THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER AND IRRIGATION

DESIGN MANUAL

FOR

WATER SUPPLY

AND

WASTE WATER DISPOSAL

THIRD EDITION

MARCH 2009

CONTENTS:

ACKNOWLEDGEMENT

The Ministry of Water and Irrigation would like to thank those who have made this new edition of the National Water Design Manual possible.

PREFACE

The March 2009 edition of the National Water Supply Design Manual has been reviewed and updated in the light of the recent National Water Policy and Technological developments. This new edition has been able to make considerable use of freely available technical articles and information published over the World Wide Web.

It contains:

- Eight Chapters on Water Supply (Volume I)
- Three Chapters on Waste Water Disposal (Volume II)
- One Chapter on Water Pipelines Standards and Technical Specifications (Volume III)

The Manual is available in electronic, pdf format (on CD and on the Ministerial Website http://www.maji.go.tz), for those that wish to avail themselves of it.

The most significant amendments to earlier edition are highlighted at the beginning of each chapter. The chapter on Water Pipelines Standards and Technical Specifications is included to enhance the National Water Pipelines Materials Policy. This is in line with the aspirations and objectives of the National Water Policy 2002and it balances the capital investment cost, the operation and maintenance cost, the social implications and the environmental health implications in the supply and installation of water pipelines. In the main, the Standard Water Pipelines Design, Materials and Construction guidelines are in the national interest to limit costly premature water scheme failures.

Whereas in earlier editions, the Ministry of Water welcomed comments on the contents and recommendations, and sought suggestions for change and improvement, the regrettable lack of these has led the Design Section to propose that in future, it shall be mandatory on all designers, be they in-house, with water authorities or with private consultants, to not only review these contents when preparing their designs but to submit to the Ministry both a summary of the design criteria they intend to use and to highlight, with reasoned arguments, any perceived serious omissions in and all deviations from these contents.

In this way, it is believed that both this and future editions will be progressively more relevant and useful to the water sector in Tanzania.

Ministry of Water and Irrigation, March 2009.

THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER AND IRRIGATION

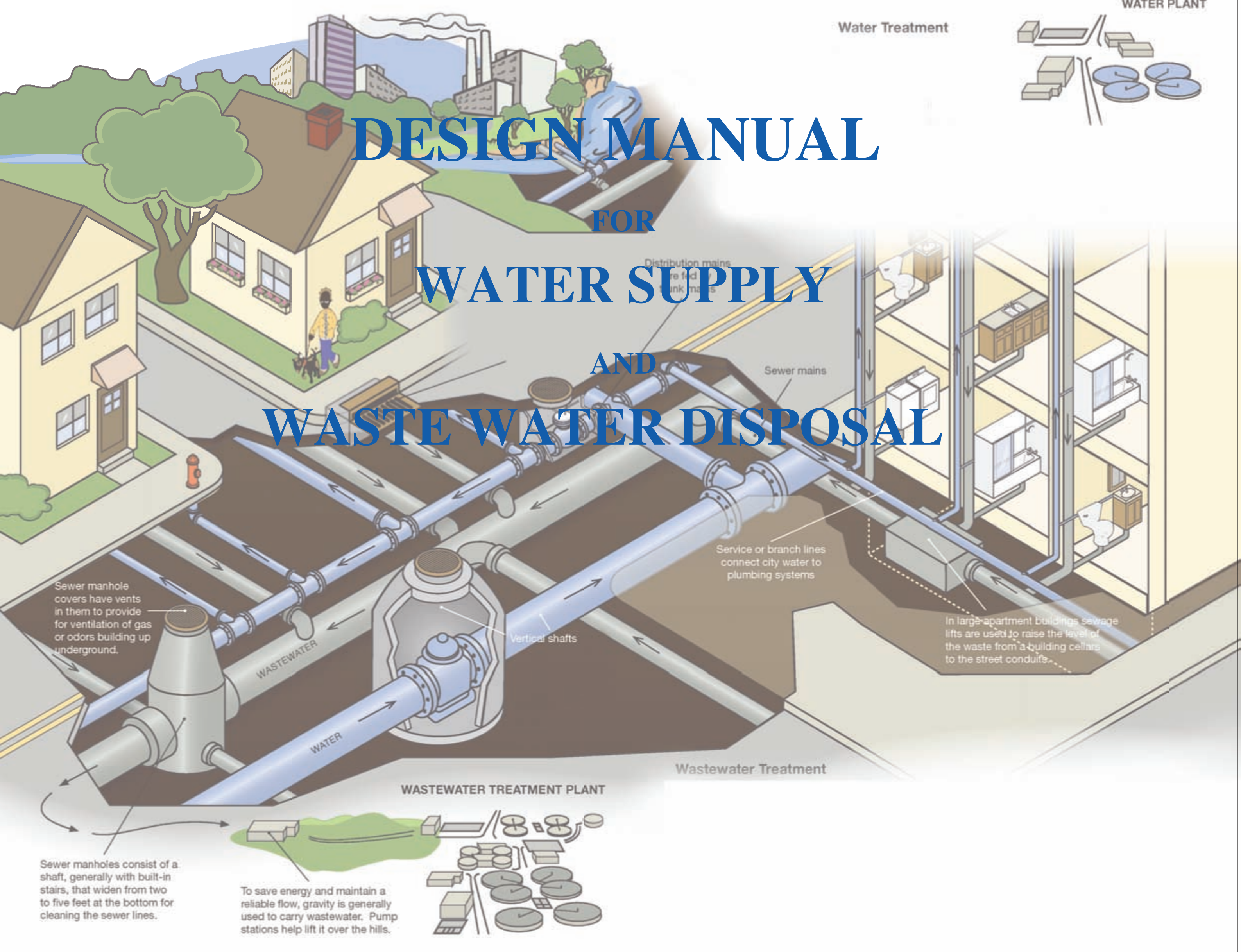
DESIGN MANUAL

FOR

WATER SUPPLY

AND

WASTE WATER DISPOSAL



VOLUME I

THIRD EDITION **MARCH 2009**

CHAPTER ONE

INDEX

TABLES

ABBREVIATIONS AND ACRONYMS

AWWA	-	American Water Works Association
BS	-	British Standard
CC	-	City Centre
DAWASA	-	Dar es Salaam Water Supply and Sewerage Authority
DAWASCO	-	Dar es Salaam Water Supply and Sewerage Company
DEM	-	Digital Elevation Model
DIN	-	Deutsches Institut für Normung e. V. (German Standards Institute)
DN	-	Nominal Diameter
DUSWA	-	District Urban Water Supply Authority
EIA	-	Environmental Impact assessment
EN	-	EuroNorm
EWURA	-	Energy and Water Utilities Regulating Authority
FAO	-	Food and Agricultural Organisation
GIS	-	Geographical Information System
GPS	-	Global Positioning System
HQ	-	Headquarters
ID	-	Internal Diameter
IPCC	-	Intergovernmental Panel on Climate Change
ISO	-	International Standards Organisation
LGA	-	Local Government Authority
MC	-	Municipal Centre
MDG	-	Millennium Development Goal
M&E	-	Mechanical and Electrical
NAWAPO	-	National Water Policy

NSGRP	-	National Strategy for (Economic) Growth and Reduction of Poverty
NWSDS	-	National Water Sector Development Strategy
O&M	-	Operation and Maintenance
ORNL	-	Oak Ridge National Laboratory, USA
RSC	-	Rural Service Centre
SABS	-	South African Bureau of Standards
TAR	-	Third Assessment Report of IPCC
TBS	-	Tanzania Bureau of Standards
TOR	-	Terms of Reference
UC	-	Urban Centre
USA	-	United states of America
UWS(S)A	-	Urban Water Supply (and Sanitation) Authority

CHAPTER ONE – INTRODUCTION AND PLANNING

1.1 THE WATER AND SANITATION SECTOR IN TANZANIA

1.1.1 National Water Policy

This partly revised version of the Design Manual has, insofar as there is relevance to project design, taken into account National Water Policy (NAWAPO) 2002; the National Water Sector Development Strategy (NWSDS) circulation draft issued by the Ministry of Water and Livestock Development in June 2004; the National Strategy for (Economic)Growth and Reduction of Poverty (NSGRP) of 2005; the draft report issued by the Ministry of Water and Livestock Development entitled, Mkukuta Based MDG Costing for the Water and Sanitation Sector; and the intentions of the National Rural Water Supply and Sanitation Program.

In addition, it has briefly considered the Third Assessment Report (TAR) 2001, the Report of the Intergovernmental Panel on Climate Change (IPCC), and the preliminary released results of the IPCC, 2007, Report.

In the rural water sector in particular, not only is this important in terms of the way to proceed and the goals to achieve but also in the need to approach the problem as being one of water and sanitation and not one of water alone.

1.1.2 Today's Water Sector Players

One of the major players in today's water sector is local government with the Ministry of Water in a supporting and advisory role.

Local government on the Tanzanian Mainland is divided into urban and rural authorities. Urban authorities comprise city, municipal and town councils. In rural areas there are two levels of authority: district councils with township authorities and village council. The district and urban councils have autonomy in their geographic areas save that in the regional centres the water supply (and sanitation) authority, the UWS(S)A, is an autonomous body whereas the semi-autonomous district urban water supply authority, the DUWSA remains under the Council.

The country is divided administratively into regions, districts, divisions and villages. In 2002 there were 21 regions, 106 administrative districts, 512 divisions, and nearly 11,000 registered villages, further sub-divided into hamlets or sub-villages. These are administrative arrangements which are also charged with maintaining law and order, and representing government at their respective levels.

District councils coordinate the activities of the township authorities and village councils in their district which are accountable to the district for all revenues received for day-to-day administration. The village and township councils also have responsibility for formulating plans for their areas, and in most cases securing district approval. Such plans are developed in association with formally established bodies such as the Ministry of Water.

The basic functions of urban and district and authorities are the:

- Maintenance of law, order and good governance
- Promotion of the economic and social welfare of the people within their jurisdiction
- Ensuring effective and equitable delivery of services to people in their areas.

In addition they must:

- Formulate, co-ordinate and supervise the implementation of plans for economic, social and industrial development in their areas

- Monitor and control the performance of the council and its staff
- Collect and ensure the proper use of council revenues
- Make by-laws, and in district LGAs approve by-laws made by village councils
- In district councils, regulate and co-ordinate development plans, projects and programmes of villages and township authorities within their areas.

Township authorities comprise the chairpersons of the villages or vitongoji within its area, not more than three members appointed by the district council, and women appointed according to political proportionality to make up at least one-third of the authority.

Village councils have between 15 and 25 members, made up of a chairperson elected by the village assembly, and other members elected by the village assembly. Women must account for 25 per cent of the council members.

From a water supply and sanitation point of view, the relevant authorities are DAWASA and DAWASCO as owner and operator respectively for the Dar es Salaam Water Supply, the various UWSSAs, district councils and village councils. In addition there is now the regulatory role provided by the Energy and Water Utilities Regulating Authority (EWURA).

In addition to Dar es Salaam, there are 19 UWSSAs, categorised depending upon their level of financial autonomy as Category A, B, and C Authorities. They are all regional capitals.

Category A Authorities are expected to meet all direct and indirect operational costs;

Category B Authorities are expected to meet all direct and indirect operational costs except personal emoluments for permanent staff; and

Category C Authorities are expected to meet all direct and indirect operational costs except personal emoluments for permanent staff and electricity costs.

In addition there are 71 District and other small town UWSAs that financially are yet to attain Category C status.

TABLE 1.1: URBAN WATER AND SEWERAGE AUTHORITIES

DAWASA/ DAWASCO	Category A (8 No.)	Category B (4 No.)	Category C (7 No.)
Dar es Salaam	Arusha Dodoma Mbeya Morogoro Moshi Mwanza Tabora Tanga	Bukoba Iringa Kigoma Songea	Babati Lindi Mtwara Musoma Shinyanga Singida Sumbawanga

Their Roles and Responsibilities are to: -

- To provide water (and sewerage) services of acceptable standards to consumers.
- To set affordable tariffs and charges, and sensitise customers on payment for the services.
- To construct/develop, operate and maintain water (and sewerage) service infrastructure.
- Create harmonious relationships with other stakeholders.

- Advise the Government in the formulation of policies related to services provided by the utilities.
- Educate and inform stakeholders on the activities of the utilities.
- Collect revenue from the consumers for service rendered.

Each district councils and township authority must have four standing committees, namely:

- Finance, administration and planning
- Education, health and water
- Economic affairs, works and environment
- HIV/ AIDS.

Village councils also have four standing committees. These are:

- Finance and planning
- Social services
- Defence and security
- HIV/ AIDS.

Other water authorities that have been established are listed in Tables 1.2 and 1.3.

TABLE 1.2: DISTRICT URBAN WATER AUTHORITIES

District & Hq WSA	District & Hq WSA	District & Hq WSA	District & Hq WSA	District & Hq WSA	District & Hq WSA
Monduli	Ngara	Mugumu [1]	Masasi	Namtumbo	Nzega
Karatu	Karagwe	Tarime	Magu	Tunduru	Igunga
Mpwapwa	Muleba	Rujewa	Ngudu	Maswa	Korogwe
Kongwa	Biharamulo	Vwawa	Sengerema	Kahama	Muheza
Kondoa	Kibondo	Chunya	Geita	Mwanhunzi	Handeni
Njombe	Kasulu	Kyela	Misungwi	Ushirombo [8]	Pangani
Mafinga	K/Masoko	Itumba [2]	Kisarawe	Bariadi	Songe [9]
Makete	Nachingwea	Tukuyu [3]	Utete [6]	Kiomboi	Lushoto
Ludewa	Liwale	Mahenge [4]	Mpanda	Manyoni	
Same	Mbulu	Ifakara [5]	Namanyere [7]	Sikonga	
Mwanga	Bunda	Kilosa	Mbinga	Urambo	

[1] Serengeti District Hq.: [2] Ileje District Hq.: [3] Rungwe District Hq.: [4] Ulanga. District Hq.: [5] Kilombero District Hq.: [6] Rufiji District Hq.: [7] Nkasi District Hq.: [8] Bukombe District Hq.: [9] Kilindi District Hq.

TABLE 1.3: OTHER WATER AUTHORITIES

District	Authority	Type	District	Authority	Type
Njombe	Makambako	small town	Mtwara	Makonde	project
Musoma	Mugango/K	project	Kahama	Isaka	small town
Mbozi	Tunduma	small town	Korogwe	Mombo	small town
Kilosa	Gairo	small town	Handeni	Handeni	trunk main

1.1.3 Climate Change

Near the start of the Millennium, and with Millennium Development Goals (MDGs) at the forefront of development goals, a Water Design Manual would be incomplete without a word on Climate Change. Change, particularly as it will effect the Tanzanian Water Source Sector must be taken into consideration.

This is clearly difficult when both perceptions and predictions vary considerably. However, southern Tanzania in particular is not predicted to benefit from the anticipated changes. Compared with the 20th century, the much greater warming forecast for the 21st century will produce considerable changes in evaporation and precipitation, allied to a more unpredictable hydrological cycle [< >]

Recent projections to 2030 indicate that the east African region will get more rain but become drier as temperatures rise and evapo-transpiration increase. For Tanzania, the predicted increase in temperature is between 2.5°C and 4.0°C. Parts of the country are projected to receive more rainfall, while the rest of the country - including the drought-prone southern areas - will receive less [< >].

Designers should therefore study the latest information and modelling predictions available and include a statement on what measures, if any, have been allowed for within the time frame of their project design.[< >]

1.1.4 The Basis for Planning, Design and Engineering Consideration

1.1.4.1 Introduction

In this contest, planning refers to project planning. But the decision to implement a project has to be coordinated through macro and .sector planning. Briefly macro planners address themselves to overall country economy and determine each sector's share of the total investment. Sector planners on the other hand determine whether such investments for the sector are feasible, and how the projects can best be carried out. In other word sector planners determine sector priorities. In project planning, projects are identified, studied, designed, appraised and objectives of the project clearly defined and implemented and managed (Operation and Maintenance). See chart 1.

1.1.4.2 Basic Design or Engineering Considerations

In the project planning the engineer has to translate the social objectives into Engineering objectives as shown in the flow chart. Engineering decisions are required to assess the water resources and determine the area and the population, industries, institutions and other consumers to be served, design period, the per capita consumption of various categories of consumers pressure zones and other needs of water in the area. The nature and location of various facilities to be provided such as source of water, intake, treatment plants, pumping stations, reservoirs, pipe alignments, public stand posts, local construction materials such as sand, gravel, stones, labour level of community

---

< > Human Development Report, 2006, Beyond scarcity: Power, poverty and the global water crisis UNDP, Nov. 2006

< > Climate Change and Global Water Resources: SRES Emissions and Socio-economic Scenarios. *Global Environmental Change* 14 (1): 31–52. Arnell, Nigel W. 2004.

< > Reference should first be made to the IPCC's reports namely the 2001 TAR Report and the 2007 fourth annual report, the four volumes of which will be released progressively during 2007 from February onwards.

participation, villagers ownership and their responsibilities, tariffs etc shall also be considered. In order to optimise the project planning and design, construction is done in stages by determining appropriate number of phases and investment and recurrent costs of the project.

It is also- necessary to determine such things as:

- The raw water quality and quantity and the degree of treatment required: The hourly, daily, monthly or seasonal variations of the source and the storage requirements to meet the peak demand.
- The geological and soil conditions at the chosen locations of intakes, treatment plants, pumps, storage, pipeline etc.
- Flood magnitude to prevent the inundation and damage of the project facilities.
- Type of instruments and equipment to be installed at various points such as removal of sludge from sedimentation tanks in the treatment plants, recording of inflows and outflows, turbidity, colour, pH, chlorine residual, dissolved oxygen, conductivity etc.
- The service buildings required at various points such as intake, treatment plants, control rooms etc.
- Availability and supply of various utilities such as electricity, water, drainage, roads, telephones, houses for staff etc.

1.1.4.3 Analysis Alternatives

There are several different analyses and factors that may be necessary including:

a) Least Cost Analysis

When evaluating a project it is sometimes necessary to choose between different alternatives. The objective is to choose the alternative that would optimise net benefits or the one that would cause least costs. In the case of drinking water supply projects benefits produced by all the alternatives are the same. In other words demand should be satisfied irrespective of costs and at the least cost. It must however be borne in mind that ‘least cost’ is not simply a matter of minimum initial investment cost and this topic is dealt with in some detail in Chapter 4.

b) Bottleneck Analysis

For proper planning of a project’s utilization of scarce resources, it is important for the project engineer to determine which components of the existing project (if any) require expansion and when these components should be expanded. At first the Engineer should analyse the existing system by sub-dividing it into major components such as intake, raw water pumping station, transmission lines, treatment plants, high lift pumping station, storage, distribution system etc. The capacity of each component is compared with the projected demand in given years.

Ideally, the needed works or expansions are then scheduled so that the bottlenecks are eliminated before they can materialize. That is, the expansion is implemented shortly before it is required. Thus, the optimal timing of investment (expansion) should be as late as possible while avoiding rationing (shortages). Generally for a short or medium term horizon only some components would require expansion.

In essence the bottleneck analysis is an investment plan where capacity of each component is gradually expanded or augmented to satisfy demand. Concurrence in time of every components expansion is a coincidence rather than a pre-requisite.

This is not always possible where external financing is required or provided in which case it is often necessary to agree a design horizon and to have all necessary components brought to the size then considered to be necessary.

c) Design Period

The design period is the period within which the project long term projected demands are estimated for a least cost project. The design period of the project is the function among other things of the discount rate (opportunity cost) and the economy of scale factor. It is generally accepted that the optimum design period is between 5-10 years and should rarely exceed 20 years. Therefore the design period of a project should be categorized as short term 5 years, future 10 years and ultimate period 20 years.

However a projects design period is not to be confused with the design life of system components which may be 50 years or even more, especially with dams. For example, it is rarely cost effective to construct a dam in stages and the spillway must in any case be designed for a flood return period considerably in excess of this.

d) Demand Forecasting

Demand forecasting is the most critical element in project planning. There is always a danger of either over-estimating or under-estimating the water demand. Over-estimation of demand may justify a project that should not have been built. This then leads to unnecessary costs, over-estimation of intended revenue and premature implementation of a project.

The consequences of under-estimation are also obvious. Hence it is logical that time should be spent on the demand analysis and projections, and this should not be hurried.

It is also advisable to project demand for short, medium and long term periods and for a Client to update this at least every five years.

In addition, water leakage, wastage control and repair of existing systems should be taken seriously before embarking on replacement or the installation of additional capacity.

e) Population Forecasting and Projections

Design population is a major component of water demand and hence much care and attention must be paid to it.

For large rural areas and District based schemes in particular, an increasingly useful web source is ORNL, the Oak Ridge National Laboratory in the USA. Based on satellite images, and using 30" × 30" latitude/longitude ESRI grid (ArcMap), population concentrations are plotted using remotely acquired data entitled the LandScan Global Population GIS Database. The latest database is for 2005. More information on this resource can be obtained from the web site: (http://www.ornl.gov/landscan) Country maps can be obtained through the FAO Country Profiles and Mapping Information System website together with other useful summary map information (http://www.fao.org/countryprofiles/default.asp?lang=en).

An overview ORNL population map for Tanzania is presented on the following page:

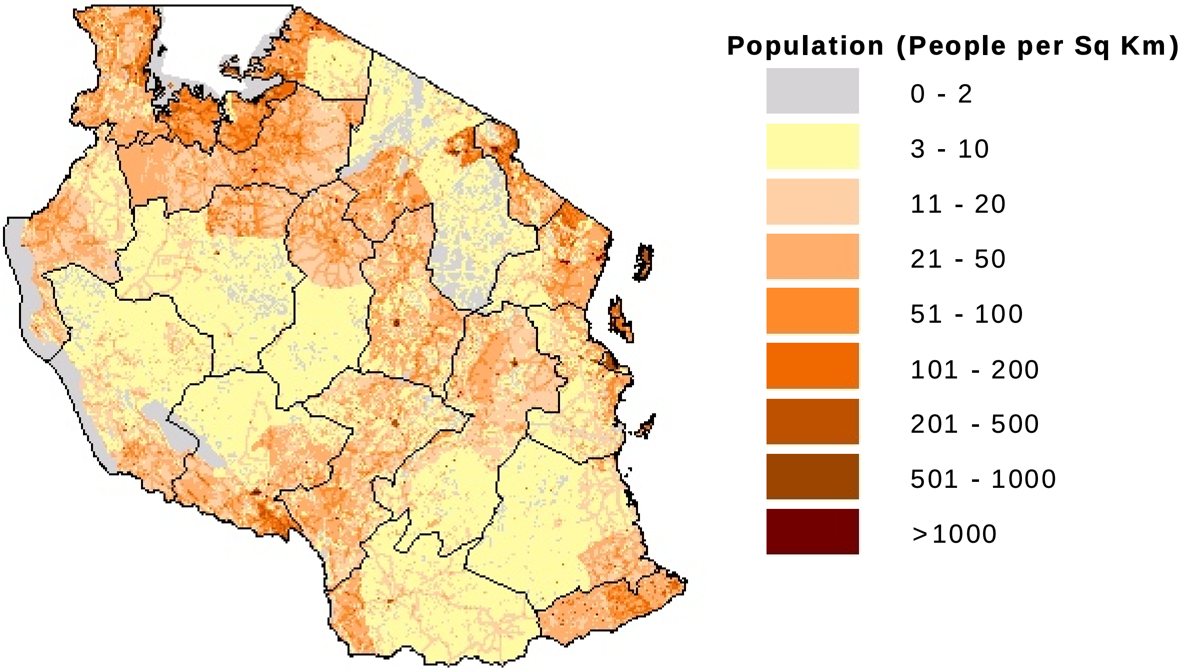


FIGURE 1.1: PICTORIAL PRESENTATION OF POPULATION DISTRIBUTION IN TANZANIA, 2002

Detailed population projections should be based on a study of the present situation and recent historic data. The best starting point are the last two National Population Censuses. In these censuses the population figures are given by enumeration areas and the comparison enables an understanding of recent historic growth rate. To obtain the maps showing boundaries of enumeration areas, the designer has to contact the Bureau of Statistics in Dar es Salaam or the Regional and District authorities. This is important in ensuring comparison is between like areas as the enumeration areas used in each Census are not always exactly the same.

Future population figures are then projected and by judgment of the future growth possibilities of the supply area, the best figure is selected. The choice of method to be adopted in each particular case will depend upon the nature of the supply area, habits of the people, in or out migration, scope for future expansion etc.

The formula to be used is as follows:

$$P_n = P(1 + k / 100)^n \qquad 1.1$$

Where,

P_n = population after n years,

P = present population, and

k = annual growth rate (%)

This can be used also for design purposes for. water schemes , keeping in mind that in practice in urban areas, this population figure is often surpassed and the authorities sometimes are not able to shift the overfill population.

Indeed, for urban areas population projections are more difficult to make than for rural areas, because of the large number of factors which influence the development of an urban area. Factors that can influence urban population growth rates are indicated here as a guide for the study:

a) Water supply in quantity, quality and efficient distribution system
b) Supply of adequate electricity
c) Availability of industries, raw materials and improvement to existing industries in the town
d) Setting up of industries in the town
e) Growth of cash crops around the town
f) Establishing trading centres in the town
g) Good communication network
h) Improvement of health services and hospitals
i) Political importance and economy of the town
j) Improvement of educational facilities and institutions
k) The non-promising subsistence agricultural economy of the rural areas, around the town pushing the people to urban centres for employment.

The designer should check all these points when he endeavours to forecast the population. As a general guide for the design of water supplies the following figures for the annual growth rate of urban areas can be used as a starting point. (For the classification of the communities see table 1.1). It must however be remembered that once a saturation population is reached in any particular area, growth rates can then drop significantly.

TABLE 1.4: PRELIMINARY POPULATION PROJECTIONS FOR URBAN AREAS

Classification		Tentative Annual Growth Rate per year		
		Low Potential	**Medium Potential**	**High Potential**
1	RSC	3%	4%	5%
2	UC	3%	4%	5%
3	MC	4%	5%	6%
4	CC	5%	7%	8%

RSC = Rural Service Centre
UC = Urban Centre
MC = Municipal Centre
CC = City Centre

However, such figures will always need refining and a thorough study analysis of the current data should always be undertaken. Demographic features such as, socio and economic conditions have to be studied before design projections can be established.

For each particular type of institution, specific requirements should be obtained from the institutions concerned. In the rural areas allowance should also be given for connection to schools, dispensaries, health centres, offices etc. Losses should always be determined from the gross. total water requirements and not from the net.

For further information see Chapter 4.

f) Water Pressure

In designing the distribution system, minimum pressure at a public kiosk or tap should not be less than 5 metres and where possible not more than 25 metres. Public supply points fed from pumping mains should be kept to a minimum with small balancing tanks provided off the pumping main wherever practicable from which several adjoining public taps are then supplied.

In undulating terrain up to 150 metres pressure may be allowed.

For storied buildings owners or occupiers should make their own arrangements for boosting the water where the pressure is not sufficient. The pressure required for fire fighting at the hydrant should· not be less than 15 metres and should not be more than 60 metres in the mains.

It should however be noted that allowance of too high pressure will mean also high water losses at joints, bursts, noises, shocks etc. See Chapter 4 for more details.

g) Water Quality Considerations

Water quality in urban areas should be within the International standards or criteria set by WHO. For rural water supplies the revised Tanzania temporary standards can however be used. Appropriate treatment plant should be designed for all surface water sources. In the rural areas as much as possible treatment by using sophisticated methods should be avoided. Where filtration is necessary, plain sedimentation or roughing filter pre-treatment followed by simple disinfection or for non-organic waters, slow sand filtration methods, should be adopted. It is necessary to start water quality analysis of the proposed source immediately the project is conceived. This practice (surveillance) should continue also during design, construction and project operation.

1.1.3 Project Phasing

Sometimes the implementation of a project is carried out in phases due amongst other things to the following parameters.

- Financial resources available
- Opportunity cost of money
- Economies of scale
- Rate of growth rate in the area
- Rate of development in the area
- The design (working) life of various installations
- Development in levels of services

Once the basic design period is decided (usually between 10 and 20 years) and water demand is computed for different years, the different elements can be phased. Exceptions do occur where Financial Assistance capital is being used and there is a fear or a probability that a further tranche will not be available just a few years later.

Generally, phasing will be as follows: -

(i) Dams, river and spring intakes, to be implemented in a Single Phase to cover all of the ultimate design demand or the hydrologically calculated water availability. This is particularly significant for dams as flood spillways form an expensive integral part and the need to raise a spillway inlet and deal with the additional energy at its exit is usually very costly.

(ii) Boreholes to be constructed in Multiple Phases according to the growth in demand.

(iii) Treatment plants and storage tanks to be constructed stepwise or by Phase, according to growth in demand.

(iv) Mechanical installations to be implemented in Multiple Phases according to the design life of the equipment.

(v) Pump houses constructed in a Single Phase with space for additional mechanical plant.

(vi) Rising mains to be constructed to cover the ultimate demand in a Single Phase.

(vii) Long transmission mains to be constructed as two parallel lines in a Single Phase where funds allow or in Two Phases where not. It can be advantageous to dedicate one of two parallel transmission mains to supplying water to the terminal reservoir whilst using the second for a mix of local distribution (daytime) and conveyance to the terminal reservoir (night time).

(viii) Distribution systems to be constructed according to growth in development in Multiple Phases.

1.2 PROJECT PLANNING

1.2.1 Introduction

Historically in Tanzania, the accuracy of most project planning and designs, is very low, mainly because of lack of sufficient and reliable data. Data collection should be given high priority at all stages of project implementation. Therefore it is necessary to have a well organized data collection system during the planning, design, construction and operation stages.

1.2.2 Investigations and Data Collection

1.2.2.1 General

Generally before detailed topographical survey and the design can be carried out the following technical investigations are necessary.

1.2.2.2 Hydrological and Rainfall Investigations

First and foremost is the hydrological investigation which determines the dry and wet weather flows and sediment transport in streams, rivers and springs, whether or not these are tapped directly through gravity or pumped or a new facility such as dam reservoir is to be constructed to ensure a dry-weather source of water in which case siltation rates are especially important. ·In case a dam has to be constructed potential evaporation information must also be obtained.

Information may be gained from Basin Water Offices and the existing national or regional hydrological, rainfall and meteorological network and for smaller streams augmented with daily flow readings from temporarily installed V-notches or rectangular weirs. These flow results may be complemented by weekly or monthly flow measurements where applicable. Since there are random fluctuations in the rainfall pattern in Tanzania whereby, at irregular intervals, years with low rainfall occur, it is most necessary to spread out these investigations over a period at the very minimum of two years even if this means continuing measurements well into a design phase or even beyond. Although such events are generally considered random there is a tendency for extreme events to cluster so during a dry year, even two years of continuous record may prove to be insufficient.

It has happened that projects have been designed based on flow and run-off figures of what proves to be one wet season only, resulting in an expensive project not delivering any water in the dry season. This must be avoided at all costs.

All this information should be supplemented by historic observations solicited from residents of long standing in the area and any visible signs at the site by the investigator, such as high flood marks, vegetation abundance, soil erosion etc. It is important at all these investigatory stages to obtain water analysis reports during all conditions of flow to establish the water quality and also of much importance, the amount of undissolved solids (for water treatment· and silting of reservoirs).

1.2.2.3 Hydro-Geological Investigations

When the source of water is to be a borehole a geophysical report must be prepared and the drilling sites for the proposed boreholes selected by the hydrogeologist. When a boreholes is completed successfully and it is known how much water it safely yields (availability is usually limited to 80% of the maximum pump test), further investigations for the village water supply can proceed quoting the borehole ref no. as source. This is then followed by the topographical survey of pumping and distribution mains etc.

In exceptional cases where groundwater knowledge from nearby previously drilled boreholes is known, designers may be required to proceed with at least the outline design in advance of the specific results from the new borehole.

1.2.2.4 Dam and Reservoir Investigations

The hydrological investigations for a dam and reservoir include the rainfall and evaporation data, silt load in the stream and the assessment of the run-off characteristics.

Rain gauges may need to be established in the catchments area, and evaporation pans set up in the proposed reservoir area. As a rule the selection of a. dam as a source will only be done when dry weather run-of-river flows are known to be insufficient and no other sources, including ground water are available. In most cases a dam site will be chosen along a river course, which is dry or almost dry outside the rainy season or which, as the only source, cannot meet demand during dry season.

Designers should not neglect the possibility of off-river storage on tributaries of the main watercourse as these can often provide topographically superior dam sites than the main river, require smaller and far less expensive flood spillways, are prone to a much slower rate of sedimentation and only require topping up by gravity diversion channels or pumping during in dry years prior to the main dry season.

Where pumping is required, and the main scheme requires this also it may be opportune to install the necessary high volume low head pumps in the same pumping station as with the systems raw water pumps thereby enabling use of the same intake and enabling the pumping main feeding water to the off-river storage reservoir to also be used for returning water from the storage reservoir during dry periods.

The follow-up investigations at a selected dam site include geological and soil investigation by means of hand-dug or mechanical drilled test holes, to determine the soil and rock formations on which the embankment will be founded. This should also include the site for the proposed spillway. With off-river storage reservoirs in particular, saddle spillways into an adjoining water course may prove to be a cost effective option.

Investigations need also to be extended to the reservoir area to determine whether or not the bottom soils are impervious and will hold water when flooded. Initial environmental examination is also recommended to look into the effects of the dam/reservoir to the surroundings. The report on these investigations needs to be completed before the final detailed studies technical, economic, financial and environmental impact assessment (if required): are started.

After the artificial, source has been constructed, in this case the dam and reservoir, the available water quantity and quality will be known. Only at this stage can investigations for the water supply be completed.

It is emphasized that immediately the project is conceived, hydrological, rainfall and other meteorological data collection must be initiated. In addition and given the long design life of such structures, consideration must be given to the possible effects of climate change.

1.2.2.5 Shallow Well Investigation

The follow-up investigations for shallow wells include the geophysical report for the general area and the exact location of the well sites. This later might involve the test drilling by hand augers, banker drills or any mechanical drilling machine. A shallow well should never be located less than 50 metres from a latrine or any pollution source. Shallow wells exploration should preferably be carried out during. a dry season and the depth should not be less than 10 metres or at least 2 aquifers. During investigations the possibility of making use of infiltration galleries should be looked into.

1.2.2.6 Sub-Surface Dam Investigations

Sub surface dams in sand rivers, with a shallow well or infiltration gallery constructed in the river bank are also practical solutions but need extensive follow-up investigations to determine the river bed gradient, thickness of the sand, impermeability of the river bottom and river banks. Where the sand load in a river is considerable, such sub-surface dams can be progressively raised to capture more sand, thereby increasing their storage capacity.

To collect water from within a sub-surface dam a shallow well is needed, either a ring well or a tube well. Thus investigations need to take account of this fact.

1.3 TOPOGRAPHICAL SURVEY

1.3.1 General

The topographical survey is the basis for the design and construction of the proposed water supply project. Consequently the work should be carried out most thoroughly and as accurate as possible. Many points regarding site conditions, alternative routes etc, have to be considered both during the design and the construction stages.

In the following paragraphs important points for consideration are set out to aid the designers what to expect and for the survey parties to obtain. It will be noted that in some instances the points covered continue in to the construction period as it is necessary to bear future construction work in mind during the design stage.

The time required for survey will largely depend on the degree of sophistication of the equipment used, the availability of existing mapping and the extent in which archived satellite imagery is used. Traditional survey instruments such as levels and theodolites have largely been replaced by Total Stations and in some instances by GPS Total Stations which allow real time centimetre accuracy and very fast survey except in close proximity to buildings and in heavily forested areas.

For small schemes and for preliminary design purposes the use of the less accurate hand held GPS devices is permissible although their inherent limitations when it comes to elevation must be recognised.

Assuming a conventional approach is being adopted then the following guidelines apply:

(i) Adequate clearing of vegetation should be carried out to enable the surveyor and engineer to obtain a clear view and an appreciation of the site conditions, which will eventually be portrayed on the survey drawings.

(ii) Adequate coverage of the area to be surveyed is necessary to permit subsequent design to cover all aspects of the proposed work.

(iii) Adequate grid of radial line points for contours

(iv) Establishment of sufficient permanent markers, bench marks and other identification points to allow additional surveys in later years to be tied-in and most importantly allow the setting out of the works prior to construction.

(v) All surveys should be linked and tied-in with any permanent topographical features such as roads, railways, buildings, hilltops etc.

(vi) Adequate coverage of difficult sections by surveying in greater detail and alternative routes and areas so as to allow the designer more choice.

(vii) Adequate linkage between survey work and hydrological work right from the start.

(viii) All survey work should be checked and rechecked.

(ix) As a follow up of the survey and design work is the setting out prior to construction, based on the permanent markers and identification paints, but in a much greater detail and in accordance to the designed working drawings.

(x) All great and small ancillaries should be included in the setting out.

1.3.2 Satellite Images, Maps, and Digital Terrain Models

During the last few years, the availability of **archived satellite imagery** has transformed the way in which schemes can be planned and designed. Archived LandSat and FAO AfriCover images are either low in cost or even freely available although the official nature of the requirement may have to be conveyed to the organization concerned in order to obtain. LandSat 7, ortho-rectified 30.25 m imagery is sufficient for most planning purposes and can form an excellent base layer for subsequent mapping.

For urban areas, where precise alignment of pipelines is important as is the location of junctions and chambers, consideration should be given to the acquisition of QuickBird 60 cm archived imagery, wherever this is available, something that is increasing every year. Here, the request for purchase will definitely need to include the Client's confirmation that the purchase is for official purposes.

By using such imagery to 'count' dwellings and assign dwelling types and average household occupancies, an excellent population estimate is also often practicable.

By accessing the freely available Google Earth software, not only can coverage on an annual basis of QuickBird imagery be determined but individual archived images can be viewed to determine such things as extent, cloud cover and environmental quality before deciding on whether or not to purchase. Procurement can then be made through such companies as MapMart or directly from Digital Globe.

However, it is still often helpful to start planning the layout of the project roughly on 1:50,000 **ordinance survey maps** which cover most of the country; from which alternative pipeline routes can be selected far the detailed survey. Also from the map the rough locations of the major structures can be determined, giving the surveying officer a good indication of what is required.

For large damsites, **digital elevation models** may be useful. They are prepared in a number of ways, but they are frequently obtained by remote sensing rather than direct survey. One powerful technique for generating digital elevation models is interferometric synthetic aperture radar; two passes of a radar satellite (such as RADARSAT-1) suffice to generate a digital elevation map tens of kilometres on a side with a resolution of around ten metres. One also obtains an image of the surface cover.

Older methods of generating DEMs often involve interpolating digital contour maps that may have been produced by direct survey of the land surface; this method is still used in mountain areas, where interferometry is not always satisfactory. Note that the contour data or any other sampled elevation datasets (by GPS or ground survey) are not DEMs, but may be considered Digital terrain models. A DEM implies that elevation is available continuously at each location in the study area.

1.3.3 Pipeline Headwords – Gravity Main

Survey and other investigations would include or aim at: -

(i) Survey of alternative sites to obtain maximum head conditions. Select preferable rock-bed foundation. Where in alluvial material position on the outer side of a bend whenever possible to minimise the capture of sediment.

(ii) Avoid backing-up of impounded water over springs or seepage areas.

(iii) Concrete-in location pegs and benchmark to be left far permanent record.

(iv) Sub surface and bank conditions to be thoroughly investigated by means of test excavations and hand auger. Ascertain exact location of impermeable and solid strata and thoroughly investigate fragmented and decomposed top layers and other doubtful strata.

(v) Springs, seepage and sandy river-bed development by adits, drainage conduit or sub-surface damming.

(vi) Investigation and survey of alternative and supplementary sources of supply.

(vii) Survey and sitting of cofferdams and diversion needed during construction.

(viii) Investigate for the design of ample intake site and bank protection against scouring and flooding.

(ix) Investigate for the upstream forest protection, establishment of restricted or reserve areas and the prohibition of cultivation and cattle watering near stream bed banks.

(x) Investigation into possible pollution source, i.e. cesspits, cattle bomas, industrial or agricultural wastes, excessive spraying of insecticides or leaching of fertilizers.

(xi) Investigations into the upstream backwater effect; seepage in basin area, through upstream river banks. or under weir structure.

(xii) Investigate for the design of cut-off walls and stream-bed width to allow for maximum flood flows.

(xiii) Investigate and ascertain existing and pending water rights and make adequate provision for the division of the waters.

(xiv) Investigate for security fencing around intake works.

1.3.4 Pipeline Headwords – Pumping main

Survey and other investigations would include or aim at: -

(i) Survey pumphouse location on solid ground as near to source as possible but above maximum flood line.

(ii) Investigate location for pump sump with infiltration channel, perforated pipe and sand / gravel filters.

(iii) Position of pumps such that the shortest possible suction pipe is used, preferably without any bends and in a straight incline from the source. Ensure suction lift will be within the permissible parameters depending on altitude.

(iv) Survey of access road to pump house

(v) Investigations and surveys for foundation, working head for the water in pumping main, including the traverse of pumping main and the height and distance of the water to be delivered.

1.3.5 Pipeline Traverse – Gravity and Pumping Main

Survey and other investigations would include or aim at: -

(i) Reconnaissance and investigations for alternative lines and possible future extensions and branches.

(ii) Detailed design survey on the shortest possible line; however on a constant falling (or rising) gradient. Avoid wherever possible valley crossings and high points. A minimum of wash-out and air valves and slightly longer pipeline is preferable but subject to a maximum distance between air valves of 800 m to 1000 m.

(iii) Levels and lengths checking during survey concreted in pegs and benchmarks to be left.

(iv) Salient permanent terrain features to be incorporated to facilitate future re-location.

(v) Survey existing and required access roads and tracks.

(vi) Detailed survey of unavoidable valleys, stream or road crossing. Make provision for the necessary tracks and bridging to be constructed.

(vii) By selecting pipeline traverse the alternative types of pipe and joint should be considered.

(viii) Test pits or hand auger holes to be dug at suitable intervals to determine depth to rock strata; to assess ground water table (i.e. risk of floatation of pipe), cohesive soils etc.

(ix) Pipeline traverse to avoid rock outcrops to eliminate the need for pipe to be laid above ground if at all practicable.

(x) Investigate necessary compensations, etc. (crops and buildings).

(xi) Investigate possible construction camp site in relation to access and construction needs as well as storage areas for pipe material.

(xii) Survey should take' account of the head limitations i.e. potential static and piezometric pressure on pipeline sections by dividing up portions into vertical intervals for head limitations on different classes of pipes where thermoplastic pipes are being considered Where necessary locate and survey sites for- break pressure tanks.

(xiii) Pipe line survey should be in greatest possible detail, while fixing all ancillary structures, valves, division boxes, break pressure tanks, storage tanks, troughs etc. Special care and correctness in determining gradients in broken country is needed to ensure a constant gradient as far as practicable. Where not and particularly for pumping mains a concave pipeline profile from start to finish is far better than a convex profile when it comes to water hammer risk.

1.3.6 Pipeline ancillaries

Survey and other investigations would include or aim at: -

(i) Siting and surveying for storage facilities (tanks) along gravity mains such that wherever possible a Ground level tank on suitable high ground can be provided.

(ii) Similar to (i) above where elevated storage tanks are unavoidable ..

(iii) Avoid using a combined inlet/outlet pipe for ground level or elevated tanks.

(iv) Siting and survey for break pressure tanks on high points with the ground falling away quickly at the down stream (outlet) side. Include for suitable drainage and the overflow.

(v) Survey for treatment plant structures, taking into account suitable foundation on preferable slightly sloping terrain to give extra head to overcome treatment head losses. Where practicable chemical storage, mixing and dosing should enable gravity flows. Investigate and ensure there is adequate drainage of the site.

(vi) Siting and surveying for high and low lift pump stations and for suitable foundations, drainage etc.

(vii) Establishing sites for livestock watering troughs at sites with adequate drainage, free of the danger of soil erosion and free of interference by livestock on human habitation and cultivation.

(viii) Siting of domestic water points (public taps or kiosks)at strategic locations in each village to keep walking distances to minimum. Not more than 250 people per tap, 1,000 to 1,500 inhabitants per domestic point location as a maximum and/or not more than 400m walking distance.

(ix) Siting .of all valve boxes for airvalves and wash-outs.

(x) Siting and surveying of all road, railway, furrow and river crossings. Consider alternative sites to enable selection of the optimum one.

1.3.7 Catchment Upstream of Reservoir

Survey and other investigations would include or aim at: -

(i) Surveying of area, shape and slopes

(ii) Investigation of vegetation and soil types

(iii) Investigation of soil erosion likely to be caused by run-off, wildlife, cattle or over cultivation and the incidence of possible siltation.

(iv) Investigations and assessment of flood and yield by spot gauging, weirs and from local knowledge establishing griffin gauges, painting of bridge and culvert abutments to show water marks, debris caught on trees etc. Check on flood water retention due to flood plains, swamps and mbugas.

(v) Establish rain gauges in the catchment and record rainfall, assembling rainfall-data from neighbouring meteorological stations institutional or private sources to allow ~ assessment of total precipitation and intensity .

(vi) Estimating total yield and balancing against basin capacity.

(vii) Water analyses of dry and wet season flows

(viii) Water rights, minimum compensation releases etc.

(ix) Compensation water and down stream effects.
(x) Protection of upstream forests.
(xi) Prohibition of river bank cultivation and in small mainly forested catchments of inhabitation in catchment area.
(xii) Investigations into supplementary catchments through flood diversion channels and road drainage diversion.
(xiii) Sub surface damming and flood retention barriers

1.3.8 Immediate Reservoir Catchment

Survey and other investigations would include or aim at: -

(i) Selection of alternative sites of wide, flat valleys bounded with steep lateral slopes, coupled with a narrow outlet for dam site.
(ii) Survey and check on full supply and possible flood levels and calculate reservoir capacity.
(iii) Establish permanent benchmarks and 1ocation pegs at F.S.L. and top embankment levels.
(iv) Investigate possibility of increase of reservoir capacity by excavation, special consideration for small dams and hafirs.
(v) Investigation into initial reservoir area clearance to assess holding capacity, specially porosity of reservoir floor, geological faults, sandy sub-strata etc.
(vi) Investigations of reservoir floor by means of hand-dug trial holes, auger and/or mechanical drilling.
(vii) Investigation and calculation of average depth to surface area relation with estimated evaporation losses (depth against area capacity curves).
(viii) Assessment of clearance of reservoir area of trees and vegetation, and the inhibition of aquatic plants, possible occurrence of bilharzia etc. Clearance of trees is also important to avoid the slow, long term release of organic material from decaying wood especially if slow sand filtration is being considered as the treatment process as such organics inhibit .
(ix) Preparation of flood detention curves.
(x) Assessment of possible silting and erosions and necessary preventive measures.
(xi) Establishing compensation and other claims.
(xii) Prevention of cultivation along reservoirs shoreline and the prohibition of entry of livestock (anti-erosion and silting).
(xiii) Liaison with Fisheries Department for stocking with fish. (It has been experienced that in large capacity reservoirs the non clearance of trees at the upstream end of the reservoir area inhibits the breeding of fish and results in the depletion of the fish stock by over fishing).
(xiv) Investigate the risk of seismic induced activity by reservoir of capacity equal or greater than one billion cubic metres.

1.3.9 Dam Embankments

Survey and other investigations would include or aim at: -

(i) Surveying of alternative sites and establish bench marks and location pegs.
(ii) Assessment of soils and/or rock on base by test pits or auger drilling.

(iii) Choice of type of embankment. i.e. earth fill, rock fill, masonry, concrete gravity etc. The choice of type of dam available and the materials the dam is to be founded upon.

(iv) Assessment of volume capacity and size in relation to storage and availability of water.

(v) Establishment of faults in vicinity of dam and especially of any fault lines at right angles to proposed embankment and risks of movement or catastrophic failure.

(vi) Soil tests on disturbed samples of base materials.

(vii) Selection-and choice of embankment fill from base materials.

(viii) Selection and choice of embankment slopes and allowance for valley slope in setting-out. Provision of berms, backfill toes, drainage, clay blankets etc. and choice of crest width (allow for passage of grader, bulldozer etc.).

(ix) Investigation for core wall (clay or concrete) and the location of solid rock or impervious layers to key-in the core wall.

(x) Examination of fragmented or decomposed rock or other pervious strata at embankment base and abutments and the selection of sealing method.·

(xi) Establishing of rock fill toes, and drains breaching section.

(xii) Allowance for settlement, gravelling of crest and crossing of slopes. Establishing of embankment top level pegs (in concrete) at minimum 10m distance.

(xiii) Investigation of diversion of perennial streams with a cofferdams etc. during construction.

(xiv) Protection of embankment from erosion by cattle, game etc.

(xv) Allowance of sufficient free-board between flood retention level and top embankment.

(xvi) Assessment of wind velocity resulting in wave action and the need to protect upstream slope of embankment with rip-rap, pitching etc against erosion of upstream face and grass turfing of the down stream face.

(xvii) plan for instruments for dam monitoring and safety precautions.

1.3.10 Dam Spillway

Survey and other investigations would include or aim at: -

(i) Establish spillway site on more appropriate embankment abutment or in a suitable saddle along reservoir shore line, discharging into adjacent valley.

(ii) Selection of a suitable site, preferable in rock, with suitable low gradient approach and side slopes. Assessment of erodibility by soil tests.

(iii) Calculate the necessary width for flood volume of water at agreed return period with low velocity and average depth.

(iv) Establish protection of all slopes with concrete spillway crest wall and other concrete steps if necessary.

(v) Protection of guide bunds, side slopes and embankment sides by pitching (grouting if necessary), paving, pitching or rip-rap etc. Provision of catch water drains on the high side of spillway channel.

(vi) Clearance of channel from trees and shrub and where necessary paving, pitching or rip-rap filling making for a level floor, slightly sloping away from embankment in cross-section.

(vii) Provision of breaching section in embankment or emergency spillway on abutment.

(viii) Investigations and design of complicated forms of spillways such as syphons, bell mouth, chutes or dropway spillways with stilling pools should be avoided wherever possible.

(ix) Assessment of the provision of natural foundation.

1.3.11 Dams Draw-off Arrangements .

(i) Choice of intake structure, i.e. concrete bell mouth with shaft and culvert, twin draw off pipes, siphon, floating draw-off etc.

(ii) Selection of alternative draw-off at different water levels to prevent floating debris or silt entering pipes or culvert.

(iii) Selection of diameters or size suitably large to allow desilting and scouring, and to prevent blockage (never less than 200mm ID) and always duplicated.

(iv) Provision of stanchion rings and recessed trenches for draw-off pipes and culverts through embankment and lain in undisturbed solid strata to prevent water flowing on the outside of pipes or culvert. Impervious materials to be well consolidated and puddled around pipes or culvert.

(v) Establishing valve gear at down stream end for supply of water and scouring purposes, together with proper stilling pool and channel to lead water quickly away from down stream toe.

(vi) Establishing for large dams similar arrangements by means of discharge tunnels and sluice gates.

(vii) Draw-off water supply should not usually be below a quarter of the total depth at full supply level from the bottom of the river bed.

1.3.12 Sub-surface Dams

(i) Investigations and surveying to ascertain stream bed slopes, cross sections to assess sand depth and incidence of impermeable strata in bed and banks, supplemented by test pits and auger drilling.

(ii) Computation of storage capacity within sand volume (approx. 25 % of that volume contains water); taking into account that the water slope is not flat as in surface reservoirs and evaporation is negligible.

(iii) Selection of a series of barrier points, preferred on rock bottom or impervious bottom and river banks.

(iv) Choice of dam medium, water proof concrete, block or masonry work, metal sheeting or impervious clay. Account should be taken of both active and passive pressure upstream of barrier, while only passive pressure acts at the down stream side.

(v) Barriers to be stopped 50 cm below surface to guard barrier against erosion and scour when river is in spate, unless specifically designed to increase depth of sand bed in which precautions against downstream scour may be necessary.

(vi) Sand temporarily removed during barrier construction to be thoroughly compacted back into excavation and surface to be left completely smooth.

(vii) Selection of draw-off point upstream of barrier. Usually a solid concrete ring well on banks of river with additional perforated pipes surrounded by gravel leading into well. Well to be covered at top to prevent filling with sand when river is in spate. Hand or small motor pumps can be provided at well head

1.3.13 Hydrams

Survey and other investigations would include or aim at: -

(i) River and stream gauging as for intake

(ii) Survey and selection of intake side and traverse of approach furrow and/or drive pipe, similar as for pipelines and intakes.

(iii) Investigations of intake and approach furrow in respect of overflow and cleaning arrangements.

(iv) Survey of drive pipe traverse, length, levels, gradient to determine size and investigate necessary anchorages etc,

(v) Establish and survey site for ram, including foundations, flood and debris protection, drive-water runaway, livestock and game protection.

(vi) Survey delivery main, length, levels anchorages and pressure relief arrangements as for pipeline (rising main).

(vii) Water rights and compensations.

(viii) Water analysis

(ix) Investigate and determine possibilities of future extensions, duplication and general increase in capacity.

(x) Investigate an alternative drive-water supply in cases where the amount of clean water available is small. (Type "B" Hydram to be used see appendix)

A simple calculation can be carried out, to find volume to be delivered, using the following formula:

$$q = Q \times h/H \times \eta \qquad 1.2$$

Where,

q = volume delivered (litres/day),

Q = volume used (litres/minute),

h = fall (metres),

H = lift (metres),

η = efficiency (use 0.66 for commercial models).

1.3.14 Water points

Survey and other investigations would include or aim at: -

(i) Location of domestic and livestock watering points in relation to one another to ensure adequate coverage. Avoid, in the case of cattle troughs, the possibility of over grazing and soil erosion due to cattle travelling to and from the troughs.

(ii) Provision of adequate hard standing surrounds with designed drainage channels and soakaways for domestic and cattle watering points.

(iii) Provision always of a constant flow valve at each domestic point, with a sturdy waste-not tap at the domestic point.

(iv) Compensation requirements

(v) Structures to be clear of road and railway reserves.

1.3.15 Miscellaneous

Survey and other investigations would include or aim at: -

(i) Provision of suitable concrete anchor blocks for pipeline in trench at each and every change of direction, at each junction, on steep slopes and under each type of valve.

(ii) Provision (sufficient and suitable air valves at all high points, and all significant grade changes on rising grades) protected in concrete box or chamber.

(iii) Provision of scour-valves at each low point, protected in concrete box or chamber.

(iv) All pipelines should be marked on the surface by concrete marker blocks, 75cm high by 25cm square whilst thermoplastic pipes should have a metallic strip marker laid on top of embedment material before final backfill is placed.

1.4. PROJECT REPORTS

In general project reports are issued in three stages although the nomenclature for each stage varies. These are:

(i) The pre-feasibility study stage

(ii) The feasibility study stage

(iii) The preliminary engineering and final detailed engineering design stage

Sometimes (i) and (ii) are combined and sometimes (iii) is undertaken in two sub-stages.

1.4.1 Pre-feasibility Study Stage

The pre-feasibility stage ends in a report that presents the findings of initial fieldwork and studies of alternative water resource development plans. If it is to be followed by a separate feasibility study, it is sometimes abbreviated and the report issued is more an outline of possibilities and a list of all the fieldwork activities that need to be accomplished at feasibility study or even preliminary engineering stage.

The objective of this initial study is to determine whether it is worthwhile to proceed with more detailed investigations. In other words at this stage various projects or alternatives are screened and this should normally reduce the number of options considered feasible to no more than three or so. The report should however contain recommendations on the proposed project and how to proceed with the detailed investigations.

These should include indications on the:-

- data to be collected
- remaining alternatives to be considered and investigated
- professional manpower required
- estimate of time that will be taken or needed
- budgetary financial requirements etc.

The above are considered taking into account

- long term needs
- deficiencies in the existing system (if any)
- phase of project implementation

Briefly the pre-feasibility report gives an outline of future development which seems most appropriate to provide the project area with water in the long term. The other major aim may be to select a short term project that may be implemented to overcome any immediate needs (crash programme) while the long term project is being prepared. The pre-feasibility study report normally has the following pattern:

1.4.1.1 Chapter 1 – Introduction

Here a brief explanation of the reason for the study and report and the methodology used in preparing it is given. The report chapter should include a :-

- Project history (how it originated etc)
- Organization and management of study
- Scope and status of report

1.4.1.2 Chapter 2 – Water Supply Programme

This chapter should give an overview of the general water supply programme in the country, dealing with such things as: -

- Country background information and National Water Policy
- Economic situation
- Water resources availability
- Sector organization and developments
- Present coverage
- Sector goals
- Staffing requirements, and training needs
- Financial implications
- External assistance

1.4.1.3 Chapter 3 – Project Area and Need for the Project

In this chapter the purpose of the project is described. The chapter comprises of the following: -

- Planning period
- Project area (geographical)
- Population pattern
- Economic and social conditions
- Initial environmental examination
- Impact of the project
- Existing and expected future land use patterns
- Institutional set-up
- Availability of water resources
- Existing water supply system
- Population served

1.4.1.4 Chapter 4 – Strategic Plan for Water Supply

This chapter should describe various alternatives that are proposed and evaluated with the aim of recommending a least cost project that can be implemented. If necessary due to such things as insufficient information or where the costs of alternatives are of a similar order of magnitude it may be necessary to describe each of them. The chapter should include:

- Project objectives
- Water supply services
- Community involvement
- Future water demand projections for various consumers
- Priority determination

1.4.1.5 Chapter 5 – Proposed Project

The chapter comprises of the technical explanations and analyses of various project components that would be possible for implementation during the planning period. The chapter should include:

- Project definition
- Institutional responsibilities (who will be responsible) for design, construction and operation and maintenance
- Financial aspect such as the financial requirements to meet both capital and recurrent costs, tariffs etc.

1.4.1.6 Chapter 6 – Conclusions and Recommendations

Here important results of the Study are presented. This comprises of:

- Conclusion – summary of results of the study based on the preliminary analyses.
- Recommended actions necessary for the completion of the project activities, schedule etc., and in particular the additional field investigations considered necessary.

1.4.2 Feasibility Study Stage

The Feasibility Study Stage develops the pre-feasibility work further and ends with a Report which normally concentrates on the project alternatives that were recommended for more detailed consideration at the pre-feasibility stage.

The study is normally carried out by a team of competent and experienced personnel from the Ministry, UWSA or with the help of a consultant. At this stage the following should be achieved.

- Collection of sufficient data,
- Alternative plans (projects) adequately studied and evaluated,
- Socio-economic analysis adequately done and completed
- Environmental impact assessment (EIA) done. For larger projects a statement on Life Cycle Assessment should be included indicating extent of quantitative and other relevant information currently available
- Preliminary engineering design is done, including a review of alternative materials
- Preliminary Cost estimates done,
- Economic internal rate of return and financial internal rate of return
- Most feasible project (lease cost) selected, and

- Feasibility report prepared and presented to the authorities for approval

The report may also include interim progress reports, appendices of data collected during the detailed study. Normally it is the feasibility report that is presented as a supporting document to apply for financing from the financing agencies.

It is recommended that the feasibility report comprise of the following sequenced chapters:

1.4.2.1 Charter 1 – Background

In this chapter the history of the proposed project and the explanation on how the project fits in the regional and national annual and long term water supply programme should be given. Previous studies overview i.e. master plans, pre-feasibility studies etc. should be given.

1.4.2.2 Chapter 2 - Project Area and Priority Ranking of the Project

This chapter should provide information and analyses which were not included in any previous preliminary study report as well as any changes to earlier tentative conclusions as a result of the additional investigations undertaken.

1.4.2.3 Chapter 3 - Plan for a Water Supply Project

In this chapter the project for implementation is selected. The previous proposed plans should be confirmed or revisions presented. The chapter should cover:

- The planning period
- Project objectives
- Areas to be covered, i.e. consumers to be covered
- Population Projections
- Demand projections
- Ranking of the selected project
- Recommended development plan

1.4.2.4 Chapter 4 - The Proposed Project

In this chapter the proposed project is described in detail. These should cover:

- Objectives (quantified)
- Project consumers (quantified)
- Rehabilitation of existing scheme (immediate works programme)
- Proposed long term project works
- Environmental impact assessment findings and recommendations including for urban schemes and larger rural projects an up to date statement on Life Cycle Analysis.
- Technical description of the project (e.g. role, location, design, criteria, number and capacity of each component etc.
- Integration of the project with the existing and future scheme
- Project implementation recommendations and methodology
- A cost estimate for the preferred project broken down into local and foreign components and elements that can be contributed by beneficiaries.

- Implementation schedule
- Cash flow of water supply system
- Operation and maintenance of project
- Procurement of materials, contractor etc.

1.4.2.5 Chapter 5 – Institutional and Financial Aspects

In this chapter various organizations that might be involved in the detailed design, construction and the operations and maintenance of the project need to be defined. This should cover:-

- organization and management
- staffing implications, and training requirements
- future staffing and training plans
- financial history of the present organization responsible for running the system
- tariffs and charging system for water supply systems
- tentative financing plan, i.e. source of funds etc.

1.4.2.6 Chapter 6 - Conclusions and Recommendations

In this chapter the feasibility of the project is stated and recommends actions to be taken made.

This should cover:

- Summary of the study and the proof that the project is feasible, economically, technically, financially, socially, culturally, environmentally and institutionally.
- Recommended action for the successful implementation and operation of the project.

1.4.3 Engineering Stages

After the feasibility report is presented and approved, the preferred alternative is selected and the finances obtained. The Engineer then prepares the preliminary engineering and then the detailed or final project report. These reports provide the basis for implementation. The initial report provides the design basics which are then developed further in the detailed designs of the project including working drawings and tender documents.

The contents and layout of these reports are considered both here and in Chapter Seven. They should however include a review all relevant aspects of this Water Design Manual and either accept or otherwise indicate, complete with detailed reasoning, why different criteria is proposed. As a minimum, a copy of this Chapter should be forward to the Design Section of the Ministry of Water before proceeding to final design for them to consider and if necessary take into account, either in an Addendum to the Manual or in future releases.

In addition the report must address the issue of costing being adopted and to what extent whole life cycle analysis and costing is being adopted, as well as a consideration of the environmental impacts of the project and its envisaged elements as well as the issue of climate change and its possible effects on the proposals being designed.

It should be noted that the conceptual designs provided at the feasibility study or preliminary engineering stages are generally inadequate for the construction of the project. Foremost, the

Engineer arranges for any outstanding detailed field investigations, surveys and data collection. Based on the detailed field data collected; detailed designs, plans and estimates are prepared.

1.4.3.1 Detailed Designs

Chronologically, this would be expected to include:

- Hydrological, hydro-geological, and meteorological data collection and analysis
- Statistical analysis of data collected for the population and demand projections
- Hydraulic computations for hydraulic works including the distribution system
- Structural and stability computations of different structures
- Calculations for pumps, motors, power generators and other machinery and equipment
- Least cost lay-outs for different components of the project, i.e. treatment plants, hydraulic and structural works, and
- Engineering analysis for deciding the most economic size of delivery mains.

1.4.3.2 Detailed Drawings

These would include:

- Index plan showing overall layout of project
- Schematic diagram showing levels of salient components of the project (may not necessarily be to scale)
- Detailed plans and sections in scale for the headwords, treatment plants, clear water storage tank, pumping station, etc., in a scale 1 :20 to 1: 100 depending on the details and size of work.
- Detailed drawings of any electrical systems and electronic networks
- Detailed structural plans for structures, intake treatment plant, clear water reservoir etc., in a scale of 1: 20
- Schematic diagrams for operation and control of the project
- Index plan of the. distribution system normally in an appropriate scale
- Longitudinal sections of the delivery main and details of appurtenances in scales:
    - Horizontal scale 1: 500 to 1: 5000 depending on distance and details
    - Vertical scale 1:20 to 1:100 depending on the terrain surface undulations.

1.4.3.3 Detailed estimates of capital costs

As far as possible this should be based on unit costs derived from recent projects of a similar magnitude, complexity and remoteness from or proximity to ports or major urban areas.

1.4.3.4 Detailed estimates of recurrent costs

As far as possible this should be based on unit costs provided by the operating authority or from schemes of a similar size and nature.

1.4.3.5 Anticipated revenue

These should be based on the recommendations made regarding tariff structures or provided by the operating authority

1.4.3.6 Detailed Design Report

A report should accompany the detailed designs, plans and estimates elaborating on the:

- Engineering aspects (inclusive of operation system and control network proposals)
- Financial aspects
- Administrative aspects, etc.
- Tender documents; specifications etc

1.4.3.7 Execution

Each phase of the project implementation should be planned in detail using techniques such as critical path method (CPM) and Programme Evaluation and Review Technique (PERT).

1.4.3.8 Tenders

In preparing the tender documents, unit rate contract is normally adopted for project components such as intake, delivery mains, distribution system, storage tanks and other appurtenances. For specialized areas like he treatment plants and pumping station it may be necessary to prepare separate tenders for the supply and installation of such facilities. The super structure may still be included in the main contract bill of quantities. As much as possible one contract should be preferred. The suppliers of such specialized equipment would then be included as sub-contractors of the main contractor.

1.4.3.9 Project write-up to be submitted to financiers

Each donor may have a different pattern of project presentation for financial. The project document should therefore follow more guidelines as indicated by the financiers.

1.5 SPECIAL CONSIDERATIONS FOR RURAL WATER SUPPLIES

1.5.1 Participation of Beneficiaries in Rural Water Supplies

For a technology to be socially appropriate it has to be received and in accordance with the preferences of the community and should lie within the capacity of that community to pay for the operation and maintenance and where possible from within the community itself.

The mutual communication between the field personnel Engineers, the consumers or villagers and their representatives, local government and other governmental representatives must be constant and open. If the community is educated on the need of clean water, hygiene and their responsibilities, then the community participates fully. The community has to be involved in every stage of project development. It is necessary to involve other sectors like AFYA and the community development personnel of the PMO, MAENDELEO and District level local government representatives.

1.5.2 Millennium Development Goals

The National Rural Water Supply and Sanitation Programme (NWRSSP) covering all Districts in Tanzania aims at reaching the 2015 MDGs, most probably in 3 programme stages, the first to

2009/10, the second to 2012/13 and the third by the end of 2015. By 2009/10, 65% of the rural population should have access to improved water sources within 30 minutes walking distance and 100% of schools have adequate sanitation facilities and 95% of the rural population have basic sanitation. By 2015, the rural population with access to improved water sources to be 76.5%.

Stage 1 is expected to concentrate on rehabilitation and limited additional small schemes whilst stage to will be primarily new schemes with some limited final rehabilitation of older projects not attended to in stage 1, and stage 3 is expected to complete the programme through new schemes.

Wherever practicable these would be individual village schemes so as to minimise disagreements between adjoining villages and enhance the sense of ownership.

1.5.3 Planning Stage

(i) Involves: target community (beneficiary), village government leaders, local government, and indirectly central government. Strategies include sensitisation, mobilization formation of action groups. In surveying the socio-cultural aspects it is most effective to use two interviewers male and female.

(ii) The reconnaissance survey involves:
- The selection of water source and geographic survey
- Project component siting
- Determining additional facilities for cattle, laundry etc
- Manpower selection and data collecting
- Socio-cultural information
- Demographic survey, including health, occupation, organization and community participation, villagers, level of interest in the project, per capital income, affordability, willingness to pay, preferred source of water, sanitation practice, resources available in the area, choice of technology and whether livestock water demand should be included in the project.

(iii) Water use for other productive activities like Agriculture and livestock.

Ranking of Projects

Criteria:

- Type of technology
- Negative environment impact
- Quality of water available
- Cost/benefit analysis; Walking distance; Scheme complexity

1.5.4 Design Stage

(i) Appraise the alternatives

(ii) Solicit the views and preferences with villagers in an open meeting

(iii) Discuss-.the merits and demerits with village representatives

(iv) Rank alternatives on basis of appropriate method cost and perceived ability of villagers to afford the costs of operation and maintenance and reach agreement in principle with District water officials.

(v) Inform the village reasons for the selection of the alternative(s) and seek their agreement.

(vi) Carry out design to a level sufficient to enable construction to proceed either using local (District) based contractors or a Force Account approach using local sub-contractors as considered feasible and appropriate or an in-house approach.

1.5.5 Construction Stage

(i) Community information and motivation
(ii) Organization of village participation
(iii) Collection of local materials procurement of materials
(iv) Safe storage facilities of materials
(v) Camping arrangements
(vi) Identification of problems
(vii) Selection of community members for special tasks and training
(viii) Define responsibilities
(ix) Proceed to construction
(x) Respect the religions and local ceremonies, migration pattern etc: according to local traditions. Hand over declaration should be presented on this day.
(xi) Test-run scheme components individually and then scheme as a whole and when successful, commission.

1.5.6 Operation and Maintenance Stage

(i) Formation of scheme operation and maintenance management team by the beneficiaries or local entrepreneur acceptable to community and hand over the scheme.
(ii) Define the responsibilities and up keep of the records, logbooks etc.
(iii) Train managers operators and maintenance mechanics.
(iv) Prepare an O&M management system and detail of M&E techniques.
(v) Formulate tariff structure and strategies of collecting revenue.
(vi) Develop appropriate maintenance schedule, check list and spare parts stock list.
(vii) Develop follow-up and health and water quality surveillance mechanism.

1.5.7 Choice of Technology

As far as possible ranking of project selection should be based by progressive consideration of:

(i) Hand pump(s) from proven permanent deep hand dug well(s) or shallow borehole(s)
(ii) Gravity scheme from protected spring
(iii) Medium or deep well with appropriate hand pump (rotary type)
(iv) Pumped / Piped Scheme

For point water sources or simple distribution systems, a prime location for a domestic point should be the village primary school followed by a village health facility (if any). Provision of improved sanitation and hand washing facilities at both primary school and health facility should also receive priority consideration in any village scheme.

1.6 APPROVAL OF DESIGNS, COMPLETION REPORTS AND MONITORING OF PROJECT PERFORMANCE

1.6.1. Design Checking and Approval

1.6.1.1 Checking

After the design engineer has completed the designs, these should be counterchecked by another competent engineer. All National project designs must be sent to the Ministry for checking and approval and all Water Authority Projects by the Authority concerned. Should a Water Authority feel it does not have the capacity to undertake a proper evaluation then these should also be sent to the Ministry for checking and agreement before implementation. Where consultants are engaged, the contracting authority must always check and approve the design as per appropriate clause in the contract.

In any event, a copy of all designs if and when implemented should be forwarded to Ministry HQ for data storage and permanent central record and reference.

1.6.1.2 Approval of Designs

All District projects must first be approved by the District Water Engineer (DWE), who if in doubt should consult the Regional Water Engineer/Adviser. All LGAs should forward a copy of the design for review and approved at the regional level and a copy of the approved design should then be forwarded to the Ministry HQ.

Designs should be sent to the Ministry, where Regional or District Water personnel consider it to be advisable for final checking and subsequent approval or if this is specifically required. All projects submitted to the Ministry will be approved by the Ministry Head of the Designs Section.

1.6.2 Completion Report

All projects executed must have a completion report (as constructed reports and drawings). It is essential that Resident Engineers or Foremen keep an up to data record of all project activities including all changes to the original design with reasons for this clearly indicated.

1.6.3 Monitoring of Project Performance

The aim of the project is to provide the services uninterrupted. To ensure this, a proper monitoring mechanism of the performance of the project should be instituted. Such a mechanism could include proper procedures for procurement and distribution of spare parts, fuel, replacement etc., a maintenance programme for the project including personnel at the village, District and if necessary at Regional and National levels also.

Likewise a water quality surveillance procedure should be instituted in the framework of the existing mechanism.

1.7 ENGAGING A CONSULTANT

Consultants may be engaged for either carrying out studies and design or for supervision of water project implementation. The employment of consultants is sometimes necessary for various reasons such as:

(i) Lack of sufficient and experienced personnel

(ii) The project to be undertaken requires highly specialized expertise not available in the Ministry, Region or District.

(iii) Training of personnel is considered an necessary component of the project
(iv) Speeding up the project cycle
(v) Using bilateral or multilateral financial assistance tied to the use of Consultants.

Before Consultants are invited to submit their proposals, the following should be done.

(i) Ensure that the funds are available
(ii) Prepare the Terms of Reference (TOR) for the Work to be carried out.
(iii) Select a short list of firms to be invited; this should not be more than six. Avoid preparing a long list. This will always discourage good coI1suIting firms.

Where international consultants are invited they should be able to show that the company has ISO 9000 accreditation. Where local consultants are invited they should be required to submit evidence of their quality assurance plan and procedures.

Before embarking on the preparation of the TOR, the engineer should first:

(i) Be familiar with the project
(ii) Have visited the project area
(iii) Know the extent of background data available
(iv) Know the seasonal variations in water source supply
(v) Have a good knowledge of the methodology for evaluating the proposals etc

The TOR should as far as possible provide the following:-

(i) Precise objectives of the work to be carried out
(ii) Scope and timing of the work to be undertaken
(iii) Inputs if any by the Government
(iv) Output required such a reports, drawing etc
(v) The TOR should be precise on the Consultants responsibilities and authorities
(vi) The TOR should indicate methodology for submitting the proposals i.e. financial and technical proposals – normally these are submitted in two separate envelopes.
(vii) The TOR should require each consultant to sign and include a formal statement on corrupt practices.
(viii) The financial proposal should be detailed to include all the cost make ups. Under no circumstances the supervision fee should be quoted as a percentage of the construction costs.

Evaluation is initially based on the Technical proposal to select the technically preferred bidder. If the most competitive firm on technical grounds appears to be not competitive on financial grounds, negotiations should be conducted to reduce the amount quoted to what are considered to be reasonable limits.

Joint ventures between the most competitive consultants on technical and financial grounds could be negotiated to minimize the cost of the project. Foreign consultants are always encouraged to form joint venture with local consulting firms or individuals and on some projects may be required to do so.

Where the consultant considered to have offered the best technical proposal is unable to agree to such a joint venture or to reduce the price to an acceptable level, then the next best adjudged consultant on a technical basis should be invited to negotiate.

1.8 WATER LAW

Water Law in Tanzania is interpreted in accordance with:

- The Water Utilization (Control and Regulation) Act No. 42 of 1974, as amended by Acts No. 10 of 1981 and No.17 of 1989 which provides the basis for all Water Law,
- Water Laws (Miscellaneous Amendments) Act No.8 of 1997, and
- Water Laws (Miscellaneous Amendments) Act of 1999.

Tanzania is at an advanced stage of drafting a new legal framework for water resources management, aimed at attaining the objectives of the National Water Policy of 2002.

The Act deals with the following issues:-

1. Appointment of Officers and Establishment of Water Advisory Boards.
2. Ownership and Inherent Rights to the use of Water.
3. Grant of Water Rights.
4. Revision, Variation, Determination and Diminutions of Water Rights.
5. Miscellaneous Powers
6. Appeals
7. Offences
8. Miscellaneous Provisions

1.9 STANDARDS AND UNITS

Standards

All locally or imported merchandise should as a minimum conform to the standards laid down by the International Standard Organization (ISO) and where such standards exist by the Tanzania Bureau of Standards (TBS). Where a designer consider there to be need for a more rigorous requirement than those laid down by ISO and TBS, these may be strengthened by regional standards such as EuroNorms or national standards such as those issued by the American Water Works Association (AWWA), Germany (DIN), Britain (BS) and South Africa (SABS)..

Units

Only System International (SI) - Units may be used on drawings and documents prepared for the Ministry of Water and District and other Water Authorities. However and to conform to local practice and to avid confusion, use should be made of the decimal point and NOT the decimal comma.

The following is a summary of some of the more frequently used SI - System Units.

(i) There are seven basic units of the system:

- Length, l - metre (m) (European and NOT American spelling)
- Mass, m - kilogram (kg)
- Time, t - second (s)
- Electric current, I - ampere (A) .
- Temperature, T - Kelvin (K)
- Luminous Intensity, I_v Candela (cd)
- Substance, n - mol (mol)

(ii) Derived and Supplementary Units to be used are:

• Area	-	square metre	(m^2)
• Volume	-	cubic metre	(m^3)
• Power	-	watt	(W)
• Energy	-	Watt second (joules)	(J)
• Velocity	-	metre per second	(m/s)
• Acceleration	-	metre per second squared	(m/s^2)
• Force	-	Newton	(N) $\equiv kg\cdot m\cdot s^{-2}$
• Density	-		(kg/m^3)
• Pressure	-	Pascal	(Pa)
• Temperature	-	Degree Celsius	(C)
• Angle	-	Degree	(^{o})

(iii) Prefixes will be used as an alternative method for writing multiples and submultiples e.g.

1,000 millions	10^9	-	Giga	-	G
One million	10^6	-	Mega	-	M
One thousand	10^3	-	Kilo	-	k
One thousandth	10^{-3}	-	Milli	-	m
One millionth	10^{-6}	-	Micro	-	µ (u)

1.10 PLANNING CYCLE

The basic aim is to sustain the water needs of the society. This planning of water supply can be represented diagrammatically as shown below:

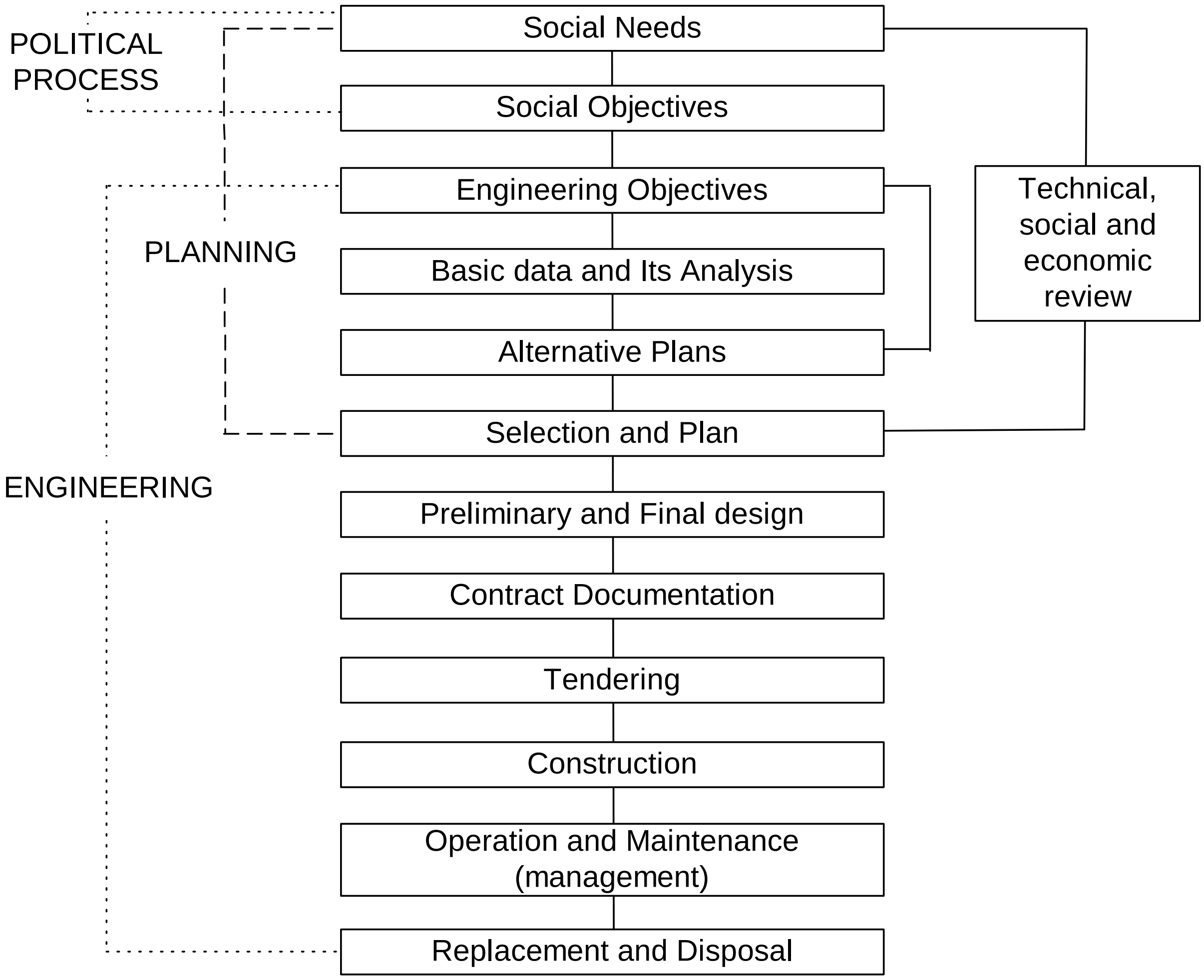


FIGURE 1.2: ILLUSTRATION OF THE PLANNING AND ENGINEERING PROCESS