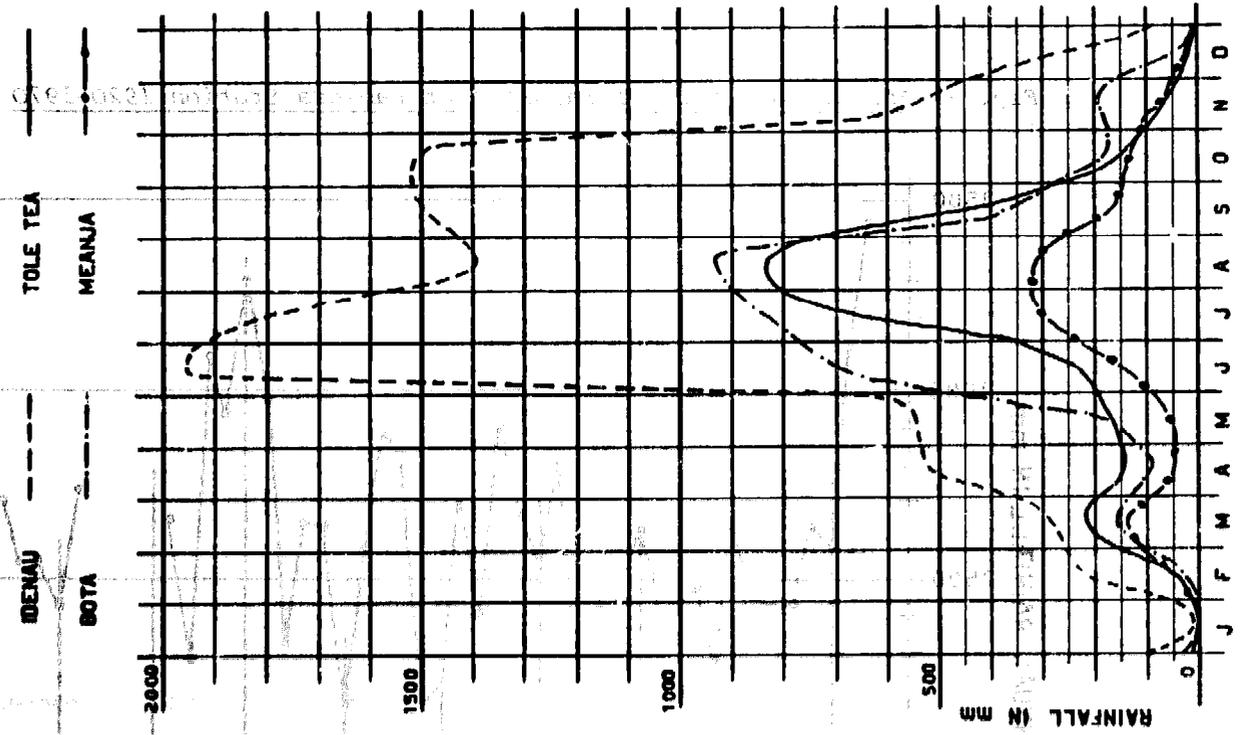


Fig. 6 Monthly variation of rainfall at Bamenda Station 1923-1953

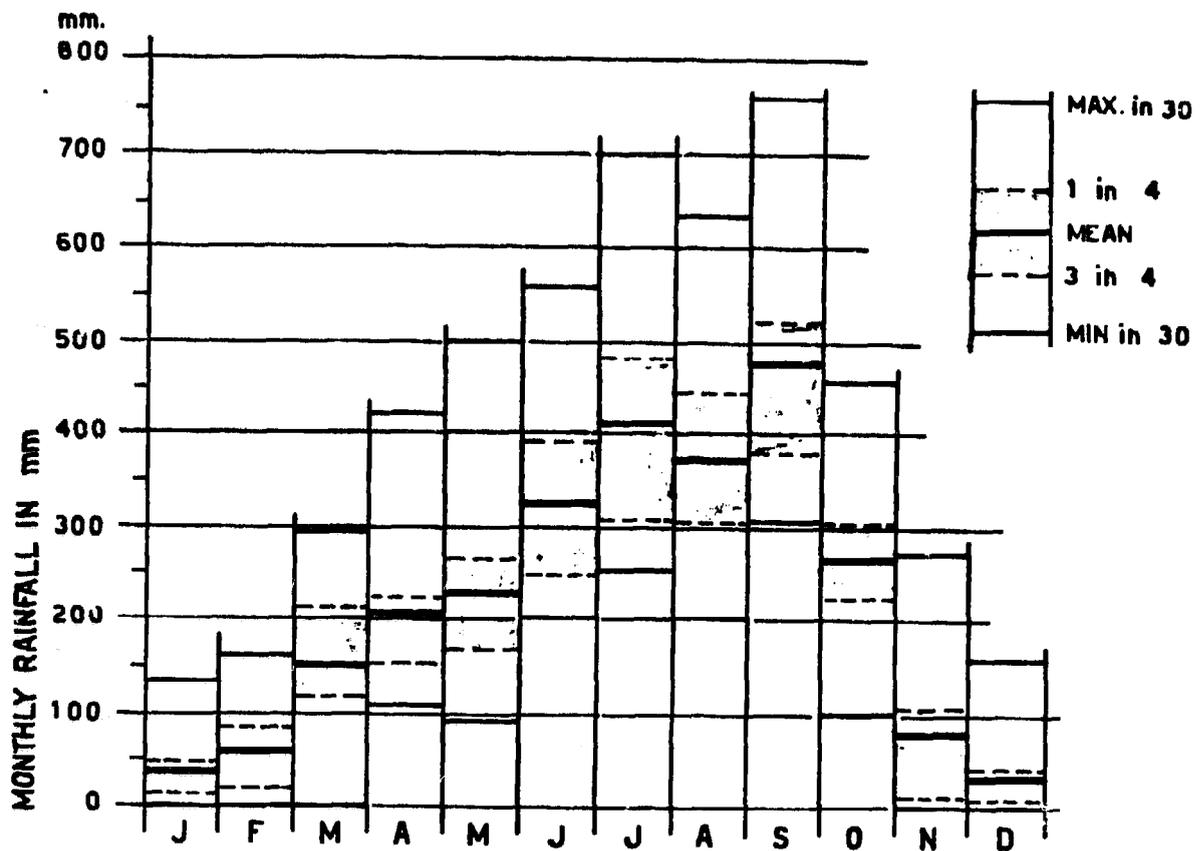
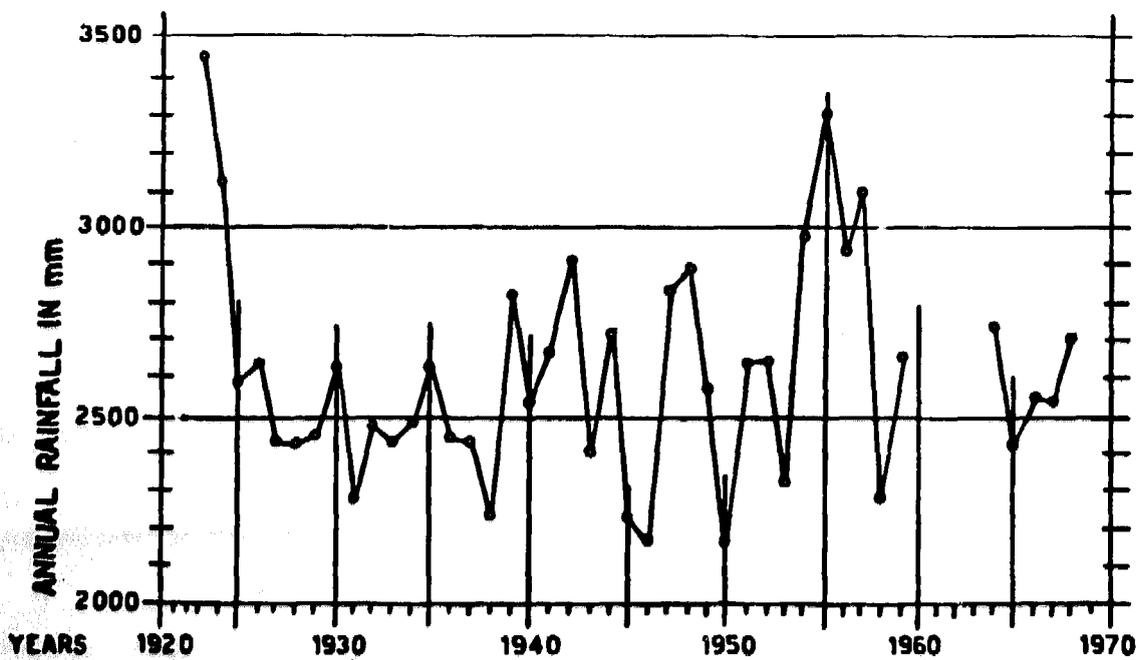


Fig. 7 Annual variation of rainfall at Bamenda Station 1920-1970



1-2.3 TABLES OF MONTHLY RAINFALL

	J	F	M	A	M	J	J	A	S	O	N	D
<u>Bomenda water station</u>												
1965	3	88	64	221	127	381	497	486	361	183	-	24
1966	25	-	131	301	291	131	463	408	480	170	163	-
1967	1	47	100	182	100	387	392	352	591	355	36	5
1968	55	50	302	223	154	456	428	395	366	145	140	1
1969	-	19	234	151	214	309	546	569				

<u>Tole Tea Estate</u>												
1965	46	61	90	199	186	266	1144	1506	410	342	39	21
1966	40	-	108	103	54	123	469	910	290	219	80	4
1967	-	47	215	141	162	236	676	835	441	155	69	10
1968	25	1	89	200	167	620	1450	750	570	166	52	12

<u>Acha Tuci Presbyterian Hospital</u>												
1966	-	-	133	401	371	326	511	353	441	307	112	-
1967	12	40	100	203	98	222	370	357	380	360	55	19
1968	33	45	170	145	246	232	297	227	389	194	57	12
1969	-	63	308	175	295	353	378					

<u>Mun Agric. Farm</u>												
1968	20	65	169	262	378	453	406	446	497	356	102	-
1969	-	27	161	274	391	430						

<u>Ndu Tea Estate</u>												
1969	-	36	115	138	150	146	272	372				

<u>Idenau (total 1967: 10556mm)</u>												
1967	11	212	288	518	547	1952	1817	1396	1490	1513	574	238

<u>Bota (total 1967: 4226 mm)</u>												
1967	-	23	161	91	177	692	1361	930	383	181	193	34

<u>Menna (total 1967: 1650 mm)</u>												
1967	-	47	140	54	54	234	293	315	170	128	191	24

<u>Kumbo Baptist Hospital Neg (1957 - 1966)</u>												
min.	-	-	38	87	118	79	186	126	196	118	10	-
max.	33	87	216	295	395	226	466	428	454	380	208	136
av.	9	13	116	176	196	188	310	270	316	224	76	16

J F M A M J J A S O N D total

Manfe Station

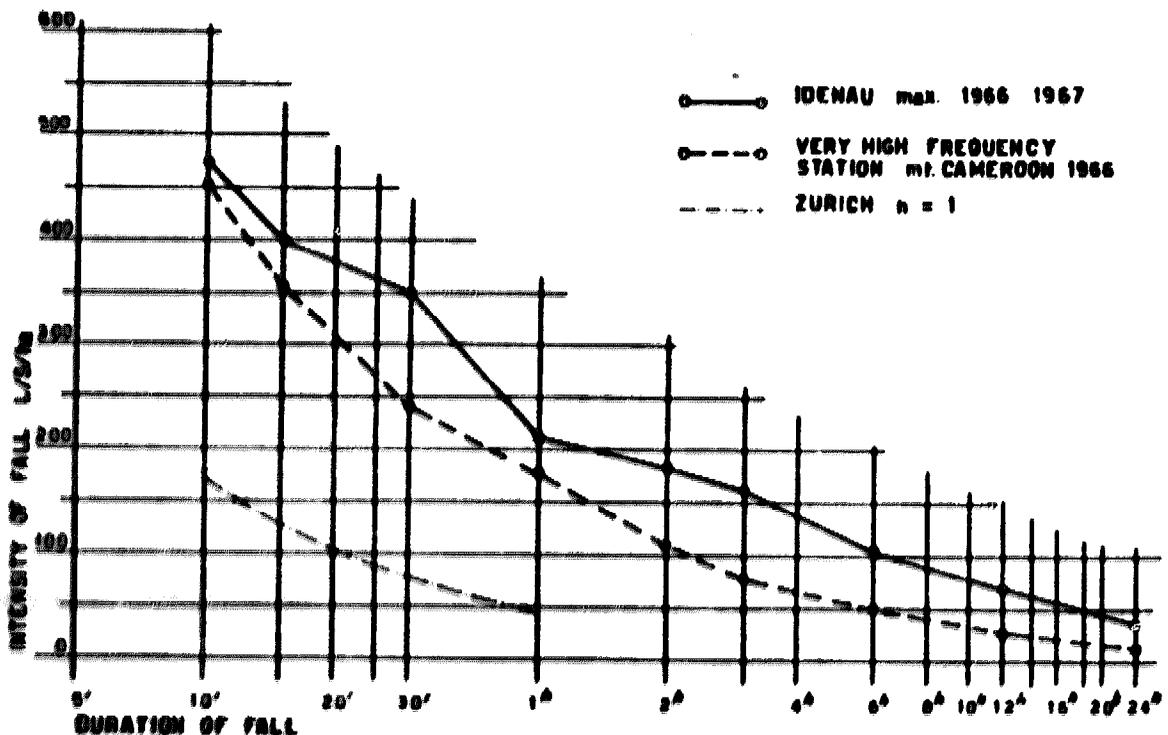
1956	5	116	208	271	213	571	526	308	354	470	127	77	3246
1957	48	52	301	208	695	453	526	608	685	510	173	142	4401
1958	36	30	145	241	411	576	249	536	754	455	261	90	3784
1959	93	5	213	241	219	472	402	337	630	487	264	6	3368
1960	23	16	334	253	417	397	312	591	332	640	151	116	3582
1961	25	-	68	291	232	499	668	419	529	492	104	-	3327
1962	8	37	371	311	363	338	348	485	460	457	209	18	3422
1963	4	65	150	264	230	305	406	369	405	398	28	22	2647
1964	-	-	272	315	349	354	667	103	563	760	181	79	3645
1965	31	83	124	271	233	500	538	726	564	441	40	-	3552
1966	51	29	214	257	300	228	528	384	557	576	141	34	3299
1967	5	30	307	257	231	417	541	532	502	400	77	53	3352
1968	73	66	309	136	294	419	416	494	560	223	45	133	3169

1-2.4 INTENSITY OF RAINFALL

The intensity of rainfall tells us how much rain falls within a certain period. (10', 15', 30', 1h, 24h)

Records of intensity are essential data for the calculations involved in designing bridges, culverts, dams and soil conservation earthworks.

Fig. 8 Intensity of rainfall



1-3 RUN-OFF AND INFILTRATION

The quantity of water running from an area into streams and finally to the sea is not the same as the rainfall.

The rainfall is equal to the total of:

- direct evaporation
- transpiration through vegetation
- infiltration
- run-off

The whole run-off and part of the infiltration supply the streams. Rocky areas provide flood and low water directly according to the rains. Lateritic or other porous, water-holding soils supply the streams with underground-water.

Infiltrated water forms the ground-water and through its natural filtration it can be used directly as drinking water (so long as protective measures for catchments are adopted and the thickness of the stratum which covers the water-bearing soil is big enough).

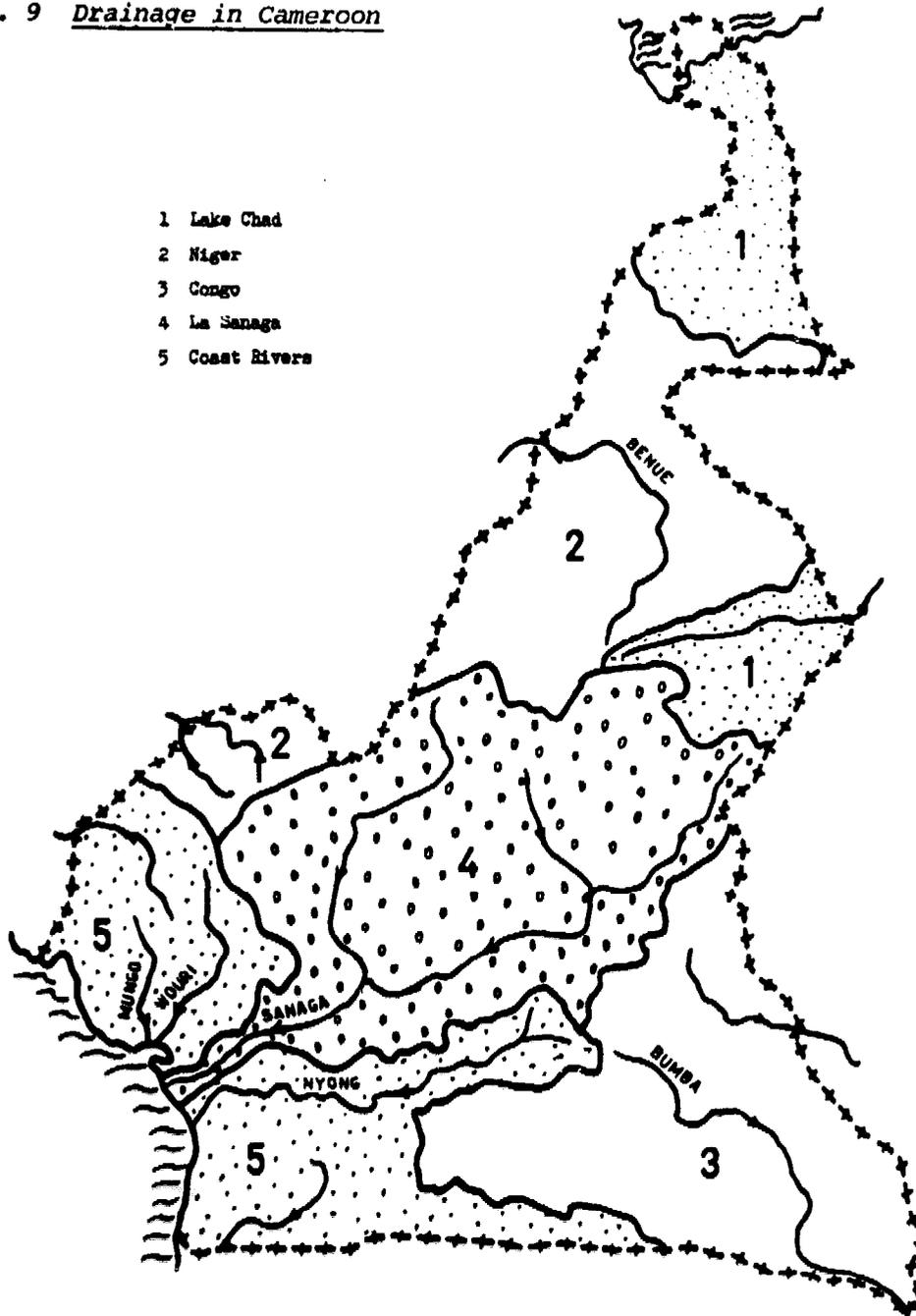
The characteristics of the yield of a spring depend on the type of soil and subsoil. In rocky areas the quantity of water will directly depend upon the rainfall. Surface springs will also dry up shortly after the rainy season and supply again after the first rains.

Springs from deep lateritic covers or from far distant catchment areas are more regular but their lowest supply quantity does not coincide with the lowest rainfall.

1-4 DRAINAGE IN CAMEROON

The principal watershed of Cameroon begins in the Rumpi Mountains north of Kumba and continues through Kupe, Manenguba, Bambutu, Bamenda Banyo and Ngaoundere to Ubangi-Shari across the frontier. It is the main source of the country's rivers, which flow in four main directions: north into Lake Chad, north-west into River Benue (Niger), south-west into Gulf of Guinea and south-east into Kadei, a tributary of River Congo. These correspond nearly to the five main drainage basins: Chad Basin, Benue Basin (Niger), Sanaga Basin, Congo Basin and Basin of Coast Rivers. (see Fig. 9)

Fig. 9 Drainage in Cameroon



Chapter 2: CHARACTERISTICS OF WATER

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2-1 WATER-SOURCES

2-1.1 GROUND-WATER

Ground-water is water which by percolating through the ground reaches the ground-water table. The quality of the ground-water depends on:

- The thickness of the stratum which covers the water-bearing soil. This is important because of indirect contamination like latrines, fertilizers etc.
- The porosity of the subsoil which influences the natural filtration process.

The quantity of ground-water depends on:

- The intake area: It is important to realize that the topographical basin does not necessarily correspond with the geological or hydrological drainage area.
- Annual rainfall percolation: This depends on the nature of the intake area, e.g. kind of vegetation (forest, farm, bush)
- Perviousness of the ground: This depends on the kind of material, stratification and its homogeneity.
- Storage capability of the ground: This depends on the same factors as perviousness and the intake area.

2-1.2 SPRINGS

If ground-water leaves the ground without artificial help we call it spring-water.

Spring-water is usually the best water quality. Whenever a water-point or water supply is planned, we investigate first if there is a possibility of using a spring. The quality and quantity which can be obtained depend on:

- Intake area: It is important to realise that the topographical basin does not necessarily correspond with the geological or the hydrological drainage area.
- Annual rainfall percolation: This depends on the nature of the intake area, e.g. kind of vegetation (forest, farm, bush).
- Continuous flow: The following points influence the continuous flow of a spring:
 - thickness of the stratum which covers the water-bearing soil
 - perviousness of the ground
 - storage capability of the ground

Therefore we know the extremes:

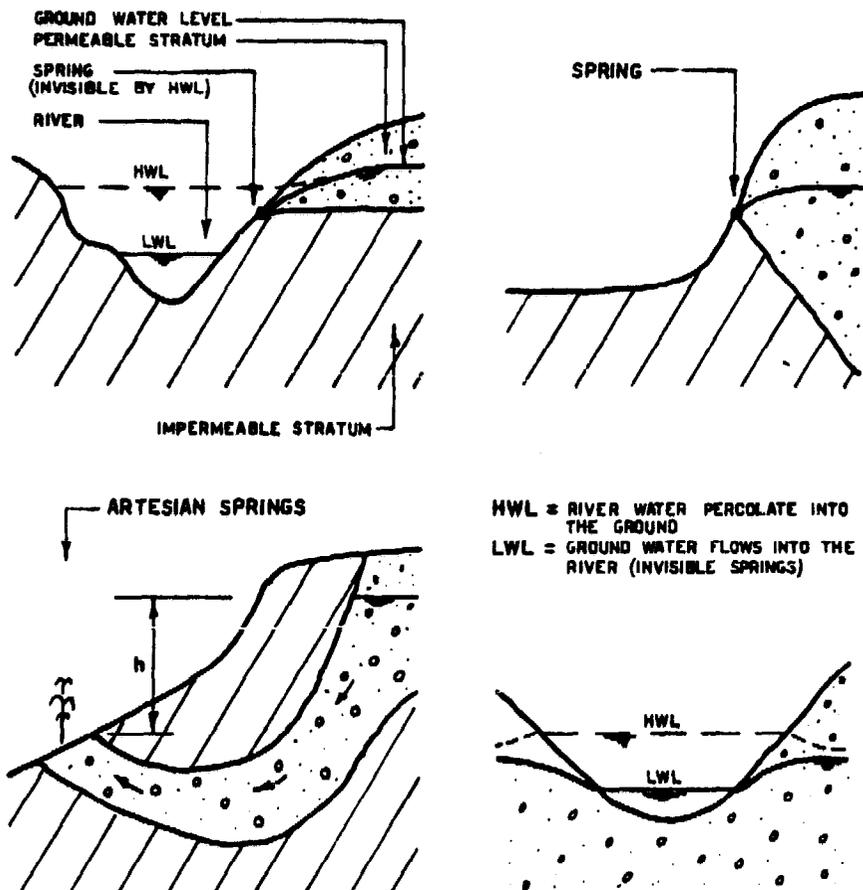
- Case 1: - A thin stratum covers the water-bearing soil.
 - The saturated stratum has a great perviousness (e.g. cracks and fissures).
 - The water-bearing soil has little storage capability (few pores which could fill with water).

- Case 2: - A thick stratum covers the water-bearing soil.
 - The saturated stratum has a small perviousness.
 - The water-bearing soil has a big storage capability.

In case 1 a single rainfall influences the flow volume of the spring.

In case 2 only the annual rainfall will influence the flow volume of the spring (continuous flow).

Fig. 1 SPRINGS



2-1.3 STREAMS

The run-off or stream-flow is the water which is gathered into rivulets, brooks and rivers. The volume and variation of run-off are influenced chiefly by the rainfall and its distribution by the size, shape, cover and general topography of the catchment area and by the nature and condition of the ground.

2-2 STANDARDS FOR DRINKING-WATER

2-2.1 INTERNATIONAL STANDARDS

2-2.1.1 GENERAL REMARKS

Water intended for human consumption must always be free from any substances which provide a hazard to health. Supplies of drinking-water should not only be safe and free from dangers to health, but should also be as aesthetically attractive as possible. The location, construction, operation and supervision of a water supply - its sources, reservoirs, treatment and distribution - must exclude all potential sources of pollution and contamination.

The problems of defining standards of quality for safe and acceptable water supplies have been studied by experts concerned with matters of water sanitation. The World Health Organization (WHO) has studied these problems to offer technical guidance for health and sanitation administrations to tighten or revise their regulations on water-quality control.

2-2.1.2 BACTERIOLOGICAL STANDARDS

Water circulating in the distribution system, whether treated or not, should not contain any organisms which may be of faecal origin. The presence of the coliform group should be considered as indication of recent or remote faecal pollution.

A standard demanding the absence of coliform organisms from each 100 ml sample taken from water entering the distribution system - whether the water be disinfected or naturally pure - and from at least 90% of the samples taken from the distribution system, can be applied in many parts of the world. Although there is no doubt that this is a standard that should be aimed at everywhere, there are many areas in which the attainment of such a high standard is not economically or technically practicable. In such circumstances there would appear to be economical and technical reasons for establishing different bacteriological standards for public water supplies with treated or disinfected water and for those with untreated water. The following bacteriological standards are recommended for treated and untreated drinking-water for present use throughout the world.

Coliform density is estimated in terms of the "most probable number" in 100 ml of water, called "MPN" Index.

To get the coliform bacterial count (MPN Index) of the water, the Millipore Laboratory can be used (see chapter 3-5.1).

a) Treated Water (by chemicals)

In 90% of the samples examined in any year, coliform bacteria shall not be detected or the MPN index of coliform micro-organisms shall be less than 1. None of the samples shall have an MPN index of coliform bacteria in excess of 10.

An MPN index of 8 - 10 should not occur in consecutive samples.

When the microfilter technique is used, the arithmetic mean of numbers of coliform group organisms shall be less than 1 per 100 ml, and shall not exceed 4 per 100 ml either in any two consecutive samples or in more than 10 % of the samples examined.

Chemical treatment of water (e.g. chlorination) has not been applied in CD/SATA-Helvetas projects in Cameroon, mainly because of uncertainty of a continuous supply of the products.

b) Untreated water (incl. slow sand filter without chlorination)

Very often communal drinking-water is not chlorinated or otherwise disinfected before being distributed. In such water schemes the following standard has to be maintained:

- in 90% of the samples examined in any year, the MPN index of coliform micro-organisms should be less than 10. None of the samples should show an MPN index greater than 20.
- if the MPN index is consistently 20 or greater, application of treatment to the water supply should be considered.
- when the micro-filter technique is used in examination of water, the arithmetic mean of the numbers of coliform group bacteria determined shall be less than 10 per 100 ml, and shall not exceed 20 per 100 ml in two consecutive samples or in more than 10% of the samples examined.

This standard is applicable for all the CD-SATA-Helvetas water supplies.

2-2.1.3 CHEMICAL STANDARDS

Chemical analysis plays an important role in the investigation of water supplies and water quality. Attention is largely directed to the detection and estimation of certain toxic chemical substances which may affect health.

a) Toxic substances

There are certain substances which, if present in supplies of drinking-water and at concentrations above certain levels, may give rise to actual danger to health. A list of such substances and of the levels of concentration which should not be exceeded in communal drinking-water supplies is given below:

<u>Substance</u>	<u>Maximum allowable concentrations in mg/l</u>
Lead	0.05
Arsenic	0.05
Selenium	0.01
Chromium	0.05
Cyanide	0.2
Cadmium	0.01
Barium	1.0

These substances cannot be analysed by simple field tests. Samples of the chosen water source should be sent to a laboratory for specific analysis, especially if the local population calls the water harmful. (see chapter 3-5.2)

b) Chemical substances affecting the potability of water

The following criteria are important in assessing the potability of water. In view of the wide variations in the chemical analyses of water from different parts of the world, rigid standards of chemical quality cannot be established. The limits thereafter designated "acceptable" apply to a water quality which would be generally acceptable to consumers; values greater than listed as "allowable" would markedly impair the potability of the water.

These limiting concentrations are indicative only and can be disregarded in specific instances.

<u>Substance</u>	<u>max. acceptable concentration</u>	<u>max. allowable concentration</u>
Total solids	500 mg/l	1500 mg/l
Iron (Fe)	0.3 mg/l	1.0 mg/l
Magnesium (Mg)	50 "	150 "
Manganese (Mn)	0.1 "	0.5 "
Copper (Cu)	1.0 "	1.5 "
Zinc (Zn)	5.0 "	15 "
Calcium (Ca)	75 "	200 "
Sulphate (So)	200 "	400 "
Chloride (Cl)	200 "	600 "
Magn. and Sodium Sulphate	500 "	1000 "
Phenolic substances	0.001 "	0.002 "
Carbon Chloroform extract	0.2 "	0.5 "
Alkyl Benzyl Sulphonates	0.5 "	1.0 "
pH Range *	7.0 - 8.5 "	less than 6.5 or greater than 9.2

*This item can be analysed by field tests, the others can be found out only in a laboratory (see chapter 3-5.2)

2-2.2 STANDARDS FOR DRINKING-WATER IN CAMEROON

The standards of Cameroon correspond with the standards of France which are laid down in article 1 of the Decree of 10th August, 1961 of the "Conseil Supérieur d'hygiène publique" and the decrees of 28th February, 1962 and 7th September, 1967.

These correspond more or less with international standards.

2-3 AGGRESSIVITY OF WATER ON BUILDING MATERIAL

2-3.1 GENERAL

The aggressivity of water plays a very large role in a water supply. Corrosion caused by the aggressivity of water means not only loss of building-material but in addition reduction of the water quality technically and hygienically. Especially endangered are those parts of a water scheme which are invisible like underground pipes, the exterior of covered constructions etc.

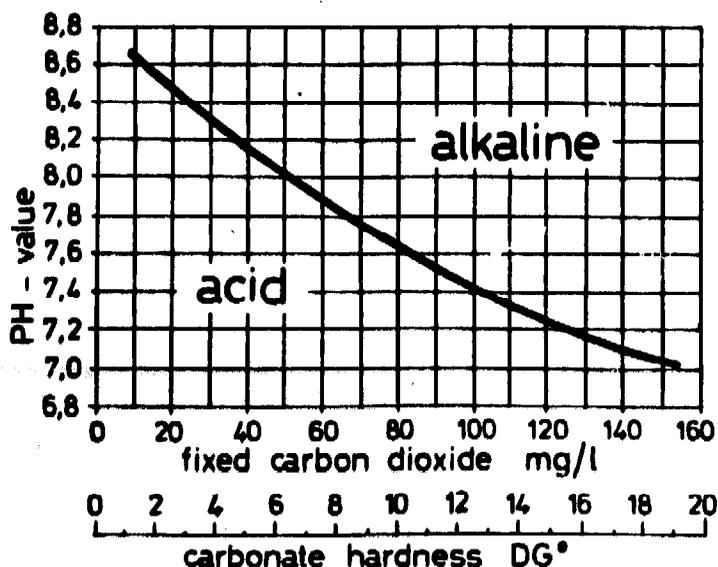
The aggressivity of water is mainly determined by its pH-value. In addition the free carbon dioxide plays an important role. Whether these two values prove aggressive or not depends much on the carbonate hardness of the water. That is why these three magnitudes are described more in detail below.

2-3.2 PH - VALUE

The pH-value is very important in water technology. It indicates how acid or alkaline (basic) a water sample is. It is the measure of H^+ -ions (hydrogen ions) dissociated in one liter of water (the pH-value is the negative logarithm of H^+ -ions concentration). One litre of pure and neutral (neither acid nor basic) water contains an equal amount of H^+ -ions and OH^- -ions (hydroxyl ions), at a temperature of 22° a concentration of 10^{-7} H-ions and 10^{-7} OH-ions = pH-value of 7. In acid water the H-ions are overwhelming the OH-ions and accordingly the pH-value is below 7. In alkaline water it is the opposite and the pH-value is above 7.

In practice this neutral point of pH-value = 7 varies with the content of calcium salt (hardness, see chapter 2-3.4). For instance water of pH-values exceeding 7 can also be aggressive if its calcium salt content is very low (see Fig. 11).

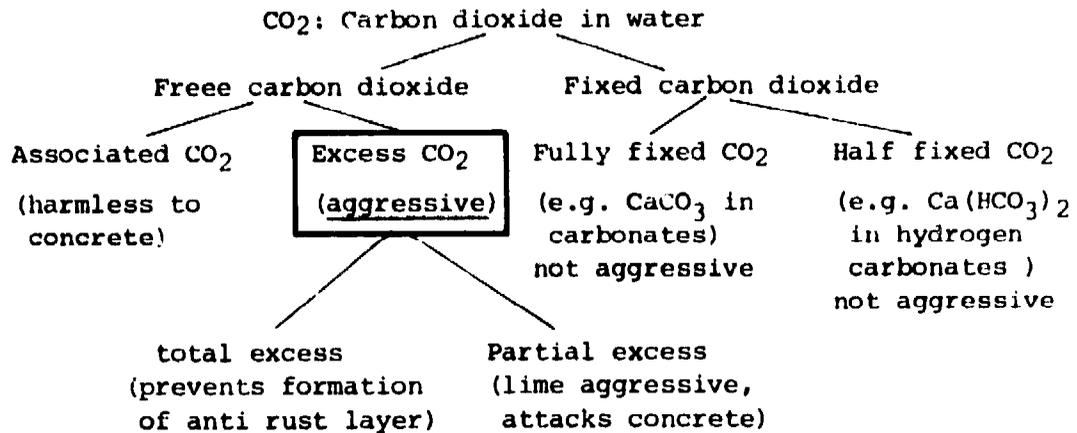
Fig. 11 pH-value for neutral water depending on the calcium salt content



2-3.3 CARBON DIOXIDE

Summary:

Only part of the carbon dioxide in water (the excess CO₂) is aggressive towards cement and iron products. The theory on this page shows the context. The figures 13 and 14 show the practical application (compare with examples of chapter 2-4.5).



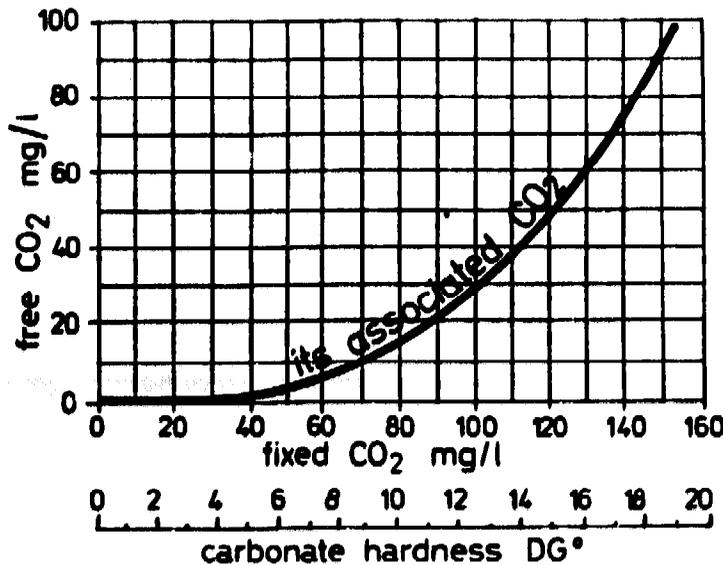
Free and fixed carbon dioxide (CO₂) is found in every natural water. Surface water generally contains much less free carbon dioxide than ground water.

The fully fixed carbon dioxide is combined with calcium or magnesium. Therefore its amount can be calculated according to the carbonate hardness: °DG · 7,85 = mg/l of fixed carbon dioxide.

The half fixed carbon dioxide is combined with bicarbonates or hydrogen carbonates. Its amount is equal to the one of fully fixed CO₂.

Part of the free carbon dioxide, the associated CO₂, is necessary to maintain the calcium hydrogen carbonates in solution. Therefore the associated CO₂ is depending on the carbonate hardness (see Fig. 12).

Fig. 12 The associated carbon dioxide



The part of free carbon dioxide exceeding the associated CO₂ is the excess CO₂. The excess carbon dioxide is able to attack and dissolve the metallic material as well as the calcium carbonate in mortar or concrete. Small amounts of calcium hydrogen carbonate, corresponding to a hardness of less than 2° DG, do not require any associated CO₂. The total free carbon dioxide of soft water is thus aggressive (compare Fig. 13 and 14).

Fig. 13 Aggressivity towards cement products (concrete, mortar, AC-pipes) depending on the DG and the free CO₂

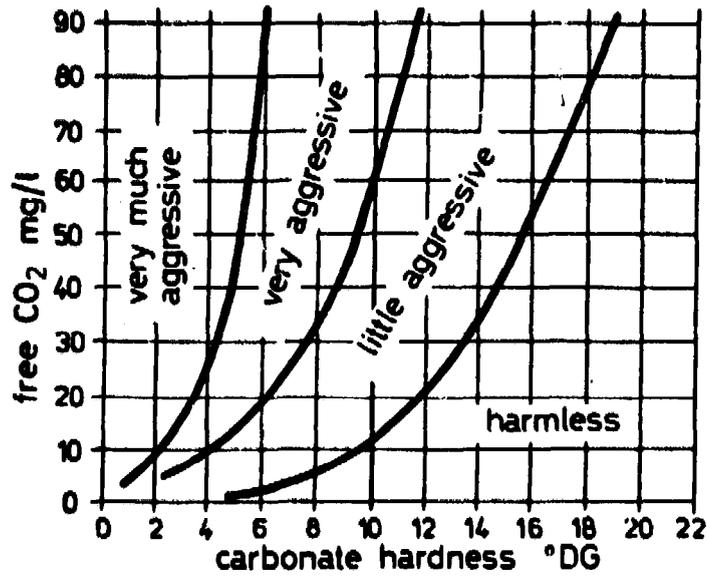
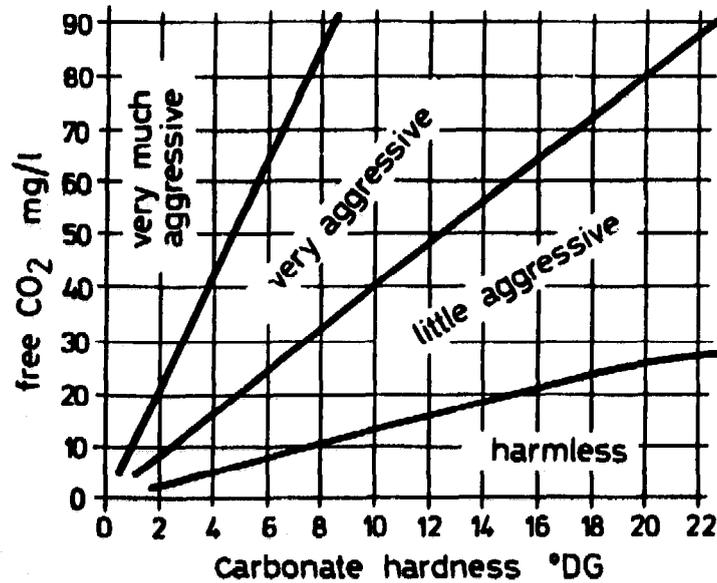


Fig. 14 Aggressivity towards iron products (steel pipes) depending on the DG and the free CO₂



2-3.4 HARDNESS

The hardness of water is dictated by its content of calcium and magnesium salts. Water containing much calcium and magnesium is termed hard, that containing little, soft. This is expressed numerically by the degree of hardness. Unfortunately there is no international unit established so far.

Degree of hardness - conversion modulus:

1 grain CaCO ₃ /gallon	=	17,1 mg CaCO ₃ /l	=	0,96°DG
10 mg CaO / liter	=	1 German degree of hardness (°DG)		
10 mg CaCO ₃ /0,7 liter	=	1 English degree of hardness		
10 mg CaCO ₃ / liter	=	1 French degree of hardness		
1° DG	=	1,25 English degree of hardness		
1° DG	=	1,78 French degree of hardness		

Degree of hardness	This water is termed as
°DG	
0 - 4	very soft
4 - 8	soft
8 - 12	medium hard
12 - 18	considerably hard
18 - 30	hard
over 30	very hard

Three different kinds of hardness are distinguished:

- Total hardness

In natural water, calcium and magnesium are largely combined with carbon dioxide, namely as hydrogen carbonate. Usually a small amount is combined also as sulphate, chloride, nitrate, silicate and phosphate. The sum of all these calcium and magnesium compounds yields the total hardness.

- Carbonate hardness

This includes only the part of calcium and magnesium which is combined with carbon dioxide. When water is boiled for a longer period, the calcium and magnesium combined with carbon dioxide are almost entirely precipitated as insoluble carbonates. One refers thus to a temporary or transient hardness, now generally spoken of as carbonate hardness.

- Non carbonate hardness

The fraction of the calcium and magnesium remaining in solution as sulphate, chloride and nitrate after boiling constitutes the residual hardness, formerly also referred to as permanent or mineral acid hardness. Now this is more accurately termed non carbonate hardness.

2-3.5 OTHER INFLUENCES

Concentrations above certain limits of sulphate (>300mg/l) or sulphite, chloride(>100 mg/l), humic acid etc. can also be very aggressive towards building materials.

To describe all these influences in detail is beyond the framework of this book. Moreover such detailed analyses require a very well equipped laboratory.

2-4 PREVENTION OF CORROSION

2-4.1 GENERAL

Where means are available the contents of water causing aggressivity are chemically or mechanically removed or neutralized before it is supplied into the distribution system. But in rural areas, for which these explanations are meant, normally the means for such methods are not available. Therefore those building materials have to be chosen which can best resist the actual aggressivity of the water.

Attention should be paid to the fact that the attack can be from inside (water to be transported or stored) and from outside (groundwater, swampy areas, or just humid acid soil, especially peat and those soils containing calcium sulphate).

Often an adequate material which can resist the actual aggressivity can not be found. In this case the material has to be protected by a bituminous or plastic coat. In some cases of attacks from outside it may be possible to drain the aggressive water away from the building.

The building materials usually applied in a watersupply are cement products, steel or plastic. Since these three materials behave differently towards the various factors of aggressivity they are described separately.

2-4.2 CEMENT PRODUCTS

Cement, mortar, concrete, asbestos cement pipes contain calcium carbonate which dissolves in contact with aggressive water.

2-4.2.1 Concentration limits

- Acid water (pH value below the neutral line, Fig. 11) must be regarded as harmful to concrete. It becomes very harmful if the pH value is more than 1 to 2 points below the neutral line.
- As it can be seen from Fig. 13, soft water (with low carbonate hardness) becomes always very aggressive if it contains free carbon dioxide. This aggressive CO₂ dissolves the calcium salts of the concrete and mortar and it destroys gradually these cement products. Flowing water with such properties performs this very rapidly.
- Moor water is often very harmful.
- Alkaline water (Fig. 11, pH above the neutral line) can also cause damage to cement products if the sulphate content is above 300 mg/l in standing or 100 mg/l in flowing water. Calcium and magnesium sulphates and, to a small extent also the corresponding chlorides, destroy concrete.
- Harmful to concrete is also water containing hydrogen sulphide and larger amounts of ammonium salts (e.g. waste water).
- Concrete is attacked by water containing sodium hydrogen carbonate (especially in coastal areas).

- Organic acids usually act less destructively on concrete. Sometimes they even yield compounds with cement calcium, which make the concrete water-tight.
- Water components such as free CO₂, sulphate, chloride etc. reinforce each other in the attack on concrete.

2-4.2.2 Prevention of destruction

- As stated earlier, it is usually impossible to eliminate the aggressivity of water in rural areas. Only the reduction of aggressive carbon dioxide may in some cases be partly possible in providing mechanical means for aeration. A certain aeration yields already when the water falls free from the inlet pipe into a basin. A better aeration can be got in trickling water over cascades or in spraying it through sieves, shower heads or perforated sheets in well aerated rooms. Spraying from 2 to 3 metres height is naturally more effective than trickling.
Attention: Even a small amount of iron content makes water unpleasantly noticeable by colouring it because of oxygen.
- Different types of cement yield concrete of different resistance to this destructive influences. Resistance increases in order: Portland cement, blast furnace cement, high alumina cement.
- Cement products can be adequately protected against little aggressive water by certain additions e.g. Porcelain or Rajasil (e.g. SIKA-products).
- Firm concrete of good quality is much more resistant than porous concrete. Therefore concrete should be manufactured at lowest possible water-cement-value, optimum grain composition of the aggregates and well pounded or vibrated fresh concrete.
- Concrete tanks are provided with protective coatings: External such as Inertol (bituminous) or internal Eucoplex (acrylisperion), plastic top coatings etc.. Concrete can still be attacked if the aggressive water finds its way to it through small cracks in the coating. That's why the coats have to be very carefully applied and examined from time to time.

2-4.2.3 Asbestos cement pipes

- AC-pipes contain calcium carbonate and show high internal and external resistance to concentrated salt solutions. Experiments have proved that asbestos pipes are not corroded by water containing 2000mg Ca SO₄/liter and 5000mg Na₂SO₄/liter and MgSO₄.
- AC-pipes are also resistant to electric currents.
- But larger amounts of aggressive carbon dioxide occurring with low carbonate hardness cause damages (see Fig. 13).
Internal linings of bitumen and external coal-tar coats improve the resistance of asbestos pipes to the limit "very aggressive" in Fig. 13.

2-4.3 GALVANIZED STEEL PIPES

The corrosion of water pipes has a technical-economical aspect (maintenance costs) as well as a hygienic one in so far as a corroded pipe could suck foul and contaminated water into the system.

2-4.3.1 Concentration limits

- Standing water effects greater corrosion in the pipes than flowing water. Therefore an aggressive water has a specially evil influence in the terminal parts of the piping system.
- Water of hardness above 2°DG and of an oxygen content of at least 6mg/l if $v=0,5m/s$ or 2mg/l if $v=0,5m/s$ (but without aggressive carbon dioxide) form a protective layer of calcium and magnesium compounds named anti-rust layer on the internal surface of the pipe.
- Every water attacks the iron pipes if the oxygen content is insufficient, even if the other corrosion factors do not favour attack. The oxygen concentration should never be below 4,0mg/l (respectively 2,0mg/l in case of $v=0,5m/s$).
If the oxygen content is excessive, not in genuinely dissolved form (milky turbidity of water), iron is likewise attacked.
- Iron is always attacked and dissolved by water containing aggressive carbon dioxide which prevents the formation of a protective layer against rust (see above and Fig. 14).
- The pH-value should always be equal to or just below the equilibrium for unprotected iron pipes; -0,5 points for galvanized steel pipes (see Fig. 11)
- Unprotected iron pipes are attacked by hydrogen sulphide (e.g. in moor-soils)
- Water with a high chloride content (e.g. brackish water) attacks iron pipes strongly. The limit for unprotected iron pipes is 150mg/liter in soft water.
- Special attention has to be given to the external attack.
- Steel pipes are more susceptible to chemical attacks than cast iron pipes. Cast iron pipes are more resistant than steel pipes against soft water of high oxygen content and aggressive properties.

2-4.3.2 Prevention of corrosion

- Reduction of the aggressive carbon dioxide, compare chapter 2-4.2.2.
- Iron pipes have to be coated by melted bitumen or coal-tar pitch (so-called "synoplasts") in case of external aggressivity (e.g. in acid peaty soils, loam and clay with little calcium and in salty ground water etc.).
- Iron pipes with a plastic covering coat have been brought into use recently.

2-4.4 PLASTIC PIPES

Plastic pipes are either of PVC (polyvinyl chloride) or of PE (polyethylene) (see chapter 4-8.2.3).

Since 1959 the fabrication of plastic pipes has been adapted more and more to the claims of water engineering.

Plastic pipes have the advantage of not being attacked by any aggressive water
They suffer no destruction from carbon dioxide, humic acids, sulphates and chlorides of any concentration in tapped water or soil. They have smooth walls and no incrustations. That is why plastic pipes are applied more and more in water supplies, in particular with aggressive water and soil. Nevertheless much attention has to be paid to an adequate fabrication. Some plastic materials, notably poor polyethylene pipes, serve as nutrient of bacteria.

2-4.5 EXAMPLES OF PRACTICAL APPLICATION

To show the practical application of chapter 2-4 three different water samples will be analysed:

Sample A: PH = 6,6
Hardness = 2 grains CaCO₃/gallon (=2° DG)
Content of carbon dioxide (CO₂) = 20mg/l

This "very soft" water (chapter 2-3.4) is acid (Fig. 11) and "very much aggressive" (Fig. 13 and 14) towards cement and steel products.

Conclusions:

In this water supply project plastic pipes have to be applied and the concrete tanks have to be provided with protective coatings. Asbestos pipes should not be used.

Sample B: PH = 7,4
Hardness = 7 grains CaCO₃/gallon (=7,7°DG)
Content of carbon dioxide (CO₂) = 42 mg/l

This "soft" water (chapter 2-3.4) is little acid (Fig. 11) and "very aggressive" (Fig. 13 and 14) towards cement and steel products.

Conclusions:

Plastic pipes or coated asbestos pipes (see chapter 2-4.2.3) can be applied. Steel pipes should only be used for parts of the pipeline where other piping material cannot be applied (e.g. crossing of rocky areas). Concrete and plastering should be protected by additions or coatings. Otherwise the cement plastering has to be replaced after a few years.

Sample C: PH = 7,1
Hardness = 11 grains CaCO₃/gallon (=10,5° DG)
Content of carbon dioxide (CO₂) = 18 mg/l

This "medium hard" water (chapter 2-3.4) is little acid (Fig. 11) and "little aggressive" (Fig. 13 and 14) towards cement and steel products.

Conclusions:

In this water project all common building and piping materials can be applied.

Chapter 3: INVESTIGATIONS AND BASIC DATA FOR RURAL WATER SUPPLIES

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The following list intends to give a summary of the field work during planning and construction of a rural water supply:

- Application for assistance is sent by the community concerned to the Community Development Department (CD) or to the local council.
- Meeting will be organized by Community Development Officer (CDO) for introduction of Department to local officials and community, eventually forming a project committee.
- Search out water sources (springs, river, etc.)
- Preliminary survey with pocket altimeter, followed by discussion of the results with the community.
- If the project is feasible collection of more information and data on:
 - a) Situation: Geographical and administrative situation, place and function of the village in the region, etc.
 - b) Population: Number of inhabitants, ethnological composition, denominations, development of the population during the past years, etc.
 - c) Infrastructure: Present infrastructure and development plans of roads, schools, markets, health centres, cooperatives, missions, other development projects, etc.
 - d) Economic aspects: Produce and income, cooperatives, agricultural potential, farms, markets, industries, coordination with other development projects, etc.
- Contacts to other Government Services, Local Administration
- Measuring of the water quantity of source
- Biological and chemical water tests (see chapter 3-5)
- Detailed survey
- Occurrence and quality of local building materials: Sand, gravel, stones and wood.
- Technical report, estimate (see chapter 5-1)
- Organization of community by Community Development Department (organization of a project committee if not already done)
- Financing of project:
application for government grants and foreign aid,
commitment to an amount for village contribution
- Organization of community work by project committee and Community Development Department according to the instructions of the technical staff
- Implementation of project
- Organization of maintenance (see chapter 6)

		average daily water consumption in litres		
		at present Stage 0*	in future Stage I* Stage II*	
Village in remote areas	per head	25	50	70
Village with school, maternity and max.10% private connections	per head	50	70	100
Urban areas with max 20% private connections	per head	50	100	120
Residential areas (private connections)	per head	100	200	250
Primary school	per pupil	10	10	10
College	per student	100	120	120
Maternity	per bed	100	100	100
Hospital without Surgery	per bed	100	150	150
Hospital with Surgery	per bed	200	300	300

The above figures merely give the design engineer a guide to the average consumptions; he has to use his own judgement to choose specific consumptions, based on experience in the country and the details of the particular project.

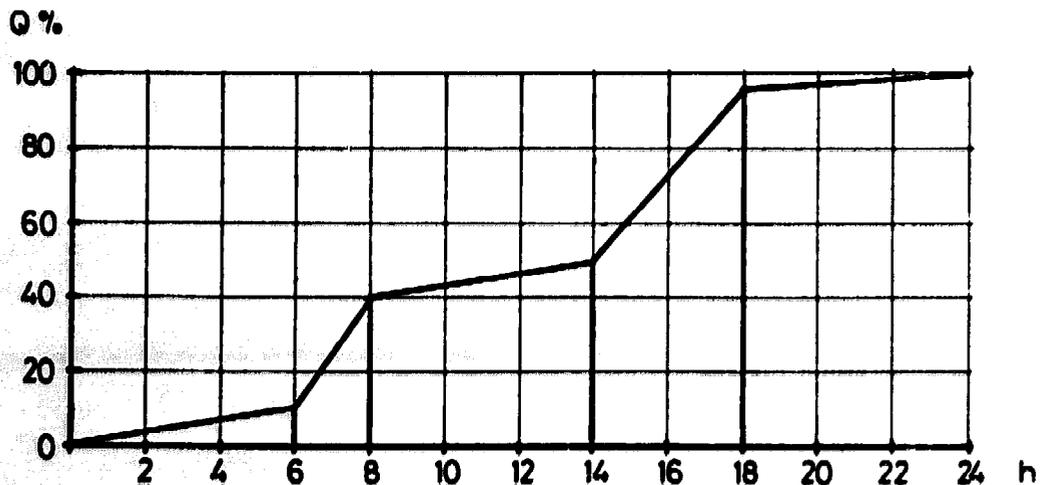
The consumption during one day in rural water supplies can have big variations. The smaller the community, the greater, in general, is the variation. Market days and local celebrations can have a big influence on daily water consumption. The following values have been experienced:

Ratio	Normal rate	Average
Maximum day: average day	(from 1.2 to 2.0) : 1	1.5 : 1
Maximum hour: average hour	(from 2.0 to 3.0) : 1	2.5 : 1

Measurements in the Ngondzen water supply have shown the same results.

* see chapter 4-1.2.2

Fig. 15 Daily consumption in a rural water supply



3-3 LOCATION OF WATER SOURCE

3-3.1 SOURCE SITUATED ABOVE CONSUMER

With first priority all possible water sources have to be investigated whether they can supply water by gravity to the consumer. It is most preferable to get water by gravity in order to avoid the installation of an engine (pump, ram, etc. to lift water to the consumer). In this way the maintenance will be simplified and the running cost kept low; moreover a continuous supply is by far safer.

3-3.2 SPRING WATER

With second priority preference has to be given to spring water which can be caught from inside the ground avoiding any contamination. In this case no treatment will be required, which again simplifies the maintenance of the water supply.

3-3.3 SOURCE SITUATED BELOW CONSUMER

With third priority sources have to be investigated which are situated below the consumer in case of failing to find a source above the village. But also in this case preference has to be given to spring water which can be caught from inside the ground. It has also to be investigated whether the water can be lifted to the consumer by natural resources (e.g. water power: hydraulic ram, possibly turbine, or wind, etc.).

3-4 MEASURING OF WATER QUANTITIES

3-4.1 GENERAL

The most important figure for any kind of water-works is the quantity of water available.

Before we start detailing a project we need to know how much water has to be considered.

- for barrage, catchment, overflows
- for intake, sedimentation, filter

Gauging should be done regularly once a week for more than one year if possible. If only one year measuring is possible, it is a necessity to measure the water quantity of the source as well as the rainfall. Compare the measured rainfall with available rainfall statistics over a long period, which helps to determine whether it is a dry or wet year. This enables to decide if the water quantity will be sufficient. In case of a river, measurement should be taken in the morning as well as in the afternoon (morning : afternoon = 1 : 0.8).

3-4.2 ESTIMATING WATER QUANTITIES OF A STREAM

The quantity of water flowing steadily in a stream is

$$Q = A \times v \times s$$

=====

Q = quantity of water (m³/sec)

A = cross-sectional area of flow (m²)

v = velocity of water (m/sec)

s = surface: for plastered surfaces = 0,9
for rough rocky surfaces = 0,5
average = 0,6 - 0,8

To estimate the flow of a stream carry out the following procedure:

- determine the cross-sectional area of the water flowing in a stream (average depth of water x width of stream = A)
- measure velocity of water:
take the distance that a piece of wood or a leaf travels during one second (Xm/sec), out of three measurements.
- calculate the quantity of water as a result of 1 and 2 $Q = A \times v$

3-4.3 MEASURING WATER QUANTITIES WITH A BUCKET AND A WATCH

This is an easy and exact method for quantities up to 300 (600) l/min.

Procedure:

- One or more pipes, depending on the quantity, are fitted into a temporary earthdam so that all the water passes through the pipes.
- The flow from one pipe should not exceed a quantity which fills a bucket in less than 3 seconds.
- Calculate the volume of the bucket if it is not a graduated one.
- Gauge the flow of each pipe three times and enter the results into the records.
- Calculate the quantity in l/min. or l/sec.

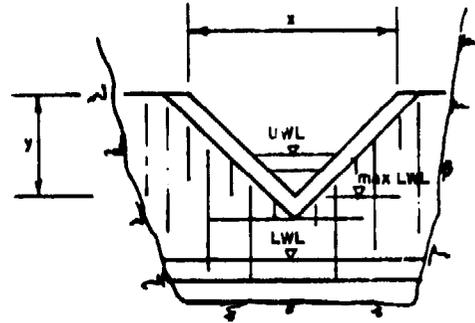
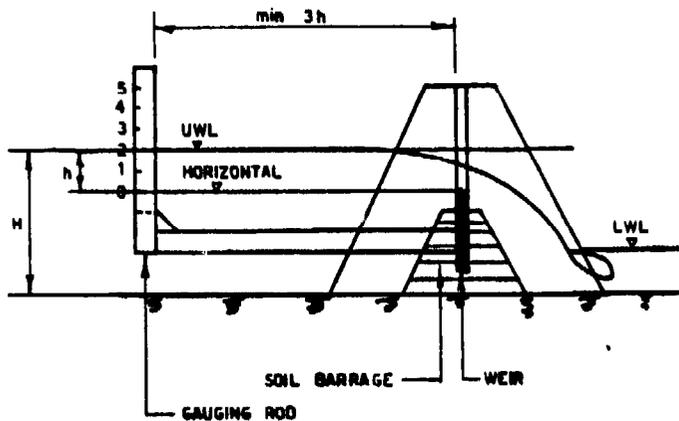
3-4.4 FLOW MEASUREMENTS WITH A WEIR

3-4.4.1 Thompson weir

This method is suitable for quantities up to about 50 l/sec.

The following arrangements have to be made:

Fig. 16



UWL = UPPER WATER LEVEL
LWL = LOWER WATER LEVEL
THE max. LWL SHOULD NEVER BE HIGHER THAN POINT 2.

- minimum $H = 2h$
- maximum velocity of water at the gauging rod = 1 m/sec
- normally a 90° weir is used $\frac{x}{y} = 2$
- important: The gauging rod must be in a distance of at least $3h$ from the weir. The zero point of the rod must be on the same level as the crest of the weir.

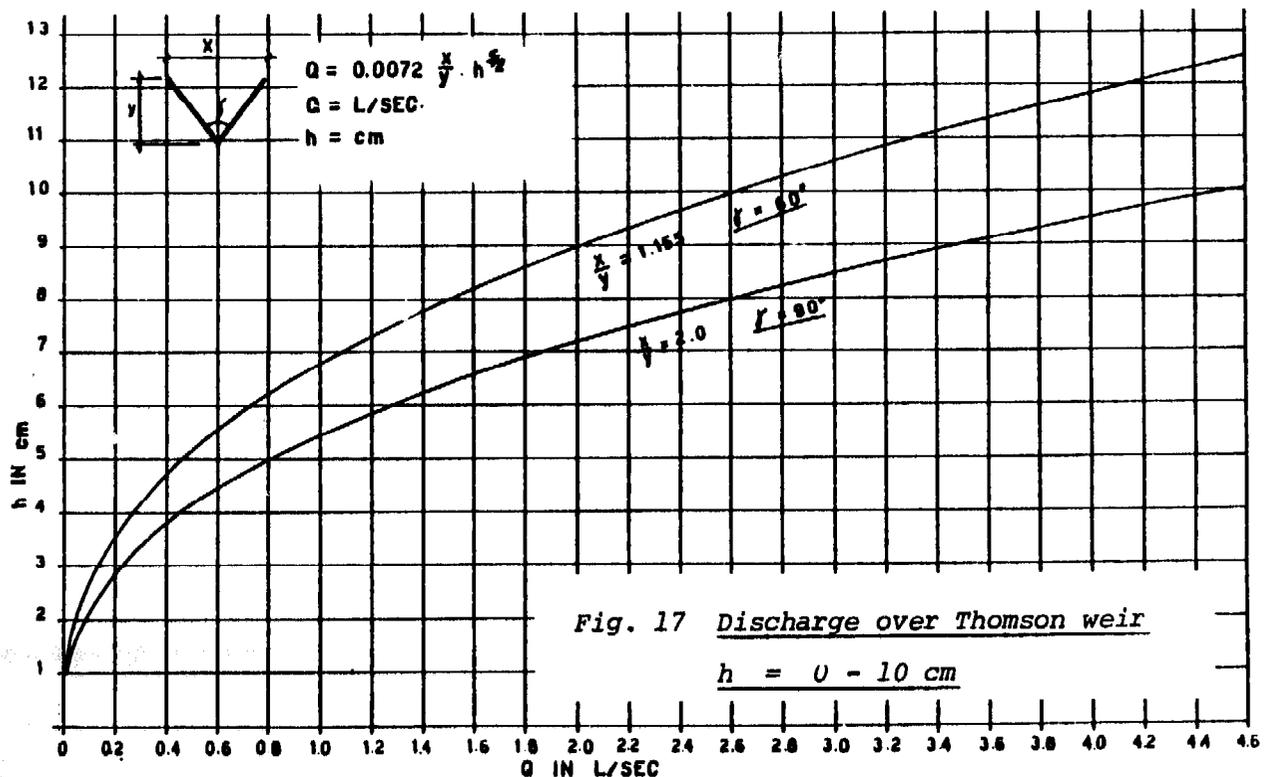
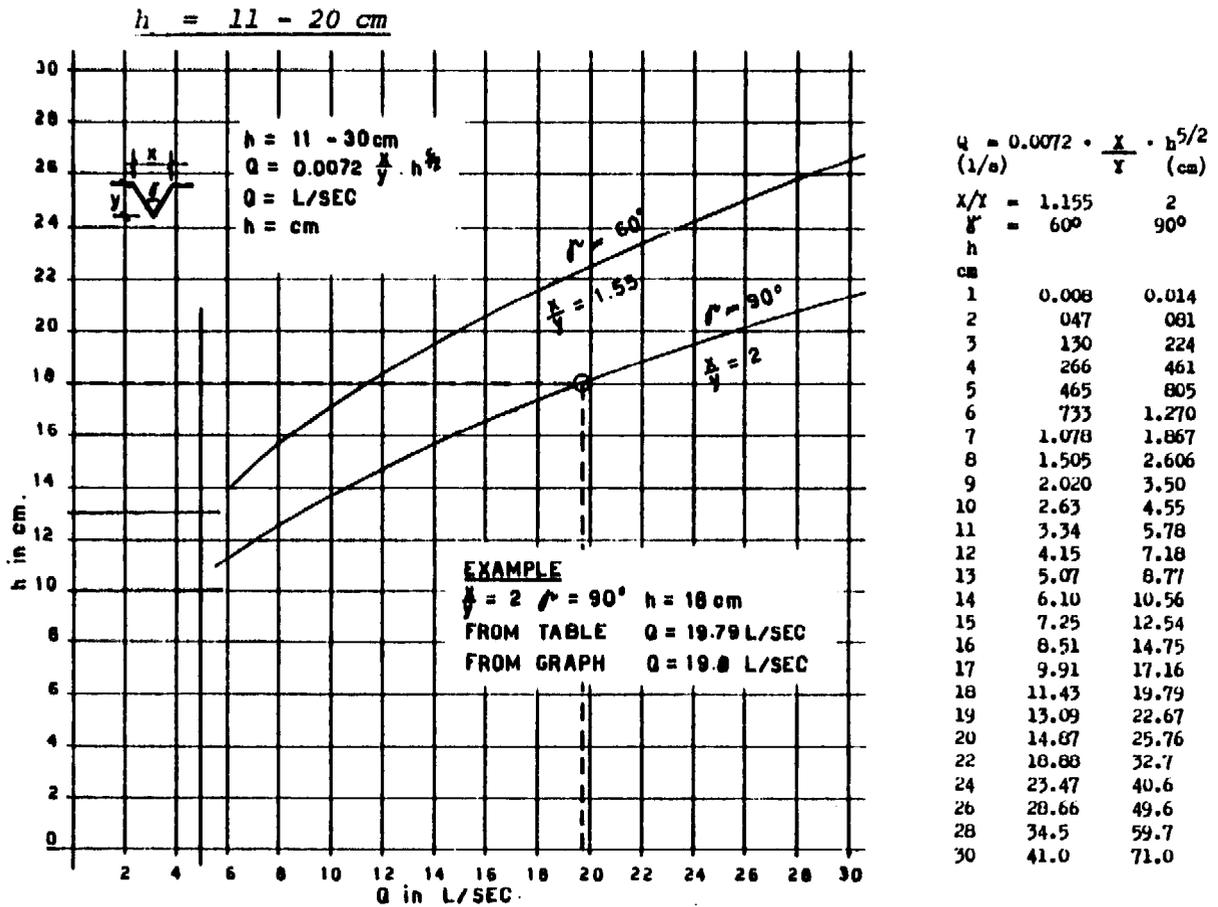


Fig. 18 Discharge over Thompson weir

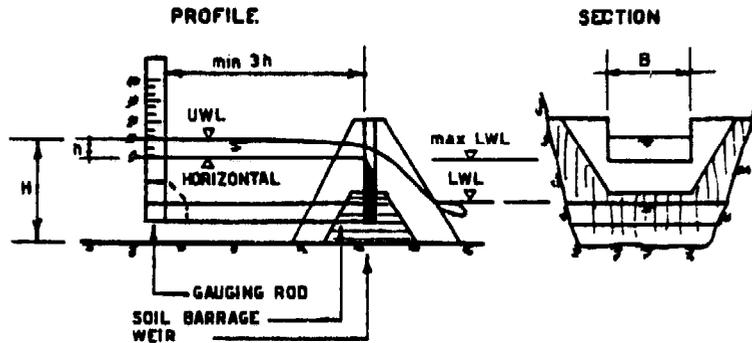


3-4.4.2 Rectangular weir

This method is applicable for quantities above 10 l/sec.

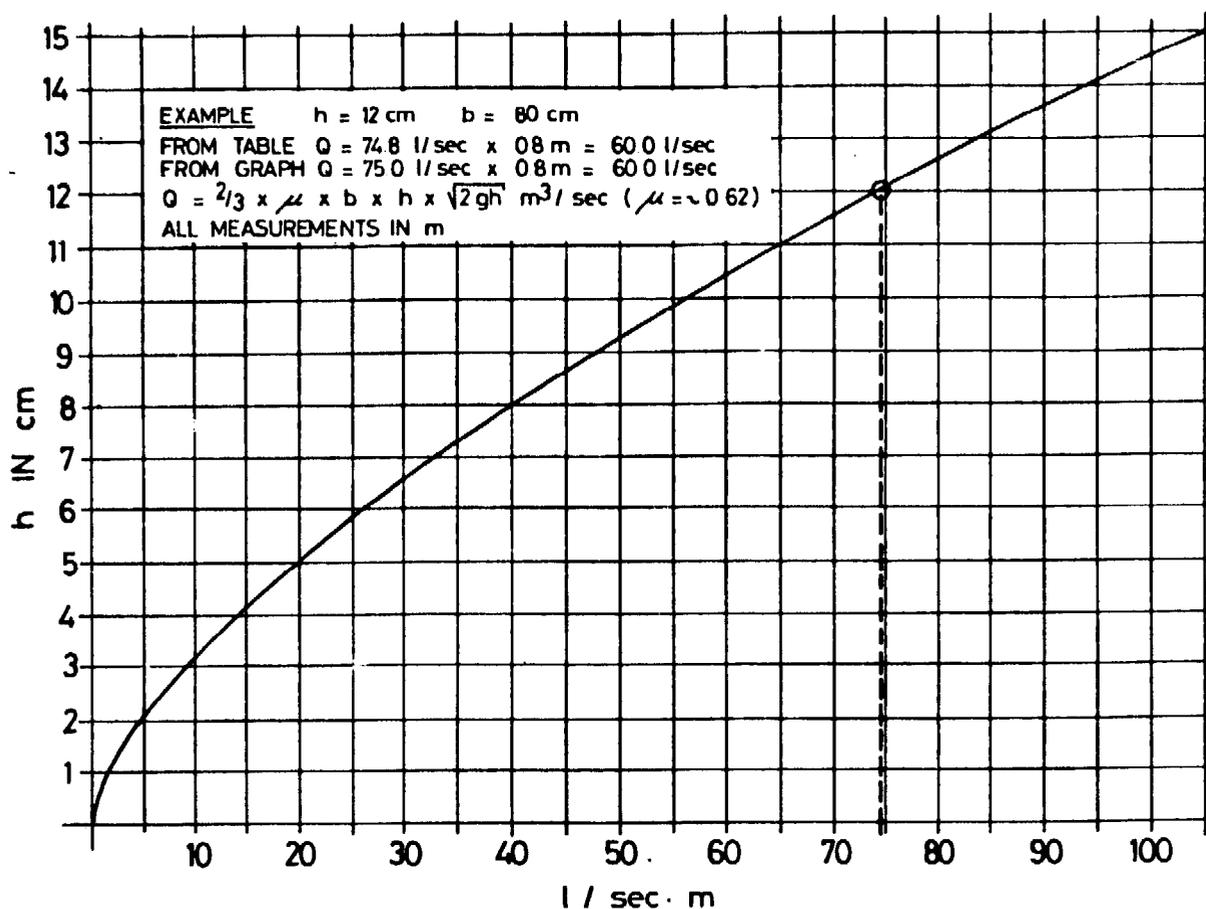
The following arrangements have to be made:

Fig. 19



- minimum $H = 4 h$
- maximum velocity of water at the gauging rod = 1m/sec
- important: The gauging rod must be in a distance of at least $3 h$ from the weir, the zero point of the rod must be on the same level as the crest of the weir.
- normally the minimum width for a weir should be 50 cm, better 1.00 m
- the crest of the weir must have a sharp edge.

Fig. 20 Discharge over rectangular weir



<u>h in</u> <u>cm</u>	<u>Q in l/s</u> <u>for B=1.0m</u>	<u>h in</u> <u>cm</u>	<u>Q in l/s</u> <u>for B=1.0m</u>
1	1.8	26	239
1½	3.3	28	267
2	5.1	30	296
2½	6.7	32	326
3	9.4	34	357
4	14.4	35	373
5	20.1	36	389
6	26.5	38	422
7	33.3	40	455
8	40.7	42	490
9	48.6	44	525
10	56.9	45	543
11	65.7	46	561
12	74.8	48	599
13	84.4	50	636
14	94.3	55	734
15	104.6	60	837
16	115.2	65	943
17	126.2	70	1054
18	137.5	75	1169
19	149.2	80	1288
20	161.0	85	1411
22	186	90	1537
24	212	95	1667
25	225		

3-5.1 BACTERIOLOGICAL FIELD TEST (MILLIPORE)

Millipore is a membrane microfilter technique for detecting coliform bacteria and other bacterial organisms in water - the principal criterion of sanitary quality for public drinking-water. In many cases, the membrane filter method has made it possible to substitute field testing for laboratory analysis.

A real and reliable information about the quality of water can only be got if the tests are done over all seasons. This means tests have to be done in dry season and in rainy season in particular after heavy rains.

Test procedure with portable water analysis kit and monitors which is available with CD-SATA-Helvetas:

1. Remove the plastic plugs from a bacteriological monitor and set them aside.
2. Carefully insert the syringe valve connection into the bottom ("spoked" side) of the monitor. Avoid excessive force.
3. Remove a sterile sampling tube from its sleeve and insert the nylon tip into the inlet hole of the monitor.
4. Draw the syringe plunger back slowly on the initial stroke (to avoid the risk of an "air lock" before the monitor fills with water) and hold the plunger forward to expel the filtered water from the syringe.
5. Filter an entire measured amount of sample water through the monitor. Samples of 100 ml are normal for potable water, but samples of 50 ml are normal when testing stream-water.
6. Invert the assembly and draw the last few ml from the filter. Use short, quick strokes to pull the monitor as dry as possible.
7. Remove and discard the sampling tube, but do not remove the monitor.
8. Crack off the tip of an ampoule (covered by a short plastic tube), but do not remove the tip or the tube. Place the forefinger over the end of the plastic tube, as when using a pipette, and break off and discard the bottom tip of the ampoule.
9. Remove the monitor from the syringe and insert the bottom tip into the BOTTOM of the monitor, placing it against the pad beneath the filter. Release the forefinger and by controlling the pressure of the ampoule against the pad, allow the medium to flow into the monitor.
10. Replace the plastic plugs, invert the monitor, and incubate at 35°C for 18 to 24 hours. Pry off the monitor top, remove and dry the filter, and count the coliform colonies which are blue-grey coloured with a metallic lustre.

In some cases it may be difficult to differentiate between coliform of fecal origin (from intestines of warm-blooded animals) and coliforms from other environmental sources. In this case a sample may be incubated at 44°C for 24 hours. The colonies which are growing under these Conditions are certainly coliform of fecal origin.

11. The count should be determined and recorded as the number of coliform organisms (colonies) per 100ml of sample tested. (compare with 2-2.1.2)
12. For more detailed instructions see "Millipore-Manual".

3-5.2 CHEMICAL ANALYSIS OF WATER

A general chemical analysis of water has to be carried out by a well equipped laboratory (e.g. of a hospital or a high school).

For general analysis a sample of at least 2 litres is required. It should be collected in a chemically clean bottle made of good quality (neutral) glass, practically colourless and fitted with a ground-glass stopper.

In the collection of samples from mineralized sources, the bottle should be completely filled and the stopper securely fastened.

Samples should be transported to the laboratory with as little delay as possible and should be kept cool during transport. Chemical analysis should be started as soon as practicable after the collection of the samples and in any case should not be delayed for more than 72 hours.

Fig. 21 shows the result of such a chemical partial analysis of different CD/SATA-Helvetas water supplies.

If a general chemical analysis is not possible, the design engineer has to analyse the water by a field test. Additionally the engineer has to find out from the local population whether the water is potable or not.

Chemical field test (Hach)

With the portable water analysis kit (model CA-24WR) of Hach, which is available with CD-SATA-Helvetas, the following chemical values can be measured:

- Content of carbon dioxide (CO₂) in mg/l (see 2-3.3)
- Content of dissolved oxygen in mg/l
- Hardness in grain CaCO₃/gallon (see 2-3.4)
- PH-value (see 2-3.2)

The test procedure is described in Fig. 22.



Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe
 Laboratoire fédéral d'essai des matériaux et Institut de recherches - Industrie, Génie civil, Arts et Métiers
 Laboratorio federale di prova dei materiali ed Istituto sperimentale - Industria, Genio civile, Arti e Mestieri

8600 Dübendorf

COPIE

**Untersuchungsbericht
 Procès-verbal
 Processo verbale**

EMPA No. 35 223

Auftraggeber: **Helvetas**
 Commentant: **Schweizer Aufbauwerk für**
 Comitatente: **Entwicklungsländer**

Z u r i c h

Eingang der Probe: **2. Dezember 1975**
 Réception de l'échantillon: **2. Dezember 1975**
 Ricevuta del campione:

Verpackung: **Plastikflaschen**
 Emballage: **Plastikflaschen**
 Imballaggio:

Bezeichnung der Probe durch den Auftraggeber:
 Désignation de l'échantillon par le commentant:
 Designazione del campione da parte del comitatente:
Fünf Doppelproben Wasser
betr. S.A.T.A. Wasserversorgung, Kamerun

Betrifft: Brief vom 1. Dezember 1975; Ref. W/h

Chemische Analyse nach Angaben

Untersuchungsauftrag:
 Nature de la commande:
 Genesi dell'ordinazione:

Result Versuchsergebnis - Résultat - Risultato (translation)

Samples: Five bottles with 1 litre pure water, additionally five bottles with the very markings each and an admixture of calcium carbonate.

Chemical analysis and examination

The analysed samples are little acid to neutral and extremely soft. They contain extraordinary little salts and also very little organic pollution. All the samples (but especially "Kai" and "Weh") have a high ability to dissolve lime (lime-aggressive carbon dioxide).

Because of the small hardness (very soft water) and the acid character, the tested waters are aggressive towards cement as well as towards steel. On the other hand, there is no objection to the use of plastic material.

Chemical water analysis

GD-SATA water supplies in Cameroon

Designation of the water samples:	Guzang	Kai	Weh	Sehn	Bangem
PH - value	6,5	5,9	6,6	6,0	7,0
Hardness (in °DG):					
Carbonate hardness	0,17	0,17	1,45	0,1	1,7
Non carbonate hardness	0	0	0	0	0
Total hardness	0,17	0,17	1,45	0,1	1,7

Content of (in mg/l):	Guzang	Kai	Weh	Sehn	Bangem
Sulfates SO ₄	1	1	1	1	1
Chlorides Cl	0,5	0,5	0,5	0,5	0,5
Alkalinity mval/l: Methyrorange	0,15	0,2	0,8	0,1	0,75
Lime-aggressive carbon dioxide CO ₂ (Meyer)	7,7	37,4	28,6	8,8	11
KMnO ₄ consumption in mg/l	1,6	0,6	0,9	1,6	0,9

Calculated in mg/l:	Guzang	Kai	Weh	Sehn	Bangem
Sodium bicarbonate NaHCO ₃	7	12	24	5	13
Magnesium Mg	0	0	2,4	0	3,5

Duebendorf, the 8th of December 1975

Fig. 21 Report on chemical analysis of water

Fig. 22 Test procedure with the portable laboratory Hach



MODEL CA 24WR

Carbon Dioxide Test

1. Fill the plastic measuring tube level full with the water to be tested and transfer to the mixing bottle by placing the mixing bottle over the tube and turning the bottle right-side-up.
2. Add one drop of Phenolphthalein Indicator Solution.
3. Add Sodium Hydroxide Solution dropwise, counting the drops and gently swirling the bottle to mix after each drop is added until the solution becomes light pink. Each drop equals 5 milligrams per liter (mg/l) carbon dioxide (CO₂).

Dissolved Oxygen Test

HIGH RANGE (1 drop = 1 mg/l DO)

1. Fill the glass-stoppered DO bottle with the water to be tested by allowing the water to overflow the bottle for 2 or 3 minutes. Be certain there are no air bubbles present in the bottle.
2. Add the contents of one pillow each of Dissolved Oxygen 1 Reagent Powder and Dissolved Oxygen 2 Reagent Powder. Stopper firmly and carefully so that no air is trapped in the bottle. See Note A. Grip the bottle and shake vigorously to mix. See Note B. A flocculant precipitate will form. If oxygen is present the precipitate will be brownish-orange in color.
3. Allow the sample to stand until the floc has settled halfway and leaves the upper half of the bottle clear. Then again shake the bottle and again let it stand until the upper half of the bottle is clear. See Note D.
4. Remove the stopper and add the contents of one pillow of Dissolved Oxygen 3 Reagent Powder. Carefully re-stopper and shake to mix. The floc will dissolve and a yellow color will develop if oxygen is present. This is the prepared sample.
5. Fill the plastic measuring tube level full with prepared sample and pour it into the mixing bottle.
6. While swirling the sample to mix, add PAO Titrant dropwise, counting each drop, until the sample changes from yellow to colorless. The dropper must be held in a vertical manner. Each drop is equal to 1 mg/l dissolved oxygen (DO). See Note E.

LOW RANGE (1 drop = 0.2 mg/l DO)

If the result from Step 6 is very low, such as 3 mg/l or less, it is advisable to test a larger sample to obtain a more sensitive result. This may be done by titrating directly in the DO sample bottle as follows:

1. Using the prepared sample left over from Step 4 above, pour off the contents of the DO bottle until the level just reaches the 30-ml mark on the bottle.
2. While swirling the DO bottle to mix the sample, add PAO Titrant dropwise, counting each drop, until the sample changes from yellow to colorless. Each drop of PAO Titrant added is equal to 0.2 mg/l dissolved oxygen in the sample. See Note E.

NOTES - Dissolved Oxygen

- A. It is a bit tricky to stopper the DO bottle without trapping an air bubble. To avoid this problem, incline the DO bottle slightly and insert the stopper with a quick thrust. This will force air bubbles out. However, if bubbles do become trapped in Steps 2 or 4, the sample should be discarded and the test started over.
- B. A small amount of powdered reagent may remain stuck to the bottom of the DO bottle at this point, but this will not affect the test.
- C. Do not allow the PAO Titrant to stand in direct sunlight, as it is decomposed by ultraviolet radiation.
- D. In samples that contain high concentrations of chloride, such as seawater, this floc will not settle. However, no interference is observed as long as the sample is allowed to stand in contact with the floc for 4 or 5 minutes.
- E. A more sensitive test can be performed by using Starch Indicator Solution (Cat. No. 349-13, not included in kit) while titrating the sample with PAO Titrant. To use affectively, titrate the sample until the color just begins to change from yellow-brown to light yellow. Add two drops of Starch Indicator Solution. Continue titration, counting the drops of PAO Titrant until the sample color changes from blue to colorless. The total number of drops of PAO Titrant used indicates the exact concentration of dissolved oxygen in the sample.

Hardness Test

1. Fill the plastic measuring tube level full of the water to be tested and pour it into a mixing bottle.
2. Add 3 drops of Buffer Solution, Hardness 1 and swirl to mix.
3. Add 1 or 2 drops of ManVer[®] Hardness Indicator Solution, Hardness 2.
4. Add Titrant Reagent, Hardness 3 a drop at a time, with swirling of the mixing bottle while the drops are counted, until the solution in the mixing bottle changes from pink to blue. The Titrant Reagent, Hardness 3 dropper should be held in a VERTICAL manner and the drops should be dispensed at a rate not faster than one drop per second. The dropper should be held slightly above the top of the mixing bottle so that it will never come into contact with the side of the mixing bottle. THIS IS IMPORTANT.
5. The hardness, in grams per gallon as calcium carbonate (CaCO₃), is equal to the number of drops of Titrant Reagent, Hardness 3 required to bring about the color change.

pH Test

1. Fill the two glass sample tubes to the 6-ml mark with the water sample. It is imperative that the tube be completely rinsed free of any solutions that may have been used previously.
2. Add 6 drops of Wide Range 4 pH Indicator Solution to one of the tubes and swirl to mix.
3. Insert the prepared sample in the right opening of the color comparator.
4. Insert the tube of untreated water sample in the left opening of the color comparator.
5. Hold the color comparator up to a light such as the sky, a window, or a lamp and view through the two openings in the front. Rotate the color disc until a color match is obtained. Read the pH through the scale window.

NOTE - pH

The presence of chlorine in the water sample will cause a slight interference in the test. Remove up to 50 mg/l chlorine by adding one drop of Dechlorinating Solution (Cat. No. 1069-13, not included in kit) to the water sample before addition of the pH Indicator.

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4-1 GENERAL LAY-OUT

The results of the investigations in the field (chapter 3-1) have to be compiled and different solutions have to be compared with respect to economy, technique, maintenance, running cost etc. It depends on the skill of the engineer to find an optimal lay-out. In the following a brief guideline and a few examples will be given.

4-1.1 SYSTEM OF THE WATER SUPPLY

The available water has to be compared with the actual water consumption as well as with the expected water consumption in future. The balances of water have to be determined in the water budget. In accordance to the balance of water the water source to supply the village is chosen. The system of the water scheme is decided accordingly with regard to the simplest, clearest and most appropriate lay-out. Special attention has to be given to a simple maintenance as described below.

4-1.1.1 Spring water by gravity

In this case the 'spring water' will be caught inside the ground (see chapter 4-3.4). Preference is always given to this system because it is the simplest : It supplies water of best quality, requires little maintenance, keeps running cost low and gives greatest safety. That's why it is applied no matter whether the spring is situated in a far distance or not and accordingly the cost of construction may even be higher than the cost of a water supply from a nearby stream (incl. treatment station).

In case the available spring water is sufficient only to supply part of the required quantity of water for stage 1 of the project, water will still be supplied from this spring in a first phase. During the dry season the water consumption may be restricted to drinking and cooking purposes only and washing may still have to be done in a nearby stream.

4-1.1.2 Stream water by gravity

Preference will be given to an open stream which can supply water by gravity in case there is no spring available higher than the village. Its advantages are almost the same as 4-1.1.1 . But a treatment station consisting of sedimentation basins and slow sand filters is usually required.

4-1.1.3 Spring situated below the consumers

In case there is no way to supply water by gravity (e.g. if the village is situated on the top of a hill) preference will be given to a spring which can supply water of good quality.

a) Water is collected from the source by the consumer

In order to ensure good quality of water and some storage facility a water point (see chapter 4-4) is constructed.

b) Water is brought from the source up to the consumer (see chapter 4-9)

There are different possibilities to do this. Preference will be given to natural driving energy (e.g. water power: hydraulic ram, water turbine or wind etc.).

4-1.1.4 Supply of ground water

Underground water is usually of good quality if the covering stratum is waterproof. The catchment consists of a well construction (see chapter 4-2). Except of an artesian well the ground water has to be lifted before it can be consumed. In remote areas the ground water is usually lifted either by a bucket on a chain or by a handpump, but only to the surface from where it is carried to the houses.

4-1.1.5 Stream situated below the consumers

In case of failing to get water supplied from a source as described above, this system may be applied. But this system requires skilled maintenance and the running cost will be high. That's why this system should only be applied in areas where the maintenance is assured technically and financially.

4-1.1.6 Rain water storage

In areas where no springs, streams and no ground water are existing rain water may be stored to supply drinking-water. The storage capacity has to be calculated according to a maximum length of the dry season. The minimal water consumption for drinking and cooking use only (no washing, bathing etc.) should be calculated with 10 - 15 liters per person and day.

In tropical climate the rain water whould be stored in covered cisterns (without any light) and it should be kept as cool as possible. The rain water stored for a long period needs to be treated before consumption (preferably by small slow sand filters). Such a system consists usually ot the waterproof catchment area, the seasonal storage tank, the small treatment station and a little storage tank for the daily consumption.

4-1.2 TEMPORAL LAY-OUT IN STAGES

After the system of the water supply has been decided upon, the engineer has to consider which stage the various elements of the system have to be designed for. He has to consider the actual project cost, the running cost, the expected increase of the population, their financial situation, the facility of extension and the durability ('service life') of the various elements.

4-1.2.1 Service life

Every element of a water supply can be used in good working order during a certain duration of time only. This period is called the 'service life' of this element.

The following list shows the service life of different elements of a rural water supply. These declarations are experience-data of solidly constructed elements under skilled maintenance:

<u>Element</u>	<u>expected service life</u>
spring- and stream catchment	30 - 50 years
storage tank, treatment station	
buildings (in concrete or masonry)	over 50 years
installations	10 - 20 years
under ground pipes	over 50 years
pumps, engines	10 - 20 years

4-1.2.2 Design in stages

At first the different stages are defined:

Stage 0: Actual stage, present population as base of the calculations for the future development.

Stage I: This is the moment when the village has the double population (2 x the actual population). This is equal to a yearly increase in population of 3%, within 24 years. Also the future development of industries, markets, cattle-ranges, roads, colleges, hospitals, etc. has to be taken into consideration. A common village in the rural area of the U.R.C. will reach stage I within 20 - 25 years. In a very fast growing village, a regional centre with functions of a rural centre, stage I may be reached within 15 years.

Stage II: A water supply designed for stage II is able to provide water to a population four times the actual population. This moment will be reached within 30 - 50 years.

Compare with 'specific consumption', chapter 3-2.

The different elements of a water supply for a village in the rural area are usually designed for the following stages:

<u>Element</u>	<u>Stage 0</u>	<u>Stage I</u>	<u>Stage II</u>
Catchment			
dam			x
intake		x	x
installations	x	x	
Piping system			
main pipes		x	x
distribution pipes		x	
Storage tank, treatment station			
buildings		x	x with extension facility
installations	x	x	
pumps, engines	x		

4-1.3 EXAMPLES

Before the single elements can be designed, a clear lay-out of the whole water supply has to be worked out. This base for the calculations should be included in the technical report.

Example 1

Short description of the water supply:

A rich spring situated above the village.

Actual population 2'000 persons.

Expected water consumption:

Stage 0: 2'000 persons at 30 l/day = 60 m³/day (0,7 l/s)

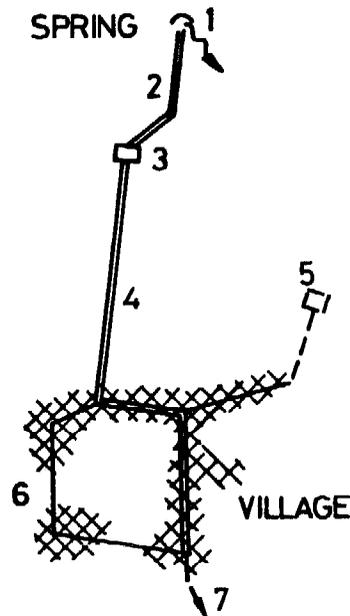
Stage I: 4'000 persons at 60 l/day = 240 m³/day (2,8 l/s)

Stage II: 8'000 persons at 80 l/day = 640 m³/day (7,4 l/s)

Water balance:

The yield of the spring is over 800 m³/day at the end of the dry season. This is enough to cover the whole consumption of the stage II.

Lay-out of the water supply:



- 1 Spring catchment with inspection chamber designed for stage II.
- 2 Pipe line calculated for stage II (q=7,4 l/s).
- 3 Interruption chamber. After stage I a storage tank has to be constructed at this site.
- 4 Main pipe. Calculated for stage I without storage tanks and for stage II with two storage tanks (q=10 l/s).
- 5 For stage II an additional storage tank is required.
- 6 Distribution pipe, calculated for stage I.
- 7 Any likely extension would have to be included into the calculations.

Example 2

Short description of the water supply:

A spring situated above the village.

Actual population 800 persons.

Expected water consumption:

Stage 0: 800 persons at 25 l/day = 20 m³/day (0,2 l/s)

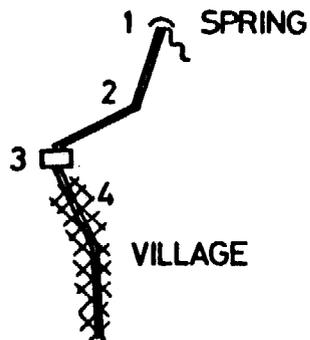
Stage I: 1'600 persons at 50 l/day = 80 m³/day (0,9 l/s)

Stage II: 3'200 persons at 70 l/day = 224 m³/day (2,6 l/s)

Water balance:

The yield of the spring is $50 \text{ m}^3/\text{day}$ at the end of the dry season and about $140 \text{ m}^3/\text{day}$ at the peak of the rainy season. During the dry season in stage I the consumption has to be limited. For stage II the yield of this spring is not sufficient.

Lay-out of the water supply:



- 1 Spring catchment with inspection chamber designed for stage I.
- 2 Transport pipe designed for stage I ($q=0,9 \text{ l/s}$).
- 3 Storage tank calculated for stage I (capacity about 40 m^3).
- 4 Supply pipe, calculated for the peak-consumption of stage I ($q = 3 \text{ l/s}$).

Example 3

Short description of the water supply:

No spring available, the stream is below the village.

Actual population 1'400 persons.

Expected water consumption:

Stage 0: 1'400 persons at $25 \text{ l/day} = 35 \text{ m}^3/\text{day}$ ($0,4 \text{ l/s}$)

Stage I: 2'800 persons at $40 \text{ l/day}^* = 112 \text{ m}^3/\text{day}$ ($1,3 \text{ l/s}$)

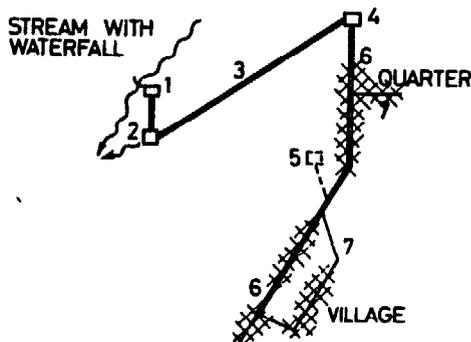
Stage II: 5'600 persons at $50 \text{ l/day}^* = 280 \text{ m}^3/\text{day}$ ($3,2 \text{ l/s}$)

(* = reduced due to high running cost)

Water balance:

The stream yields during the dry season at least 15 l/s . Therefore the consumption of stage II can be covered.

Lay-out of the water supply:



- 1 Stream catchment with a short-time-sedimentation.
dam and intake for stage II
sedimentation for stage I
After stage I this is the proposed site for a pumping station.
- 2 Driving pipe and hydro ram calculated for stage I. The driving water is not sufficient for stage II. Therefore after stage I the hydro ram has to be replaced by a pumping station at site 1.
- 3 Pressure pipe, calculated for stage I ($q = 1,3 \text{ l/s}$).

- 4 Treatment station: Sedimentation and slow sand filters designed for stage I ($q = 1,3 \text{ l/s}$) with extension facilities. Storage tank for stage I (capacity about 60 m^3).
- 5 After stage I an additional storage tank is required.
- 6 Main supply pipe, calculated for stage II.
- 7 Distribution pipe, calculated for stage I.

4-1.4 MATERIALS AND CONSTRUCTION METHODS

The materials and construction methods have to be chosen according to local availability and to the skill of local workmen (e.g. stony area but no gravel \rightarrow stone masonry, unemployment \rightarrow labour intensive method etc). The skill of local workmen has to be developed in such a way that all constructions are done in best quality in order to increase their lifetime.

Much attention has to be paid to the possible aggressivity of water in choosing the piping material as well as in designing the watertight coat in tanks etc. (see chapter 2-3 and 2-4)

4-2 WELLS

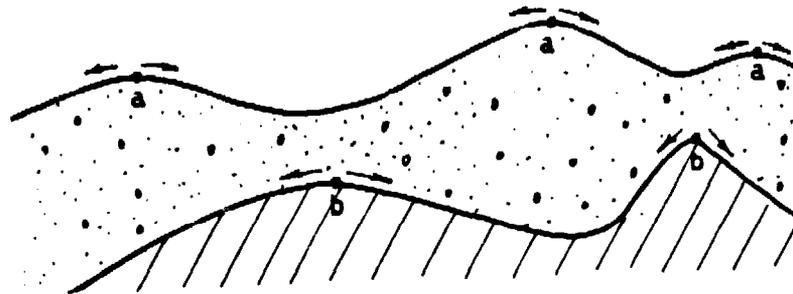
4-2.1 GENERAL

Wells make it possible to use the underground water for economical applications (e.g. water supplies, irrigation).

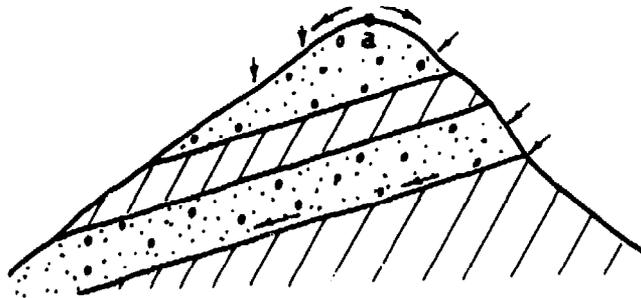
The quality of the water obtained from a well depends on:

- The thickness of the stratum which covers the water-bearing soil. This is important because of indirect contaminations for example by latrines, fertilizers etc.
- The porosity of the subsoil which influences the natural filtration process.

Fig. 23



Point a : surface watershed
Point b : subterranean watershed

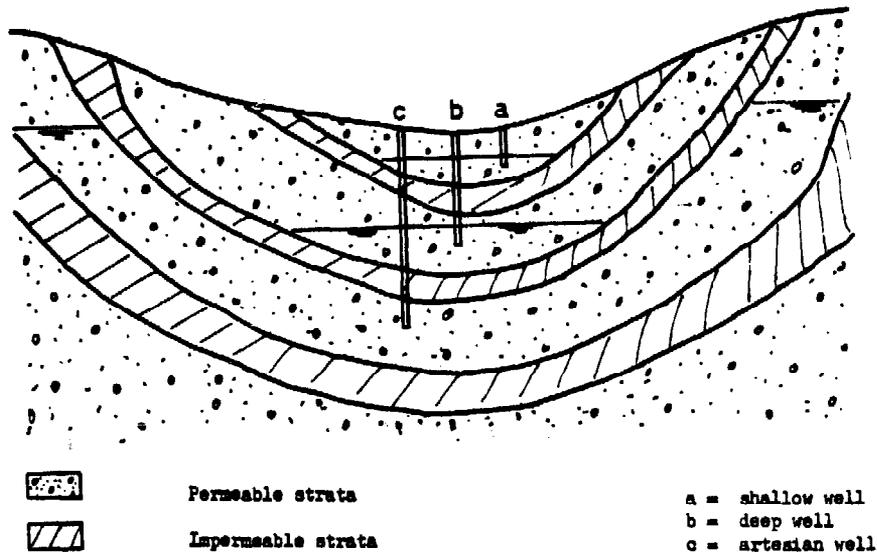


The quantity of water obtainable from a well depends on:

- The intake area: It is important to realize that the topographical basin does not necessarily correspond with the geological or hydrological drainage area. (see Fig. 23)
- The annual rainfall percolation: this depends on the nature of the intake area, e.g. kind of vegetation (forest, farm, bush)
- The perviousness of the ground: this depends on the kind of material stratification and its homogeneity.
- The storage capability of the ground: this depends on the same factors as perviousness and intake area.
- Type of well: its diameter and depth.

4-2.2 TYPES OF WELLS

Fig. 24



a) Shallow well

The shallow well draws its water from the permeable strata between surface and soil. The storage possibility in this upper permeable strata is very limited and consequently the capacity of such a well is unreliable and probably intermittent. The well is supplied by surface water which is liable to pollution (no natural filtration). A shallow well should be lined with impervious material to within a few meters of the bottom.

b) Deep well

The supply is derived from strata unaffected by surface impurities. There is at least one impervious stratum between the water-bearing stratum and the surface water (natural filtration). It is however possible for surface water from the upper strata to gain access to the well through cracks and joints in the impervious stratum. Compared to a shallow well the yield of a deep well will be much more dependable. The yield will be greatest when the well has just been opened. If the water has to pass through a porous stratum before it reaches the well the pores tend to become choked in time and the flow is considerably reduced. This does not occur with limestone or volcanic stone as the water finds its way through cracks and fissures and gradually dissolves the rocks so that the voids are increased.

c) Artesian well

These have similar characteristics to deep wells, the essential difference being that the underground water is tapped under pressure and may rise to the surface of the ground under its own head.

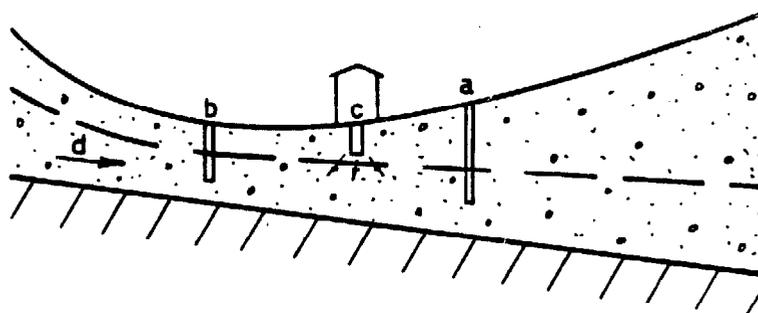
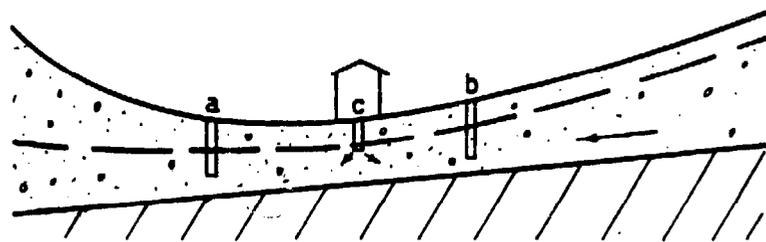
This type of well is rarely found in Cameroon.

4-2.3 SITE OF WELL

It is not always easy to determine the site of a well. Only test boreholes could give certain information, but in general in large plane areas or near the sea shore, the river or lake, we can be sure to reach a water table within a certain limit.

Choosing a good well site is one of the most important phases in well construction. The site should be also placed in a well drained ground, avoiding the vicinity of overhanging trees.

Fig. 25 Siting to prevent pollution



- a = bad site for shallow well
- b = suitable site for shallow well
- c = latrine
- d = flow direction

The site of a well should be upstream of any possible source of pollution.

4-2.4 CONSTRUCTION METHODS

4-2.4.1 Traditional

This well consist of a hole with a diameter of 80 to 120 cm. The life of such wells is short because there is no protection of the walls and the surface around the wells.

4-2.4.2 Dug wells

These wells are protected during construction by consolidating the surface. After a certain depth is reached the walls will be secured either by concrete or masonry before digging deeper.

A dug well is usually constructed with a diameter from 90 to 300cm. It can be dug to depths of about 60 to 80 m.

The site should be carefully chosen. It should be at a good distance from any possible source of contamination. Areas known to contain rock layers should be avoided if possible.

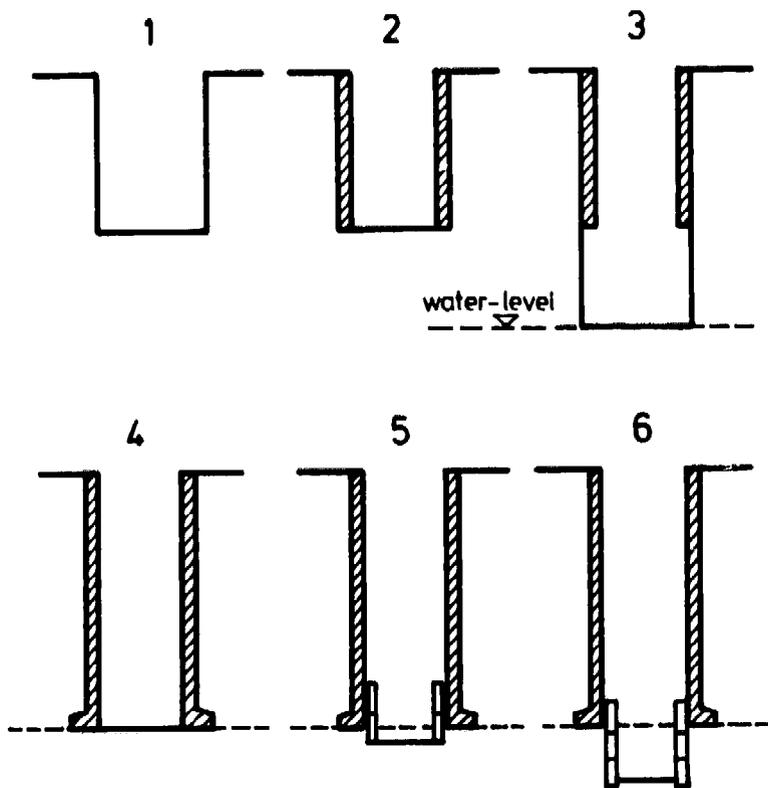
It has been found that the cost of a lined well varies in proportion to its diameter. The minimum diameter is limited by the room available for one or several men to work in. A diameter of about 90 to 100 cm is necessary for one man and 120 to 130 cm for two men. It has also been found that the efficiency of two diggers working together is more than twice that of a single man, we can then say that a diameter of 120 to 130cm is a convenient standard size.

With the exception of wells sunk into consolidated rock, a lining of permanent material is always necessary. This lining serves several purposes; it is a protection against caving in and collapses, it retains the walls after completion. It is better to build a permanent lining already during construction thus avoiding the expense of temporary supports and the danger of collapse which may occur when the temporary lining is removed. Reinforced concrete is usually employed for the lining.

a) Working method

In normal ground the shaft is sunk from ground level to the top of the water level by the method known as "alternate sinking and lining". The hole is excavated and trimmed to a diameter of 120 to 130cm and depth depending upon soil conditions. The excavation can be done as deep as it is possible without endangering the workers in the well. In any case the first meter dug should be secured properly before the digging continues; This method is applied until the water level is reached. From this depth onward the caisson ring method is adopted. The caissons have to be precast on the surface. The caissons should have a height of no more than 50cm. These caisson-rings are lowered singly into the lined well and each one is fastened to the ring below. The depth to which the caisson-rings can be lowered depends on the depth of water which can be removed by bailing. (see Fig. 26)

Fig. 26 Working method for a dug well



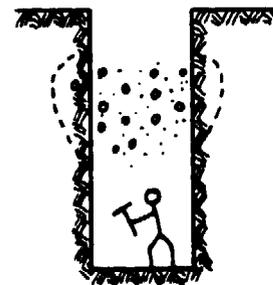
1. Digging as deep as possible, according to the soil conditions
2. Concrete lining
3. Digging as deep as possible or until the water-level is reached
4. Concrete lining
5. Lowering of caisson ring, digging continuously
6. Lowering of caisson rings, digging as deep as possible into the water. This job has to be carried out during the driest period of the year when the water table is at its lowest point.

b) Precautions during the construction

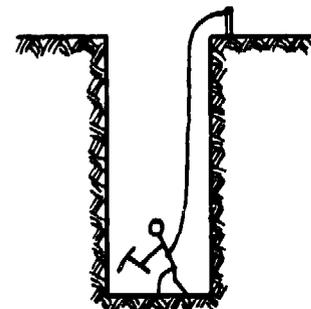
The following points are very important. They should help to prevent accidents.

Most of the accidents in a well are caused by:

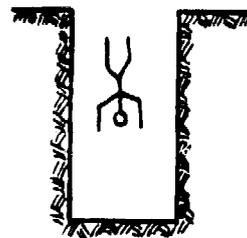
collapse of walls which are not lined properly



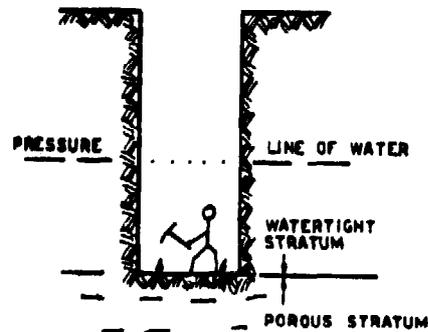
Nobody should work alone in a well. In case of an accident the workman on top should organize aid. If possible the workman who works inside the well should be secured with a rope.



Falling into the well.

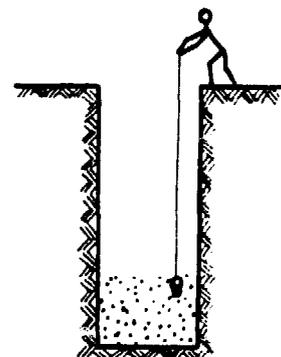


Sudden collapse of water;
danger of drowning

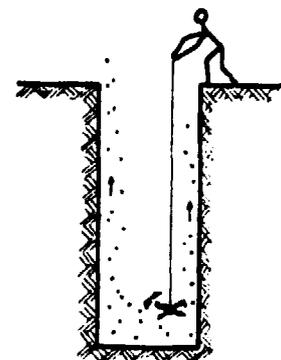


Before entering the well, make sure
that there is no accumulation of
sulfuric or carbonic gas.

Introduce a lit lamp (kerosene) into
the well. If the flame dies it means
that there is gas and danger.

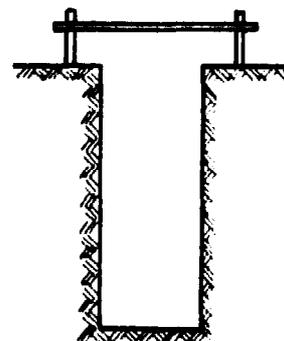


This gas can be removed either by
sending air down into the well with a
compressor or by using a bunch of
grass or paper tied to a rope as a
fan by twisting it energetically.



Never place a combustion engine
inside or near a well as the carbonic
exhaust gas being heavier than air will
fill the well and endanger the workers.

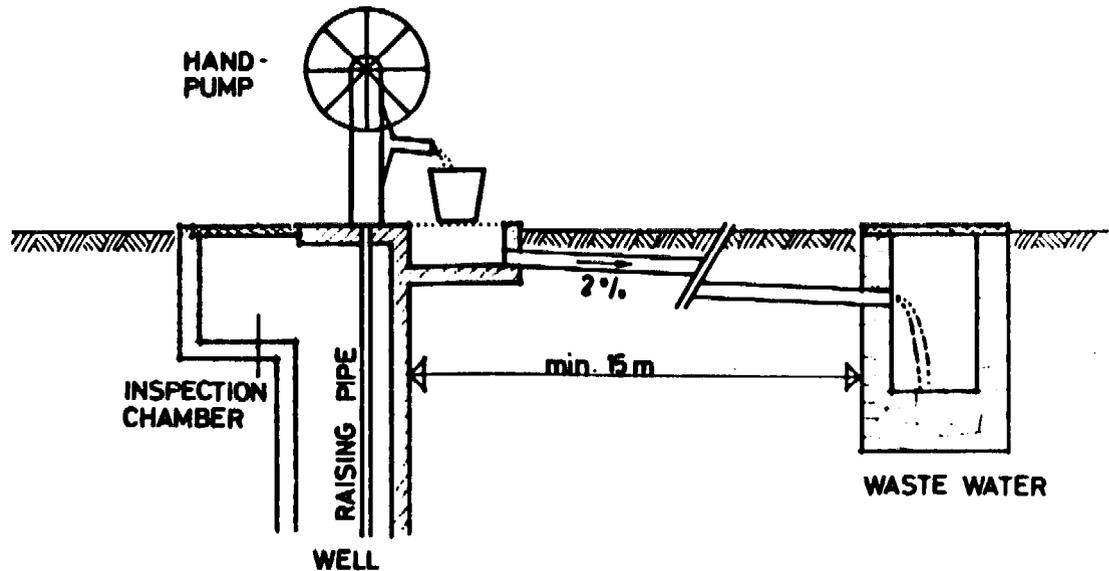
It is always advisable to construct
a protection at ground level all around
the well in order to prevent accidents.



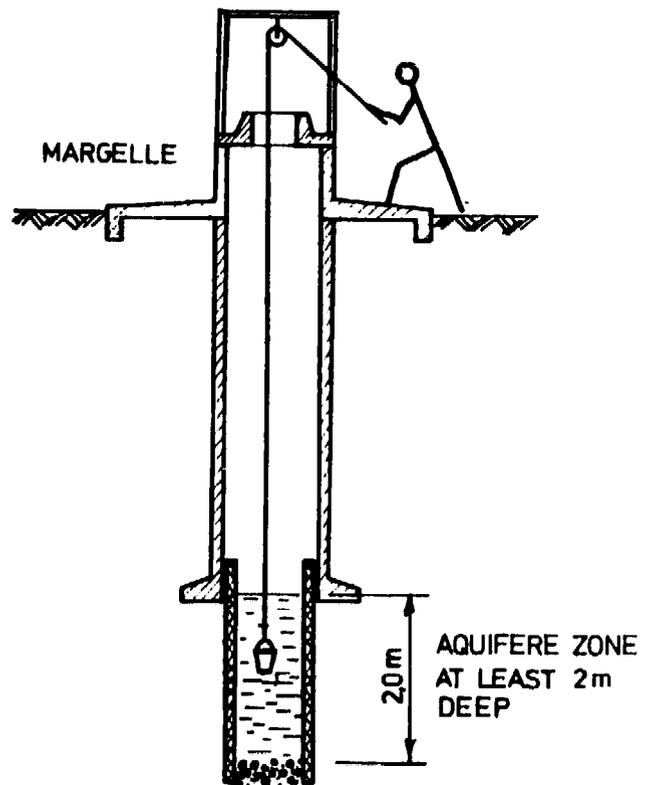
c) Superstructure

The superstructure or sealing of a well must be done very carefully. It is important to look for a good drainage for excess water; furthermore, the well should always be completely sealed except for a man hole. If possible a hand pump should be installed to avoid contamination of the water with buckets (see chapter 4-9).

Fig. 27

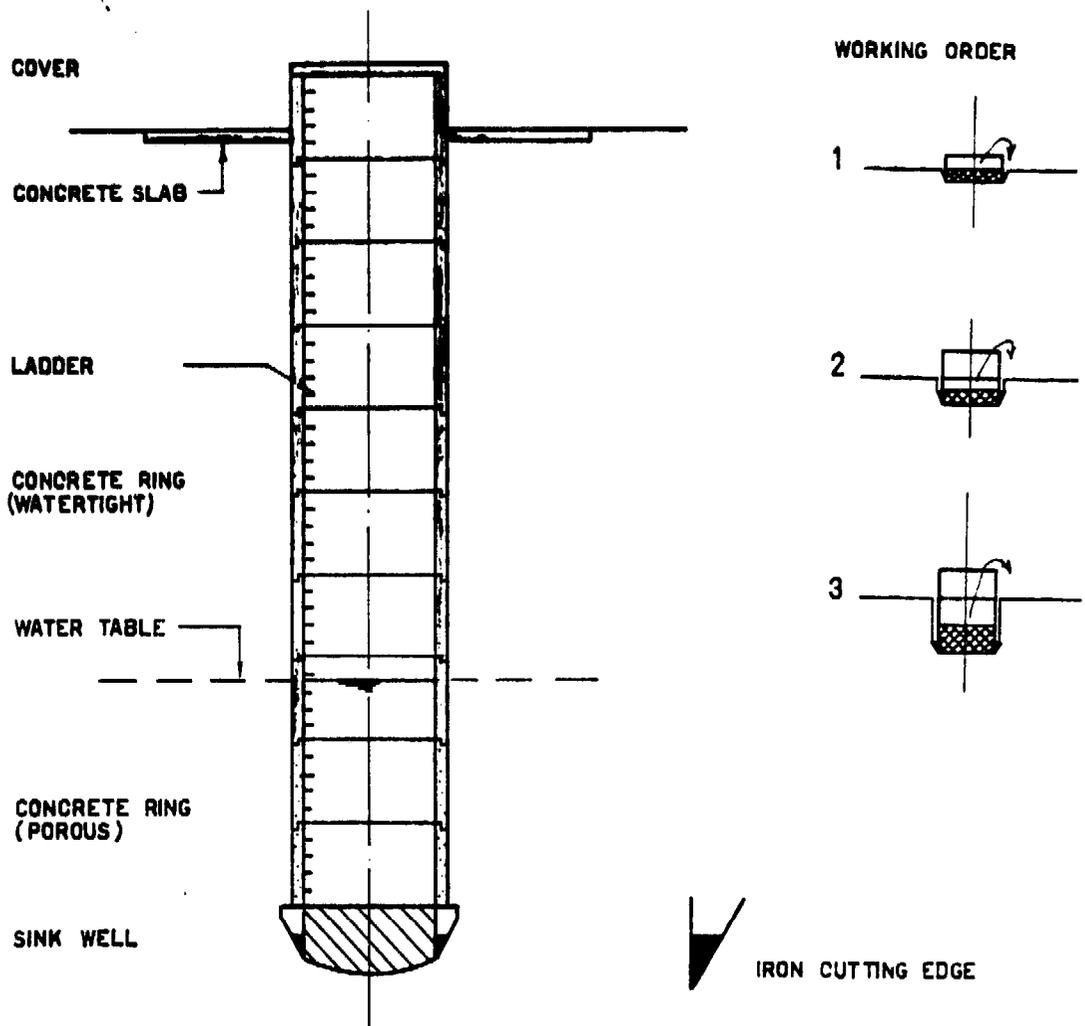


In case water should be lifted with bucket and pulley, a margelle must be built at 70 - 90 cm above ground level. A cement apron around it will keep the place free of stagnant water.



4-2.4.3 Sunk wells

These wells consist of prefabricated rings which sink through their own weight as soon as digging is done. This system cannot be applied in all types of ground. But it is very good for homogeneous ground (e.g. sand).



4-2.4.4 Sinking a tube well

In areas where the subsoil is sandy and the water table situated between 5 to 20 m deep, there is a good possibility to sink a well without using a drilling machine nor any other machine. All that is needed are a few bamboo or other wooden poles, several lengths of rope, sufficient water to fill the pipe, an iron beak (with a small hole on the side), a plastic filter of 1,20 to 2,00 m and the necessary tools and fittings for joining the pipes together.

A team of three men is sufficient for sinking a tube well of a size up to 5 cm diameter and 15 m depth. Bigger diameter and greater depth require more people.

Procedure of sinking:

Once the site of the well is chosen, dig the soil about 30 cm deep in a diameter of 2,00 meters; moisten the hole with water, install a small scaffolding and tie a pipe equipped with an iron beak at the bottom (see Fig. 28a). Move the lever in order to have a perpendicular up and down movement. The pipe will sink with these movements provided it is filled with water.

The sinking continues; the next pipe element is screwed to the first one and so on, until it reaches the water table (see Fig. 28b and 28c).

If pressure water is available and can be fixed directly to the top of the pipe, the sinking can be done much faster. The structure of the subsoil is the main factor for sinking a well. If rock or other hard soil is found a new site for the well has to be chosen.

As soon as the pipe has reached the water table it is necessary to remove it entirely by lifting it carefully (see Fig. 28d). (note that the hole created is about 15 to 25 cm diameter). This operation is needed to allow the filter to be placed at the head of the pipe instead of the iron beak. The tube well is sunk. Fine gravel or coarse sand should be placed into the space between the tube and the soil. A hang pump or motor pump can now be installed. A shallow pump (with the plunger situated above the ground) will be able to lift water from a depth of 6,50 meter maximum. For depth greater than 6,50 m a deep well pump has to be chosen and the diameter of the suction pipe must be big enough to allow the plunger cylinder to enter it.

Fig. 28a

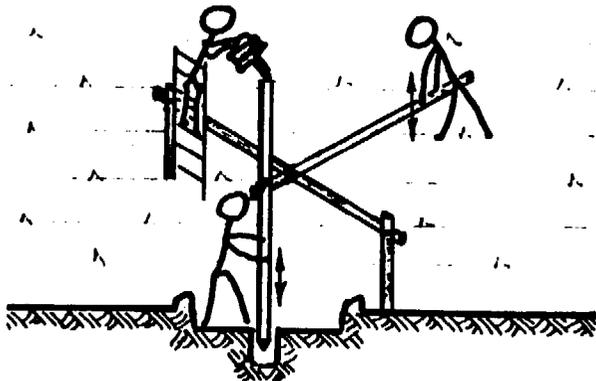


Fig. 28b

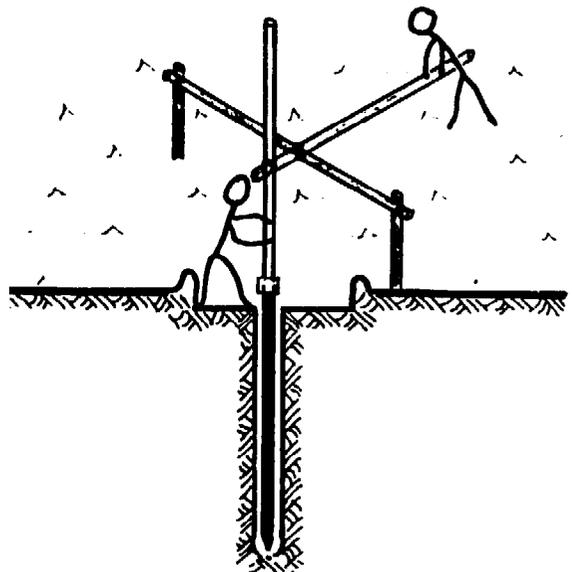
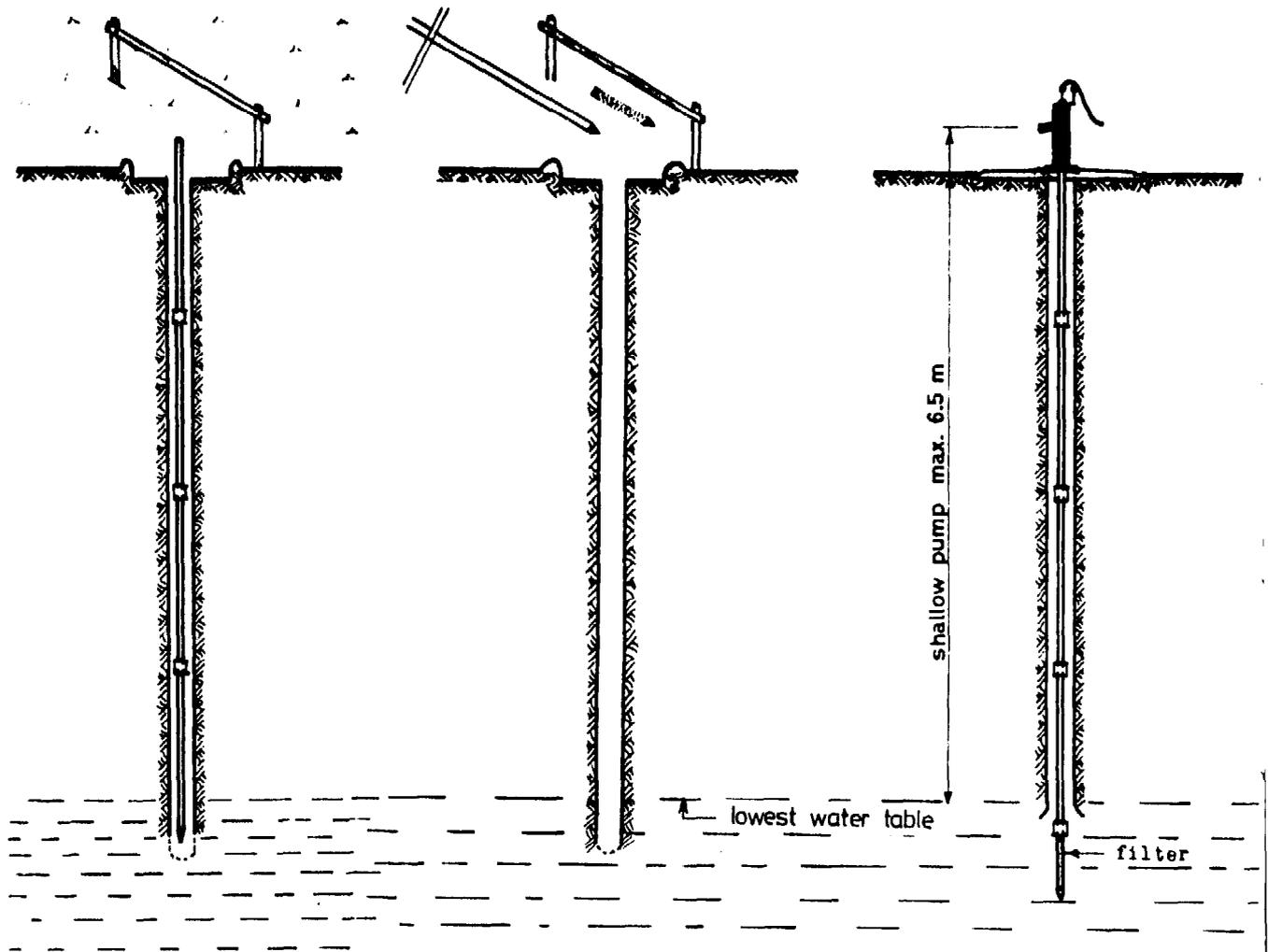


Fig. 28 c

Fig. 28 d

Fig. 28 e



General description of springs: See chapter 2-1.2 'Springs'.

4-3.1 QUALITY AND QUANTITY OF SPRING WATER

The quality of spring-water depends on factors similar to those in a continuously flowing spring:

- The thickness of the stratum which covers the water-bearing soil: this is important to prevent indirect contamination (e.g. from latrines, fertilizer).
- The perviousness influences the natural filtration process.
- The storage capability influences the water velocity. If the water velocity in the saturated stratum gets too high, the pores through which the water passes tend to become choked so that the flow becomes considerably reduced. This does not occur in limestone or in volcanic rock.

As continuous flow and quality of a spring depend on the same factors, we take the relation between

$$\frac{\text{spring capacity in the rainy season}}{\text{spring capacity in the dry season}} = 3 - 5 \text{ for good springs}$$

as a criterion for the quality and quantity which is available.

There is a time interval between maximum/minimum rainfall and maximum/minimum yield of a spring. This means that the lowest yield should not be expected at the end of the dry season but 2 to 4 months later.

The springs intended to feed a water supply should be gauged before construction starts for at least one year but better over a longer period.

The water temperature may also give some information about the quality of the spring: E.g. in the grass land zone of Cameroon an underground source of good quality shows a temperature of 18°C (if it is not in a volcanic area). Especially the way the water-temperature changes during a day informs about the quality of the spring. Spring water of good quality will show constant temperature.

A special problem in the grassland:

Raffia bushes cause the growing of ferric bacteria in supplying carbon hydrates. In connection with air the ferric bacteria develop rapidly and cause a coloration (red) and an unpleasant taste although the water is still harmless to human beings. In order to avoid this occurrence, springs should always be caught above raffia bushes.

4-3.2 LOCATION OF SPRINGS

We distinguish three zones:

Grass-land - Forest - Volcanic areas

In grass-lands, springs are mainly found in valleys and along streams inside raffia bushes.

In forest areas, springs usually appear at the bottom of valleys, but it is difficult to locate them because rich vegetation covers everything.

In volcanic areas, springs can suddenly appear and disappear almost anywhere, especially during and after eruption or earthquakes.

Geological springs normally appear

- Where the impermeable stratum reaches the surface
- Where two different kinds of subsoil meet
- Where topsoil meets rock

Tracing of springs:

Villagers and hunters, who know the area, may be most able to give information about the possible water sources.

In addition it is often necessary to follow all streams and springs to discover the rising points, where the possibility of construction of a spring catchment has to be investigated. Sometimes it may be essential to measure the change of the water quantity along the stream in order to discover possible underground side drains.

Most important is to investigate on the area above the rising point of the spring, because it may happen that an open stream sinks into the ground above the rising point and passes underground before reappearing on the surface as a spring. That is why it is also necessary to gauge the yield of the spring over the whole year. Special attention should be given to the yield of the spring and the colour of the water after heavy rains. If abrupt increase of flow or change of colour or temperature of the water is discovered, it is proved that short connection to the surface does exist and that accordingly the spring is certainly not of reliable quality.

4-3.3 CATCHMENT AREA

The catchment area includes the area which is situated above the catchment and may drain into it. This area has to be established as protective zone. The radius of the protective zone from the catchment depends on the depth of the spring catchment and the nature of the covering stratum. The radius should be the bigger the shallower the spring catchment is and the more permeable the covering stratum is, but at least 50 m.

Within this area strictly no farming, no domestic animal grazing, no fish ponds, no rubbish pits (oil), no stables or houses, etc. are allowed. Existing streams and drains situated in the catchment area have to be made water-tight. In case of danger that surface water may enter the spring catchment or may cause erosion, it has to be drained off.

To have a good control over the protective area it is advisable to plant grass within a radius of 10 m and keep it cut short. Outside of this radius the protective area should be afforested. Attention has to be given to the fact that some trees like Eucalyptus suck much water and are, therefore, not useful in this zone. Suitable trees are for instance Cypress or Pine trees. It is also advisable to fence the area with barbed wire. In areas with long dry seasons attention has to be given to protect the afforested area from bushfires.

In an extended protective area (water intake area above the spring: Radius 100 to 200m) there should be no petrol-stations or workshops where waste mineral oil or petrol are thrown away. Also no fertilizer should be used within this area. It is advisable to afforest the extended protective area too.

4-3.4 SPRING CATCHMENT

4-3.4.1 General

A spring catchment has to be constructed in a simple and practical way. It depends on the topographical situation, the structure of the ground and the type of source.

No attempt should be made to change the spring's natural flow rate. If there is any obstruction the spring can get dirty or the water will try to find another route.

The installation has to be carefully built to avoid the possibility of water pollution by accident or negligence or even on purpose.

The depth and the construction of the catchment depend on geological and hygienic consideration as well as on material covering the water-bearing soil. The spring catchment should be covered at least by 3 m. If it is not possible to cover it properly, it is necessary to make special protective arrangements. If possible the catchment should be built right up to the impermeable strata. Blasting near springs should be avoided. The free flow of the water must be guaranteed during the construction.

There are three main parts in a spring catchment:

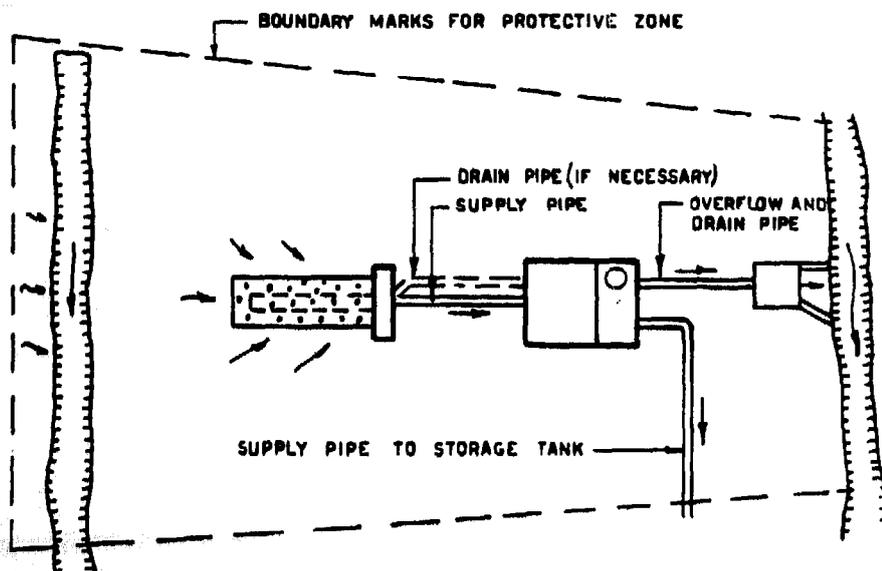
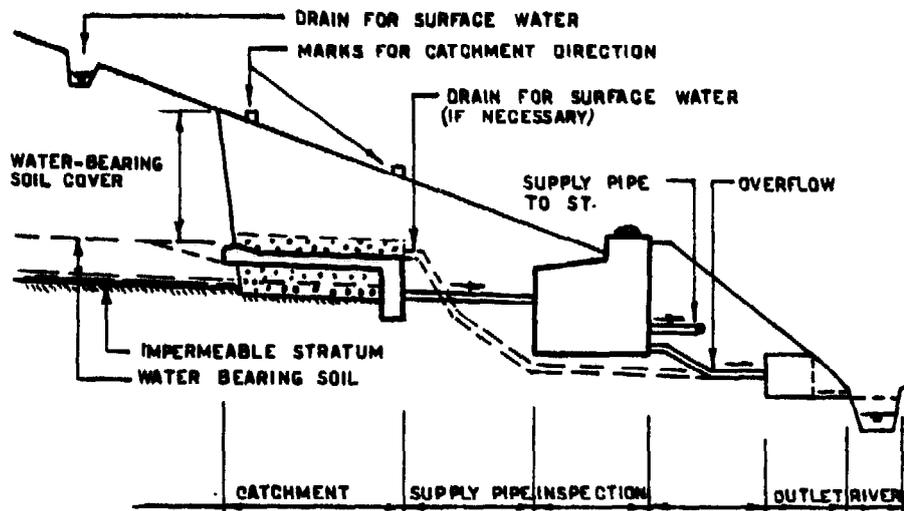
- The actual catchment (perforated pipes or a channel built with dry walls)
- The supply pipe to the inspection chamber
- The inspection chamber (not to be confused with the storage tank)

The inspection chamber has two parts:

an entrance basin for the water and
an operation chamber for the appropriate installation

The purpose of the inspection chamber is to control water quantity and quality (sometimes by sedimentation).

Fig. 29 Spring catchment - Lay-out



4-3.4.2 The actual catchment

It is important to construct the catchment most carefully because it is the heart of the water supply. In case of failure to do so, it may cause a total breakdown of the entire water supply. Moreover the catchment will not be accessible after backfilling.

Much experience is required to interpret the flow of the source underground and to design and construct the catchment accordingly.

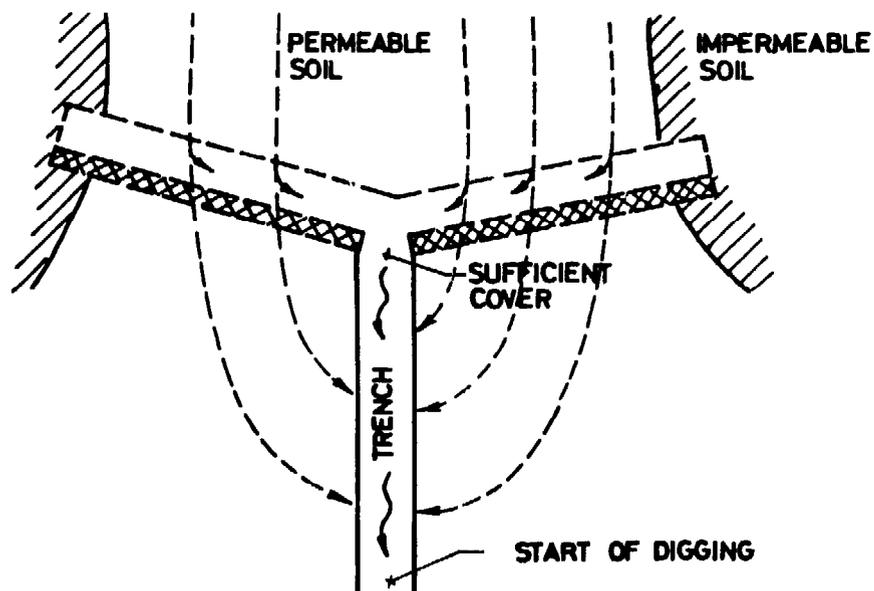
a) Excavation

Normally the digging on the source is started on the point where the water comes out of the ground. While following the flow of the source into the ground a drain has always to be kept open to ensure a free flow off. This is required to avoid any increase of pressure of the source inside the ground and hereby forcing it to find another way out which may not be controlled anymore. Moreover, this provision will enable the technician to have a clear picture of the direction of the flow of the source.

The few following examples are given as a guideline:

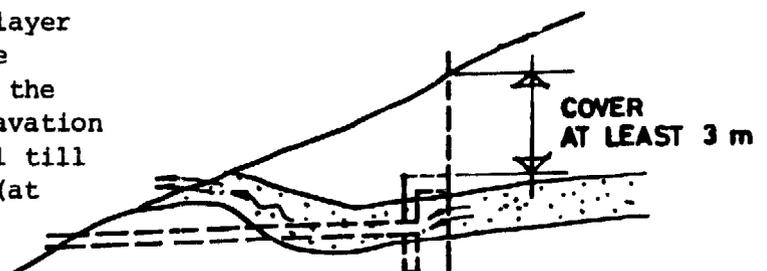
Example 1:

The amount of water coming out at the mouth of the trench decreases with digging. Therefore, water is entering on one or both sides along the trench. In this case the trench has to be split up in a V or T shape to the two sides as soon as the cover on the mouth of the trench is big enough. In this way the bypassing water may be caught behind the dam with sufficient cover.



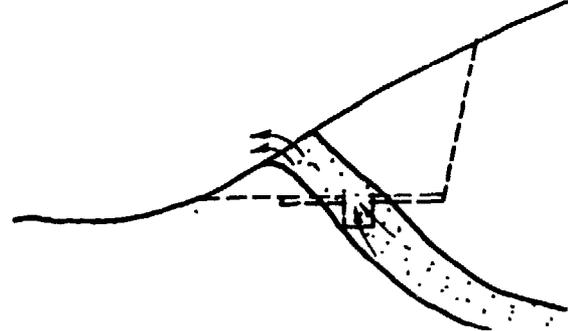
Example 2:

Spring water is coming up from the ground. The drain has to be dug down till the horizontal layer is discovered out of which the water is originating. In case the cover is insufficient the excavation has to follow the source level till the cover becomes sufficient (at least 3m).



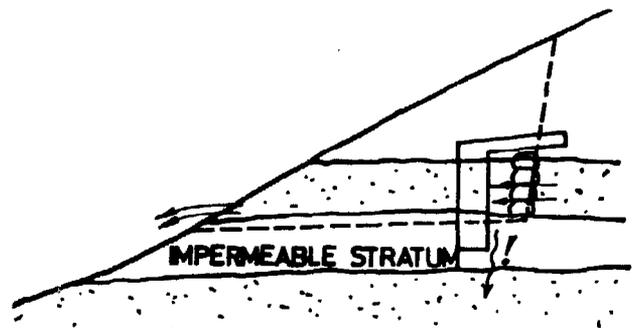
Example 3:

In case the drain cannot be dug as deep as the horizontal layer the construction has to be done like for an artesian well.



Example 4:

Much care has to be taken during excavation not to cut through the impermeable layer on which the source is running. Otherwise the source water may penetrate into the permeable stratum below. Therefore the foundation of the dam has to be cast into the excavation directly against the ground, before the dam is built in masonry or concrete.



Example 5:

The distance between the catchment and any tree should be large enough to be sure that no roots can enter the catchment.

b) Building

Once the excavation is completed the building work can be started. There are two parts: A permeable construction into which the water enters and a barrage which has to avoid the bypassing of water.

- The permeable construction consists usually of a drain in dry stone masonry or perforated pipes. The cross section of this catchment drain should be sufficiently large to ensure the maximum out-flow without any obstruction to the natural spring flow. The drain has to be sloped 1 to 2%. In case of firm ground no flooring is done. But in case of sandy ground a dry pavement has to be foreseen. The speed of water should be limited by providing additional catchment drains, because the speed increases the drag force of the water.

Around the drains a filter will be built with gravel. The minimum diameter of the gravel has to be in relation to the holes of the perforated pipes or the spaces in the dry wall. To avoid any contamination never walk on this gravel.

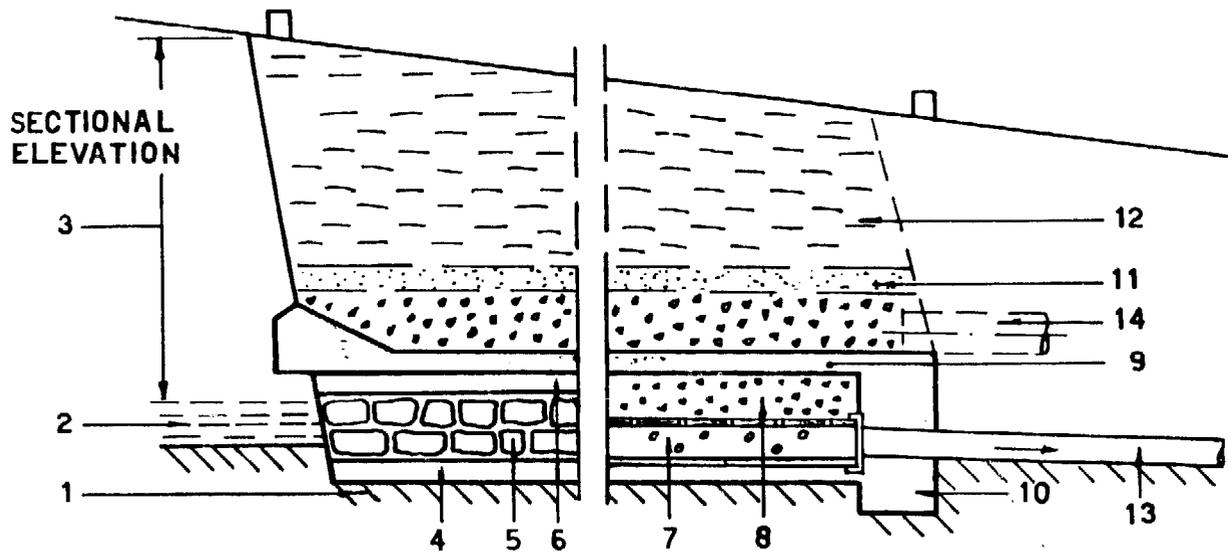
A water tight cover of 5 to 10cm concrete has to be placed on the top of the drains and the gravel. This cover needs to be extended on all sides 20cm into the walls. Surface water reaching this cover needs to be drained off.

- The barrage is constructed on the opposite side of the point where the water is entering into the catchment. It guides the water to enter the supply pipe leading to the inspection chamber. The barrage has to be built into the impermeable stratum as well as into both side walls to prevent the water from bypassing. The foundation of the barrage (dam) is cast into the excavation directly against the ground in order to get a tight connection to the ground. The barrage is constructed on top of the foundation, either in concrete or

stone masonry. The height of the dam should only be to the height of the water-tight cover which is on top of the drainage.

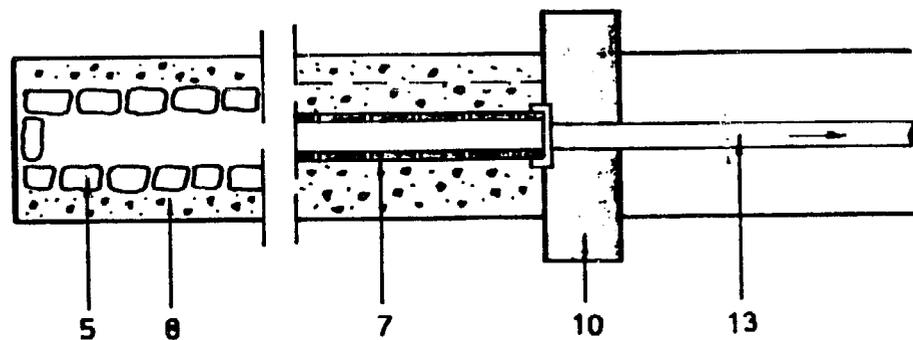
Compare with figures 30 and 31

Fig. 30 Spring catchment in line

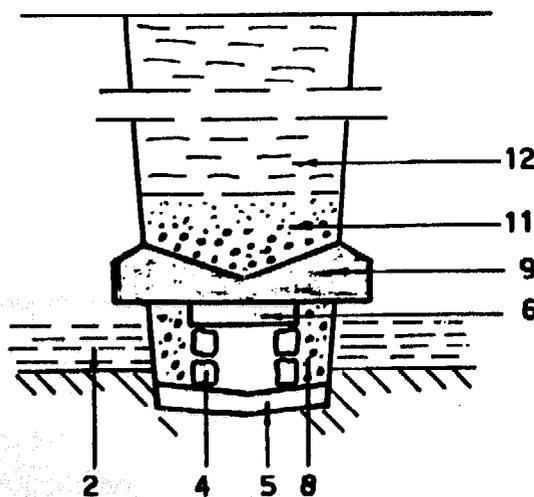


- | | |
|-------------------------------|----------------------------|
| 1 IMPERMEABLE STRATA | 8 GRAVEL |
| 2 WATER-BEARING SOIL | 9 WATER-TIGHT COVER |
| 3 COVER OF WATER BEARING SOIL | 10 DAM |
| 4 BED PLATE 1-2 % | 11 PERMEABLE MATERIAL |
| 5 DRY WALL | 12 IMPERMEABLE BACKFILLING |
| 6 SLABS | 13 SUPPLY PIPE 2 % |
| 7 PERFORATED PIPE | 14 DRAIN FOR SURFACE WATER |

PLAN



CROSS-SECTION TYPE 1



CROSS-SECTION TYPE 2

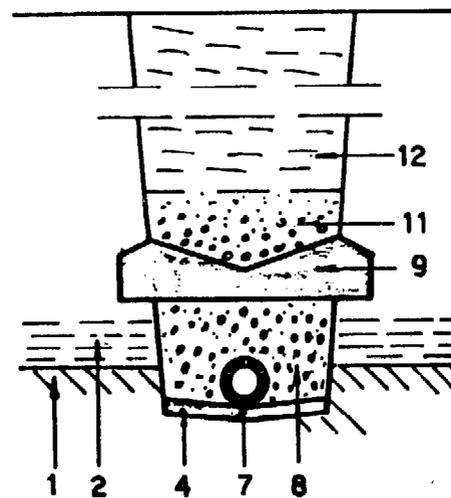
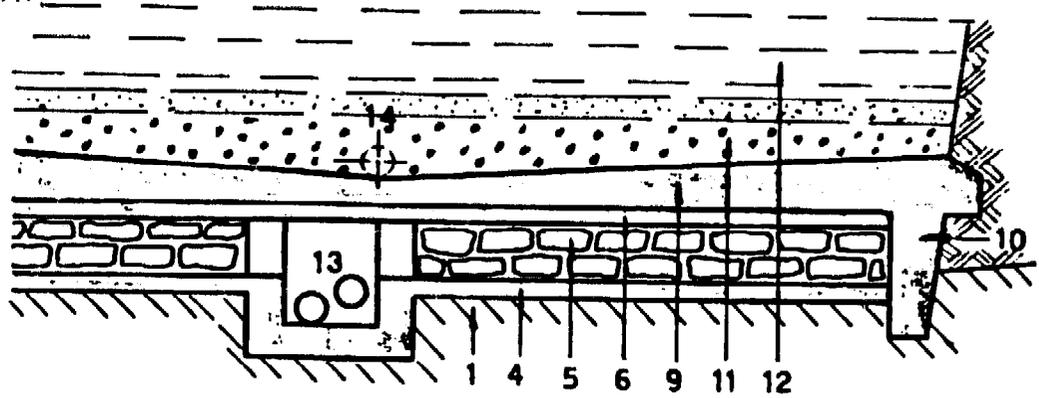


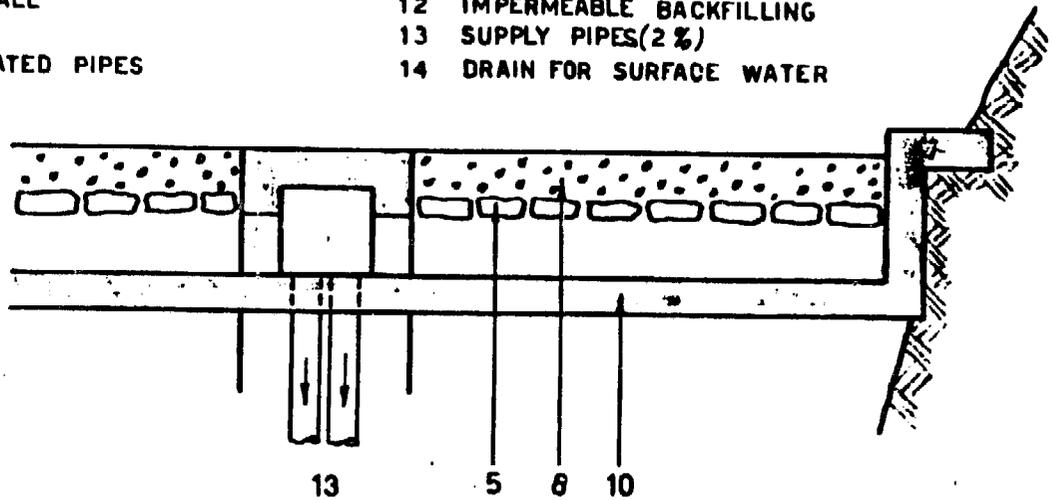
Fig. 31 Spring catchment in shape of a T

SECTIONAL ELEVATION

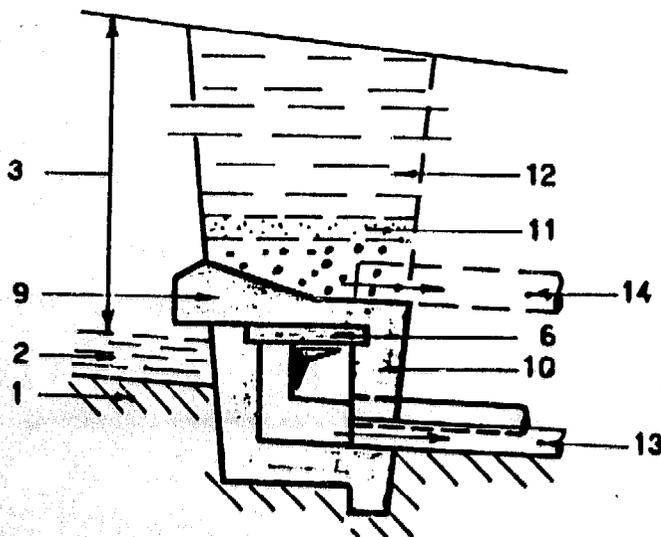


- | | |
|-------------------------------|----------------------------|
| 1 IMPERMEABLE STRATA | 8 GRAVEL |
| 2 WATER-BEARING SOIL | 9 WATERTIGHT COVER |
| 3 COVER OF WATER-BEARING SOIL | 10 DAM |
| 4 BED PLATE (1-2%) | 11 PERMEABLE MATERIAL |
| 5 DRY WALL | 12 IMPERMEABLE BACKFILLING |
| 6 SLABS | 13 SUPPLY PIPES(2%) |
| 7 PERFORATED PIPES | 14 DRAIN FOR SURFACE WATER |

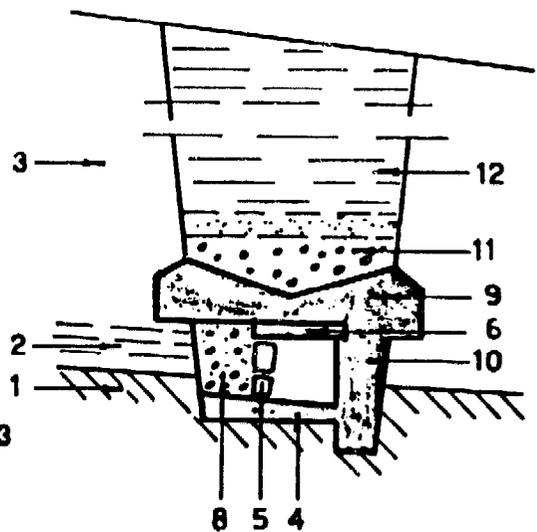
PLAN



CROSS-SECTION COLLECTION CHAMBER



CROSS - SECTION



4-3.4.3 Supply pipe to the inspection chamber

The piping material has to be resistant to aggressive water. The pipe should slope at least 2%. The diameter of the pipe has to be according to the maximum yield of the source, but at least 80mm. It is advisable to install one additional pipe in reserve. This extra pipe should be installed a bit higher than the first one, so that the caretaker knows when the first pipe is not working that a failure has occurred which he has to follow up. The installation of an extra pipe is necessary because once the catchment is blocked, the source will build up pressure behind the catchment and force another outlet. This may cause an unrepairable failure because the source may disappear completely.

4-3.4.4 Inspection chamber

Every catchment should be equipped with an inspection chamber to allow easy access to the spring. The chamber should not be too small to ensure sufficient room for all the installation works.

It may be necessary to calculate the inspection chamber as a small sedimentation chamber with a retention time of 10 minutes.

The building has to be water-tight inside and outside. Corners and edges have to be rounded. Each chamber should be ventilated, if possible in combination with a drain-pipe or an entrance. Ventilators and manholes should not be directly above the water, they should rather be placed in the operation room. Entrances or manholes should be 50 cm above ground-level with door-steps at 25 cm. Manhole covers should be locked to prevent unauthorized persons from opening them. It is advisable to cover the chamber (incl. entrance) and all openings (incl. overflow and doors) so as to prevent any possibility of pollution and the entering of small animals into the chamber.

Each spring catchment needs its own entrance basin, from where the water flows into a collection basin. If necessary it should be possible to cut off a single spring from the supply.

The inlet must be 20 cm above the highest possible water level. It is important that each basin can be drained. There should be no obstruction to the water flow caused by placing the inspection chamber too high in relation to the spring.

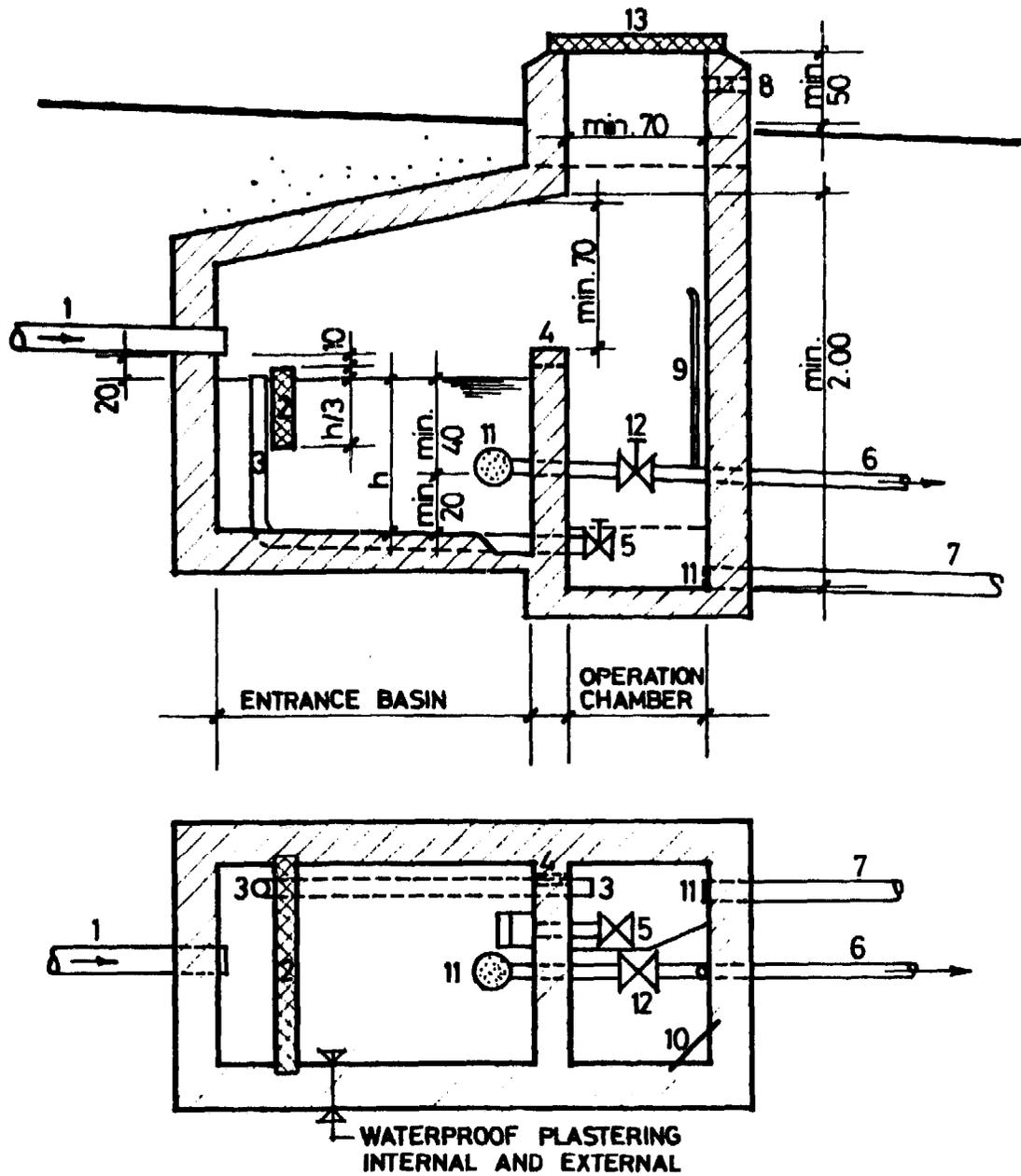
The dimensions of overflows and drains have to be capable of draining off the maximum spring capacity without restricting spring flow.

Note: For hygienic reasons, it is important that timber is not used as a building material and that no timber is left in the catchment or inspection chamber (the timber gets rotten and will become a breeding place for insects).

Stone masonry and concrete seem to be the most suitable and long-lasting building materials for spring catchments. Buildings in stone masonry may require an outside plastering coat in a swampy area. The chemical behaviour of the water and the ground influences the building material (see chapters 2-3 and 2-4).

See figures 32 and 33

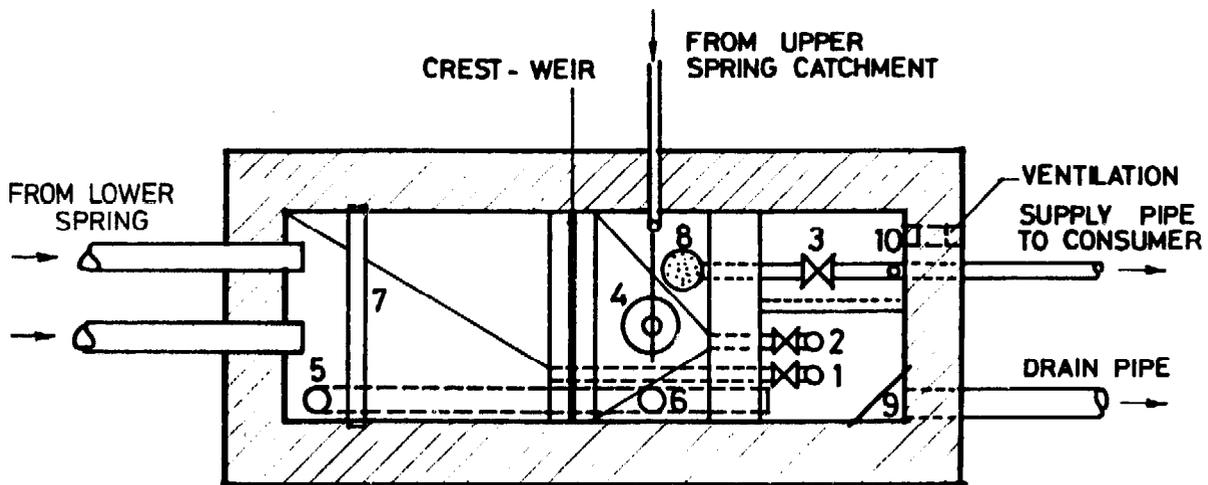
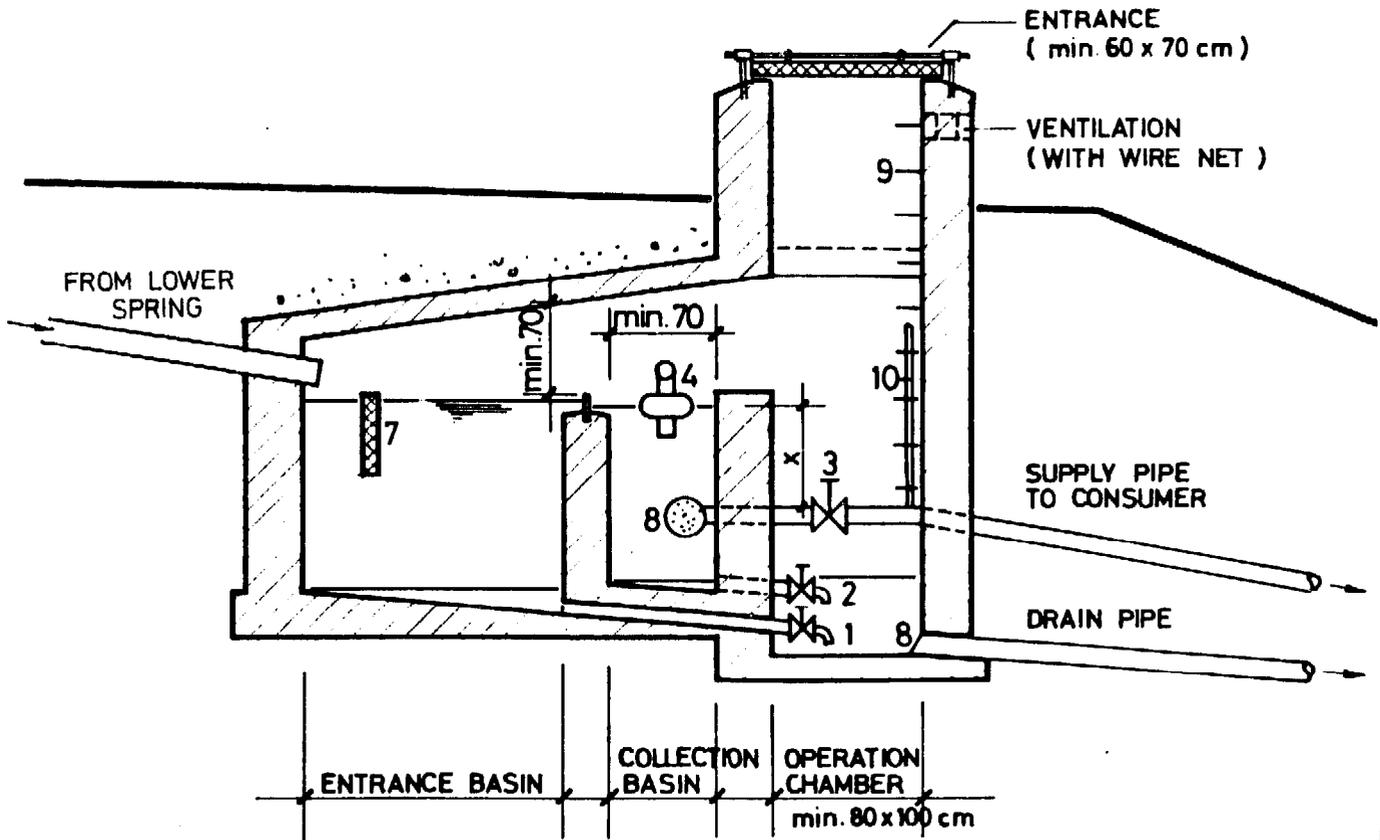
Fig. 32 Inspection chamber



- 1 Pipe from the spring catchment
- 2 Baffle plate
- 3 Overflow pipe
- 4 Overflow edge
- 5 Cleaning pipe
- 6 Supply pipe to consumer
- 7 Drain pipe
- 8 Ventilation (with wire net)
- 9 Aeration pipe
- 10 Climbing iron
- 11 Strainer
- 12 Main valve
- 13 Entrance (Min 60 x 70 cm)

Fig. 33 Inspection and collection chamber

(Incl. connection of an upper catchment which has already an inspection chamber. An additional overflow may be foreseen in the entrance in case of much overflow expected from lower source in order to get sufficient retention time in the entrance basin.)



- | | |
|----------------------------------|------------------|
| 1 cleaning pipe entrance basin | 7 baffle plate |
| 2 cleaning pipe collection basin | 8 strainer |
| 3 main valve | 9 climbing iron |
| 4 ball-valve for upper source | 10 aeration pipe |
| 5 overflow entrance basin | |
| 6 overflow collection basin | |

x = operating height of the ball-valve + 30 cm

4-3.4.5 Outlet buildings

The outlet building has to prevent animals to enter the inspection chamber.

Fig. 34 Simple outlet

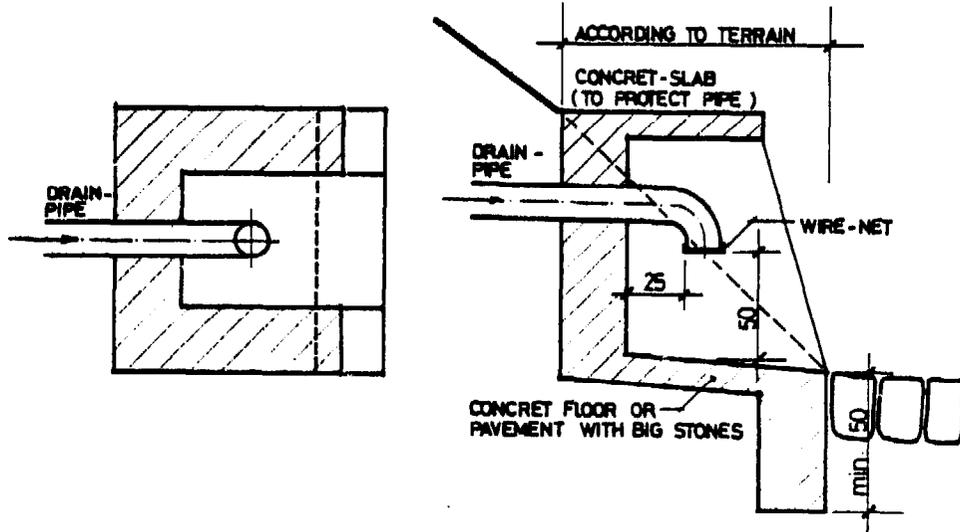
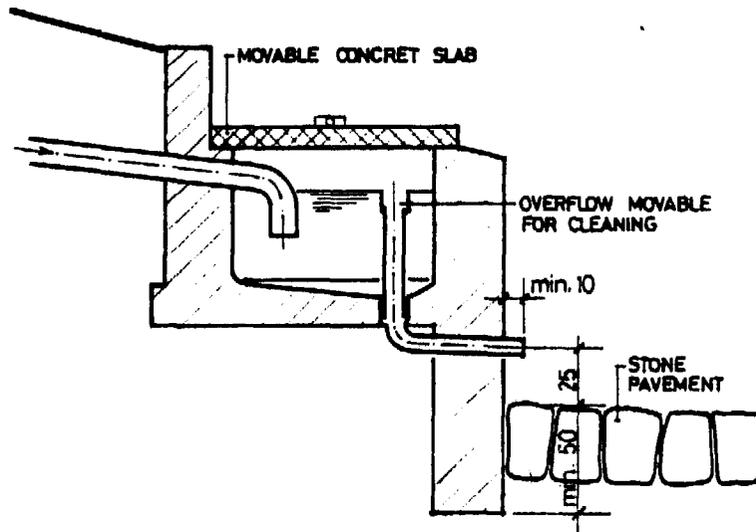
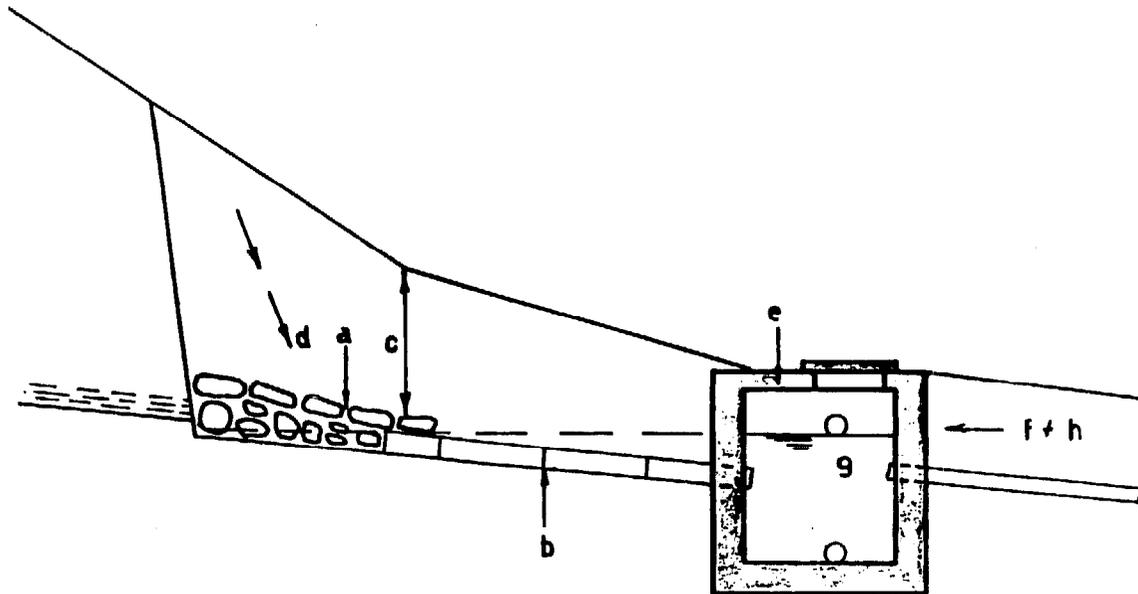


Fig. 35 Siphon outlet



4-3.4.6 Common mistakes on spring catchments

Fig. 36



- a) permeable cover
- b) leakage from pipe joints
- c) covering over the spring is inadequate
- d) no surface water drainage
- e) chamber cover should be above ground level
- f) position of overflow too high
- g) position of outlet too high
- h) no wire-mesh covering the overflow

surface water can pollute the spring water

obstruction to spring flow
animals or dirt can pollute the spring water

4.4 WATER POINT

4-4.1 GENERAL

Water points can be built anywhere if there is a small spring with a supply of minimum one l/min. during the dry season and the possibility to get at least 1 m difference in height from the catchment to the drainage of the storage chamber.

The construction of a water point gives two main advantages:

- improvement of the quality of the water
- storage of water during the night for use in the day-time

If the spring supplies more than 15 l/min. in the dry season there is no need for a storage chamber. A wash-basin into which the water enters directly from the catchment can be built instead.

If the spring delivers less than 3 l/min. during part of the year only a storage tank should be built, since a basin would never be filled, not even during the night.

4-4.2 CONSTRUCTION OF A WATER POINT

The water point itself normally consists of a storage chamber and a wash-basin. Attention has to be given to provide a good foundation, especially in swampy areas and on hill sides.

A proper drainage for all overflowing and used wash water has to be installed. The design should be such that all water runs to a certain point, from where a drainage trench with a good slope will lead it quickly to a nearby natural gutter.

A storage tank should be built if the spring gives less than 15 l/min. in the dry season. Usually a wash-basin is connected to the storage tank if the spring flow is above 3 l/min. minimum, below 3 l/min. minimum. The water should be limited for drinking purposes only.

See figures 37 and 38.

Fig. 37 Small water point

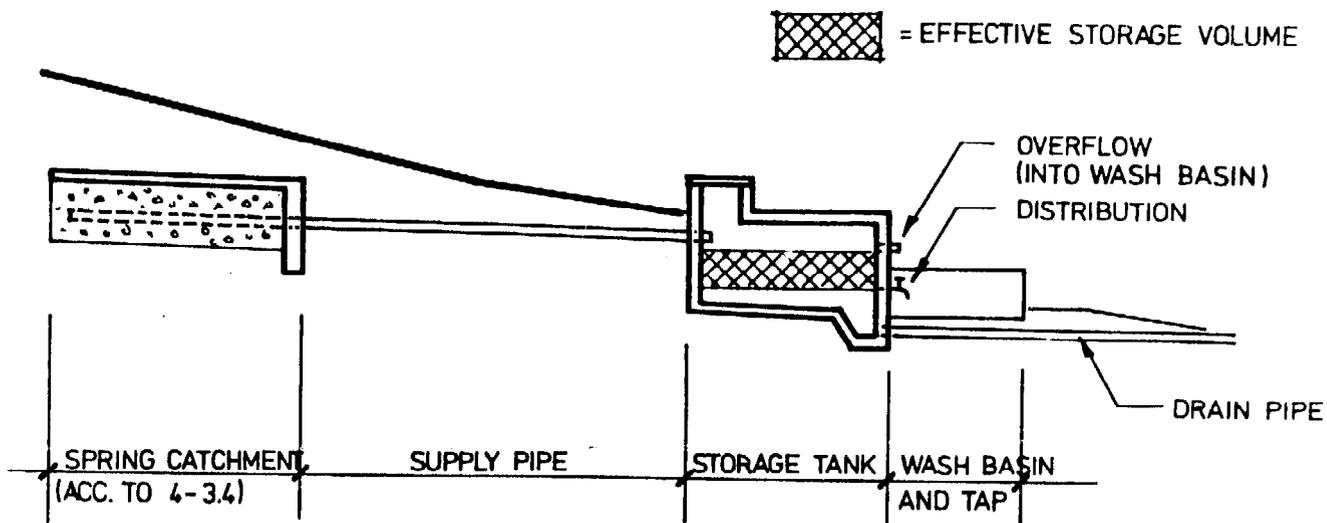
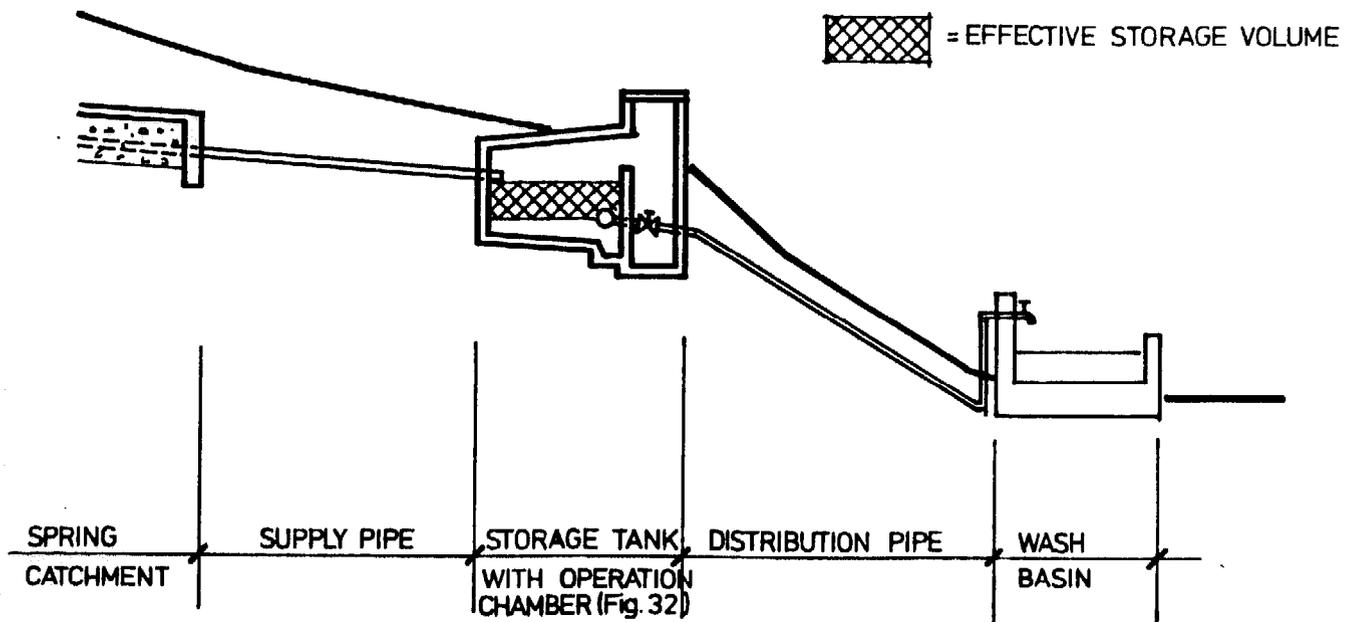


Fig. 38 Large water point



4-5 BARRAGE AND RIVER INTAKE

In the construction of a barrage its size, height and foundations are determined by the stream, its bed and its embankments.

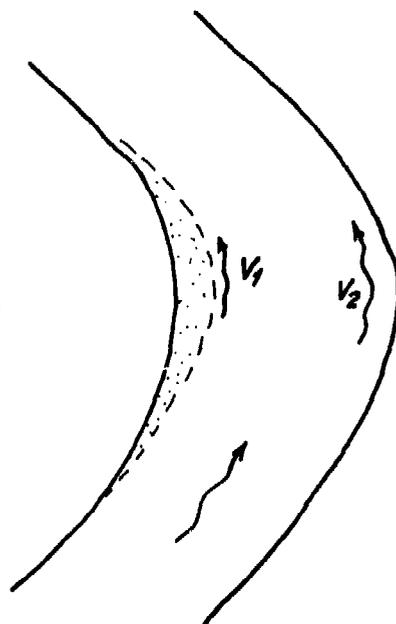
For our purposes the barrage does not retain water for storage and later consumption (dry season, weekly variations), but is only built to assure the supply. It should be perpendicular to the streambed. Special attention is needed for the foundation to guard against:

- seepage
- washouts, leakages
- extensions of the wing-walls
- erosion of the river bed

4-5.1 DETERMINING MAGNITUDES FOR THE POSITION OF THE BARRAGE

- a) above consumer
- b) above populated areas (if necessary resettlement before the construction work starts)
- c) above farming areas, if not possible farming must be stopped along the stream
- d) no cutting of trees in the catchment area, afforestation at least 100 m to each side of the stream and on a length of 500 m to 1000 m
- e) no watering place for cattle above the barrage
- f) no laundry and no washing of cars above the barrage
- g) good soil-bearing capacity
- h) perpendicular to the stream bed
- i) narrow stream bed which allows high speed to avoid standing water behind the barrage and settlement
- k) in stream bends the intake should always be at the outside of the bend

$V_1 =$ low speed
deposits of sand,
dirt, leaves etc.



$V_2 =$ high speed
no or little
settlements

4-5.2 DESIGN OF BARRAGES

The cross section of the barrage must be constructed in a way that the overflowing water never separates from the barrage-surface because this would cause heavy erosion on the foot of the barrage. (see Fig. 39 and 40)

The overflow area (A_b) has to be equal to the river cross section (A_r) by high water or it will be calculated from the flow measurements.



Any standing water behind the barrage must be avoided. The speed of the water before the barrage, in the spillway and along the sidegate should be as high as possible.

Fig. 39 Cross section of a construction in concrete

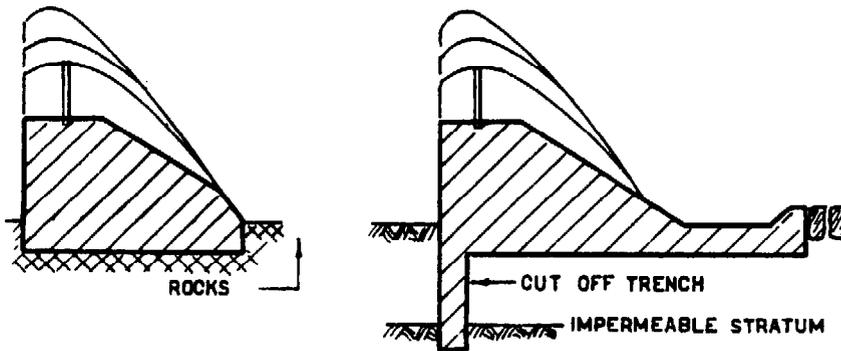
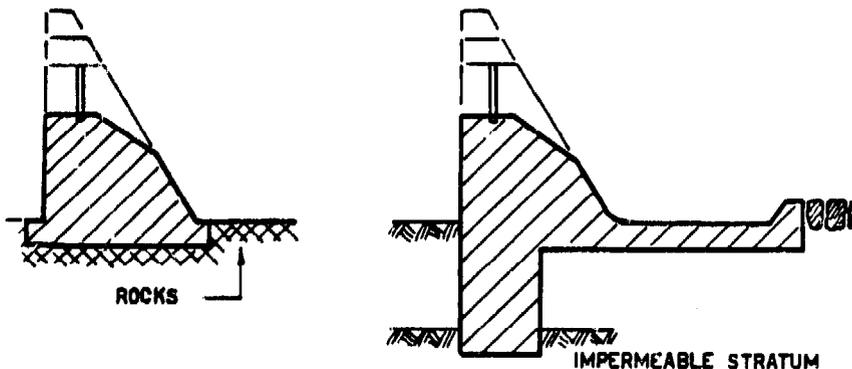


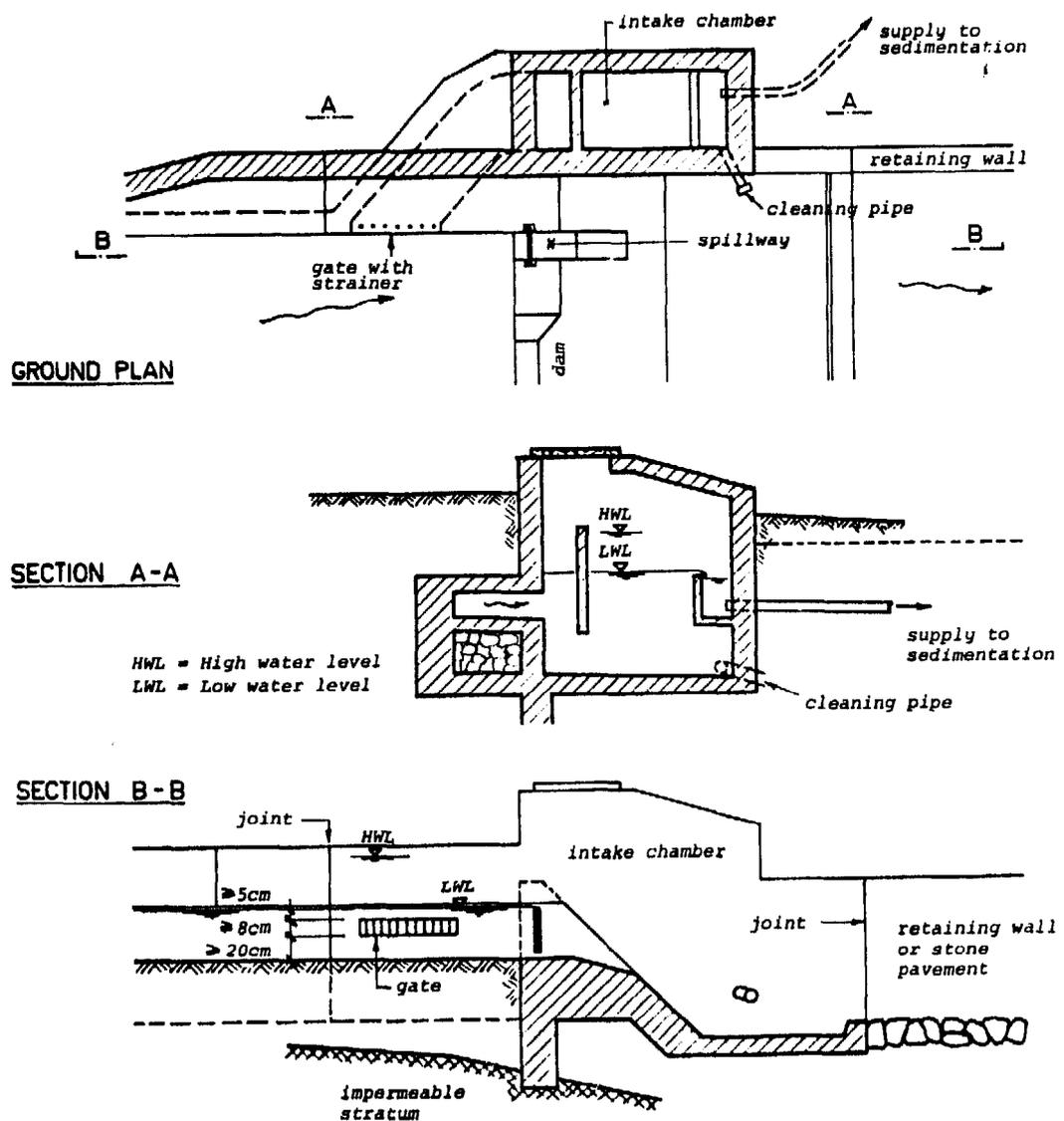
Fig. 40 Cross section of a construction in stone masonry



4-5.3 DESIGN OF INTAKES

The most suitable type of intake under these conditions are sidegates, the entrance velocity V_{entrance} should be ≤ 0.1 m/sec, using a spillway as a cleaner and regulator. The current along the gate helps to wash away leaves, sticks and sand. The bottom of the spillway should be low enough to allow dry season water to flow past the bottom of the intake. It is useful to keep the deviation pipes which are used during construction so as to permit maintenance and repairs by lowering the water. The gate with the strainer which must be removable should be at least 5 cm, better more, below the low water-level (LWL). The gate should have a minimum height of 8 cm. (see Fig. 41)

Fig. 41 Intake Construction



4-6 WATER TREATMENT

4-6.1 GENERAL

It is obvious that rural water supplies should be designed to safeguard the quality of the natural water selected. It should always be the policy of a responsible engineer to restrict the use of water treatment under rural conditions to only those cases where such treatment is absolutely essential and where correct plant operation and maintenance can be secured and supervised. The design engineer should also vigorously oppose the use of treatment processes which the community concerned can ill-afford to procure, operate and maintain with meagre financial resources. This explains in part why a careful study, based on engineering and economic analysis may have to be made to compare, in doubtful situations, the relative merits of water treatment against those of long pipelines bringing untreated water from distant springs, wells, etc. Experience shows that whenever possible it is wise to make a large investment in order to eliminate operational and maintenance problems.

(partly from "Water Supplies for Rural Areas and Small Communities" WHO)

Furthermore, all the water supplies constructed in the Technical Section of CD/SATA-Helvetas apply to the WHO Standards of untreated water (see chapter 2-2). We consider this water quality as sufficient for any rural water supply. In a future step chlorination can be introduced easily.

Treatment stations (sedimentation and slow sand filters) are normally calculated for continuous flow over 24 hours in stage I (see 4-1.2).

4-6.2 SEDIMENTATION

4-6.2.1 General definition

Definition: Sedimentation is the removal of suspended particles heavier than water by gravitation settling.

Natural existence: In the rainy season the erosion of the land by run-off from rain-storms carries vast amounts of soil into streams and other water-courses. Some of the eroded particles are heavy enough to settle when flood waters subside, often to be picked up again and be redeposited further downstream during successive floods until eventually reaching the ocean.

Influence on water supplies: such suspended particles prevent water supplies from working continuously because they block pipes and filters, reduce the capacity of storage tanks and the water quality. Therefore, these particles have to be removed immediately after the catchment.

Methods of sedimentation:

The undesired suspended particles are removed from raw water by sedimentation in a special tank. There are three kinds of sedimentation:

- Plain sedimentation: The impurities are separated from the suspending fluid by gravitation and natural aggregation of the particles.

- Coagulation: Chemical substances are added to induce or hasten aggregation and settling of finely suspended matter, colloidal substances and large molecules.
- Chemical precipitation: Chemicals are added to precipitate dissolved impurities out of solution by changing them into insoluble substances.

Plain sedimentation would be used where water contains much suspended matter and particularly in warm climates, where higher temperatures lower the viscosity of the water permitting thus more effective sedimentation. The plain sedimentation requires less and simpler maintenance than the other methods of sedimentation. Therefore, only this method is employed by CD/SATA-Helvetas for rural water supplies in Cameroon.

All the following remarks refer to plain sedimentation.

4-6.2.2 Design of sedimentation tanks

Sedimentation tanks are designed to reduce the velocity of the water flow so as to permit suspended solids to settle out of the water by gravity.

The raw water (of rivers) contains impurities of three physical kinds:

- Particles large enough to be strained out of the water or which will settle gravitationally in still water (sedimentation)
- Particles of microscopic or colloided form which will not settle in still water and are too small to be strained out (filtration is required to remove these substances)
- Substances held completely in solution, i.e. dissolved in the water can be removed by chemical treatment only.

a) Factors affecting sedimentation efficiency:

- settling velocity
 - mass density of suspended particle
 - shape density of suspended particle
 - mass density of the fluid
 - viscosity of the fluid
- drag force
 - shape of suspended particle
 - velocity of the fluid
 - viscosity of the fluid
 - mass density of the fluid
- concentration of suspended solids in the fluid (settling hindered by wall effect)

The only factor which is altered by plain sedimentation is the fluid velocity. The smaller the size of the particles removed, the smaller is the velocity of the fluid. The reduction in flow velocity needed depends on the nature of the sediment and the required efficiency of sedimentation (e.g. gritty, granitic or volcanic sediments being heavier, need less flow velocity reduction to deposit them than fine lateritic top-soils).

The efficiency depends also on design:

- inlet and outlet have to be constructed so that short-circuiting is prevented;
- agitation of settled solids from the sludge zone has to be prevented. Hence certain relations between length and depth are needed.

The required efficiency of a sedimentation-basin will depend on the need to prevent blockage of the sand-filters (following). Further details have to be determined by observation and research on similar existing installations.

b) Calculation of the required dimensions

The dimensions of a sedimentation tank can be calculated from the surface load and the period of detention.

"Surface load" is the settling velocity of the particles in the water:

$$S_L = \frac{\text{quantity of water per h}}{\text{surface of tank}} = \frac{\text{m}^3}{\text{m}^2 \times \text{h}} = \frac{\text{m}}{\text{h}}$$

In the reverse we can calculate the necessary surface as follows:

$$S_n = \frac{\text{quantity of water per h}}{\text{surface load}} = \frac{\text{m}^3/\text{h}}{\text{m}/\text{h}} = \text{m}^2$$

The capacity or volume of the basin can be calculated with the quantity of water per hour and the period of detention:

$$V = (\text{quantity of water per h}) \times (\text{period of detention})$$

$$\frac{\text{m}^3}{\text{h}} \times \text{h} = \text{m}^3$$

The surface load and the period of detention varies widely because of the kind of material to be retained, the stage of extension considered, and the treatment added after passing the sedimentation (e.g. granitic and volcanic soils bring heavier material than lateritic top-soils so the surface load can be bigger and the period of detention shorter or vice-versa).

The figures below should only be taken as an approximate value:

- S_L = surface load max. = 0.6 m/h
 (0.6 m/h is the settling velocity of a silt grain with a diameter of 0.01 mm)
- t = periode of detention = 4 - 6 h
- d = depth of tanks 1.50 m - 2.50 m (2.50 should be the maximum)
 relation between length and depth 5:1 up to 10:1

The effect of sedimentation varies only with the surface load and not with the depth of the tank.

The smaller the surface load the better the sedimentation.

Example:

quantity of water		= 20 m ³ /h	
surface load		= 0.6 m/h	
period of detention		= 4 h	
relation between length and depth		5 : 1	
therefore:			
necessary surface S_n		= $\frac{20.0 \text{ m}^3/\text{h}}{0.6 \text{ m/h}}$	= 33.3 m ² =====
capacity V		= 20.0 m ³ /h x 4 h	= 80 m ³ =====
depth		= $\frac{80.0 \text{ m}^3}{33.3 \text{ m}^2}$	= 2.40 m
length		= 5 x 2.40 m	= 12.0 m
width		= $\frac{33.3 \text{ m}^2}{12.0 \text{ m}}$	= 2.70 m
length	= 12.00 m	width	= 2.70 m
	=====		=====
		depth	= 2.40 m
			=====

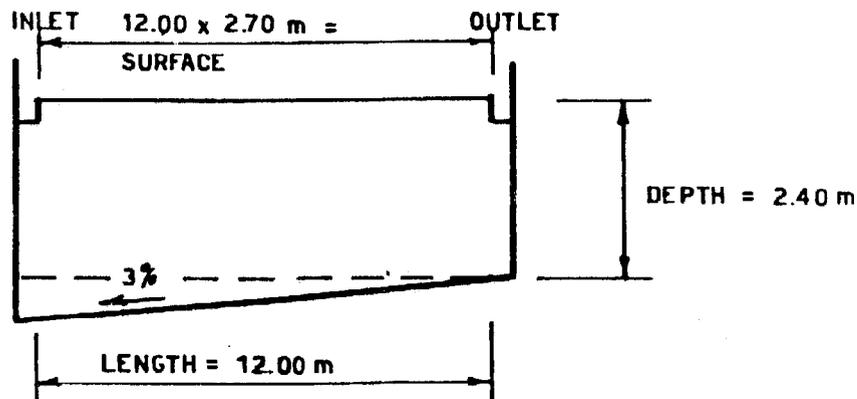


Fig. 42 Inlet: Variant 1

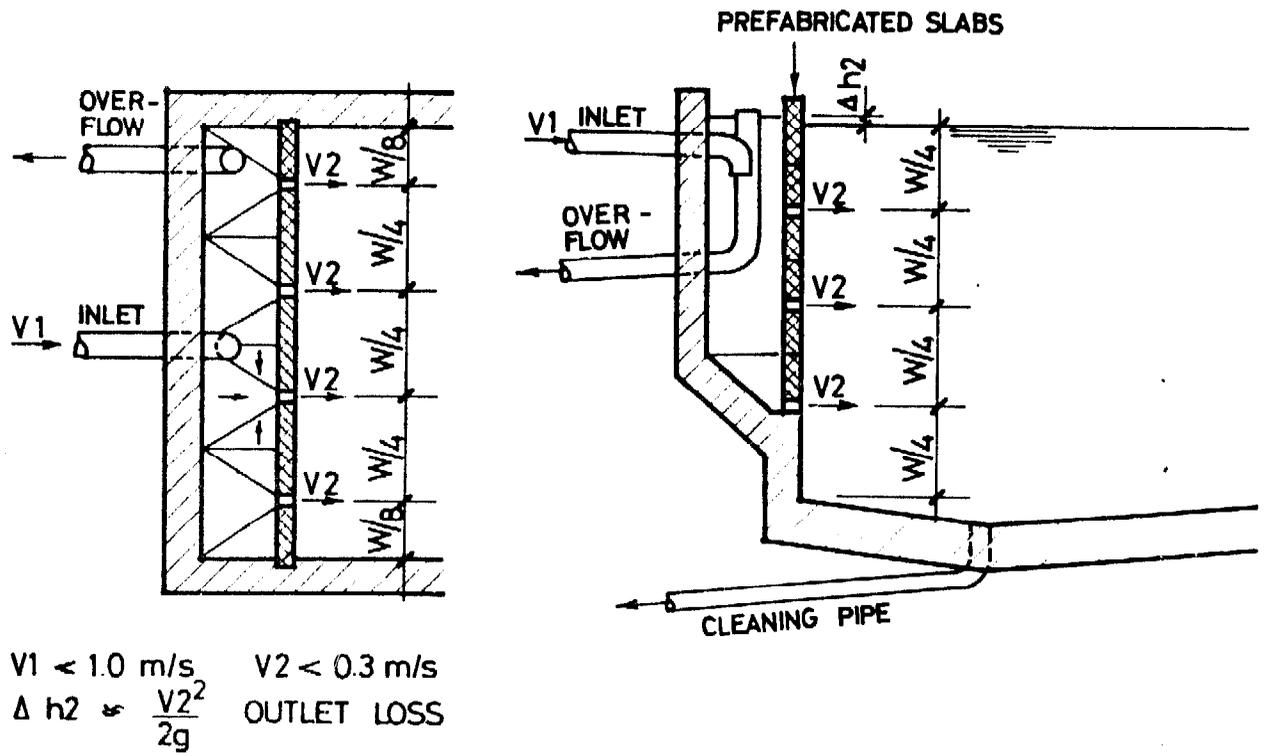
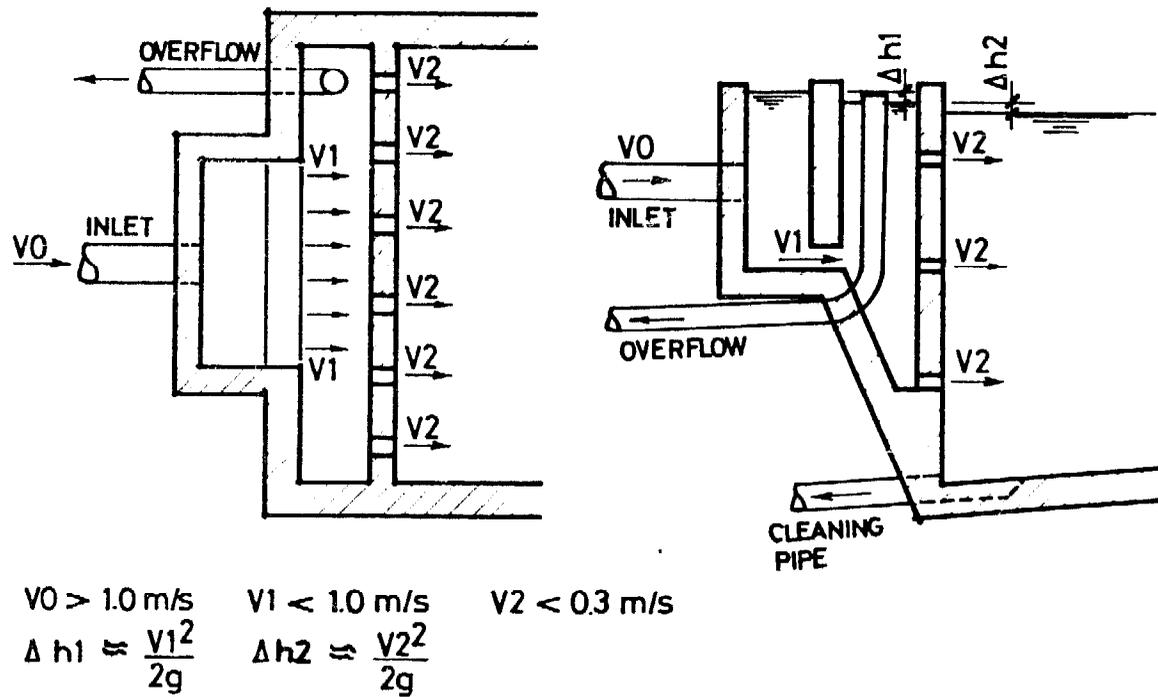
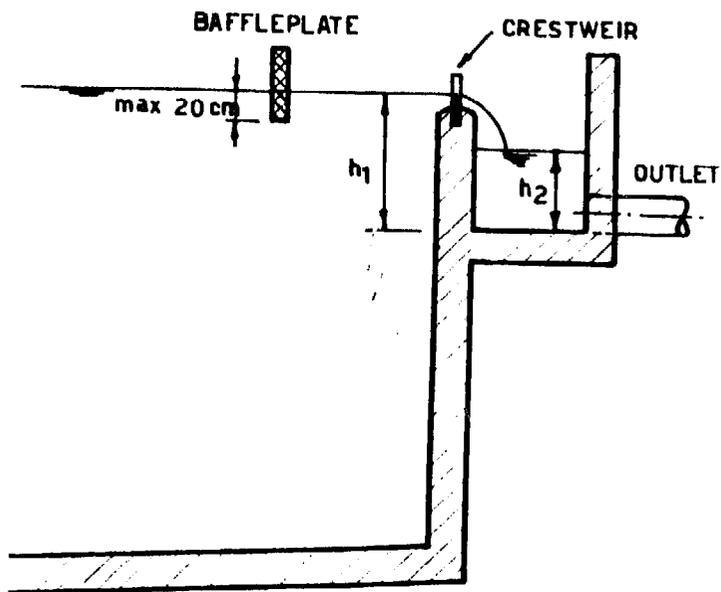


Fig. 43 Inlet: Variant 2



A good working inlet shows a horizontal calm watersurface in the gutter

Fig. 44 Outlet



The crestweir is necessary to have an equal overflow along the weir

The outlet gutter should always be reasonably deep to avoid submerging the crestweir because there is a considerable slope of the water surface in the gutter

4-6.3 SLOW SAND FILTER

Slow sand filters have been installed in many CD/SATA-Helvetas water supplies with a stream or river as a source. This is due to the fact that these filters can be easily maintained by the communities concerned if they are properly instructed. Also, slow sand-filters show good results in respect of water treatment, and their mode of action is quite simple

Definition: Slow sand filters are filters with a surface charge of 7,25 m³/m² day (filter velocity 0,3 m/h) or less.

4-6.3.1 Mode of action

The raw water is led gently on the filter bed and percolates downwards. Suspended matter in the raw water is deposited on the surface of the filter bed. This layer of organic and inorganic material increases the friction loss through the bed. The water level therefore rises gradually until it reaches a predetermined value, not more than 100 cm. The bed must then be taken out of service and cleaned.

The slow sand-filter does not act by a simple straining process. It works by a combination of straining and bacteriological action of which the latter is the more important. The mode of operation is complex. There is no doubt that the purification of the water takes place not only at the surface of the bed but for some distance below. Dr. A. Van de Vloed distinguishes three zones of purification in the bed. 1st, the surface coating, 2nd the autotrophic zone existing a few millimeters below and 3rd the heterotrophic zone which extends some 30 cm into the bed.

1st stage = acts as an extremely fine-meshed strainer

2nd stage = decomposes plankton and the filtrate becomes oxidised by chemical reaction

3rd stage = bacteriological filtration

In order to guarantee a good bacteriological filtration, attention should be paid to achieving:

- favourable conditions for bacteriological reproduction and digestion
- slow filter velocity
- raw water quality (pre-treated by sedimentation only, no chemical additives like chlorine etc.)
- Minimal charge (steady flow) ca. 5 - 10% of the max. charge, in order to keep the temperature on the filter steady and to avoid the growing of seaweed.

4-6.3.2 Hydraulic system

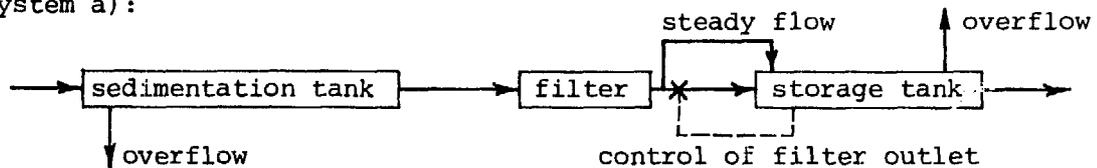
From the hydraulic point of view a slow sand-filter and sedimentation basin form an inseparable unit. Our main aim is to increase the service time of a filter as much as possible. First, we treat the raw water by sedimentation and secondly, we regulate the filter charge in such a way that no unnecessary water is filtered. Flow into the sedimentation basin should be determined as exactly as possible by water requirements. This can be done by choosing different sizes of inlet pipes, or better, by constructing a distribution chamber with a weir (measuring weir). An adjustment of the inlet by throttle valves is not advisable; it may cause blockages due to leaves etc. in the raw water.

There are two ways to control the filter:

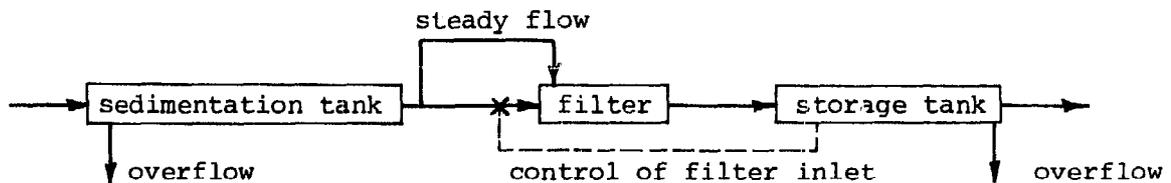
- a) In controlling the filter outlet: this can easily be done by installation of a ball valve in the storage tank. A reduction tee fitted immediately before the ball valve guarantees a minimum filter charge (steady flow = 5 - 10% of the nominal charge). A continuous circulation through the storage tank is ensured if the storage tank overflow is installed at the opposite end of the tank to the inlet.
- b) In controlling the sedimentation tank outlet: this can be done with a similar installation as the one above. This solution has the advantage of no extra water being retained in the filters. Therefore, the growth of the algae is reduced and the service time of the filter increases.

In Case a) and b) the excess water overflows in the sedimentation tank.

System a):



System b)



4-6.3.3 Size and number of filters

The size of the filter bed can easily be calculated with the following equation:

$$S = \frac{Q}{V}$$

S = surface m²

Q = quantity of water per h or per day, m³/h or m³/day

V = velocity below 7.25 m³/m²/day or 0.3 m/h

The ratio of length to width should be between 1 and 4.

The number of filter beds depends upon the quantity of water desired as well as on the size of each bed. Nevertheless, it must be kept in mind that the filters will have to be cleaned from time to time and therefore, at least one additional stand-by bed must be available to avoid interruption of the supply. If the two filters work together the velocity will only be 0,15 m/h.

Example:

Quantity of water = 20m³/h

Filter velocity = 0,3m/h

Surface required = $\frac{20\text{m}^3/\text{h}}{0,3\text{m}/\text{h}}$ = 67m²

a) Chosen: 2 filter beds in action plus one stand-by
Hence the dimensions are as follows:

A per filter = 67m² : 2 = 33,5m²

chosen width = 3m

length = $\frac{33,5\text{m}^2}{3\text{m}}$ = 11,2m

Total filter surface (incl. stand-by) = 3 x 3.0 x 11,2 = 100,8m²

b) Chosen: 3 filter beds in action plus one stand-by
Hence the dimensions are as follows:

A per filter = 67m² : 3 = 22,5m²

chosen width = 2,5m

length = $\frac{22,5\text{m}^2}{2,5\text{m}}$ = 9,0m

Total filter surface (incl. stand-by) = 4 x 2,5 x 9,0 = 90m²

Preference may be given to solution b) because less surface will be required. But cleaning a surface smaller than in a) will be more often required. It is up to the engineer to decide which solution is most adequate for the actual site circumstances.

4-6.3.4 Construction details

Fig. 45 Filter bed construction

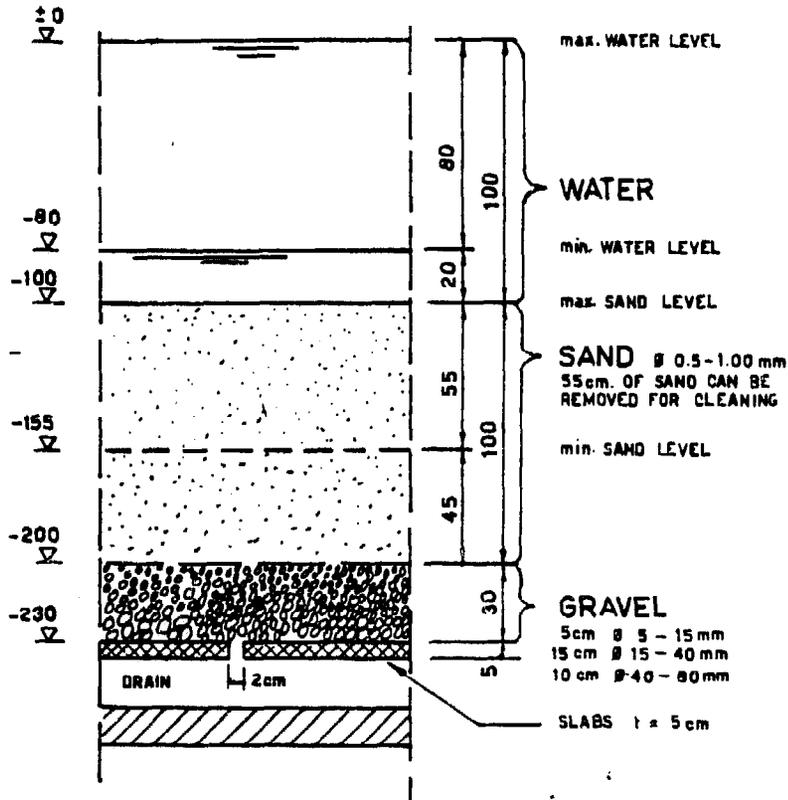


Fig. 46 Filter - long section

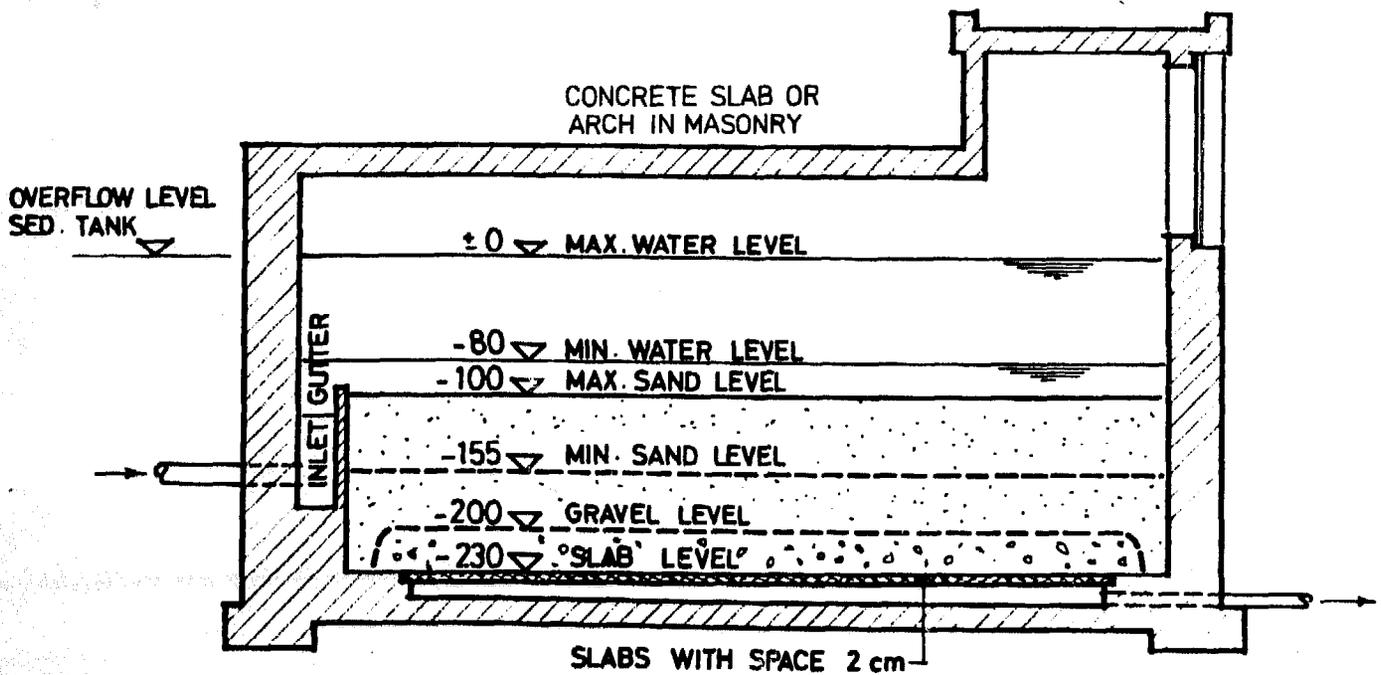


Fig. 47 Filter - groundplan

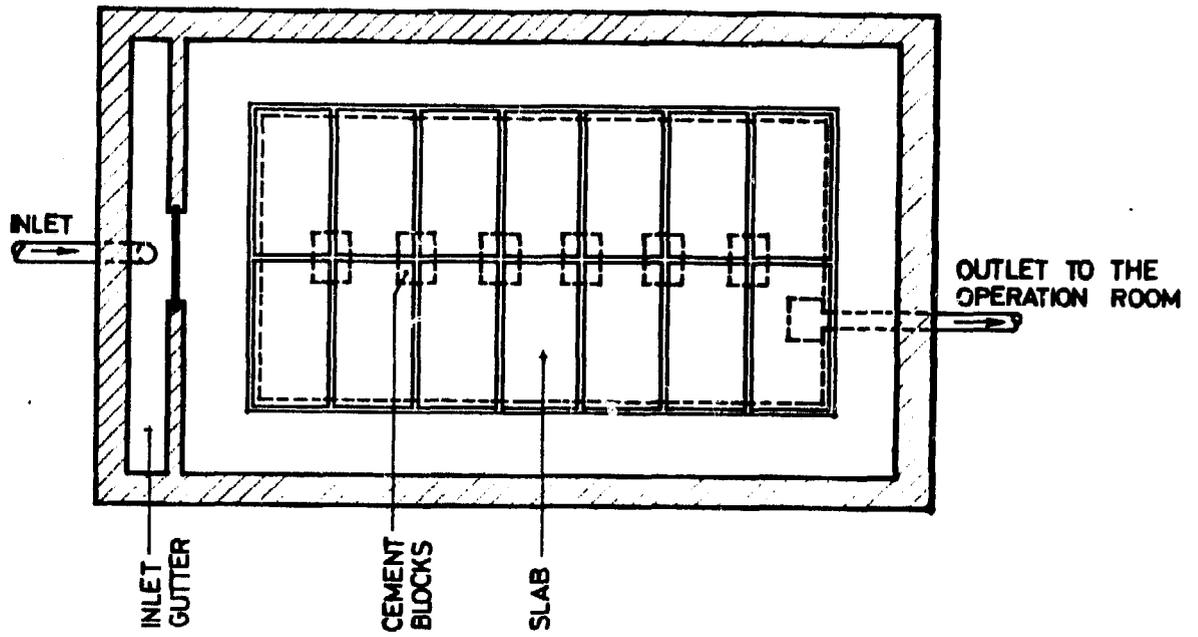


Fig. 48 Filter bottom - cross section

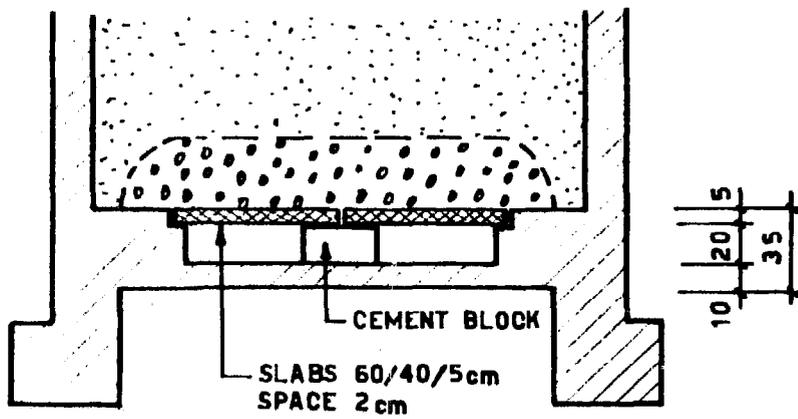
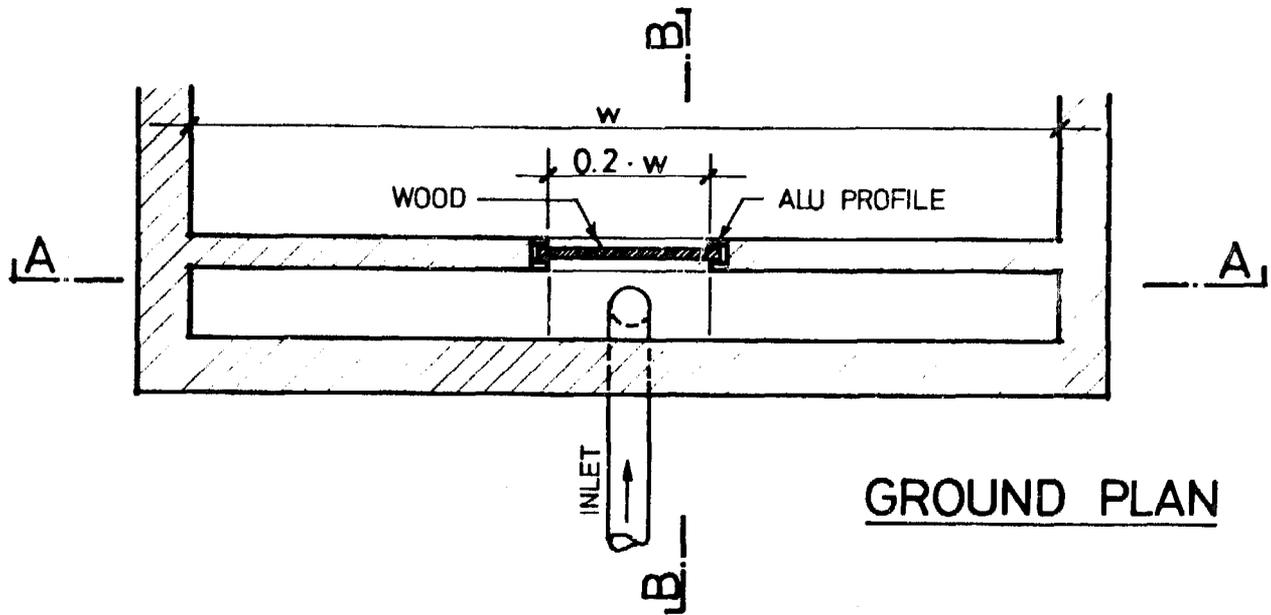
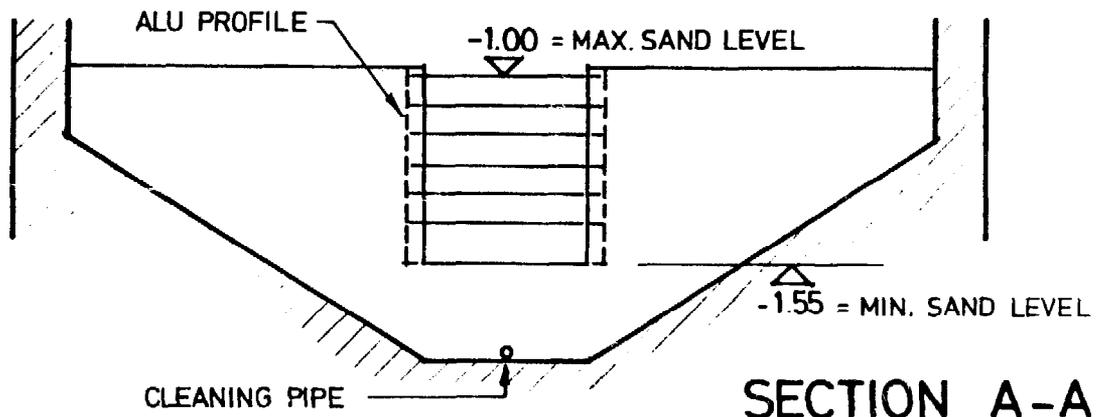


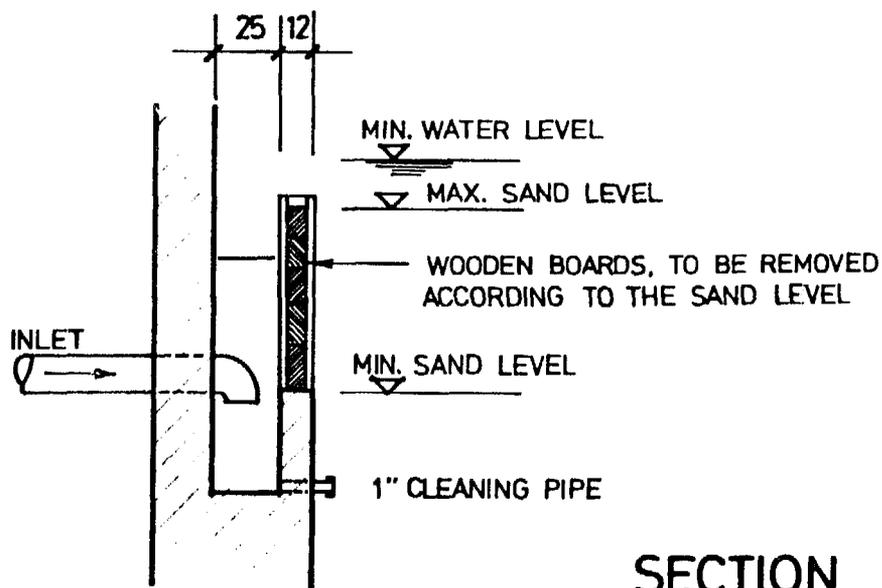
Fig. 49 Inlet gutter details



GROUND PLAN



SECTION A-A



SECTION B-B

4-6.4 OTHER FILTER TYPES

4-6.4.1 Rapid gravity filter

Rapid gravity-filters owe their name to the fact that the rate of flow through them is about twenty times faster than through the slow sand-filter (144 m³/m²/day for tropical areas only). Rapid filters work on other principles than those of a slow sand-filter. There is no "Schmutz-decke" film acting as a strainer on their surface; the sand bed is cleaned regularly by forcing air and water upwards through the bed and discharging the dirty wash water to waste; also the incoming water must be chemically treated. The rapid gravity filter acts more as a "strainer in depth" than the slow sand-filter but the process of water purification is not entirely one of straining. As with the slow sand-filter, certain complex biological and chemical changes are induced in the water as it passes through the bed and these - as far as is known - are believed to be the chief mode of action of the filter.

Rapid gravity-filters generally require too much maintenance and supervision to be adopted in rural areas.

Nevertheless a rapid gravity filter has been introduced in a treatment station as an experiment. The reasons are the following:

It has been experienced in slow sand filters that they are blocked after one to two weeks in rainy season because streams carry a lot of suspended matter which cannot be settled out by the common plain sedimentation. Due to this blockage filters need to be cleaned continuously and the biological purification is disturbed. After cleaning, it takes several days to build up the biological process again. In order to avoid this continuous disturbance on the operation of slow sand filters a rapid gravity filter has been preinstalled. It is expected that this rapid gravity filter ($v=60\text{m}^3/\text{day}$) will work as a strainer to the suspended matters which have passed the sedimentation tank. While this rapid gravity filter will require continuous cleaning the slow sand filters are expected to work for months without blockage.

4-6.4.2 Pressure filter

Pressure filters are identical in bed construction and mode of action to open rapid gravity-filters, except that they are contained in a steel pressure vessel.

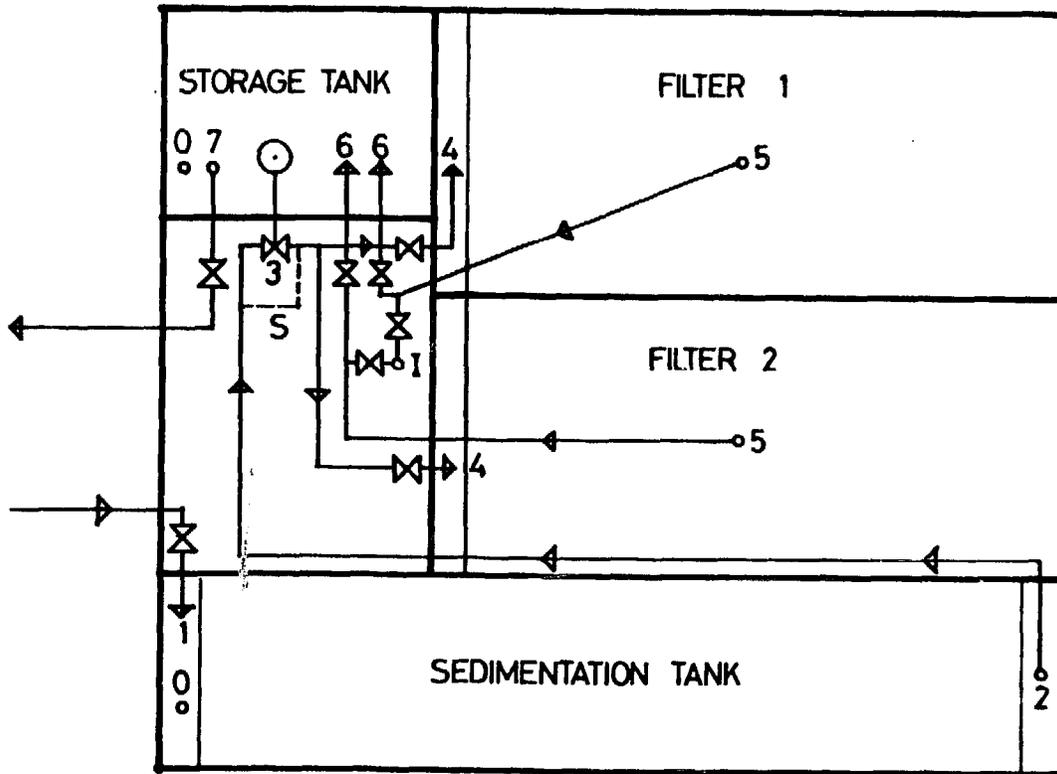
The advantage of pressure filters is that the pressure of water in the mains (not above 75 m pressure) is not lost when the filter process takes place, as is the case with an open rapid gravity plant (friction loss 1 m to 3 m).

4-6.5 TREATMENT STATION: LAY-OUT

Lay out for one sedimentation tank, two sand filters and one storage tank (collection basin).

Fig. 50 Hydraulic system - ground plan

According to system b) in chapter 4-6.3.2

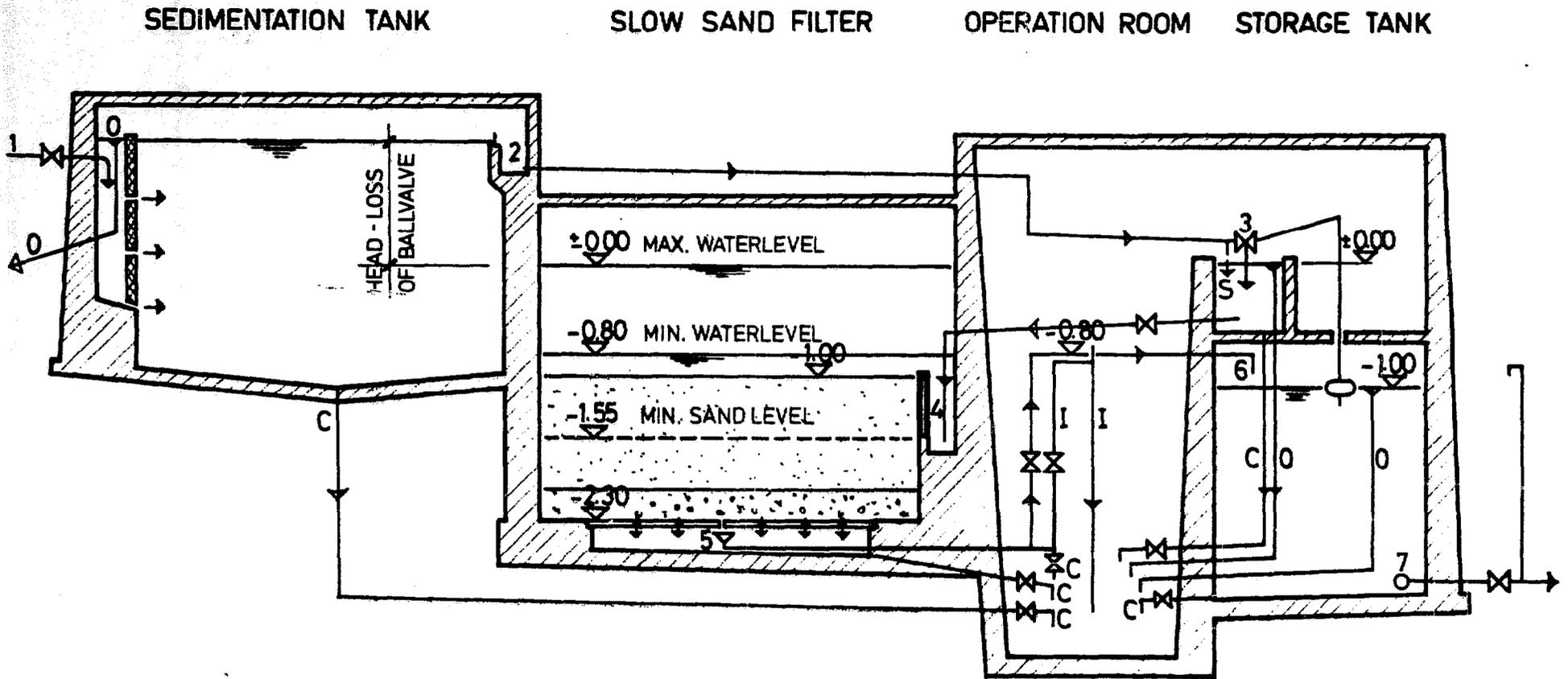


(the cleaning pipes are not shown)

- 1 inlet to sedimentation tank
 - 2 outlet of sedimentation tank
 - 3 ball valve (depending on storage tank water level)
 - 4 inlet to slow sand filters
 - 5 outlet of slow sand filters
 - 6 inlet to storage tank (collection basin)
 - 7 outlet of storage tank (supply to consumer)
 - 0 overflow
 - I idle pipe
 - S steady flow
- △ = valve
 ○ = outlet
 → = inlet

See section in Fig. 51

Fig. 51 Hydraulic system - section



- 1 inlet sedimentation tank
- 2 outlet sedimentation tank
- 3 ball valve
- 4 inlet slow sand filter
- 5 outlet slow sand filter
- 6 inlet storage tank
- 7 outlet storage tank

- 0 overflow
- I idle pipe
- S steady flow
- C cleaning pipe
- X valve

(Ground plan see Fig. 50)

4-7 STORAGE

4-7.1 GENERAL

The necessity of providing a storage tank is depending on the following points:

- a) A storage tank has to be provided in case the source's continuous supply over a day is just sufficient to cover the daily demand of the consumer. Because the hourly rate of consumption varies widely during the 24 hours of a day water has to be stored during the time of lower consumption. The maximum hourly consumption amounts up to 3 times the average consumption. (compare chapter 3-2)
- b) In case the continuous supply of the source is sufficient to cover the peak demand of the consumer, generally no storage tank is required. But the supply pipe from the source to the consumer has to be designed for peak consumption.
- c) Between the critical cases a) and b) are many other possible cases c).

4-7.2 CAPACITY OF A STORAGE TANK

When designing a storage tank the first thing to consider is the capacity which has to be provided. This depends mainly on the amount of supplied water compared to the amount of consumed water. In some circumstances a certain amount of water has to be stored additionally to cover normal breakdowns or maintenance interruptions (e.g. for hospitals).

In the following the determination of the storage tank capacity for the cases a) to c) (as described above) are shown:

- a) Water has to be stored during time of lower consumption to be available at the time of high consumption. Hence it follows that the required storage capacity depends on the consumption by a village over a day. The conditions vary in different parts of the world. Also local customs cause local variations. A typical pattern of consumption in a village in a rural area of the United Republic of Cameroon:

30 % of the day's supply between 6am and 8 am
10 % of the day's supply between 8am and 2 pm
35 % of the day's supply between 2pm and 5.30 pm
20 % of the day's supply during the other hours of day light
5 % of the day's supply between sunset and sunrise

A diagram of consumption has been drawn (Fig. 52) according to above figures. In case a) of a continuous supply of the daily demand a storage volume of 40 % is required as it can be seen from the diagram Fig. 52.

- b) As described above in case b) generally no storage tank is required. In practice the supply pipe from the source to the proposed storage tank for stage II is calculated for a continuous supply of stage II (compare example I, chapter 4-1.3). This capacity of the pipeline may be slightly below the peak demand of stage I. Normally a small storage tank, in form of an interruption tank, will only be constructed at the proposed site for the storage tank stage II in case of hydraulic requirements (pressure at taps).

- c) As an example the case c) is shown in the diagram of consumption (Fig. 52) where the source is able to supply the daily demand in 16 hours. As it can be seen from the diagram the required capacity of the storage tank is about 23 % (c1 + c2) of the daily consumption.

Fig. 52 Water consumption in a rural village with different cases of supply.

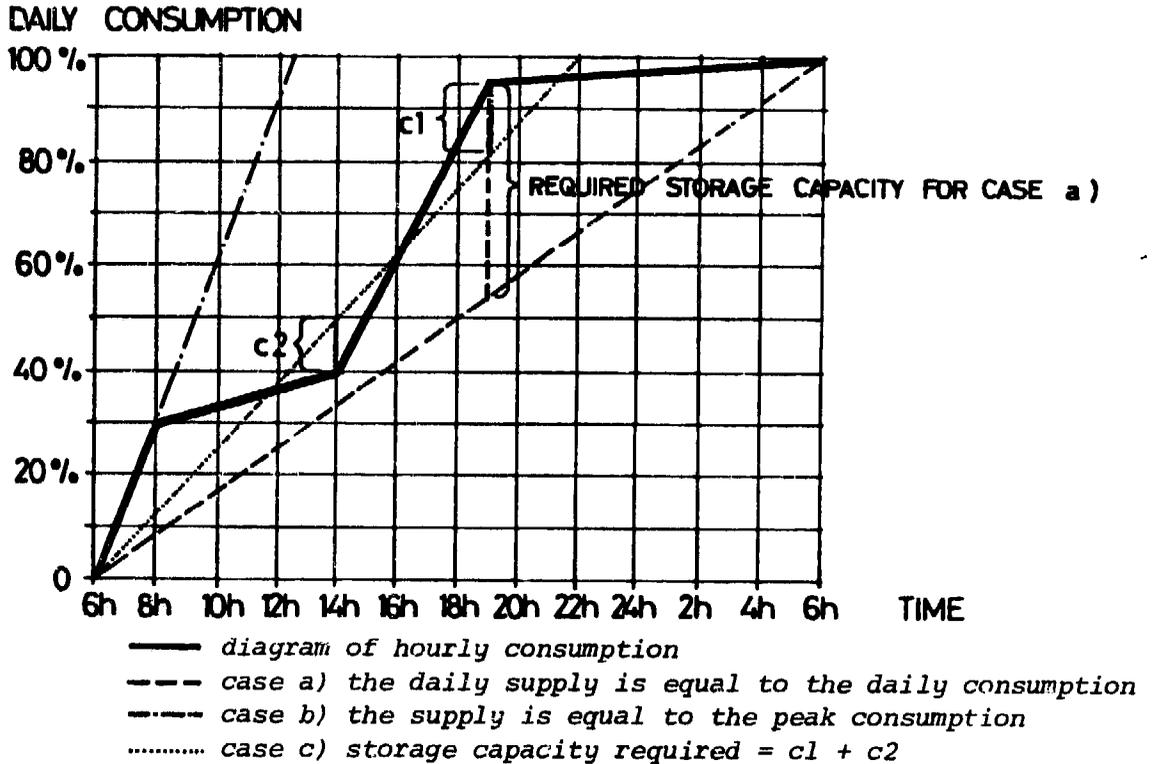
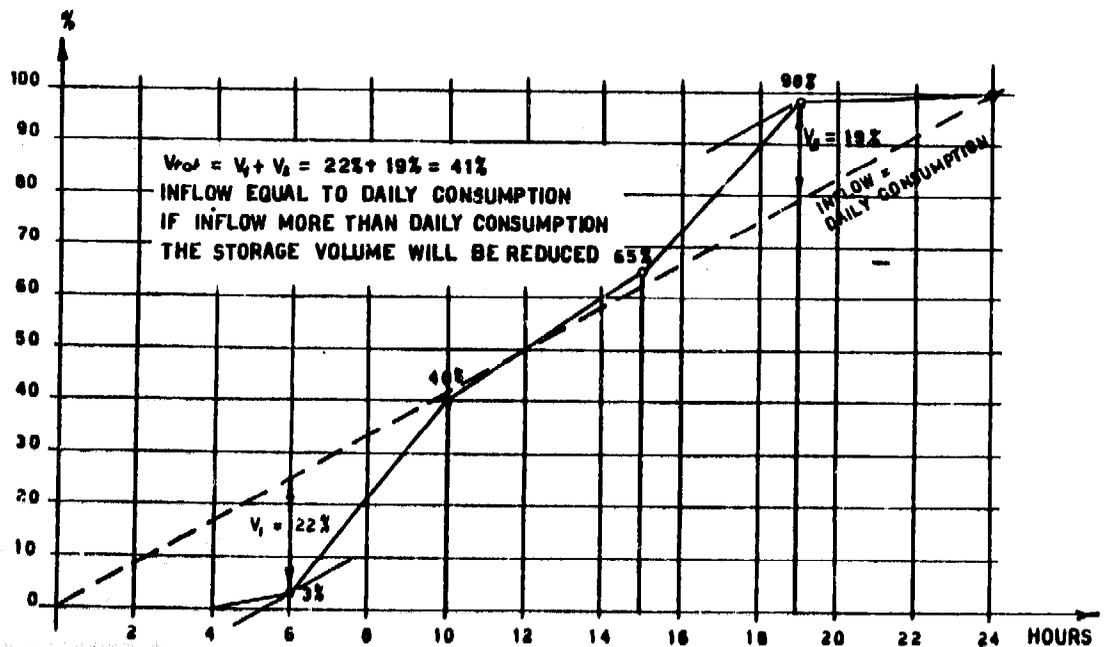


Fig. 53 Daily water consumption in Ngonzen water supply (grassland)
(an other example of case a)



4-7.3 DESIGN OF STORAGE TANKS

The site for a storage tank should be chosen as close as possible to the area of highest consumption.

The minimum water level in the reservoir should be between 20 - 80 m above the area which will be supplied. If the level difference is exceeding 80 - 100 m the system has to be divided in several pressure zones and the necessary storage tanks or pressure reducing stations (interruption chambers) have to be provided for.

The water has to be protected against external influences. A good circulation of the water has to be ensured, due to the warm climate in tropical countries. Aeration must be provided. Doors and windows have to be insectproof (mosquito screens). There should be no entrance above the water level.

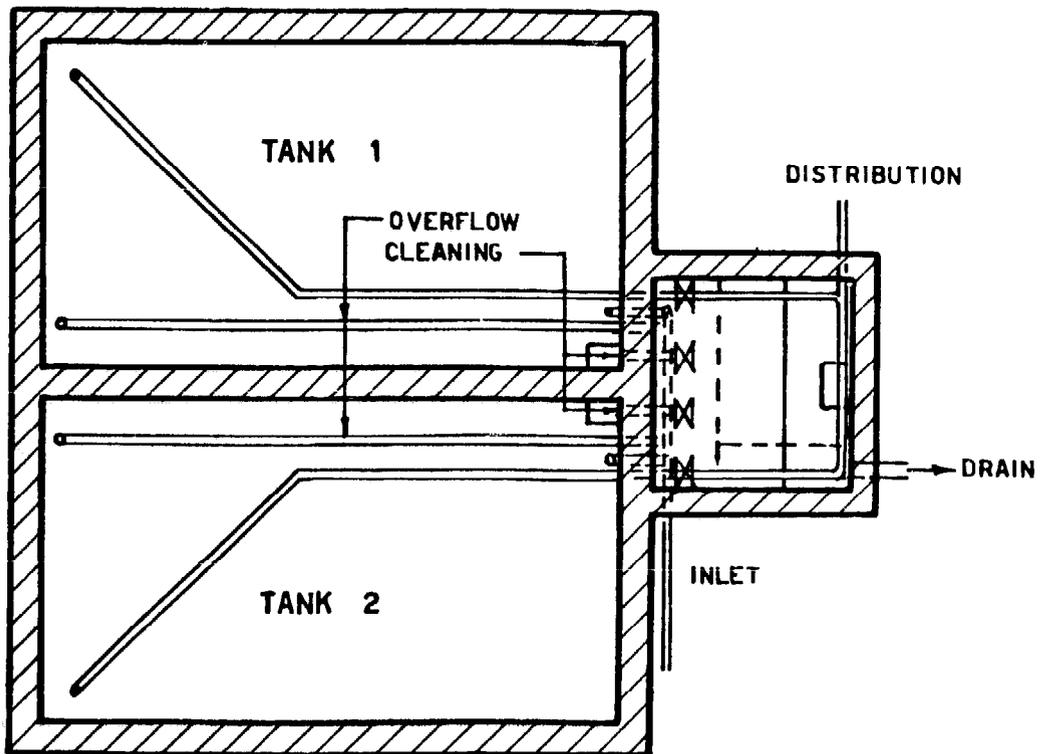
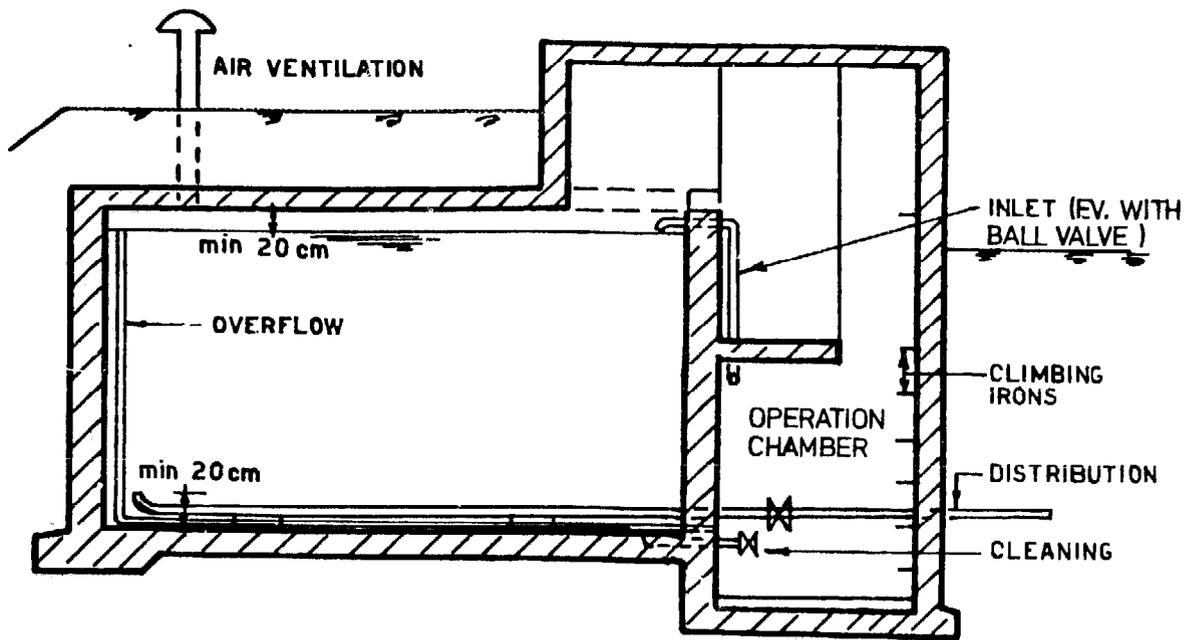
The operation chamber as well as the storage room have to be provided with good access for installation, checking, maintenance and repairs. During cleaning work the supply must continue. Therefore two independent chambers must each have an overflow capable of draining all the incoming water. Each chamber has to be provided with a cleaning pipe to allow complete emptying of the chamber. Independent chambers have to be provided with volumes above 30 m³.

Storage tanks are usually constructed rectangular in shape, but it might be more economical to construct masonry tanks in circular shape. Rectangular tanks allow easy extension.

The water depth in the tanks should be as follows:

<u>Volume</u>	<u>Water depth in m</u>	
	usual	optimal
100 m ³	2.00 - 2.50	2.50
100 - 200 m ³	2.50 - 3.50	3.00
200 - 300 m ³	3.00 - 4.00	4.00

Fig. 54 Storage tank construction



4-8 DISTRIBUTION SYSTEM

The aim of the distribution system is to transport the water safely from the main pipe to different places of consumption, such as stand-pipes, wash-places, showerhouses, etc.

4-8.1 LAY-OUT OF THE DISTRIBUTION SYSTEM

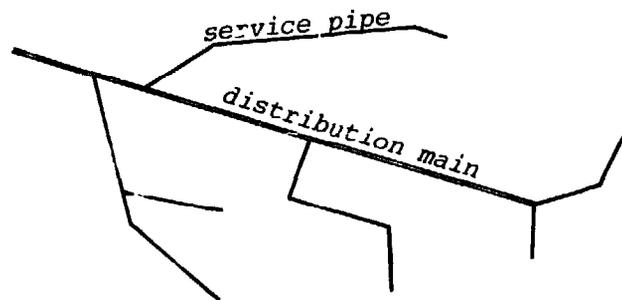
When designing a distribution system of a water supply the following two points have to be considered:

- the advantages and disadvantages of the different types of distribution systems and
- the subdivision of the system into different pressure zones, if necessary.

4-8.1.1 Types of distribution systems

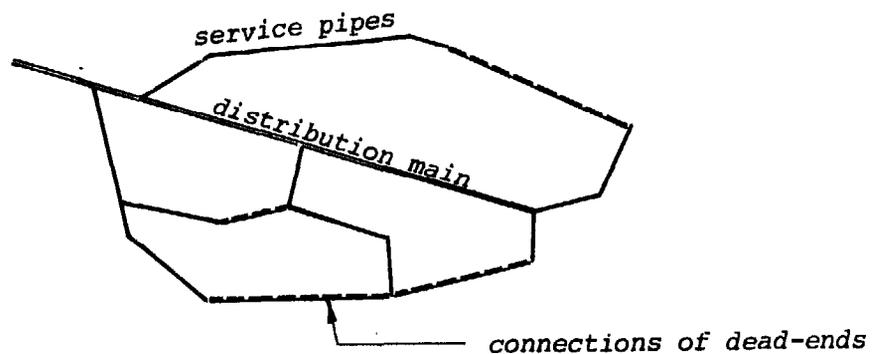
a) Branch system or dead-end system

In this system the distribution is done from a distribution main to the different points of consumption. The service pipes for individual supplies are like branches of a tree. This system has the disadvantage of possibly causing stagnant water in the dead-ends.



b) Gridiron system

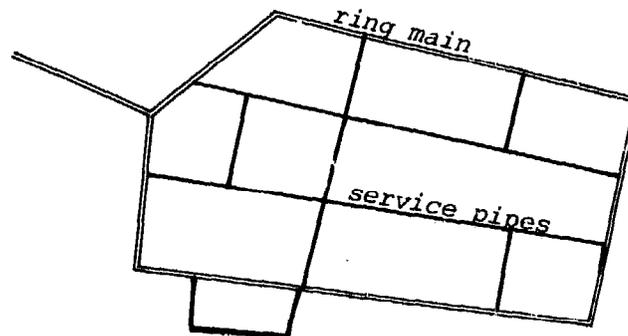
This system is similar to the Branch system but here the dead-ends are connected together with the result that the circulation is much better and the possibility of stagnant water is reduced.



c) Ring system

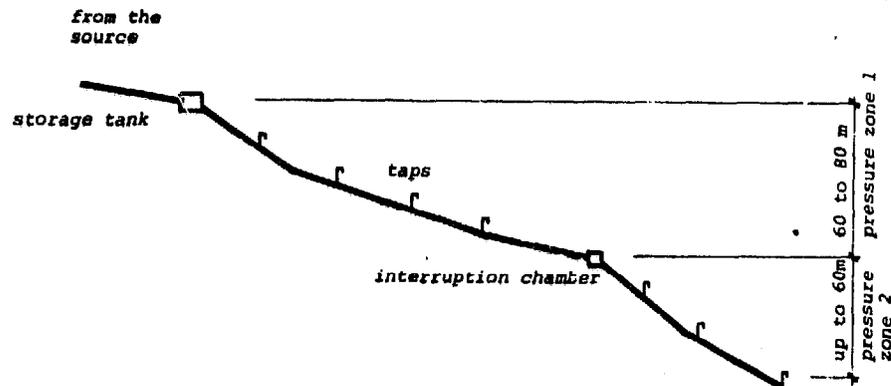
In this system the distribution main is connected as a ring. The advantages are considerable:

- good circulation of the water
- safe in case of breakdowns
- supply not interrupted in case of repairs



4-8.1.2 Pressure zones

The distribution system must be divided in different pressure zones if the difference in height between the lowest and the highest tap is more than 80 meters. The maximum water pressure at the tap is 60 to 80 m.



4-8.1.3 Disposition of taps

Public standpipes and wash-places are installed according to the following requirements:

- a) population concentration: not more than 80 - 100 persons per tap; no one should have to carry water more than 100 to 150 m
- b) technical considerations: cleaning and aeration

4-8.2 PIPING MATERIAL

4-8.2.1 General

There are three requirements for a pipeline:

- a) it must convey the quantity of water required
- b) it must resist all external and internal forces
- c) it must be durable

In order to deal with this subject adequately it is necessary to classify pipelines into the following categories which may be defined as follows:

- "Trunk mains" are for bulk conveyance of water over long or short distances from the source to selected focal points in the distribution system. The following trunk main categories have to be distinguished by their main functions:
 - a) "supply mains" for the conveyance of water from the water source (spring, river, lake) to the storage tank;
 - b) "distribution or service mains" are, as their name implies, the "street mains" from which individual house supplies are tapped;
 - c) "gravity mains" These last two classifications are made to specify
 - d) "pumping mains" the physical working principle of the supply.
- "ring main" is a special case of connecting two distribution mains together. Ring mains are always of great value to a distribution system because:
 - they tend to reduce the size of service main required
 - they maintain good pressure and flow within a distribution system
 - they give alternative means of feeding an area when shut downs for repairs are necessary
 - they avoid stagnation of water at dead-end of main
- "Service pipe" is the supply line, laid under ground from a main to a village section quarter, a house, or a farm.
- "Plumbing pipes" are pipework within a building for the distribution of water to the various appliances.

The following types of pipes are in use for the construction of mains:

Applicable	Trunk main	Service pipe	Plumbing pipe
cast iron pipes	x	x	
asbestos-cement pipes	o	o	
galvanized steel pipes	o ¹	o	o
bitumen coated steel pipes	x		
prestressed concrete pipes	x		
plastic pipes (PVC + PE)	o	o	x
copper pipes			x

x = applicable

o = applied in CD/SATA projects in Cameroon

1 = in special cases only

4-8.2.2 Asbestos cement pipes

Asbestos pressure pipes are made exclusively out of standard cement grades, mainly Portland cement. The other raw material, asbestos, is a mineral of magmatic origin, crystallized into very slender fibres (1/10'000 mm). Crude asbestos fibre bundles are broken up into fine fibres between edge runner rollers and are then fed into a pulp mill. Here, about 10 - 15 parts of asbestos are mixed with 85 - 90 parts of cement, with the addition of water.

Classification:

Asbestos pressure pipes are supplied in nominal sizes of 50 to 1'500 mm and in pressure classes 5, 12, 20, 25 and 30 kg/cm².

The classes denote the test pressure in kg/cm² of the tightness test in the manufacturer's works. The tightness test pressure is twice the working pressure of the pipes.

Pipes are marked in the customary way, e.g. a pipe of 250 mm inside diameter designed for a working pressure of 10 kg/cm bears the code:

Durabest ϕ 250, class 20

Couplings are similarly coded, i.e.:

ϕ 250, class 20

All pipes are tested at twice the working pressure before leaving the factory.

Note:

Asbestos cement pipes in Cameroon are only used bitumen coated inside and outside (compare chapter 2-4). They were the main type used for CD-SATA-Helvetas projects until 1976. Now plastic pipes are applied more often due to appearance of corrosion in AC pipes by aggressive water.

4-8.2.3 Plastic pipes

Plastic pressure pipes and plastic pressure hoses offer considerable advantages compared to pipes made of other material, due to their great resistance towards all known aggressive matter (see chapter 2-4.4), to their light weight and their easy handling.

The raw material for plastic pressure pipes (e.g. Symadur pressure pipes) is Polyvinylchlorid (PVC) in powder form.

The plastic pressure hoses (e.g. Symalit PE-hoses) are made of Polyethylene (PE) mixed in powder form.

Much attention has to be paid to an adequate fabrication. Plastic pipes for the purpose of transporting drinking water must be fabricated according to established regulations (e.g. in Germany: DIN 19'532). A well equipped laboratory is required to examine the plastic material accordingly. Only plastic pipes marked with a test mark which guarantees adequate quality, must be used for water supplies.

Of course, as we know from other material, we have to consider simple rules to gain the required result. Care has to be taken when offloading, storing or laying the pipes.

The following explanations are based on many years international and factory internal experience.

Transport:

When transporting plastic pipes, it is essential that the bottom row of pipes is supported along the entire length of the truck. The following layers of pipes have to be piled up in such a way that sliding and damaging of the pipes is avoided.

Stacking:

Symadur pressure pipes are resistant to influence of weather and corrosion. The pipes can be stored outside for an unlimited time but it is advisable to cover them during long stacking periods. The pipes must be stacked on an even surface. The manufacturer advises to use wooden batons at the base and between each layer. The sealing rings are to be stored in a cool and dry place. They have to be protected against direct sun rays.

Trenching:

Large stones and rocks are pointsupports which may cause the pipe to break. In case of rocky soil, the pipe has to be covered at least with a 15 cm thick layer of stonefree material (e.g. sand). In normal dry soil without stones, it is not necessary to take special precautions.

4-8.2.4 Steel pipes

Steel pipes are widely used because they are among the cheapest form of service pipes and can sustain high pressure. They are supplied in straight length of 6 m.

Note:

Only untreated pipes (black) can be bent to curves. If treated pipes are bent to curves the protection may get cracks where in due course corrosion will start.

Steel pipes may be supplied black (untreated) or galvanized, or bitumen coated inside and out, or additionally sheathed on the exterior with glass fibre cloth and a further coating of bituminous compound. They have screwed ends and are connected by steel couplings. A great variety of special ones are made, including flanges which are screwed on to the pipe ends. Most steel service pipes laid by water undertakings are galvanized.

Applicability on CD/SATA-Helvetas projects in URC:

Galvanized steel pipes are applied mainly as plumbing pipes. But they are also used on trunk mains and service pipes where the pipes have to be exposed or where the earth cover is insufficient (e.g. crossing of streams, rocks, roads, etc.).

4-8.2.5 Valves

There are three main reasons for including valves in a pipeline system:

- to allow easy closing of a pipeline
- to control the flow
- to control the pressure

Types of valves in general:

applicable for	tight closure	flow control	pressure control	
sluice valve (gate valve)	x	-	-	a)
plug valve	x 1)	x	- 2)	
butterfly valve	x 1)	x	- 2)	
screw down plug valve (stopcock)	x	x	- 2)	b)
non return valve	x	-	- 2)	c)
control valve	x	x	- 2)	d)
pressure reducing valve	-	-	x	

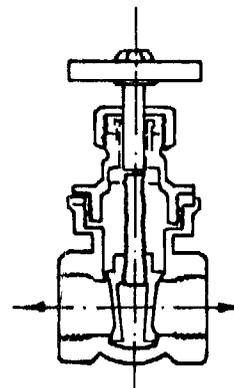
a), b), c) and d) are applied in CD/SATA-Helvetas projects in Cameroon

1) only with special equipment

2) pressure control functions only if water is flowing

a) Sluice valve (gate valve)

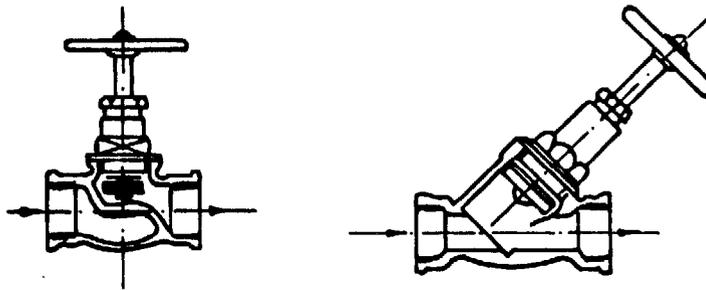
They are used to force a gate across a pipeline. The gate is wedge shaped and is lowered into a groove cast in the body of the valve.



Sluice valves which are left shut for a long time tend to stick and it requires great force to lift the gate off the sealing. Similarly valves which have been left open for a long time may not close properly because of the collection of dirt in the gate groove which prevents proper insertion of the gate. The difficulty with sticking valves and dirt on the gate groove can be greatly reduced by operating valves regularly. If valves are not operated for years they probably will not close. Serious difficulties could arise if it became essential to close such a valve effectively.

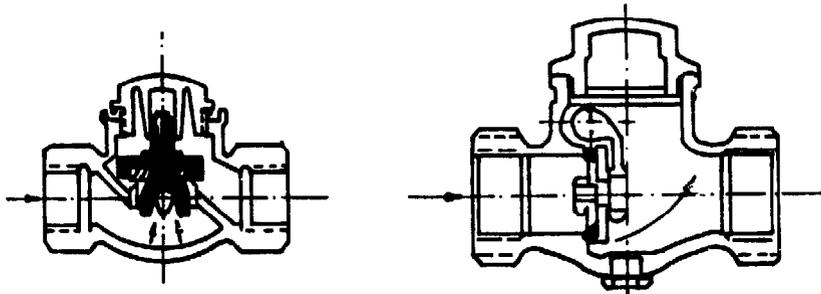
The sluice valve is not the proper device for controlling the rate of flow through a pipe because only the last 10 % travel of the gate towards closure has any substantial effect on the flow rate (depending on the pressure of the water in the pipeline).

b) Screw down plug valve (stopcock)



These are normally made only in smaller sizes. The body of the valve is cast so that the water must pass through an orifice which is normally arranged in the horizontal plan. A plug, a diaphragm or a jumper can then be forced down on to this orifice by a screwed handle, thus shutting off the water flow. The principle is used in all sorts of valves for shutting off or controlling flow. The same principle applies to ball valves, to pressure or flow control valves, to hydrant valves etc. When the size of pipe (and therefore of orifice) is small then high pressure can be controlled as is the case with the ordinary domestic tap. The defects of these particular types of stopcocks are that their sealing need renewal from time to time if they are frequently in use and that, even when wide open, they cause a considerable loss of pressure head.

c) Non return valve



The universal type of non-return valve consists of a flat disc set within the pipeline and pivoted so that it is forced open when the flow of water is in one direction and forced shut against a seating if the flow tries to reverse. Another type of non-return valve is similar to a screw-down valve except that there is no screwed handle. (It is possible to get a combined stopcock and a non-return valve). In this type the plug or jumper will be forced down on to the orifice by a spring or a weight.

Some water engineers are of the opinion that if a non-return valve has to act very rarely, in a case of emergency the valve will either fail or function too slowly. Therefore, it is necessary to operate non-return valves from time to time to keep them working properly.

d) Control valve (e.g. ball valve)

Both flow control and pressure control valves are said to work on the same principle since there can be no control of flow without control of pressure. Whether flow or pressure is to be controlled the actual physical control will have to be by destroying some of the pressure energy of the supply by forcing the water to pass through a restriction. The over-riding control of this restriction may be related to pressure or to flow.

The simplest type of controller is the ball-valve. A plug-valve, a butterfly valve or a screw-down plug-valve which is controlled by a floating ball is called a ball-valve (float-valve). This controls flow from a pipe according to the water level in a tank. The rise of the float progressively closes off the pipeline to diminish the flow for any given head.

4-8.3 DESIGN OF THE DISTRIBUTION SYSTEM

As a base for the calculation and the design of the distribution system the following points should be known:

- The general lay-out of the water supply (see chapter 4-1)
- The lay-out of the distribution system (chapter 4-8.1)
- The ground plan of the system, including the location of the consumers.
- the longitudinal section (with heights and slopes)
- the choice of the piping material.

4-8.3.1 Hydraulic calculation of piping

Whenever water flows in a piping system, there is a continuous loss of pressure along the pipes in the direction of the flow. This loss of pressure is due to friction between the moving water and the inner surface of the pipes.

Experiments show that the head loss as a result of friction is

- a) directly proportional to the length of piping
- b) directly proportional to the roughness of the interior surface of the pipe
- c) approximately proportional to the square of the velocity

Calculations of friction-losses are actually determined by formulas developed by Reynolds, Nikurades, Prandtl, Colebrook and Strickler.

For practical use we have tables and graphs or diagrams.

Tables: series of figures related to each other. Pay attention to: headlines, dimensions, decimal points, remarks

Diagrams: lines or curves on a scaled raster. Pay attention to: dimensions, scales, interpolation

There are three ways to do the hydraulic calculation to determine the dimensions of a piping system:

1) known: the quantity of water needed (e.g. the water flow at peak consumption) and the slope of the hydraulic gradient of the pipeline (friction loss).

To determine: The diameter of the pipe required.

2) known: The diameter of pipe available and the quantity of water needed (water flow).

To determine: The friction loss (= the slope of the hydraulic gradient).

3) known: The diameter of the pipe line and the slope of the hydraulic gradient (= friction loss)

To determine: The quantity of water flowing through the pipe line.

Peak consumption

The distribution system should be calculated for a peak consumption which is equal to the sum of:

- the number of stand-pipe taps times 8 litres/min (ϕ 1/2"-tap)
- the number of wash place taps times 12 litres/min (ϕ 3/4"-tap)
- the number of shower heads times 8 litres/min (ϕ 1/2"-head)

or: 3 times the average supply in 24 hours ($3 \times Q_{24h}$)

The following diagrams will help you to calculate the friction loss for:

- Asbestos cement pipes (Fig. 56)
- Plastic pipes (Fig. 57)
- Galvanized steel pipes (Fig. 58)

Abbreviations for the following diagrams:

- ND = Nominal diameter
- D = Outside diameter
- d = Inside diameter
- v = Velocity of water
- t = Thickness of the pipe
- k = Roughness of the interior of the pipes

Fig. 56 Diagram of friction loss in asbestos cement pipes

The nominal diameter = the inside diameter (ND = d)

$k = 0,05 \text{ mm}$

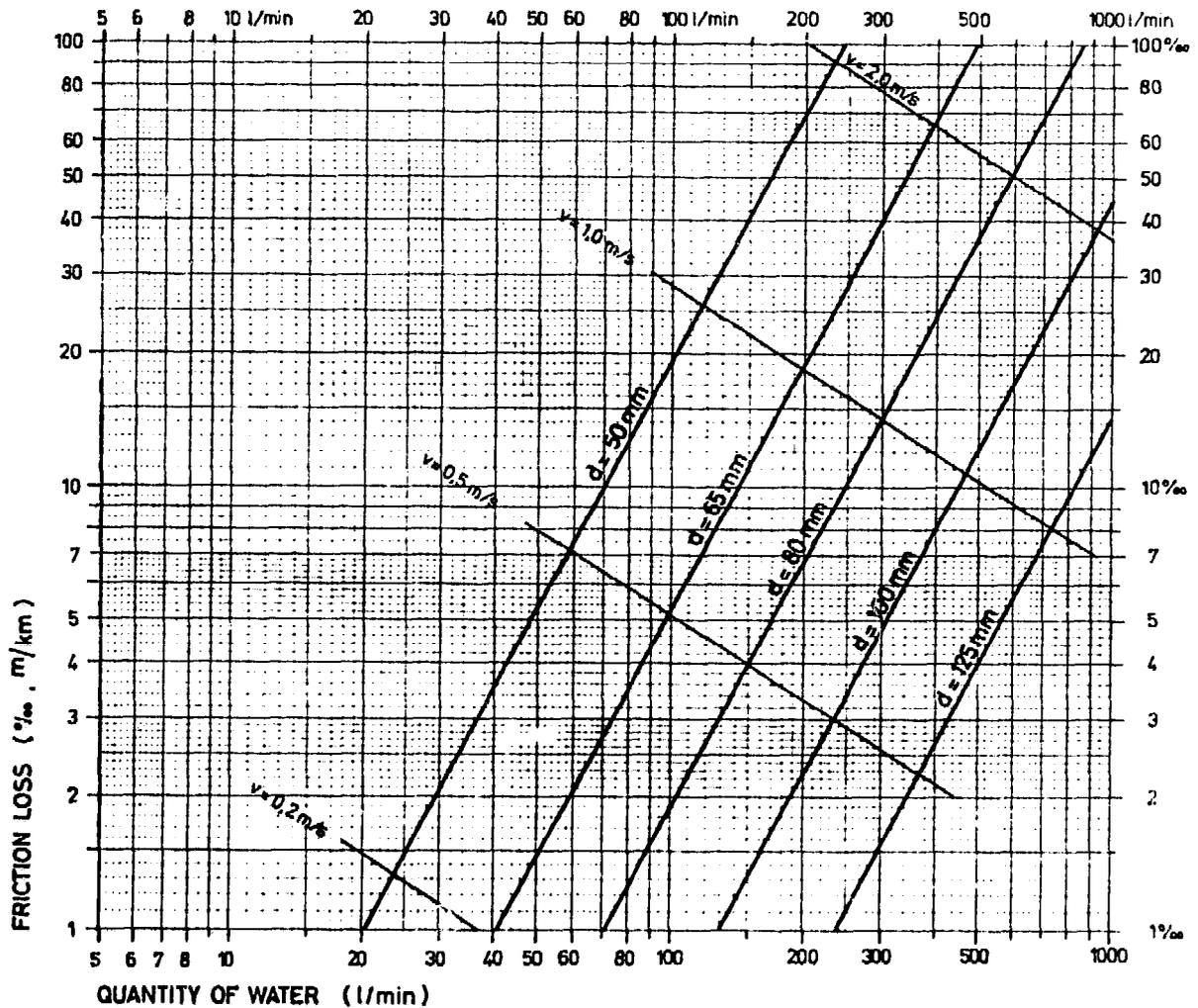


Fig. 57 Diagram of friction loss in plastic pipes (PVC and PE)

Nominal pressure = 10 at

$k = 0,01 \text{ mm}$

	nominal diameter	outside diameter	t	inside diameter
PE hoses		32 mm	5,4 mm	21,2 mm
		40 mm	6,8 mm	26,4 mm
		50 mm	8,4 mm	33,2 mm
PVC pipes	50 mm	63 mm	3,0 mm	57,0 mm
	65 mm	75 mm	3,6 mm	67,8 mm
	80 mm	90 mm	4,3 mm	81,4 mm
	100 mm	110 mm	5,3 mm	99,4 mm
	125 mm	140 mm	6,7 mm	126,6 mm
	150 mm	160 mm	7,7 mm	144,6 mm

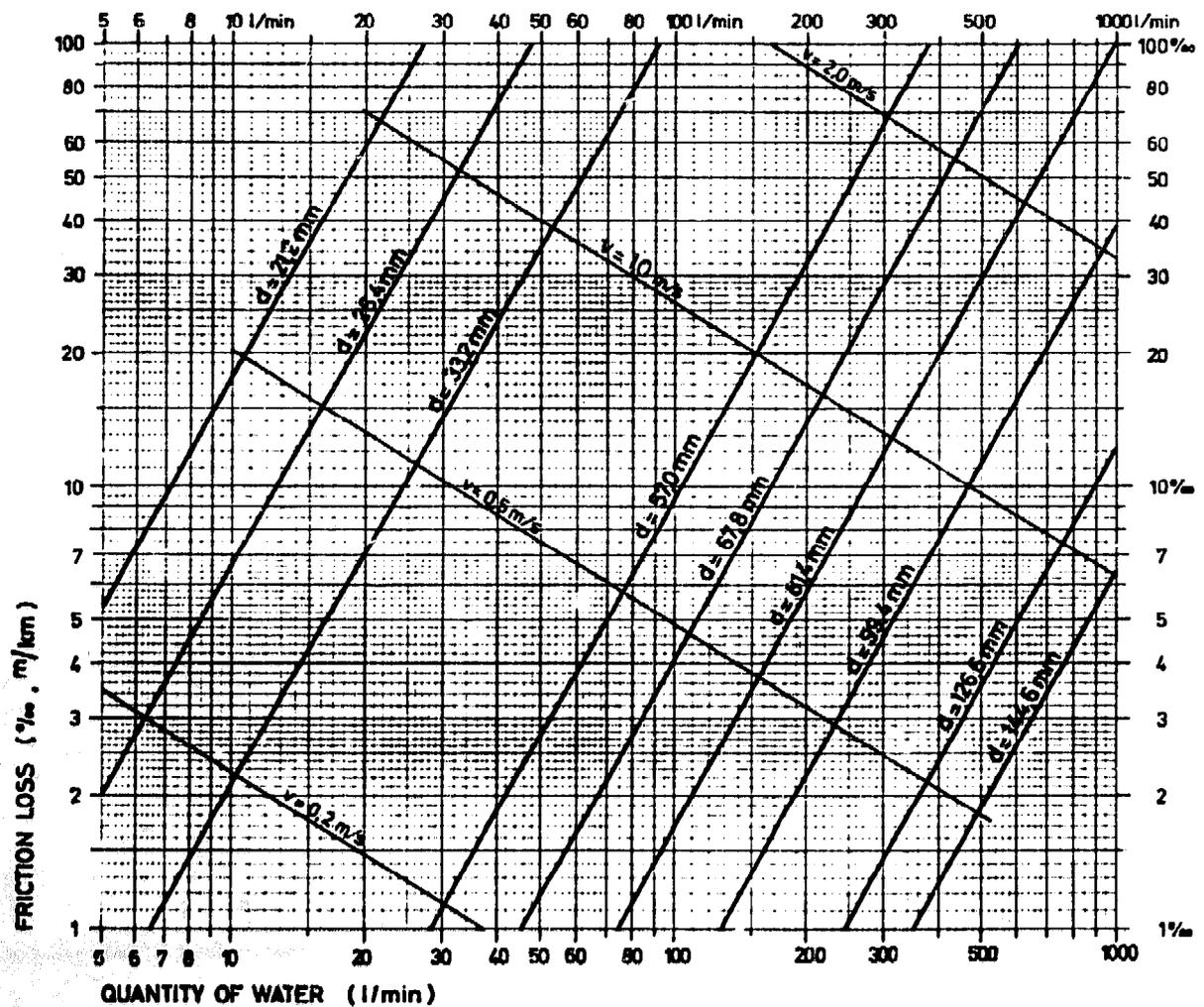


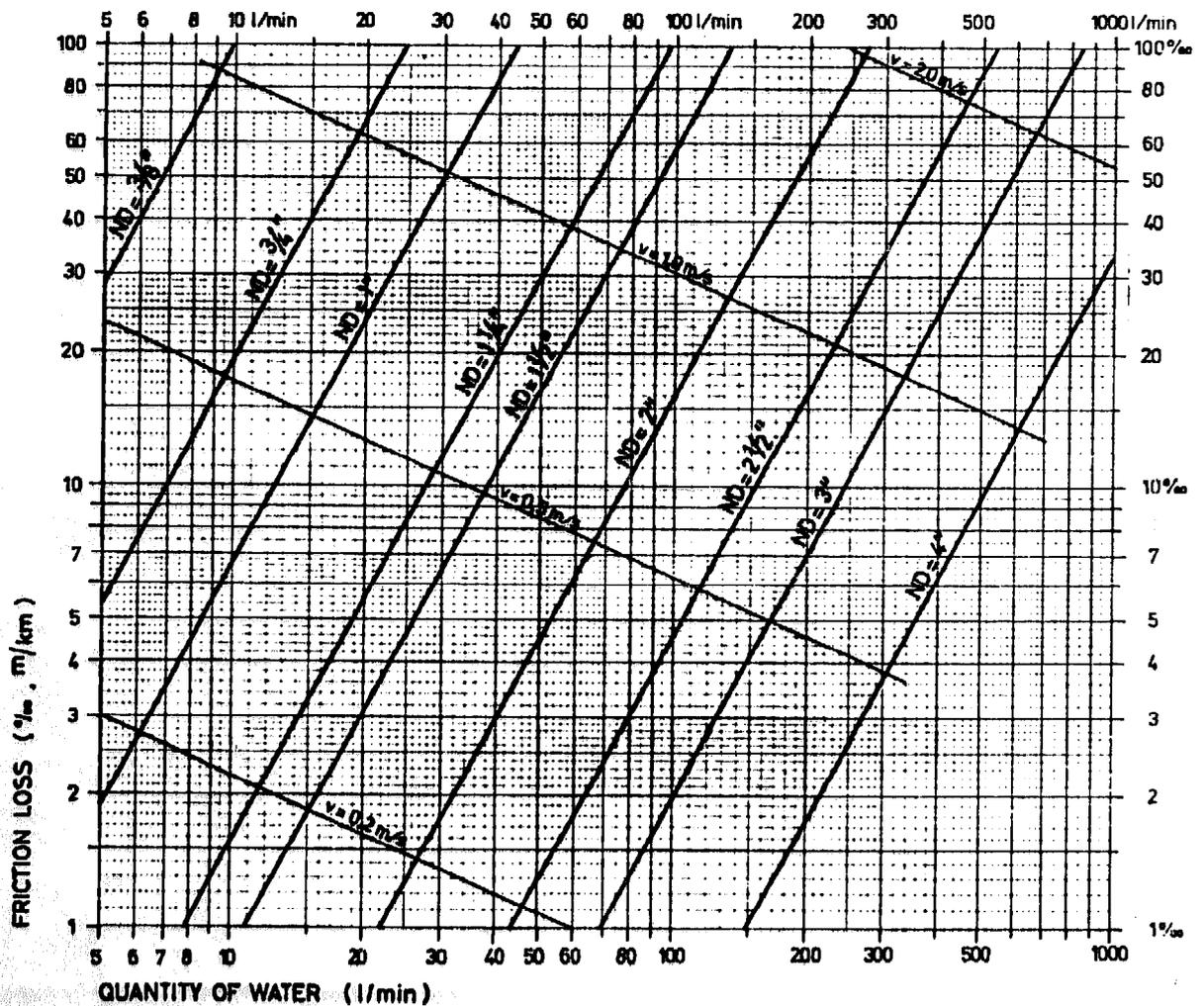
Fig. 58 Diagram of friction loss in galvanized steel pipes

Pipes according to DIN - Norm 2440

$k = 0,1 \text{ mm}$

The nominal diameter ND the inside diameter d

3/8"	or	10 mm	12,5 mm
1/2"	or	15 mm	16,0 mm
3/4"	or	20 mm	21,6 mm
1"	or	25 mm	27,2 mm
1 1/4"	or	32 mm	35,9 mm
1 1/2"	or	40 mm	41,8 mm
2"	or	50 mm	53,0 mm
2 1/2"	or	65 mm	68,8 mm
3"	or	80 mm	80,8 mm
4"	or	100 mm	105,3 mm



It is quite clear that a certain water velocity in the pipes is most economical. The following table should give a general guideline:

Trunk main-lines, supply main, pump discharge pipes

stage I $v = 0.8$ m/sec

stage II $v \approx 1.5$ m/sec - 2.0 m/sec

Main-lines without house or stand-pipe connections

stage I $v = 1.0$ m/sec

stage II $v = 1.5$ m/sec

Distribution or service main

stage I $v = 1.0$ m/sec

stage II $v = 1.8$ m/sec

4-8.3.2 Prevention of air pockets

The presence of air in a water main can cause serious blockages to the flow even when the main is of a large diameter.

Air pockets can be caused:

- where the static head on the pipe is lower than 5 m
- by high points in the pipeline and where the pressure in the pipeline decreases (compared to the hydraulic gradient)
- by operating a pipeline with insufficient means of aeration when
- the flow capacity of the pipeline is bigger than the inflow

The minimum pressure in a pipeline should be at least 5 m.

Fig. 59

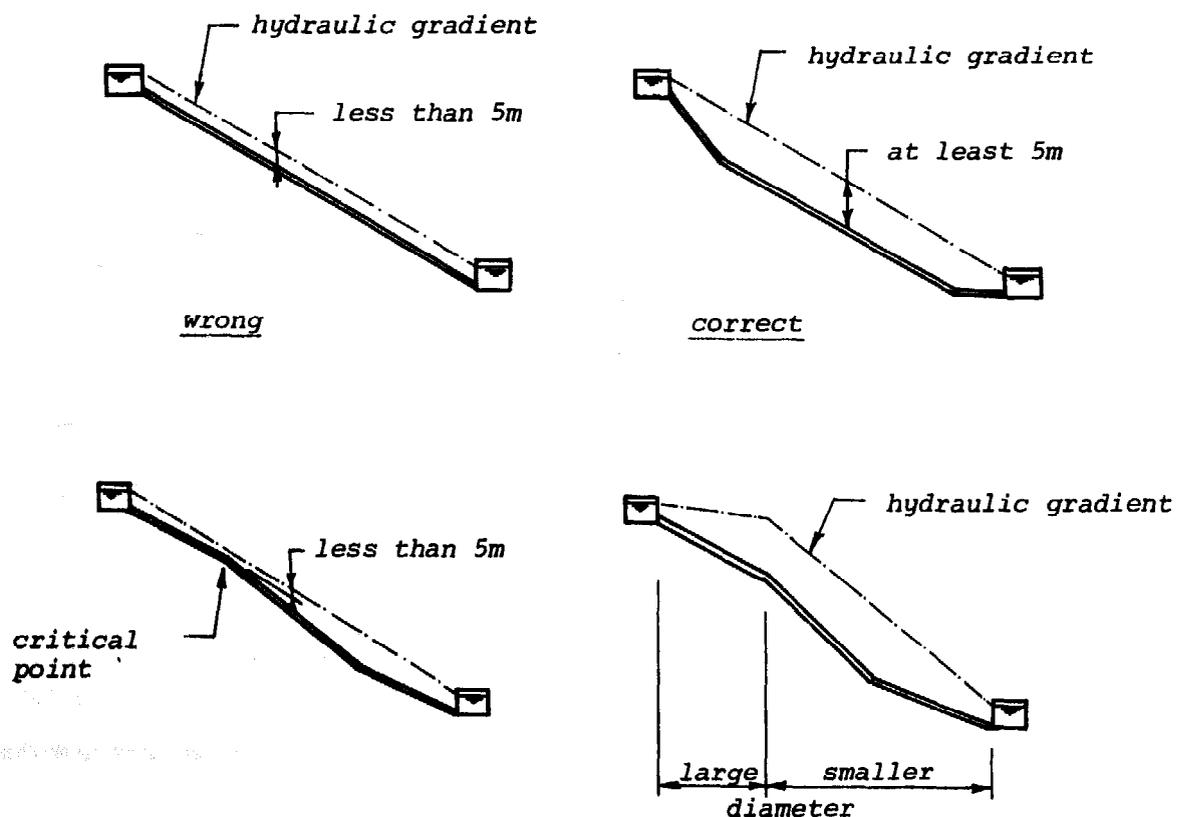
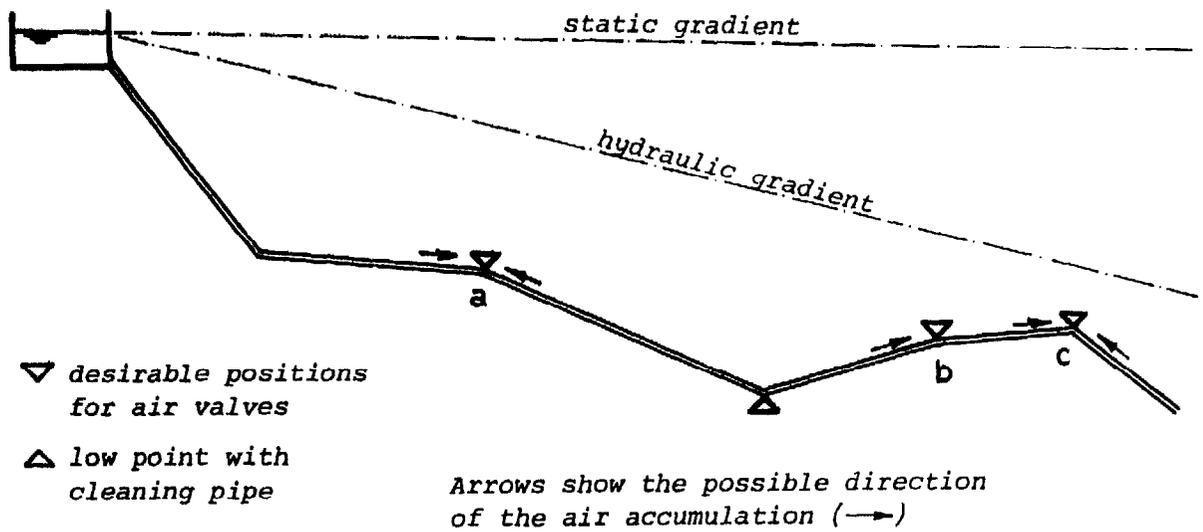


Fig. 60 Longitudinal section showing desirable positions for air valves on a length of pipeline



- Point a: Air likely to accumulate because of lessening of hydraulic gradient and steeper downgrade in direction of flow
- Point b: Lessening of upgrade in direction of flow will cause accumulation of air
- Point c: Summit; large air valve for filling purposes will be required

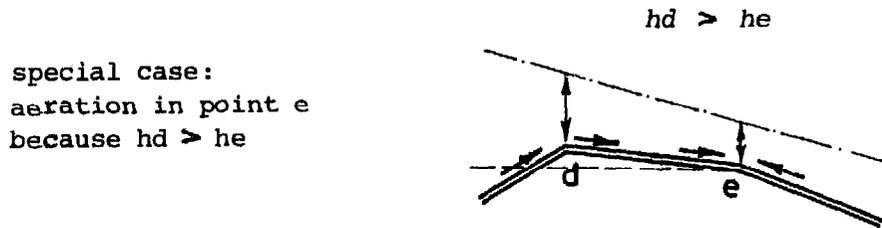
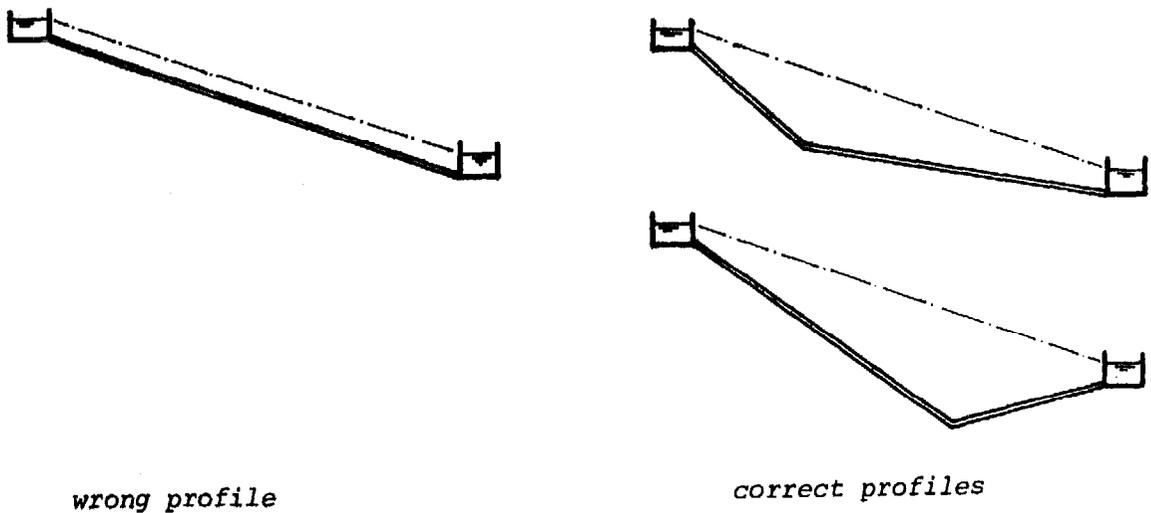


Fig. 61 Hydraulic profile



- It is obvious that air can collect at high points in a main, but what is not so obvious is that the high points are determined relative to the hydraulic gradient existing on the main. (Fig. 60 shows an example). A water main should not be laid parallel to the hydraulic gradient (Fig. 61) it should be laid with a rise or a fall (if possible). At the top of each rise there must be an air release valve. An air valve must also be inserted where a pipeline rises steeply, and then changes gradient so as to rise less steeply. The valve should be at the point of change of grade, even when there is no definite high point on the main.

When filling a main, large valves for releasing air need to be fixed only at those high points where it is obvious that air will have to emerge to permit filling of the pipeline. Elsewhere, a smaller diameter air valve will suffice. Where long stretches of main exist with no distinct high point, one air valve should be inserted at least every 1 to 1.5 km. This is especially important when the pressure along the main is decreasing and thus allows air to come out of solution from the water. On flat pipelines subjected to very low heads, open-ended vertical pipes taken above the static gradient can be used instead of air release valves, provided precautions are taken to prevent pollution of water. (Compare with Fig. 62)

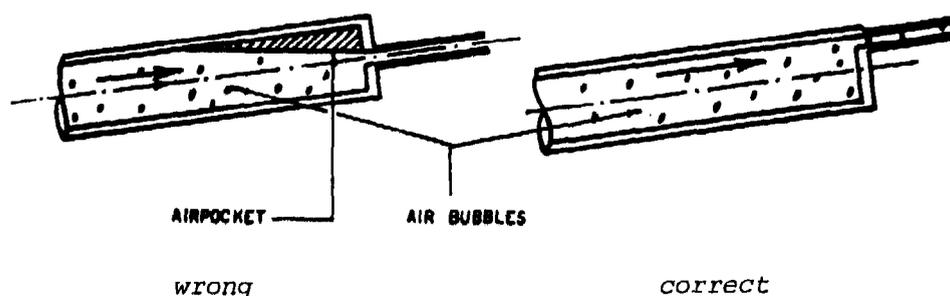
It should be kept in mind that air does not necessarily move forward with the water but may move backward against the flow of water, slowly or erratically (waterhammer).

- Before a pipeline can be filled with water, means must be provided for releasing air from it. Once the pipe is full of water, however, any aperture for release of air must be closed so that no water is lost. Ventilation on high points should be open as long as air is escaping.

- When the outflow is bigger than the inflow it is obvious that the outlet basin is empty all the time and therefore, the top of the outlet pipe will not be covered with the required 20 cm of water. If this happens the out-flowing water sucks air into the pipe and air bubbles will reduce the capacity of the pipeline (more friction) more and more until the inflow is bigger than the outflow. The water level in the basin will then increase so that no air enters into the pipe. The capacity of the pipe will then increase to be greater than the inflow and the process will repeat itself again.

Note: Intermittent flow cannot occur with automatic air release valves, but blockages to flow can happen with hand-operated air release valves because air pockets can build up in a very short time.

Special case of air pocket which reduces the flow rate and can cause water-hammer:



4-8.3.3 Prevention of vacuum

Vacuum can be caused:

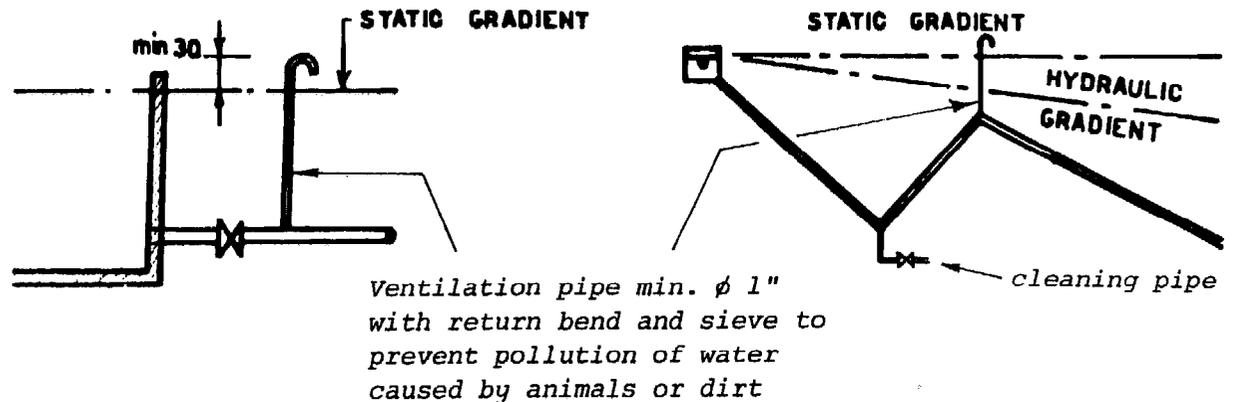
- if the hydraulic gradient drops below the pipe axis
- if there is a closed valve in a main and the water from the continuous main which is lower than the valve is drawn out for emptying purposes.

a) There is no doubt that in a well-planned supply system a vacuum caused by dropping of the hydraulic gradient below the pipe axis can be avoided. But if a pipeline bursts at a low point a vacuum will occur at each of the high points. Therefore, it is important to install automatic anti-vacuum valves on all extreme high points, if there is a possibility of more than 5 m vacuum (and in steel pipes of large diameter, even less). Where the high points have a very low head, open-ended vertical pipes taken above the static gradient can be used instead of anti-vacuum valves, provided that precautions are taken to prevent pollution of water (see Fig. 62).

b) Means to ventilate the pipeline should be provided after each main valve to prevent building up of vacuum when the main valve is closed.

4-8.3.4 Air release valves and anti-vacuum valves

Fig. 62 Automatic valves



Open ended pipes taken above the static gradient can be used instead of air release or anti vacuum valves.

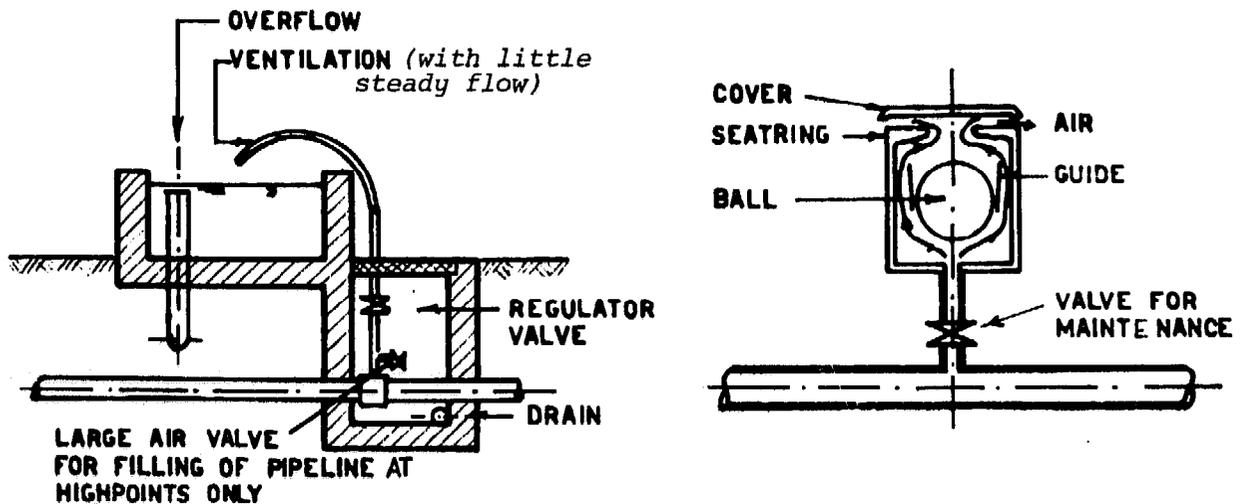
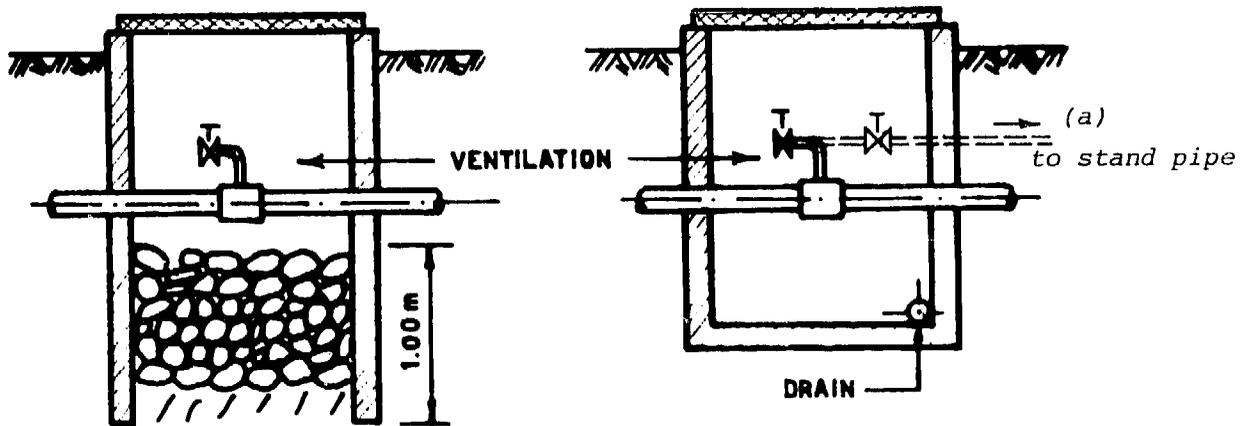


Fig. 63 Intermittent ventilation

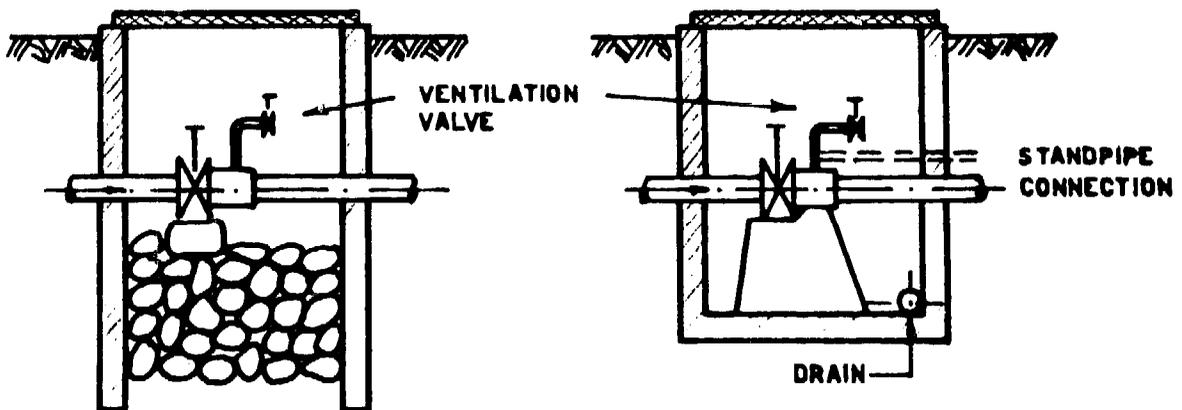


The ventilation valve has to be opened from time to time to ventilate the pipe-line (prevention of air pockets)

(a) Also regularly used standpipes can prevent air pockets at high points.

Fig. 64 Anti vacuum valve

After closing the main valve the ventilation valve must be opened (prevention of vacuum).



Note: The greatest care should be taken to keep all air valves well above the highest possible ground-water level that can occur in any pit in which they are sited. If this is not done, then polluted ground-water could enter the main if it is emptied. The pit in which the air valve is sited should have a permanent drain leading to an open outfall which cannot be drowned. This factor is an important one which will decide on the exact location of the air valve.

4-8.4 IMPLEMENTATION

4-8.4.1 Trenching

The pipeline should be laid along the straightest route possible. Road crossings should be done at a right-angle to the road whenever possible.

Every length of main should be laid with a continuous rise of about 2% to 5% to high points, so that air can be released through air valves, or with a continuous fall to a low point, where a cleaning valve should be fixed for emptying that portion of the main. Flat lengths of pipelines, or those laid parallel with the hydraulic gradient, should be avoided since they may give air-lock problems.

Changes of direction should be made, whenever possible, by using:

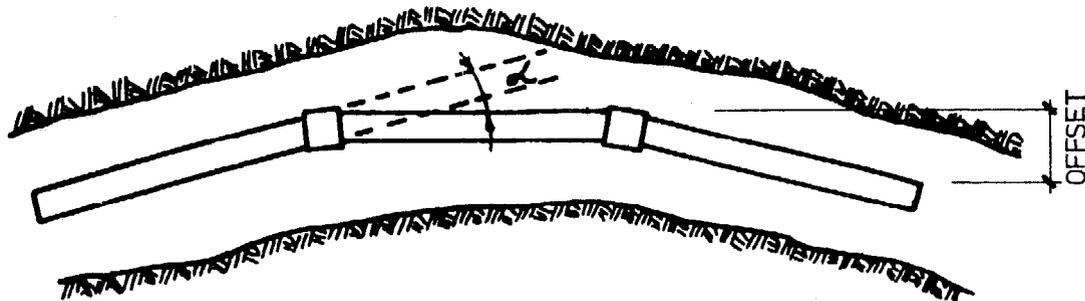
- flexible joints, such as Viking Johnson coupling for steel pipes, or RK coupling for A/C pipes allowing gradual deflection
- rigid joints using prefabricated, flanged or screwed bends.

Treated steel pipes should not be bent into curves because the internal protective coating may get cracks. It would be very difficult to remove pipes with screwed joints.

Insertion of pipe into a coupling should preferably be done along the axis of pipes already laid, the shift being carried out after the pipe has been inserted.

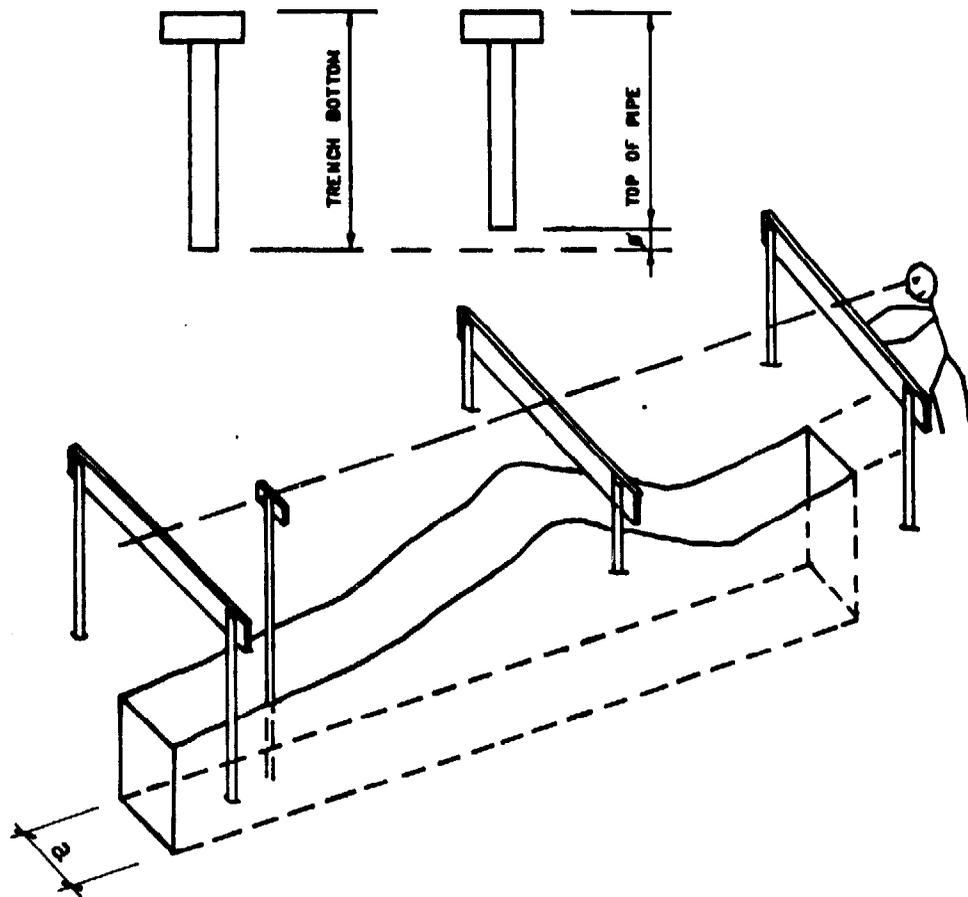
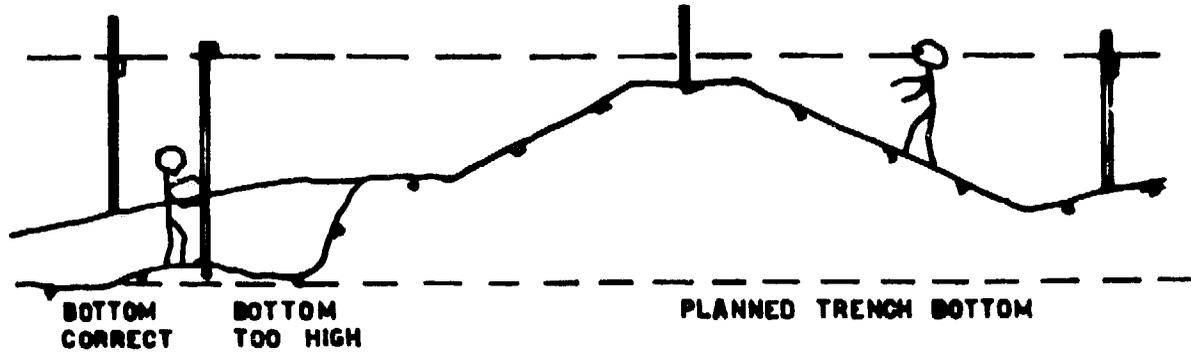
The maximum deflection recommended for asbestos pipe is $d = 5^\circ$. ($5^\circ = 9$ cm offset/m length)

For other joints - according to the manufacturer



Note: the trench has to be wider at a bend than along a straight, to allow space needed to complete the above pipe-laying instruction.

Fig. 65 Trenching with profiles



The width of the trench (a) generally depends on:

- diameter of pipes
- soil type and conditions
- cost considerations

The recommended economical width of trench at pipe level is at least $a = 60$ cm.

Depth of trench:

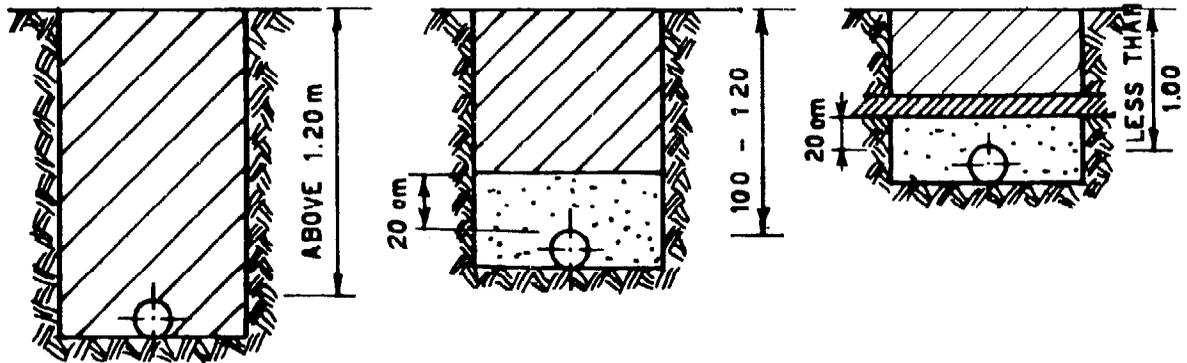
In order to protect the pipe against damage from traffic and from weather conditions, it is buried in the ground at a suitable depth. In the tropics an earth cover of at least 90 cm (min. 60 cm) should be provided in order to protect the pipes against great variations of temperature, root growth into flexible joints (between sealing rings and pipe) and against falling trees. If the pipe is not buried, the water temperature increases and provides excellent breeding conditions for microbes, and any tree falling onto the pipeline may cause damage. When pipes are laid with more than 1.5 m to 1.8 m cover, a special investigation is called for to ensure that they are strong enough to stand the earth pressure. If they are not the remedy is to bed or fully surround the pipeline with concrete.

Trench depth like trench width also has an important bearing on laying costs. All factors should, therefore, be considered very carefully before excavating the trench.

Recommended depths for pressure lines in different situations:

- through bush 100 cm (min 60 cm)
- along roads 100 cm
- underneath roads 150 cm

Fig. 66 Crossing of main roads



normal back-filling

The pipe should be laid into a sand bed and be covered with at least 20 cm sand. The remaining back-filling is done normally.

The pipe should be laid into a sand bed and be covered with approx. 20 to 30 cm sand. An additional concrete slab will help to reduce the load caused by traffic. The remaining back-filling is done normally.

Note:

Back-filling should always be completed in layers. Bulk back-filling is unsuitable as it results in excessive settling.

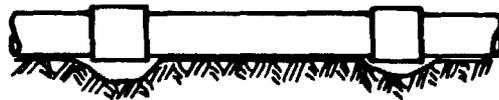
4-8.4.2 Laying of pipes

The pipe should be laid on firm ground or foundation in order to prevent uneven settlement, which may damage pipe joints. In rocky soils, rocks and stones should be cleared away from the bottom of the trenches for 15 cm beyond the pipes and should be replaced by plain earth, sand, pea-size gravel or concrete. A very large proportion of burst mains are caused by pipes settling on large stones or rock points.

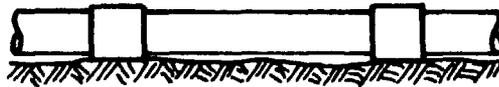
All tree roots between the surface and a depth of 1 m should be cut to prevent damage to pipes from root growth (moving or squeezing of the pipe) or by uprooted trees. This is very important if the pipes are joined with rigid couplings because an uprooted tree can damage a lengthy section of a rigidly joined pipeline.

Just before lowering pipes into the trench the pipes should be reinspected (the first inspection having been done when the pipes were delivered and stacked). This inspection should be concerned with finding cracks, blemishes, punctures or other discontinuities of the external protection of all pipes. At the same time - just before lowering them into the trench, the inside of the pipes should be inspected for foreign bodies (like snakes, mice, gravel or sand). The pipes, as well as their joining ends should be wiped and cleaned.

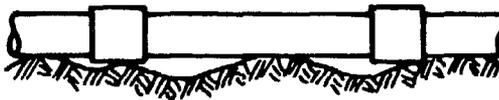
A small depression should be dug out under the couplings or sockets so as to allow an adequate support for the pipe over its entire length.



correct The pipe is supported over its entire length.



wrong The pipe is supported on two or more points only (i.e. on the couplings). Statically it acts like a beam. When back-filled the whole weight of the cover rests on the pipe which may cause it to fracture in due course.



wrong

Moreover the couplings (rubber sealing rings) may be loaded unevenly and leak.

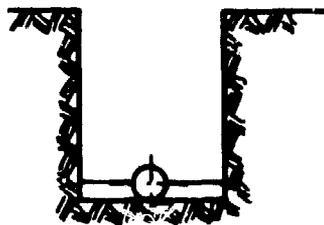
Instructions for back-filling:

Back-filling onto a pipe requires as much care as preparing the trench. The material must be soft and must not contain lumps of rock or large stones. Once the pipe has been covered with 20 cm of suitable material bulk filling of the remaining trench can be permitted. If there are a lot of big stones that have been excavated it is not advisable to use them for the bulk back-filling of the trench. If these stones are replaced by soft material it will make it easier to excavate if the need arises (i.e. repairs). Initial back-filling (at least 20 cm above the top of the pipe) should be done as soon as possible after the pipe has been laid to protect the pipe from falling rocks, trees, flooding and cave-ins. Provide a continuous bed by carefully selecting the material for use under the pipe and couplings and between the pipeline and the trench walls. A proper back-filling between the pipeline and the trench walls is also important to prevent a horizontal movement of the pipe which will occur if the pipe is not laid in a straight line.

Water tamping may be used where drainage is good. Do not lift the pipe while tamping.

Couplings or sockets are normally left exposed until the line has been tested. After testing, the initial back-filling around the couplings should proceed until each coupling has been covered by at least 30 cm of well-selected material.

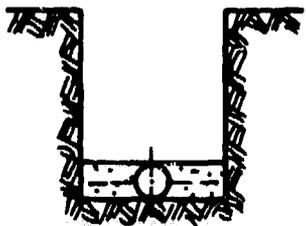
Fig. 67 Back-filling



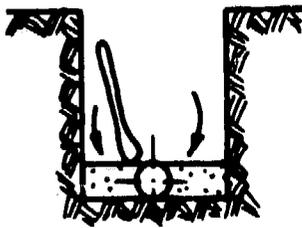
1. Place soil up to $\frac{1}{2}$ external diameter.



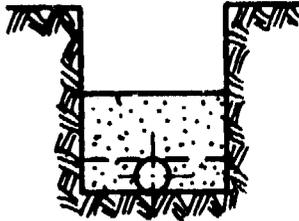
2. Tamp soil under pipes and between pipeline and trench wall at both side. Water tamping may be used where drainage is good.



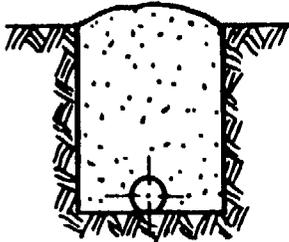
3. Place soil up to the top of the pipe.



4. Tamp soil between pipeline and trench wall at both sides.



5. Back-filling by hand until 20 cm over the pipe. Tamp each 10 cm layer.



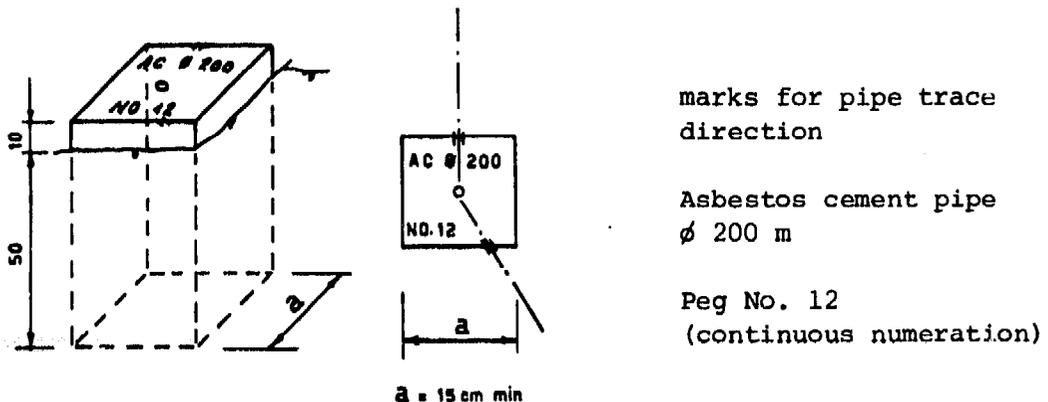
6. Bulk-filling of the remaining trench.

If the pipe trace has not been marked during construction it will later be difficult and sometimes very costly to find the pipe trace. It is important that immediately after back-filling the pipe trace should be marked by permanent signs to be able to follow the pipe if need arises (e.g. building of new houses or roads).

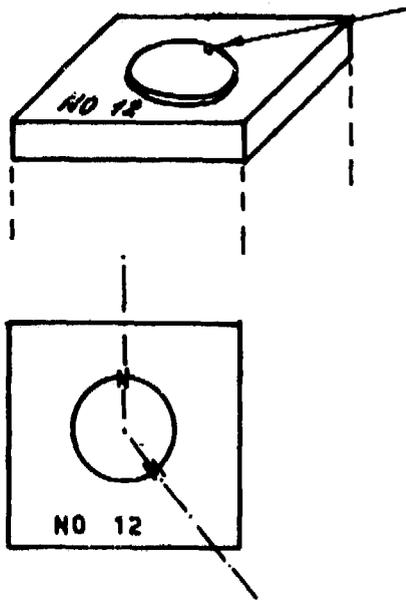
A concrete peg which contains the following information may be the best way to mark the pipe trace permanently:

- a) Pipe material and diameter laid into the ground
- b) The directions of the pipe trace
- c) Continuous numeration in sequence of all concrete pegs.

Fig. 68 Examples of marking pegs



Example for pipe sizes buried into the ground up to ϕ 100 mm

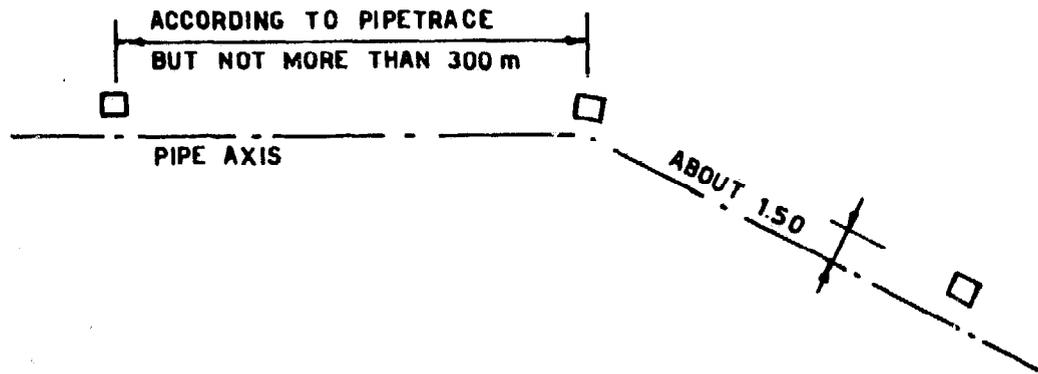


Notches cut into the pipe piece indicate the pipe trace direction

A piece of pipe embedded into a concrete peg which is identical to the pipe laid in the ground, e.g. a 1 1/4" galv. pipe piece concreted into the peg means that a 1 1/4" galv. pipeline is buried in the ground.

The concrete pegs should generally be buried to one side of the pipe axis, because:

- a) In case of a burst pipeline some of the pegs may be removed while looking for the leak and afterwards they may not be correctly replaced.
- b) The material above the pipe initially will not be fully consolidated and the pegs may sink with any subsidence and eventually get covered.



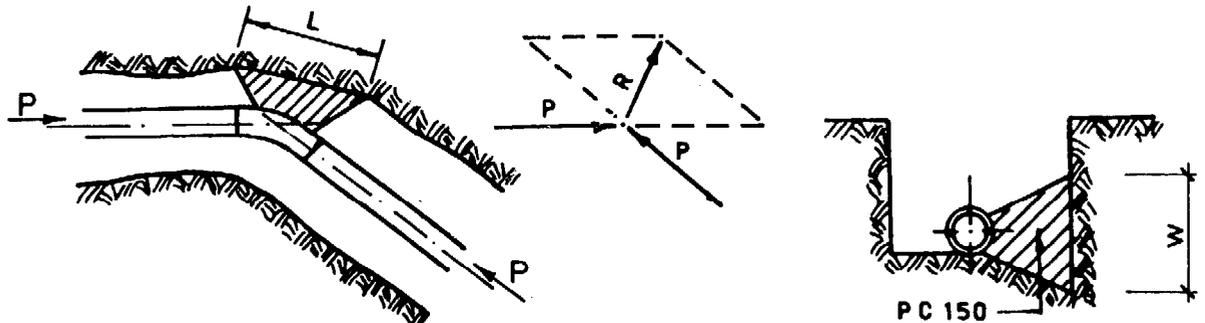
4-8.4.3 Thrust-blocks and anchoring

A pipe laid on sloping ground should be anchored frequently by having a concrete anchor-block cast around it. Further thrust-blocks are necessary at bends, tees, valves and tapers, and also at branch take-off unless flanged joints are used. These blocks often have to be very large and they must, of course, be well keyed into firm ground.

Note: The size of the thrust-block has to be decided on according to the external forces occurring during testing of the pipeline, as the operating pressure is lower than the testing pressure.

In soft soils, make sure that the concrete thrust-block is not firmly attached to the line, or it may endanger line safety if the line beds down unevenly.

Fig. 69 Thrust-blocks for changes of directions



$$\text{required thrust-block area} = \frac{R}{\text{soil-bearing power } \sigma} = L \times W = A$$

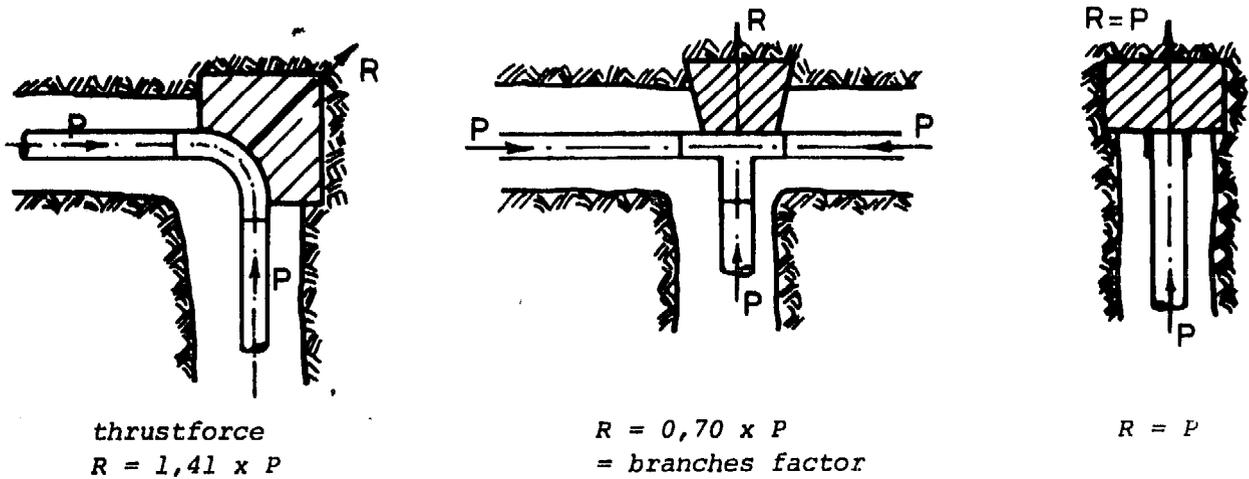
Fig. 70 Thrust forces P in metric tons at end closures:

ϕ of pipe mm	internal pressure p = kg/cm ²					
	1	3	5	7.5	10	15
80	0.08	0.23	0.38	0.57	0.75	1.13
100	0.11	0.34	0.57	0.85	1.13	1.70
125	0.17	0.52	0.87	1.31	1.74	2.61
150	0.25	0.75	1.24	1.87	2.49	3.73
200	0.44	1.31	2.19	3.28	4.37	6.56
300	0.94	2.82	4.70	7.05	9.40	14.10

Factors for calculating thrust force R at bends and branches:

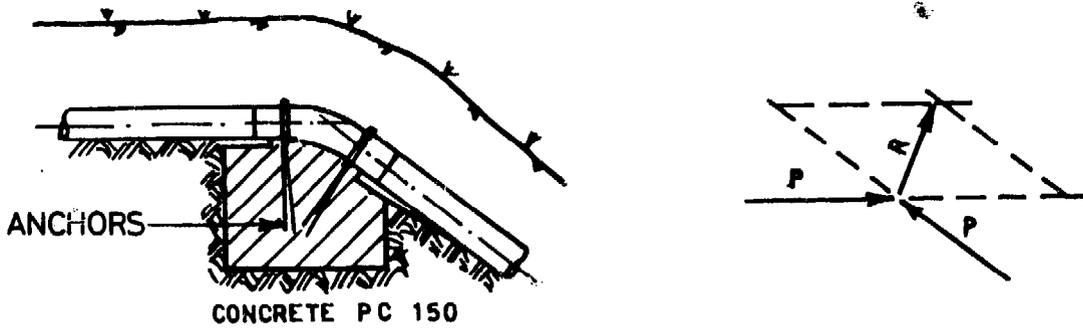
Bends:	90°	60°	45°	30°	22 1/2°	11 1/4°
Factors:	1.41	1.00	0.76	0.52	0.39	0.20

Branches factor = 0.70 (empirically drawn from experience)



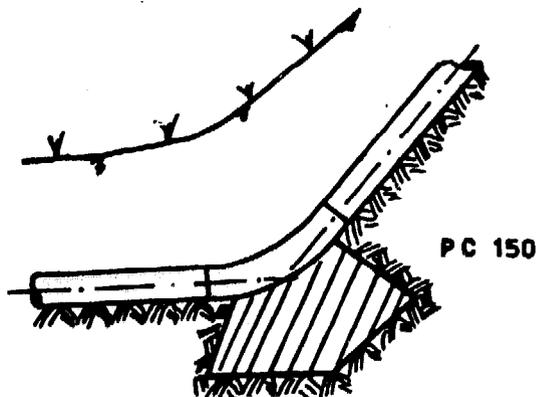
The thrust-block at changes of directions in the ground plan distributes the forces so that the foundation pressure does not exceed the permissible soil-bearing power.

Fig. 71 Thrust-blocks for changes of slopes

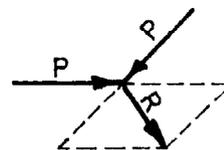


longitudinal section

This thrust block relies on its weight to withstand occurring forces.



The following calculations are similar to those for a thrust-block for changes of directions.



Examples of calculation:

Example 1:

Thrust-block for a branch ϕ 100 mm

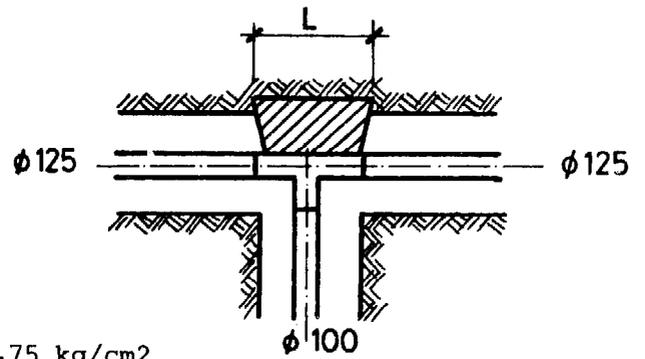
Water pressure = 10 kg/cm²

Permissible soil-bearing power $\sigma = 0,75$ kg/cm²

Out of Fig. 70: $P = 1,13$ tons, the factor for branches = 0,70

The required thrust-block area $A = \frac{R}{\sigma} = \frac{0,70 \times 1130 \text{ kg}}{0,75 \text{ kg/cm}^2} = \underline{\underline{1060 \text{ cm}^2}}$

Chosen: $\left. \begin{array}{l} L = 40 \text{ cm} \\ W = 30 \text{ cm} \end{array} \right\} \text{ with } 30 \times 40 \text{ cm} = 1200 \text{ cm}^2$



Example 2:

Thrust-block for a change of slope

Pipe ϕ 150 mm

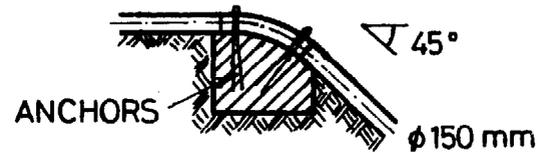
Water pressure = 7,5 kg/cm²

Specific weight of concrete = 2,4 t/m³

Out of Fig. 70: $P = 1,87$ tons, the factor for 45° = 0,76

The required thrust-block volume = $\frac{R}{2,4} = \frac{0,76 \times 1,87 \text{ t}}{2,4 \text{ t/m}^3} = \underline{\underline{0,59 \text{ m}^3}}$

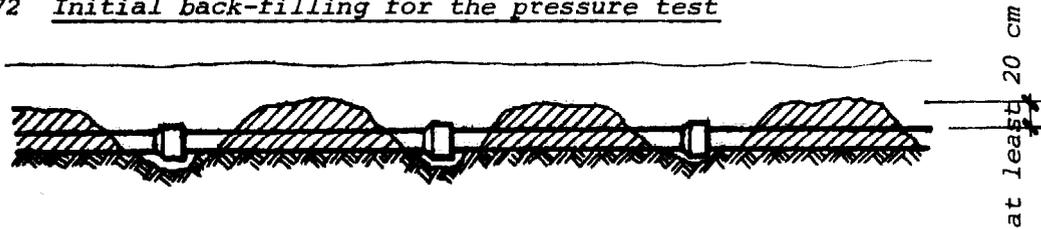
Chosen concrete thrust-block of 0,85 m x 0,85 m x 0,85 m (with 0,61 m³)



4-8.4.4 Pressure test of the pipeline

It is very important to test the pipeline before the trench is back-filled to discover in time leaks and damages on the pipes (e.g. cracks). After laying the pipes, the initial back-filling should be done as soon as possible.

Fig. 72 Initial back-filling for the pressure test

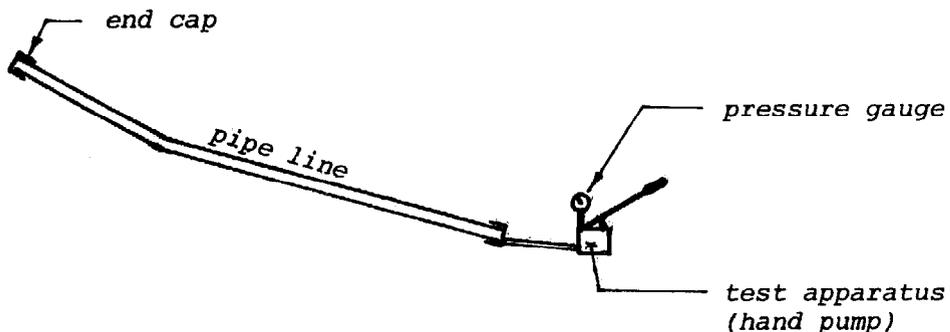


This initial back-filling prevents a movement of the pipe during the testing and protects the pipe from falling stones, trees, etc. Before the test can be started all the changes of directions and slopes have to be secured according to chapter 4-8.4.3 by thrust-blocks and anchors.

Where lines cannot be tested under pressure in a single operation, they shall be tested in sections. In that case, the joints linking individual test sections shall be tested for leaks by a final overall test.

The test pressure should be 20% to 50% higher than the service pressure of the very pipe section. But at the lowest point of the section it should never be higher than 1,2 times the nominal pressure of the pipes.

Fig. 73 Testing by pump

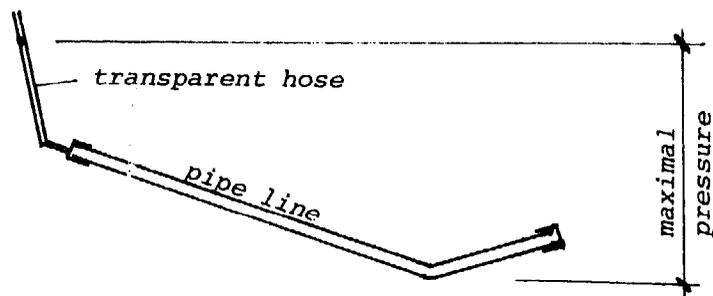


Calibrated pressure gauges shall be used for testing, graduated to permit correct reading to 0,1 kg/cm² pressure changes. It should be placed at the lower end of the section.

For plastic pipes, the pressure should be constant if the pipe-line is tight.

The limit for A/C pipes: The correct test pressure shall be restored every half-hour. Restoring is done by pumping water from the test apparatus into the pipeline. The volume of water required to compensate the loss by absorbtion shall not exceed 0,05 l/m² inner surface per hour.

Fig. 74 Testing by natural slope



For plastic pipes, there should be no loss of water in the transparent water hose.

For A/C pipes, the refilled amount of water should not exceed 0,05 l/m² inner surface per hour.

Notes:

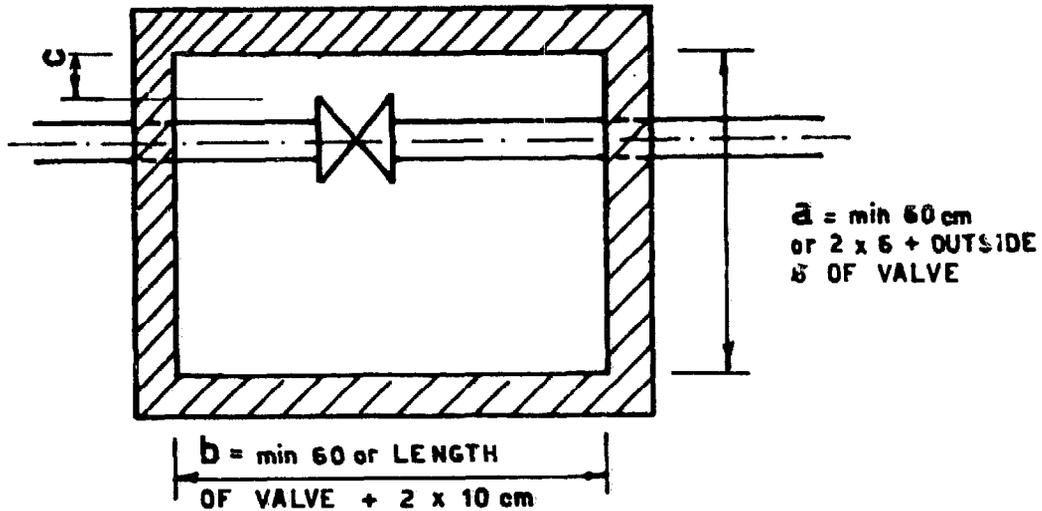
- The testing pressure shall last for 15 minutes/100 m length of pipeline.
- The air at high-points has to be released during the filling of the pipeline with water for the testing.
- The test procedure for asbestos cement pipes must take into account the limited degree of water absorbed by the pipe raw material. Therefore, the A/C-pipeline has to be filled with water under service pressure for at least 24 hours before the main test can start.

4-8.4.5 Valve chambers

It is necessary to have valves at intervals along a pipeline which can be used to control the flow of water. These valves are preferably situated in a chamber built of concrete or cement blocks.

Fig. 75 Chambers with a depth up to 1,0 m

C = min 20 cm for pipes ϕ 50 and 80) depending on the length of
 min 25 cm for pipes ϕ 100 and 150) the spanner to open the
 screw of the joint



Note: Length of valve always includes length of main valve and of ventilation valve.

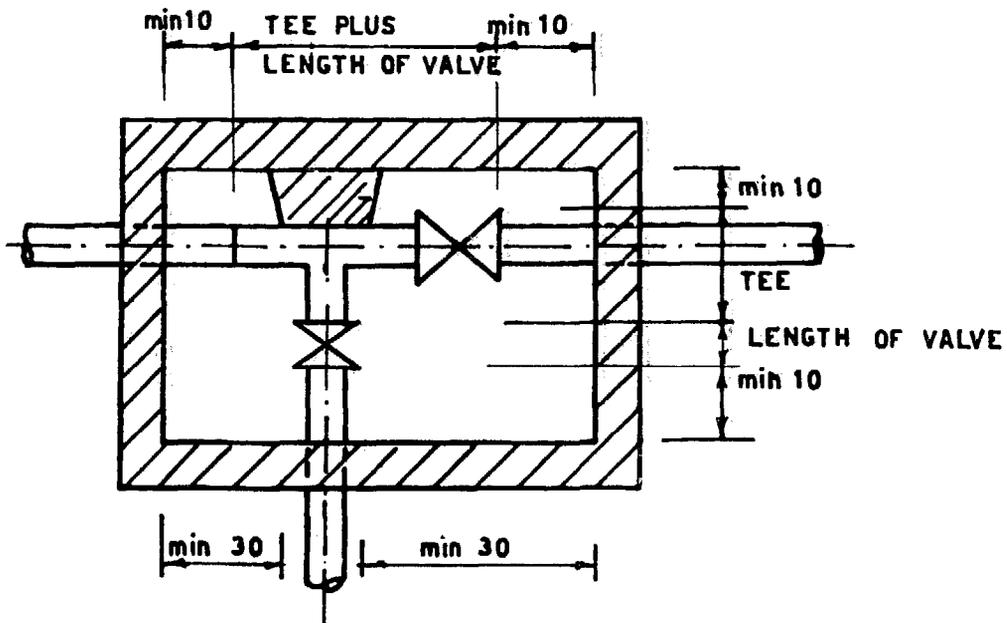
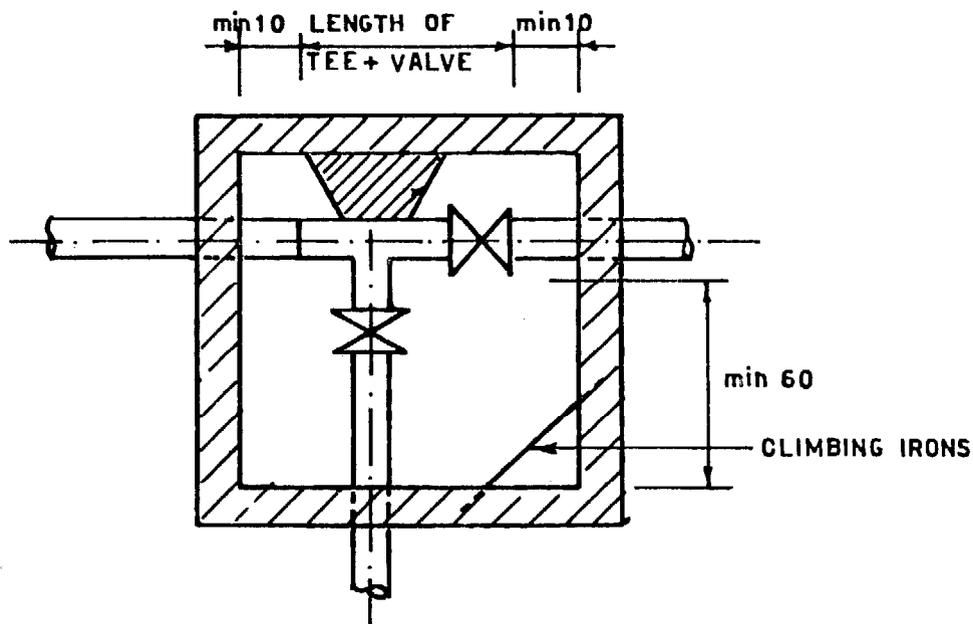
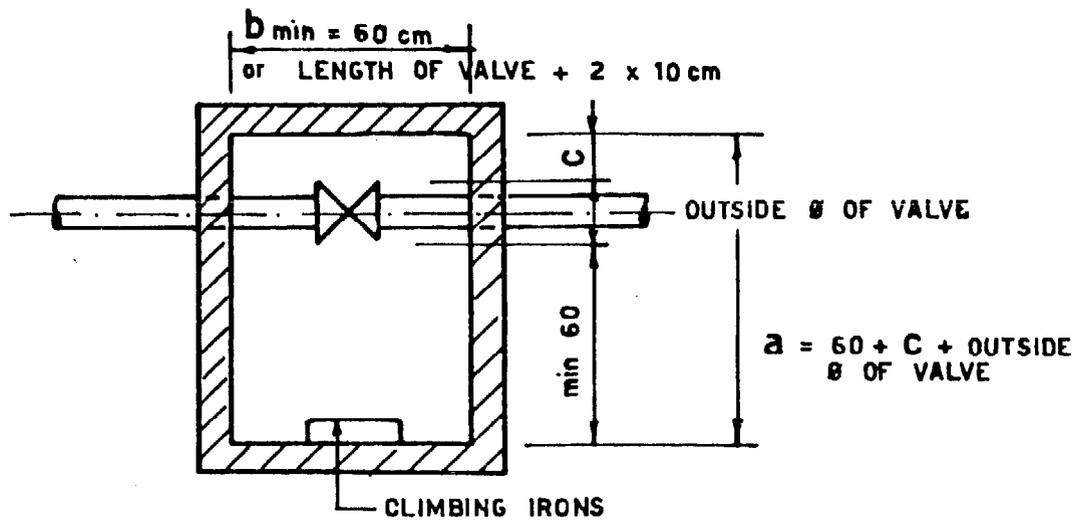


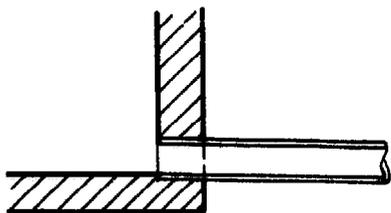
Fig. 76 Chambers with a depth more than 1,0 m



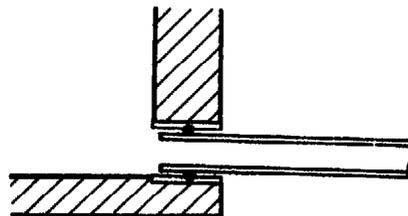
Note: Length of valves always includes lengths of main valve and of ventilation valve.

4-8.4.6 Pipe connections to buildings

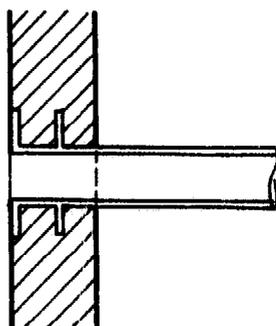
If a pipe passes through a wall, certain stresses from outside may affect it and could damage the pipe. It is, therefore, very important to prevent stresses by using constructional details as shown.



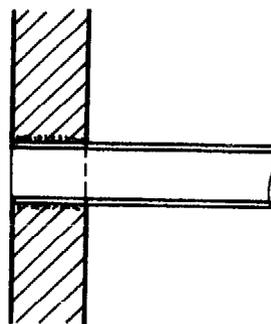
Rigid connection applicable for cleaning pipes or pipeline inside a building only



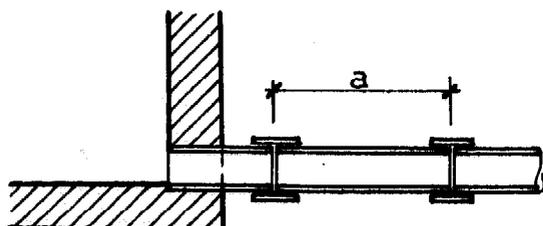
Flexible connection applicable for pipelines between different buildings or for pipelines which are laid into the ground and must be connected into a tank (rigid)



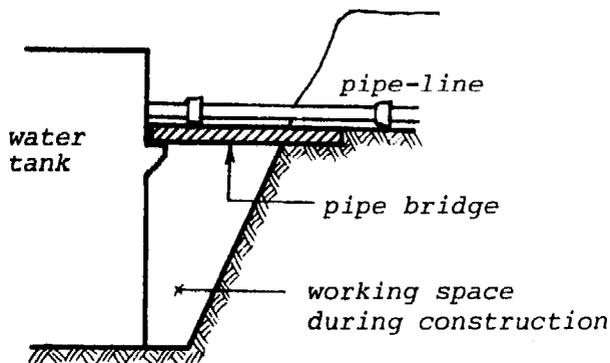
To make sure that there will be no leak where the pipes enter into the tank a single flange fitting with one flange in the middle of the wall is very useful



At the end of PVC pipes a layer of sand can be glued (with plastic glue). This solution allows to connect this pipe end directly to concrete



expansion/contraction slip joints



To prevent the pipeline from breaking by the settling down of the soil, a pipe bridge has to be constructed

4-8.5 DISTRIBUTION BUILDINGS

The most important distribution buildings are

- the public standpipes from where the consumers carry water
- the public washplaces where the population washes clothes, food crops or coffee
- and public shower houses.

Public standpipes and washplaces are installed according to the following requirements:

- a) Population concentration: Not more than 100 persons per tap
- b) Distances: No one should have to carry water more than 100 to 150 m.
- c) Technical consideration: Possible combination with high-points (aeration) or low-points (cleaning pipe).

Public shower houses should be constructed in projects where enough water is available and where no natural bathing facilities are at hand.

A standard rate is 100-150 persons per shower head.

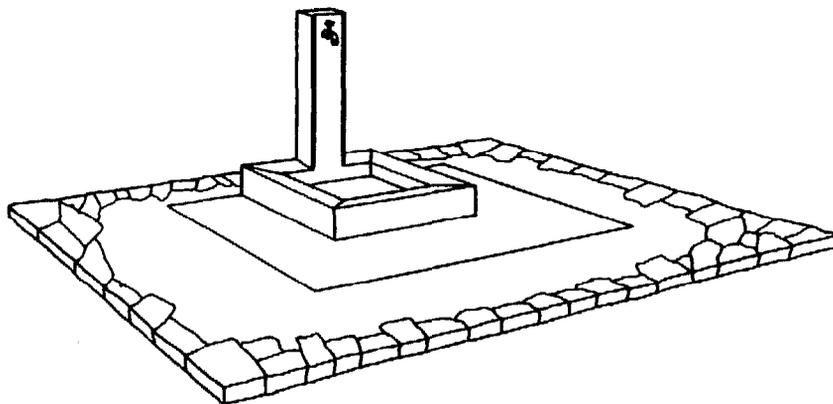
No one should have to walk more than 500 m to the nearest shower house.

Constructional hint:

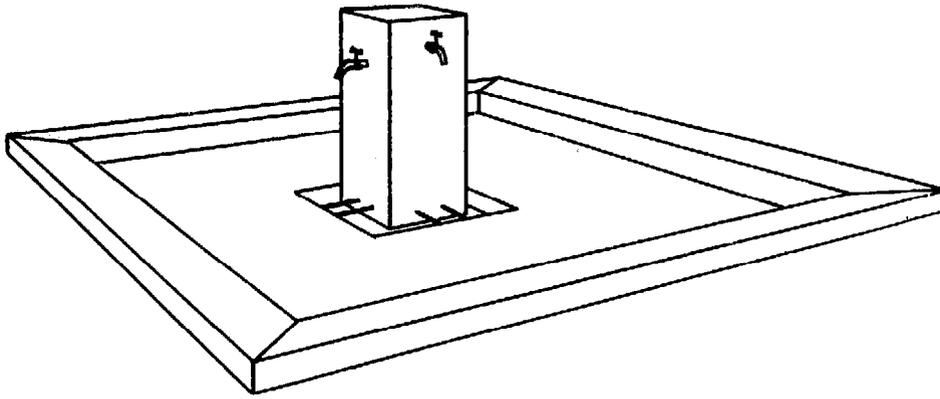
Every connection of a distribution building to the main pipe must have a valve or a stop-cock so that repairs on the pipe branch can be made without interruption of the main water supply.

4-8.5.1 Public standpipe

Fig. 77 Public standpipe



The standard designs in the appendix show the construction details and the list of materials for the public standpipe (Fig. 77) and the public fountain (Fig. 78).



Usually the public fountain is constructed on market places or in centres of towns.

4-8.5.2 Public washplaces

Fig. 79 Public washplace in concrete construction

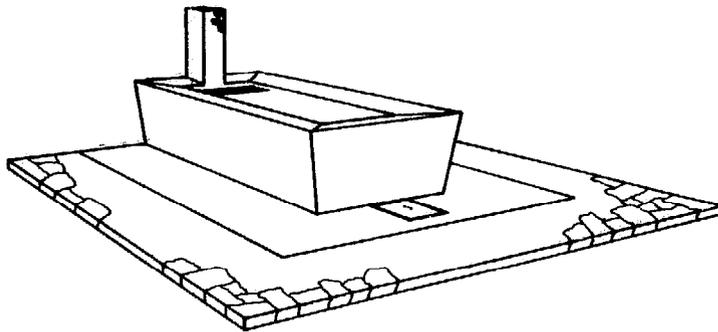
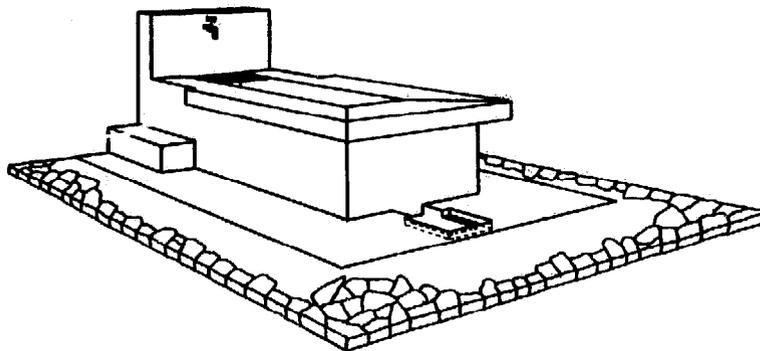


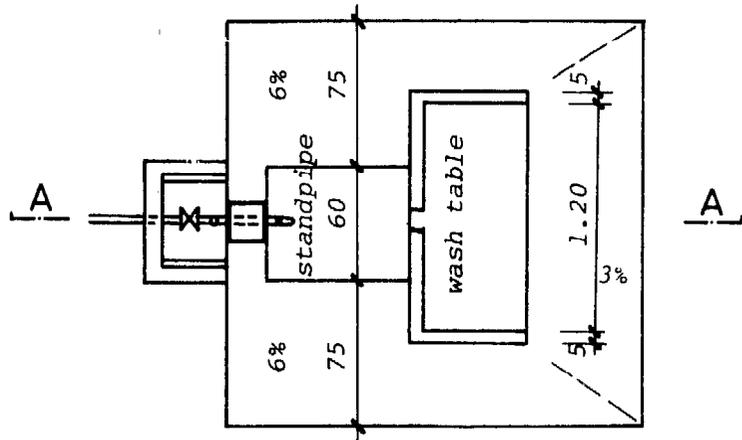
Fig. 80 Public washplace in stone masonry construction



The standard designs of Fig. 79 and Fig. 80 are shown in the appendix

Fig. 81 Standpipe with washtable

Ground plan



Section A-A

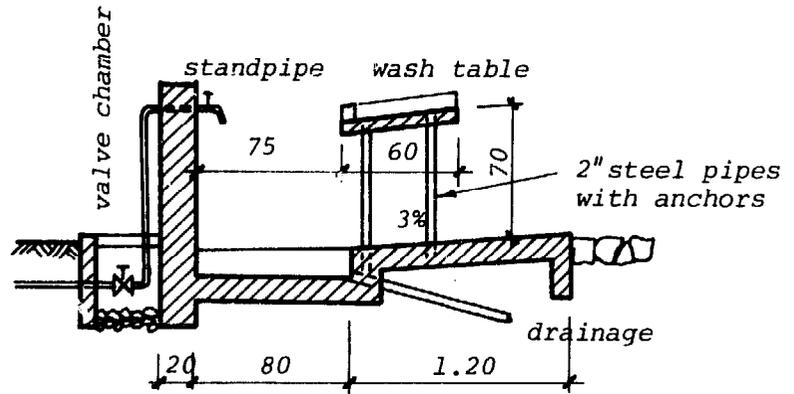
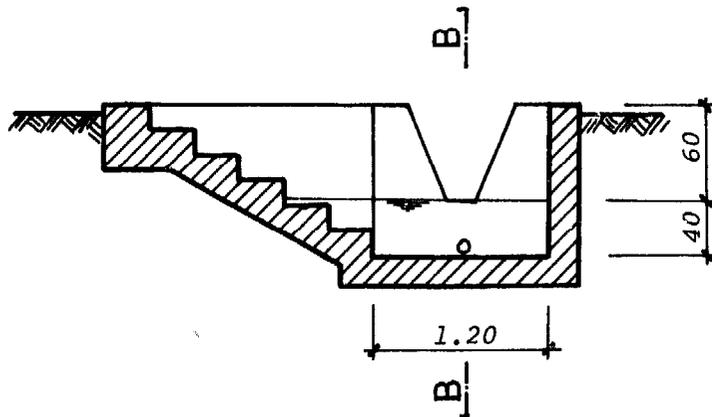
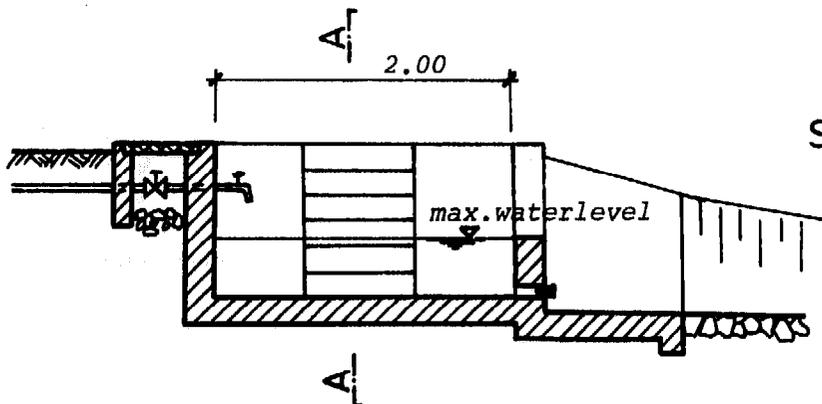


Fig. 82 Coffee wash-place



Section A-A



Section B-B

4-8.5.3 Public shower house

Fig. 83 Standard shower house

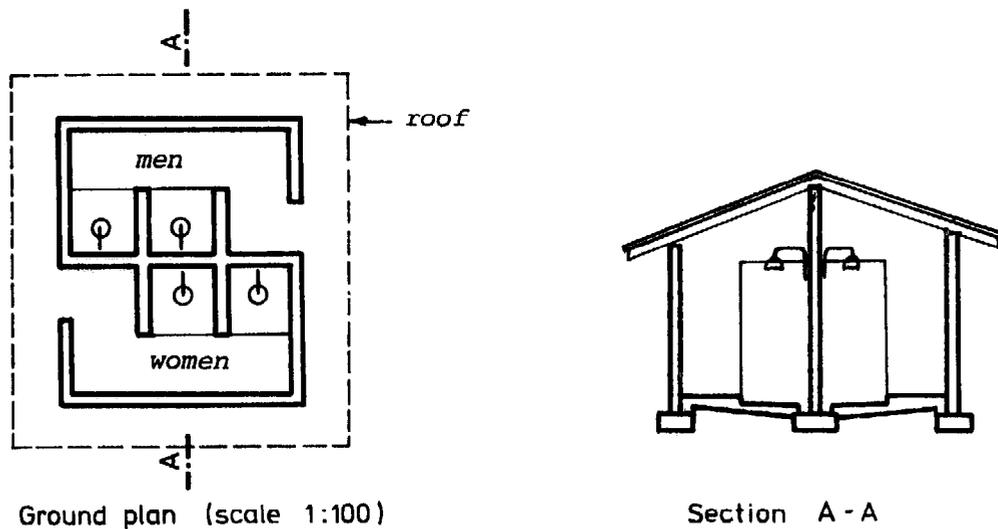
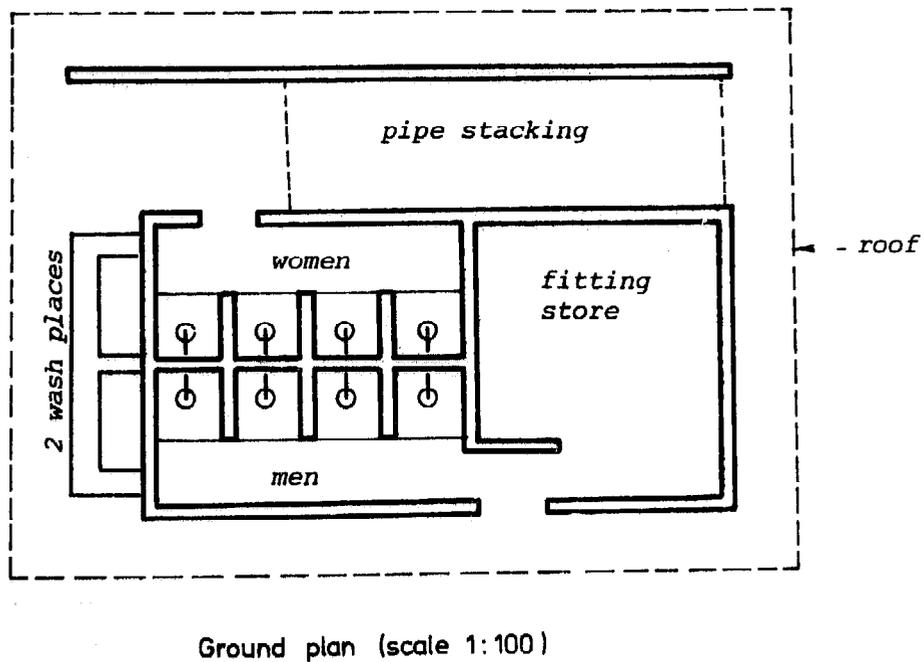


Fig. 84 Public shower house with 8 heads combined with a fitting store and 2 washplaces



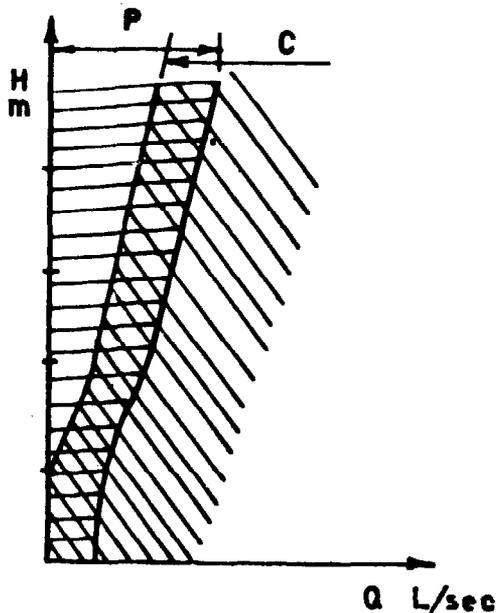
In rural areas, some villages may be situated in a way that enables them to obtain their water supplies entirely by gravity. This is a big advantage and should always be considered first when investigations for a water supply start. It can be said that it is always safer to construct a water supply which works by gravity, if this is possible, than one which requires pumping. The gravity system needs less maintenance and keeps the running cost low. The running cost and maintenance for pumps can be considerably high for a community which is financially weak. Nevertheless, in certain cases it is inevitable to install pumps to obtain the necessary water.

4-9.1 TYPES OF PUMPS

There are two main types of pumps which are suitable for water supplies

- plunger pump (or piston pump)
- centrifugal pump

The following diagram shows the application of each one in relation to discharge and delivery head.



P = Plunger pumps

C = Centrifugal pumps

The economical limit between the application of plunger pumps or centrifugal pumps lies at the ratio:

$$\frac{Q \text{ (l/sec)}}{H \text{ (m)}} = \frac{1}{30} \text{ to } \frac{1}{50}$$

Plunger pump:

The most common pump of this type is the reciprocating plunger pump in which water is moved by the direct push of a plunger or piston which reciprocates in a closed horizontal or vertical cylinder.

Centrifugal pump:

The pump-wheel turns with very high speed and centrifuges the water outwards producing the water pressure.

Summary:

Pumping systems	type of pump, application	driving energy, remarks
plunger pump	deep well pump (the pumping mechanism is located inside the well) for pumping-heights over 5m (see chapter 4-9.2.1)	- hand pump - driven by wind mill - animal drive - electrical or diesel engine
	Wing pump for suction-heights up to 5 meters	- hand pump
centrifugal pump	for high discharges of water	requires fast running drives: - electrical engine - diesel engine - petrol engine - water turbine
other systems	hydraulic ram (see chapter 4-9.4.1)	self drive by water (waterhammer)
	hydro pump (see Fig. 90)	- foot pump
	bucket and rope with rope pulley for wells	- manpower - animal drive - diesel engine

4-9.2 HAND PUMPS

4-9.2.1 Deep well pump

The hand-operated pump can be used in wells of any depth. In those which have a suction lift of less than 5 m, the pump-cylinder is usually placed above ground (shallow well pump, common pitcher pump). When the static water lift is more than 5 m, the cylinder is attached to a drop-pipe and placed in the well (deep well lift pump).

The deep well lift pump is one in which the driving mechanism (or power head) is separated from the pumping mechanism (or cylinder). The deep well operating pump must be located directly over the top of the water source, with the cylinder either submerged or within the suction lift (ca. 5 m) of the water. Since the water table level changes at different seasons of the year, it is best to have the cylinder in or very close to the water.

The experience has shown that this type of pump needs proper maintenance and frequent checking. Specially the stuffing box, made of brass, is not resistant to wear. The bolts for the pump head-connection have to be tightened properly. Heavy use of the hand pump can produce wear on loose bolts. Properly used, these pumps rarely require any expensive replacements, and any work done on them can be carried out by relatively unskilled persons.

A well designed deep well lift pump is a simple and economical solution to lift water from a deep well.

Fig. 85 Deep well pump
construction and maintenance needs

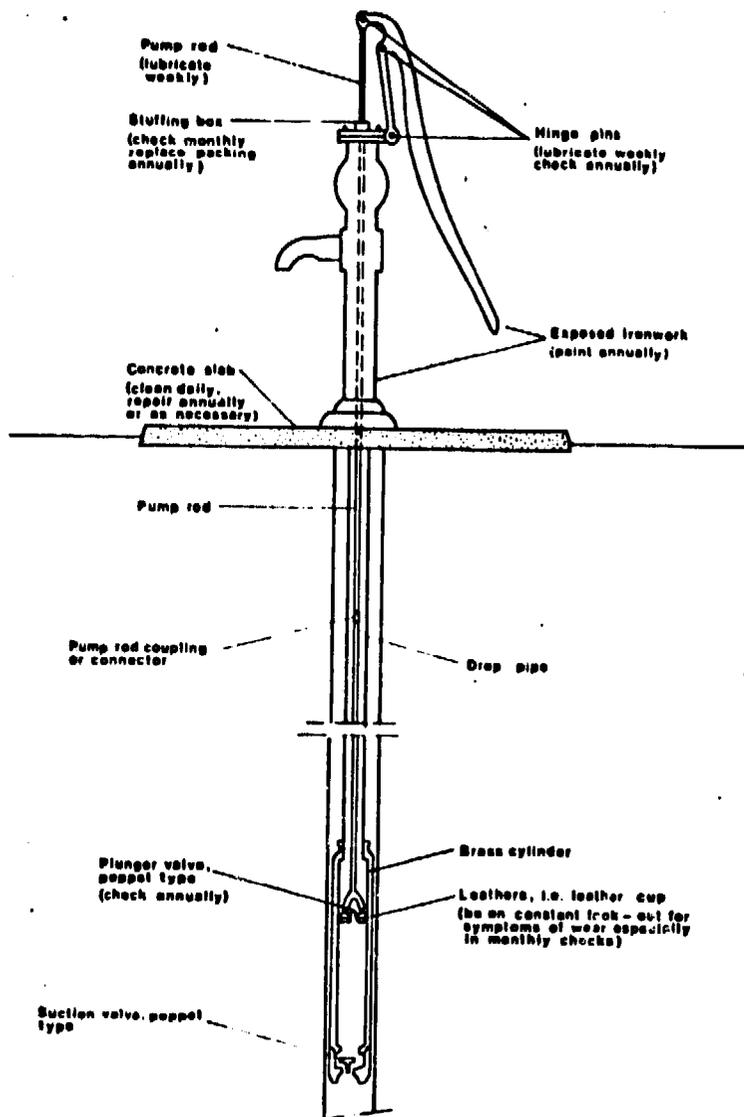
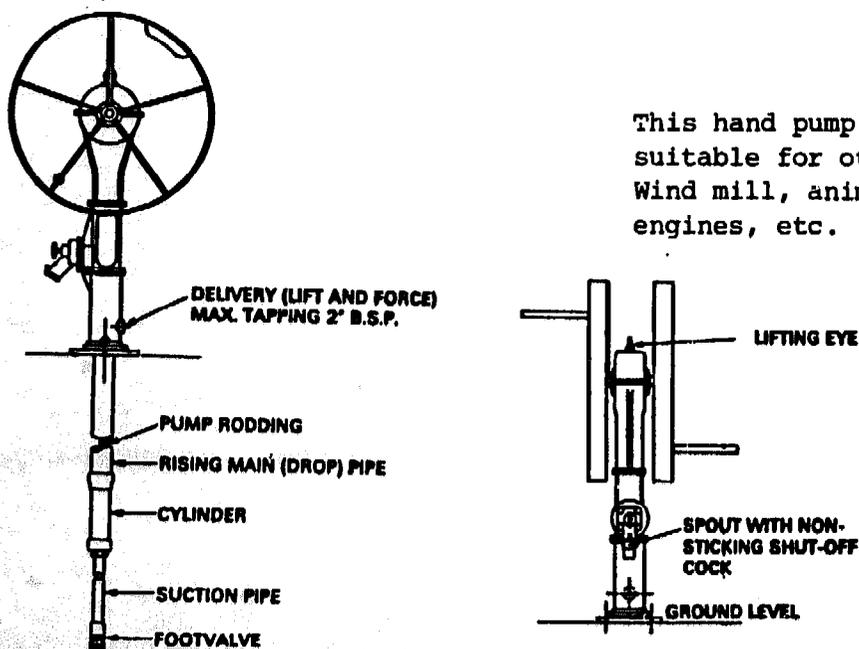
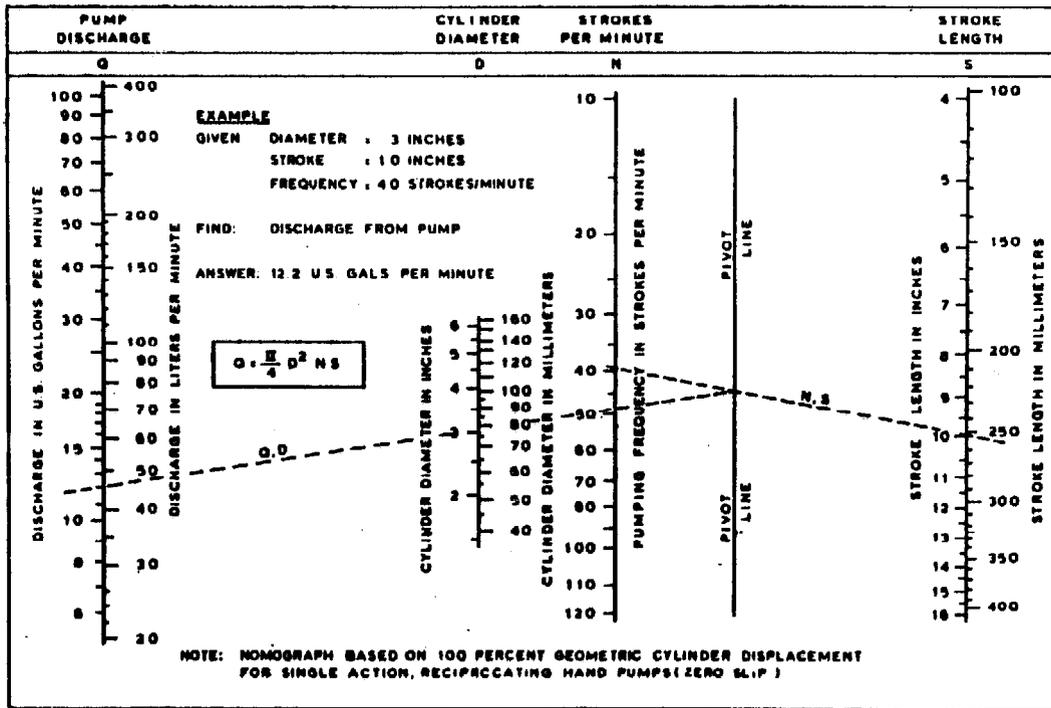


Fig. 86 Deep well pump with fly-wheel



This hand pump is also suitable for other drives: Wind mill, animal drive, engines, etc.

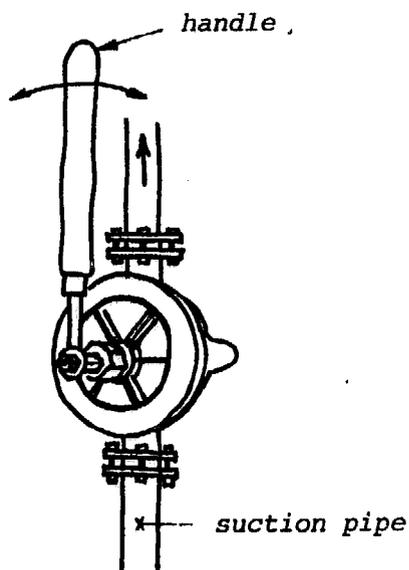
Fig. 87 Nomograph for hand pump discharge



Literature reference: 7 (see selected Bibliography)

4-9.2.2 Wing pump

Fig. 88



The wing pump is constructed differently to the plunger pumps but the working system is the same. Applicable for suction heights up to 5 meters only (with foot valve). Without a foot valve, wing pumps are only satisfactory for very short suction lifts.

4-9.3 CENTRIFUGAL PUMPS

These pumps are often used because they are light, simple and need only limited space for installation. Air vessels are normally not required. Regulation is done by the use of throttle valves. The connection to fast running engines is required.

Caution if the water contains sand !

The different types of construction:

- with vertical axle for installation in wells
- with horizontal axle for normal installation
- one or more stage units to meet high delivery heads

Mode of action:

In the centrifugal pump, energy is applied by a rapidly rotating impeller in which kinetic energy is transformed into water pressure. As a result water is propelled out of the discharge opening.

4-9.3.1 Planning of centrifugal pump installations

It must be very clear that the planning of centrifugal pumping plants should be done by an experienced engineer. The following explanations are not aimed to give all the required information in this respect. For more detailed information see "Planning of Centrifugal Pumping Plants" by Sulzer Brothers Ltd, 8400 Winterthur/Switzerland, or other relevant literature.

It will always be necessary when designing a pumping system to involve the manufacturer of the pump and the pump drive as early as possible in the planning.

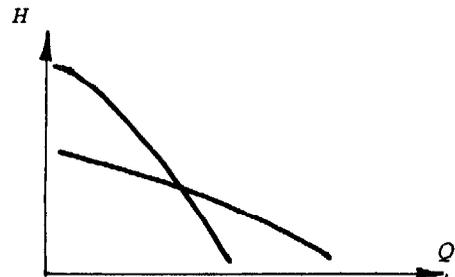
Pump characteristics:

Each centrifugal pump has a characteristic ratio between discharge, delivery head and revolutions. This characteristic is shown in a curve called characteristic line.

The characteristic line of a pump is calculated by the manufacturer and checked with a test installation.

There are pumps with steep and flat characteristic lines:

- steep characteristic line: small change of Q results big change of H
- flat characteristic line: Q changes very much even if H is changed only a little.



The head H as shown in the characteristic curves of centrifugal pumps is the total or manometric head, i.e. the increase in pressure that takes place between the suction and discharge branches of the pump, expressed in meters liquid column.

The head losses in piping installations include all losses due to friction, losses due to changes of direction of flow and sectional area, and any inlet and outlet losses into and out of containers.

Velocity in suction pipe:

$\phi < 100$ mm	max. 1.0 m/sec
$\phi \geq 100$ mm	max. 1.5 m/sec
normally	0.6 m/sec

Velocity in discharge pipe 1.5 m/sec to 2.5 m/sec. This velocity is quite high but with this it is possible to keep lower the costs for fittings.

Required number of pumps:

Each pumping station needs at least two independent pumping sets capable of providing the required delivery in order to ensure an adequate stand-by facility. Also, the system should be capable of pumping the maximum daily requirement ideally in 16 hours, and always in less than 20 hours.

Parallel running of centrifugal pumps is never economical. The discharge conditions have to be checked seriously if a second plant is installed to run parallel to an existing one.

4-9.3.2 Pump drives

There are various ways of driving a pump. The choice is generally governed by a community's financial resources. Always contact the manufacturer during the planning stage. Look for a drive which is sold on the local market (maintenance, repairs), if possible.

Water turbines:

A water turbine has the lowest running cost as a pump drive. Even though the initial investment is quite high, this system is in the long run cheaper than other drives.

The rotation of the turbine wheel or runner is caused by water flowing over curved vanes fixed to the rim. The action of these blades is to change the velocity of the water in magnitude and direction. The impulse given to the wheel is entirely due to this change of velocity. A force causing rotation results as the water passes over the vanes.

Turbines can be used in all cases where water is available in sufficient quantity with a head of at least 1.0 m. It is essential to contact the manufacturer in order to determine the correct type of turbine for a specific project as early as possible.

Diesel engines:

The most common pump-drive is a diesel engine, as such an engine is quite independent. It only requires gasoil and lubricants and these can be transported to nearly any place.

In the diesel engine, air is compressed to a high pressure, hereby raising its temperature to over 1000°C. Gasoil is injected by the injection pump through the injection nozzles and ignites spontaneously. Diesel engines are four stroke engines (some are two-stroke).

Diesel engines can be used to drive plunger as well as centrifugal pumps, provided suitable transmissions are fitted. A diesel engine should have about 25 % to 30 % more power than is required to drive the pump under normal conditions. For exact determination of the engine it is necessary to get in touch with both the engine and the pump manufacturer. It is important to state in your enquiry the altitude above sea-level, because the output of an engine decreases with increasing height.

Electric drive:

Electric Drive is to be preferred if electricity is available at reasonable cost. Electric motors are relatively low in original cost and are economical to operate. Mains electricity supplies can rarely be used for our purposes. Therefore, this drive is not explained more detailed.

4-9.3.3 Pumping stations

Pumps are installed in a covered pumping station to protect them from rain and bad weather. If the pump is driven by a diesel engine it is necessary to provide adequate space for fuel storage. Fuel should, whenever possible, be stored in a separate room planned for this purpose. The pumps as well as the engines (electric or diesel) should be placed to allow easy access. The height of the pump-basis should be about 70 cm above the floor. The minimum distance between two pumps should be at least 80 cm.

Some more important points are:

- suction lift never more than 5.0 m
- install always a strainer with a non return foot valve in the suction pipe
- the suction pipe and the reducers should be laid without any slope to avoid air-pockets
- install always a valve before and after the pump (possibly throttle valves)
- the stuffing boxes of the pumps should be leaking always
- pumps with big manometric heads should be operated in the following way:
 1. starting the pump
 2. open the valve
 3. running
 4. close the valve
 5. stop the pump
- the exhaust system of diesel drives should be properly installed. Ensure good aeration and ventilation of the operation room
- Never run the pump without water! If possible a security switch should be installed to avoid working of the pump without water.

4-9.3.4 Data needed by an enquirer

- 1) Arrangement or as per enclosed sketch No. altitude above sea level m
- 2) Purpose of pump
- 3) Duty of pump
 - a) Discharge in l/sec or cu.m/sec
 - b) Manometric suction head m liquid column
 - c) Manometric head m liquid column
(including manometric suction head under 3b)
- 4) Data for installation (only answer questions 4a and 4b if 3b and 3c above cannot be answered)
 - a) Static or geodetic head:
 H_d geo = Height between pump centre line and upper water level m
 H_s geo = Height between pump centre line and lower water level m
 H geo = Height between upper and lower water levels m
 H max
or
 H' max = Height between lower water level and free outlet m
 - b) Piping data:
 ϕ = Inside diameter of suction pipe mm
 L_s = Total length of suction pipe m
Number of bends in suction pipe
 - c) Supplementary information:
- 5) Water temperature °C
Specific gravity
Is pure water being handled?
Has the water corrosive properties?
Solid constituents, nature and quantity of mud, sand, quartz, etc. If large foreign bodies are present in the liquid, state maximum diameter of these mm
- 6) Drive
 - a) Electric motor drive:
Type of current: Direct, single or three-phase alternating current.
Frequency Hz (cycles/sec)
Voltage volts
Is the installation subject to dry, damp, wet or dusty conditions or is there a fire explosion hazard?

- b) Other drives:
 Petrol engine, Diesel engine, steam turbine
 If existent: Power N = Speed n = r.p.m.
- c) Belt drive:
 Driving pulley Diameter mm
 Width mm
 Speed r.p.m.

7) Service and economy

Is the pump to work in parallel with an existing unit and discharge into the same system ?
 If so, was the existing pump supplied by us ?
 Order No.
 If of other manufacture, enclose characteristic curve of pump. Is the pump to operate occasionally under conditions other than stated under 3a and 3b? If so, what are these conditions?
 Approximate number of working hours per year
 In case of electric drive, cost per kWh of electricity

8) Information required for approximate calculation of pressure fluctuations in the piping

The following additional data is necessary for this purpose

- a) For the working conditions at maximum discharge
 - If the new pump is to discharge into a common pipe with an existing pump or pumps, how great is the total maximum discharge quantity? l/sec
 H_{mano} would then be m

b) Discharge pipe:

- Total length of the pipeline m
- Mean inside diameter mm
- Static head at the pump m
- Longitudinal cross-section of the pipeline, also showing vertical elevations as per Sketch No. or Drawing No.
 (If necessary indicate the various inside diameters)
- Is the pipe directly connected to a reservoir?
- Is the pipe indirectly connected to a reservoir through a reticulation network?
- Is water continuously being tapped along the pipe, and if so, how much?

- c) Existing equipment to counteract pressure fluctuations. These may be: flywheels, air vessels, controlled non-return and discharge valves, air injectors, surge tanks, etc. If any such device is available please give brief particulars of its design, size, arrangement and the experience acquired with it

d) Remarks:

4-9.4 OTHER PUMPING SYSTEMS

4-9.4.1 Hydraulic ram

A hydram is the best water lifting device, provided sufficient water flow (drinking water) and head are available. Drinking water must be available in sufficient quantity because it is also used as driving water.

Mode of action:

In the hydraulic ram (hydram), power is derived from water-hammer effect, produced intentionally. The force of the water is captured in a chamber where air is compressed by the sudden stopping of the main flow of water, and released when the compressed air expands, pushing a small amount of the water to a higher elevation than that from which it originally came. The water not lifted to the higher level is wasted. Each compression and decompression of the air in the chamber propels a definite quantity of water up to a storage tank (reservoir).

There are two types of hydrams. Both types are in operation in North-West and South-West Provinces of the United Republic of Cameroon.

The two types are supplied by:

- John Blake Limited, P.O. Box 43, Accrington Lancashire, England
- Schlumpf AG, Maschinenfabrik, 6312 Steinhausen, Switzerland

Installation:

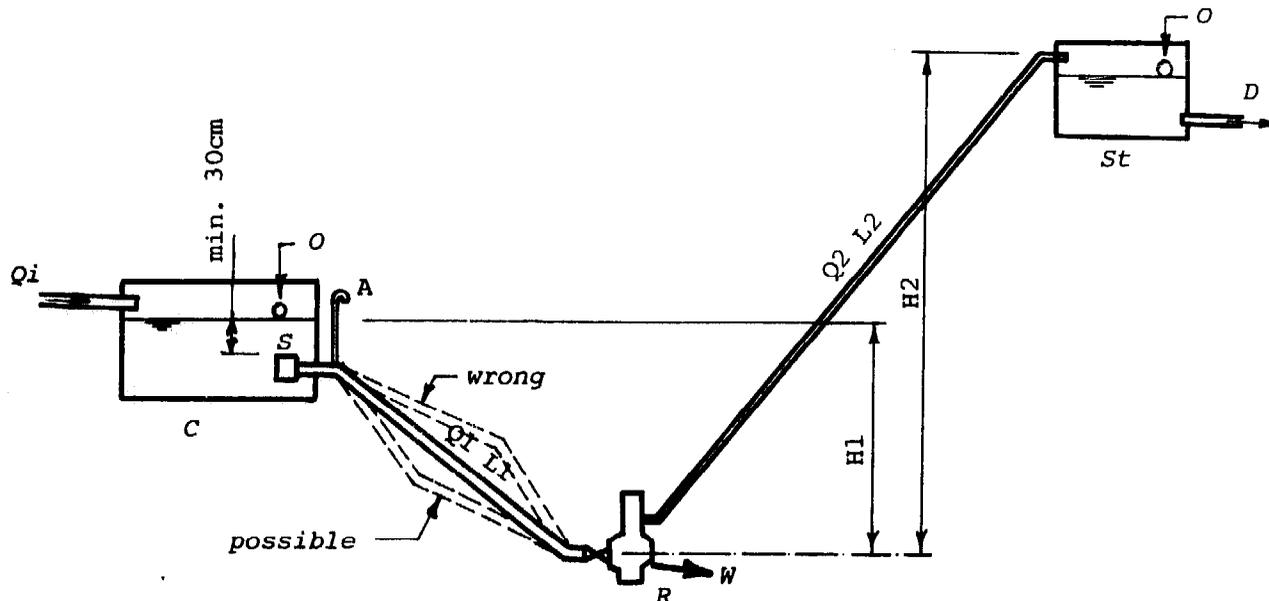
- Blake; this hydram must be firmly bolted to a concrete base
- Schlumpf; this hydram must be firmly bolted to its drive pipe (no concrete base). Only steel pipes should be used as drive pipes.

Ensure that the hydram is installed level. When a stop-valve is fitted on the drive pipe close to the ram, the valve should be fixed in a horizontal or oblique position to ensure that no air-pockets will form in the valve.

Note:

If a sluice valve is installed near a hydraulic ram it is necessary to fix the valve with its horizontal spindle (level) or if a special valve with an air tap is fixed the spindle should be at a 45° angle so that the air tap in the crown of the valve would be in a vertical position, so as to release any air which might accumulate there occasionally. If this point is not taken into consideration air may accumulate in the crown of the valve and this will influence the smooth operation of the ram or in some cases the ram will either stop or fail to pump water.

Fig. 89 Hydraulic ram



- A = airtation of driving pipe
- C = collection tank or sedimentation tank
- R = hydraulic ram
- St = storage tank
- Qi = supply from source
- O = overflow
- S = strainer at drive pipe
- Q1 = driving water
- L1 = length of drive pipe
- H1 = difference in elevation between ram and supply - power head
- H2 = difference in elevation between ram and storage tank to which water is to be elevated - pumping head
- W = waste-water
- Q2 = supply from ram to tank - possible daily consumption
- L2 = length of supply pipe
- D = distribution pipe

Given suitable circumstances - a situation similar to that shown in which the supply of water is considerably in excess of the needs, and is situated in a way that permits the ram to be located well below the supply - the hydram can be an excellent solution to a pumping problem. It requires practically no maintenance and will work 24 hours per day requiring neither attention nor operating costs!

When the driving water is delivered by a stream, the water has to pass a sedimentation tank in order to permit sand to settle out of the water. Period of detention approx. 1 hour.

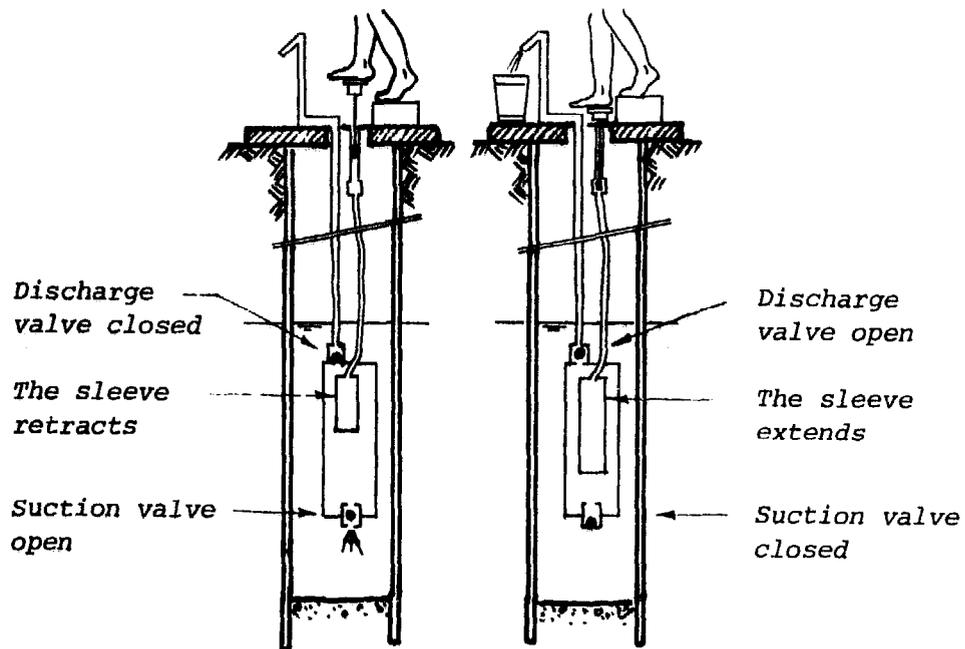
When writing to the manufacturer about ram sizes, the information in items Q1, L1, H1, Q2, L2, H2 is necessary.

Keep in mind $\frac{H1}{H2} = 1:4$ to $1:8$. The drive pipe should have a static pressure H_1 of max 15 m, if more, we need more stages.
(1:4 to 1:5, for rams of the make "Blake").

4-9.4.2 Hydro pump

The hydro pump can be used in wells of depths up to 60 m.

Fig. 90 The principle of the hydro pump



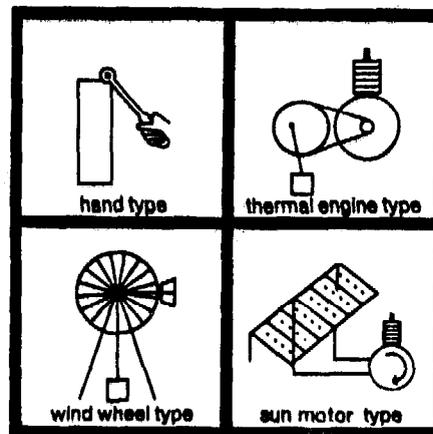
***Suction:** The pedal goes up, the sleeve retracts: water is sucked into the stainless steel pump body.*

***Discharge:** The pedal goes down. Hydraulic pressure is exerted in closed circuit on the elastic sleeve which expands and chases water to the surface.*

The advantages of this pumping system are:

- the easy installation of the pump
- the simple maintenance (all wearing parts are located in the pump head and are directly accessible).

Hydro pumps can be adapted for other types of drive:



Chapter 5: ADMINISTRATION OF PROJECTS

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5-1 TECHNICAL REPORT

5-1.1 THE AIM OF THE TECHNICAL REPORT

The technical report is an important document, necessary in the various steps of planning and implementing water schemes or other constructions.

In the hands of the Ministry concerned, the technical report is the basic tool for preparing the budget of the new financial year as well as for the planning of the yearly activities. The technical report is required by the engineer or the technician in order to plan and to start a project.

Foreign aid organizations interested in co-financing a project will find all necessary information and details in the technical report.

The technical report must be well presented and should be attractive to the reader. Each page should be numbered and clear reference to the various chapters should be given.

5-1.2 CONTENTS OF THE TECHNICAL REPORT

Listed below, as a guide line for technicians and engineers, are the main points that make up a technical report. Emphasis should be put on the preliminary surveys of the sources, before drafting the technical report (see chapter 3-4.1).

1. Introduction

Reasons for proposing the project (e.g. present water conditions)
Situation and actual infrastructure
Population and demographic development
Socio-economical aspects (here, detailed and clear information is especially necessary)
Self help activities
Map of the country showing the situation of the village

2. Water budget

Available water and analysis
Water consumption, actual and future
Water balance

3. Project description

Hydraulic system (general lay-out, chapter 4-1)
Catchment
Sedimentation, other purification plants (e.g. slow sand filter)
Pumping station, interruption chamber
Storage tank, other tanks
Distribution
Construction methods, choice of material

4. Estimated cost

The estimated cost should be as accurate as possible. It is necessary to indicate the size and quantity of material (cement, reinforcing iron, pipes, etc.). If possible, include the inflation cost during the estimated construction time.

Cost in cash:

a) Buildings

Catchment
Sedimentation tank (or interruption tank)
Storage tank
Stand pipes, wash basins
Shower house & store

b) Hydraulic installations

Pipes (plastic, galvanized, asbestos, etc.)
Pump with driving engine (motor-pump)

c) Sundries (10 to 15 % of buildings & hydraulics)

Transport
Tools, lubricant, spare parts
Contingencies

Cost in kind:

a) Community

Bush clearing, opening access roads - excavating & backfilling of trenches and pits (foundations)

Supply of stones, gravel, sand, wood and other material available locally

Organization of community work

b) CD Department / SATA-Helvetas

Survey, projecting & planning
Administration and supervision

Total cost of the project (= cash + kind)

Cost per capita / actual & stage I

5. Proposed financing

Village contribution in cash	10 %
Village contribution in kind	10 %
Government contribution in cash (various grants)	20 %
CD / SATA-Helvetas in kind	20 %
Foreign aid in cash	<u>40 %</u>
	100 %

6. Organization of the project

The Project Committee:

- organizes meetings & community work
- organizes the supply of local material
- collects the village cash contribution
- prepares applications for grants (government & other)

Consultants to the Committee:

- the community development officer and the engineer are consultants to the Committee

7. Maintenance of the project

Maintenance is one of the most important points to consider before planning a water scheme. Please read with attention Chapter 6 where all important information is given.

8. Final remark and recommendation

These remarks are meant to recommend in a summary the construction of the project.

The completed report will be signed by the engineer (or technician) and by the CD-Officer of the area.

Annexes to the technical report

Map of the country indicating the situation of the village.

Plans of the village (lay-out) including all buildings and installations to be constructed.

Hydraulic profile of a water supply.

5-2 EXECUTION OF PROJECT

5-2.1 BEFORE STARTING A PROJECT

A project should not start before it is approved by the Community Development Department and by the local authorities.

It is necessary to have a clear picture of the financial sources as: dates of instalment from external aid, confirmation of government grants, etc. At least 50% of the village contribution should be paid to the project account before starting the construction work.

It is necessary also:

- to have recruited all masons & labourers needed
- to have all tools, material & machines ready
- to have completed the technical report with execution plans
- to have prepared the list of material to be ordered

5-2.2 DURING THE CONSTRUCTION

Close supervision is necessary to build properly the different elements of a construction project.

At the project site, daily reports must be made and a log book with material book must be kept regularly by the foreman.

Periodic reports have to be prepared by the engineer. These reports show the progress of the work, the problems, the contact with the local population, the financial situation and include a proposition of how the project will continue.

When financial grants are given according to the progress of the construction, a report and a financial statement are required in order to receive further amounts (Progress Report).

5-3 COMPLETED PROJECT

5-3.1 FINANCIAL STATEMENT

As soon as the project has been completed a financial statement will be handed over to the department concerned (Community Development or other departments).

The statement will show clearly the cost in cash on one side and the cost in kind on the other side for each partner involved in the project.

5-3.2 FINAL REPORT AND HANDING-OVER FILE

A final report of the completed project will be handed over at the same time as the financial statement to the CD department and to the Project Committee.

The final report should include the following:

- Technical report, technical details & plans of all constructions.
- A brief history of the project.
- Comments on the technical aspects (possibility of extension, lifetime expectation of installations, output, special care) and on the expected influence of the new construction on the villagers and their surroundings.
- Handing over note concerning the buildings & installations to the Project Committee and a duty sheet to the caretaker.

5-3.3 DRAWING OF PLANS

A complete set of execution plans for all constructed buildings and installations of the project should be drawn. These plans must include all modifications made during the construction.

A site plan (lay-out) of the project should be drawn to scale 1 : 1000, 2000 or 5000 and show all new buildings and hydraulic installations (air valves, cleaning valves, etc.) and houses of the village with foot path.

5-3.4 DOCUMENT FILE OF A COMPLETED PROJECT

Technical report, estimates, calculations, instructions (pumps, turbines & other engines).

Correspondence and receipts of material.

Minutes of meetings and opening addresses.

Repairs, possibilities of extension.

Final report with financial statement.

All situation and execution plans.

Chapter 6: MAINTENANCE OF RURAL WATER SUPPLIES

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6-1 MAINTENANCE GENERAL

Once a water scheme is completed it is necessary to pay great attention to its maintenance so as to ensure a continuous supply of drinking water of good quality and sufficient quantity.

The completed construction of a water scheme has to fulfill all expected hygienic and technical requirements. Therefore, an improperly maintained water scheme can be a great danger to the entire population of a village because everybody assumes that the water flowing from the tap is good drinking water.

Water is one of the most important elements of your life.

WITHOUT WATER NO LIFE !

Organization of the maintenance:

Before the completed project is handed over to the villagers the maintenance of the water supply should be organized taking the following points into consideration:

- A water supply maintenance committee should be formed in the village which takes the responsibility of the completed project.
- A caretaker should be employed. He will carry out the entire maintenance of the project as it is described in the following chapters.
- The engineer concerned is responsible to instruct the caretaker before handing over the project.
- All financial matters and distribution of responsibilities for an efficient maintenance should be regulated in advance.

6-2 MAINTENANCE-INSTRUCTIONS

6-2.1 MAINTENANCE OF WELLS

Every week:

Control the cleanliness of the well, hand pump and surroundings. If necessary arrange for cleaning work, to be carried out by the population. The drainage of waste water (overflow) is very important, to prevent any contamination of the ground water.

Every month:

Grease or lubricate every hand pump (compare Fig. 85). With an engine-driven pump, follow strictly the manufacturer's instructions regarding service and maintenance.

Every four months:

Check the construction and buildings and repair all damages. Minor repairs should be done without delay as soon as they are discovered.

All necessary maintenance work should be done regularly. If any problem cannot be solved by yourself, contact the nearest Community Development Office, which will give the necessary assistance in cooperation with the community and local council concerned.

6-2.2 MAINTENANCE OF CATCHMENTS

6-2.2.1 Maintenance of spring catchments

Protective zone of the catchment area:

Do not permit clearing and cutting of trees from the catchment area but maintain the fire boundaries (gaps) around the area (in the grassfield).

Weekly inspections are necessary, especially during the farming season. Prevent any farming inside the catchment area, report people concerned to the local authority or to the administration. Special attention must be given to hair roots entering the catchment; if they are not removed they can cause a blockage in a short time.

Spring catchment and inspection chamber:

Once a month the overflow and surface drainages have to be inspected and the grass must be kept short. Water measurements should be taken whenever possible. Additional checking is necessary after heavy rainfalls.

Two times a year (March and September) inspect and clear the collection and inspection chambers if necessary. Clean and grease locks. Check up whether there are any damage or cracks in slabs, chambers, pipes etc.

Minor repairs:

Damage such as leaking pipes, cracked slabs etc. have to be repaired without any delay as soon as they are discovered. If the supply has to be stopped for necessary repairs the population has to be informed in advance.

Major repairs:

Repairs which require the attention of the engineer have to be reported as soon as they are discovered.

Comments:

All necessary maintenance work should be done regularly. If any problem cannot be solved by yourself, contact the nearest Community Development Office, which will give you the necessary assistance in cooperation with the community and local council concerned.

6-2.2.2 Maintenance of barrages and river intakes

Inspections:

Weekly: inspect dam, especially the spillway and intake. Check water quality. If unusual contamination is observed find its cause (farming, fertilizer, washing, fishponds, latrines etc.)

Monthly: inspect the overflow, check if there are any cracks or other damage.

Minor repairs:

Minor repairs, once a fault is discovered, have to be done without any delay.

Major repairs:

Repairs which require the attention of the engineer have to be reported as soon as they are discovered, to prevent waste of water, contamination and further damage.

6-2.3 MAINTENANCE OF TREATMENT STATIONS

6-2.3.1 Maintenance of sedimentation tanks

Inspections:

Monthly: clean and drain the tank. Keep installations, overflow, vent holes and drains clean. Cut the grass around the entrances. Grease doors, locks, valves etc.

Twice a year: general check up of the buildings for damages such as cracks or leakages.

Minor repairs:

Minor repairs, once a fault is discovered, have to be done without any delay to prevent waste of water and contamination.

Major repairs:

Repairs which require the attention of the engineer have to be reported as soon as they are discovered, to prevent waste of water, contamination and further damage.

6-2.3.2 Maintenance of slow sand filters

Cleaning of the filter:

If a filter requires cleaning, the water has to be drained first. Then 1 cm to 2 cm of the sand surface must be carefully scraped off. When the sand-bed requires cleaning again a further layer of 1 cm to 2 cm of sand is removed from the surface. This process is repeated until the minimum thickness for efficient filtering of about 45 cm is reached. This level is marked in every filter. After each cleaning the filter is returned to service. Though the flow of water is reduced at first and the effluent is not connected to the supply until it shows that it is properly purified after an interval of about one to two weeks. The intervals for cleaning will depend on the amount of water which passes through the filter as well as on the contamination. It might be necessary in some areas to clean the filters every 3 to 4 weeks and in others every 8 to 12 weeks.

If the sand-bed has reached the minimum thickness it is necessary to wash out all the sand removed previously as well as the remaining sand in the filter. After this it will take at least 2 weeks until water from this filter can be used again for drinking.

Washing of contaminated sand:

It is absolutely essential to stir the sand in such a way that all contamination is washed out. To check if the sand is clean, take a hand-full and rub it between your hands, if there is any sign of dirt on your hands the sand is not yet clean enough.

The above should be understood as a general guideline. All instructions given by the engineer for each project should be followed strictly.

Engineers in Cameroon are presently testing special sand wash places. Once the results are available, a standard design could be worked out.

General inspection:

Twice a month: Inspect the filter plant, keep installations, overflows and drains clean. Cut the grass around the entrance.

Twice a year: General check up of buildings for damages (cracks or leakages).

Minor repairs, once a fault is discovered, have to be done without any delay to prevent waste of water or contamination.

Major repairs, requiring the attention of the engineer, have to be reported as soon as a fault is discovered, to prevent waste of water, contamination and further damage.

6-2.4 MAINTENANCE OF STORAGE TANKS

Inspections:

Monthly: Clear the surroundings. Keep vents, drains, etc. clean. Check the water quality and for possible contamination. Check installation (valves), look for leaks.

Twice a year: Clean the storage-tank, look for damages on the buildings, cracks, leakages, plastering, installation.

Minor repairs:

Once a fault is discovered, repairs have to be done without delay to prevent waste of water or contamination.

Major repairs:

Repairs which require the attention of the engineer have to be reported as soon as a fault is discovered, to prevent waste of water, contamination and further damage.

6-2.5 MAINTENANCE OF WATER POINTS

Maintenance of the spring catchment: see chapter 6-3.1

Weekly: clean wash-basin, if any

Monthly: clear the surroundings, cut grass. Keep air vents, drain, etc. clean, check quality of water and for possible contamination.

At least twice a year: clean the storage-chamber, look for damages such as cracks.

Important: Greatest attention must be given to the drainage.

Minor repairs, once a fault is discovered, have to be done without any delay to prevent waste of water or contamination.

6-2.6 MAINTENANCE OF DISTRIBUTION SYSTEM

Stand pipes, wash places and shower houses:

Daily: Cleaning by the consumer. Special care should be given to the drain pipe.

Weekly: General check up and special cleaning.

Monthly: Cut the grass if necessary.

Leaking taps have to be repaired immediately to avoid loss of water.

Soakaways don't need much maintenance. In case they are blocked by dirt they have to be cleaned immediately.

Valve chambers:

Twice a year: Inspect and clean them. Any broken slab should be replaced. Repairs have to be done without delay once a fault is discovered. All valves should be closed and opened during these inspections.

6-2.7 MAINTENANCE OF PUMPING STATIONS

Pump and drive:

The manufacturer's maintenance instructions have to be strictly followed.

A special instruction manual for each pumping station regarding maintenance can be made available (from the appropriate engineer).

Buildings:

Monthly: Check installation for correct functioning (valves or stopcocks). Look for leakages. Paint the installation, grease locks, etc. Check that overflows and drains are clear.

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CH-9000 St. Gall, Switzerland

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Appendix: NORM PLANS AND SCHEME PLANS

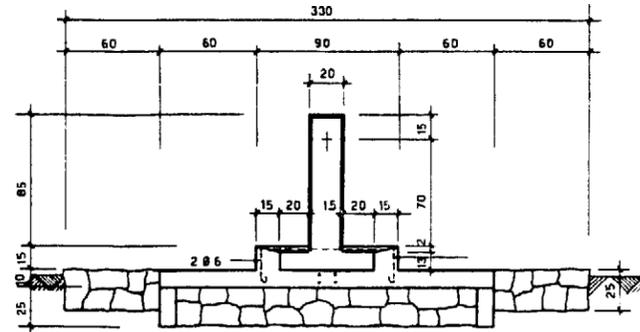
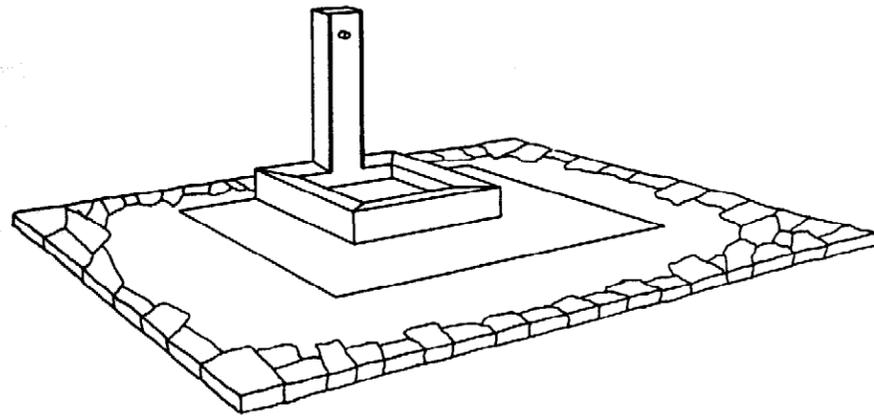
Norm plan No.	Title of plan
1	Public stand pipe
2	Public wash place (in concrete construction)
3	Public wash place (in masonry construction)
4	Public fountain (in masonry construction)
5	Interruption chamber with ball valve
6	Water point (in masonry construction)

Scheme plan No.

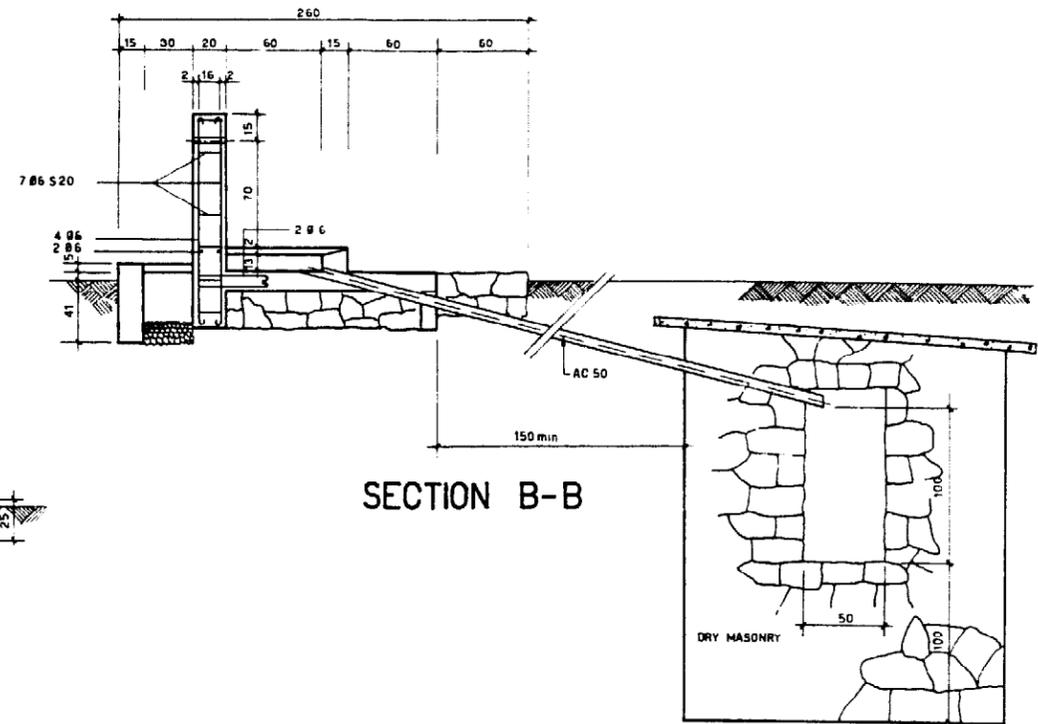
7	Plumbing scheme of single storage tank
8	Plumbing scheme of double storage tank

Project plans as examples

Mankaha Bafut Water Supply (Situation plan)
Mankaha Bafut Water Supply (Hydraulic Profile)



SECTION A-A



SECTION B-B

LIST OF MATERIALS

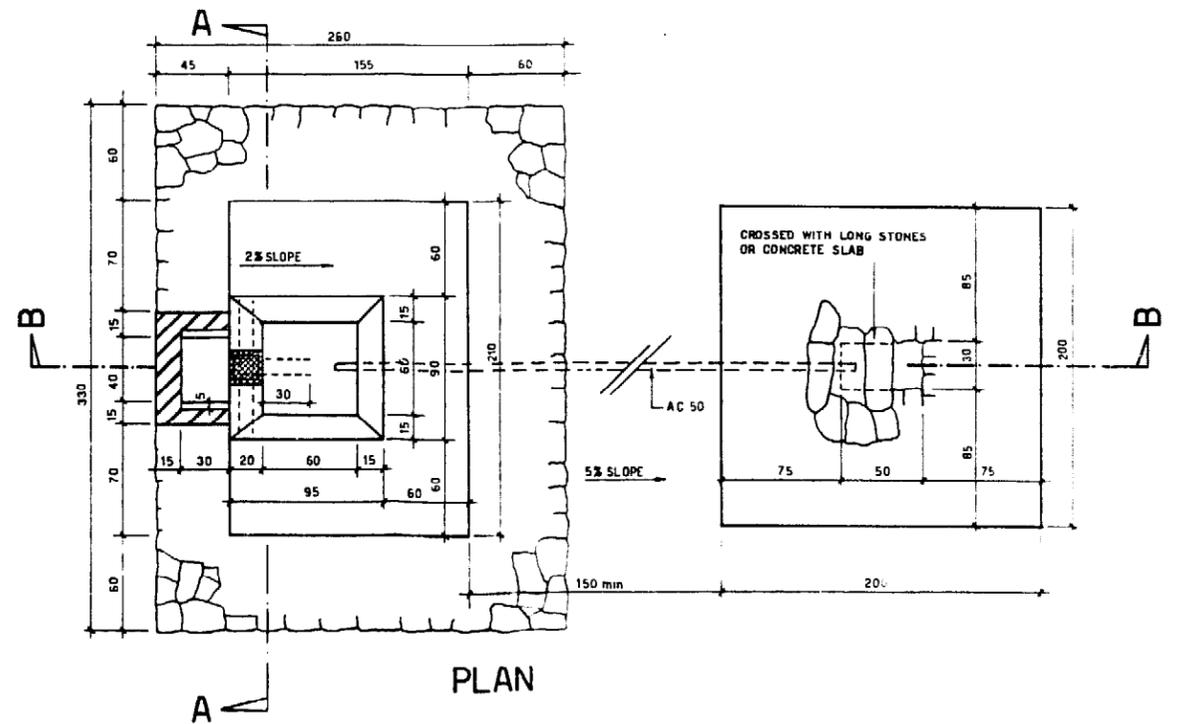
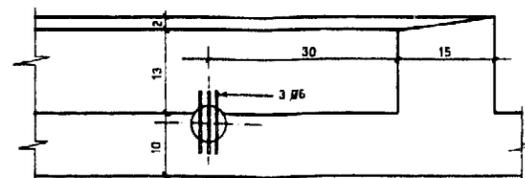
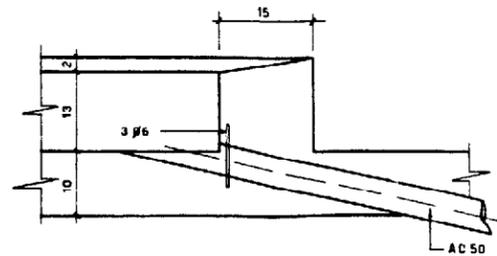
STAND PIPE

- CEMENT 5 BAGS
- WELDED MESH 26 x 46 cm
- RODS ϕ 6mm 30m
- 2no. ϕ 6mm $\frac{10}{10} \times \frac{95}{10} = 1.45m$
- 2no. ϕ 6mm $\frac{10}{10} \times \frac{475}{475} = 1.20m$
- 7no. ϕ 6mm $\frac{10}{10} \times \frac{10}{16} = 0.67m$
- 4no. ϕ 6mm $\frac{10}{10} \times \frac{10}{10} = 1.50m$
- 3no. ϕ 6mm $\frac{10}{10} = 0.10m$

- A.C 50 4.0m 1 PIECE
- G.I. $\frac{3}{4}$ " 0.25m 1 PIECE, TAP $\frac{3}{4}$ " 1 $\frac{3}{4}$ " or $\frac{1}{2}$ "
- G.I. SOCKET $\frac{3}{4}$ " 1, G.I. ELBOW $\frac{3}{4}$ " 1 $\frac{3}{4}$ " or $\frac{1}{2}$ "
- STONES 5m³
- SAND 1m³
- CEMENT BLOCKS 6no 15 x 20 x 40cm

SOAKAWAY

- CEMENT 1 BAG
- STONES 10 m³
- SAND 0.11m³



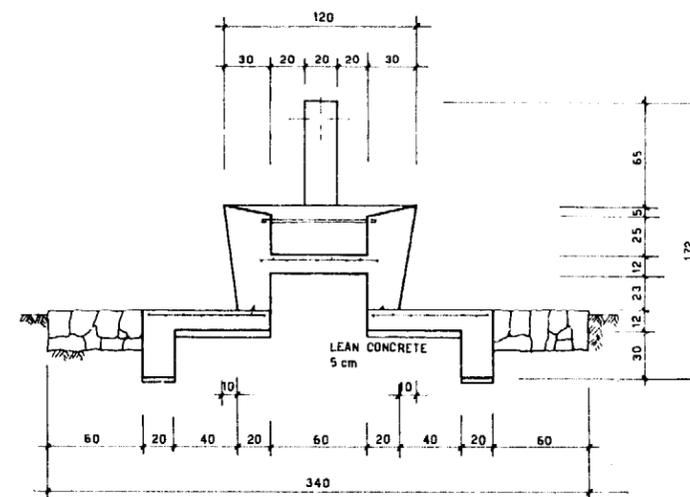
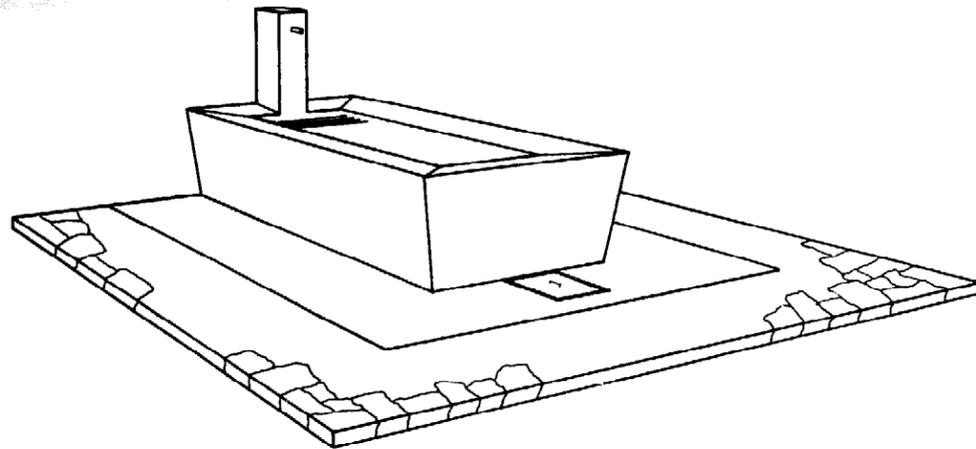
PLAN

COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE
 UNITED REPUBLIC OF CAMEROON
 HELVETAS
 SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (S.A.T.A.)

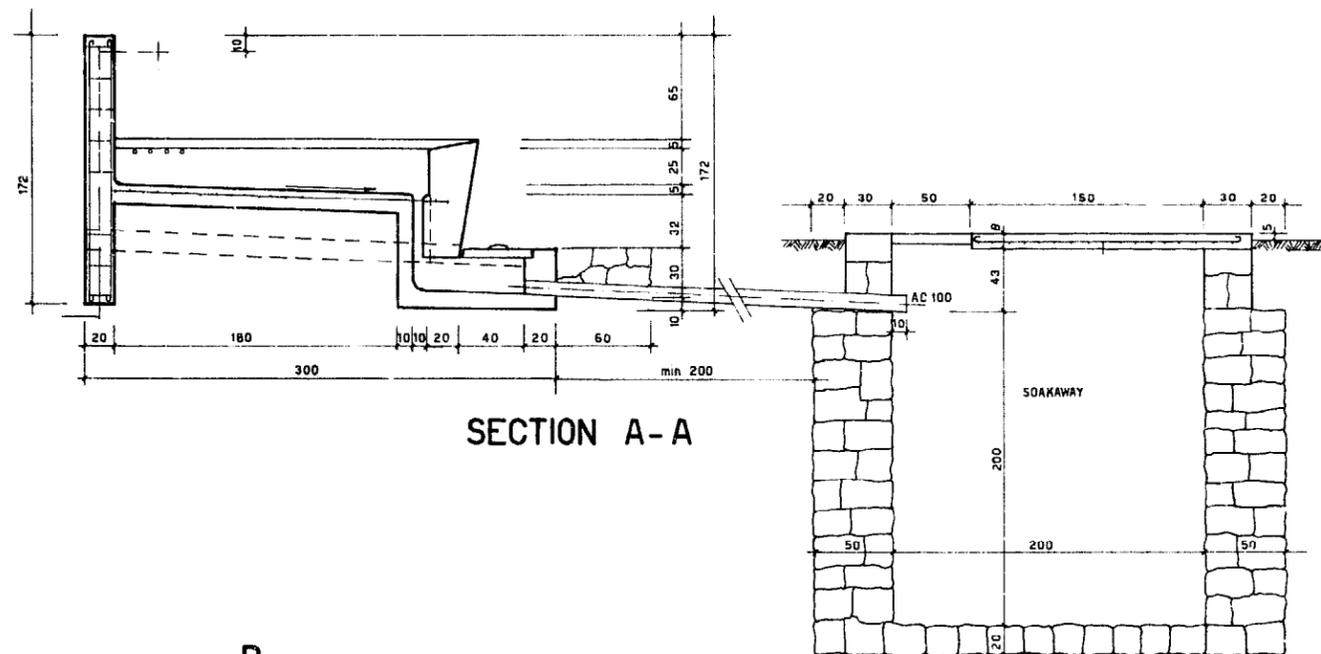
MANUAL FOR RURAL WATER SUPPLY
 PUBLIC STAND PIPE

DRAWN UD
 DATE NOV 1975

NORM PLAN
 No. 1



SECTION B-B



SECTION A-A

LIST OF MATERIALS

WASH PLACE

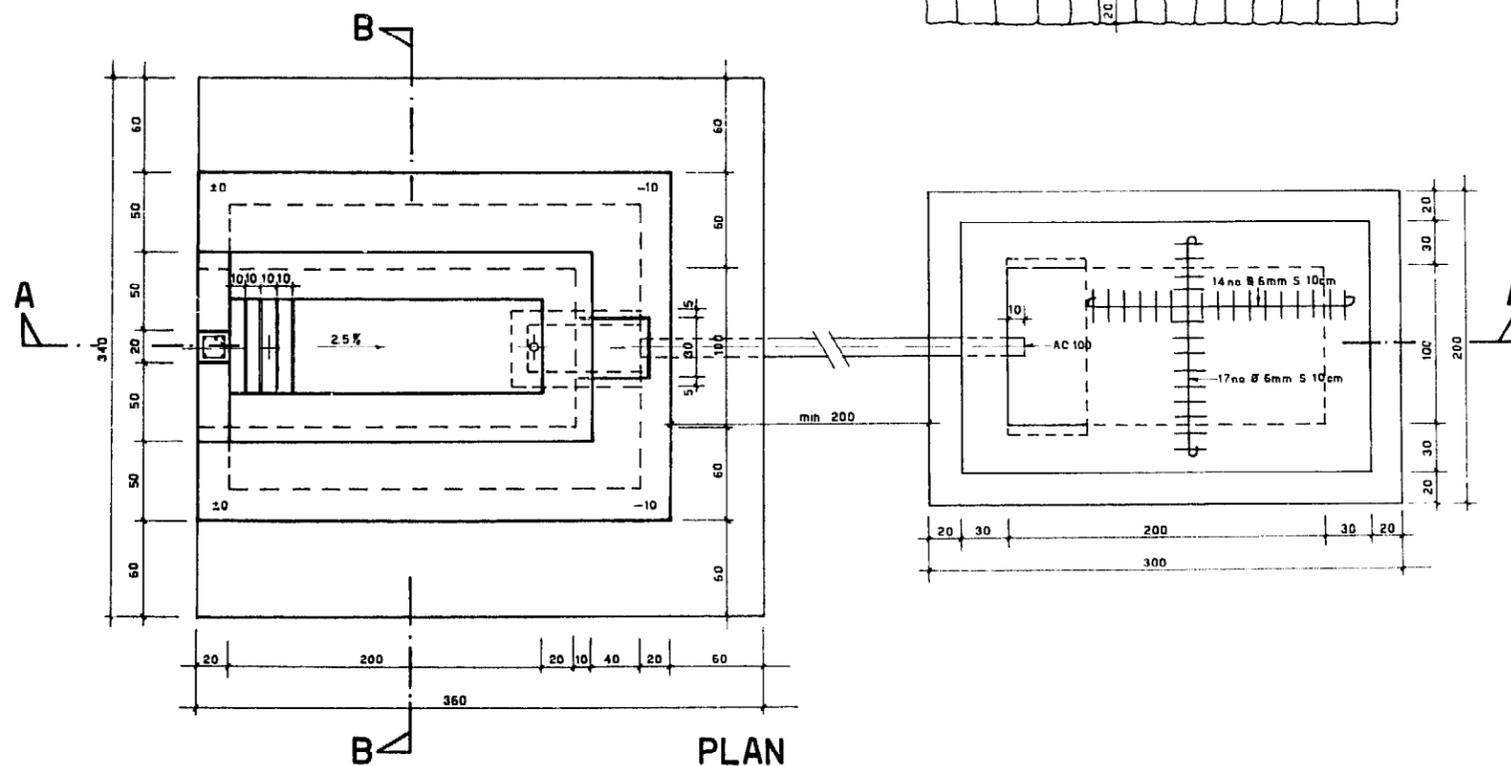
- CEMENT ~ 15 BAGS
- SAND ~ 2 m³
- GRAVEL ~ 2.5 m³
- STONES ~ 2.5 m³
- G.I. 1/2" THREADED BOTH ENDS 1 PIECE (OR 1/2")
- G.I. 1/2" 90° 4 PIECES
- G.I. 2" 50 cm WITH SOCKET 1 PIECE
- G.I. 2" 30 cm THREADED ONE END 1 PIECE
- TAP 1/2" 1 or 2"
- SOCKET 1/2" 1 or 2"
- ELBOW 1/2" 1 or 2"

- WELDED MESH 1 no. 2.10 x 0.70 m²
- 2 no. 1.95 x 0.75 m²
- 1 no. 0.35 x 0.25 m²

- AC 100 4 m
- RODS 10 no. 6 mm 16 x 16 = 0.95 m
- 6 no. 6 mm 10 x 10 = 1.05 m

SOAKAWAY

- CEMENT ~ 15 BAGS
- SAND ~ 1 m³
- GRAVEL ~ 0.5 m³
- STONES ~ 12 m³
- WELDED MESH FOR ENTRANCE SLAB 45 x 105 cm.
- RODS: 6 mm 54 m
- 17 no. 6 mm 10 x 10 = 1.60 m
- 14 no. 6 mm 10 x 10 = 1.90 m



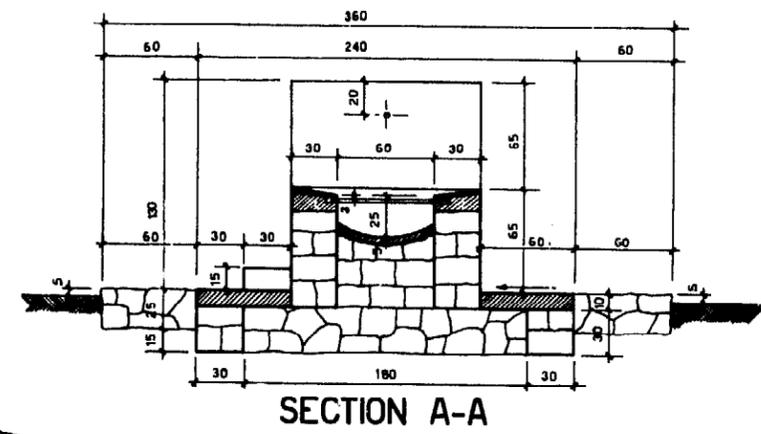
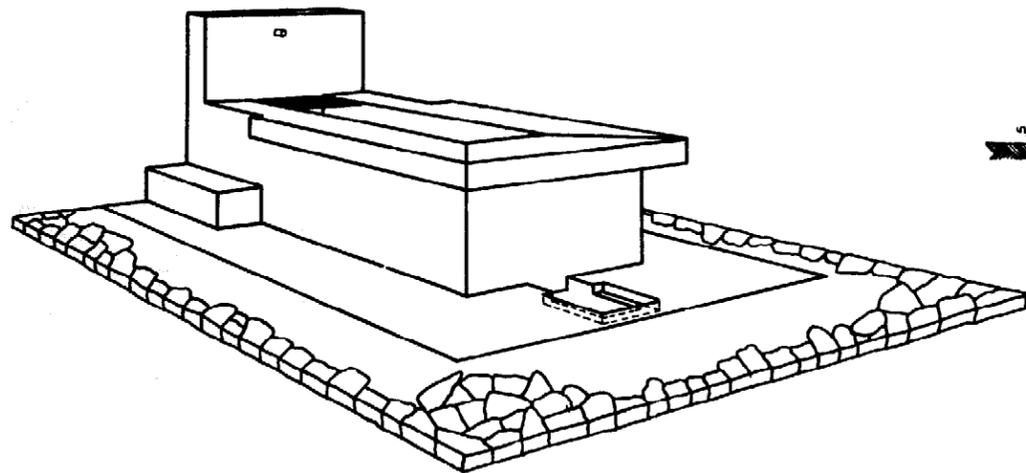
PLAN

COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE
 UNITED REPUBLIC OF CAMEROON
 HELVETAS
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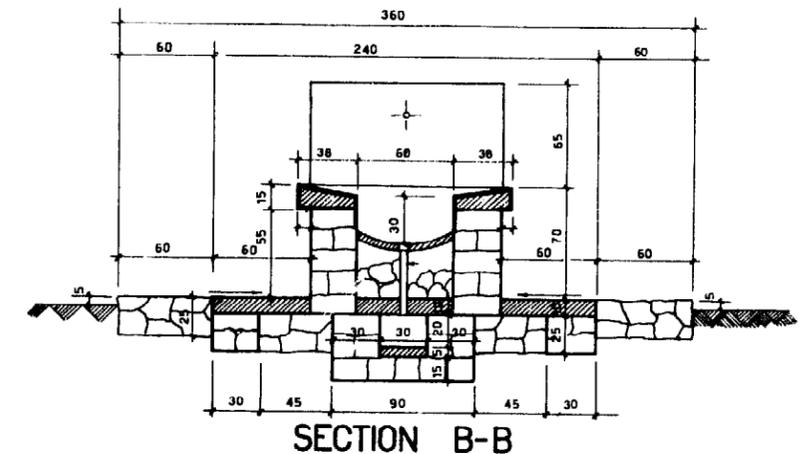
MANUAL FOR RURAL WATER SUPPLY
 PUBLIC WASH PLACE
 IN CONCRETE CONSTRUCTION

DRAWN : UD
 DATE : NOV. 1975

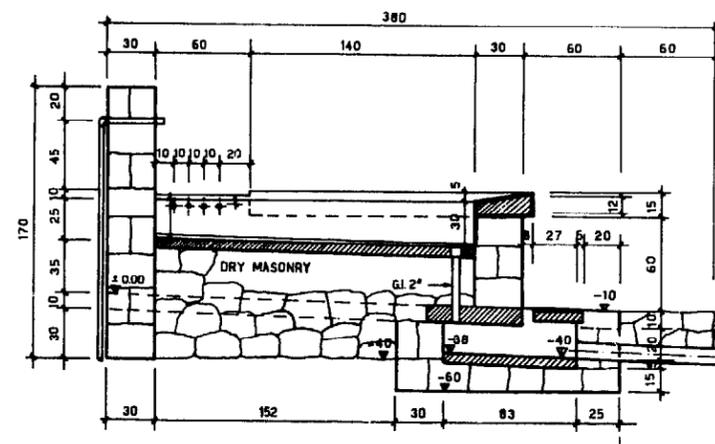
NORM PLAN
 No. 2



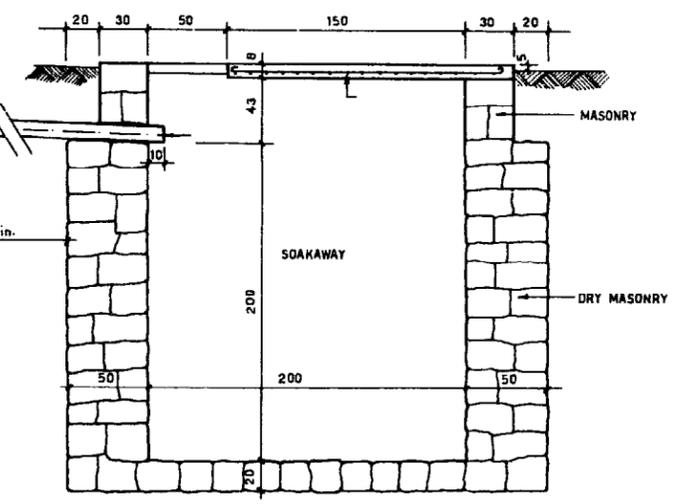
SECTION A-A



SECTION B-B



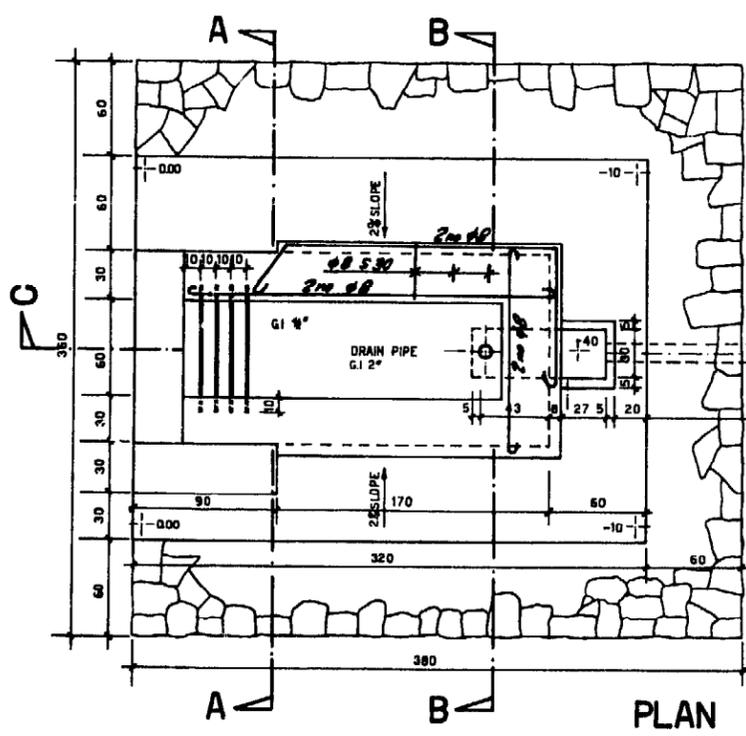
SECTION C-C



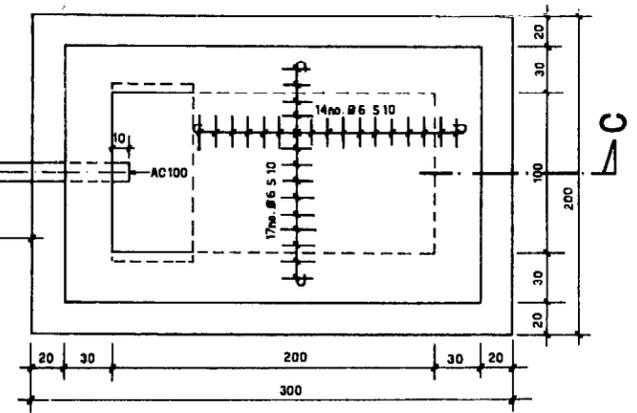
LIST OF MATERIALS

- WASH PLACE**
 CEMENT 15 BAGS
 G.I. 1/2" 35cm DIRED BOTH ENDS 1 PIECE OR 1/2"
 G.I. 1/2" 60cm 4 PIECE
 G.I. 2" 50cm WITH SOCKET 1 PIECE
 G.I. 2" 30cm DIRED ONE END 1 PIECE
 TAP 1/2" 1 or 1/2"
 SOCKET 1/2"
 ELBOW 1/2"
 WELDED MESH FOR SLABS 35x30cm
 A.C. 100 4m
 STONES 10m³
 SAND 4m³
- SOAKAWAY**
 CEMENT 4 BAGS
 RODS 8mm 54m
 12mm 42m

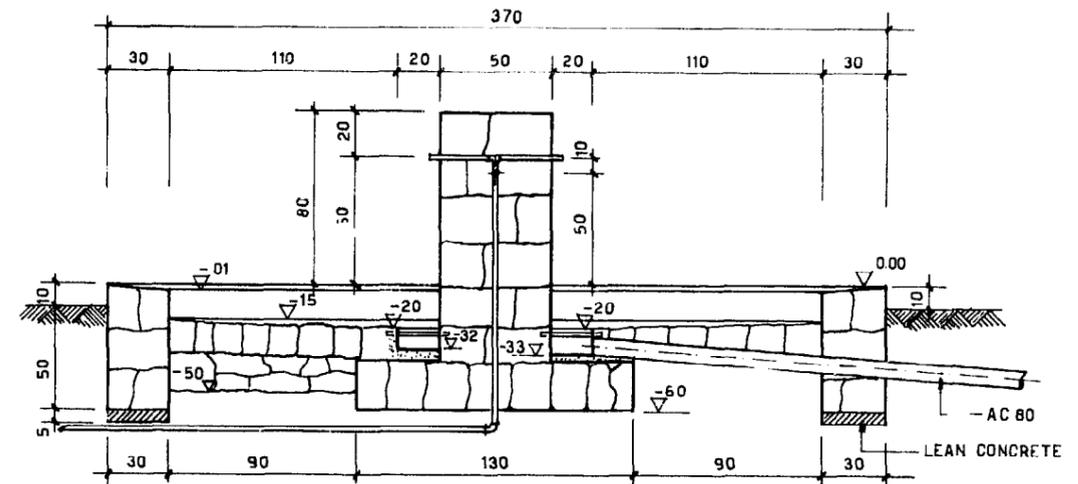
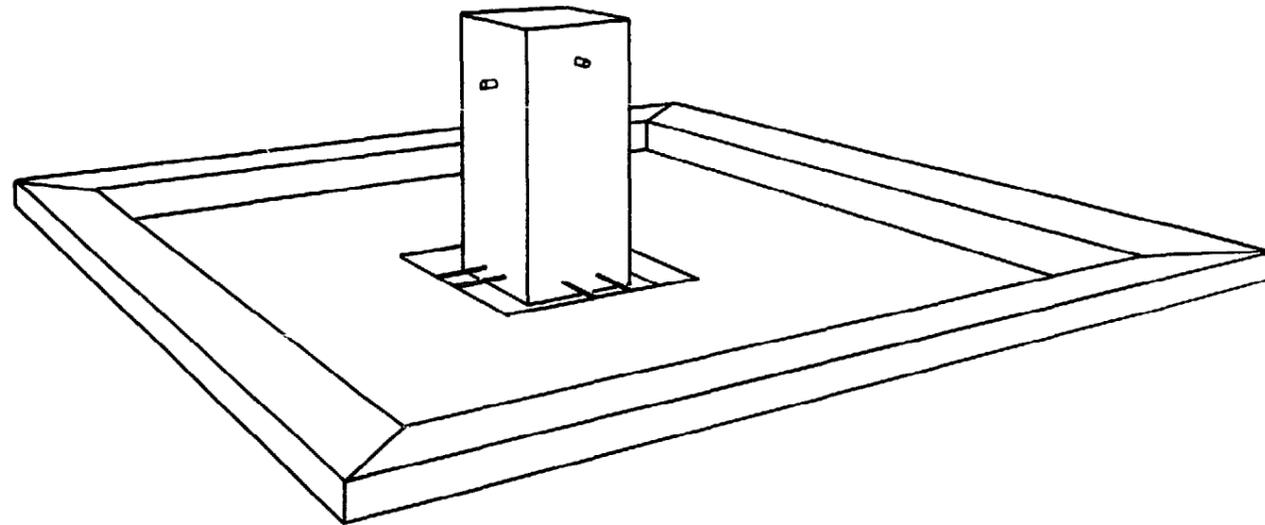
- WELDED MESH FOR ENTRANCE SLAB 45x105cm
 STONES 12m³
 SAND 1m³
 GRAVEL 0.5m³



PLAN



COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE UNITED REPUBLIC OF CAMEROON	
HELVETIAS SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (SATA)	
MANUAL FOR RURAL WATER SUPPLY	DRAWN : UD DATE : NOV. 1975
PUBLIC WASH PLACE IN MASONRY CONSTRUCTION	NORM PLAN No. 3



SECTION A A

LIST OF MATERIALS
FOUNTAIN

- CEMENT 15 BAGS
- G.I. PIPES 1/2" 30cm 8 PIECES
- G.I. SOCKETS 1/2" 4 "
- TAPS 1/2" 4 "
- G.I. TEES 1/2" 1/2" 2 "
- G.I. TEE 1/2" 1/2" 1 "
- G.I. NIPPLES 1/2" 2 "
- G.I. PIPES 1/2" 25cm 4 "
- G.I. PIPE 1/2" 115cm 1 "
- G.I. ELBOW RED 1/2"-1/2"
- G.I. PIPE 1/2" min 250cm
- A.C. PIPE 80mm 4m

SOAKAWAY

- CEMENT 4 BAGS
- RODS 6mm 54m

17no 6mm $\frac{10}{140} \frac{10}{140} = 160\text{cm.}$

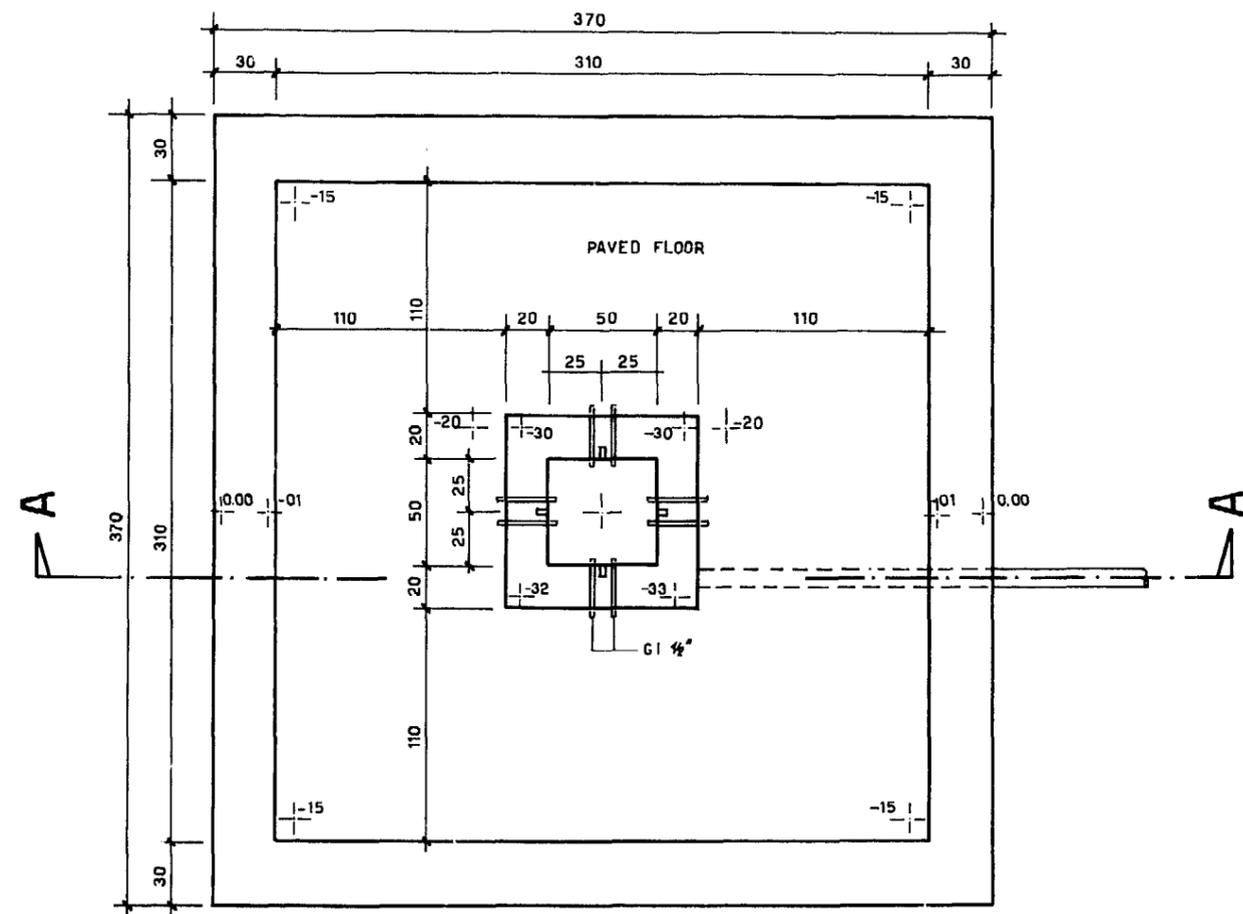
14no 6mm $\frac{10}{170} \frac{10}{170} = 190\text{cm.}$

WELDED MESH FOR ENTRANCE SLAB 45 x 105 cm

STONES 12 m³

SAND 1 m³

GRAVEL 0.5 m³



PLAN

COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE
UNITED REPUBLIC OF CAMEROON
HELVETAS
SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (SATA)

MANUAL FOR RURAL WATER SUPPLY

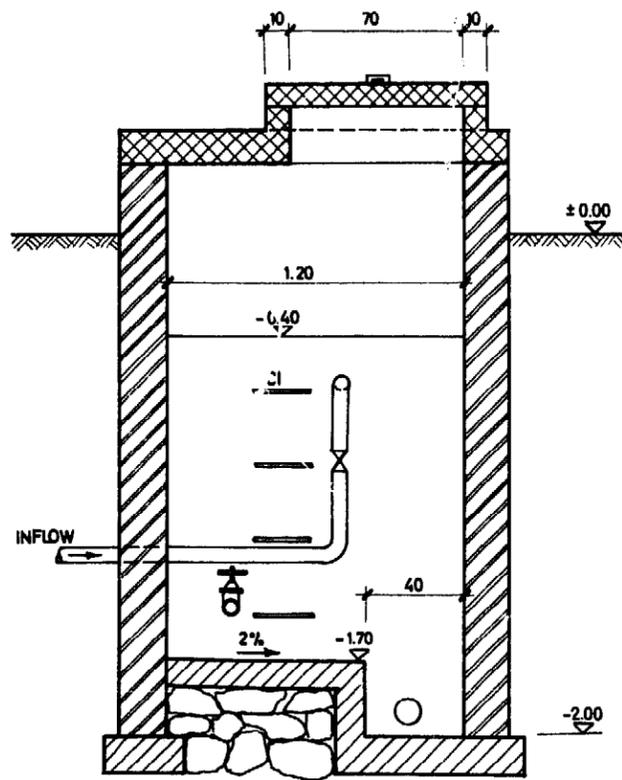
PUBLIC FOUNTAIN
IN MASONRY CONSTRUCTION

DRAWN : UD
DATE : NOV. 1975

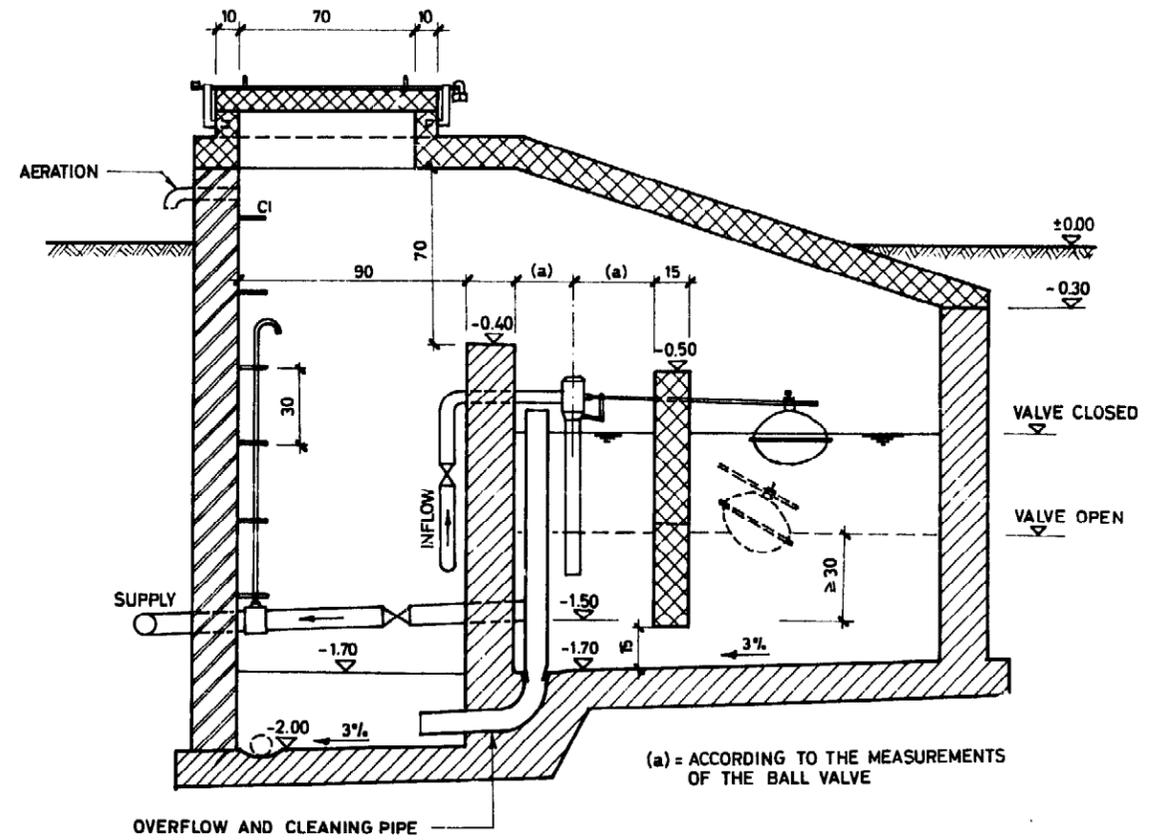
NORM PLAN
No. 4

KEY :

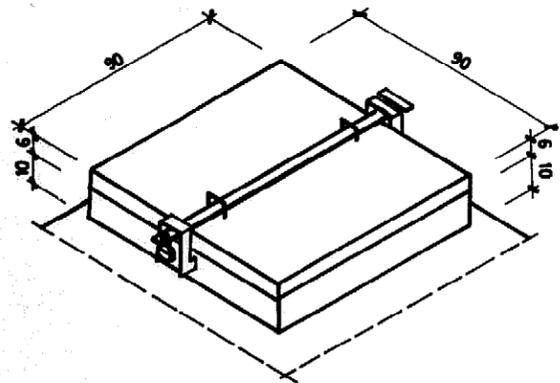
-  CEMENT BLOCKS OR STONE MASONRY
-  CAST CONCRETE OR STONE MASONRY
-  REINFORCED CONCRETE



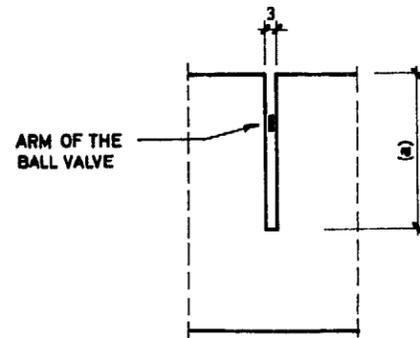
SECTION B - B



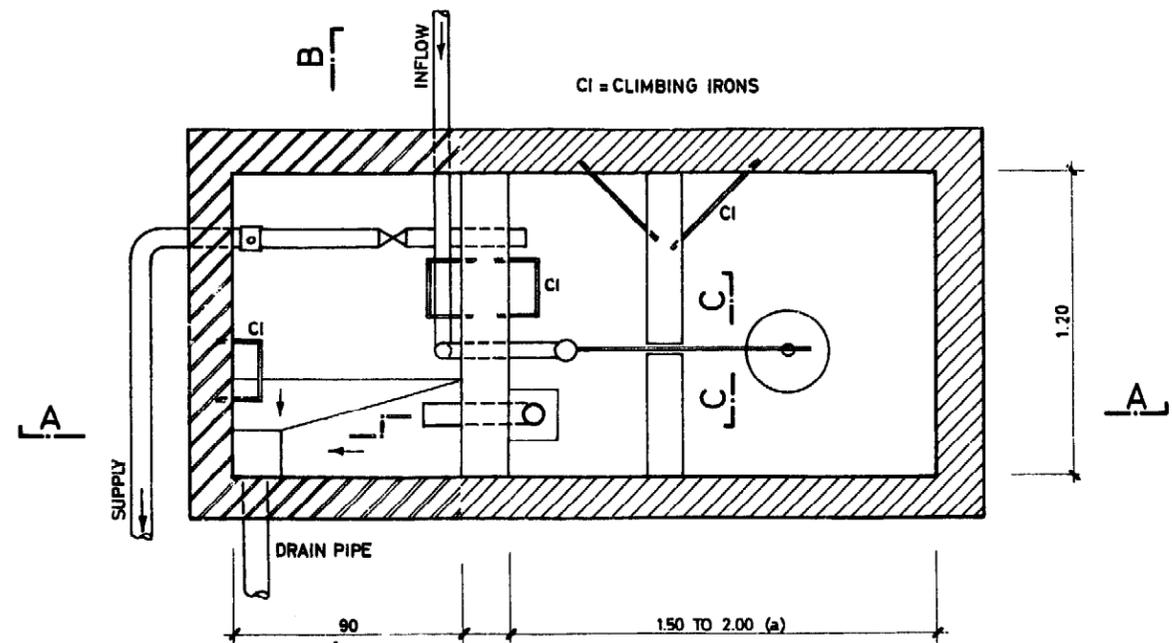
SECTION A - A



ISOMETRIC VIEW OF MANHOLE

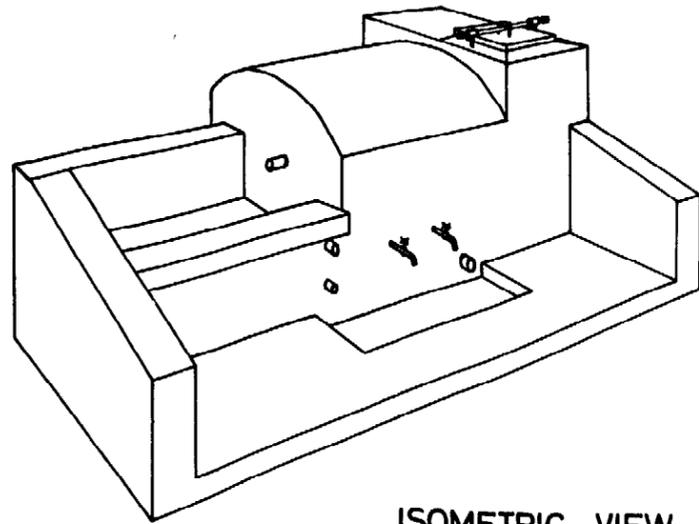


VIEW C - C



GROUND PLAN

COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE UNITED REPUBLIC OF CAMEROON	
HELVETAS SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (SATA)	
MANUAL FOR RURAL WATER SUPPLY	DRAWN: BH DATE: MAY 1980
INTERRUPTION CHAMBER WITH BALL VALVE	NORM PLAN No. 5

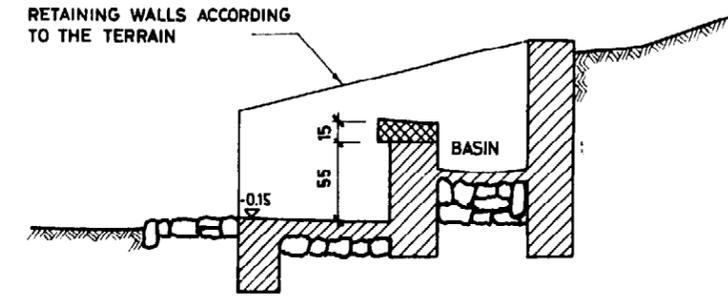


ISOMETRIC VIEW

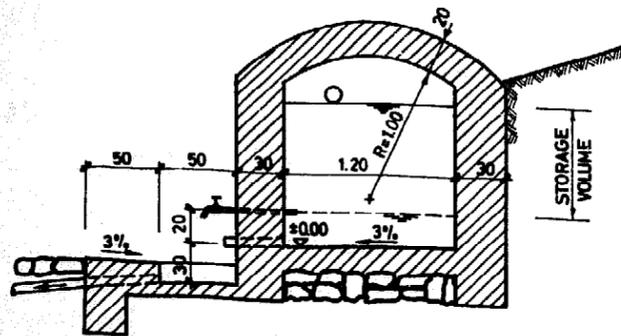
STORAGE VOLUME :
ACCORDING TO THE YIELD OF THE SPRING
DURING DRY SEASON AND TO THE DAILY
CONSUMPTION

KEY:

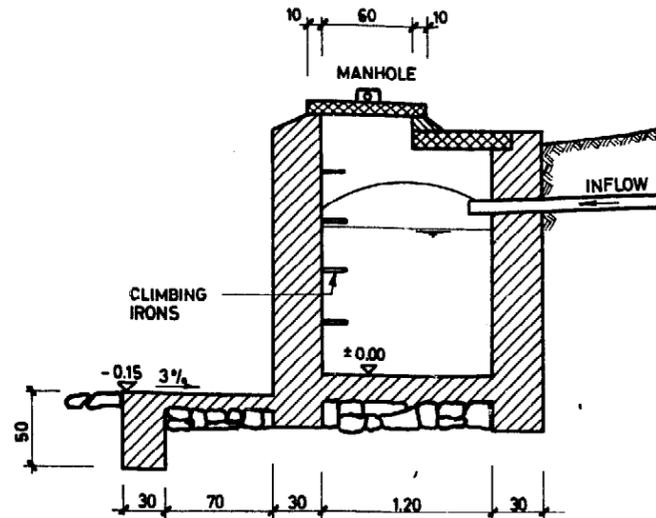
- STONE MASONRY
- CAST CONCRETE
- REINFORCED CONCRETE



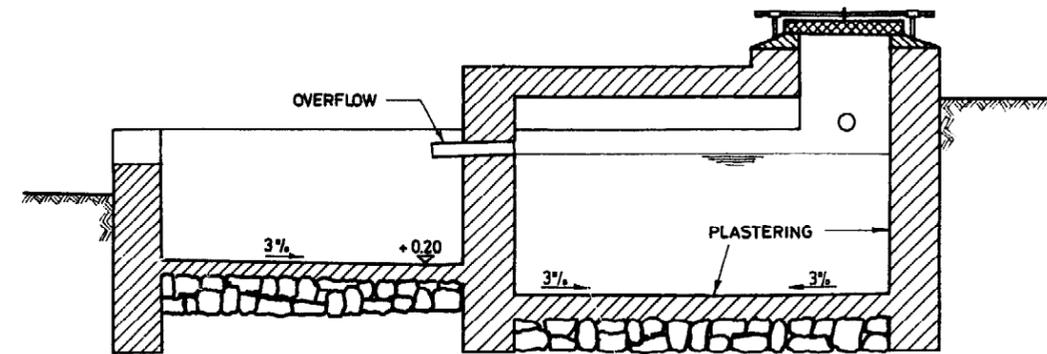
SECTION B - B



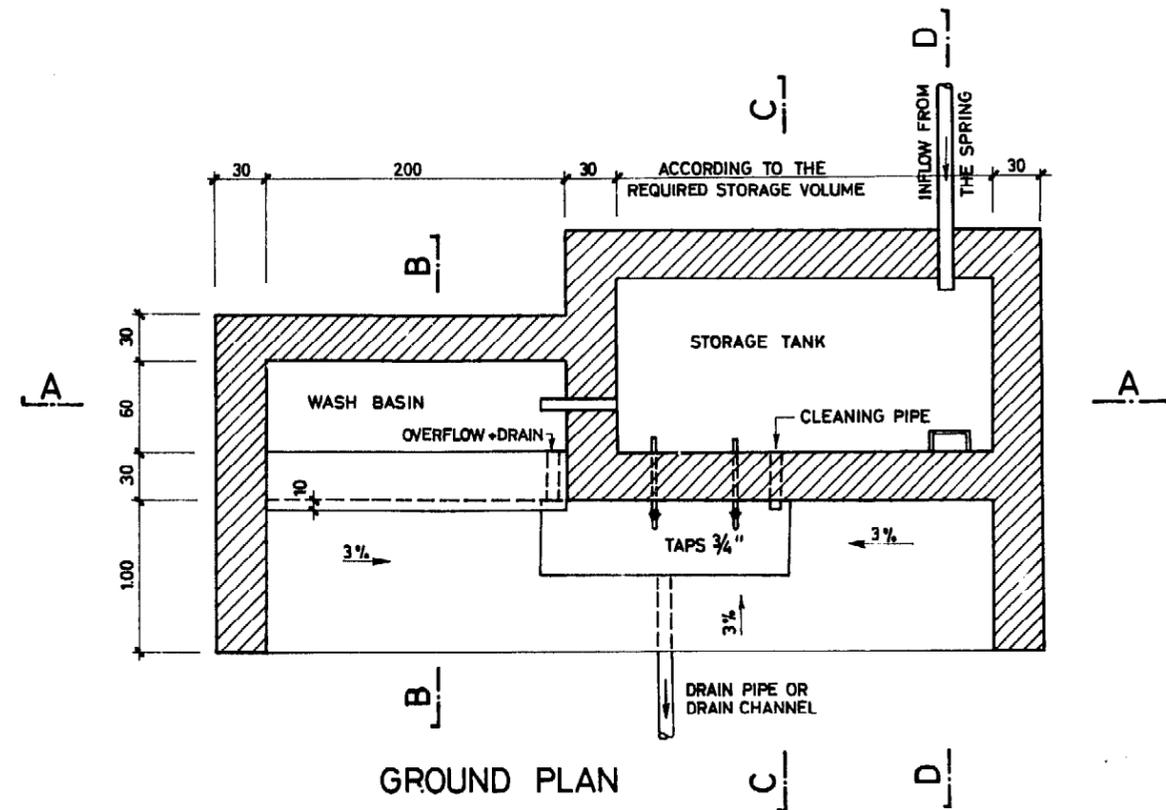
SECTION C - C



SECTION D - D

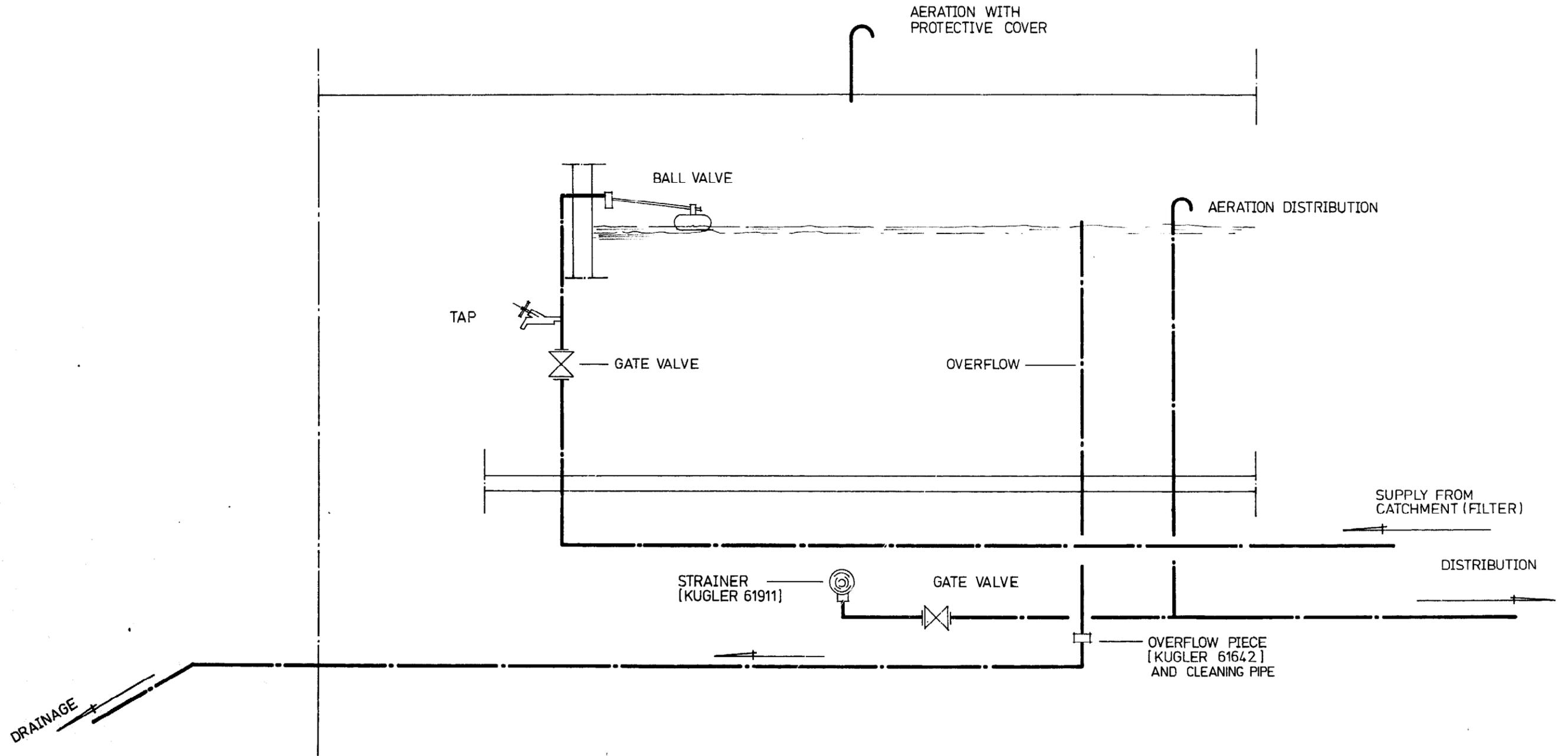


SECTION A - A



GROUND PLAN

COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE UNITED REPUBLIC OF CAMEROON	
HELVETAS SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (SATA)	
MANUAL FOR RURAL WATER SUPPLY WATER POINT IN MASONRY CONSTRUCTION	DRAWN : BH DATE : MAY 1980 NORM PLAN No. 6

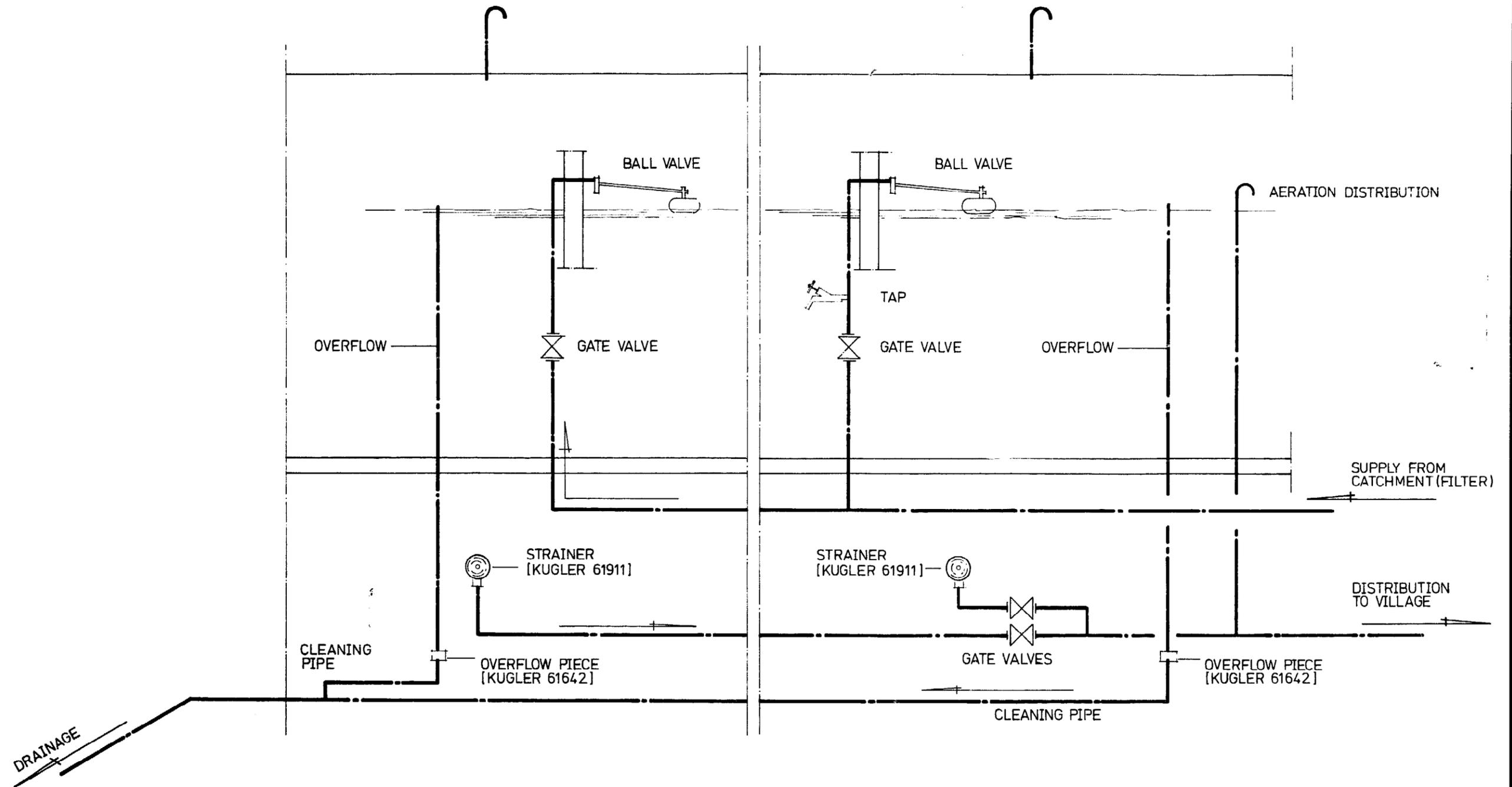


COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE UNITED REPUBLIC OF CAMEROON HELVETAS SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (SATA)	
MANUAL FOR RURAL WATER SUPPLY PLUMBING SCHEME OF SINGLE STORAGE TANK	DRAWN BY BTC DATE : MAY 1980
	SCHEME PLAN No. 7

PLUMBING SCHEME
SINGLE STORAGE TANK

AERATION WITH PROTECTIVE COVER

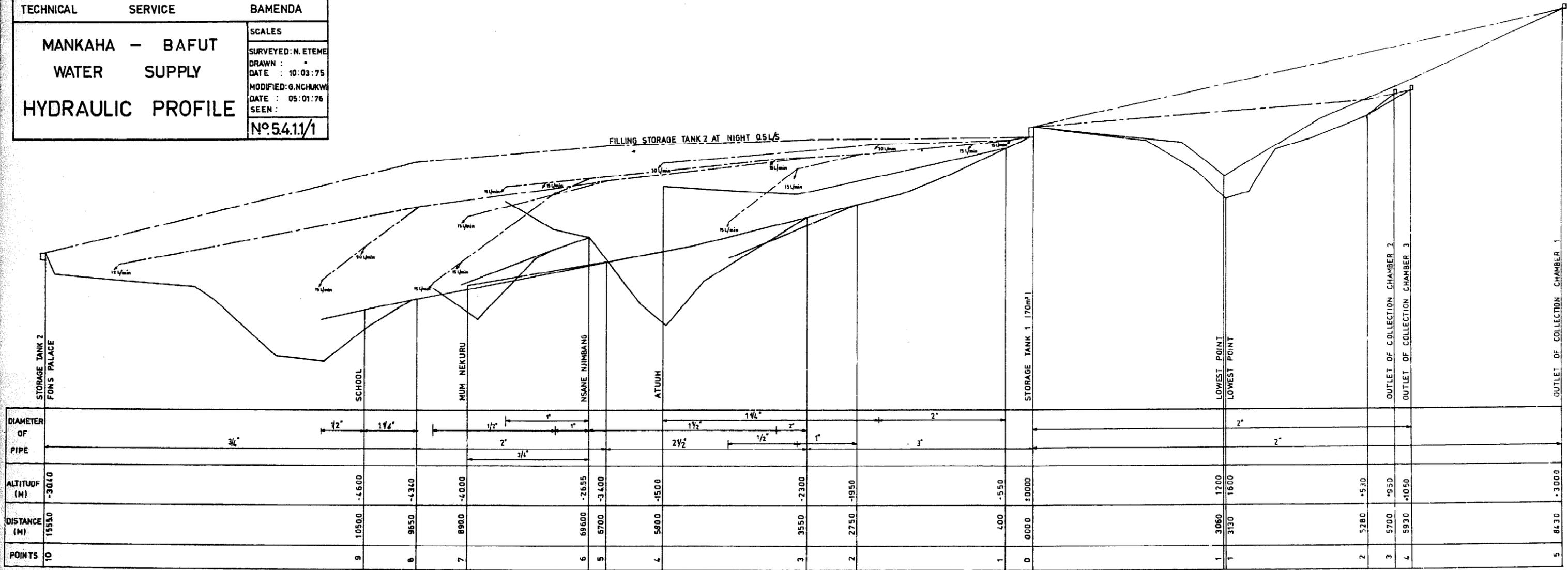
AERATION WITH PROTECTIVE COVER



COMMUNITY DEVELOPMENT DEPARTMENT MINISTRY OF AGRICULTURE UNITED REPUBLIC OF CAMEROON	
HELVETAS SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE (SATA)	
MANUAL FOR RURAL WATER SUPPLY	DRAWN BY BTC DATE : MAY 1980
PLUMBING SCHEME OF DOUBLE STORAGE TANK	SCHEME PLAN No. 8

PLUMBING SCHEME
DOUBLE STORAGE TANK

COMMUNITY TECHNICAL	DEVELOPMENT SERVICE	DEPARTMENT BAMENDA
MANKAHA - BAFUT WATER SUPPLY HYDRAULIC PROFILE		
SCALES		
SURVEYED: N. ETEME		
DRAWN :		
DATE : 10:03:75		
MODIFIED: G. NCHUKWI		
DATE : 05:01:76		
SEEN :		
No. 54.1/1		



DIAMETER OF PIPE	3/4"	1/2"	1 1/4"	1/2"	2"	2 1/2"	1 1/2"	2"	3"	2"	2"						
ALTITUDE (M)	-30.00	-4.600	-4.340	-4.000	-26.55	-34.00	-15.00	-23.00	-19.50	-5.50	±0000	1200	1600	+5.30	+9.50	+10.50	+3.000
DISTANCE (M)	15550	10500	9650	8900	69600	6700	5800	3550	2750	400	0000	3060	3130	5280	5700	5930	8430
POINTS	10	9	8	7	6	5	4	3	2	1	0	1	1	2	3	4	5

MANKAHA BAFUT WATER SUPPLY

SITUATION PLAN

ENLARGED BY G. NCHUKWI

DATE 17: 12 : 75

KEY

- | | | | |
|---|--------------------|---|------------|
|  | STREAM |  | MOTOR ROAD |
|  | PIPE LINE |  | FOOT PATH |
|  | STAND PIPE |  | POPULATION |
|  | WASH PLACE | | |
|  | SHOWER HOUSE | | |
|  | STOP COCK OR VALVE | | |



SKAT PUBLICATIONS

Publ.

No.

1. Jean-Max Baumer: Schweizerische Kontaktstelle für Angepasste Technologie (SKAT), St. Gallen 1977, 39 Seiten, gratis
2. Jean-Max Baumer: Angepasste Technologien für Entwicklungsländer, Literaturstudie, St. Gallen 1977, 132 Seiten (out of print)
3. Jean-Max Baumer: Angepasste Technologien für Entwicklungsländer, Bibliographie, St. Gallen 1977, 307 Seiten (out of print)
4. Jürg Nipkow: Angepasste Technologien für Entwicklungsländer, Sonnenenergie-Geräte für Haushalte, St. Gallen 1977, 62 Seiten, Fr. 8.50
5. Sabine Huber: Probleme des Technologie-Transfers von Industrieländern in Entwicklungsländer, St. Gallen 1978, 43 Seiten (out of print)
6. Gerhard Schwarz: Hemmnisse und Hindernisse bei der Verwirklichung des Konzepts der Angepassten Technologie in Entwicklungsländern, St. Gallen 1978, 53 Seiten, Fr. 14.--
7. Otto Langenegger: Einsatz von Bohrmaschinen für die Wasserbeschaffung in Aethiopien, St. Gallen 1979, 43 Seiten, Fr. 14.--
8. Helvetas: Manual for Rural Water Supply, St. Gall 1980, 175 pages, with many detailed constructional scale-drawings, SFr. 34.-- (US\$ 20.--)