JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ARUSHA REGIONAL DEVELOPMENT DIRECTORATE
THE UNITED REPUBLIC OF TANZANIA

THE FEASIBILITY STUDY ON MONDULI TOWN AND THE SURROUNDING AREA WATER SUPPLY IN ARUSHA REGION

EDUCATION MANUAL FOR OPERATION AND MAINTENANCE

JANUARY 1996

SANYU CONSULTANTS INC.
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Foreword

Water supply facilities are essentially designed to last for a long time. However, one often sees facilities that, despite having been constructed relatively recently, are in poor condition or have lost their functions. The accumulation of silt, profuse growth of weeds, poorly functioning structures and other undesirable conditions are making the actual storage and supply of water difficult to achieve.

However, as a result of proper maintenance and the cooperation of local residents in such work, there are some water supply facilities that remain functional for periods in excess of those imagined by their designers and builders.

There are a number of reasons for why maintenance work is apt to become sloppy, and the following are some of the most important:

- Insufficient funds for operation,
- Low level of interest among residents who are participating in and cooperating with the maintenance work,
- Weak organization to support the work.

The most common reason for poor maintenance work within the public water supply utility is the fact that funds required for daily maintenance and repairs are not sufficiently available. This affects not only the maintenance but the whole water management system.

There are cases where the main reason for why water supply facilities fall into disrepair is because the residents who should participate in their maintenance work do not have enough interest. Studies have brought to light various reasons behind this lack of interest, which is demonstrated by those residents who themselves avoid maintenance work and repairs, and it seems that these reasons often combine. In some cases, residents not only are unaware of the importance of maintenance work, they do not know how to carry it out and, in some cases, they even believe that such work is more beneficial for other people rather than for themselves. In other cases, residents deliberately avoid participating in maintenance work because they do not realize that the water supply facilities belong to themselves. In order to improve such situations, it is necessary to carry out analysis to find out the reasons for non-participation in each case, and there are times where enlisting the help of sociologists can prove useful in

performing such work.

Poor maintenance may be caused by inappropriate work planning, or, it may be because effective measures have not been utilized effectively.
Conducting project management should impress on all those concerned that they have a responsibility to carry out the maintenance of water supply facilities.

1. Major Functions

Maintenance offices have overall responsibility for ensuring that water supply facilities function in a satisfactory manner within the bounds that they were originally designed for. Similarly, the major functions of operating work are accepted as being as follows:

- Planning the work involved in maintenance,
- Carrying out the maintenance activities (both the planned and difficult to forecast activities),
- Monitoring the above-mentioned activities.

Forming work plans for the coming year is particularly important in countries where the government burden for operations and maintenance is determined based on planned costs. All work should be justified, and, even if the planned work may not be accepted, this is the most important factor in obtaining funds for maintenance. Even in places that do not offer such opportunities, the planning of that work which can be carried out within the bounds of limited funds is an effective practice.

Maintenance work is simple during the dry season. This is because there is an ample supply of labor during this period. Furthermore, if residents participate in maintenance work for their own benefit and near their own homes, they will only be too glad to work. Moreover, maintenance staff have more freedom in this period and can carry out partial maintenance work.

The planning of maintenance activities requires data that has been collected in an ordered fashion. Without reliable data relating to the costs for the various units of work and the effect of the facilities, it is impossible to form realistic plans. Consequently, efforts should be made to obtain data on project sites based on the special conditions within those sites.

2. Forms of Maintenance

There are three main forms of maintenance, and they are described below.

a) The first form of maintenance involves daily operations and other prescribed maintenance work that covers all the work necessary to ensure that water supply facilities continue to function in a satisfactory manner. This form of maintenance is carried out every year in a customary manner.

b) The second form of maintenance is special maintenance that includes the repair of damage caused by major disasters such as torrential rain and flooding.

c) In areas that are prone to such disasters, it is generally necessary to install safety equipment. An example of this would be the establishment of a sediment dam upstream of a dam in an area that is prone to flooding. However, the taking of special preventive measures against natural phenomena, which are not easy to predict, is an extremely difficult task. Special reserve funds and the allocation of operating expenses are measures that should be established in order to aid restoration work.

3. Maintenance Activities

The maintenance activities for which the maintenance offices are responsible should be clearly stated within the irrigation utility by-laws. Although there are some activities which are very clearly the responsibility of the maintenance offices (removal of sediment within reservoirs, cutting of weeds, etc.), there are other activities which are not accurately limited. Examples of such activities are access roads and ancillary works. Despite this, by stating briefly about the features and level of importance of such activities, it should be possible to contain all those activities that can said to be for the purpose of maintenance within an activities list.

Maintenance activities are grouped according to the type of water supply facility. Those groupings are: 1) Dam and reservoir, 2) Conduit, 3) Pumping station, and 4) Ancillary works. The following sections proceed to explain each of these work areas.

3.1 Dam and Reservoir

Maintenance work in reservoirs consists of the following activities.

- Controlling aquatic plants
- Removal of large items of rubbish (for example, large fallen trees) which may have an adverse effect on the dam body
- Monitoring of water. This is not only necessary to control the salt content, it is also necessary in biological terms in order to detect sources of pollution.
- Surveying solid deposits at the bottom of the reservoir
- Reading water gage graduations in order to have a grasp of current water quantities

Except for the controlling of aquatic plants, each of the above activities is performed regularly and does not take much time. The control of aquatic plants is an extremely important issue in tropical zones in particular. For example, there are cases where the immense reproductive powers of green weed combine with a deficiency of dissolved oxygen. A problem such as this can be of major significance in cases where the stored water is to be supplied for living purposes. Earth dams require greater amounts of maintenance work. In particular, the control of weeds on the upstream slope of a dam needs to be done once or twice each year.

Dam bodies are eroded away by heavy rains, strong winds, the releasing of livestock to drink water and the passage of animals. Rain and wind can cause great damage to dams that are unprotected. The cutting of grass on the slopes of the dam body is a cheap and effective means of protection, and the planting of short grass can also be effective.

Cattle and sheep harm dam bodies in different ways. When cows drink water, they tend to push on the levee materials that are made wet by the reservoir water. However, the releasing of sheep makes the levee bare and can result in the levee materials being washed away by the wind and rain.

Dam body erosion can be repaired through the re-banking of earth by mechanical or manual means. However, great care needs to be taken in connecting old and new areas. If care is not taken, the work can result in worsening the same part of the dam body.

The most effective means of dam body protection is to plant grass that grows quickly to protect the dam body, and to set up special areas reserved for drinking by animals and bathing.

3.2 Conduit

If conduits were built well and potential problems were researched slightly, maintenance would hardly be necessary at all. Normal maintenance work includes the checking of connections for leaks, the replacement of damaged piping, the control of weeds around the conduits, and the treatment and removal of silt.

In normal circumstances, water flows rapidly in pipe conduits and silt is not a major problem because the speed of the flowing water removes any silt and mud layers that may reduce the water passage section area. However, the accumulation of sediment is still something that should be avoided at all costs.

3.3 Pumping Station

The two main types of pumping station used in the water supply utility are as follows.

a) Force pumping stations used mainly for supplying water (surface water or groundwater)
b) Relay pumping stations that perform additional finishing on main or branch conduits

Both kinds of pumping station need to raise forecast amounts of water for long continuous periods by methods that are designed to lift water to higher levels. The operation and management of electric pumping stations is relatively simple, whereas such work becomes a little complicated in diesel pumping stations. Station managers must be provided with clear knowledge on safe methods, pump motor operating, and methods that ensure ample control. In cases of emergency, there must be a simple communication system between the station manager and other staff by means of telephone or signals or messengers.

4. Planning of Maintenance Activities

The following methods can be considered for making maintenance plans official.

a) Prepare a list of all the activities where maintenance is required.
b) Determine the quantities of maintenance work that are to be planned for each year.
c) Establish optimum maintenance cycles for each type of activity.

d) Establish the required amounts of machinery and labor for the planned maintenance.
e) Establish an order of priority for the maintenance and secure the necessary budget.

4.1 List of Activities

Many water supply organizations already possess effective planning drawings and records on major activities and structures. However, in order to achieve the objectives of maintenance, it is necessary to classify the latter according to similar characteristic forms. By doing this, budgets can be simplified and facilities can be utilized in the optimum way.

4.2 Quantities of Maintenance Work

When preparing maintenance plans, it is necessary to know the quantities of work that are planned for each maintenance department. Many of these activities were given in Chapter 3. Detailed lists of maintenance activities will probably be prepared for dams and reservoirs, conduits, service roads, buildings and workshops.

The scope of the planned activities is determined based on site observations, and detailed measurements will be made in order to gain an understanding of capacity, scope or the unit length of each job. When all the measurements for the maintenance activities are completed, they are classified through studying necessary conditions in terms of labor and machinery.

4.3 Optimum Maintenance Cycles

The optimum cycle for maintenance is the period that safely passes (with overall efficient operation and no breakage or collapse of elements) between two consecutive maintenance plans for constructed elements (dams, conduits, pumping stations). The optimum maintenance cycle with respect to each water supply activity must be known. In order to ensure that cycles are determined according to local characteristics such as climate, water quality and the quality of structures, etc., experiences of particular plans that have made improvements should be set as a basis. During the first year of a project and at times where there is no past experience, it is usually wise to rely on the experiences of other domestic water supply organizations that face similar situations.

4.4 Required Quantities of Machinery and Labor

The next stage of the maintenance planning process is to establish the quantities of machinery and labor that are required to carry out the already confirmed amount of work. Various methods are used to plan maintenance work, however, the first thing to decide is whether to conduct the work by manual labor or by machinery. Generally speaking, machinery is preferred in expensive technical plans. This is because the initial motivation behind construction is influenced by the effectiveness of skilled engineers and the deficiency of laborers. In contrast to this, inexpensive technical plans should be carried out with manual labor as far as possible. For reasons of practicality and economic feasibility, maintenance work should be conducted with local labor as much as possible, and machinery should only be relied on in those areas where the procurement of labor is impossible. In some cases, there may not be sufficient labor to plan the necessary amount of work in the time that is available and, in such cases, the use of machinery cannot be avoided.

Regarding the required quantities of machinery and labor, these can be easily calculated providing that the working capacity of the machinery or labor for the maintenance work and the amount of work that needs to be done are known. The working capacity of machinery and labor for extremely important activities is examined in the following paragraphs.

1) Sediment Removal

Assuming that reservoir water levels can be reduced or, even better, that reservoirs can be dried for a few days, sediment is still removed by hand in many parts of the world. Even though the organization of the work may be a problem, this method is still rather effective.

In places where it is known that water-borne diseases are prevalent, the use of laborers should be limited to those reservoirs which can be completely dried out for a number of days. If that can't be done, mechanical means should be adopted to carry out the work.

The working capacity of laborers generally falls in muddy conditions. Although efforts are being made to raise working capacity levels through the use of various developing

and suitable machine tools such as specially designed sediment excavation hoses, forks and dredging spades, etc., traditional tools (head baskets and spades) are still being used and are lowering working capacity levels. Depending on a whole range of elements such as working conditions, tools, lifting and carrying distances, sediment removal capacity can vary between 2-8 m3 per person per day.

As for machinery, many machine models are used in order to remove sediment. The capacity of machinery is largely dependent on how well a machine is adapted to cope with a special kind of job. The selection of machinery is mainly affected by the working conditions and scope (wetness or dryness, ease of access, work quantity and type of work, vegetation covering, etc.).

2) Control of Aquatic Plants

Weeds are usually removed by cutting, mowing or sweeping away. As for floating or underwater vegetation, it is best to cut it close to the base of the stem and it doesn't matter if roots or underground stems are left behind. When cutting weeds, it is necessary to leave them for set periods throughout the seasons and, depending on the environmental conditions, it is sometimes necessary to change the periods. In warm regions, the cutting frequency is often set at four weeks during the summer. Cutting vegetation during its growth period affects the rate of growth. Cutting weeds in the early growth stage will be more effective than cutting them later on.

3) Maintenance of Access Roads

Access road maintenance can easily be performed with laborers, however, in cases of roadbed and subgrade material spreading and compacting work over distances in excess of 200 m, machinery is more suitable.

4.5 Determine Cost and Estimate the Priority of Maintenance

The determining of costs to be devoted to a maintenance plan is an easy task because the overall work quantity has been established and basic prices are known. It is important to make a detailed confirmation for a certain job that stresses the economic and social content and significance of the work in the case where it is not carried out. It is wise to put aside a separate fund for the sake of unexpected repairs. Usually,

between 10-20% of the overall budget is appropriated for this purpose. Regardless of the actual amount of the operating budget, the initial estimate will probably be subject to reconsideration or cutting depending on the financial relationship that can be obtained. With this in mind, the establishment of priority rankings for water supply facilities is something of great significance that should be carried out together by all water management organizations.

5. Maintenance Plan Implementation

Maintenance activities are of special importance. Basically speaking, a number of general maintenance principles are used, and the most suitable of those are described below.

a) A good plan is particularly important in cases where time and the available methods for conducting the work are limited. Even if the use of plan preparation methods such as CPM (critical path method) and bar graphs, etc. is extremely unusual, such methods are useful.

b) The monitoring of reservoir water levels is not only reflected in the compiling of plans using existing materials, it is important in managing the progress of the planned work.

c) The participation of farmers in maintenance work is something that should be encouraged. Maintenance activities should involve technical guidance and the planning and management of the actual work.

d) Maintenance work done on a voluntary basis is performed as a natural course of action among old water supply organizations, however, this is not the case with new water supply utilities. In the case of new water supply utilities, it is necessary to explain the importance of securing water and make the operators aware of the fact that the facilities do belong to them. Moreover, the work should be limited to those special repairs that cannot be forecast and require many workers.

e) In those cases where non-skilled labor is required, the workers should always be recruited from among the beneficiaries of the facilities in question.

f) The partial subcontracting of maintenance work is a wise policy to a limited extent and should frequently be adopted. This enables the number of permanent staff in the maintenance department to be reduced and helps create a setup that can adapt to changes in the state of maintenance over many years.

In the case of water supply operators that possess hardly any vehicles or machinery, rather than keeping a poor quality workshop with low levels of maintenance technology, greater emphasis should be placed on the maintenance capacity of subcontractors.

6. Staffing for Maintenance Activities

The following staff members are required to perform maintenance activities.

1) Laborers
2) Foreman or work leader
3) Supervisor
4) Inspectors
5) Machine operators
6) Mechanics
7) Maintenance chief

6.1 Laborers

Most maintenance workers are unskilled laborers. The basic staff formation is for a group of 8-20 laborers to be placed under the guidance of a foreman or work leader. The number of laborers that are gathered together to perform maintenance work varies largely according to the nature of the job. For example, there are numerous factors such as the adoption of machinery for some jobs due to water supply utility reasons and the working situation, etc. Unskilled laborers are hardly ever made into permanent staff and they are hired on contract only for the period they are involved in a certain job.

Unskilled laborers are also required in jobs such as the laying of pipes and the piling of stones. It is often the case that they only bind contracts with a single work organization. Such workers are difficult to find in rural areas and, if enough work that they can be used in can be secured throughout the year, it is desirable to recruit the

required number of staff as permanent employees.

6.2 Foreman or Work Leader

The work leader is usually one of the laborers and is almost always chosen in an extremely natural manner from among the work group members on traditional grounds or due to leadership abilities. The work leader's fundamental duty is to keep order and ensure a rate of production that fits with the objective. Most jobs do not require any special training, reading and writing ability is not necessary and salary is only slightly higher than that of unskilled laborers. As was mentioned previously, one foreman or work leader will supervise a group of between 8-20 laborers.

6.3 Supervisor

On occasions when maintenance work is largely performed by laborers, the supervisor will be responsible for managing the work of a group of between 5-10 laborers. The most specialized duty of the supervisor is to manage the group bodies in a more compact manner.

a. Work Contents
- Planning and management of the work of a group
- Stabilization of the quality and productivity of the workers
- Recording of the work time and performed contents
- Proper supply of materials and tools

b. Qualifications

Supervisors are usually chosen from among the foremen because they display greater qualities in terms of leadership and initiative. Supervisors must be able to read and write and be able to grasp work quantities. They are mostly qualified workers who possess a number of years experience in maintenance work, and they display competent leadership skills.

c. Numbers

One per work group of 5-10 workers (laborer group).

6.4 Inspectors

In the maintenance field, inspectors are central figures who must ensure that the maintenance work reaches top quality standards. Inspectors decide on those items that require regular maintenance, make preparations and estimates for the work to be done, and lead the actual work performed on site.

a. Work Contents

- Inspection and, if necessary, preparation of estimates for the maintenance of structures (conduits, roads, buildings)
- Reporting of necessary repairs to the maintenance chief
- Preparation of work that is to be performed by laborers or machinery
- Inspection of completed work
- Ensuring that appropriate technical standards are complied with
- Ensuring that safe methods are adopted in cases where machinery or chemicals are used

b. Qualifications

Inspectors are mostly promoted from within the ranks of laborers and operators. They must be endowed with high levels of technical skill and leadership abilities. Most of those who are promoted do not previously have the opportunity to obtain technical skills, however, they raise their competence through their work or other training.

c. Numbers

Usually one inspector is required for each group of between 4-6 supervisors.

6.5 Machine operators

As much of the equipment used in maintenance work (drag lines, motor graders, trucks, loaders) is expensive, the operators need to be sufficiently qualified. Depending on the level of skill of the operator, the productivity of the same item of machinery can vary greatly. Moreover, the service life of machine parts is also largely dependent on operator handling and routine maintenance.

a. Work Contents

- Operation of allotted machinery

- Participation in the regular maintenance of the allotted machinery
- Reporting of finished work to the inspector
- Reporting of consumed quantities of fuel and oil
- Reporting of sudden damage or breakage

b. Qualifications

Operators need to have spent five years at a technical college learning about the operation of the types of machinery that are used in maintenance work.

c. Numbers

It is normal to have one operator for each item of machinery. In cases of multiple items of machinery or where the machinery is not used every day, one operator can operate two or three items. In places where all maintenance work must be completed in a very short time, the working day will be divided up into two or three shifts in order to maximize the time spent on machine work each day.

6.6 Mechanics

Qualified mechanics are needed in order to carry out the repairs of machinery. They are employed as staff of maintenance workshops.

a. Work Contents

- Precision inspections of and parts replacement and supply for the machinery needed to perform maintenance work.

b. Qualifications

Mechanics need to have spent five years at a technical college learning about repairing diesel engines and maintenance machinery.

c. Numbers

The number of mechanics in a workshop varies greatly according to the contents of the work performed. The most common case is for a workshop to perform only simple repairs and send machinery to specialist workshops when large repairs are needed. In such a case as this, a work group consisting of two or three mechanics and a similar number of assistants or trainees could handle a workshop that possesses between 20-30 items of machinery.

6.7 Maintenance Chief

As well as being responsible for the general matters such as the planning and operation of maintenance work, the chief is also responsible for the following.

a. Work Contents

- Annual evaluation of all necessary maintenance work
- Planning of maintenance work to allow effective elements to be utilized to the full
- Preparation of technical and economic specifications for work carried out under subcontract
- Ordering, explanation and supply of tools and materials
- Storage of machinery
- Authorization of contract payments
- Guidance to staff on the work to be done
- Reporting of maintenance costs to the organization management

b. Qualifications

A maintenance chief needs to be a Bachelor of Engineering and possess five years of experience in maintenance. It is desirable for chiefs to have had experience in maintenance in the water supply utility. Leadership and the ability to plan are also indispensable qualities.

c. Numbers

One maintenance chief is required in each community water supply facility. In small operations it is often the case that the same person will combine the duties of chief of maintenance and operation. Depending on the size and complexity of the operation, the maintenance chief will carry out his job aided by various support staff (records and storage manager, secretary, driver, etc.).

7. Organization

In medium and small water supply enterprises, it is usual for operation and maintenance work to be carried out within the same organization. The responsibility for operation and maintenance work often resides with the same person, thus making the division of maintenance work very difficult. If any division of work is done, it is

limited to the holding of a small work group devoted to the repair and dismantling of machinery.

In cases where operation and maintenance work is carried out by the same work group, a certain degree of the maintenance responsibility is left up to the operating staff. For example, a water monitor would also act as a supervisor, a facility manager would also act as a work monitor, and a group leader would be responsible for both operation and maintenance work. Because the maintenance work is basically performed by the same staff, its organization runs parallel to the operation work.

In large water supply enterprises or in cases where there is enough maintenance work for staff to be kept busy throughout the year, the organization is usually divided into separate operation and maintenance departments. In such cases, the maintenance department will be composed in one of the following two ways:
a) According to specific maintenance work groups
b) According to district (water supply district)

Organizations that are divided according to function are suited to cases where the effects of special machinery on the work are great. For example, such an organization would be appropriate in projects of expensive technology, or in cases where obtaining labor is either difficult or expensive. Conversely, in districts that are not fully developed, or which rely heavily on manual labor, or which do not possess well developed means of communication, a diversified approach according to district is considered to be more effective. The following paragraphs give a detailed explanation of both of these approaches.

a) Organization According to Function

The basic thinking behind this is as follows. For example, with respect to work areas such as the sediment removal and cleaning of small and medium sized reservoirs, the repair of dam bodies and the maintenance of roads, etc., this approach aims to raise work efficiency by organizing specific small work groups according to work types. The size of the work groups in terms of labor and machinery is determined from standard contents that are determined according to the local conditions for the target work and maintenance work cycles. Each group is supervised by a work manager and the work of all the groups is planned and controlled by the Chief of the Maintenance Service. If the group contains too many operators to manage effectively

(8-10 members or more), it is further divided into teams, each of which is led by a team leader (most experienced operator). The work manager will then supervise the team leaders.

b) Organization According to District

The operating area is divided up into districts that are suited to the maintenance work. The size of the districts is not uniform but varies according to the work methods and topography. To act as a basic rule, the maintenance work for each district should be completed within cycles of three years. A maintenance manager is appointed to each district and these managers are responsible for organizing the maintenance work in such a way that the districts operate as independent operating districts. In order to manage and supervise each type of work, the maintenance manager is supported by a number of team leaders, each of whom is responsible for organizing each different work area. (The work area of each team leader would be reservoir sediment removal, dam body repairs, road repairs, and so on). In this method of organization, special tools need to be collected together to perform specific work according to the needs of each of the districts.