APPENDIXES

APPENDIX C.1

Application of Guideline Values to Rural and Small-Community Water Supply

Appendix C.1 Application of Guideline Values to Rural and Small-Community Water Supply

1.1 Introduction

Guideline values for drinking-water quality are given in Volume 1 of the Guidelines for drinking-water quality (WHO,1985). A guideline value represents the level of a constituent that ensures an aesthetically pleasing water and does not result in any significant risk to the health of the consumer. The quality of water defined by the guideline values is such that it is suitable for human consumption and for all usual domestic purposes. When a guideline value is exceeded, the cause should be investigated with a view to taking corrective measures. The amount by which, and the duration for which, any guideline value can be exceeded without affecting public health will depend on the specific substance or characteristic involved.

In developing national drinking-water standards based on the guidelines, it will be necessary to take account of a variety of local geographical, socio-economic, dietary and industrial conditions. This will lead to the formulation of national standards that differ appreciably from the guideline values.

In the case of rural and small community water supply, the guideline values have often to be considered as long-term goals rather than rigid standards that have to be complied with at all times and in all supply systems. Similarly, the parameters used in assessing and measuring the quality of water intended for water supply must necessarily be limited in number (WHO,1985).

1.2 Microbiological aspects

Ideally, drinking water should not contain any microorganisms. It should be also be free from bacteria indicative of excremental pollution. Guideline values ensuring bacteriologically safe supplies of drinking water are provided in the following Table :

Guideline values for bacteriological quality (WHO,1985)

Organism	Guideline	Remarks
A.Piped water supplies		
A-1.Treated water entering the distribution system		
1) Faecal coliforms	0	turbidity<1 NTV; for disinfection with chlorine, pH preferably<8.0, for chlorine residual 0.2-0.5 ppm following contact time of 30 minutes.
2) Coliform organisms	0	
A-2.Untreated water entering the distribution system		
1) Faecal coliforms	0	in an occasional sample but not in consecutive samples.
2) Coliform organisms	3	
A-3.Water in the distribution system		
1) Faecal coliforms	0	in an occasional sample but not in consecutive samples.
2) Coliform organisms	3	
B.Unpiped water supplies		
1) Faecal coliforms	0	should not occur repeatedly; if occurrence is frequent and sanitary protection can not be improved, an alternative source must be found if possible
2) Coliform organisms	3	

Unit : number/100 cc

1.3 Biological aspects

It is not easy to give guidelines on biological hazards in respect to parasitic protozoa and helminths, and the application of any guidelines and procedures procedures proposed must be governed by epidemiological considerations in at least two respects : (1) many parasites have a complex geographical distribution and it may be unnecessary to take precautions against those not occurring locally ; and (2) the majority of water-borne parasites are also transmissible by the routes, such as food and direct faecal-oral spread, and these routes should also be considered.

1.3.1 Protozoa

Species of protozoa can be introduced into a water supply through human or.animal faecal contamination. Coliform organisms do not appear to be a good indicator in treated water because of the greater resistance of these protozoans to inactivation by disinfection. In non-disinfected water, the presence of indicator bacteria could suggest the presence of pathogenic protozoa. Since there is no good indicator for the presence or absence of pathogenic protozoa, drinking-water sources not subject to faecal contamination should be used where possible.

1.3.2 Helminths

The infective stages of many parasitic roundworms and flatworms can be transmitted to man through drinking-water. While there are methods for detecting these parasites, they are quite unsuited for routine monitoring.

Dracunculus may be a cause of severe morbidity in rural populations and is transmitted by freshwater copepods, such as Cyclops. Larvae reach the copepods when a blister on the limb of an infected person bursts and the larvae are washed into open wells and ponds. The parasites infect man when the copepod is ingested. In order to determine whether a risk of infection exists, copepods may be collected in plankton nets and examined for parasitic larvae under the microscope.

1.4 Chemical and physical aspects

Although the great majority of water-quality problems in the rural areas of developing countries are related to bacteriological or other biological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water resources. Such contamination may arise from certain industries, such as mining and smelting, or from agricultural practices and malpractices (e.g., the use and misuse of nitrates as fertilizers) or from natural sources (e.g., fluoride, iron). In order to establish whether such problems exist, a selected number of physiochemical parameters may need to be measured. However, particularly in the case of rural water supplies in developing countries, it could be both very costly and physically impracticable to cover a large number of parameters, and in most cases, testing may initially have to be limited primarily to sanitary inspection and bacteriological analysis.

If there are chemical constituents of local significance, the levels should be measured and the results evaluated in the light of the guideline values and other recommendations. In other areas, although no general recommendations or universally applicable selection of parameters can be given, there are a few indicative parameters of practical importance, which can provide useful guidance in assessing water quality. Guideline values for turbidity, colour, and taste and odour are recommended by WHO (1985) for use in the surveillance of small-community supplies

In the ASAL areas of the country, electrical conductivity is higher than 1000 micro S/cm and high contents of electrical conductivity more than several thousand are predominant, as compared with WHO guideline value, 750 micro S/cm as mentioned in Chapter .

High contents of fluoride more than 1.5 mg/l, WHO guideline value, are predominant in the volcanic rocks and sedimentary rock areas as shown in Chapter . Similarly, high contents of iron more than 0.3 mg/l, WHO guideline value, are common in the Rift Valley area and south eastern part of the country.

From the viewpoint of local and specific geographical conditions, electrical conductivity, fluoride and iron as well as the three components recommended by WHO (1985) should be measured for use in the small-community water supply.

1.4.1 Turbidity

High turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria and exert a significant chlorine demand. The recommended guideline value is 5 nephelometric turbidity units (NTU), but levels should preferably be less than 1 NTU when disinfection is practised. Turbidity more than 5 NTU may be noticeable and consequently objectionable to consumers. According to Design Manual for Water Supply in Kenya, the maximum permissible value of turbidity is 25 NTU.

1.4.2 Colour

Colour in drinking water may be due to the presence of coloured organic matter,e.g., humic substances, metals such as iron and manganese, or highly coloured industrial wastes. Experience has shown that consumers may turn to alternative sources, when their drinking-water shows aesthetically displeasing levels of colour. The guideline value is 15 true colour units (TCU). Levels of colour above 15 TCU can be detected in a glass of water by most people. According to Design Manual for Water Supply in Kenya, the maximum permissible value of colour is 50 TCU.

1.4.3 Taste and odour

Taste problems in drinking water supplies represent the largest single class of consumer complaints. The taste buds in the oral cavity specifically detect inorganic compounds of metal such as magnesium, calcium, copper, iron, and zinc.
Water odour is due to the presence of organic substances. Sanitary surveys should always include investigations of possible or existing sources of odour, and attempts should always be made to correct a odor problem.
The guideline criterion is "not offensive to most of the consumers", as water should be free of objectionable taste and odor for the large majority of the consumers.

1.4.4 Electrical conductivity

The higher the mineral content of the water, the higher its conductivity. This has several important consequences. First, the higher the conductivity, the more freely can electrical current flow through the water. Second, the higher the conductivity, the less completely ionized are the minerals dissolved in the water, as the ions are packed more closely together and collide more frequently.

Electrical conductivity is often also expressed for by the total dissolved solids (TDS) content. The relation between electrical conductivity and TDS depends on the ions in the water. In general, especially for irrigation purpose, 1000 micro S/cm is often equivalent to 600 or 700 mg/l TDS.

The recommended maximum limit for human consumption is believed to be 750 micro S/cm. In places where no other water is available, water with double or triple of this limit is used

1.4.5 Fluoride (F)

Fluoride is naturally present in some food and water. There is no evidence of harmful effects associated with the relatively low levels. At levels above 1.5 mg/l, the maximum limit guided by WHO, mottling of teeth has been reported very occasionally, and at 3.0 to 6.0 mg/l,skeletal fluorosis is observed. When a concentration of 10 mg/l is exceeded, crippling fluorosis can follow. According to the Design Manual for Water Supply in Kenya, the maximum value of fluoride content , 3 mg/l, may be accepted in exceptional cases.

High fluoride content is believed to be related to geology, particularly volcanic rocks in the Rift Valley area . It is believed that the fluoride content originates from volcanic and fumarolic gases. In the sedimentary areas, a high content of fluoride may be related to the degradation of fluorite.

1.4.6 Iron (Fe)

Although iron is an essential element in human nutrition, drinking water is not considered to be an important source. At levels of 0.3 mg/l, maximum limit of WHO guidelines, iron strains laundry and plumbing fixtures and causes an undesirable taste. Methods of removal have evolved, but in developing countries lack of knowledge of these methods and lack of finance to implement them often leads to abandonment of the iron-rich potable water for other sources, which are often polluted. This, in turn, leads to higher incidence of gastro-enteritis and other water-borne diseases. The presence of iron may lead to deposits in pipes and at levels higher than 0.3 mg/l there may be increased maintenance costs. According to the Design Manual for Water Supply in Kenya, the maximum value of iron content , 1 mg/l, is permissible.

The guideline values for distributed water, especially in urban areas, should be virtually the same as those which were published in the WHO guidelines.

In the case of rural and small community water supply, the WHO guideline values have often to be considered as long-term goals rather than rigid standards. At the same time, the parameters of water quality must necessarily be limited in number (WHO,1985) as discussed in Appendix C.1. Taking account of local geographical, socio-economic, dietary, and industrial conditions in the country shows that following water quality parameters should be used in assessing and measuring the quality of water intended for water supply :

1) Bacteriological aspects
2) Chemical and physical aspects
    --- Turbidity
    --- Colour
    --- Taste and odour
    --- Electrical conductivity
    --- Fluoride
    --- Iron

In fact, data on bacteriological quality, colour, and taste and odour are seldom available as shown in the groundwater database. Some data on turbidity are found in the database, but the number are too little to be used as criteria for checking of drinking-water. The last three parameters (electrical conductivity, fluoride, and iron) were selected as water quality criteria for rural and small-community water supply.

Water quality parameters for rural and small-community water supply

Parameter	Unit	Permissible	Limit
Electrical conductivity	micro S/cm	750	2000
Fluoride	mg/l	1.5	3.0
Iron	mg/l	0.3	1.0

APPENDIX C.2

Point-of-use Treatment of Groundwater with High Content of Fluoride and Iron

Appendix C.2 Point-of-use Treatment of Groundwater with High Content of Fluoride and Iron

When a water supply contains an inorganic contamination in concentrations that exceed the guide-line, the community or individual has the following possible solutions (Ref. C.4): (1) a new source of water. (2) blending of high and low content waters in pre-determined proportions, (3) treatment of the existing source water to remove the contamination. If the last option is chosen, a treatment system must be designed and implemented. In a large community, or when sufficient funds are available, a central treatment plant can generally be built, but in a very small community or for a private well system, the cost of a full-scale treatment plant is beyond the capabilities of the water users. In the latter case, one possible solution is to install point-of-use treatment devices in each home or building in a small community or in any home using a private well system.

There are five treatment techniques to remove inorganic contaminations : (1) reverse osmosis, (2) activated alumina systems, (3) ion exchange systems, (4) granular activated carbon systems, and (5) distillation.

Point-of-use reverse osmosis systems are typically composed of a prefilter for removal of sediments and a preactivated carbon filter to remove chlorine.

Activated alumina and ion exchange units are normally designed as cartridge systems for point-of-use treatment devices.

Distillation processes may be effective for removing most inorganic contaminants, if the cost and consumption of fuel are left out of consideration.

(1) Defluoridation

Fluoride in drinking water has been the subject of worldwide controversy. It is added to water as a means of minimising tooth decay in some countries such as USA. On the other hand, in Kenya, most of the water supply are thought to contain too much fluoride which causes fluoride poisoning or the risk of fluorosis.

Bone char and bone meal devices have been made an advance by the Central Public Health Engineering Research Institute of India and were also tested in Kenya.

(2) Removal of iron

Treatment methods of groundwater with excessive iron can be grouped into high-technology and appropriate-technology (Ref. C.5). The former method is restricted to large-scale urban or industrial uses mainly in the more developed nations. Three of the most common methods for removal of iron and manganese are (1) aeration-filtration, (2) chrolination-filtration, and (3) potassium permanganate-manganese greensand filtration.

The latter method has been applied to rural supplies to a greater or lesser extent of finance, availability of alternative sources and level of knowledge about the nature of the problem and how to attempt to resolve it. The appropriate-technology method usually involves aeration and filtration , with or without additional storage facilities. Several iron removal plants have been developed, (1) the Richardson and Cruddas package water treatment plant in India, (2) the Natural Environmental Engineering Research Institute iron and manganese removal plant in India, and (3) the iron removal plant in Bangladesh. Iron removal plants were also introduced in the Western Province by the Kenya-Finland Western Water Supply Programme (KFWWSP).

APPENDIX C.3

Importance of Hand Pumps and "Appropriate" Technologies of Rural and Small-Community Water Supply

Appendix C.3 Importance of Hand Pumps and "Appropriate" Technologies of Rural and Small-Community Water Supply

Drinking water supply is one of the most vital services for mankind. Particularly developing countries have considered water supply a social service from their birth. This means that the governments have supplied drinking water free of charge. This policy has been based on equity requirements.

The policy of free drinking water has, however, in practice led to a situation where the governments of developing countries have been able to supply the service only to a minority of consumers, not necessarily even to the urban and rural poor, as originally wished. From the equity point of view, this is contrary to the original objective.

In the 1960's and the early 1970's, it was generally believed that water supply could be arranged by piped, pumped and other conventional systems even to rural areas (Ref. C.6). In the late 1970s, the concept of appropriate technology was introduced to the water sector of developing countries. This meant that hand pumps and other appropriate technologies were developed and designed for the needs of developing countries. This concept of appropriate technologies developed towards the use of local materials as well as least maintenance. This concept is , however, somewhat controversial.

In 1977, the International Drinking Water supply and Sanitation Decade (IDWSSD) was proposed by the United Nations Water Conference. The Decade was to supply safe drinking water and adequate sanitation for all mankind by the year 1990, but this objective proved to be far too optimistic.

In the early 1980s, the concept of "community participation" was introduced. This concept means that consumers should participate in all phases of projects. Along with community participation, women in water supply can play an important role including operation and maintenance, water fee collection, and other management issues.

The gap between the actual conditions and ideal ones in developing countries can be reduced by the following three concepts : (1) low-cost and appropriate technology, (2) reduction of maintenance costs through community level management, and (3) monetary and non-monetary contributions of the ultimate beneficiaries.

APPENDIX C.4

Improvement of Shallow Wells

Appendix C.4 Improvement of Shallow Wells

Improvement of shallow wells, especially concrete tubes with wide diameter, at least 1 meter, allows communities to supply permanent and safe water sources in rural areas. Rural and small-communities can dig shallow wells and make concrete tubes with a minimum of outside assistance because of their ease of construction.

The technique of well sinking is a combination of two methods ; the first is known as "sink-and-line" or "dig-down-build-up" and is used for the shaft from the ground level down to the water level . The second is called "caissoning", and this method is employed for constructing the intake and that part of the shaft that lies within the aquifer.

In the "dig-down-build-up" method, the shaft is excavated to a greater diameter than the finished dimension, after which a lining is built up from the bottom by poring concrete behind removable shutters. The advantage of this method is that a close, strong, waterproof and permanent bond is made with the walls of the excavation, excluding contaminated water that may be in the soil near the surface, and giving a smooth, regular internal finish to the shaft. For reasons of safety, any well of depth greater than about 5 meters is sunk and lined in a series of stages or "lifts", each being completed before the next lift is started.

When the water table is reached, the method is changed to "caissoning", by which a tube is built upwards from the bottom of the well and allowed to sink under its own weight to its final position as the soil is excavated from within it. The outside diameter of the caisson is slightly less than the internal diameter of the lining while its inside measurement must be sufficient to enable a man to work inside to carry out the excavation.

In sandy areas, where the well wall will not support continuous digging of the well, availability of water can be tested using a test hole hand dug or augered with a hand auger. If water is sufficient, the well can be enlarged and the first ring put in place at whatever depth is permissible by the soil structure. The tubes are slowly dug into place through alternate digging around the perimeter and each new tube are added as one descends.

APPENDIX C.5

Disinfection of Shallow Wells

Appendix C.5 Disinfection of Shallow Wells

It can happen that shallow wells become polluted through some unforeseen cause, although tube wells are less liable to bacterial contamination by their siting and design. The contamination can be easily recognized by a bacteriological water quality check.

The contaminated water in the well should be disinfected or sterilized by applying a bactericide like chlorine. The following procedure is recommended :

1) Pump two (2) buckets of water from the well
2) Add 1 liter of bleach such as chlorite to each bucket and mix completely
3) Pour the water in the buckets into the well through a hose and a funnel
4) Leave about 2 litre (1.8 or 1.9 liters)
4) Remove the hose and funnel
5) Attach a short hose about 2 or 3 meters long to the pump spout and put the other end into the well
6) Let the water circulate by pumping slowly for about 10 minutes.
7) Remove the sort hose
8) Wash the concrete cover and foot plate of the pump with the remaining of the water of chlorine solution.
9) Pump water until chlorine odour can no longer be detected about 12 hours after disinfection).
10) Take water samples 1 or 3 days after disinfection for the bacteriological test.
11) Repeat the test.

The most common causes and their remedies are as follows :

Causes of contamination and remedy

Causes	Remedy
1) A latrine has been located too close to the well : the groundwater flowing towards the well may have become contaminated by faecal bacteria	Have the latrine filled in and dug somewhere else at least 50 m from the well.
2) Cattle have been allowed to come too close to the well : their excreta may have polluted the groundwater.	Have a fence of thornbushes, built around the well and make sure that watering of cattle takes place away from the well.
3) The gasket is leaking or absent : dirty water can then splash back into the well in between the concrete cover and the foot plate of the pump.	Check if the foot plate and cover are still flat and install a new seal.

APPENDIX C.6

Water Balance at the Ground Surface

Appendix C.6 Water Balance at the Ground Surface

It is essential for climatologists and planners to know the rates of actual evaporation/ evapotranspiration in different climatic zones of the country. This will serve as an indirect measure of available moisture in the soil and recharge rate to groundwater.

Although various methods have been developed to estimate actual evaporation/ evapotranspiration, it has been observed that it is difficult to estimate actual evaporation/evapotranspiration. Morton's model(1975) out of the various methods have been recognized to be one of the best methods.

The model assumes that there exists a complementary relationship between the potential evaporation estimated from climatological observation data using modified Penman method(1948) and the evapotranspiration from the surrounding area.

The climatological data needed for this method 1)mean monthly air temperature, 2)mean monthly dew point temperature, 3)incident global radiation, 4)extra-atmospheric radiation, 5)mean annual station surface pressure, 6)observed and maximum possible sunshine hours and 7)mean annual precipitation.

Mr. Nyenzi(1978) worked out actual evaporation/evapotranspiration for 84 representative stations in East Africa using Morton's method. He found that the estimated annual evaporation/evapotranspiration values for the highland, Lake Victoria basin and savanna areas compare well with the long-term mean annual precipitation. However, the estimated values for semi-arid and arid areas and coastal zones are slightly higher than the long-term mean annual precipitation. Figure CA6.1 shows the estimated annual actual evaporation/evapotranspiration in East Africa.

The long-term annual precipitation and the above-mentioned climatological data are available in 40 representative stations in Kenya. The following table shows the annual precipitation, actual evaporation/evapotranspiration and residual between the two by station. The residual includes surface runoff and groundwater recharge.

From hydrogeological view of point, the following classification of groundwater recharge rate or groundwater potentiality is proposed,

Classification of groundwater recharge rate
in connection with groundwater potential

Classification	Value of the residual (mm/Year)
High	Value >=600
Good	600> Value >=300
Fair	300> Value >=0
Poor	0> Value >-200
Low	-200 > Value

In coastal areas and near Mt. Marsabit, some corrections are made from hydrogeological view of point.

Water balance at the ground surface

Station	Latitude		Longitude		Ea	Rainfall	(R-Ea)
	(°)	(")	(°)	(")	(mm/year)	(mm/year)	(mm/year)
Bugusege*	1	9	34	16	1054	1687.1	633.1
Busia	0	28	34	8	1626	1775	149
Eldoret	0	31	35	17	1265	1124	-141
Embu	0	-30	37	27	1084	907	-177
Equator	0	-1	35	33	1089	1219	130
Garissa	0	-28	39	38	550	321	-229
Hola	-1	28	40	0	1037	736.7	-300.3
Kericho	0	-22	35	21	1231	2081	850
Kimakia	0	-48	36	45	1218	2288	1070
Kisii	0	-41	34	47	1326	1957	631
Kisumu	0	-6	34	35	1150	1306	156
Kitale	1	0	34	59	1139	1191	52
Kitui	-1	22	38	0	1479	1162	-317
Lamu	-2	16	40	54	1560	917	-643
Lamuria	0	-8	36	52	1091	758	-333
Lodwar	3	7	35	37	329	178	-151
Lokitaung	4	43	35	45	755	410	-345
Machakos	4	43	35	45	1168	798	-370
Makindu	-2	17	37	50	607	621	14
Malindi	-3	14	40	6	1574	1096	-478
Mandera	3	56	41	52	264	255	-9
Maralal	1	6	36	42	602	613	11
Marigat	0	28	35	58	632	645	13
Marsabit	2	19	37	59	1322	859	-463
Molo	-1	13	35	43	1208	1177	-31
Mombasa	-4	2	39	37	1622	1073	-549
Moyale	3	32	39	3	749	713	-36
Muguga	-1	13	36	38	1074	995	-79
Nairobi	-1	18	36	45	1027	918.6	-108.4
Naivasha	0	-44	36	27	781	620	-161
Nakuru	0	-16	36	4	987	956	-31
Namalu*	1	48	34	33	1047	911.7	-135.3
Nanyuki	0	0	37	2	883	759	-124
Narok	-1	8	35	50	912	736	-176
Oljoro Orek	0	-2	36	21	1089	1013	-76
Oloitokitok	-2	56	37	30	927	776	-151
Ruiru	-1	5	36	54	1069	1065	-4
Rumuruti	0	32	36	32	1086	745.6	-340.4
South Kinangop	0	43	36	41	1086	1417	331
Thika	- 1	6	37	10	1113	1020	-93
Toroto*	0	42	34	10	951	1687.1	736.1
Voi	-3	24	38	34	612	549	-63
Wajir	1	45	40	4	601	279	-322

* : Station is located in Zaire.

Fig. CA6.1

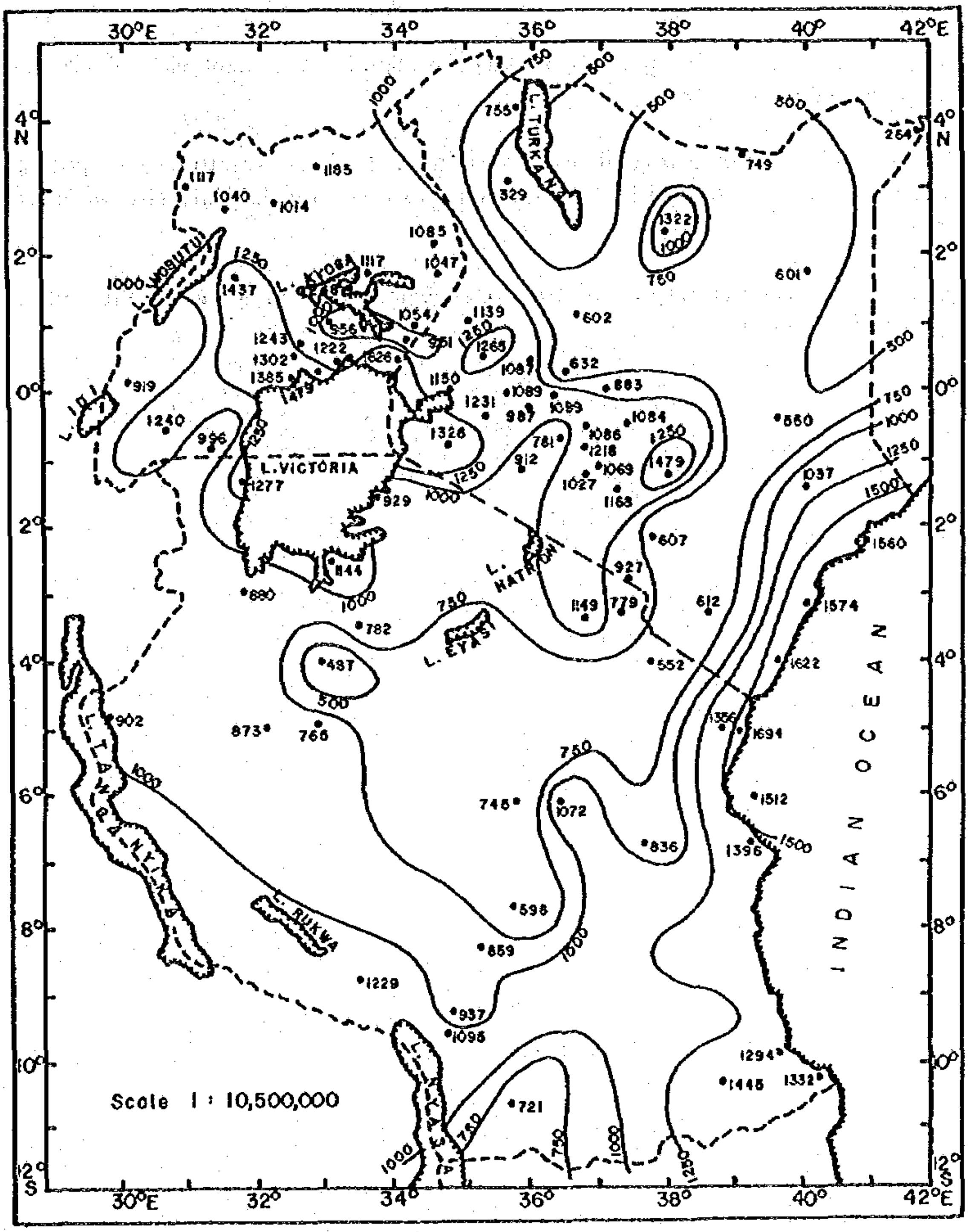

Figure CA6.1 the estimated annual actual evaporation/evapotranspiration(mm/year) in East Africa(Nyenzi, 1978).

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